An Energy Efficient & Hybrid Adaptive Next Hop Routing For Wireless Sensor Networks

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BY

ZIA UR REHMAN

573-FBAS/MSCS/F09

SUPERVISED BY

Dr Muhammad Zubair

DEPARTMENT OF COMPUTER SCIENCE,

FACULTY OF BASIC AND APPLIED SCIENCES

INTERNATIONAL ISLAMIC UNIVERSITY, ISLAMABAD

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International Islamic University Islamabad

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Final Approval

It is certified that we have examined the thesis report submitted by Zia Ur Rehman, Registration number 573-FBAS/MSCS/F09, and it is our judgment that this project is of sufficient standard to warrant its acceptance by the International Islamic University, Islamabad for the Masters of Science in Computer Science.

Committee:

External Examiner

Dr. Hasan Mahmood

Assistant Professor
Department Of Electronics,
Quaid - i -Azam University,
Islamabad.

Internal Examiner

Prof Dr. Muhammad Sher

Chairman,
Department of Computer Science and Software Engineering,
Faculty of Basic and Applied Sciences,
International Islamic University,
Islamabad.

31-1-12

Supervisor

Dr. Muhammed Zubair

Assistant Professor
Department of Computer Science and Software Engineering,
Faculty of Basic and Applied Sciences,
International Islamic University,
Islamabad.

ABSTRACT

Wireless Sensor Network (WSN) consists of distributed nodes to cooperatively monitor physical or environmental conditions; these nodes are operated with battery and have limited energy. We consider that if one node will become dead it will effect the life time of the network, so energy efficiency is the most critical parts of this network. we focus on increasing the lifetimes of sensor nodes through power management. An efficient routing mechanism can save energy resources and deliver the information more quickly and efficiently. We proposed a new routing mechanism which is adaptive next hope routing and will take the benefit of one hope and multi hope routing which save the energy of node and increase the life time of network, load balancing between nodes finding next hope and to locate the intermediate node is the key concept of proposed Algorithm

DECLERATION

I hereby declare that this work, neither as a whole nor as a part has been copied out from any source. It is further declared that I have conducted this research and have accomplished this thesis entirely on the basis of our personal efforts and under the sincere guidance of my supervisor Dr. Muhammad Zubair. If any part of this project is proved to be copied out from any source or found to be reproduction of some other project, I shall stand by the consequences. No portion of the work presented in this dissertation has been submitted in support of any application for any other degree or qualification of this or any other university or institute of learning.

ZIA UR REHMAN

573-FBAS/MSCS/F09

A Dissertation submitted to the

Department of Computer Science

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As a partial fulfillment of requirements for the award of

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This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time

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573-FBAS/MSCS/F09

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

WSN:	Wireless Sensor Network
LAN:	Local Area Network
MAN:	Metropolitan Area Network
WAN:	Wide Area Network
WLAN:	Wireless Local Area Network
TOSSIM :	TinyOS Simulator
NesC:	Network Embedded System C
OS:	Operating System
SOS:	Sensor Network Operating System
CH:	Cluster Head
BS:	Base Station
QoS:	Quality of Service
CPU:	Central Processing Unit
GHz:	Giga Hertz
ROM:	Read Only Memory
RAM:	Random Access Memory
EEPROM:	Electronically Erasable Programmable ROM
FPGA:	Field Programmable Gate Array
DSP:	Digital Signal Processor
ASIC:	Application Specific Integrated Circuit

DPM:	Dynamic Power Management
DVS:	Dynamic Voltage Scaling
RSSI:	Received signal Strength Indicator
CRC:	Cyclic Redundancy Check
ADC:	Analog to Digital Converter
GUI:	Graphical User Interface
CLI:	Command Line Interface
IDE:	integrated Development Environment
DBG:	Debug
LED:	Light Emitting Diode
RFM:	Radio Frequency Module
AM:	Active Messages
LASER:	Light Amplification by Stimulated Emission of Radiation
LEACH:	Low-Energy Adaptive Clustering Hierarchy
EYES:	Energy Efficient Networks
AICR:	Adaptive Intra Cluster Routing
EECR:	Energy Efficient Clustering Routing
CIDRSN:	Cluster ID based Routing in Sensor Networks
IEEE:	Institute of Electrical and Electronics Engineers

Chapter 1

Introduction

1. Introduction

Wireless sensor network (WSN) is playing very vital role in many industrial and consumer applications including area monitoring, air pollution monitoring, forest fire detection, greenhouse monitoring, landslide monitoring, machine health monitoring, agriculture monitoring, structural monitoring etc.

1.1 Wireless Communication

"Wireless communication is the exchange of information between two or more than two nodes without physical connectivity", Wireless technology is playing an imperative role in revolutionizing technology and has influenced many factors of technological advancement. Some products including wireless technology are remote control devices, cellular telephones, Personal digital assistants (PDAs), two-way radios, wireless Networking (Wireless LAN & Wireless WAN), international mobile telecommunication, satellite communication etc.

Industries are increasingly turning to wireless technology to use the advanced features of technology and to avoid high costs, As compared with wired structure, wireless technology offers many advantages including increased flexibility by providing redundant and frequency hopping wireless communication with any multimode, better performance ,easy installation and low cost .

1.2 Sensor

"A sensor is a device that determines some physical change in environment and converts it into signal that can be read by an instrument or an observer", Thermometers for temperature measurement, hygrometers for humidity measurement, barometers to measure atmospheric pressure, rain gauges, snow gauges, pyranometers and solarimeters (solar radiation sensors), lightning detectors, anemometers, wind vanes, weathervanes etc are the common examples of sensor. Sensing, computing and communication are three main aspects which combine in single tiny device called motes which are used in Wireless data communication.

1.3. Wireless sensor network

"A wirelesses sensor network consists of various autonomous devices which are interlinked or connected to each other and distributed in selected area, using sensor for checking and balancing the environmental factors"

According to above stated definition we extract an equation.

Sensing + Computing + Communication = Wireless sensor network Application.

There are two main portions of WSN function, the sensing and computing. Sensing portion is a combination of small, cheap and efficient sensor nodes called motes. These tinny nodes collect the required information by sensing the area of interest while computing portion consists of a very high profile system that has high processing capabilities called base station. Both these devices communicate with each other by their radio transmitters.

1.4 Application of Wireless sensor network

The recent advancement in wireless sensor technology makes practical vision to deploy it in thousand of applications; initially sensor technology was used for military applications in battlefield context and defense advanced research purposes but during the last few years, a lot of research has been directed to use sensor technology in civil applications as well.

Following are some popular domains which use Wireless sensor technology.

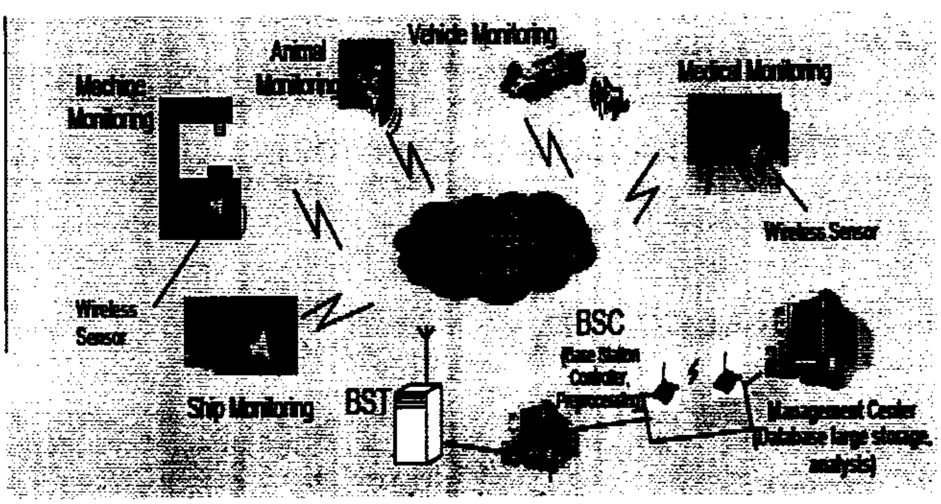

Figure 1.1 Application of Wireless sensor network

1.4.1 Military Application

Wireless sensor network plays very important role in military operation, like Monitor Troops, Friendly forces and equipment, Threat control, enemy military investigation, target tracking, war damage assessment, nuclear, biological and chemical attack detection.

1.4.2 Environmental Applications

Wireless sensor network is also used to deploy on large geographical area to measure the environmental factors like temperature, humidity, moisture , rain and snow gages , wind speed and direction, meteorological forecasting, fire risk and providing early Warning for high risk areas. Further it could help to monitor the crops and guide about irrigation and harvesting to improve the quality and quantity of crops. Some renowned applications for measuring environmental factors are Environment Observation and Forecasting System (EOFS), CORIE, ALERT etc.

1.4.3 Health Application

Recent advancement in Wireless sensor network benefits health sector and presents some application for healthcare domain to collect data about people's physical, psychological and behavioral process, to monitor medical equipment, to control and trace drug administration etc. These applications are playing very important role in saving human life and bringing advancement in the field of medicine to improve latest treatment and further research.

1.4.4 Home Application

Many concepts have been devised by the researchers and architects by utilizing wireless sensor technology to develop home applications which are used in our normal life. Currently many applications have been developed and they are being used in our daily routine which use Wireless sensor technology like remote control for television and air conditioner, biometric security system, access control systems, human sense power systems etc.

1.5 Structural Design of Wireless sensor network

As we discussed in our previous discussion that wireless sensor network is the combination of three main tasks; Sensing, Computing and Communication. These three tasks are divided into two main portions, Sensing and Computing. Sensing portion is a combination of small, cheap and efficient sensor nodes called motes. These tiny nodes collect the required information by sensing the area of interest while computing portion consists of a very high profile system that has high processing capabilities called base station.

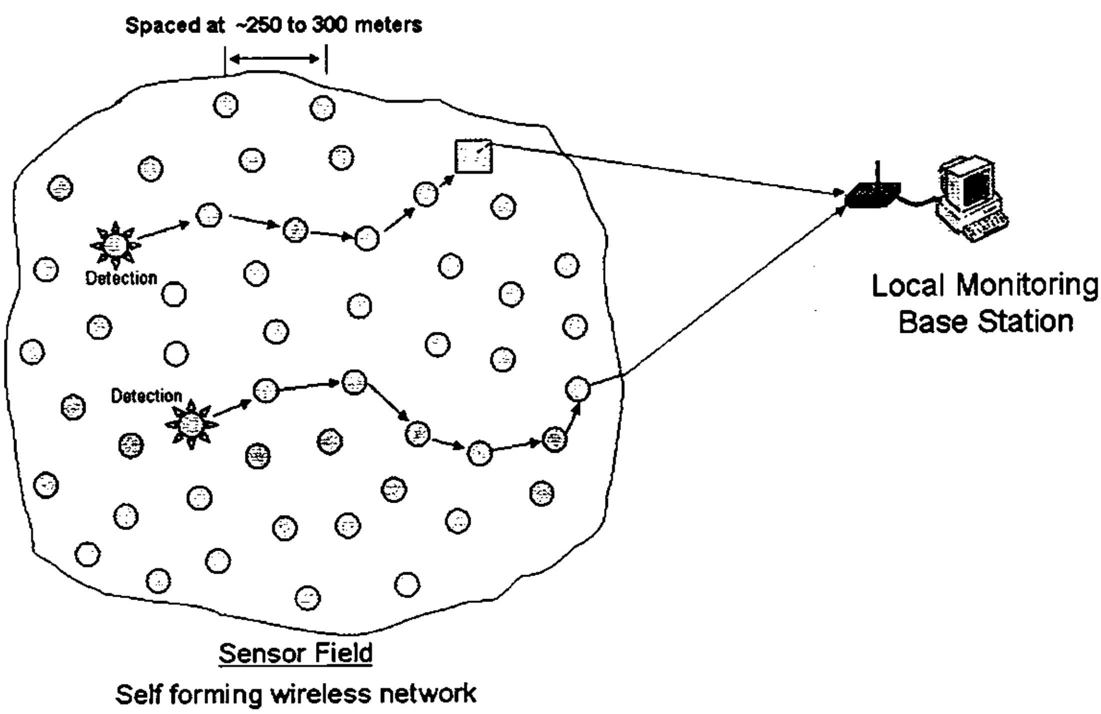

Figure 1.2: Architecture of a Wireless sensor network

We further divide WSN's architecture in two main parts, Hardware architecture and software architecture. This helps us to deeply discuss the structure and design of wireless sensor network.

1.5.1 Hardware Architecture

Hardware platform design is an important part of wireless sensor networks. As we already discussed, WSN consists of large number of small nodes with sensing, computation, and wireless communication capabilities, and on a very high profile system that has high processing capabilities. Typical hardware architecture along with both units has been described in Figure 1.3

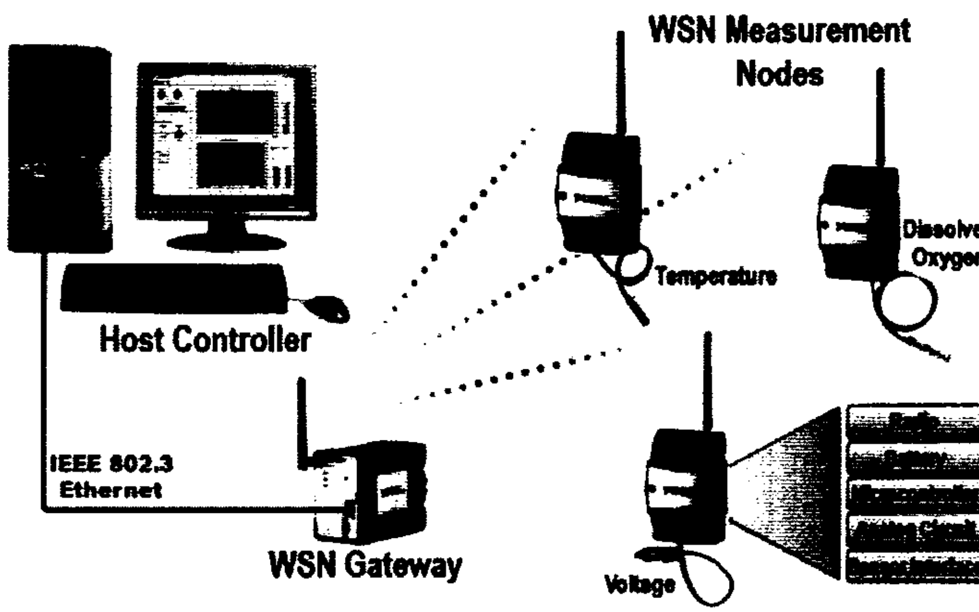

Figure 1.3: hardware Architecture of a Wireless sensor network

1.5.1.1 *Wireless Sensor Node*

A wireless sensor node consists of sensing, processing, transforming and power units with their responsibilities to determine the physical change in environment, process it by converting it into signals and sending it to the base station. Sensor node is powered by the battery which is attached with it so node can easily be deployed anywhere but only constraint is limited battery as sensing node stops the work when the battery power ends. Many Sensor Node products are available in market. These are used for different wireless sensor applications. Two commonly used sensor node are MicaZ and T-Mote Sky. Figure 1.4 shows the image of wireless sensor node.

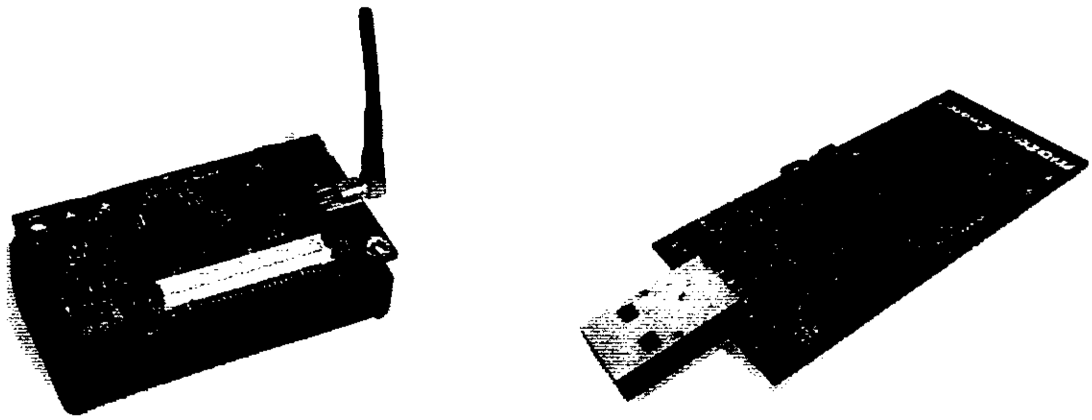

Figure1.4: The MicaZ wireless sensor node and The T-Mote Sky wireless sensor node

1.5.1.2 Components of Wireless Sensor Node

We further categorize a sensor node into four basic components which include sensing, processing, power units and transceiver. A typical node with its components is presented in Fig 1.5

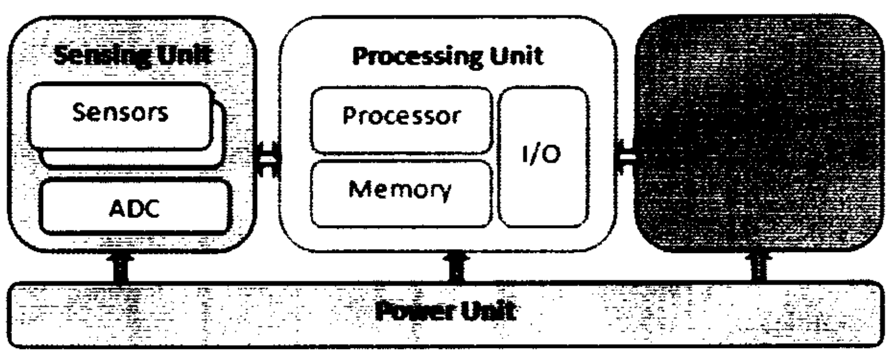

Figure 1.5 Architecture of a Wireless Sensor Node

A. Sensing Unit

A sensor is a device that measures any physical changes on desired area and converts it into a signal. A wireless sensor node may include multiple sensors providing complimentary data. A sensing unit is typically composed of a number of sensors and an analogue to digital convertor (ADC) which digitizes the signal.

B. Processing Unit:

A Processing unit provides the processing power for sensor node and coordinates the activity. A microcontroller integrates processing with some memory provision and I/O peripherals; it is not uncommon for a wireless sensor node to include some external memory.

C. Transceiver

A transceiver unit allows the transmission and reception of data to and from other devices connecting a wireless sensor node to a network. Wireless sensor nodes typically communicate using an RF (radio frequency) transceiver and communications tend to operate in the RF industrial, scientific and medical (ISM) bands which are designed for unlicensed operations.

D. Power Unit

Wireless sensor nodes must be supported by a power unit which is typically some form of storage called battery. In wireless sensor node environments where maintenance operations like battery changing are impractical.

2.2.1.2 Base Station

Base station serves as a gateway in wireless sensor network (WSN) for collecting data from different sensor nodes and further processing it as per requirement to generate results; it is a very high profile system that has high processing capabilities, storage capacity and energy lifetime as compared to individual sensor nodes.

1.5.2 Software Architecture

A critical step towards achieving the vision behind wireless sensor networks is the design of software architecture. Software of wireless sensor networks must be efficient in terms of real time on-sensor processing, time synchronization, and maximizing battery life, managing data and events, and an easy to use user interface.

1.5.2.1 Operating system

Different operating systems are available to implement and develop routing algorithms for WSNs which are specifically designed to address the needs of wireless sensor networks. Some renowned and well-defined operating systems are given below

A. Contiki

It is designed by Adam Dunkels for wireless sensor network which provides dynamic loading and unloading of individual programs and services. It is multi threading which is applied per process basis.

B. Energy Efficient Networks (EYES)

Paul Havinga et al presented an operating system which has capability for wireless communication and ability to organize flexibly for large variety of wireless sensor network applications.

C. Sensor network operating system (SOS)

Chih-Chieh Han et al. presented an operating system for wireless sensor network that supports runtime configuration of software, SOS ability to dynamically load modules like sensor driver, application program and memory allocation.

D. TinyOS

It is a very renowned and well-defined operating system which is free, lightweight and open source, developed for wireless sensor network. It is a component based operating system which is designed to use minimal resources and its configuration is defined at compile time by combining components from the TinyOS library and custom-developed components.

1.6 Wireless sensor network (WSN) Evaluation Metrics

Many evaluation metrics are used to evaluate a wireless sensor network which has various influences on the network in terms of lifetime, converge, cost, response time, security, accuracy and reliability. Given below are some factors which have deep influence on wireless sensor network.

1.6.1 Network Lifetime

Network Lifetime is a key characteristic for evaluation of the sensor Network. Lifetime of the sensor network is the time of start of sensor network till the death of first node in the network. So a single node failure would be the cause of end of lifetime of the whole Network. Each node in the network has limited size of battery which provides power to node for specific time from the start of node. As the deployment of sensor network sensor nodes are scattered in the desired area so it is very difficult to replace or recharge its battery. So we can easily say that Power is a major constraint which plays important role in the lifetime of node. To maximize the lifetime of Network, average energy consumption of the nodes should be as low as possible. A node performs many important operations like sensing, processing and transmitting. More than 80 % of energy is utilized during communication therefore an Efficient routing mechanism is required which minimize the energy consumption and maximize the lifetime of the node and network.

1.6.2 Routing

Sensor nodes are scattered at selected areas with the responsibility to collect the information from desired area and send it to the base station by routing data either to other nodes or directly to base station. However sensor nodes are constrained with energy supply as limited power is available for node and more than 80 % of energy is consumed during communication therefore an efficient routing mechanism is required to minimize the energy consumption by avoiding unnecessary processing and communication. Many routing models like direct /one hope model, indirect/multi-hope routing model and cluster base routing are available to enhance the lifetime of the network.

1.6.3 Cost

The high rate of research and advancement in wireless communication has enabled the development of low cost sensor hardware/software and ease of deployment. Total cost of the WSN includes initial deployment and configuration cost, testing cost and maintenance cost.

1.6.4 Security

Security of any network system is a very common concern now days but security for wireless sensor network has great importance as many sensor application are used in security matter like military operation, battlefield etc, So it is important to keep the sense information secure and authentic which blocks the intruder to communicate false information and may harm the network or network operations. Therefore a lightweight security mechanism is required which can fulfill the security requirements.

1.6.5 Response Time and Accuracy

System response time and accuracy is also a critical metrics for evolution of sensor network. Response time is a time in which a system responds to input user. In wirelesses sensor network node must have ability to immediately communicate the high priority messages between other nodes directly to base station. Response time should be less as information is transferred quickly to base station and measurement result must be accurate and reliable.

1.7.4 Round-Robin

Round-Robin is a method for choosing all elements in a given group equally in balanced order, usually from top to end of list and then again starts form the top of list till the completion of task. Round-robin is a method of choosing a resource for a task from list which has main purpose of load balancing. Every resource will be eventually chosen by the scheduler who prevents starvation. It is a simple scheduling algorithm for processes in operating system where time slices are assigned to each process in circular order and equal portion for each process. round-robin technique is also used in packet scheduling when there are more then on nodes are available to receive the data then round-robin algorithm select every node one by one till end of the last packets and each node will take equal share for receiving packets.

Round-robin scheduling work on fairness policy which has equal portion of time and packets for each node and the node are waiting for log time will give scheduling priority. Round robin method is implemented in load balancing required like DNS server where more then one server IP address are available and there IP address are assign to user on round robin basis. In multi-access networks token access and channel passing schemes are also the examples of round-robin.

Fig 1.6 shows the Round robin scheduling where total 8 nodes are available to receive data and round robin selection will send the packet to every node one by one till the completion of all packets.

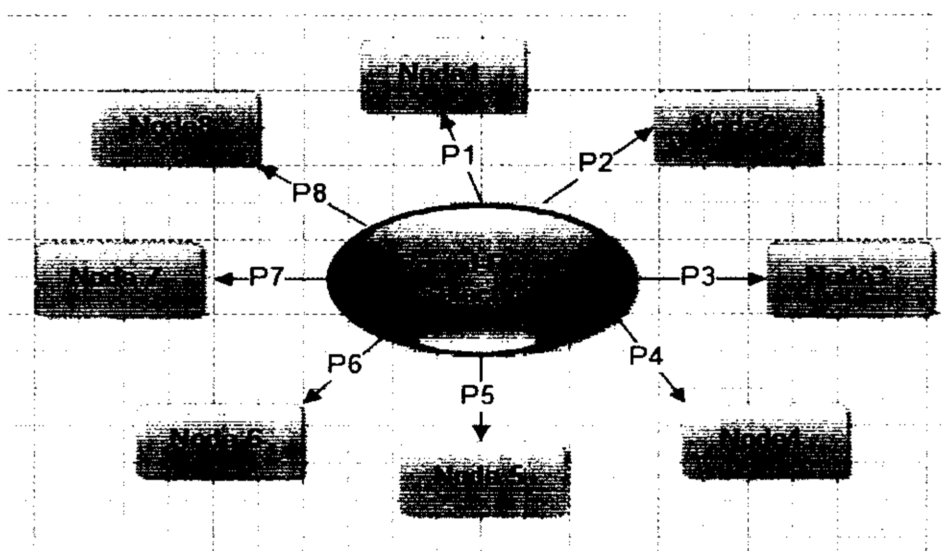

Fig 1.6 Round Robin Selection

Chapter 2

Literature Survey

2 Literature Survey

Ideally, we would like the sensor network to perform its functionality as long as possible. My focus in to save the energy through efficiency routing mechanism for that purpose in literature review I have studied some of latest work done published in this area.

Kemal Akkaya and Mohamed Younis complete a survey on routing protocols in wireless sensor network [10] for energy aware. They categorized routing protocols in three Different categories Data-centric; hierarchical and location-based are discussed for routing protocols. In data-centric routing, routes are created between addressable nodes which are managed by the network layer, SPIN and Direct diffusion, energy aware routing, rumor routing , gradient base routing, CADR, CAUGAR and ACQUIRE routing protocols are the example of data-centric routing. In Hierarchical base protocols involves multi-hop communication, the main purpose of hierarchical protocols to avoid latency in communication by overloading with the increase in sensor density. Cluster base routing is the latest development in hierarchical routing in which a cluster is created in the network which shares the information with his cluster head to efficiently maintain of energy consumption. LEACH, PEGASIS, TEEN, APTEEN, and Cluster base routing are the example of hierarchical routing. Location base protocols are designed to know the location information of the sensor node which helps to calculate the distance between tow nodes and to route the specific information to particular region. Location base protocol mostly designed for mobile ad hoc network for purpose of efficient consumption of energy by routing data to particular region. MECN, SMECN, GAF and GEAR are example of location based protocols.

Jamil Ibriq and Imad Maghoub discussed design the routing protocol for wireless sensor network. They grouped all routing model into three different models. Following is the description of work done in each routing model.[11]

2.1 One Hop Model:

This is simplest routing model of WSN which send data directly to base station, it does not matter how far the node is from Base station, if it is in the range of base station then it send the data to base station directly.[11],

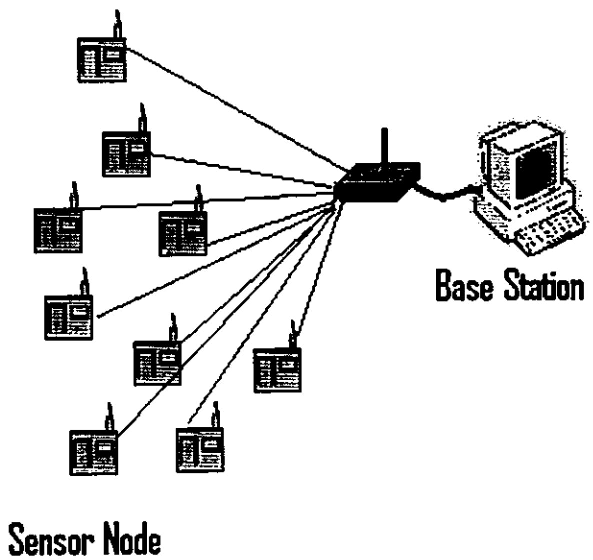

Figure 2.1 One Hop Model

Limitations of One Hop Model

One hop model is not feasible because each node has limited transmission range and many times their transmission cannot reach to base station. If we use direct routing in large network then all nodes will send their data directly to Base Station. The node at maximum distance to BS will have to consume extra energy to send its data to BS. So after sending very small amount of data packets it utilize large amount of energy the death of that node will occur very soon which leads to small network lifetime, So adopting direct routing in large network size is not feasible

2.2 Multi-Hop Model:

In Multi-hop model sensor nodes chose their neighbor node to forward data toward the base station instead of direct sending to base station. In this model less energy is utilized depending upon the topology of WSN.[11]

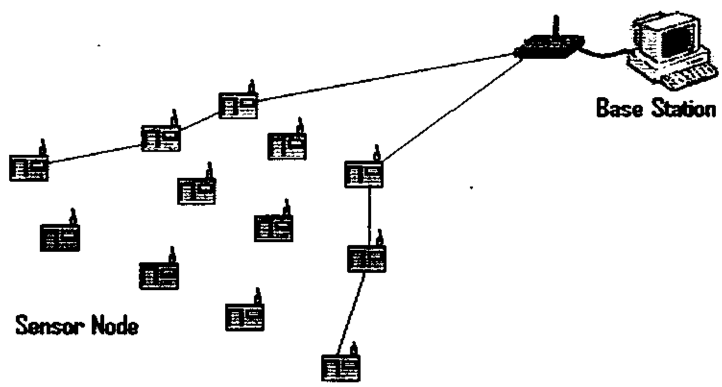

Figure 2.2 Multihop Model

Limitations of Multi-hop Routing

If we use Multi-Hop routing In WSN then each node send its data packet to its neighbor so the nodes closer to the BS will get maximum load of the network because they have to send their own data as well as data from other nodes therefore the node closer to the BS will dead very soon. If this scenario is considered in large network size, then huge number of data packets will be routed through these closer nodes. This will drain the energy levels of the closer nodes very quickly. So MultiHop routing in large network size is also not feasible.

2.3 Cluster-Based Model:

A cluster is a group of resources that act like a single system and enable high availability and, in some cases, load balancing and parallel processing. In WSNs whole network is grouped into clusters. Each cluster one nose is act as cluster head that gets the sensed data from cluster member nodes and then sends it to other cluster heads or direct to the base station [11]

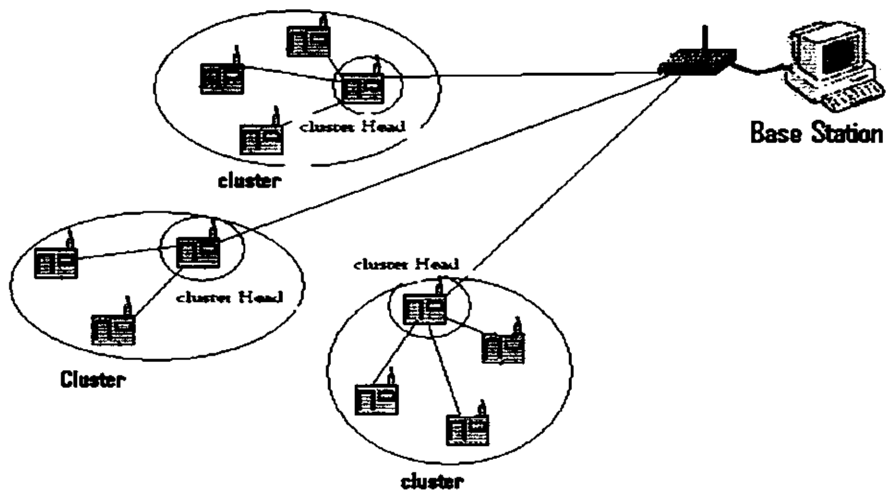

Figure 2.3 Cluster Based Model

Limitations of Cluster Base Routing

In cluster based model when cluster being created then no node can be added or removed at runtime it remains as it is till the death of all the nodes. So this solution works only for static networks. And the network near to base station will carry out the information of the many nodes and overloaded which died quite early resulting in end of lifetime of network whereas some nodes remained with lot of energy.

Heinzelman et al [16] developed a well-known classic routing protocol named LEACH (Low-Energy Adaptive Clustering Hierarchy), Author analyzed the energy efficiency of different routing protocols like direct transmission, minimum-transmission-energy, multi-hop routing, and static clustering. As per analysis of author in direct routing protocols the nodes located at far from the base station required more power to send the data directly to base station and they die quickly as well as in multi-hop routing the nodes located near to base station transmit heavy amount of data as it carry the information receive from its neighbor so that nodes die quickly and in static clustering nodes are organized in cluster which communicate with local base station if the base station is an energy-constrained node, it would die quickly. Author proposed a new clustering base routing protocol LEACH (Low-Energy Adaptive Clustering Hierarchy) which evenly distribute the energy load among the different sensor of the network. It is a self organized routing protocol in which nodes organized themselves in a cluster and selected a Cluster Head. And with the passage of time randomization rotation of Cluster Head based on high energy. author compare the result of LEACH with other conventional routing protocol and proved that by transferring of CH role from one node to other one, energy utilization can be reduced and network life will be improved ultimately. But in this paper author focused only the selection of the cluster head and have no change in routing techniques so as Moving the cluster head from one node to another again involves execution of cluster head selection algorithm, which in turn consumes energy and reduces the network lifetime

Goyeneche et al [13] presented a data gathering technique for wireless sensor network. According to author's proposed algorithm for data is gathered from distributed environment in which each node in the network sends its data to its neighbor and that neighbor send data to its neighbor and so on until data reached to that node who direct send data to base station and that node will become Cluster head for all nodes who sending their data to it. That technique is only used for data gathering as no energy efficiency is increase so for as the node who receiving data from other nodes and sending to BS will dead very soon

A Manjeshwar classify sensor network based on their mode of functionality and then proposed an energy efficient protocol for sensor network. According to author, there are two types of network in sensor network. First one is proactive network in which nodes periodically switched on their sensor and transmitters to sense the environmental changes and transmit data to interested node. Second one is reactive network in which nodes sudden sense the change in environment and transmits it to interested node. Further author proposed a routing algorithm named TEEN (Threshold sensitive Energy Efficient sensor Network protocol) which is targeted to reactive network. According to algo, every change in cluster, cluster head broadcast hard threshold and soft threshold value to it member nodes. Sensor sense the information and saved in internal variable called sensed value and then transmit the data only if the current value of the sensed attribute is greater then hard threshold and the current value of sensed attribute is equal or greater then soft threshold . As transmission takes more energy than sensing, according to this scheme sensing node continuously sense the information, so the energy consumption is potentially is less. Author simulates and compares its results with LEACH and considered the most efficient protocols, in terms of both energy dissipation and longevity. Although author proved that his proposed technique is most efficient in energy but he didn't describe the routing issue.

Ming Ma and Yuanyuan Yang [15] proposed a cluster routing protocol for hybrid sensor network by considering the problem of positioning of mobile cluster head. Proposed protocol is based on two-layered structure which consists of two types of nodes, Basic static nodes and mobile CH. Static node work at lower layer to sense that information and sent to the CH. At the higher layer sensor works as a cluster heads which collect data from sensors and forward it to outside observers. For maximizing the lifetime of the network cluster Head are allowed to change their position and find the best location by moving in the sensing area at higher layer. According to authors algorithm he proposed dynamic positioning technique for position of CH, and by getting better location for a CH prolongs the lifetime and causes a balanced network. But author used static routing technique for sending data to CH if effect adoptive routing would be used energy efficiency can be achieved.

Anu Tuan Hoang and Mehul Motani proposed energy saving model [12] based on broadcasting of sensor information directly to its cluster head by using Time division multiple access (TDMA). According to his proposed algorithm two types of nodes are, sensing node and cluster head node. Sensor node collects the data and sends it to cluster head by using direct routing model and time division multiple access. Sensors in each cluster collaborate in transmitting their data and at the same time receiving and compressing by using collaborative broadcasting and compression (CBC) approach which conserve the energy. The node in one coverage area hear the information even it is not for them, as information is broadcasted in one converge area so nodes receive and utilize this information in compressing its own data. So the node carries out joint data compression in cluster base wireless sensor network. By using this functionality one node can reduce the processing of its own data by overhearing other's transmission. By using that technique authors although achieved the energy but he used only direct routing between sensor and cluster head communication which reduce the efficiency. If both Direct and Multi-Hop routing used at the same time more efficiency can be achieved.

Bandyopadhyay in his paper [14] discuss many clustering algorithm for creation of cluster in the network and election of cluster head and then define a technique for cluster creation in sensor network and generate hierarchy of cluster head which extended more then one level of clustering. He proposed an algorithm in which sensor nodes are organized into clusters randomly, then first elects the level-1 cluster heads, then level-2 cluster heads, and so on, In one cluster, a cluster head can be advertise a limited number of hops which minimize the energy consumption by limiting the CH advertisement to specific no of hops. Author simulate its algorithm and results that energy spent in the network reduce by increasing the number of levels of cluster

In hierarchal clustering algorithm author proved that energy can be minimize. Author used direct routing while communication between sensor and cluster head. As the mixture of the two routing techniques are out of scope in this paper which results in reducing the network lifetime.

Israr [17] proposed multi-hop clustering algorithm based on cluster based routing concern with Load balancing in WSN with energy efficiency. According to his proposed algorithm, two layered communication is achieved by using temporary Cluster Head. Authors algorithm comprise with two distinct phase, the setup phase in which temporary cluster head are elected , cluster head selection is random and is dependent on the amount of energy of a node has left and the data transmission phase in which all node transmit data by using TDMA . According to proposed algorithm, the network is divided into two layers. Nodes at bottom layer send data to respective temporary CH and at top layer the temporary CHs adopt multi-hop routing to deliver the data to the Base station. Although author proves that his algorithm is energy efficient but selecting temporary CH phenomena required another algorithms. As execution of some cluster head selection require more energy and lifetime of the network will decrease

Another Efficient Self-Reorganizing Slot Allocation (SRSA) mechanism for WSN is proposed by Tao Wu and Subir Biswas [18] in which Author used Self-Reorganizing Slot Allocation to avoid the collision. Due to broadcast nature of the sensor node one node may fall in the coverage area of other cluster which causes the data collision. Author avoid collision by using (SRSA) in two steps. First it detect the collision, in second round reorganize the TDMA frame to collision, but that research work is related MAC layer protocol which is based on feedback adaptive reorganization of slot allocation mechanism on MAC layer that reduces the inter cluster interference. Author achieved energy efficiency by using SRSA mechanism but routing issue is not described in this paper.

Irfan Ahmed et al. [19] presented algorithm for WSN which is cluster ID based routing scheme for energy efficiency .Cluster based WSN worked in rounds in each round routing table are formed, large number of energy consumed during formation of routing tables and cluster head in the middle and those near to the base station carry heavy data and become dead very soon. Authors proposed new routing protocol CIDRSN (Cluster ID based Routing in Sensor Networks) which used cluster size adoption method to distribute the load uniformly and used Cluster ID based routing instead of CH-ID in routing table. When node send data to cluster then Cluster ID is used as a next hop instead of cluster head ID. That scheme eliminates the cluster creation process in each round. And w increase energy efficiency and lifetime of the network. Author only consider adaptive feature in routing and cluster will remain static till the end of network as no node could be add or remove from one cluster.

Another adoptive intra-cluster routing protocol presented by Akhtar et al. [20] in which direct and multi-hop model are both used. Authors proposed algorithm comprises on three phases. Phase I include cluster head selection. Base station will select the cluster head on the basis of energy level, geographical area and least ID. Phase II include cluster formation in which each selected cluster head broadcast its status. The nodes getting high Received Signal Strength Indicator (RSSI) value will join the cluster. Phase III include inter cluster routing in which a close region is formed by the nodes near cluster head. Nodes related to close region will send data direct to the cluster head and the nodes outside from close region will send data to their neighbors. Author complied the simulation result and compared it with well know existing technique and found that his proposed technique is more energy efficient .Although author achieve energy efficiency and improve the lifetime of the network but the nodes near to close region and using multi-hop routing overloaded as sending the data of many node along with itself which cause early death of that node and the lifetime of the network will decrease.

Bashir Ahmed presents a Hybrid Adaptive Intra-cluster Routing protocol for energy efficiency. He uses direct routing along with multi-hop routing. Nodes change their routing model from direct to multi-hop on the basis of their current energy level. At the start of the network every node in the network send its data to base station, after some time a close region is created for long distance node and these nodes start multi-hop routing. Close region size will increase with the passage of time. All nodes that have their energy level equal or less then specified energy level will become the part of close region and use multi-hop routing. Researcher use technique in expanded size of region on the basis of remaining energy of nodes and achieve the energy efficiency but he didn't describe that how many intermediate node will be use in multi-hop routing and which node will be used as intermediate node.

Chapter 3

Problem Definition

3 Problem Definition.

As we discussed previously, wireless sensor network is used in many applications which helps in different fields like military applications, civilian technologies like monitoring the physical conditions such as weather conditions, regularity of temperature controlling traffic etc.

Sensor nodes have very limited size of battery. Energy awareness is an important design issue so different routing models are developed to perform the routing tasks efficiently with using low power recourses to save the energy.

In above research work, we thoroughly discussed the routing models and their limitations subjected to energy efficiency and scalability of network and various different routing protocols to make utilization of energy more efficient.

Adaptive routing mechanism for WSN is an efficient energy utilization technique taking benefit of both direct and multi-hop model and change the routing model according to the conditions. Our major research objective is to achieve efficient utilization of energy of each node within the WSN. We will provide a routing protocol which provides load balancing for transformation of nodes data to base station.

According to latest work done by the researcher to present adoptive intra-cluster routing protocol for WSN two main problems arose; one is to find the next hop and second is to find the next node. We will further discuss these problems in detail.

3.1 Problem Scenarios:

There are two problems in latest research of intra-cluster based routing which are discussed in following scenarios.

3.1.1 Problem Scenario 1

Fig 3.1 shows the problem scenario within intra-cluster routing model. We also discussed an adoptive intra-cluster based routing protocol in which nodes enter from one hop model to multi-hop model on the basis of remaining energy. Initially each node uses hop routing model and send its sensed information directly to the cluster head but with the passage of time and on the basis of remaining energy node will change its routing model from one hop to multi-hop routing model. When a node switched from one hop routing model to multi-hop routing then how many hops used to find next node.

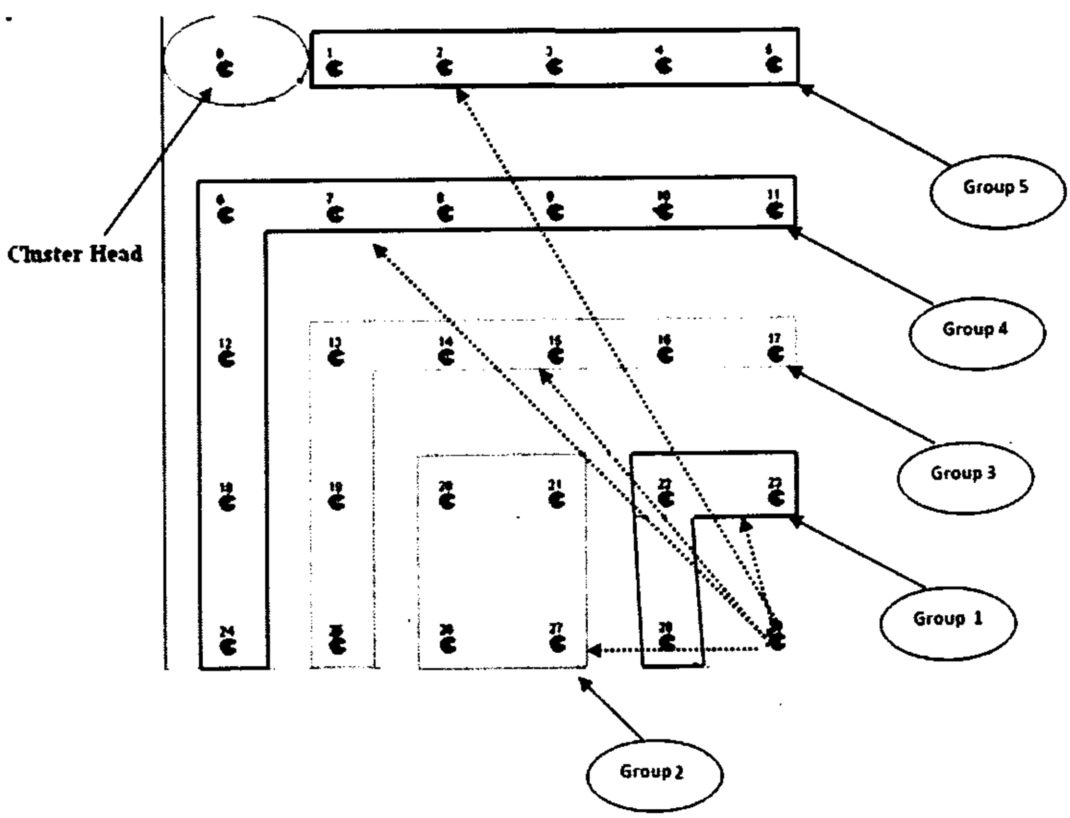

Figure 3.1: Next Hop Scenario

In above mentioned figure, we categorized node in 5 different groups on the basis of distance. We choose node number 29 as a source node that wants to send its sensed information to cluster head. Each group contains some nodes which have same distance to node number 29 i.e. nodes in group 1 have same distance from node 29. Nodes in group2 have same distance and so on till groups 5. Now at the start of the network, Source node (29) uses one hop routing and sends its sensed information directly to the cluster head, when its energy level becomes less than a specific level it shifts its routing model from one hop model to multi-hop model. Now the problem is when source node uses multi-hop model then what intermediate node can be used and what would be its distance from source node, as there are five different groups in cluster and in each what is the criteria to use intermediate node. Since it is not described that how many nodes will be used as intermediate nodes, this solution remains incomplete and inefficient

3.1.2 Problem Scenario 2

Fig 3.2 describes the second problem in intra-cluster routing which is to find the next node. Same scenario as describe in previous figure. The source node want to send its sensed information to cluster head and the nodes are grouped in the cluster on the basis of distance. When source node (29) use multi-hop routing model and also find its next hop. Now it has to find, what will be the next node used for the multi-hop routing as there are five different groups. Each group has more than one node which has same distance from source node, now the question is which node will be used as intermediate node then.

In below figure, we assume that source node selected group 3 to send its data through that distance of group 3. Eight nodes are in selected group which are at same distance to source node, now which node will be selected to routing and on which basis intermediate node will be selected. Absence of this information affects the overall efficiency of routing protocol and reduces the network lifetime.

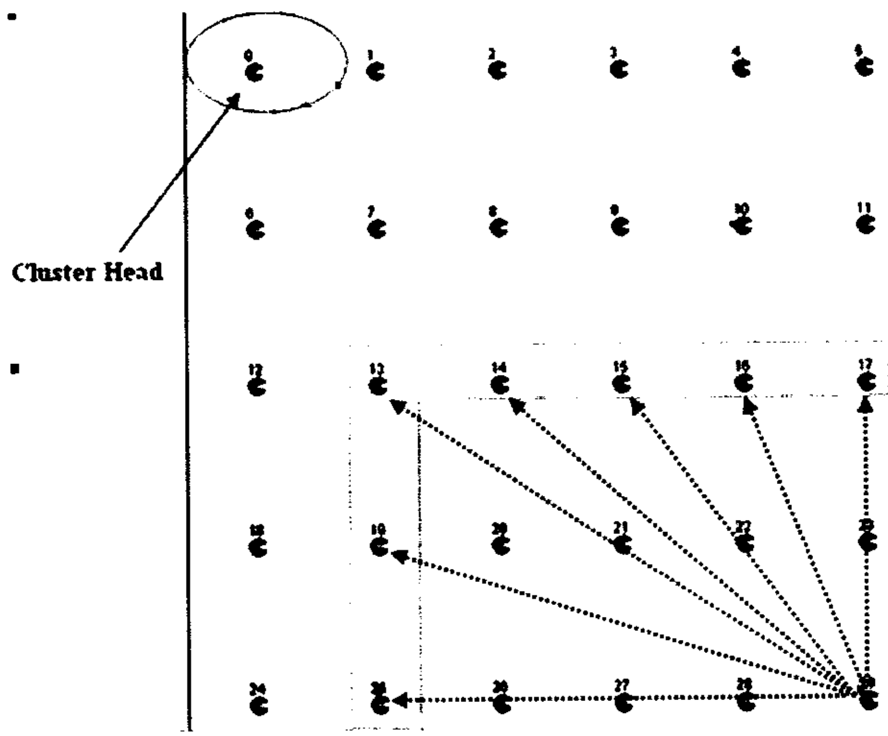

Figure 3.2: Next Node Scenario

In above problems scenarios, we found the two problems when node will use multi-hop routing model in intra-cluster routing. First problem is to find the next hop and second is to find the next node. The absence of this information will affect the mechanism of selection of multi-hop routing model.

Chapter 4

Solution & Methodology

4.1 Proposed Routing Mechanism

To overcome above mentioned problems, we proposed a solution which is complete in every aspect for present problems of finding the next hop and next node in wireless sensor network.
In this chapter, we will discuss the proposed solution and methodology.

4.1.1 Energy Efficient & Hybrid Adaptive Next Hop Routing

Routing is the key point in wireless sensor network, it effects on the energy consumption of each node while communication to other node, because as much complex and non efficient routing used in wireless network it increases the energy consumption of node. This results that the node will be dead soon, so every researcher specially focus on routing in WSN while doing research in WSN.

Adaptive routing mechanism for WSN is an efficient energy utilization technique which takes the benefit of both direct and multi-hop model and change the routing model according to conditions.
Our major research objective is to achieve efficient utilization of energy of each node within the WSN. We will provide a routing protocol which provides load balancing for transformation of nodes data to base station.

4.1.2 Design Features

Our proposed routing protocol "Energy Efficient & Hybrid Adaptive Next Hop Routing" have following features.

- Solution of two problems "to find next hop and to find next Node".
- Energy efficient routing mechanism.
- Adaptive routing mechanism to change routing model from one hop to multi hop.
- Increase to lifetime of the network.
- Better than traditional routing techniques.

Our proposed solution is based on two problems. One is to find the next hop and second is to find the next node. We proposed an energy efficient routing mechanism for WSN and we called it Adaptive Next Hop Routing. In our proposed mechanism all the nodes start with one hop routing model. It means at the start of the network every node sends data directly to BS or to cluster head in case of cluster based computing.

After some time energy of few far distance nodes start decreasing very quickly as compared to the nodes those are near to the BS or cluster head. Whenever energy of the nodes reach up to a specific threshold it can shift from one hop routing to multi-hop routing. In Multi-hop routing calculation of remaining energy of node will continuously perform to select intermediate node. Fig 4.1 shows the process of shifting a routing to multi-hop routing node from direct.

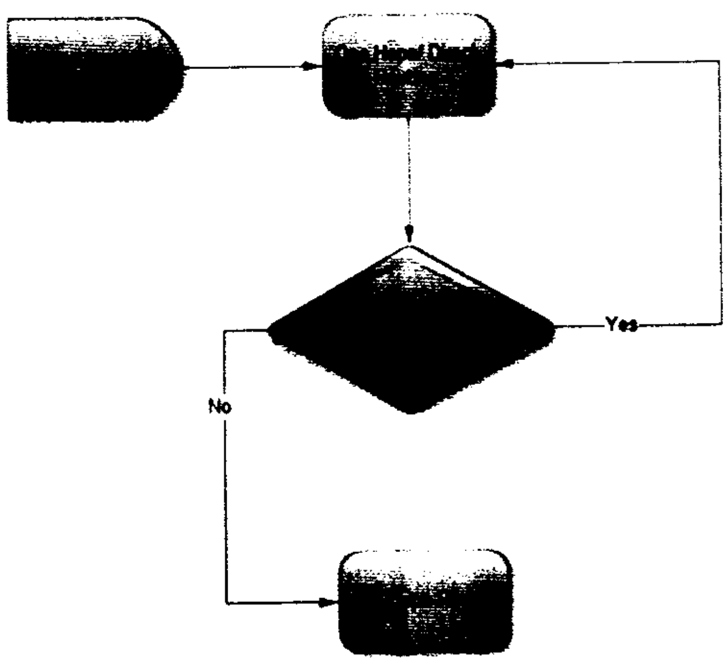

Figure 0.1 direct and multi-hop selection process

When a node is shifted from direct routing to multi-hop routing, two main tasks have to be performed which are the core objects of the protocol. First one is to find the next hop and second one is to find the next node. Which node is to be selected as intermediate node when we have decided that next hop will be after four hops and more than one nodes are available at 4 hops then which node will be selected for routing.

In multi-hop routing two main processes will run by the algorithm. One is next hop selection process and second is next node selection process. Next hop selection process will select the next hop for the source node. After selection of next hop it needs to find the next node, as if the number of node in selected group for next hop is more than one then another selection process needed to find the next node which is next node selection process. So our proposed algorithm first checks the number of nodes in selected group if there is only one node in next hop group then it is selected as a next node but if the nodes are more than one then next node selection process will be selected to chose the perfect node to carry the data to base station. Fig 4.2 show the selection of intermediate node process

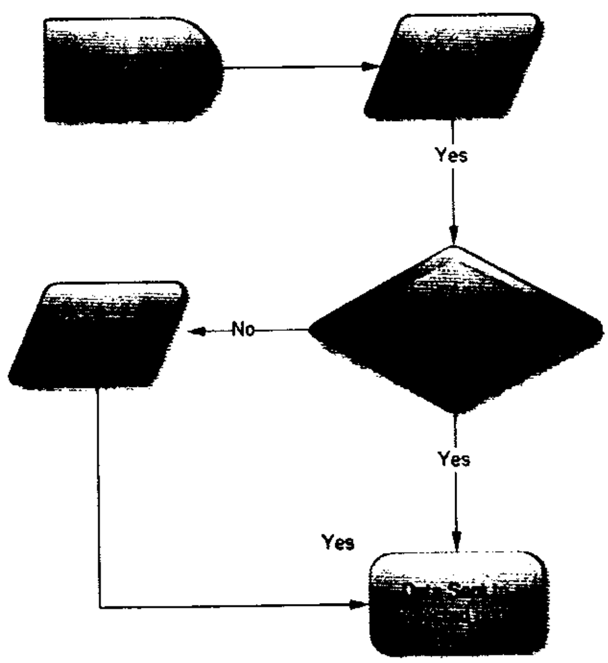

Figure 0-2 Selection of intermediate node

As the time passes and the remaining energy of the nodes further decreases, the adaptive nature of our proposed solution changes the formula to calculate the next hop and the next node to send data to base station. This mechanism efficiently allocates the next hop to the sensor nodes and balances the load on the network nodes to increase the overall network lifetime.

4.2. Solution Scenarios

We divided the working of proposed solution in different scenarios on the basis of time slots. As the time passed the working of algorithm will change. We denoted that time slot as t_0, t_1, t_2 ..... t_n. In following sections we discussed each scenario in detail.

4.2.1 Scenario 1: At time slot t_0

Fig 4.3 shows the area of sensor network at the start time which is denoted as t_0 where sensor node place in the area by using grid topology. Each node in the given area has same distance to other node. We chose node 0 as a cluster head. First, algorithm calculates the energy of each node. If the energy is greater than a specific threshold which is defined in the algorithm to chose direct routing then direct routing model is selected and data sent directly to cluster head by the source node. At the start of the network each node has full energy so every node chose direct routing. As shown in the fig 4.3 the source node 29 sent its data directly to cluster head.

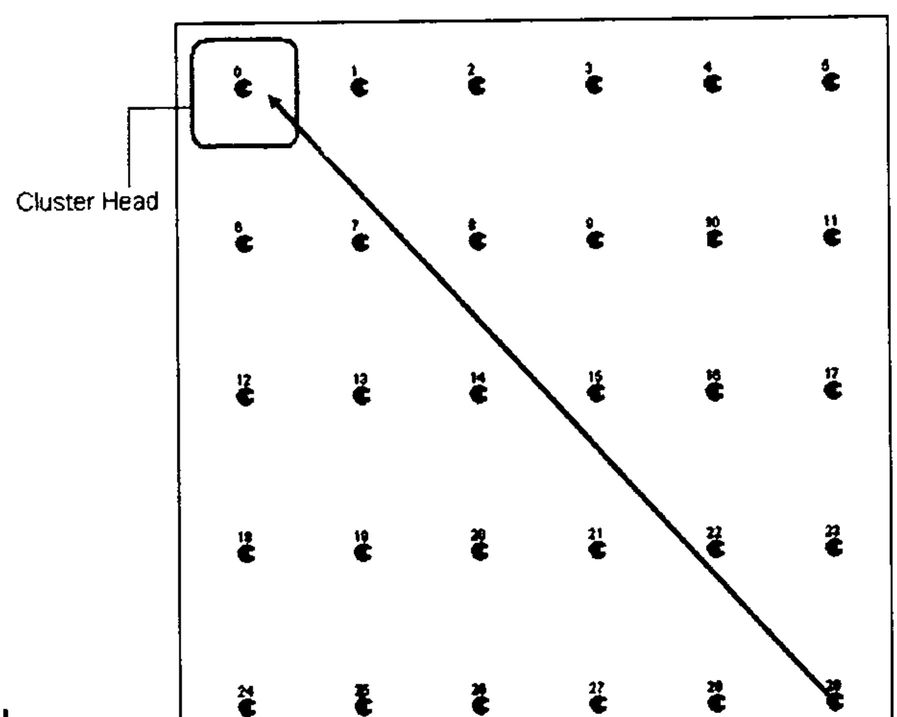

Figure 0.3 algorithm at time t_0:

4.2.2 Scenario 2: At time slot t_1

The nodes which are at far distance form cluster head consuming more energy to transmit their data directly to cluster head, after some time their energy level become less than a specific threshold which are selected for direct routing . Fig 4.4 shows that time interval which is denoted as t1 where source node 29 select multi-hop routing. Now it is time to select the intermediate node. Intermediate node selection process has divided in two main parts. One is to select next hop and second is to find the next node. Algorithm first calculates the energy level of the source node and as per remaining energy of the node next hop is selected, Described below is the formula is to calculate the next hop.

THV= Thrash Hold value

If the remaining energy of the souse node > THV0 then Direct routing (direct to cluster head)

If the remaining energy of source node > THV1 then multi hop routing (Cluster head -1)

If the remaining energy of source node = THV2 then multi hop routing (Cluster head -2)

If the remaining energy of source node = THV3 then multi hop routing (Cluster head -3)

If the remaining energy of source node = THV4 then multi hop routing (Cluster head -4)

If the remaining energy of source node = THVn then multi hop routing (Cluster head -n)

Else source node = dead node.

Fig 4.4 shows the selection of next hope group. Algorithm calculates the remaining energy of the source node and declares that its remaining energy is greater than THV1 then it selects CH-1 as next hop. Now it checks that how many nodes are in CH-1 group and finds that three nodes 1, 6 and 7 have the same distance from the source node and selected in CH-1 and they have their distance on one hop form cluster head and they are selected as next hop for the source node 29.

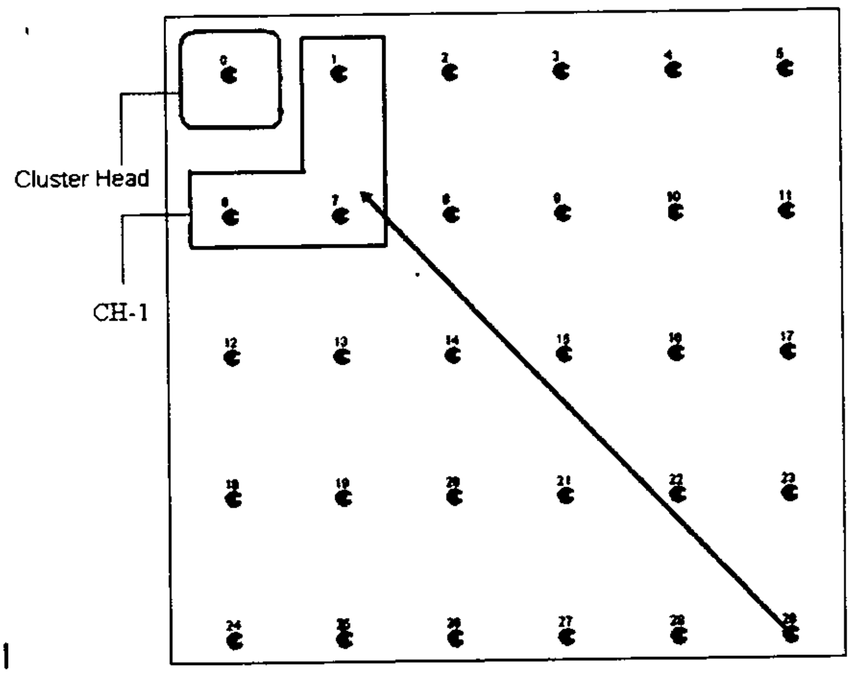

Figure 0-4: working of algorithm at time t_1

Now the second process is to find the next node as if there is only one node which have CH-1 distance then it is selected as next node but if there is more than one node CH-1 distance then we require another process to find the best node to chose as a intermediate node, we selected two methods for choosing the next node.

1 On the basis of remaining energy

If the nodes are more than one in having one hop distance from cluster head then we check the remaining energy of each node and the node have more energy then each other will be selected as next node as shown on fig 4.4a. Where three nodes are selected as next hop and node 1 is selected as next node because it has more remaining energy than other two nodes

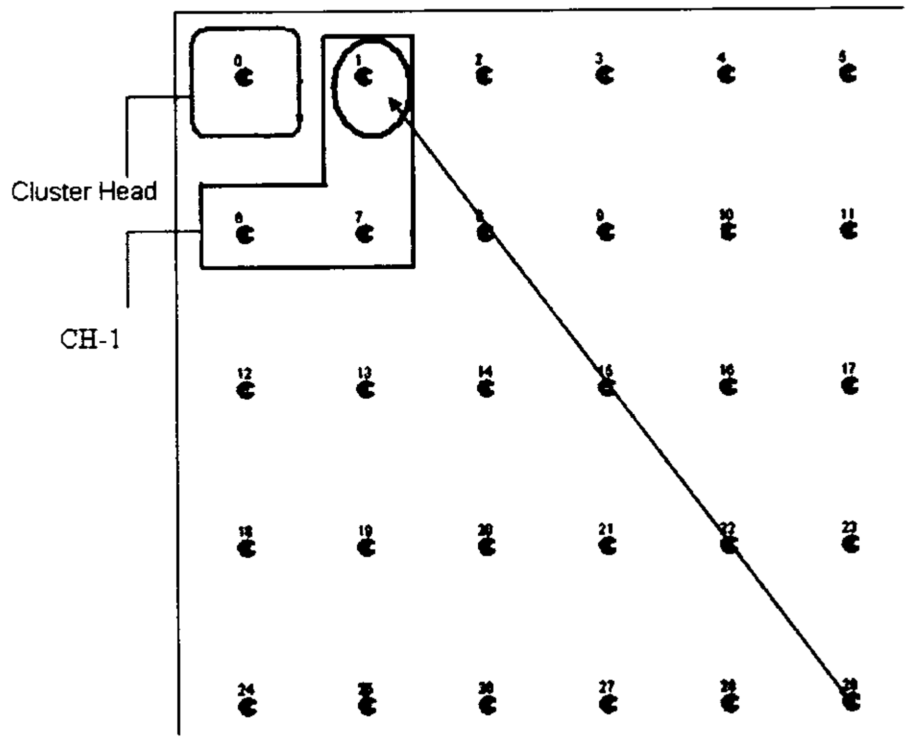

Figure 0-4a: working of algorithm at time t_1

2 On the basis of Round Robin selection

Second method is selection of next node by round robin method which equally loads on each node and send data one by on each node. As shown in fig 4.4b that three nodes1, 6 and 7 are selected as next hop source node sends it data to CH-1 node it equally divides its load on these three nodes and sends one by one packet to each node. First packet to node 1 second packet to node 7 and third packet to node 6 and then comes to node 1.

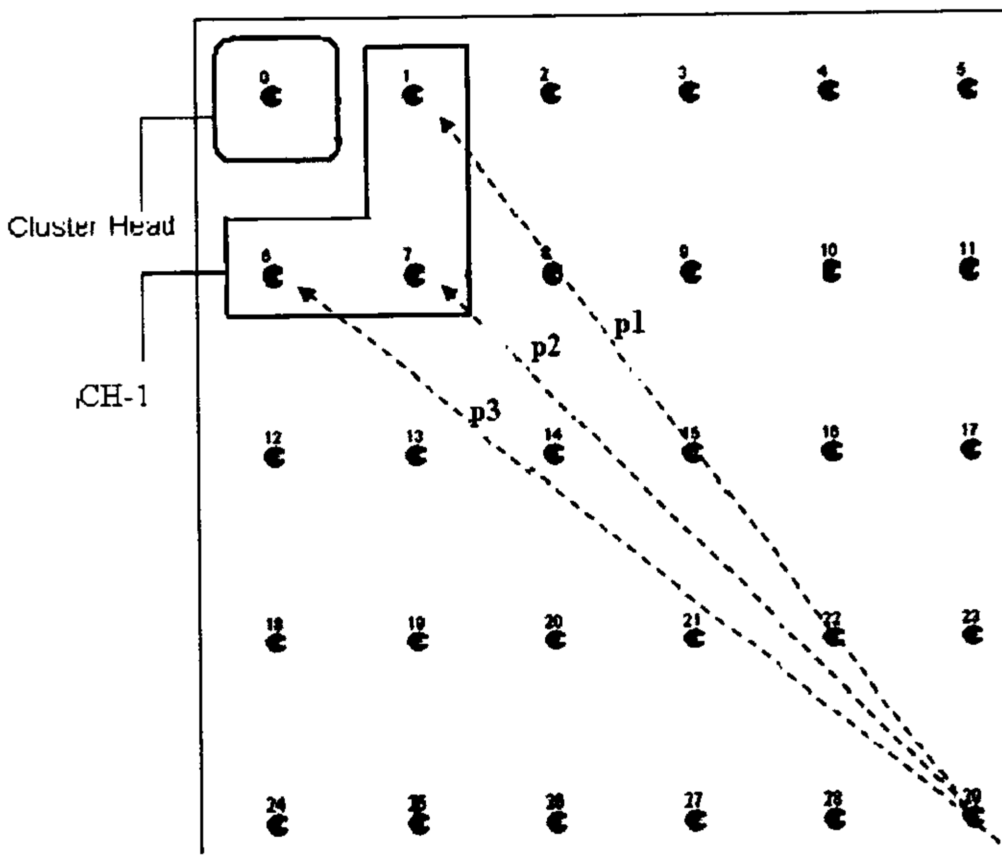

Figure 0-4b: working of algorithm at time t_1

After some interval the remaining energy of the source node will again decrease. That time is denoted as t2. Then the same procedure will repeat to find the intermediate node. Algorithm first calculates the remaining energy then selects the next hop and then finds the next node. In fig 4.4, 4.4a and 4.4b next hop is selected as CH-2 and where nodes 2, 8, 12, 13 and 14 have 2 hop distance form cluster head then by using next node selection method source node sends it data to node 12 which have more remaining energy then other nodes and second method is round robin where source node sends its data to each node equally distributing the load b sending each packet to each node.

4.2.3: Scenario 3: At time slot t_2

After some time interval the remaining energy of the node will decreases more. Now the intermediate node will be change because as per formula source node will change the intermediate node on the basis of remaining energy. As energy decreases the new intermediate node will be selected. In time slot t_2 when remaining energy of **source node will less the THV2** then is till selected the intermediate node which is CH-2 which is on the distance of 2 hop from Cluster head. Fig 4.5 shows the next hop group which is selected as intermediate node.

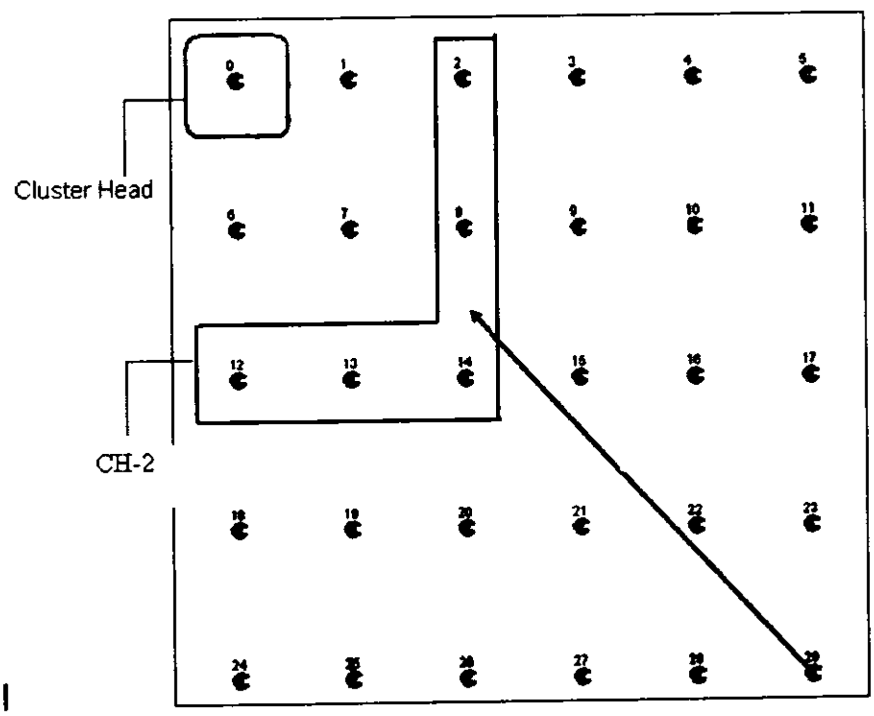

Fig 45 selection of next hop

When the next hop is selected from source node to send the data to cluster head then it is needed to decide the next node from selected next hop group. If there is only one node in next hop group then data will be sent to that node but if there are more than one node in next hop group then there are two methods to find out the next node which are discuss following

1 On the basis of remaining energy

Same as time slot t1 algorithm calculates the remaining energy of each node and selects the node with maximum remaining energy and that node will be chosen as next node from that specific group fig 4.5a shows the node 12 with maximum energy is selected as next node

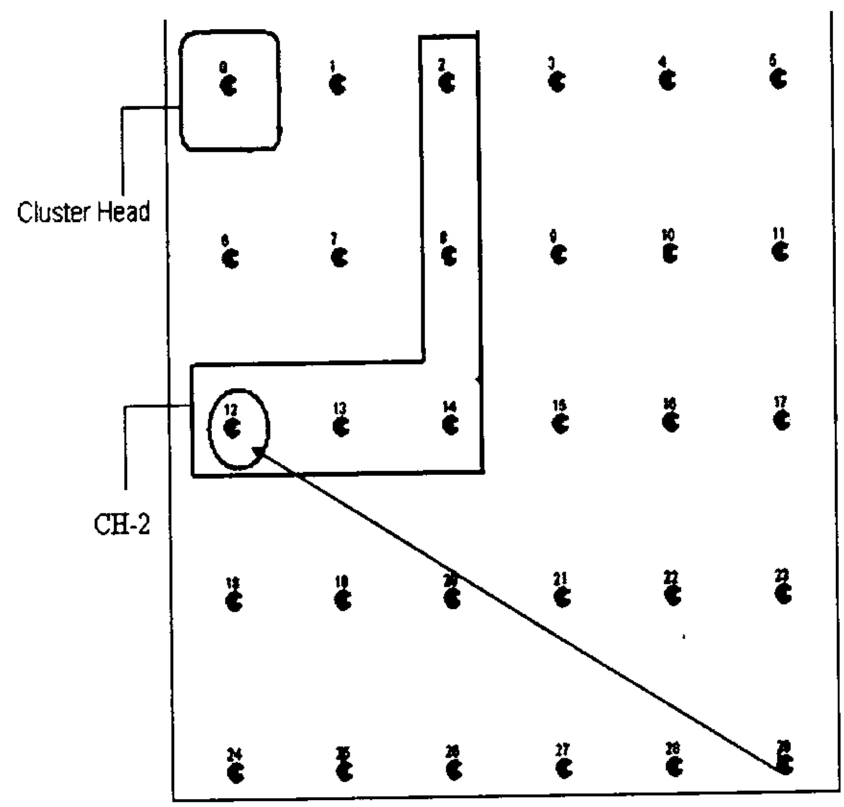

Fig 4.5a selection of next node with MRE

2 On the basis of Round Robin selection

Second method to select next node is round robin method which equally loads on each node and sends data one by one on each node, as shown in fig 4.5b where total five nodes2, 8, 14, 13 and 12 are selected as next hop. Source node sends its data to CH-1 node it equally divides its load on these five nodes and sends one by one packet to each node. First packet to node 2 second packet to node 8, node 14, node 13, and node 12 and then comes to node 2

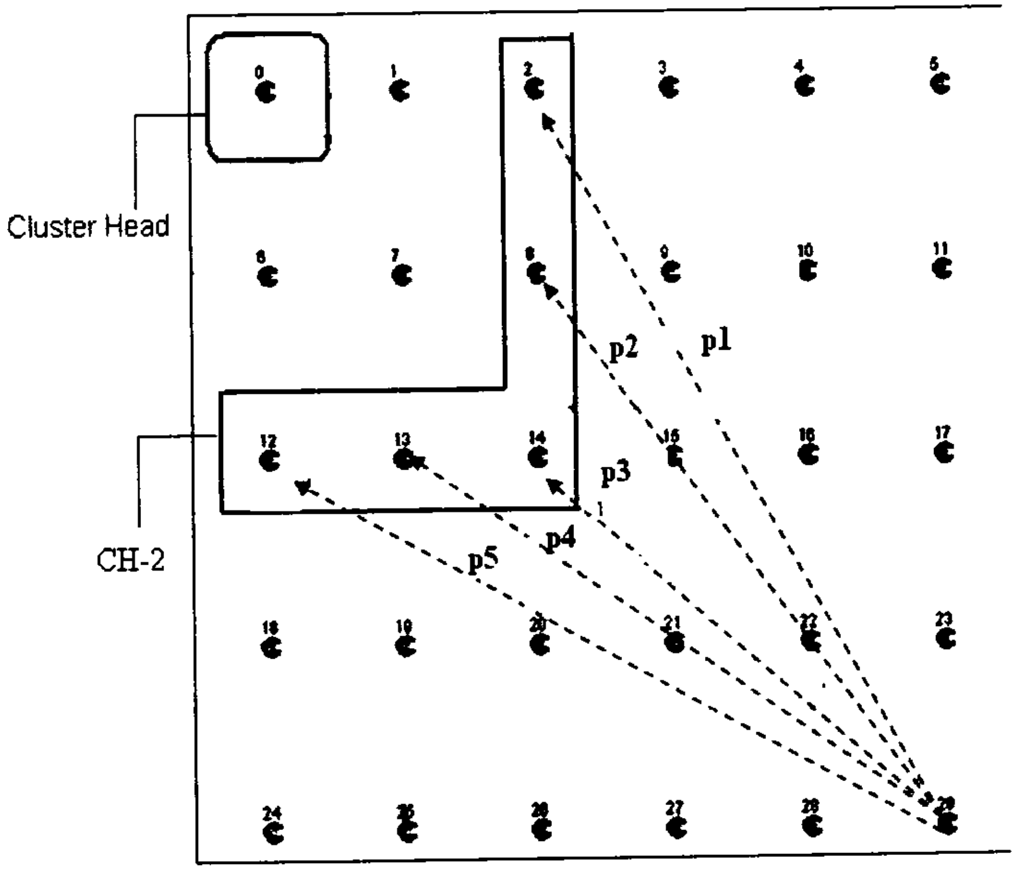

fig 4.5b selection of next node with RR

By implementing the above mentioned mechanism, we achieve long life of wireless sensor network because the load is balanced among all the nodes, resulting every node can utilize its maximum energy with more efficiency.

4.3. Flow diagram

Flow diagram will illustrate the flow of data from source node to cluster head from the start of the network to death of first node.

Before we study the flow diagram we must know the following terminologies:

1: At the start of the network, every node has 100 % energy.

2: Every node will share its remaining energy to each other node.

3: Direct Routing = source node send data directly to Cluster Head.

4: THV= Thrash hole value specified by the user.

5: R.E= Remaining Energy.

6: CH-1= all the nodes that are at the distance of one hop from cluster head.

7: CH-2= all the nodes that are at the distance of two hops from cluster head.

8: CH-3= all the nodes that are at the distance of three hops from cluster head.

9: CH-4= all the nodes that are at the distance of four hops from cluster head.

10: CH-n= all the nodes that are at the distance on hops from cluster head.

11: Dead node= the node with 0 % remaining energy.

We have two methods for selecting the next node. One is the selection of next node on the basis of maximum remaining energy and second is on the basis of round robin selection.

4.3.1Method 1: On the basis of Maximum remaining Energy

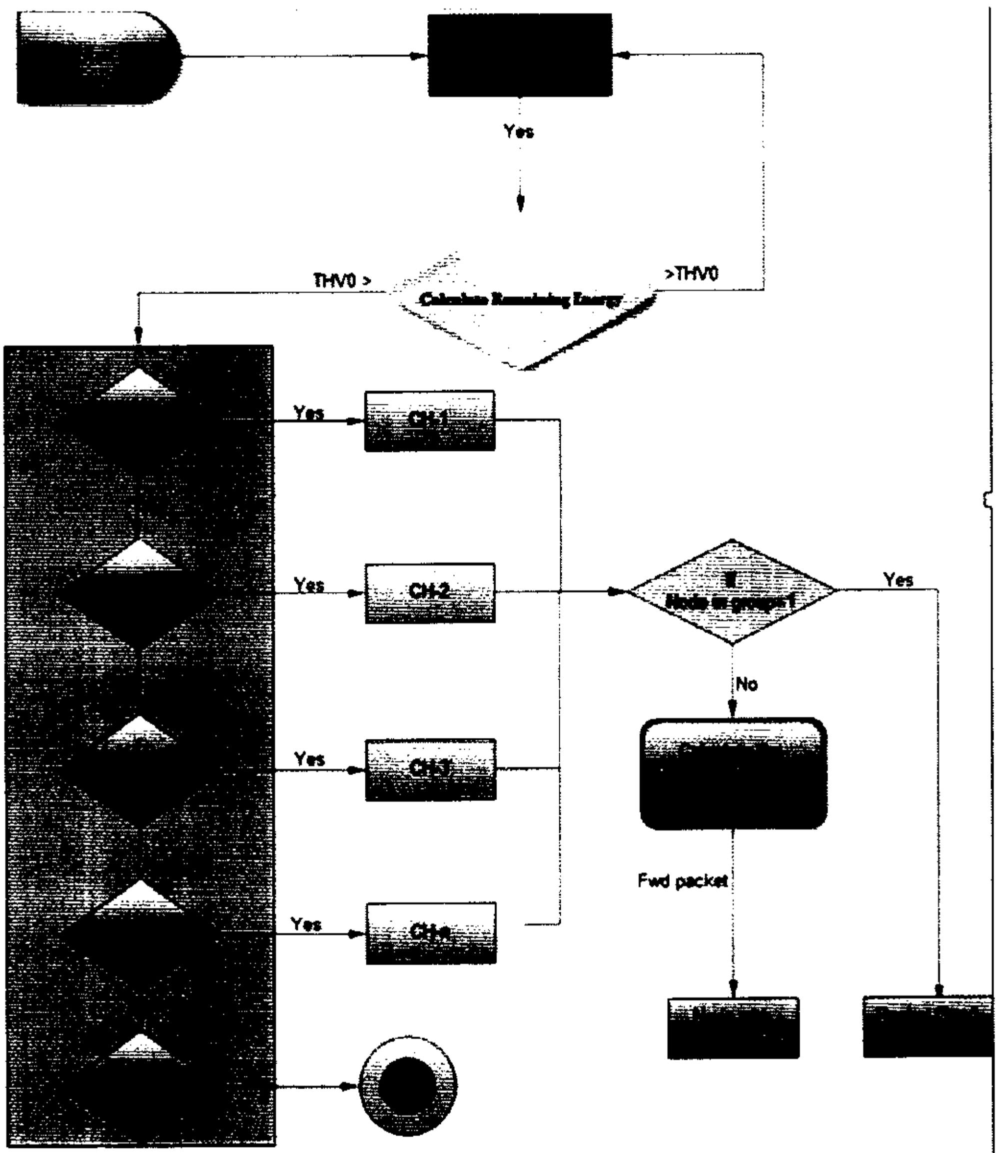

fig 4.6 Flow Diagram of algorithm with MRE

4.3.2: Method 1: On the basis of Round Robin Selection

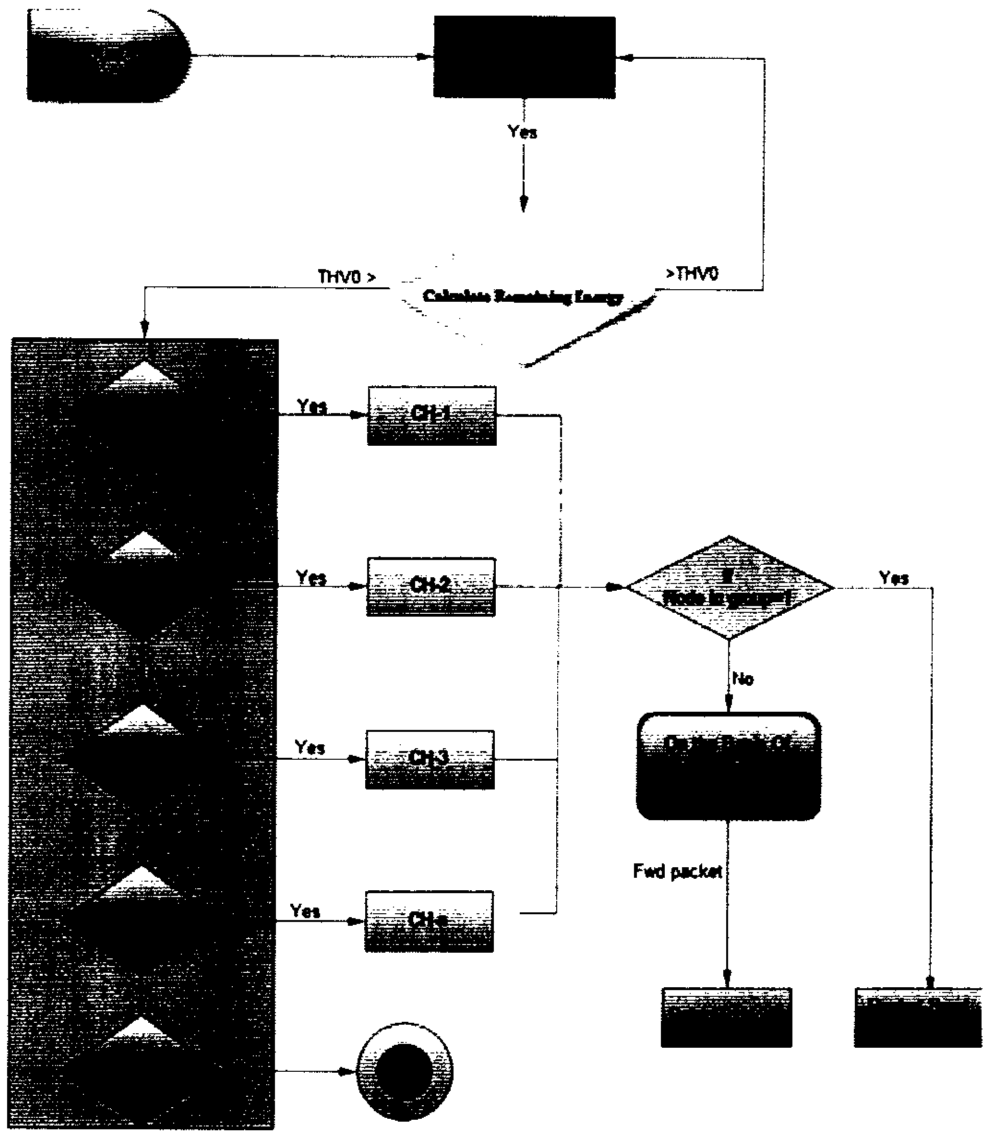

fig 4.7 Flow Diagram of algorithm with RR

4.4 Pseudo Code

Initialization

Direct Routing = source node send data directly to Cluster Head.

THV= Thrash hole value specified by the user.

R.E= Remaining Energy.

CH-1= all the nodes that are at the distance of one hop from cluster head.

CH-2= all the nodes that are at the distance of two hops from cluster head.

CH-3= all the nodes that are at the distance of three hops from cluster head.

CH-4= all the nodes that are at the distance of four hops from cluster head.

CH-n= all the nodes that are at the distance of n hops from cluster head.

Dead node= the node with 0 % remaining energy.

START

1: Send Data Directly to Cluster Head.

2: Calculate Remaining energy periodically.

3: If the Remaining energy <TV0 then

Start Multi-Hop Routing

Else

Continue Direct Routing

Multi-hop routing

```
                    Compare Remaining Energy with THVs
                    If (Next Hop = = Nodes hop+1)
                        Next hop will remain same
                    else
                        Select Next Hop on the basis of THV
                            If Number of node in Next Hop=1 then
                                Send Data
                            Else
                                Select Next Node
                            If Remaining Energy= 0 then
                                Node= Dead
        End
```

Next Node Selection Process

```
    Check the Next Node Calculation Method
    If Method = MRE
        Calculate the R.E of every node of the Next Hop
        Select  node with maximum energy
        Send data to selected node
    If Method = RR
        Send data to the next hop nodes on round robin basis
```

Chapter 5

Implementation & Results

5 Implementation & Results

In this chapter, we will discusses the simulation details, assumptions ,topology, implementation details and scenarios and obtain the results with two proposed methods and further discuss the comparison of recent results with traditional algorithms then explain the results and comparisons by graphs. We will use TOSSIM simulator for simulation. We will discuss its features then compiling procedure of application, nesC language and its details. Three different methods will be used to obtain the result with two proposed solutions. Simulation results of proposed solutions will be compared with the results of traditional algorithms

5.1 Simulation

Simulation is the process to check and verify the proposed application in artificial environment so before real implementation the error and flaw can be checked. Wireless sensor network contains costly hardware and is not commonly available for research purpose. So researcher prefers simulator to check and verify the proposed algorithm for WSN.

There are many simulators available in the market for WSN applications. We use TOSSIM Simulator with tiny OS operating system and with nesC language for simulation of our proposed solution. The details of each simulation tools is given below

5.1.1 TOSSIM Simulator

TOSSIM simulator is specially designed for simulation of wireless applications which can easily handle the network with more than thousand nodes with user-friendly and easy to handle features. It has special characteristic for WSN that after compiling the code it can be burnt on motes without further modification. It has 4MHz simulation time which is equal of 4×10^6 ticks/second and that code in TOSSIM runs without any delay which mean that TOSSIM has 99.9 % accuracy in term of time.

TOSSIM has feature of flexibility which means that a module can be added or removed and can easily connect the external tools to achieve the required functionality which has no effect on efficiency, for example radio model is not available in TOSSIM but a java base tools

"LossyBuilder" can be used to achieve radio model and the input file is imported in TOOSIM to simulate the radio application, same like power/energy, building, network etc models can easily be added in TOSSIM for specific related applications.

5.1.2 TinyOS

Tiny OS is component based operating system written in nesC language designed for wireless sensor network. It is an open source embedded operating system which was initially release in 2000.Tiny OS provides interfaces and component for routing, packet communication, storage, sensing many common abstraction. TinyOS provides sensor driver which can be easily configured and tested. It also provides the radio component which has many features like media access control (MAC) capability, detection of channel activity, collision avoidance, scheduling, data transfer, and power management. TinyOS has become the platform for sensor network research as sensor motes have limited hardware in terms of memory, power and processing so a very flexible and lightweight operating system is required for that hardware. TinyOS has all the features which a sensor mote requires. It is not an operating system in traditional sense rather it is a programming framework for embedded systems to set the components to achieve the required target. Each component in TinyOS has one or more interface and three computational abstractions which are command, event and task, .command and event is used to inter-component communication and task is used for inter-component concurrency.

5.1.3 nesC Language

nesC is the abbreviation of "Network Embedded Systems C" which is programming language having the syntax same like C language. It has characteristics of component -based and event driven which are special requirements to write the programs for embedded devices. Wireless sensor network also uses embedded devices like motes which operate by Tiny OS and these motes sense information and forward it to required destination with event driven characteristics.

We required rpm packages and cygwin to install nesC complier. nesC has interfaces as port with each component which is used to communicate with other components. These ports are called bidirectional because these are used for receiving and sending both at same time. Two files are created for nesC Programming Configuration file and module file. Configuration file contains the information of connection or wiring of one component to other component or how two components are bound to each other by their interfaces and module file contains the actual implementation of application

5.1.4 Simulation Setup

We used TOSSIM as a simulator for simulation of our proposed technique, basically TOSSIM runs on Linux. We used a Linux emulator Cygwin to use TSSIM in windows environment and then configured Tiny OS. After configuring Tiny OS, code is written in nesC language and for compilation of the code we run Cygwin shell, after running cygwin shell we go to the Application directory and write make pc. Pc is used for simulation purpose in TOSSIM. Fig 5.1 shows the compiling process of application in Cygwin.

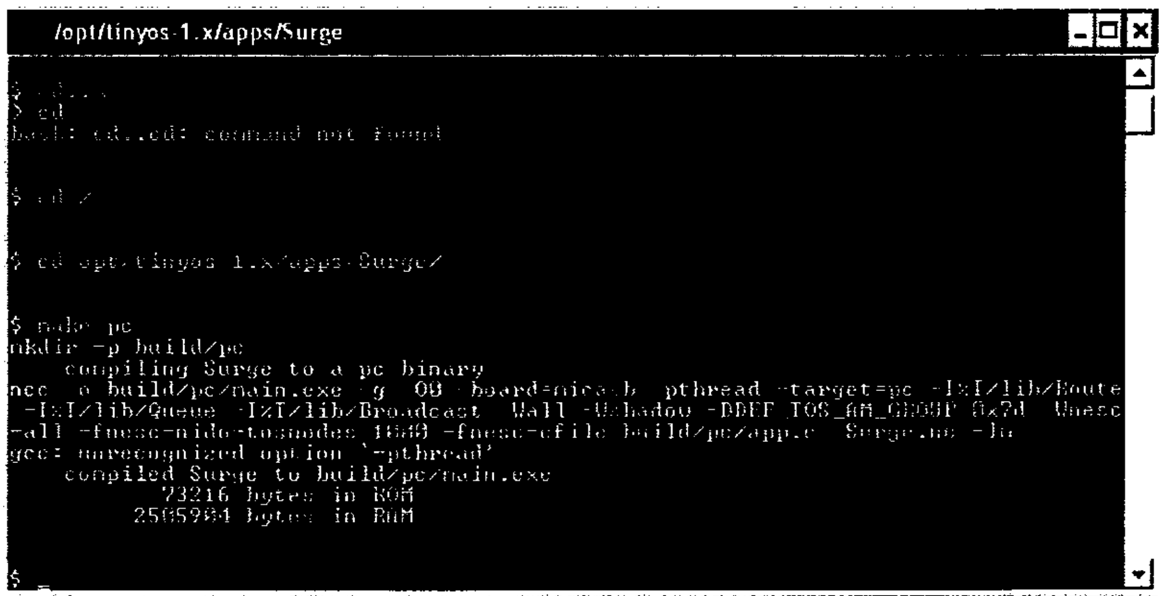

Fig 5.1: Compiling the Application

After compiling we need to run the application, TOSSSIM also supports GUI where we can see the graphically view of running application. TinyViz is a popular tool for TOSSIM to support GUI, for running the compiled application. We need to open Cygwin shell, go on the director of the application and write command build/pc/main.exe –gui 30 –t120sec it means that simulation will automatically stop after 120 second . Fig 5.2 shows the connectivity of application with TinyViz Gui module.

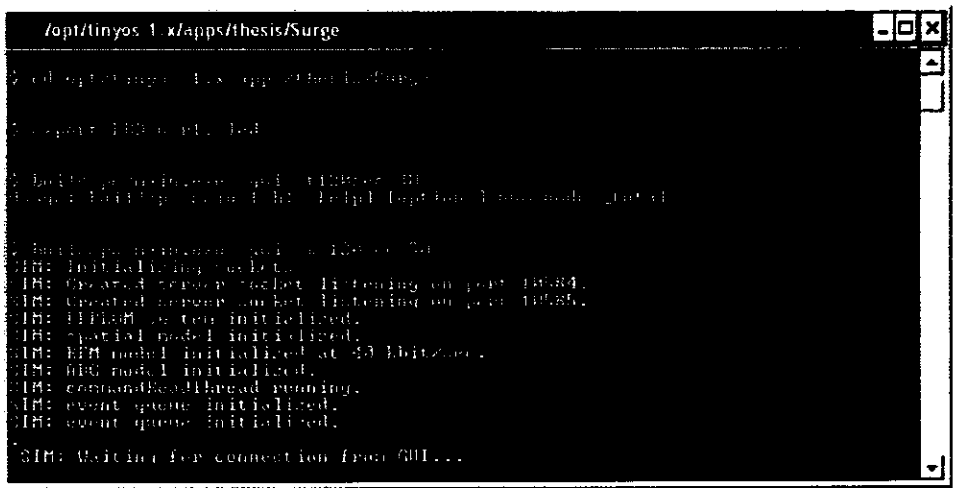

Fig 5.2 Connection with GUI

For graphical presentation we need to run another command to open GUI interface of application. We open another Cygwin and run command java net.tinyos.sim.TinyViz .fig 5.3 shows the graphical presentation of running application

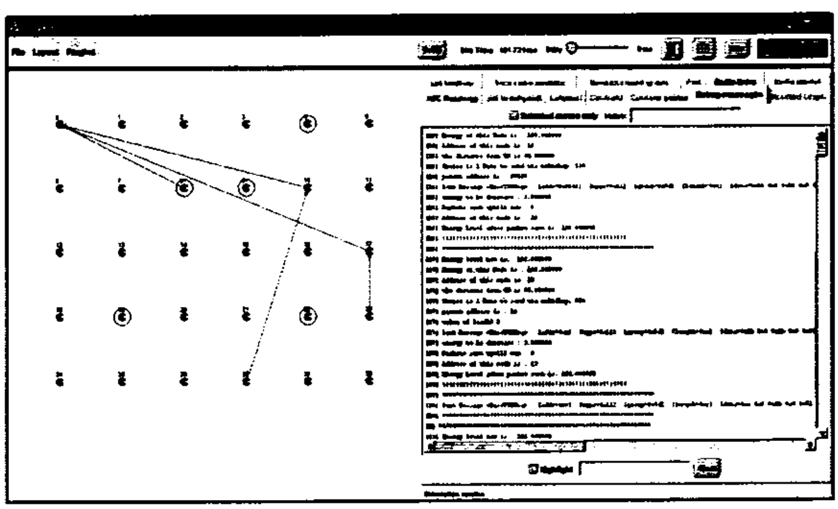

Fig 5.3 Graphical Presentation of application

In Fig 5.3 you can see two portions one is showing the graphical presentation of node. Node with circles mean initialization of nodes and nodes with line means data transferring, second portion showing the details of each node with packet sending and remaining energy.

Following are the setup for simulation of our proposed application.

1: Geographical area is 75 sq Feet.

2: Total 30 nodes is used in a cluster.

3: Nodes IDs from Node 0 to Node 29.

4: All nodes are in grid layout.

5: Distance between two nodes is 15 feet which will remain fixed.

6: Node 0 is selected as cluster Head.

7: every node will share its current energy level to other node.

8: Remaining Energy will periodically checked by every node.

9: Each node will have 100 % energy level at the start of the network.

10: Energy Efficient & Hybrid Adaptive Next Hop Routing protocol runs on every node.

11: Physical environment will remain same for all the nodes.

5.2 Implementation details

The main purpose of our proposed algorithm is to find the intermediate node and perform energy efficiency, in our proposed algorithm two types of selection process for choosing the intermediate node, one is next hop selection process and second is next node selection process when next hop group is selected and there is only one node in selected group then data sent to the that node but if there are more than one nodes in selected next hop group then we used two methods for selection of next node, one is on the basis of maximum remaining energy and second is on the basis of round robin. Following are the details of two methods

5.2.1 Energy Efficient & Hybrid Adaptive Next Hop Routing with Maximum remain Energy selection

We assume that every node will check its reaming energy periodically and inform to all other nodes about its current energy level. In this method energy is calculated of each node of the next hop group and the node with maximum remaining energy is selected as destination node.

5.2.2 Energy Efficient & Hybrid Adaptive Next Hop Routing with Round Robin selection

In this method next node selection is based on round robin method each node in the next hop group will be chosen as a next node one by one for a particular time period and data is sent to that selected node

5.3 Simulation Experiments

We perform four different experiments with different scenarios and parameters in simulation.

5.3.1 Experiment No 1

In first experiment we select the energy level of each node that is 300 mJ, Total number of nodes in the network is only 30 nodes, geographical area covered by the network is 75 sq Feet, topology layout is grid, node 0 is selected as cluster head and simulation time is approximately 20 minutes. Table 5.1 shows the list of parameters considered for the simulation.

Table.1: Simulation Parameters - Experiment no 1

Parameters	**Value**
Layout Topology	Grid
Simulation Time	20 min
Maximum Energy level	300 mJ
Distance Unit	Feet
Cluster Size (Nodes)	30
Cluster Head	Node 0

5.3.2 Experiment No 2

To check the efficiency in details we changed the energy level and simulation time In this 2nd experiment. Energy level of each node is taken 600 mJ at the start of the network and simulation time is 40 minutes. Other parameters are kept constant.

5.3.3 Experiment No 3

In this 3rd experiment energy level of each node is increased from 600mJ to 900 mJ and simulation time for that experiment is 60 mints. Other parameters are kept constant.

5.3.4 Experiment No 4

In this 3rd experiment energy level of each node is increased from 900mJ to 1200 mJ and simulation time for that experiment is 120 mints. Other parameters are kept constant.

5.4 Performance Matrix

Following are the performance matrixes which we will measure after implementing our proposed Algorithm

5.4.1 Energy Consumption

Energy consumption is very crucial and important part in wireless sensor network by optimizing the energy consumption we increase the lifetime of network. Energy consumption in WSNs is greatly based on Routing protocol, every protocol which optimizes the energy consumption with accurate result in WSNs is known as best routing protocol, our next hop routing protocol is also on energy efficiency and aims to increase the lifetime of the network with target to achieve desired results. So in result we measure the energy consumption of every node in the network.

5.4.2 Network Lifetime

The time when first node in the network becomes dead is considered the lifetime of the network. It is also a key characteristic of wireless sensor network for evaluating performance of network. Our proposed protocol is specially designed to increase the lifetime of the network and we will measure the network lifetime of wireless sensor network in our proposed protocol by calculating the first and last packet received form each node.

5.4.3 Average Packet Sent

Every node sends its sensed information to other node or cluster head in form of packets, to know the efficiency of routing protocol we measure that one node send how many packets and what are the number of average packets within the network, an efficient algorithm is with more packets within specific time periods.

5.4.4: Local work

In wireless sensor network two types of work are done by a node, local work and remote work. Local work means that a node to sense the information from environmental changes and then send it to the next node or cluster head. Our proposed algorithm is to keep the balance between local work and remote work to increase the efficiency of the network so we measure the local work done by the each node in the network.

5.4.5 Remote Work

Node is also responsible for remote work which means to receive the data from other nodes and then send it to the next node or cluster head. Our proposed method which is mixture of direct and multi hop routing so we find the remote work done by each node and then analyze its performance.

5.5 Results

We simulated our proposed algorithm with above mentioned simulation parameters and obtained the results. We compared our obtained results with other four techniques i.e. Direct, Multi hop, Adaptive and hybrid adaptive. On the basis of four experiments with energy level 300,600,900 and 1200mJ we calculated the results and then compared obtained results with other techniques. Comparison of our proposed method's results is shown in form of graphs which show the efficiency of proposed algorithm. The comparison of results with other techniques intermesh on following matrix.

5.5.1 Total packet sent in the network with Maximum energy remaining

In this experiment we set 300mj as initial energy level on all nodes of the deployed network. After that we activate the network and measure how many packets are sent during the lifetime of the network. We find that our solution gives the better results as compared to other solutions. 1440 packets are sent by deploying direct routing, 1229 packets are sent through multi-hop routing. Adaptive solution sent 2070 packets and hybrid adaptive solution results in transmission of 2520 packets. When we test our proposed mechanism we find that total 2730 packets are sent in the network. So our solution is transferring 210 more packets as compared to latest available technique. The reason of this increase is efficient use of the intermediate nodes according to the requirements and energy of the sending node.

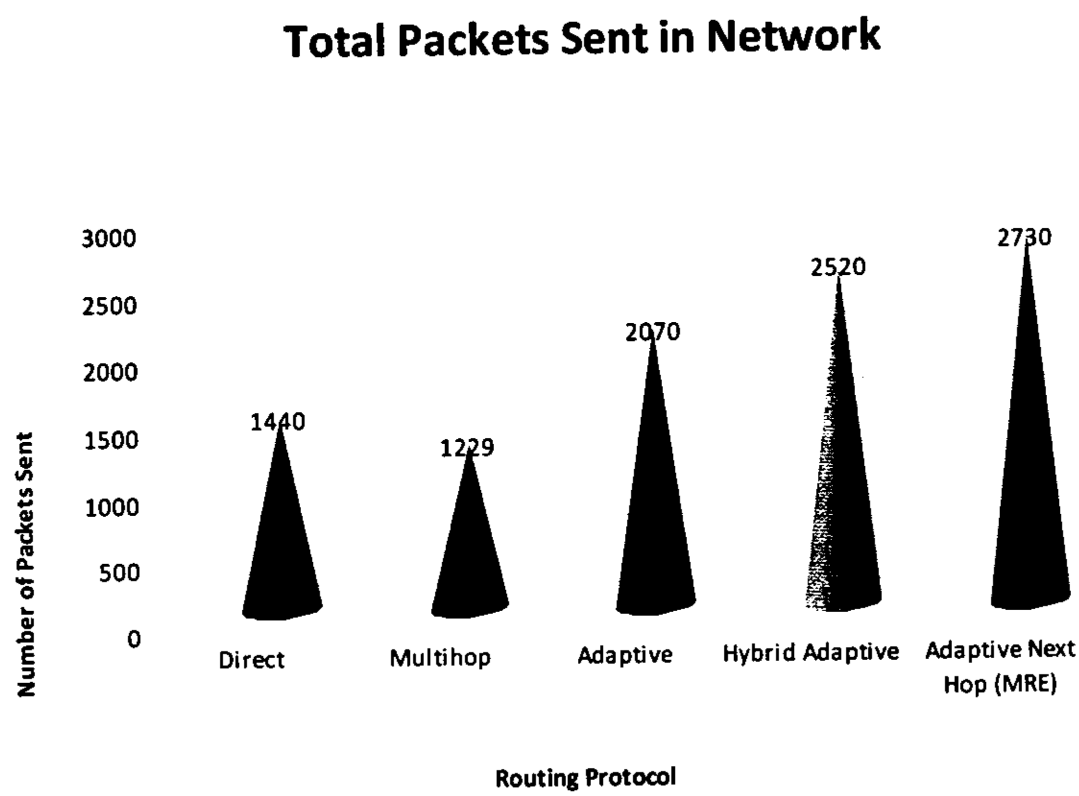

Figure 5.4: Total Packet Sent in the Network with MRE

5.5.2 Total packet sent in the network with Round Robin Selection

We simulate the same matrix (packet send in the network) with same parameter by using round robin selection method and found that its results are also better than all other techniques. The total number of packets sent in the network for specific energy level is 2610 which mean that our proposed method with round robin technique transfers 90 packets as compare to other available techniques. Fig 5.2 shows the graphical presentation of comparison of next hop routing round robin selection method with other techniques

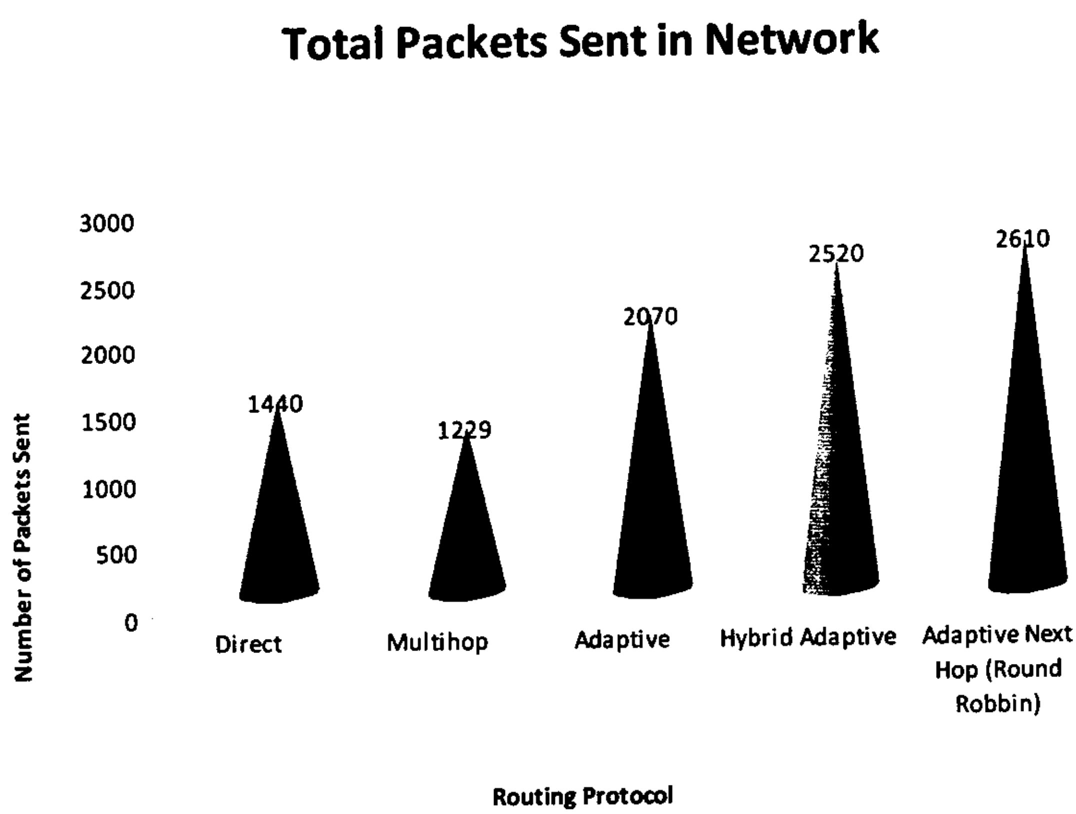

Figure 5.5: Total Packet Sent in the Network With Round Robin Selection

5.5.3 Average packet sent in the network with Maximum energy remaining

Figure 5.3 shows the comparison of our proposed algorithm which is adaptive next hop routing protocol with maximum energy remaining method with other four techniques by calculating average packet sent in the network . We calculate average packets sent in the network by finding how many packets sent by all nodes during specific time period and then divide total packets with total number of nodes then we find the average packets sent in the network in a specific time duration. We calculate this average packet by setting four different energy levels of every node. Firstly we calculate average packets by setting 300 mJ energy level of each node then 600 mJ then 900 mJ and finally 1200 mJ and found the average packets transmitted in the network which are 87,198,314 and 386 simultaneously then compare these results with direct, multi-hop, adaptive and hybrid adaptive. As a comparison we find our proposed technique sends more packets than other techniques in all four energy level. At 300 mJ energy it send 7 packets more than other technique at 600 mJ energy it sends 15 packets more at 900 mJ energy its sends 27 packets more and at 1200 mJ energy level its sends 25 packets more than the other techniques. The reason of this increase is efficient use of the intermediate nodes according to the requirements and energy of the sending node

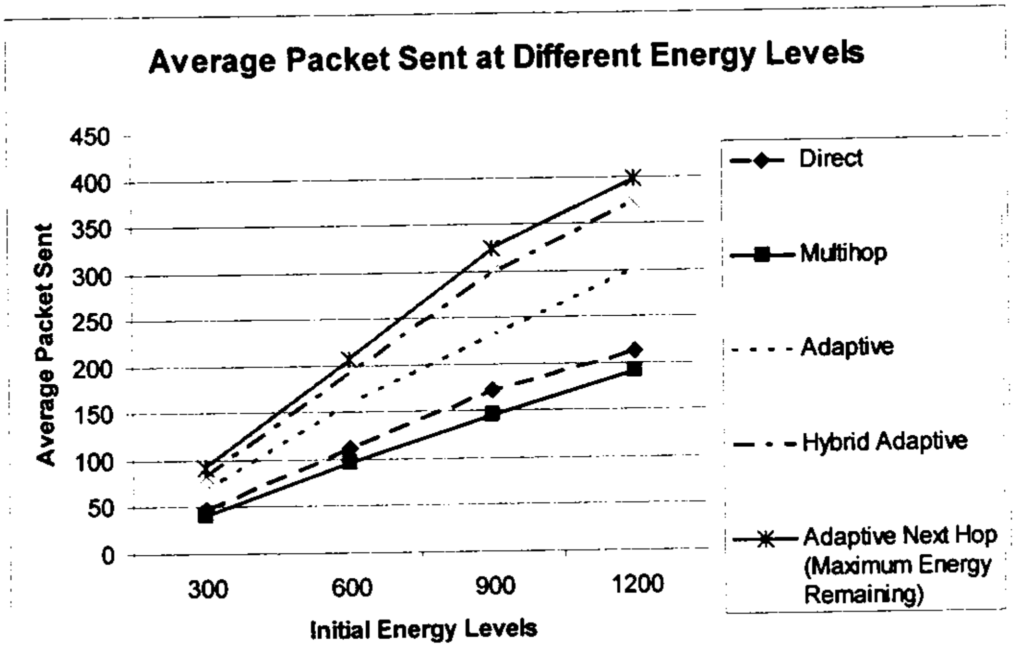

Figure 5.6: Average Packet Sent in the Network With MRE

5.5.4 Average packet sent in the network with Round Robin Selection

We simulate the round robin method for calculating the average packets in the networks

Fig5.2 show the comparison of next hop routing round robin selection with other routing techniques in average packet send in network.

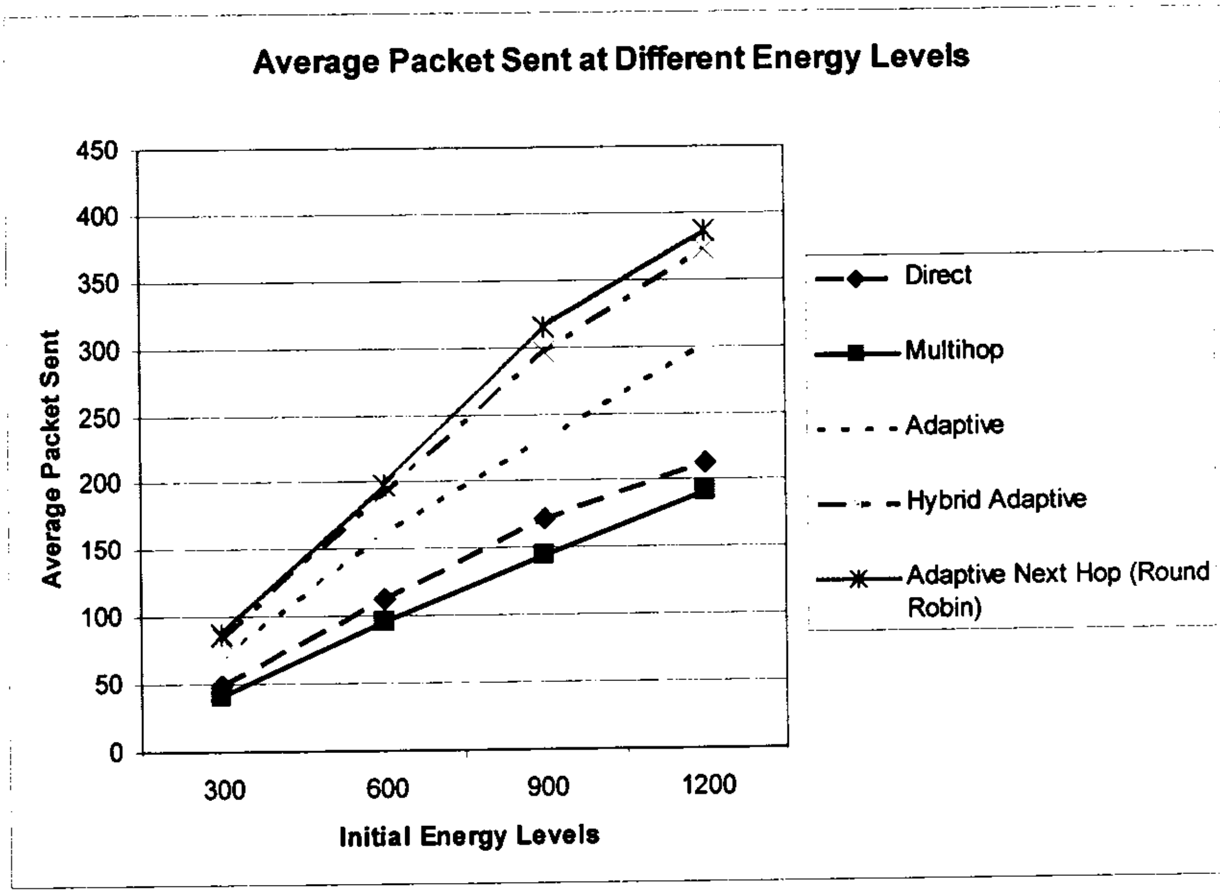

Figure 5.7: Average Packet Sent in the Network with Round Round Robin

In above mentioned graph you can see the performance of five different protocols and in which adaptive next hop is showing better results than all other methods. We calculate the average packet sent in the network by setting 300 mJ energy values and calculate that 87 packets sent in the network then increase the energy value from 300 mJ to 600 mJ and calculate 198 average packets sent at 900 and 1200 energy level average packets sent in the network were 314 and 386 simultaneously .we compare these results with other routing techniques and found our proposed techniques is better than all other techniques in terms of average packet sent in the network by sending 3,7 17 and 13 packets than other techniques.

5.5.5 Network Lifetime with Maximum Remaining Energy

As we discussed earlier that lifetime of the network means the death of first node in the network and any network which have long lifetime is consider an efficient network. We measure the lifetime of the network by simulating with different parameter and found that next hop routing protocol's results are better than other routing techniques. Fig 5.3 shows a graphical presentation of all routing techniques in terms of network lifetime.

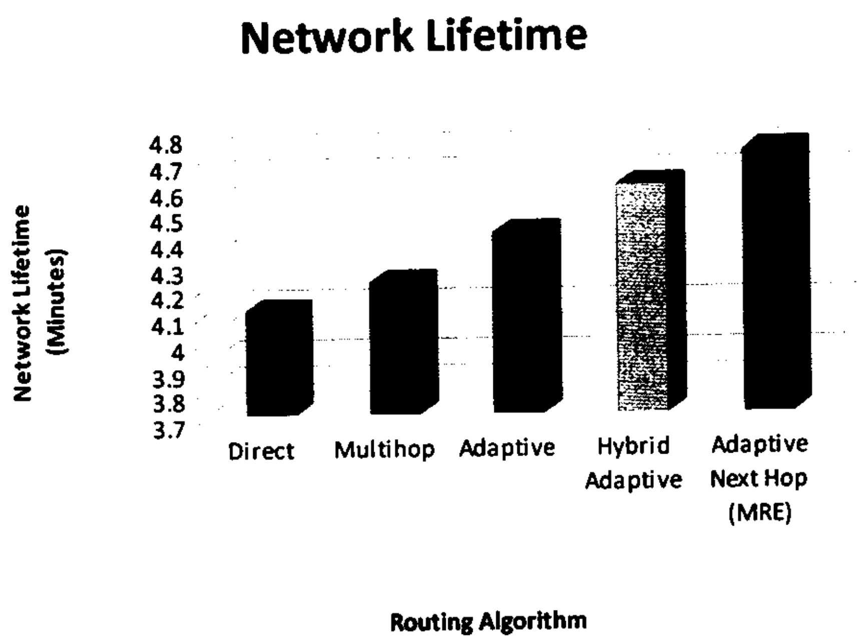

Figure 5.8: network lifetime with maximum remaining energy

We set parameters as 300mJ energy level of each node and start the network so the first node becomes dead after 4.71 minutes and in other routing techniques (Hybrid Adaptive) the first node becomes dead after 4.58 minutes which means our proposed routing protocol has 0.13 minutes grater lifetime than all other routing techniques.

5.5.6 Network Lifetime with Round Robin selection

We simulate the same matrix network lifetime with same parameter by using round robin selection method and found that its results are also better than all other techniques the network lifetime is 4.62. Fig 5.4 shows the graphical presentation of comparison of next hop routing round robin selection method with other techniques.

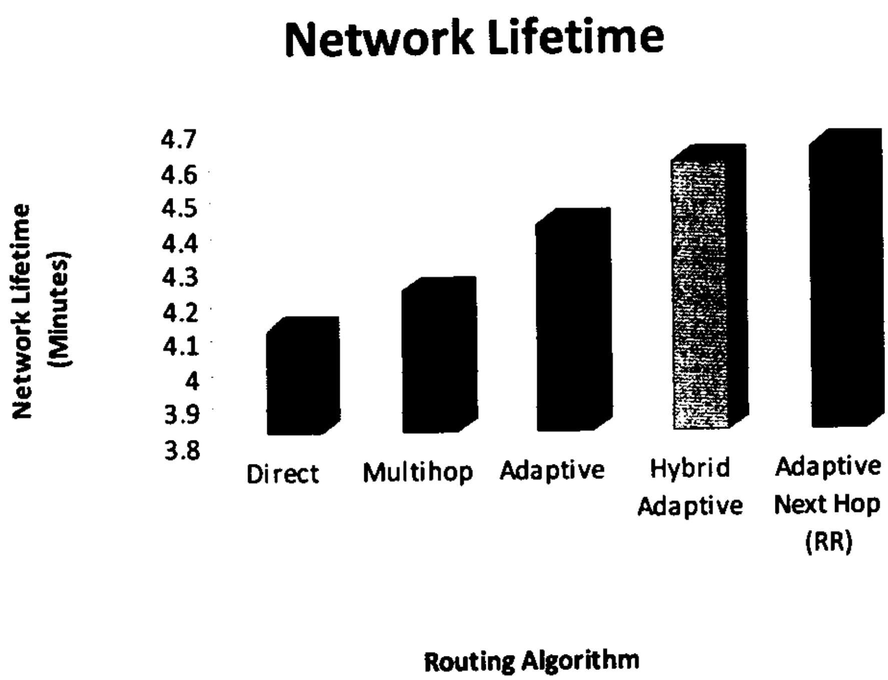

Figure 5.9: Network lifetime with Round Robin selection

We select energy level 300mJ for each node and then found the lifetime of the network by checking that when the first node will become dead after 4.61 minutes the first node will become dead then we compare these results with other techniques which shows that lifetime of the network in our proposed protocol is .04 minutes better than all other techniques.

5.5.7 Average Network Lifetime with Maximum Remaining Energy

To find the average lifetime of the network we simulate our proposed routing protocol with four different experiments by setting the energy level of each node by 300 mJ, 600 mJ, 900 mJ and

1200 mJ and found that the average lifetime of the network is 4.71, 9.67, 14 and 18.89 minutes then compare these results with other routing techniques and found that our proposed method is much better than other techniques in terms of lifetime of the network as it has 0.13, 0.47, 0.40and 0.89 minutes more lifetime than other routing techniques. Fig 5.5 shows the graphical presentation of the comparisons between next hop routing maximum remaining energy with other techniques.

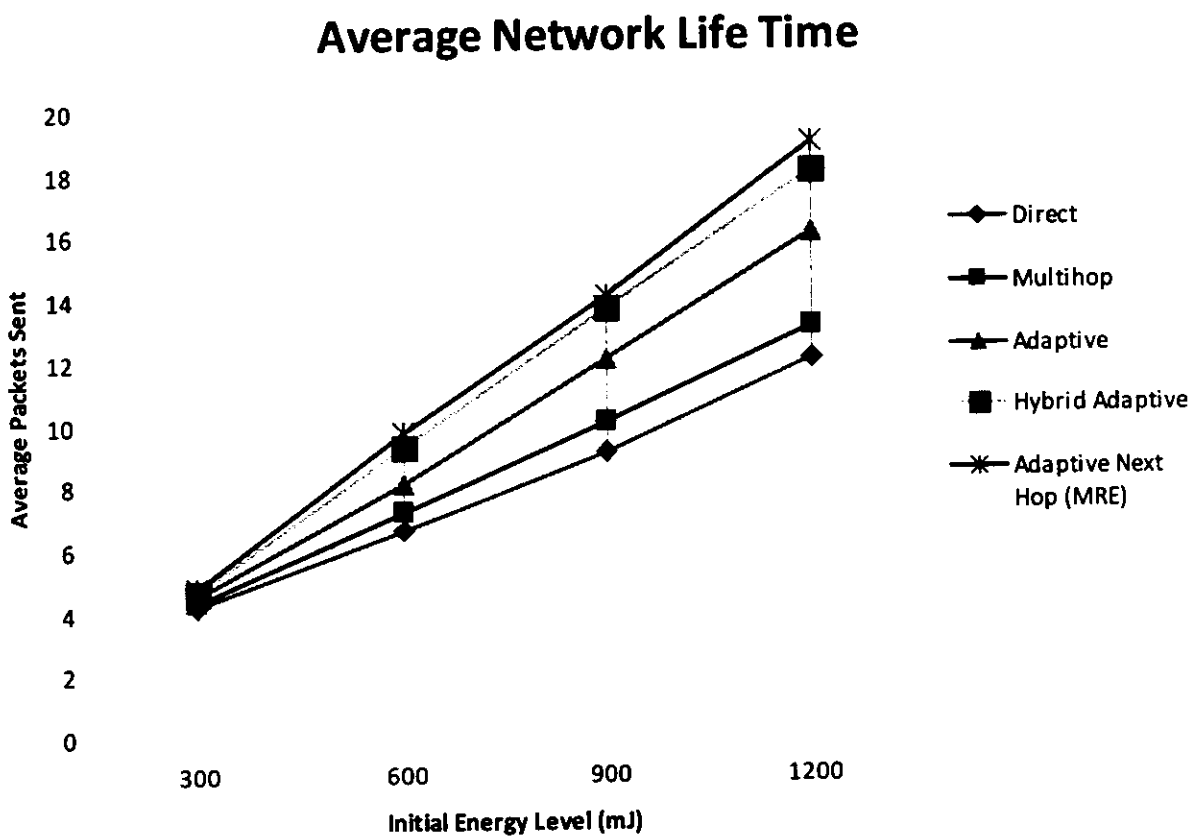

Figure 5.10: Average network lifetime with maximum remaining energy

5.5.8 Average Network Lifetime with Round Robin selection

Fig 5.6 shows the comparison of next hop routing round robin selection in with other routing techniques in terms of average network lifetime.

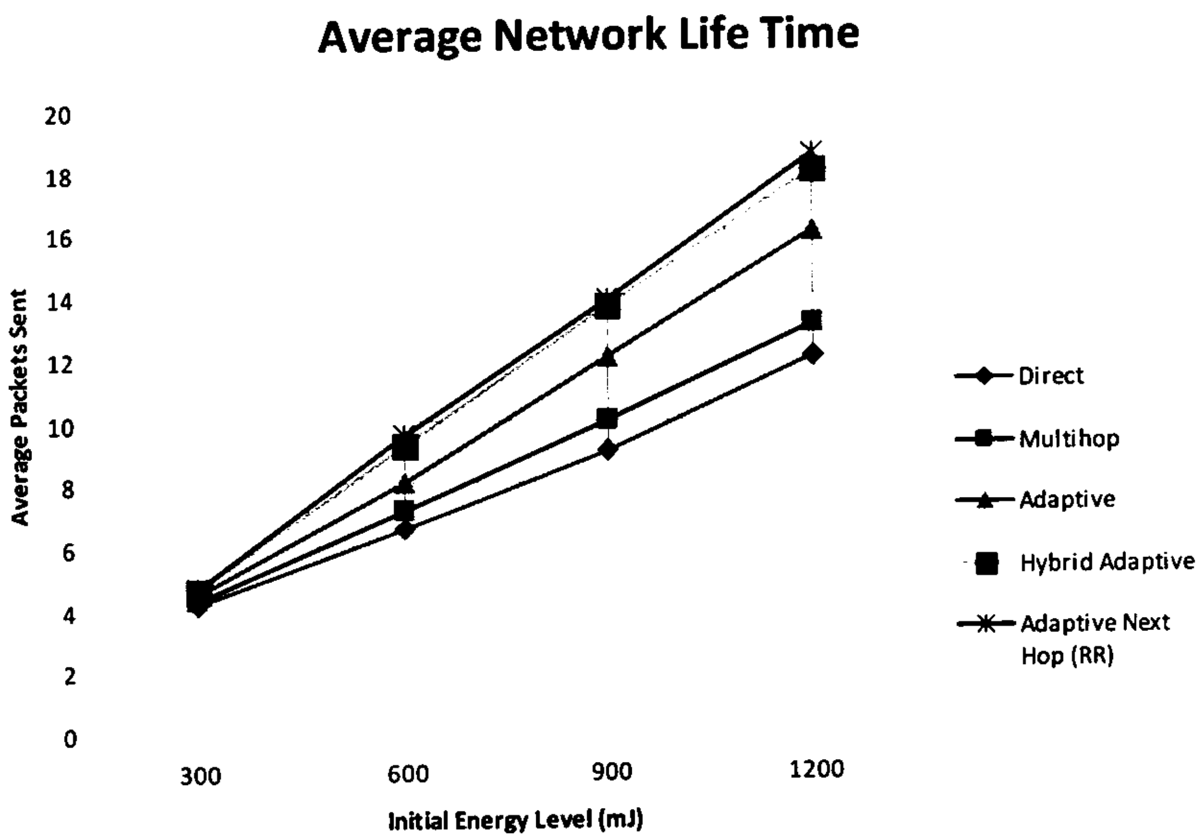

Figure 5.11: Average network lifetime with maximum remaining energy

We set the energy levels 300,600,900 and 1200 mJ for each node and then calculate the average network lifetime of the network by using round robin selection method, network lifetime in given energy level were 4.62, 9.48, 13.8 and 18.52. Results show that our proposed protocol is much better than other protocol in terms of network lifetime as it has 0.04, 0.28, 0.2 and 0.52 minutes greater lifetime than other techniques.

5.5.9 Local and remote Work

Fig 5.9 shows the graphs in which the comparison of our proposed routing protocol with other routing techniques.

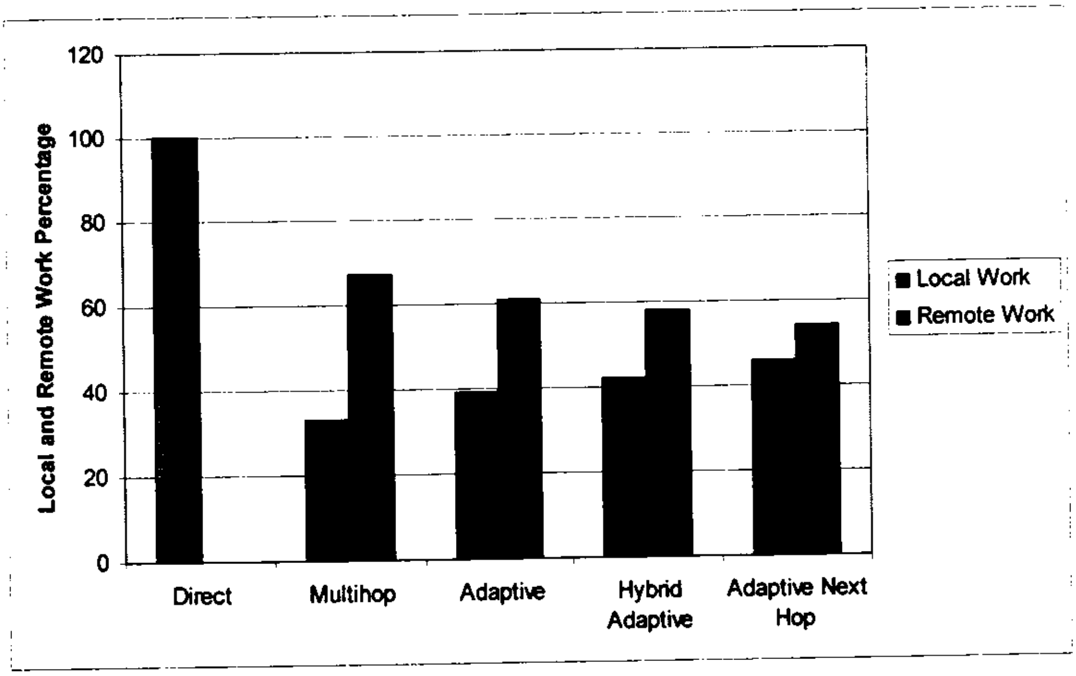

Figure 5.12: Local and Remote work

In above graph we can see the difference between workload of node in each routing algorithm. In direct routing method every node sends data directly to cluster head therefore all nodes doing 100 % local work and no remote work, in multi-hop technique nodes send data to its neighbor so mostly remote work done by the node, furthermore adaptive and hybrid adaptive techniques also keep the local and remote work of the node but next hop routing technique the best balance between local and remote work which is 46% local work and 54 % remote work. As comparison with other routing technique our proposed technique has 4 % increase in local work of the node and 4 % decrees the remote work of the node, which keeps the good balance of work load on the node, thus increase the efficiency of the network. The reason of this increase is efficient use of the intermediate nodes according to the requirements and energy of the sending node.

Chapter 6

Conclusion and Future Work

6.1 Conclusions

Wireless sensor networks (WSN) are used for different applications, typically involving some kind of monitoring, controlling, tracking, fire detection, landslide detection and traffic monitoring. Direct routing and indirect routing are the two main techniques used for routing inside the cluster. To add more flexibility and efficiency in these techniques few authors proposed their extended versions including adaptive routing and hybrid adaptive routing. Every new technique results in better throughput and higher network lifetime. However few parameters, those can make the solution more efficient, are still ignored by every solution discussed above. Almost all the solutions talk about multi-hop routing within cluster but till now no solution describes that which and how many intermediate node should be used as next hop in order to deliver data to cluster head. We developed a solution that on the basis of the remaining energy calculates that which node should be selected as next hop. Moreover it is also selected that how much distance should be covered through direct routing.

We proposed an energy efficient routing mechanism for WSN and we called it Adaptive Next Hop Routing. In our proposed mechanism all the nodes start with one hop routing model and send packets directly to cluster head after some time period remaining energy of some nodes reaches up to a specific threshold so these node shift from one hop routing to multi-hop routing. In Multi-hop routing each node periodically calculates its remaining energy to select intermediate node. To find out the intermediate node two main tasks have to be performed which is the core object of the protocol first one is to find the next hop and second is to find the next node. Next hope selection is performed on the basis of remaining energy of node, we set some threshold.

values to select next hope for source node whenever nod's remaining energy will be less than specific threshold value it selects the next hope with specific distance from cluster head. After selection of next hop then it needs to find the next node as if the number of the node in selected group for next hop is more than one then another selection process needs to find the next node, so our proposed algorithm first checks the number of nodes in selected group and if there is only one node in next hop group then it is selected as a next node but if the nodes are more than one then we use two methods to chose the perfect node to carry the data to base station. First method is selection of next node on the basis of maximum remaining energy in which remaining energy of all nodes in next hope group is calculated and the node with maximum remaining energy is selected for next node and second method is on the basis of round robin selection in which each node in the next hope group is selected as next node for a specific time period and every node gets equal opportunity for acting as intermediate node. This process will continuous till any of the nod's remaining energy becomes 0 and that node is declared as dead node and that will be the end of network lifetime.

To obtain the results we simulate the scenarios in TOSSIM and we find that the proposed solution is better in terms of average packet sent within the network, total packet sent by all nodes, network lifetime etc. We also measured that how much local and remote work is done by every node. It will help us to decide about fairness and information about coverage area. We find that our solution is fairer in terms of local and remote work as compared to existing solutions.

6.2 Future Work

In future this work can be extended through different ways

6.2.1 Testing at Other Topologies

We test our proposed solution by deploying node in Grid topology. The work can be extended by implementing the same solution on different other topologies, specifically the irregular topology because if the nodes are thrown from a plane or from a Helicopter then the resulting topology will be irregular.

6.2.2 Mobility

To test our proposed solution we use the wireless sensor network where nodes are static and don't move their positions. But since mobility is becoming the demand of modern age so this solution can also be tested over mobile sensor network. Results of our proposed solution may vary in case of adding mobility.

6.2.3 Use of Mobility Models

Different mobility methods exist. Results of one mobility model can be different as compared to other mobility models. So if mobility is added in wireless sensor network to use our proposed solution then the role of different mobility models can also be analyzed.

6.2.4 Testing at Different Parameters

We obtain the results by configuring the same parameters those were configured by the researchers who worked earlier on this topic. The reason of using the same parameters is to compare the results efficiently. However at different other parameters, for example in very dense network or in very spread network the results can be different.

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