INVESTIGATION ON DESIGN ASPECTS OF POWER AWARE ROUTING PROTOCOL IN WIRELESS SENSOR NETWORKS

THESIS

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by

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To

My Mother

Mrs. Ramwati Tanwar

Who has always been my source of love and inspiration

DECLARATION

I hereby declare that this thesis entitled "**INVESTIGATION ON DESIGN ASPECTS OF POWER AWARE ROUTING PROTOCOL IN WIRELESS SENSOR NETWORKS"** by **DHARAM VIR**, being submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in **ELECTRONICS ENGINEERING** under faculty of Engineering & Technology YMCA University of Science & Technology Faridabad, during the academic year 2013-2014, is a bona fide record of my original work carried out under guidance and supervision of Dr. S. K. Agarwal, Department of Electronics Engineering, YMCA University of Science and Technology, Faridabad and Dr. S.A.Imam, Faculty of Engineering & Technology, Jamia Millia Islamia, New Delhi and has not been presented elsewhere.

I further declare that the thesis does not contain part of any work which has been submitted for the award of any degree either in this university or in any other university.

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CERTIFICATE

This is to certify that this Thesis entitled "**INVESTIGATION ON DESIGN ASPECTS OF POWER AWARE ROUTING PROTOCOL IN WIRELESS SENSOR NETWORKS"** by **DHARAM VIR**, being submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in **ELECTRONICS ENGINEERING** under faculty of Engineering & Technology YMCA University of Science & Technology Faridabad, during the academic year 2013- 2014, is a bona fide record of work carried out under my guidance and supervision.

I further declare to the best of my knowledge, that the thesis does not contain part of any work which has been submitted for the award of any degree either in this university or in any other university.

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ABSTRACT

This thesis aims to investigate for WSN routing protocols to consider the energy & power level of sensor nodes through the organization of routing processes in order to increase lifetime of the network and reduce the energy consumption ratio of wireless sensor nodes. The proposed work relates to incorporating the investigation on power consumption and energy optimization in wireless sensor networks and ad hoc network environment by ensuring the power consumption of the intermediate nodes in the network. The proposed protocol simulated on the computer system using QualNet and Matlab simulation software's.

This thesis includes the Quality of Service (QoS) for performance analysis of more than eighteen MANET and WSN routing protocols: reactive routing protocol like OLSR, on demand routing protocols DYMO, AODV and DSR and which are based on IEEE 802.11, and hybrid protocol ZRP. The implementation was achieving over a real practical designed scenario considering some fundamental metrics with MAC layer and physical layer models, in order to investigate the performance of effectiveness of wireless routing protocols. Performance is investigated and compared on the performance measuring metrics of application layer like Packet Delivery Ratio (PDR), Throughput, E-E Delay, Jitter, Network layer based performance metric Hop Count, Power consumed in transmit, Receive and idle/sleep modes and Average Waiting Time of messages and MAC layer based performance metrics RTS, CTS, ACK packet send, Broadcast Received, Broadcast Received Clearly, etc with varying number of nodes, mobility with constant bit ratio (CBR) traffic load, and network node design.

Mobile Ad hoc Network (MANET) and wireless sensor network (WSN) is a collection of nodes (mobile) temporarily connected in order to provide data communication. In order to provide efficient and reliable path between a pair of nodes, a routing protocol is used. Various routing protocol are available in literature such as table driven, on demand and hybrid. All these routing protocols are analyzed and compared using various mobility models, antennas and number of nodes. It is observed that Optimized Link State Routing (OLSR) protocol employing Omni-directional antennas, mica-motes energy model and having random way point mobility provides nearly 15% less power consumption in comparison to any other routing scheme. Therefore, our research work concentrated on the work that how to

minimize further reduce power consumption of OLSR protocol. To achieve this, new energy efficient Sleep/Idle Optimized power model is developed, implemented and examined which included the idle algorithm to extend the network lifetime and QoS parameters for wireless sensor networks. The implementation of the new Sleep/Idle Optimized power algorithm dramatically improved not only on the network lifetime but also energy consumption in different modes such as receive, transmit, idle and sleep modes and delivered superior performance in terms of QoS parameters for the wireless sensor networks. By using this strategy approximately 12-18% power consumption is reduced in comparison to OLSR protocol in literature and this strategy provides far better results in comparison to LEACH protocol.

In addition, the dissertation work also used switching scheme that minimizes the power consumption by switching during the idle or sleep mode in order to extent the battery power of nodes thus increasing the network lifetime.

In addition to, another proposal for Power Awareness Routing model an implementation has been presented. Power Aware Routing is implemented in-to the $OSPF_{V2}$ and RIP_{V2} routing protocol using QualNet 5.0 network simulator software. Power management lifetime models, based on power consumption model for number of nodes are being used to emulate the battery lifetime of a wireless sensor device. Two power aware routing protocols $OSPF_{V2}$ and RIP_{V2} are using different schemes for generating Link State Updates (LSU) in power awareness $OSPF_{V2}$ routing prototypes are presented and implemented in QualNet based model.

In addition, this dissertation studies the effect of power and bandwidth deficient nodes. It is shown that nearly 10% of power and a bandwidth deficient node do not hamper the performance of routing protocol. It is also shown that the network doesn't become dead even if all the nodes are power deficient.

The simulation work is carried out using QualNet Simulator 5.0 and Matlab software's, the performance of above protocol has been demonstrated, compared and verified the remarkable improvement of performance in term of investigation and reducing the rate of power consumption and increasing the lifetime of the WSN, which is compared with the original LEACH and cluster tree routing protocols in standard lab environment.

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ABBREVIATIONS

ACK	:	Acknowledgment Packet
ACQUIRE	:	Active Query forwarding in the WSNs
ADC	:	Analogue to Digital Converter
AODV	:	Ad hoc On-demand Distance Vector
APTEEN	:	Adaptive Threshold sensitive Energy Efficient sensor Network
BW	:	Bandwidth
CBR	:	Constant Bit Rate
CCA	:	Clear Channel Assessment
CH	:	Cluster-Head
CID	:	Cluster ID
CSMA-CA	:	Carrier Sense Multiple Access with Collision Avoidance
DD	:	Designated Device
ED	:	Energy Detection
EMV	:	Energy Mean Value
FFD	:	Full-Function Device
FIFO	:	First in First out
GAF	:	Geographic Adaptive Fidelity
GEAR	:	Geographic and Energy-Aware
GPS	:	Global Positioning System
GTS	:	Guaranteed Time Slot
HPAR	:	Hierarchical Power-Active Routing
IEEE	:	Institute of Electrical and Electronics Engineers
IETF	:	Internet Engineering Task Force
IOS	:	International Organization for Standardization
ITM	:	Irregular Terrain Model
LAN	:	Local Area Network
LEACH	:	Low Energy Adaptive Clustering Hierarchy
LLC	:	Logical Link Control
LNCA	:	Local Negotiated Clustering Algorithm
LQI	:	Link Quality Indication
LR-WPAN	:	Low Rate-Wireless Personal Area Network
MAC	:	Medium Access Control

MAN	:	Metropolitan Area Network
MWNs	:	Multi Hop Wireless Networks
MLDE	:	MAC Layer Data Entity
NLDE	:	Network Layer Data Entity
NLME	:	Network Layer Management Entity
MECN	:	Minimum energy communication network
NS-2	:	Network Simulator-2
OSI	:	Open Systems Interconnection
OLSR	:	Optimized Link State Routing Protocol
PAN	:	Personal Area Network
PDA	:	Personal Digital Assistants
PEGASIS	:	Power Efficient Gathering in Sensor Information Systems
PHY	:	Physical Layer
QoS	:	Quality of Service
REQ	:	Requesting the data Packet in SPIN
RERR	:	Route Error Packet
RFD	:	Reduce-Function Device
RREP	:	Route Reply Packet
RREQ	:	Route Request Packet
SAP	:	Service Access Point
SPIN	:	Sensor Protocol for Information via Negotiation
TDMA	:	Time Division Multiple Access
TEEN	:	Threshold sensitive Energy Efficient sensor Network
WAN	:	Wide Area Network
WLAN	:	Wireless Local Area Network
WN	:	Wireless Network
WPAN	:	Wireless Personal Area Network
WSN	:	Wireless Sensor Network
E2E Delay	:	End to End Delay

Chapter1

INTRODUCTION

This chapter explains the introduction, background and significance of the research undertaken. The importance of investigation on energy and power of different routing protocols in WANET in comparison with a new experimental investigations and algorithm are explained with respect to the overall objectives of the research. The author's contributions and layout of the thesis are also presented.

1.1 INTRODUCTION

Wireless technology has huge prospective to change the way people and things to communicate. Wireless cellular networks allow people on the move to communicate each other using a range of multimedia services [1]. Wireless sensor networks allow devices to collaborate on the monitoring of stress and strain in buildings and bridges, detection of hazardous events, tracking of enemy targets, and the support of unmanned robotic vehicles. Wireless broadband access networks allow people and devices to have high-speed connections to the backbone network from any place at any time [2].

As technology advances, people start to have more expectations about future wireless networks: reliable and reasonable communications among people and devices is desired regardless of physical limitations. In addition, these networks have hard energy constraints since every node is powered by a small battery but that may not be rechargeable. Therefore, reducing energy consumption in power aware routing protocol is the most important design consideration for such type of networks. Since all the network layers in the network protocol stack is affects the overall system performance [1].

The wireless sensor nodes are usually battery driven and appropriate to their deployment in insensate or hostile environment, wireless sensor nodes battery is usually un-chargeable and un-replaceable. Moreover, since the node size is too small to accommodate a large battery, they are constrained to operate using an extremely limited energy and power backup budget. The total stored energy in a smart dust mote, for instance is only 1Jule [4]. Since this small amount of energy is the only power supply to a sensor node, it plays a vital role in determining lifetime of the sensor networks. All the research works therefore have a common concern of minimizing power and energy consumption and it is a significant issue at all layers of the WSN.

1.2 WIRELESS SENSOR NETWORK

Recent hardware advances allow more signal processing functionality to be integrated into a single chip. It is believed that soon it will be possible to integrate an RF transceiver, analog to digital (A/D) and digital to analog (D/A) converters, baseband processors, and sensors into one device that is as small as a coin and can be used as a fully-functional wireless sensor node. Specifically, a wireless sensor node is equipped with three basic functional elements: a sensing unit, a processing unit, and a wireless networking unit [5]. The sensing unit collects information from the neighboring environment; the processing unit performs some local information processing such as quantization and compression; and the wireless networking unit transmits the locally processed data to a fusion center, where the information from different sensor nodes are aggregated and fused to generate the final intelligence. The mobile ad-hoc network and wireless sensor network is composed of number of nodes which are connected inefficient way to each other as shown in Fig. 1.1. The figure shows that the wireless sensor information from the sensors flows through the nodes. These networked sensors are scattered and collect information on entities of interest. These nodes are circulating in the air, bodies, inside buildings and vehicles to detect events of interests and monitor environmental parameters [6].

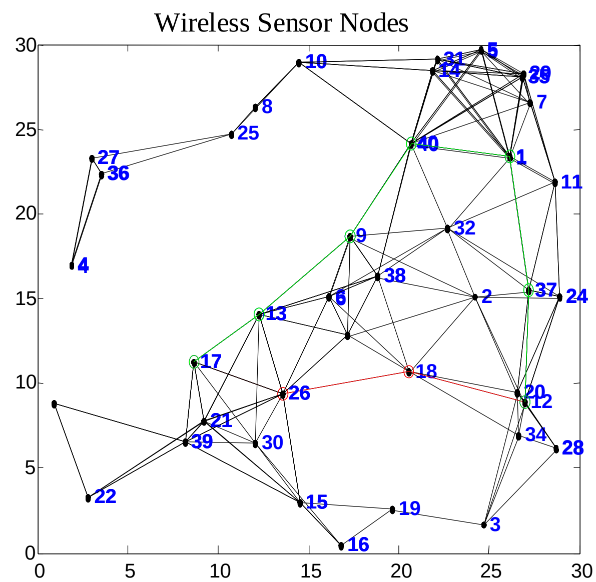


Fig. 1.1A Representation of Nodes in Sensor Networks

1.3 WIRELESS SENSOR NETWORK V/S AD-HOC NETWORK

Wireless Sensor Network (WSNs) forms a subset of Ad-Hoc Networks as shown in Fig.1.2. Wireless Sensor Networks have many restrictions compare to Ad-Hoc networks in terms of sensor node's capability of processing, power consumption, memory storage and their available energy sources [7].

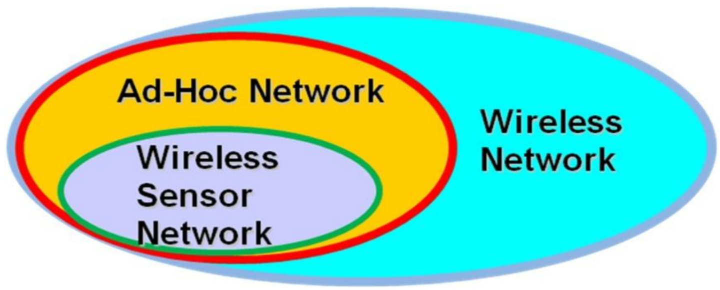


Fig. 1.2 Wireless Sensor Network as subset of Wireless Network

In order to compare WSNs with the other wireless network, we will discuss the main differences between the nodes in both the WSN and Mobile Ad hoc Network (MANET). Mobile Ad hoc Network is a self-configuring wireless network that has the capability to keep updating the network configuration based on information from the mobile nodes. These differences can be summarized as following [8-10]:

- The number of nodes in Wireless Sensor Networks can be much higher than the number of the nodes in a Mobile Ad hoc Network, which means that the WSN has a very high density of nodes.
- Any node failure in the WSN frequently causes many changes in the network topology.
- The wireless sensor nodes have many constraints such as limitation in power, computation unit, and memory size.
- WSNs aspire to reduce the power consumption, while other networks aim to reach high quality of service (QoS).
- The wireless sensor nodes may have more nodes failing than in a MANET.
- The nodes in a Mobile Ad hoc Network are much more scattered than in a Wireless Sensor Networks.
- The wireless sensor nodes use broadcast communication more than point-to-point communication, which is the base of a MANET.
- The wireless sensor nodes may not have identification number because of the large number of sensors.

- Table 1.1 and table 1.2 shows the performance comparisons between Wireless Sensor Network with other networks.

Table 1.1 Performance comparisons between WSN with other networks

Wireless Types	No. of Nodes	Power consumption	Mobility	Range	Data Rate
WLAN	Small	Medium	Medium	Long	High
Bluetooth	Small	Low	Low	Short	Medium
Cellular	Large	High	High	Long	Medium
WSN	Large	Very Low	Low	Short	Low
Ad-hoc N/W	Small	Medium	High	Long	Medium

Table 1.2 Comparison of Wireless Sensor Network and Ad-hoc Networks

Standards & characteristics	Wireless Sensor Network 802.15.4	Ad-hoc Networks
Operation frequency	868Mhz,902-982Mhz,2.4Ghz	b/g-2.4Ghz a-5.0Ghz
Network Topology	Ad-hoc, static, peer to peer	Infrastructure less,(Ad-hoc also possible), Point-to–multipoint
Distance	10-50km	50Km
Complexity	Low	Medium
Data Rate	20Kbps,40Kbps, 250Kbps	100-500Mbps
Power	Very low	High
Key Attributes	Cost, Power	Throughput, Coverage

1.4 DEVELOPMENT AND BACKGROUND OF SENSOR NETWORKS

1.4.1 Brief History of WSNs

History of development [2] of wireless sensor nodes may start to the 1977s,some advancement in research on nodes of sensor networks started around 1980 with program at Defense Advanced Research Projects Agency (DARPA) with Distributed Sensor Networks (DSN) where, the Arpanet (predecessor of the Internet) approach for communication was wide-ranging to sensor networks. The network was assumed to have many scattered low cost sensing nodes that are collaborating to each other but operate alone, and the information routed to either nodes can best use the information [11]. A computerPDP12/35used an array based processor processed the auditory signals. The Motorola processor based nodal computer (for target tracking events) consists of three MC68000 processors with 256-K byte memory and 512-K byte shared memory used for first time tracking exchange information, and a custom operating system used for communication was by Ethernet and Microwave Radio. The table 1.3 shows the enhancement evolution of sensor networks [12-14].

Table 1.3 Enhancement evolution of Sensor Network

S.No	Parameters	1980's – 1990's	2000-2010	2013
1	Topology	Point to Point, Star	Client-Server, Peer to Peer	Peer to Peer
2	Size	Large shoe box and up size	Pack of cards to shoe box	very compact size like as Dust Particles,
3	Weight	Kilograms	Grams	Negligible
4	Cost	Higher	Average	Low
4	Node	Separate Sensing	Integrated Sensing	Integrated Sensing
5	Architecture	Processing and communication	Processing and communication	Processing and communication
6	Power supply lifetime	Large batteries; hours day and longer	AA batteries; days to week	Solar months to year
7	Development	Vehicle-placed on air dropped single sensors	Hand-placed	Embedded
8	Manufacture	Custom Contractors	Commercial: Crossbow Technology Inc. Sensoria Corp.	

1.5 WIRELESS SENSOR NETWORKS CHARACTERISTICS

A WSN is different from other popular wireless networks like cellular network, wireless local area network (WLAN) and Bluetooth in many ways. Compared to other wireless networks, a WSN has much more nodes in a network, distance between the neighboring nodes is much shorter and application data rate is much lower also. Due to these characteristics, power consumption in a sensor network should be minimized. WSN having the following characteristics of networks as under [11]:

- Limited power they can collect or store.
- Ability to survive with node failures
- Mobility of wireless nodes

- Dynamic network system topology
- Communication failures
- Heterogeneity of nodes
- Unattended operation
- Ability to withstand harsh environmental conditions

1.6 CHALLENGES AND MOTIVATIONS IN WANET's

- **Path breakage:** It occurs frequently due to node mobility, node failure and channel impairment.
- **Channel fading:** In wireless communication fading is defined as the attenuation that signals experiences over certain propagation media. Fading may be due to multipath propagation, time, geographical condition, shadowing etc [14].
- **Shadowing:** Shadowing is due to the obstacle that affects the wave propagation. Shadowing may occurs due to buildings, rocks mountains etc [14].
- **Interference:** Interferences is anything that alters, modifies or disrupts a signal as it travels along a channel between the source and the receiver. The term typically terms to the addition of unwanted signals to a useful signal [15].
- **Node Mobility:** If nodes change their location over a time, the other nodes are required to update its information. But if by any chance the node goes out of the range or unable to convey its presence it may lead to the node failure [6].
- **Power failure:** Each node in the WSN requires energy to maintain its own health and function well in the network, failure in the power will lead to interruption in the communication [16].
- **Energy conservation:** In wireless sensor networks each and every node is equipped with sensor devices which are in working condition depending upon the power supplied by attached battery. To have better performance of wireless network nodes, the network should operate for longer time [17-19].
- **Scalability:** Wireless sensor node is composed of large number of sensor node deployed in the sensing area may be in the sequence of hundreds or thousands, and further as per required by the application and coverage area. Any routing scheme must be capable to work with this huge amount of sensor nodes [20].

The entire above challenging characteristic of WANETs to design of energy efficient power aware routing protocol is a demanding and challenging assignment even today.

1.7 APPLICATIONS OF WIRELESS SENSOR NETWORKS

The various application and specifications of the wireless sensor nodes have to lead these sensors to work in many fields and wide applications. Some of applications need source to destination delivery requirements makes both hardware as well as software design of Wireless Sensor Network more challenging.

Obviously, WSNs are used in critical application areas and real time systems. Therefore, they need to be stable in design and structuring to data transfer among the wireless sensors safely and without any problem [5, 12, 21-23]. Designing wireless sensor networks (WSN) is much more difficult than any other computer networks, because of the limitation of the power resource, computation unit, and memory size as summarized in Table 1.4.

Table 1.4 Applications of Sensor Network

Application Type	Applications	Topology
Home networks	Home appliances, location awareness (blue tooth [2]). Person locator [17].	Three Tiered
Targeting and Tracking	Tracking of doctors and patients in hospital, Tracking of animal in forest, Tracking of inhabitant in a building [12] [22-25].	Multi-hop
Military	Military situation awareness [6]. Sensing intruders on basis.	Multi-hop
Physical world	Environmental monitoring of water and soil [7].	Multi-hop, Multi-path
Medical and health	Sensors for blood flow, respiratory rate, (electrocardiogram), pulse oxy-meter, ECG. oxygen measurement [10].	Star, Cluster Head
Emergency situations	Disaster management [9]. Fire/water detectors [2]. Hazardous chemical level and fires [4].	Cluster Head
Automotive	Tire pressure monitoring [2-3]. Active mobility [8].Coordinated vehicle tracking [6].	Multi-hop
Industrial	Factory process control and industrial automation [6]. Monitoring and control of industrial equipment [2].	Multi-hop
Data Gathering and	Home/office smart environments, Health	Multi-hop

Periodic Reporting	applications, Environmental conditions monitoring, Monitoring humidity, temperature and light etc. [5, 20-22].	
Sink-Initiated Querying	Environmental control in buildings, Environmental control in buildings, Weather monitoring, Biological attack detection, Soil condition monitoring, Fire alarming [24].	Cluster Head and Multi-hop

1.8 WIRELESS SENSOR STACK

A simplified network protocol stack is shown in Fig. 1.3 and the most important functions of every layer are described as follows [26]:

(i)**Hardware Layer**

This layer is composed of the basic hardware blocks, where, the upper layer algorithm is implemented. Most of the power is consumed physically in this layer. Hardware layer considered as a cross-layer power and energy minimization framework.

ii)**Link Layer**

Link layer is also referred to as the physical layer in the network, which deals mostly transmitting over a peer-to-peer wireless link. The design criteria associated with the link layer include coding, equalization, modulation diversity, adaptive techniques, Multi-Input-Multi-Output (MIMO), multi-carrier modulation, and spread spectrum [28].

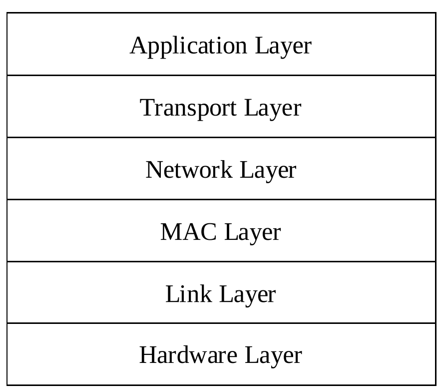


Fig. 1.3 Simplified Layered Structure

(iii)**MAC layer**

The MAC layer controls of given reliable packet transmissions spectrum. Allocation of signaling dimensions to different users is done through random access, dedicated or deterministic access. Where, the most common methods these are used in MAC layer are Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA) [28].

(iv)**Network Layer**

This layer establishes point to point link and maintains end to end connections between the networks. The main functions of the network layer are neighbor discovery, dynamic resource allocation and routing in a sensor network[29].

(v)**Transport Layer**

This layer provides the end to end delay functions of flow control, retransmission and error recovery etc. This is the most common protocol used at this layer is the Transport Protocol (TCP) [29]. However, the TCP protocol does not work well in wireless networks, since it assumes that all packet losses are due to congestion.

(vi)**Application Layer**

The application layer generates the data to be sent over the network and processes the data received over the network. The main functions of the application layer are source coding/decoding and error detection and corrections [29].

1.9 SCHEMES OF POWER CONSTRAINTS OF DIFFERENT WIRELES SENSORS STACK

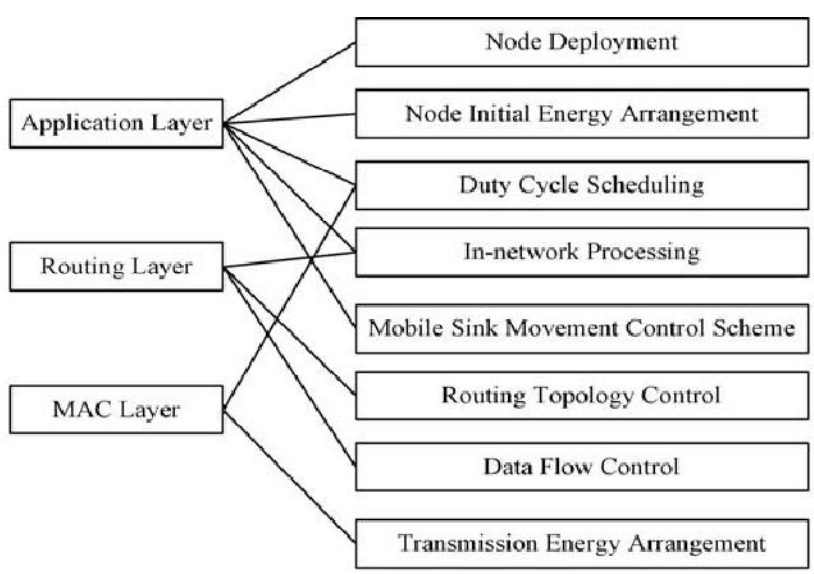


Fig. 1.4 Scheme of power constraint on different wireless sensors layers stack

Schemes that solve the power and energy constraint problem of the sensor network system by conserving the battery energy of the nodes and consequently prolonging the network's lifetime can be designed on different layers as shown in Fig.1.4.

1.9.1 Scheme on the Application Layer

The sensor network system being an application-specific system cannot depend exclusively on the modeling on the lower layers to obtain expected performance. The requirements of the application need to be taken in consideration; hence it is necessary to exploit the high-level design concerning all the characteristics of the system. On the application layer, all these properties can be considered and thus the full optimization to the system can be achieved [33].

1.9.2 Scheme on the Routing Layer

Scheme on MAC layer for energy conservation can only control the energy consumption for each single node on transmission. In order to increase the energy efficiency of the whole network, the balance or unconsumed energy is sent back to MAC layer during communication. Therefore it can be noticed that this goal can only be achieved through the mechanisms on higher layer. The schemes on the routing layer are designed to solve this problem [33].

1.9.3 Scheme on MAC Layer

Since transmitting data through a wireless channel is normally the most energy consuming modeling for a sensor node, many researchers have focused on designing the energy efficient transmission control schemes on the MAC layer in order to save the energy of each single node [16, 30]. There are two methods to control the data transmission on the MAC layer, either through exploiting a duty cycle scheduling scheme during transmission or by properly arranging the transmission power of the node. As the scheme on the MAC layer is independent of the network's deployment, these mechanisms can be applied to both the static sensor network system and the mobile sensor network system [31].

1.10 POWER MANAGEMENT

The wireless sensor nodes in wireless network are energy efficient with some power constrained and having inadequate battery power intended for their operation. Hence the power management is a significant problem in wireless sensor networks. Power management is the process to managed energy as well as power constraints in the desired network. Power Management is a major issue by means of scheduling and arrangement of power sources increases the lifetime of the sensor network nodes, schedule of battery recharge, transmission power adjustment and efficiency of the node in the network. The node energy efficiency in a wireless network is defined as the relation between the amount of data delivered and total energy [34-35].

1.10.1 Need for Power Management in WANET (Wireless Sensor Network and Ad-hoc Networks)

The reasons for power management are [36-38]:

- Due to wireless communication advancement, the power consumption requirements and power availability increases the gap between source and destination.
- Difficult to recharge or restore the batteries. Hence, power conservation becomes important
- Energy storage in batteries tends to increase the size and bulky need power management.
- Energy management techniques are necessary to maximized utilizes the battery capacity in the best possible way.
- Need to reduce the size of the battery,
- Transmission power increases when optimal value optimized maximum battery power.
- Power control is essential to maintain their required (SIR) signal to interference ratio between the source node and destination node which is increase the channel reusability and retransmission in the network.

1.10.2 Classification of Power Management Schemes

To increases the lifetime wireless network, the routing protocol must be designed in such manner that reduce the information exchanged among the nodes using minimum battery consumption. Since communication between source to destination incurs loss of energy. When increases the number of communication tasks between source and destination also increases the traffic in the wireless network, which results in loss of received data, retransmissions power, and consequently more energy consumption. Fig. 1.5 shows the brief classification of Power Management Schemes.

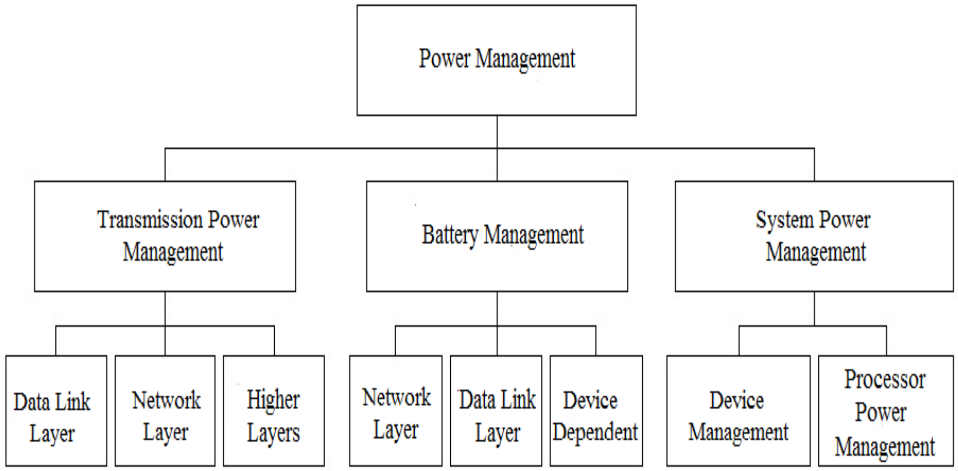


Fig. 1.5 Classification of Power Management Schemes

The longer lifetime of the nodes can be achieved by increasing the battery energy to increase efficiency of desired network. Battery management capacity manages the link between network layer, data link and operational unit which connected to the desired network. Internal characteristics of the battery also increasing the lifetime of nodes can be achieved by either, power management and transmission power management, which also deals to utilize the maximum battery capacity to maintain the maximum possible amount required by nodes for proper functioning. The power preserved in communication operations is due to transmitting and receiving unit present in the nodes [38-41].

In the power aware routing (PAR) protocols the maximum power efficiency can be achieved by using efficient metrics and battery management [46].

The researchers mainly focus on increase in power efficiency, increasing lifetime of nodes and reducing power consumption, but also prime focuses on increasing the lifetime of node where network maintains certain performance level. Recently it was observed in the protocol stack power efficiency increases by using power management schemes [42-44].

1.11 PROBLEM ASSIGNED AND RESEARCH OBJECTIVES

The various objectives of the thesis are as follows:

- To study the background of wireless sensor networks and mobile ad hoc networks.

- To study the background of power aware routing protocol and compared with original energy efficient LEACH protocol wireless sensor networks and mobile ad hoc networks
- To study the different wireless sensor network routing protocols and compare these with the conventional routing protocols. Ultimately this must lead to an advice for a routing protocol in which power awareness routing can implemented.
- To increase network lifetime.
- The second aim will be to balance the load evenly among all the nodes of the network so the network lifetime is increased. A strategy similar to CMMBCR can be used here for energy efficient MAC layer routing protocol.
- To optimize transmission range of nodes that aims in reducing total power consumption and at the same time the probability of reachability is attained at a satisfactory level as the energy consumption is directly proportional to Erα (where Er is the transmission radius of the node). Thus, with increase in transmission range, the total power consumption increases and at the same time when transmission radius is low then the probability of reachability becomes too less.
- To design and build a multi-hop wireless network test bed by implementing power aware routing into an existing implementation of the RIP_{V2} (Routing information protocol $_{version\ 2}$) and $OSPF_{V2}$ (Open Shortest Path $_{version2}$) routing protocol and compare to other wireless routing protocol.
- To minimize the delay incurred in routing data packets.
- To facilitate provision for redundant paths when route errors occur.
- To investigate different power aware routing protocols in a design network scenario and consider residual bandwidth as performance metrics.
- Residual energy as performance metric also consideration.
- Enhancement of power control and aggregate throughput in MAC layer.

1.12 RESEARCH METHODOLOGY ADOPTED

The followings steps will be taken to achieve the above mentioned targets

- Step 1: First of all the literature survey of the entire table driven and on demand routing protocols will be done. It is also desired to compare these routing mechanisms through simulation in NS-2 or QualNet.

- Step 2: The literature survey of all the power and energy efficient MAC routing protocols will be done and in this phase it is desired to find out strategies as mentioned in our aims to reduce power consumption in wireless networks.
- Step 3: The protocol will be implemented in NS-2, QualNet or MATLAB to test its actual feasibility.

1.13 PROTOCOL INVESTIGATION AND PERFORMANCE EVALUATION

1.13.1 Tool Used

For evaluation the performance metric needs a suitable environment for designing the scenarios on power efficient reactive, proactive and hybrid routing protocols. Investigation of power aware routing protocol requires such type of environment is felt to which would ensure that the protocol performance investigation is properly evaluated and checked also try to practical feasibility in market implementation. There following alternatives are:

- To take up an actual wireless sensor network protocols of mobile ad hoc network (MANET) scenario and evaluate the performance using Matlab and QualNet simulator [45].
- To use QualNet 5.0 simulator software, this simulator is commercially available software that provides real time simulation facilities for incorporating and modification through additional programming.
- In QualNet 5.0 simulator constituting the facility for protocol modification that existed in the protocols compared to other protocols.

The consideration of QualNet simulator for our work because of the following reasons:

- QualNet simulator is a wide-ranging collection of tools for modeling large wired and wireless networks. Through simulations, it can predict the behavior of routing protocols.
- QualNet simulator evaluates the performance of new protocol model with preferred designed network to improve the operation and manages the power.
- QualNet simulator having the facility for designing WANs, to cellular, satellite, WLANs and wireless mobile ad hoc networks,

- QualNet’s library having the feasibility for wide-range of communication between sources to destination, due to its efficient kernel.
- QualNet can design a new model for heavy traffic, large scale networks and mobility is a parameter in realistic simulation times [47-49].
- To optimize new commercial protocol models and evaluation the existing models,
- To design large wired and wireless networks also analyze the performance of networks and optimize user-designed and pre-configured models of 802.11s protocol.
- QualNet is Multi-platform support and scalable up to tens of thousands of nodes with fast simulation results.
- QualNet provides a wide-range set of tools of all the components for network modeling and simulation.
- QualNet 5.0 provides (GUI) Graphical User Interface for visualize designed scenarios.
- Network scalability can be easily done in QualNet simulator as compare to other wireless network simulator. Models are used for source form provide developers a solid library on which the scenario easy to build new network functionality.

1.14 IMPLEMENTATION AND SIMULATION

The network topology in Wireless Sensor Networks is dynamic due to nodes mobility and leading to the change in the connectivity between source and destination the nodes in the network. The connectivity between the nodes may increase and also vary through time as parameters departure of source node or arrival of nodes in the network. With the instance the nodes which were previous cooperative may become self-centered due to loss of power.

All above characteristic and specifications of node of power aware routing protocol of wireless sensor network and mobile ad hoc network design of protocol is a demanding and challenging assignment still today. The requirement of energy efficient routing protocols which is enables the nodes to communicate between sources to destination over multi-hop paths without federal routers. These types of composite issues include abundant barriers for researchers and provide them with new opportunities for making considerable changes and modifications required in this area.

The investigation and implementation and of the power aware routing protocol was done in Visual C++ by designer some modification by taking appropriate parameters in the module programs of the QualNet 5.0.

The investigation is performed on theQualNet-5.0 simulation software. Fundamental basic parameters used for simulation process are given in Table 1.5.

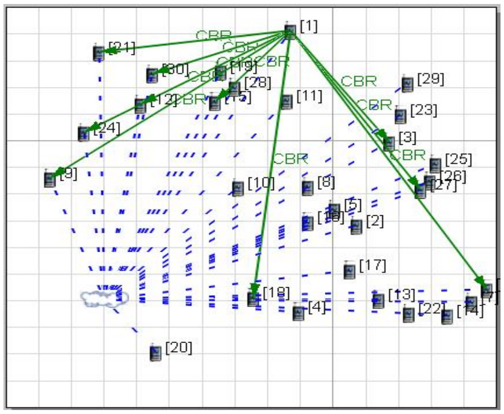
Table 1.5 Essential parameters for simulation

Simulator	QUALNET 5.0
Examined Protocol	AODV,DSR,ZRP, $OSPF_{V2}$, $RIPv_2$, STAR,LEACH
Simulation Time	30-2000 sec (variable)
Transmission range	300-600 (variable)
Energy Model	Mica- Motes
Simulation Area	$1500^{m2}*1500^{m2}$
MAC Model	IEEE 802.11
Battery Model	Linear
Data Rate	1 mbps
Default Battery	1200mah
Performance Metrics used	Packet Delivery Ratio, Average Delay, Throughput, Hop Count, Network Lifetime, Average Jitter, Packet ACK, Packet CTS, etc.
Performance Metrics in Physical Layer	Power consumed in transmit, received, ideal and sleep modes

1.14.1 Quantitative Matrices Used for Investigations

The following is a list of number of quantitative metrics that are appropriate for assessing the performance investigation of proposed routing protocol. Fig. 1.6 &1.7 shows snapshot of designed scenario and running outcome of designed scenario.

- **Average jitter:** The jitter is standard deviation in time taken too intended for packet to reach their destination (source to destination). Jitter is calculated by considering the standard deviation in packet delay. [50].



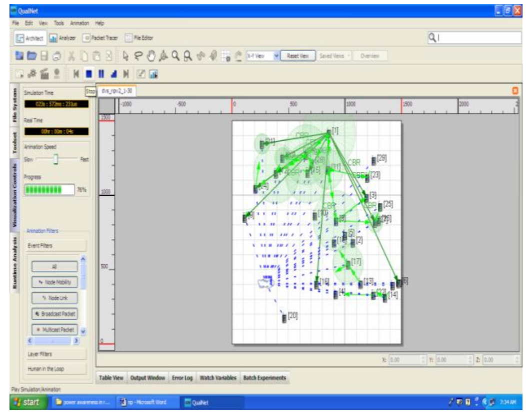


Fig.1.6 Snapshot of designed scenario   Fig.1.7 Snapshot of running designed scenario

- **<u>Average End to End Delay</u>:** The average time taken by the packets to pass through the network is called average end to end delay. This is the time when a sender generates the packet and it is received by the application layer of destination, it is represented in seconds [50].
- **<u>Network Lifetime</u>:** It is defined as the time in which NL% of the nodes becomes dead in nature [51].
- **<u>Hop Count</u>:** Hop count is defined the total number of in-between nodes to reach source to destination node.
- **<u>Throughput</u>:** It is the regular rate of successful data packets received at destination over a communication link channel. It is measured in bits per second (bit/s or bps), or occasionally in data packets per second [50].
- **<u>Power Consumed in Transmit mode</u>:** Power consumption in transmission mode when data packet sends to other nodes in network (source to destination). These nodes are required some power or energy to transmit their data packet, such type of energy is called Transmission Energy (Tx), or Transmission power of that nodes. The transmission energy is depended on amount or size of data packet (in Bits), by means the size of a data packet is increased in size than the required transmission power is also increased [38, 52].
- **<u>Power Consumed in Receive Mode</u>:** In receive mode the node receives a data packet from source to destination then the node is said to be in Reception Mode and the power taken to receive packet is called Reception Power (Rx) [38].

- **<u>Power Consumed in Idle Mode</u>:** When the node is neither transmitting nor receiving any data packets from source to destination said to be in idle condition. When the node in idle mode condition it consumes power [37].
- **<u>Routing Power</u>:** This is the power at which a node has transmitted the packet to neighbor.

  Routing Power (RP) = (Average Throughput / Average E2E Delay) [37].

1.15 INVESTIGATION ACHIEVEMENT AND FINDING

Implementation of a routing strategy to help in achieving the below mentioned aims and comparing the designed protocols with the current power aware routing protocols will help in achieving the following.

- ➢ QoS based performance analysis of various routing protocols.
- ➢ Quantitative Analysis and Evaluation of MANET Routing Protocols in effect of varying Mobility Models and number of Network nodes.
- ➢ Analysis on the effect of Directional Antennas on Energy in Routing Protocol.
- ➢ To study the Impact of Minimum Total Transmission Power Routing (MTPR) Protocol in Power Deficient node concentration and Performance Evaluation.
- ➢ Analysis of Low Bandwidth Estimation in Mobile Ad-hoc Network (MANET).
- ➢ Dynamic Approach for Optimization of Energy consumption in OLSR,RIP and Fisheye Routing Protocols using QualNet 5.0 Simulator. From the above research work the following outcome is expected.
- Minimizing delay
- Minimizing total Energy consumption
- Increase network life time
- Load balancing among all the nodes
- ➢ Investigation through implementation of Power Awareness in $OSPF_{V2}$ (Open Shortest Path First $_{version\ 2}$) and RIP_{V2} (Routing Information Protocol $_{version\ 2}$) Routing Protocol in Wireless Sensor Networks (power aware protocols), using simulation software.
- ➢ Investigation of Power Management approach for Optimized Link State Routing (OLSR) Protocol.

1.16 LIMITATIONS AND ASSUMPTIONS

The following limitation and assumptions are considered for the simulation purpose: The nodes in the network are stationary.

- All nodes have similar capabilities, (processing/communication) and equal significance.
- Each of the nodes is battery operated and the battery is not recharged.
- Designed simulation done in QualNet 5.0 is very much practical but the designed protocol is not tested in real world applications.
- Nodes are left unattended after deployment.
- Distance between the nodes is same.

1.17 THE AUXILIARY WORK

The above mentioned protocols investigated in QualNet are also validated through MATLAB software. The above work is also carried out to study and investigation of following parameters on WANET performance.

- Transmission range
- Number of nodes in network (variable)
- Deployed the shape of the area in WANET (area may be rectangular, triangle or square)
- Node Mobility
- Bandwidth

1.18 ORGANIZATION OF THESIS

The primary focus of this thesis is routing and investigation on power aware routing protocols in WANETs (wireless sensor network and ad-hoc network). The type and classification with the characteristic is studied. Such as Reactive, Proactive, Hybrid and power aware routing protocols. Investigation and comparison of eleven broadcast routing protocol (AODV, DSR, DYMO, Fisheye, LANMAR, LAR, $OSPF_{V2}$, OLSR, $RIP_{V2,}$ STAR and ZRP) for different networks like IEEE 802.11(MANET), IEEE 802.15.4 (WSN) is done using Matlab and QualNet simulators.

Chapter 2 "Wireless Sensor Networks: An Overview" describes the general application characteristics and assumptions, applications of WANETs. We also discusses in relation to the basic routing protocols used in wireless network and ad-hoc networks.

Chapter 3 “Power& Energy Saving Schemes in Wireless Sensor Networks”: Factors affecting of routing protocols to consume maximum power in WSN. A brief description of Power management and energy optimization with different duty cycling approaches for saving energy techniquesalso provided in this chapter.

Chapter 4 “QoS based performance analysis of various routing protocols”, discusses the results of experiments conducted on designed scenarios based on QualNet study and analysis the energy models with varying number of network nodes and analysis of the effect on Directional Antennas on energy in different routing protocol based nodes on MANETs performance.

Chapter 5 “Protocols based on power saving schemes in wireless sensor network”, an experimental result is studies and discusses the results which conducted on MATLAB simulator software. to study the transmission range impacts between source and destination, number and size of nodes, shape of the rectangular area, mobility between nodes, impact of Minimum Total Transmission Power Routing (MTPR) protocol in power deficient node concentration and performance evaluation of MANET with Low Bandwidth Estimation.

Chapter 6 In this chapter we proposed “dynamic approach for optimization of energy consumption and power awareness in routing protocol “we avoiding a node which has a minimum residual battery power and check status in designed scenario in QualNet. The projected approach is implemented by introducing a threshold value to change on every node and transmitting the equivalent length size of packet on the route. In this chapter we did two simulation based experiments on dynamic approach to optimize energy consumption in OLSR, RIP, and Fisheye protocols using simulator and proposed power aware $OSPF_{V2}$ and RIP_{V2} routing protocols.

Chapter 7 In this chapter another investigation proposal for “power management approach for optimized link state routing (OLSR) protocol” The modification is done with effect of power and energy management issues in existing OLSR and modified OLSR routing protocol with the metrics like TC message received, signal received and forward to MAC, Hello message received, signal received but with errors, three power consumption modes receive, transmit and ideal modes, For above implementation simulation purpose QualNet 5.0 has been used as the tool.

Chapter: 8 Conclusions and Future Scopes: Final conclusions and future extension of the work and future scope in this field are elaborated in this chapter.

Chapter 2

WIRELESS SENSOR NETWORKS: AN OVERVIEW

This chapter gives review of literature and general consideration of WANET (wireless sensor networks and Ad-hoc Network) considered for thesis. Here brief overview of the contents of chapters is described.

2.1 INTRODUCTION

Now there is new field called mobile computing which gives the basic idea of anytime and anywhere computing. The major reason of mobile computing is advances in wireless technology. But here in this ubiquitous computing environment we can't follow the normal architecture and protocols which have been used in the fixed network due to it's battery powered devices involved in the computing and transmission of the data. The advancement in miniature computing model and wireless transmission techniques lead to the development of the wireless sensor network. Due to battery limitation and ad-hoc nature of sensor network , energy efficient protocols are required at all the layers of the protocol stack .Since with an objective of gathering information, sensor network is deployed for a given initial battery energy, it is desired that the network continues to function and provide data updates for as long as possible. This is referred to as the maximum lifetime problem in sensor networks.

Nodes spend a part of their battery energy on transmitting, receiving and relaying packets during each data gathering phase. Hence the routing algorithm should be designed to maximize the time until the first battery expires, or a fraction of the nodes have their batteries expired,

Besides the battery energy in certain low bandwidth network, the channel bandwidth presents itself as another constraint, and the routing problem has to take this into account. There are already several routing protocols developed for mobile ad hoc network what deal with these issues. In a mobile ad hoc network nodes are often powered by batteries. The power level of a battery is finite and limits the lifetime of a node. Every message sent and every computation performed drains the battery. This means that the routing protocol should try to minimize control traffic, such as periodic update messages. To improve the lifetime of the nodes and network even further, one should also try to keep the data traffic as low as possible. This optimization can be achieved by utilizing power awareness routing. This means that routing decisions make by the routing protocol is based on the power-status of the nodes. Nodes with low batteries will be less preferably for forwarding packets than nodes with full batteries thus increasing the life of the nodes. However, not every routing protocol is suitable for implementing power awareness routing and different approaches on power awareness routing can be followed [54-55].

2.1.1 Sensor Network Model

This chapter is introductory, we refer primarily to the sensor network model as shown in Fig. 2.1 which consisting one sink node (or base station) and a (large) number of sensor nodes deployed over a large geographic area (sensing field). Data are transferred from sensor nodes to sink through multi-hop communication models [56].

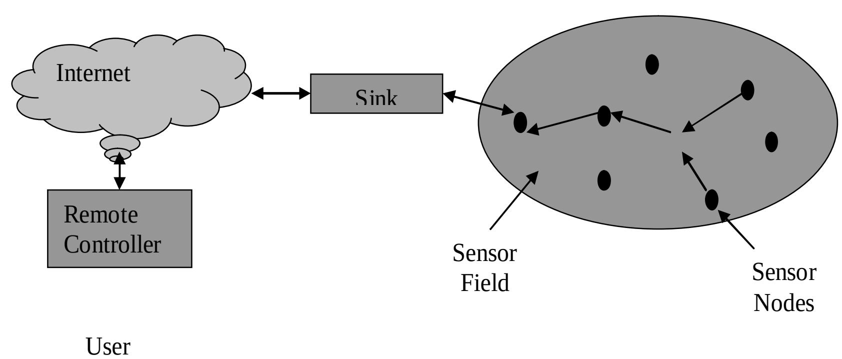


Fig. 2.1Sensor Network Model

2.1.2 Power Consumption

Devices in wireless sensor networks are battery operated and it should be intended to consume as less power as possible. Energy and power conserving functions also have been implemented at different levels of software. In fact, operating systems are having the functions for controlling the power utilization and consumption of hardware containing in BIOS interfaces. Power consumption strategy used in space applications, high energy consumed by hardware such conditions displays of hardware can be turning off instead of instantly invoking screen saver of system.

2.1.3 Components of Sensor Node

Wireless sensor networks are basically two types: structured and unstructured. In a structured WSN all or some of the sensor node are deployed in a pre-planned manner. The advantage of a structured network is that fewer nodes can be deployed with lower network maintenance and management cost.

For example, energy efficient protocols are aimed at minimizing the energy consumption during network activities. However, a large amount of energy is consumed by node components (CPU, radio, etc.) even if they are idle. Power management schemes are thus used to switch off node components that are not temporarily needed as shown in Fig. 2.2.

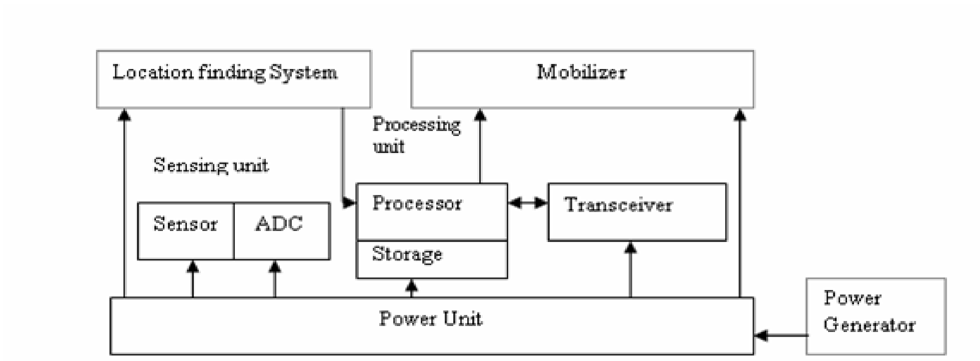


Fig. 2.2 Components of a sensor node

2.2 TYPES OF WIRELESS SENSOR NETWORKS

During the last few decades' advancement in hardware as well as software techniques has changed, resulting in most of mobile hosts and wireless networking using common platform. Commonly there are two different approaches intended for enabling wireless mobile units to exchange the information with each other through computational environment [2]:

2.2.1 Infrastructure based Wireless Sensor Network

Wireless mobile networks have been conventionally which is based on the cellular thought and relied on excellent infrastructure support, in which mobile devices correspondence with access points said to be base stations and connected to the fixed network infrastructure.

The access point or router does not just control medium to be access, however it acts like a bridge to wired and wireless sensor networks. Usually, the purpose of infrastructure based network is very simple in design because most of the functionally and components are established around the access point, where the wireless client can remain quite simpler.

Infrastructure based networks offer flexibly wireless networks. This type of network cannot be used for disaster relief in some cases where no infrastructure is left. Some examples of wireless networks are wireless local area network (WLAN), wireless local loop (WLL) etc [59].

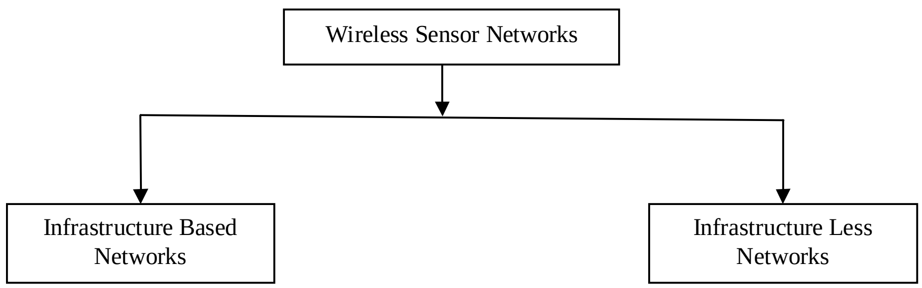


Fig. 2.3 Types of Wireless Networks

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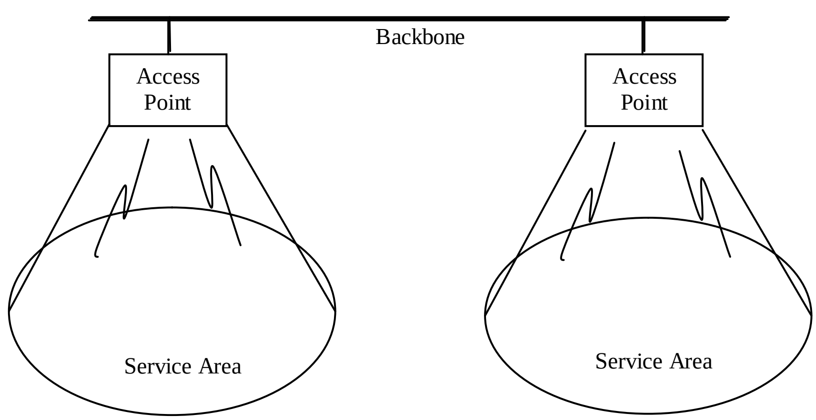


Fig. 2.4 Infrastructure based Wireless Sensor Networks

2.2.2 Infrastructure less based Wireless Sensor Networks

Infrastructure less based wireless sensor network is a collection of wireless network nodes that they can dynamically constitute a network to swap their information without using any pre-existing network communications. This technology is very significant part of communication to facilitate and supports truly pervasive computing. Wireless ad hoc networks themselves are an independent, today's very broad area of research and applications [59].

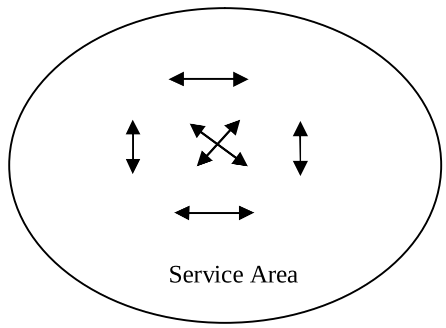


Fig. 2.5 Infrastructure less Wireless Sensor Network

2.3 CHARACTERISTICS OF WIRELESS SENSOR NETWORKS

A Wireless Sensor Network is an autonomous system consisting of sensor nodes in the wireless network to facilitate data exchange in the presence of any fixed network infrastructure. Depending on the nodes environmental positions also matter, there are transceiver coverage patterns, transmission power levels, and co-channel interference levels, a network can be formed and unformed on the fly. This Wireless Sensor network topology changes as sensor nodes migrate, "disappear" (failure or depletion of battery capacity), or adjust their transmission and reception characteristics. The main characteristics of Wireless Sensor networks include [60]:

Dynamic Topology: Nodes are free to move about arbitrarily. In addition, radio propagation conditions change rapidly over time. Thus, the network topology may change randomly and rapidly over unpredictable times [61].

Bandwidth Constraints and Variable Link Capacity: Wireless links have significantly lower capacity than wired links. Due to the effects of multiple accesses, multipath fading, noise, and signal interference, the capacity of a wireless link can be degraded over time and the effective throughput may be less than the radio's maximum transmission capacity [62].

Energy Constrained Nodes: Sensor nodes rely on batteries for proper operation. Since a Wireless Sensor networks consists of several nodes, depletion of batteries in these nodes will have a great influence on overall network performance. Therefore, one of the most important protocol design factors is related to device energy conservation. Hence power consumption constraint for nodes using batteries or energy harvesting [52, 63].

Multi-hop Communications: Due to signal propagation characteristics of wireless transceivers, Wireless Sensor networks require the support of multi-hop communications; that is, sensor nodes that cannot reach the destination node directly will need to relay their messages through other nodes.

Limited Security: Mobile wireless networks are generally more vulnerable to security threats than wired networks. The increased possibility of eavesdropping, spoofing, and denial-of-service (DoS) attacks should be carefully considered when a Wireless Sensor wireless network system is designed. To support mobile computing in Wireless Sensor wireless networks, a sensor node must be able to communicate with other sensor nodes; this may not lie within its radio transmission range. To support Wireless Sensor Network communications under the influence of the above-mentioned factors, and Wireless Sensor routing protocol will need to perform four functions, namely [64]:

- Determining/detecting changing network topology
- Maintaining network topology/connectivity
- Scheduling of packet transmission and channel assignment

2.4 PROPERTIES OF WIRELESS SENSOR NETWORKS

The desirable properties of Wireless Sensor Routing protocols are discussed below.

2.4.1 Distributed Implementation

Since Wireless Sensor Networks are autonomous and self-organizing systems, routing protocols must be distributed in nature without relying on centralized authorities [65].

2.4.2 Efficient Utilization of Bandwidth

If a routing protocol incurs excessive control traffic, the available network bandwidth will be consumed by control traffic. This can impact communication performance. Since the bandwidth of a wireless network is limited, reduction of control overhead is an important design factor [65-66].

2.4.3 Efficient Utilization of Battery Capacity

The lifetime of sensor nodes will deeply impact the performance of the Wireless Sensor Network. To prolong the lifetime of each node, Wireless Sensor routing protocols should consider power consumption. For example, routing protocols should be able to accommodate sleep periods without causing any adverse consequences; that is, hosts can stop transmitting and / or receiving for arbitrary periods of time when it is ideal. Moreover, transmission power can be used as a routing metric [66].

2.4.4 Optimization of Metrics

End-to-end throughput and delay are widely used performance metrics in wired and wireless networks. However, since the network topology is dynamically changing, the bandwidth and battery power are important factors in Wireless Sensor networks but one has to consider other metrics as well. Such metrics can influence the design of routing protocols, and there exist trade-offs in using different metrics. For example, although on-demand routing algorithms can reduce control overhead (i.e., optimizing the bandwidth), it requires some route acquisition time (i.e., the time required to discover and establish a route when desired), thus increasing end-to-end delay. Therefore, in routing protocol design one should optimize some reasonable metrics in addition to others. The following is a list of metrics worthy of consideration [67]:

- Maximum end-to-end throughput
- Minimum end-to-end delay
- Shortest path/minimum hop
- Minimum total power (battery capacity)
- Load balancing (least congested path)
- Minimum overhead (bandwidth)
- Adaptability to the changing topology
- Association stability [15] (i.e., longevity of routes)
- Route relaying load [16]

2.4.5 Fast Route Convergence

Since the network topology dynamically changes, routing protocols should provide a new and stable route as soon as possible after a topology change.

2.4.6 Freedom from Loops

The paths derived from the routing tables of all nodes should not have loops. Some routing algorithms can cause temporary loops (i.e., a small fraction of packets spinning around the network for an arbitrary period of time). Looping of packets can result in considerable overhead in terms of bandwidth and power consumption. Using time-to-live (TTL) values can help mitigate this problem, but a more structured and well-thought-out approach is desirable because it can lead to better communication performance [67].

2.4.7 Power-Efficient Wireless Sensor Networks and Efficient Utilization of Battery Power

Since most sensor nodes of a Wireless Sensor network today operate using batteries, it is important to minimize the power consumption of the entire network (implying maximizing the lifetime of ad hoc networks). The power required by each sensor node can be classified into two categories [68-69]:

- Communication-related power
- Non-communication-related power

The former can be further divided into two parts, namely:

- Processing power
- Transceiver power

Each sensor node spends some processing power to execute network algorithms and run applications. Transceiver power refers to the power used by the radio transceiver to communicate with the other sensor nodes. In mobile power consumption, each protocol layer is closely coupled. For example, if a routing protocol requires frequent updates of routing information, it is difficult to implement sleep mode at the data link layer [69].

2.4.8Advantages of Mobile Ad Hoc Networks

Common issues in wireless sensor network and MANETs, the motivation behind their popularity and their benefits will be discussed.

- **Low Cost of Deployment:** Less expensive infrastructure, such as data cables, copper wires, etc [69].
- **Fast Deployment:** WLANs, ad hoc networks are very convenient and simple to deploy.

- **Dynamic Configuration:** Ad hoc network configurations change dynamically with time. In comparison to configurability of LANs, it is very easy to transform the network topology [71].
- **Flexibility:** Within radio coverage, nodes are able to communicate without further restriction [71].
- **Planning:** Only wireless ad-hoc networks allow for communication without previous planning.
- **Design:** Wireless networks allow for a design of small, independent device[70].
- **Robustness:** wireless sensor network and MANETs can be survived in disasters.
- **Cost:** After providing wireless access to the infrastructure through an access point for the primary user, adding additional user to access a wireless network will not increase the cost [72].

2.4.9 Disadvantages of Mobile Ad hoc Networks

- **Quality of Service:** Wireless network typically offer low quality of service as compare to the wired networks. The main reason for this is the low bandwidth due to limitations in radio transmission [73].
- **Proprietary Solution:** Due to slow Standardization procedures, many companies come up with proprietary solutions offering standardizing functionality plus many enhanced features. However these homogeneous environment [74].
- **Restrictions:** Several government and non-government institutions worldwide regulate the operation and restrict frequencies to minimize interference [75].
- **Safety and Security:** Using radio waves for data transmission might interfere with additional high-tech equipment [76].

2.5 ROUTING PROTOCOLS

Wireless sensor networks (WSNs) are specialized relatives of MANETs whose main purpose is to sense or monitor a predetermined type of event, such as vibration levels, temperatures, and pressure in various environments, many of them hostile to or difficult to access by humans [72]. WSNs do not necessarily have to be mobile; a mobile ad hoc network consists of a set of mobile node that is connected by wireless links. The network topology in such a network may keep changing randomly. Routing protocols that locate a path to be followed by data packets from a source node to the destination node used in traditional wired networks cannot be directly applied inad-hoc wireless networks due to their higher dynamic topology, absence of established infrastructure for centralized administration [77]. A variety of routing protocols has been proposed in the recent past year. We then discuss the working of several existing routing protocols in next chapters.

2.5.1 Reactive and Proactive Routing Protocols

The protocols in the above section are study for wireless networks and MANET where changes in the topology infrequently. This projected protocol called proactive (also called table-driven). In ad-hoc networks cannot use an optimal strategy because routes might be maintained futilely. The nodes in an ad hoc network moves at a very high speed.

Routing protocols for mobile ad hoc network have been developed and discover these routes on an on-demand basis. These protocols are called reactive. We investigated popular routing protocols some of them given below;

- AODV
- DSR
- DYMO
- LAR

2.5.2 Overview of WSNs Routing Protocols

There is a need to examine the types of routing protocols and see if they are suitable for wireless networks. Many routing protocols may have different requirements on the design of their routing metrics. Therefore, it is necessary to understand the routing protocols and their properties and to find out which routing metrics effectively support the routing in wireless networks. Routing protocols can be grouped into three main categories based on how the packets are routed along the paths. The categories are namely; on-demand routing, proactive routing and hybrid routing. Hong et al. (2002) classified the routing protocols according to the role of nodes in the three classes, as shown below:

(1) Flat routing strategies, which are further classified into two classes, proactive and reactive according to their design philosophy.

(2) Hierarchical routing strategies.

(3) Geographic position assisted routing.

The flat routing assumes a flat addressing strategy. Each node participating in routing has an equal role. The hierarchical routing usually assigns different roles to network nodes. In geographic position routing, the nodes equipped with the Global Positioning System (GPS) are assisted by the geographic location information required with the routing. This requirement is realistic today because such devices are inexpensive.

2.5.3 Classification of Routing Protocols

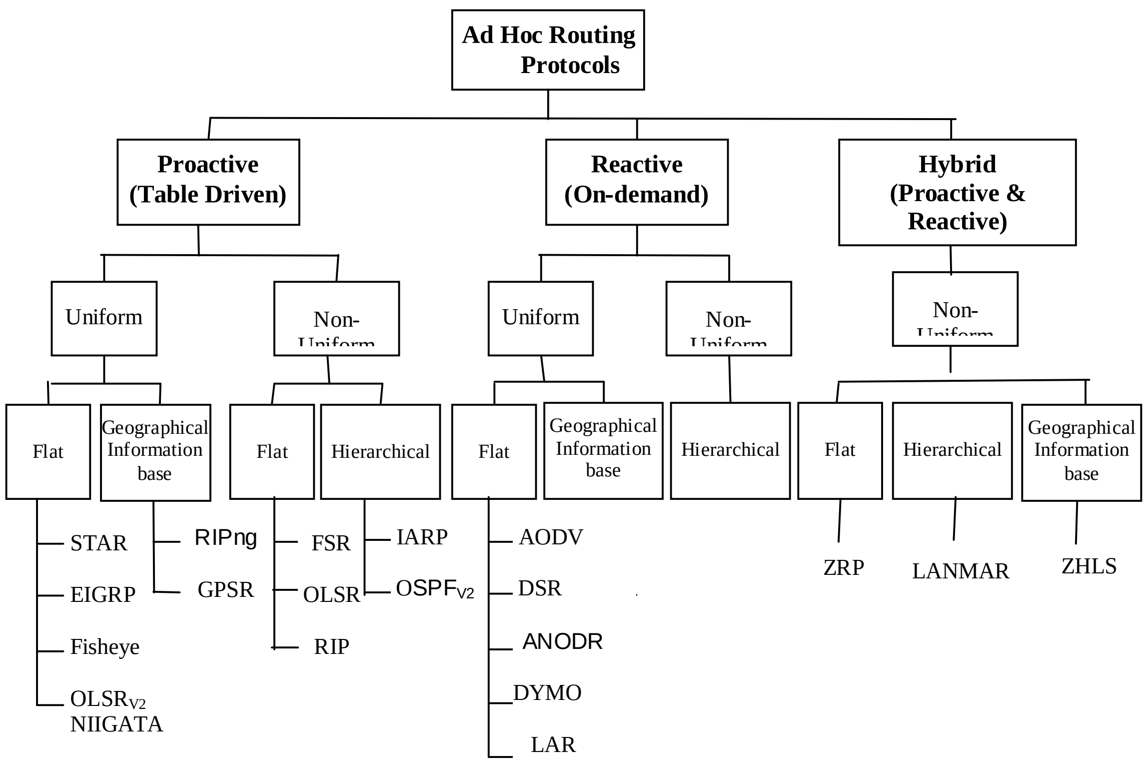


Fig.2.6 Classification of Routing Protocols in WANET

Routing protocols for mobile ad hoc wireless networks can be classified into several types based on different criteria. A classification tree of routing protocols is given below [49].

2.5.4 Comparative Description of Wireless Sensor Network and Ad Hoc Network Routing Protocols

After a deep study about wireless and Ad-Hoc Network, the author observed that there is many differences among all the routing protocols and explain these differences in the following tables 2.1 [48].

Table 2.1 Comparative Description of Routing Protocols in WANET

Name	**Description**	**Type**	**IP Version(s)**	**Model Library**
ANODR	Anonymous On-Demand Routing(ANODR) protocol. This is a secure routing protocol.	Reactive	IPv4	Network Security
AODV	Ad-hoc On-demand Distance Vector (AODV)	Reactive	IPv4, IPv6	Wireless
IERP	Inter-zone Routing Protocol (IERP) This is an on-demand routing protocol and is a component of ZRP.	Reactive	IPv4	Wireless
DSR	Dynamic Source Routing (DSR) protocol.	Reactive	IPv4	Wireless
DYMO	Dynamic MANET On-demand (DYMO) routing protocol.	Reactive	IPv4, IPv6	Wireless
LAR	Location-Aided Routing (LAR) protocol, version 1.This protocol utilizes location information to improve scalability of routing.	Reactive	IPv4	Wireless
EIGRP	Enhanced Interior Gateway Routing Protocol (EIGRP). This is a distance vector routing protocol designed for fast convergence	Proactive	IPv4	Multimedia and Enterprise
Fisheye	Fisheye Routing Protocol. This is a link state-based routing protocol.	Proactive	IPv4	Wireless
LANMAR	Landmark Ad-hoc Routing (LANMAR) protocol. This protocol uses Fisheye as the local scope routing protocol.	Proactive	IPv4	Wireless
Bellman Ford	Bellman-Ford routing protocol.	Proactive	IPv4	Developer

IARP	Intra-zone Routing Protocol (IARP). This is a vector-based proactive routing protocol and is a component of ZRP.	Proactive	IPv4	Wireless
IGRP	Interior Gateway Routing Protocol (IGRP). This is a distance vector Interior Gateway protocol (IGP).	Proactive	IPv4	Multimedia and Enterprise
OLSR	Optimized Link State Routing (OLSR) protocol. This is a link state-based routing protocol.	Proactive	IPv4, IPv6	Wireless
$OLSR_{V2}$ NIIGATA	Optimized Link State Routing, version 2 ($OLSR_{V2}$) protocol. This is a successor of the OLSR protocol.	Proactive	IPv4, IPv6	Wireless
$OSPF_{V2}$	Open Shortest Path First ($OSPF_{V2}$) routing protocol, version 2. This is a link state-based routing protocol for IPv4 networks.	Proactive	IPv4	Multimedia and Enterprise
RIP_{V2}	Routing Information Protocol (RIP_{V2}) routing protocol, version 2. This is a link state-based routing protocol for IPv6 networks.	Proactive	IPv6	Multimedia and Enterprise
RIPng	Routing Information Protocol, next generation (RIPng) routing protocol. This protocol can be used for IPv6 networks.	Proactive	IPv6	Developer
STAR	Source Tree Adaptive Routing (STAR) protocol.	Proactive	IPv4	Wireless
ZRP	Zone Routing Protocol	Hybrid	IPv4	Wireless

2.6 AODV

The (AODV) [79] protocol by nature is a reactive and unicast routing protocol particularly designed for (MANET) mobile ad hoc networks. As a reactive protocol, AODV needs to retain the routing information through dynamic paths. In AODV, routing information is store and maintaining in tables on their nodes. Each node maintains a next-hop routing of packet table and decides its route. If no route is remaining, then it performs route discovery process for finding a path to the destination. Therefore, route discovery phase becomes on-demand.

The route discovery normally consists of the network-wide flooding of request packet message. If route has been established, than it maintained route maintenance procedure until the destination becomes inaccessible, because AODV routing protocol is a destination based reactive routing protocol.

In AODV, if a source node requires sending a packet to its destination but no route is available, than initiates a route discovery operation. In the route discovery operation, the source node floods route request (RREQ) packets as shown in fig 2.7.

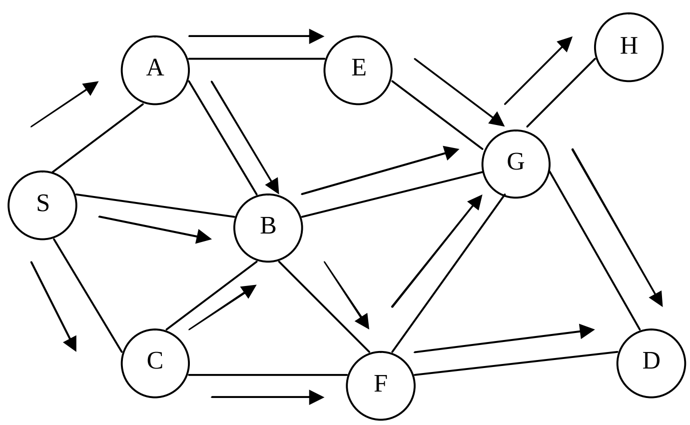


Fig. 2.7 Flooding route request (RREQ) packets in AODV

A route request (RREQ) includes address to the source and destination, the broadcast ID, which is its identifier, the source nodes sequence number and last seen sequence number of the destination matched with source node's sequence number. Sequence numbers are very important to make sure it is loop-free as well as up-to-date routes. For reductions the flooding overhead, the node discards route request (RREQs) algorithm is used for route discovery operation [80].

2.6.1 Route Discovery

When a node wishes to transfer a packet to some defined destination node and does not consist of a suitable route present in its routing table for the given destination, then it starts a route discovery process. Then the source node sends a route request (RREQ) packet for its Neighbors, which in turn passes on the request to its neighbor and so on. Then the nodes generate a Route Request with defined destination address, Sequence number and Broadcast ID which is delivered to his neighbor nodes. Each and every node receiving the delivered route request delivers a route back (Forward Path) to the node as shown in the figure 2.8

When the RREQ is received by a particular node i.e both a destination node and an intermediate node with a new route to that destination, then replies by uncasing the route reply (RREP) in the direction of the source node. As soon as the RREP is routed back on its reverse path, the intermediate nodes beside this path build up forward path entries for the destination in its route table and as soon as the RREP reaches the source node, a route from source to the destination is established. Fig. 2.8 depicts the pathway of RREP originating from the destination node and concluding at the source node.

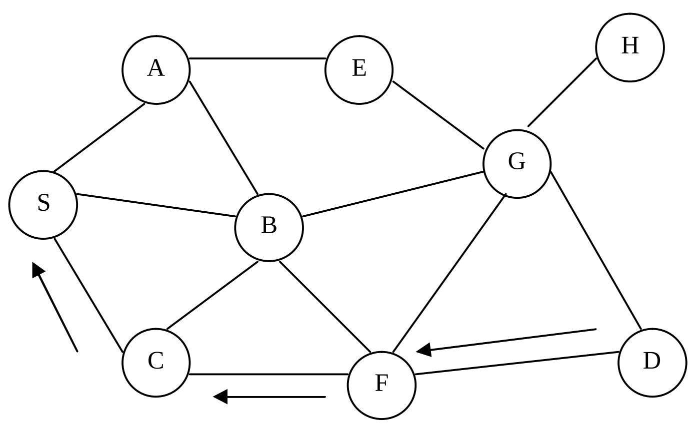


Fig.2.8 Route Reply (RREP) packet in AODV

2.6.2 Route Maintenance

A route is established between sources to destination pair is maintained needed as long as by the source. When an active route link break is detected, then broken link is unacceptable and a RERR message is sent to other network nodes. The RERR propagate with precursor nodes until the source node is reached. The affected node may stop sending the data or choose to new route destination for sending RREQ message [71, 80].

2.7 DSR

The Dynamic Source Routing protocol (DSR) is reactive unicast routing protocol, it is very simple and efficient routing protocol which was designed for specifically multi-hop wireless mobile ad hoc networks of mobile nodes. DSR allows the network to be entirely self-reliant and self-configuring, without the need for any existing network infrastructure or administration. In DSR, every data packet completes their routing information and sends to dissemination by using source routing to sending packets.

DSR uses source routing this means that the source must know the complete hop sequence to the destination. Additionally, each node maintains a route cache, where all routes it knows are stored. The route discovery process is initiated only if the desired route cannot be found in the route cache in DSR each node uses caching technology to maintain the route information. There are two major phases in DSR;

(i) Route Discovery Phase

(ii) Route Maintenance Phase

2.7.1 Route Discovery Phase

Route Discovery phase is used whenever a source node required a route to reach the destination node. Than a source node wants to communicate and sends a packet, it firstly discovers the route cache and looks up its route cache to determine if it already contains a route to the destination. If the source finds a suitable route to the destination, than it uses this route towards send its data packets. If the node does not contain a valid route to its destination, then it initiates the route discovery process by broadcasting a route apply for request message. The route request message contains the address of the source to destination, with a unique identification number. An intermediate node to facilitate receives a route request message searches its route cache intended for a route to the destination. If no route is found, it appends its address for the route record of the message packets furthermore forwards the message to its neighbors [81].

The message propagates throughout the network until it reaches either the destination or an intermediate node through a route to its destination. Then a route reply message request packet is forwarded to its neighbors containing the appropriate hop sequence for reaching its destination.

There are three possibilities to obtain a backward route. The first is that the node previously has a route to its source. The second prospect is that the network has symmetric or bi-directional links [82]. In the final case, there exists only asymmetric or uni-directional links than a new route discovery process is initiated at their source. The route reply packets send their collected routing information in the route record field, but in a reverse arrangement as shown in Fig.2.9.

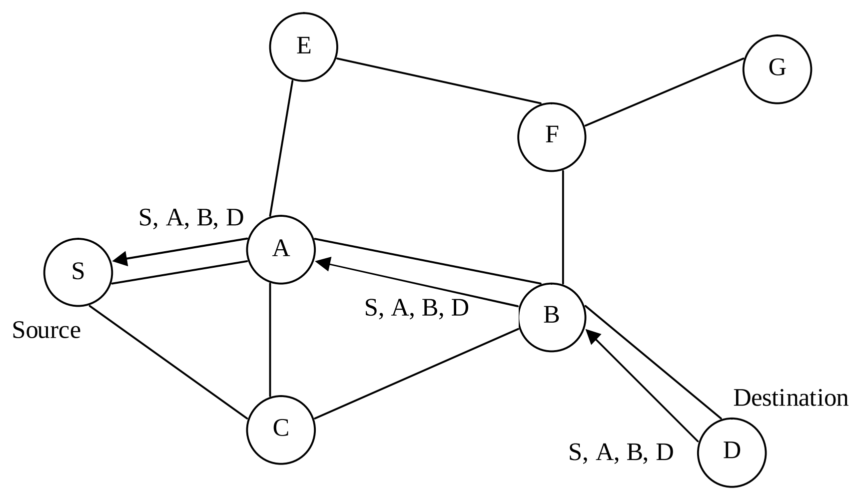


Fig. 2.9 Route Reply with Route Record in DSR

2.7.2 Route Maintenance Phase

Route Maintenance is used to handle route link breaks between sources & destination. When there is a node constituting the fatal transmission problem at the data link layer, it removes the route initiated from its route cache and in turn produces a route error message. The route error message is then delivered to each node of packet routed over the broken link. When a node receives the route error message, it then deletes the hop in error from its route cache.

An acknowledgment message is there to verify the correct process of the route links. In wireless networks, acknowledgments are frequently used in an existing standard part of the MAC protocol.

Moreover, all routes constituting the broken link should be detached from the route caches of the immediate nodes where the ROUTE_ERROR packet is transmitted to the source [82]. DSR increases traffic overhead into each data packet, which degrades its routing performance.

2.8 DYNAMIC MANET ON-DEMAND PROTOCOL (DYMO)

Dynamic MANET On-demand (DYMO) routing protocol which enables reactive, multihop unicast routing between participating DYMO routers. DYMO is an improved version of AODV routing protocol. DYMO operation is dividing into route discovery and route maintenance. Routes are discovered on-demand when the designer begins hop-by-hop allocation of a RREQ (rout request) communication throughout the network and find a route to its target, presently not in its routing table. This RREQ route request message is flooded in the entire network using broadcast the packet then reaches their targets. The target then sent a RREP (route reply) to the designer. For maintenance of routs which are in employ, routers lengthen route lifetimes upon successfully forwarding a packet. When a data packet is received for forwarding and a route for the destination route is broken, missing or unknown, then the source of the packet is notified by sending a RERR (route error) massage. Upon receiving the RERR massage, the source deletes that route. The basic operations of DYMO are [84]:

- Route Discovery Process
- Route Maintenance Process

2.8.1 Route Discovery Process

In Route Discovery Process a source requests to send a data packet, it sends RREQ and discovers a route to for particular destination shown in Fig. 2.10. After issuing an RREQ, the source DYMO router discovers route to send the packets. Until and unless the route is not sensed in RREQ request time, it may again give a try to discover a new route by issuing another RREQ. Reduction in congestion of a network, frequent attempts at route discovery for an exacting target node must utilize an exponential back off. If any data packets pending in a route that must buffed by the source's DYMO router. Due to limitation of buffer size the old data packets should be redundant first. Buffering of data packets has both positive and negative effects in the network. [84-85].

2.8.2 Route Maintenance

The data packet is forwarded and it cannot be transferred to the next-hop as there is no forwarding path route for the IP destination address exists, so an RERR is issued shown in Fig. 2.11 Based on this condition, an ICMP.

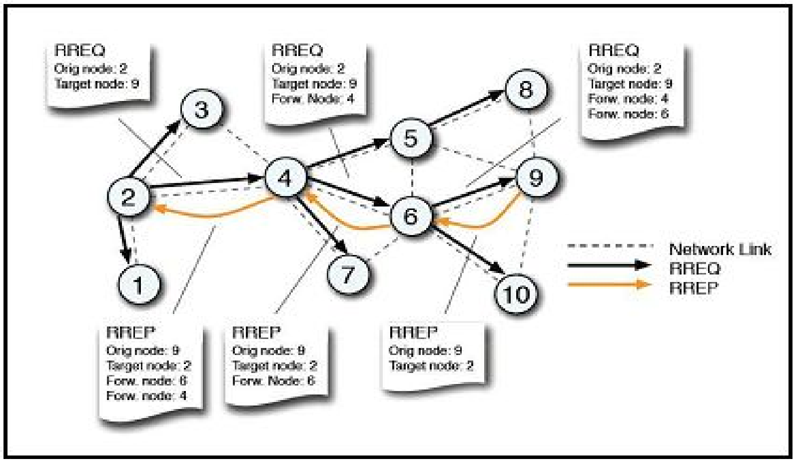


Fig. 2.10 DYMO Route discovery

Furthermore, an RERR should be issued after detection of broken link of a forwarding route and rapidly notify DYMO routers to a link break occurred in the network. If the route with the broken link is not used at that moment, the RERR should not be generated [85].

The DYMO protocols is used mostly for memory constrained devices in mobile ad hoc networks (MANETs) because of quickly determines route information dynamically.

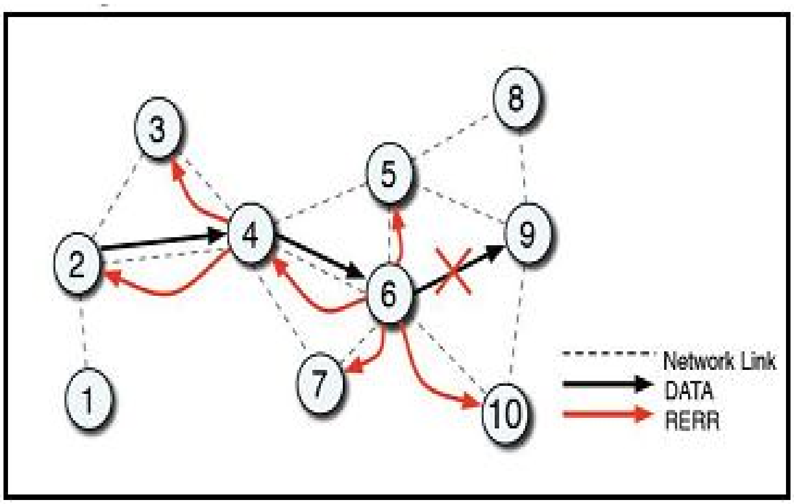


Fig. 2.11 Generation and dissemination of RERR messages

2.9 OPTIMIZED LINK STATE ROUTING PROTOCOL (OLSR)

The Optimized Link State Protocol (OLSR) [93] characterized as proactive routing protocol so employs an efficient link state packet forwarding called multipoint relaying. The optimization technique of OLSR is based on pure link state routing algorithm and optimized them. Optimizations in OLSR are done in two ways, reducing the size of control packets and through links reduction are used for forwarding their link state packets to destination. By reducing the size of link state packets it is declared that only a subset of the links in the link state is updated. These subset of links and neighbors was designed for link state updates and assigned for the task of packet forwarding are called multipoint relays. This link state update mechanism could not generate any additional control packet after a link breaks or after a link is newly added.

The optimization of link state updates achieving higher efficiency when operated in highly dense networks. Fig.2.12 given below shows that how much messages required for transmissions, a analytical flooding-based new approach is employed. In few cases, the number of message transmissions in approximately equal to the number of nodes desired network. The set of consisting nodes that are multipoint relays is referred in the direction of MPRset. Every node (say, K) in the entire network selects an MPRset that to facilitate processes and then it forwards each and every Link state packet that node K originates. The neighbor nodes MPRset that are not belong to the link state packet originated by node K but do not forward them. Similarly, all of node maintains a subset of neighbors called MPR selectors that are nothing but a group of neighbors that encompass the nodes as the multipoint relay. A node transfers the packets that are received from nodes belong to its MPRselector set. The contributors of both MPRset and MPRSelector set and then keep changing over time. The numbers of MPRset of a defined node are chosen in such approach that each node in a node’s two-hop neighborhood has a bidirectional link in between the nodes. The selection of the node that constitutes the MPRset continuously affects the output of OLSR because a node investigates and calculates routes to all destinations because of the members of its MPRset.

Each node periodically sends Hello messages then enclose the list of neighbors through the node that are bidirectional links along with the list of neighbors whose transmissions were recognized in the previous years, but with whom bidirectional links have not been confirmed till now. The collection of multipoint relays is well indicated in the Hello packet. Storage of data structure is established for neighbor then a table is used to preserve the list of neighbors and the condition of neighbor nodes.

The MPRset need not be optimal through initialization of the network it may be same as the neighbor set. Efficiency higher when MPRset smaller the number nodes size and compare to link state routing protocol. Each node is periodically originates topology control (TC) packets that have topology information with which one of the routing table is updated.

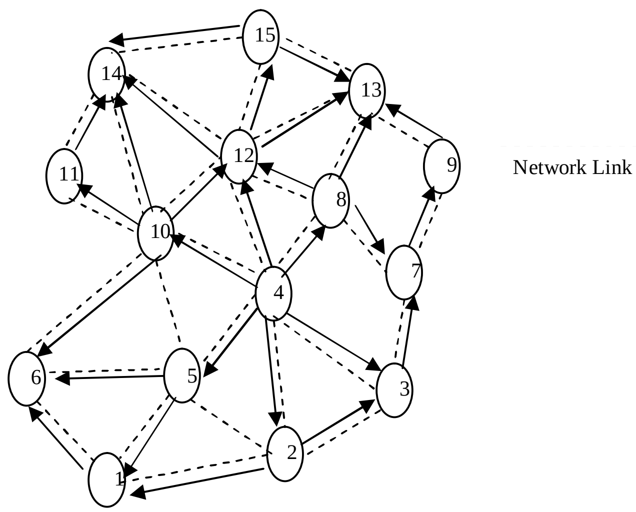


Fig.2.12Flooding the network by nodes

2.9.1 Selection of Multipoint Relay Nodes

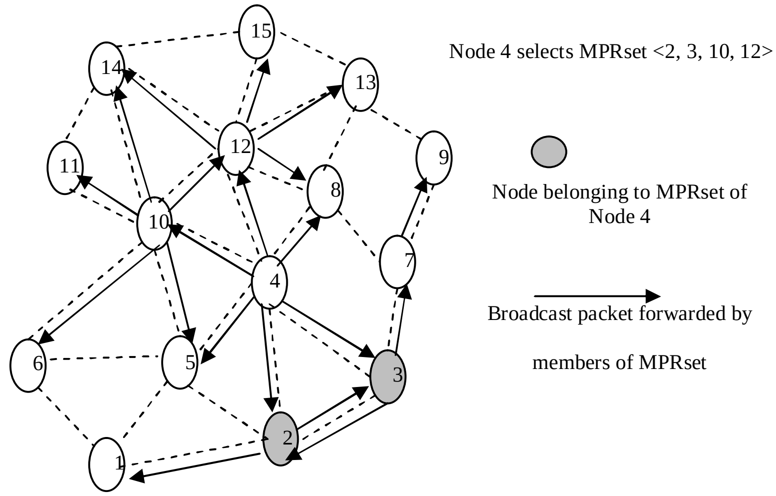


Fig. 2.13Flooding the network using MPR scheme

Fig. 2.13 above shows the forwarding of TC packets using the MPRset of node number 4. For example, node 4 selects the node 12, 10, 3, and 2 as members of its MPRset. Forwarding these nodes to makes the TC packets reach all nodes inside the transmitting node's two-hop local topology. The collection of optimal MPRset is NP-complete [87].

2.9.2 Advantages of Optimized Link State Protocol

- The OLSR has many advantages make it superior option more other table-driven protocols.
- OLSR is flat routing protocol no need of central administrative
- This protocol provides routing information to all the participating hosts in the network.
- This protocol requires that each host periodically sends the updated,
- The reactiveness of the topological changes can be changed by changing the time interval for broadcasting of the Hello messages.
- This protocol need not require that the link is reliable for the control messages.
- This routing protocol has the simplicity in using interfaces.
- This protocol is appropriate for the application which inhibits the long delays.

2.10 LOCATION-AIDED ROUTING PROTOCOL (LAR)

Location-Aided routing protocol (LAR) [86-88] mostly uses for improving the efficiency of the preferred location also reducing the control overhead in wireless sensor network. The LAR protocol checks the environmental condition and availability of the global positioning system (GPS) for their routing. Location-Aided routing protocol (LAR) designates two geographical environmental regions selected for forwarding the control packets, namely, Request Zone and Expected Zone. In the Expected Zone the region in which the destination node is predictable orbe present, and gives the information regarding its location in the past and its mobility condition information. In this incident of non-availability or availability of past information regarding the destination, in some conditions whole network is considered as Expected Zone of the destination. Similarly, with the availability of additional information about its mobility also, the Expected Zone of the destination will be able to be determined with more accuracy and also improved their efficiency. The Request Zone is geographical or environmental region inside path found of destination then forward the control packets to be allowed for propagated. This region is determined by the source of the data transfer session. The control packets used for path-finding are forwarded by nodes which are present in the Request Zone and are discarded by nodes which are present in the Request Zone and are discarded by the nodes outside the Zone. In situation where the sender or the intermediate relay nodes are not present in the Request Zone, additional area is included for forwarding the packets. This is done when the first attempt for obtaining a path to a destination using the initial Request Zone fails to yield a path within a sufficiently long waiting time.

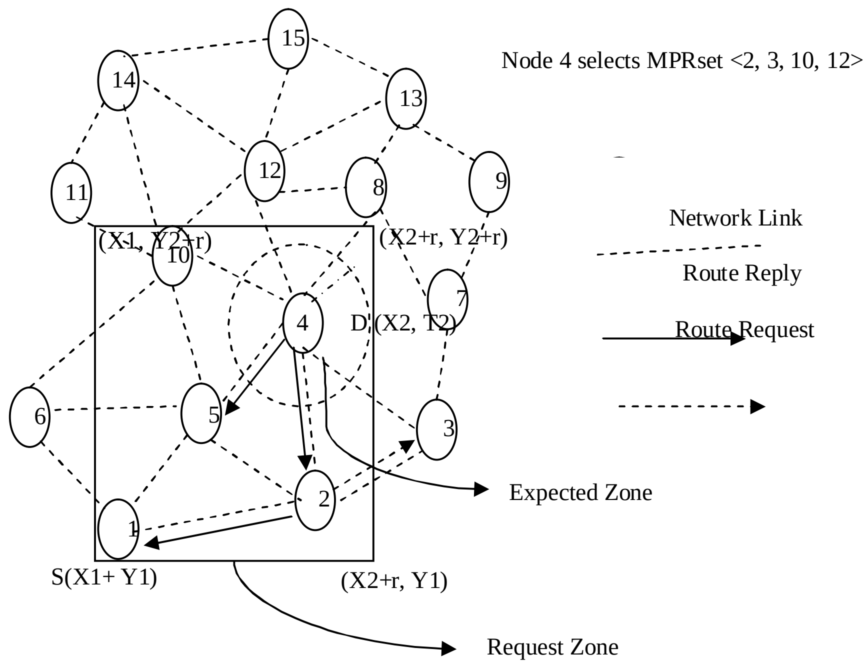


Fig. 2.14 ExpectedZone and RequestZone for LAR1 and LAR2

In this case, the second attempt repeats the process with increased Request Zone size to account for mobility and error in location estimation.LAR use flooding is restricted to a small geographical region. The nodes take decision for forward or may discard the control packets based on two algorithms, namely LAR1 and LAR2.

In the algorithm of LAR1, the source node (say, S) clearly specified the Request Zone in the Route Request packet. As per LAR1 algorithm Request zone and expected zone is illustrated in Fig.2.14above, the RequestZone is the smallest rectangle that includes the source node (S) and the ExpectedZone, the sides of which are similar to X and Y axes, when the node S is outside the ExpectedZone. Then node S is within the ExpectedZone, then the RequestZone is reduced to the ExpectedZone itself. Every intermediate node that receives the Route Request packet verifies the

RequestZone information contained in the packet and forwards it further if the node is within the RequestZone; otherwise, the packet is discarded. In Fig. 2.12 the source node (node 1) originates a Route Request, which is broadcast to its neighbors (2, 5, and 6).

These nodes verify their own geographical locations to check whether they belong to the ExpectedZone. Nodes 2 and 5 find that they are inside the ExpectedZone and hence they forward the Route Request. But node 6 discards the packet. Finally, when the Route Request reaches the destination node (node 4), it originated a Route Reply that contains the current location and current time of the node. Also, as an option, the current speed of movement can be included in the Route Reply if that information is available with the node. Such information included in the Route Reply packet is used by the source node for further route establishment procedures [88-89].

2.11 OPEN SHORTEST PATH FIRST $_{\text{VERSION 2}}$ ($OSPF_{V2}$)

Open Shortest Path First $_{\text{version2}}$ is link state protocol was developed for an open standard of internet routing (IP) across huge multi-vendor networks [96]. A link state routing protocol will send link state advertisements to the entire associated neighbors of the same region to communicate the route information. Each $OSPF_{V2}$protocol enabled router, when in progress it will send hello packets toward all directly connected $OSPF_{V2}$ routers. The hello packets enclose the information in router, router IDs and subnet mask. If the routers need the information they become $OSPF_{V2}$ neighbors.

$OSPF_{V2}$ is classified as an Interior Gateway Protocol (IGP). An IGP distributes routing information between routers belonging to an Autonomous System (AS). The protocol is based on link-state routing scheme. It requires each $OSPF_{V2}$ router to maintain a database of internal topology of the AS domain. From this database, routing table is obtained by performing SPF algorithm (Dijkstra's Algorithm) and by constructing a shortest-path tree.

A major advantage of $OSPF_{V2}$ is that it will be able to operate within a hierarchy. The largest entity with in arrangement of Autonomous System (AS), which is the collection of networks under a single administrative control. Though $OSPF_{V2}$ is an Interior Gateway Protocol, it can receive and update external routing information from other Autonomous Systems. As a dynamic routing protocol, $OSPF_{V2}$ quickly detects topology changes in the Autonomous System and calculates new loop free routes after a period of convergence.

2.11.1 Key Benefits of $OSPF_{V2}$

- **Cost based routing metrics:** The $OSPF_{V2}$ routing protocol supports expressive metrics to designate the bandwidth and ability of each individual wireless network link. $OSPF_{V2}$ gives administrators flexibility in wireless networks [96].
- **Multi-path Routing:** $OSPF_{V2}$ is competent to maintain multiple paths between source to given destination; preference is given to routers for deciding how to deliver the balance data and forwarding over multiple paths. This increases the ability to implement load balancing and redundancy [96].
- **Hierarchical Routing:** $OSPF_{V2}$ supports the model of different areas and multilevel routings; this provides the scalability and redundancy to control the thousands of routers.
- **Dijkstra Shortest Path First algorithm:** This is basic capability of $OSPF_{V2}$to allow it to calculate a cost to every source to destination in the wireless sensor network [96].
- **High Level of Security:** $OSPF_{V2}$ supports verification mechanisms to authenticate routers contribution in the wireless network.
- **Traffic Engineering:** $OSPF_{V2}$is competent for characterize the traffic engineered networks.

2.12 ROUTING INFORMATION PROTOCOL (RIP_{V2})

This routing protocol (RIP $_{Version\ 2}$) is an Interior Gateway Protocol (IGP) used for switch over the routing information surrounded by area or in independent system [96]. This protocol (RIP_{V2}) exchanges their information through routing by router in the form of nodes. Destinations of nodes may be through networks, individual hosts or special destinations used to communicate a default route. RIP_{V2}routing protocol enhance version of RIP routing which is based on the Bellman-Ford routing protocol which was based on distance-vector algorithm. This means RIP_{V2}routing protocol is decisions based protocol that the hop count between a router, source and destination used for their implementation. RIP_{V2} does not change IP packets, its routes them based on destination packet address only.

The router in the wireless network needs to survive or able to appear at a source packet's and sent to destination address and then establish the output ports for their best choice to obtain the packets form the address port [97-98]. The router consulting their decision and makes it on forwarding to routing table. The fundamental problem in RIP_{V2}routing protocol is: "How do routers acquire the information in their forwarding tables"?

Routing algorithms is necessary to construct the routing tables and then forwarding this table to router. The fundamental problem of routing is to discover the lowest-cost path among any two nodes, where the cost of a path equals then the sum of the costs of all node edges make up the path between source and destination. Routing is achieved in mainly realistic networks by management in routing protocols between the nodes. These types of protocols provide a distributed, dynamic technique to solve this type of problem to finding the lowest-cost path in the occurrence of link and node failures and shifting edge costs.

2.13 HYBRID ROUTING PROTOCOLS

Hybrid routing protocols are proposed to come together or combination of reactive and proactive routing protocols and overcome their limitations.

- Zone Routing Protocol (ZRP)
- LANMAR

2.14 ZONE ROUTING PROTOCOL (ZRP)

Zone Routing Protocol (ZRP) is hybrid (proactive and reactive combination)type of routing protocol which was developed for ad hoc networks (mobile). The main design purpose of hybrid protocols was reducing bandwidth and control overhead in desired wireless network. The hybrid routing protocols approaches towards to decrease the latency caused by route search operations in reactive routing approaches [101-102].

2.15 LANDMARK AD-HOC ROUTING PROTOCOL (LANMAR)

Landmark Ad-Hoc Routing Protocol combines the properties of distance vector algorithm and link state algorithm and builds subnets of each group of nodes which are probable to move collectively in the sensor network [101].

2.16 COMPARISON OF ROUTINGCATEGORIES

After a deep study about Ad-hoc Network and wireless sensor network, we observed that there are many differences among all the routing protocols and explain these differences in the following tables 2.2 [90-102].

Table 2.2 Comparison of routing categories

Routing class	Proactive	Reactive	Hybrid
Routing Philosophy	Both flat and hierarchical structures are available.	Mostly flat, except for CBRP.	Mostly hierarchical.
Route availability	Always available.	Determined when needed.	Depends upontheir location of the source to destination in the network.
Control traffic volume	Regularly high attempt in reduction mode. e.g. OLSR.	Lower than Global routing and further improved using GPS.	Mostly, lower than proactive and reactive.
Periodic updates	Yes, However some may use conditional.	Not required. However, some nodes may require periodic beacons.	Frequently used inside each zone, or between gateways.
Routing Technique	On demand	Table Driven	Combination of both
Handling effects of mobility	Usually updates occur at fixed intervals. Alters periodic updates based on mobility.	ABR introduced LBQ. ROAM employs threshold updates. AODV used local route for discovery.	Usually more than one path can be available for handling mobility.

Delay level	Small routes are encoded.	Higher as compare than proactive.	Restricted for small destinations. Inter zone large in reactive protocols.
Scalability	OLSR and TBRPF scalability is higher than other protocols. Normally used for 100-150 nodes.	Source routing protocols up to 200 nodes. Point to point may scale higher. Also depends on the level of traffic and the levels of multi hopping.	Designed for up to 1000 or more nodes.
Storage requirement	Low	Depends upon number of routes kept	Depends upon size of the zone
Overhead in Routing	Low	High	Medium

2.17 FACTORS INFLUENCING THE DESIGN ISSUE IN WSNS

Many factors should affect to be covered during the design stage of the Wireless Sensor Network or the design of the routing protocol. These factors include the following:

- **Reliability or Fault Tolerance:** Sensor nodes are easily broken and they possibly fail due to depletion of batteries or destruction by an outside event. Realizing a fault-tolerant operation is critical, for successful working of the WSN, since faulty components in a network leads to reduced throughput, thereby decreasing efficiency and performance of the network. The failure of any wireless sensor node should affect the functionality of the WSN [103].
- **Scalability:** In WSNs, the deployment of these sensors may reach thousands of sensor nodes. Therefore, the design of the WSN must have the ability to work with numerous nodes and a high-density environment of sensor nodes. A

given sensor's observation i.e environment is limited both in range and accuracy; it can only cover a limited physical area of the environment [103].

- **Production Cost:** The production cost of wireless sensor has to be low as possible, because the sensor network consists of a large number of sensor nodes, otherwise deploying traditional sensors will be more cost effective [103].
- **Redundancy:** Due to the regular node failures and inaccessibility of failed nodes, WSNs are required to have high redundancy of nodes so that the failure of few nodes can be negligible [103].
- **System Lifetime:** The WSNs should function as long as possible. Their system lifetime can be measured by using generic parameters such as time until the nodes die or by using application precise parameters like time until the sensor network is no longer providing acceptable excellence results [76].
- **Energy and Power:** The sensor nodes are generally inaccessible after deployment and normally they have a limited source of power and energy that must be optimally used for processing and communication to extend their lifetime. In order to make optimal use of energy; consequently communication should be minimized as much as possible [77].
- **Power Consumption:** The wireless sensor nodes are micro-electronic device and it can be equipped with a limited energy or power source. In some of application replenishment of power resources might be impossible.
- **Hardware Constraints:** The sensor nodes must consume very low power in order to live as long as possible, and they may use solar cells to generate power or produce more energy to recharge the sensors Therefore, designing any WSN should consider the limitation of the hardware's resources [100].
- **Node Deployment:** Node deployment is also affects designing of some application which are deployment is either deterministic or self-organizing. The sensors are manually placed and data is routed through pre-determined paths [15].
- **Environment:** Sensor nodes are heavily deployed either extremely close or directly within the phenomenon to be observed. Therefore, nodes in the network usually work unattended in remote geographic areas.

- **Harsh Environment:** The wireless sensor nodes must be designed to work under insensitive conditions, such as high pressure at the bottom of the ocean, high temperature in the nozzle of aircraft, and hostile environment in a battlefield.
- **Latency:** Latency refers to delay from when a source to destination packet until the packet is successfully received by the receiver. The sensor data has a temporal time period in which it is valid, since the nature of the environment changes constantly, it is therefore important to receive the data in a timely manner.
- **In-Network Processing:** In general transport protocols used in wired and wireless networks have assumed end-to- end approach guaranteeing that data from the senders have not been modified by intermediate nodes until it reaches a receiver. The concept of in-network processing also called data aggregation or diffusion in WSNs.
- **Real-Time:** WSNs are tightly related to the real world. Therefore, strict timing constraints for sensing, processing, and communication are present in WSNs.
- **Security:** The need for security in WSNs is evident, especially in health care, security, and military applications. Most of the applications relay data that contain private or confidential information.
- **Data Communication and Data Processing:** It is the main events for consuming power in a wireless sensor node. Therefore, the consideration of the energy consumption is very important in designing any communication protocol in the WSNs and this wireless communication can be created from radio, infrared or optical media [103].

2.18 PREVIOUS RESEARCH

Several researchers have done the qualitative as well as quantitative analysis of wireless sensor network routing protocols by means of different investigating metrics. They contain different simulators for investigation purpose. Most of this analysis focuses on the main challenges of wireless sensor network which are reliability, energy/power consumption, bandwidth, and battery power. Although the use of simulation has increased, the credibility of the simulation results has decreased. The most important disadvantage of simulation studies that leads to this is that they are not based on real life scenarios, but their research field is general and based on random assumptions. As a result, the conclusions of these simulation studies cannot be done before, mainly because it is difficult for one to choose a proper routing protocol for a given wireless sensor network and ad-hoc network applications.

In this chapter we analyze the research that has been already done, the simulation parameters that have been used and the conclusions that have been made. The research work generally classified based on the methodology used and the subject to study.

2.18.1 General Studies

Much of the initial research was based on the comparison and investigation of routing protocols using NS-2, QualNet, OPNET simulator and Matlab. More specifically, they concentrate on the comparison of both proactive, reactive and hybrid routing protocols. Next are presented the most considerable studies from this section [51,103].

Table 2.3 General studies and previous research

Study	**Protocols**	**Simulator/ Parameter**	**Performance metrics**	**Conclusion**
"Performance of Two Any cast based reactive Routing Protocols for Ad hoc Networks." [70]	ARDSR and A-AODV	NS-2.23 simulator random waypoint model, CBR traffic source	PDF, Average E2E delay of data packets, Energy consumption and Routing load.	ARDSR better performance in PDF and E2E delay at low mobility, AODV better at high mobility
"Performance Analysis of Proactive and Reactive Routing Protocols for Ad hoc Networks." [65]	DSR, AODV and DSDV	NS-2 simulator generate scenario files for simulation	Packet Delivery Ratio, Average e-e delay, Packet Loss and Routing Overhead	AODV best than DSR and DSDV in PDF, AODV and DSDV best in average E2E delay, DSR is better than AODV and DSDV in packet loss.
"A Simulation Based study on the Performance Comparison of Routing Protocol	OLSR, DYMO, AODV, ZRP	QualNet 4.5 CBR traffic source, two-ray path propagation, path loss model,	PDF, Average E2E delay, average Jitter, Average Throughput	DYMO best in PDF, OLSR and ZRP good in average E2E delay, ZRP better than others in

on Mobile Ad-hoc Network."[60]		mobility based on pause time		throughput
"Performance Comparisons of AOMDV and OLSR Routing Protocols for Mobile Ad Hoc Network." [104]	AOMDV and OLSR	NS-2 simulator random waypoint mobility model file transfer application of TCP for traffic	Packet loss rate, average E2E delay and power routing load	OLSR superior than AOMDV
"A Performance Comparison of Routing Protocols for Security Issue In Wireless Mobile Ad Hoc Networks."[75]	DSR and TORA	OPNET 10.0	Throughput media access delay, Traffic sent and Down Load response time	DSR performance affected by proxy as compared to TORA
"Performance Comparison between Two Routing Protocols for MANET." [76]	DSR and AODV	NS-2 simulator	PDF, Average E2E delay	DSR(best when smaller number of nodes) , less mobility and lower load otherwise AODV
"Performance estimation and Simulation of (MANET) Mobile Ad-hoc Network Routing Protocols." [79]	AODV, DSDV, DSR and OLSR	NS-2 simulator Two different scenarios files	Average Routing Overhead, PDF Ratio, Average E2E delay	AODV performs better in terms of packet delivery ratio. DSDV is better in case of overhead and DSDV and AODV performs quite same in E2E delay.
"Simulation Comparison between Four Wireless Ad hoc Routing Protocols." [118]	DSDV, TORA, DSR, AODV	GLOMOSIM Nodes movement according toward the RWP model	E2E delay, control packet overhead, route acquisition, throughput	DSDV suitable for small networks with limited topology, TORA is good for highly mobile and dense network, AODV overall best.
"Ad-hoc Networks Routing Protocols and Mobility." [95]	WRP, FSR, DSR, AODV, ABR and LAR	GLOMOSIM Mobility model and propagation model,	Data Reception Rate, Consumed Energy, Overhead,	Mobility cause more packet loss, latency, congestion and energy consumption

"Performance Comparison of different Routing Protocols For Mobile Ad Hoc Networks." [148]	AODV, DSDV,TORA, DSR	NS-2 simulator CBR traffic source, movement model based on pause time	Weighted Path Optimality, Network's Load Deviation, Average end-to-end delay, Jitter	DSDV having best in Path Optimality, DSDV and AODV in delay, DSR in load balancing and DSDV in average jitter
"Performance Analysis of DSR & Extended DSR Protocols." [162]	DSR and Extended DSR	GLOMOSIM Random waypoint mobility model, CBR traffic source	Collision, Throughput, latency rate and Packet Loss/Drop	Tradeoff between delay and collisions results in less packet drops and slightly better throughput then traditional DSR
"Performance Evaluation of Ad Hoc Routing Protocols Using NS2 Simulation." [153]	DSR, AODV and DSDV	NS-2 simulator Constant Bit Rate traffic source, random waypoint mode of mobility	PDF, Average E2E delay and routing load	AODV and DSR perform equally for packet delivery fraction, DSDV is better than other for average E2E delay
"Performance of mobile ad hoc networking routing protocols in realistic scenarios." [193]	AODV, OLSR, DSR and ZRP	QualNet, model realistic scenarios	Packet delivery ratio, latency and jitter of data packets	"AODV is overall better as compared to other protocols"
"Performance Evaluation of DSR and DSDV Routing Protocols for Wireless Ad Hoc Networks." [148]	DSDV and DSR	NS-2.29 simulator Random waypoint model	Packet Delivery Fraction and Throughput	DSR gives better performance than DSDV
"Performance Evaluation of the DSDV, TORA, DSR and AODV Protocols." [95]	AODV DSDV, TORA and DSR	NS-2	PDF ratio, routing overhead, number of hops count	"DSR is better than DSDV, TORA and AODV"
"Evaluation the performance of routing protocols." [81]	SPF, DSDV, TORA, DSR and AODV.	Maryland Routing Simulator, Random waypoint mobility model, CBR traffic	FDF delivered E2E delay and power routing load	"AODV is better than other protocols"

		source		
"Performance metrics evaluated in DSR, CBRP and AODVs for different varying pause times of mobile nodes." [149]	DSR, AODV and CBRP	NS-2 simulator	Average E2E delay of data packets and routing overhead	DSR and CBRP has higher throughput with comparison AODV, CBRP has high routing overhead than DSR.
"The comparison of both proactive and reactive routing protocols." [150]	OLSR, DSR, DSDV, AODV and ZRP	NS-2 Simulator	Significant performance metrics like latency and throughput	OLSR and DSR perform equally for packet delivery fraction, DSDV is better than other for average end- to end delay
"A performance comparison of proactive and reactive protocols DSDV, AODV and DSR based routing protocols." [154]	DSDV, AODV, DSR, DYMO, OLSR, LAR and RIP	NS-2 Simulator, OPNET	Metrics such as throughput, varying network size, simulation time. PDF and average E2E delay	AODV and OLSR is better than other protocols
"Performance Comparison of on demand Routing Protocols for Ad-Hoc Networks." [93]	AODV and DSR	NS-2 Simulator, OPNET	PDF, Average E2E Delay and Normalized routing load	As per performance metrics DSR is better than AODV
"Performance Comparison of reactive Routing Protocols for MANET." [53]	DSR and AODV	NS-2 Simulator	PDF, Average E2E delay of data packets, Normalized routing load and Normalized MAC load	AODV gives better performance as compare DSR
"A behavior study of OLSR Proactive routing protocol using two traffic types multimedia	OLSR	QualNet 4.5	Traffic models	OLSR change according to the model and the used traffics. Maximize the lifetime of the

(VBR) and CBR" [42]				network

Previous Research on Power, Energy, Mobility, Antenna, Multimedia transmissions, Network size, Security and Trust, Scenario, Traffic based power consumption in Wireless Sensor Network and Ad-hoc Networks.

"Studied on routing scheme in home ad-hoc networks wherein the packets are routed through the outlet-plugged devices instead of the battery-powered one to prolong the life of the batteries." [128]	MTPR, MCBR	Matlab	Energy consumed by nodes	Routing to minimize absolute consumed power.
"Basic Energy-Conserving Algorithm (BECA) and Adaptive Fidelity Energy-Conserving Algorithm (AFECA) to reduce the energy consumption of mobile nodes." [160]	BECA, AFECA	NS-2 Simulator	Energy constraints in the network	sleep mode time is increase or decrease for minimum power consumption
"Compared the energy consumption behavior of the Ad hoc On Demand Distance Vector (AODV) and the Destination Sequenced Distance Vector Routing (DSDV)." [181]	AODV, DSDV	NS-2 Simulator	To maximize the lifetime of the network, the traffic load	AODV consumed less energy than DSDV
"Evaluation was based on energy consumption in	LAR,AODV and DSR	GLOMOSIM Simulator	Varying network load, mobility and network size	DSR gives better performance

mobile ad hoc networks.” [183]			and energy consumption in mobile ad hoc networks	
“Comparing performance of protocols for routing packets between wireless mobile hosts in an ad-hoc network.” [185]	AODV and DSR from On-Demand protocols compared with DSDV	GLOMOSIM, NS-2 Simulator	Mobility, optimal performance	Mobility pattern does influence for low network size for higher size mobility affected.
“Evaluation and investigation of most popular routing protocols for different video transmissions.”[188]	AODV, DSR and OLSR	GLOMOSIM Simulator	PDF ratio, E2E delay, jitter and the overhead	complexity minimum the routing process
“Performance investigation of four different mobile ad-hoc routing protocols.” [194]	AODV, DSR, LARI and ZRP	NS-2 Simulator	different network sizes, varying number of nodes and area sizes	small packet sizes and one source node were selected for congestion situations
“Performance of scenario based evaluation of three routing protocols.” [201]	DSDV, DSR and SEAD	GLOMOSIM Simulator	tradeoffs between performances	SEAD is best suited for security purpose

2.19 CHARACTERISTICS OF AN IDLE ROUTING PROTOCOL

After case study of above literature, we conclude for idle routing protocol having the following characteristics:

- Idle routing protocol must be entirely scattered, because of centralized distribution of routing node is additional fault-tolerant than centralized routing.
- The idle routing protocol must be more adaptive for frequent topology changes due to the mobility of nodes.
- Involvement of node in route computation and maintenance should be minimum number of nodes.

- The number of packet collision kept to minimum.
- It must optimally use limited resource.
- Low bandwidth
- Low consumption and computing power
- Good memory and battery power.
- The idle routing protocol must be able to provide a certain level of quality of service (QoS).

2.20 NEED FOR INVESTIGATION ON THE ABOVE LITERATURE STUDIES

Several categories of routing protocols as discussed above have been proposed in literature. The major concern addressed in these protocols was to develop a route between a pair of node by simply identifying the intermediate nodes with minimum power consumption in an environment where the nodes can be mobile. All these protocols assumed that the nodes in the wireless sensor network and ad hoc network will faithfully forward the data and control packets of other nodes. While designing these protocols the possible power awareness and power consumption behavior of the nodes was taken into consideration. However with the time, the realization was made that there is a need to develop protocols which are able to handle the problem of saving of energy and power consumption in ad hoc network as well as WSNs.

2.20.1 Energy and Power Based Performance Investigation and Comparisons

Power & Energy consumption in wireless sensor network and ad hoc networks is a very important factor for investigation and comparison. For many WSNs, the nodes are small and moveable, imposing stringent constants on the battery size and power. Dropping of power during process in nodes is becomes a bigger issue in mobile ad hoc networks because, as each node is acting as both router then end user, if energy resources is less then same time, additional energy is required to forward packets from other nodes [66, 68, 106].

2.20.2 Mobility Based Performance Comparisons

Mobility model, in many earlier studies was assumed to be random waypoint. Random waypoint is a simple model and also easy to analyze and implement for designing a scenarios. File mobility and group mobility models is used for our simulation. The group option divides the nodes into different mobility group surrounded by which every node follows the same random waypoint model [61-62].

2.20.3 Multimedia Transmissions Based Performance Comparisons

As the mobile and handheld devices are becoming even more popular, and the use of WANET (wireless sensor network and ad-hoc network) is increasingly perceived as significant, there is substantial relative work by the research community, regarding the differences between the existing ad hoc routing protocols [72].

2.20.4 Network Size Based Performance Comparisons

Furthermore we were focus on different network sizes, when varying number of nodes and area sizes also increased, if area size is small the congestion problem occur during simulation. This investigation did not include the protocol's operation under heavy load [59, 67].

2.20.5 Security and Trust Based Performance Comparisons

Security and Trust in wireless and mobile ad-hoc network is of major importance in a number of scenarios of operation such as battlefield, event coverage, etc., however, very few researchers to consider these protocols in highly demanding for real-life scenarios which may impose apparently contradicting constraints as well as security, power conservation, reliability, and performance [93].

2.20.6 Scenario Based Performance Comparisons

To characterize the challenge our scenarios placed on the routing protocols, we measured the lengths of the routes over which the protocols had to deliver packets, reliability, performance, power conservation and the total number of topology changes in each scenario [60].

Two papers are produced out of research work carried in this section of thesis.

[1] Dharam Vir, S.K.Agarwal, S. A. Imam "Investigation on Performance of Trust Based Model and Trust Evaluation of Reactive Routing Protocols in MANET" Proc. International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) ISSN: 2278 – 1323, www.ijarcet.org Volume 2, Issue 3, March 2013, PP. 875-880, IC Value 5.53.

[2] Dharam Vir, S.K.Agarwal, S. A. Imam "Impact of Mobility Model on Table Driven Routing Protocols of MANET" Proc. 8th IEEE conference on Industrial Electronics and Application, (ICIEA 2013), Melbourne, Australia (Accepted). 2013.

[3] **Dharam Vir**, S.K.Agarwal, S. A. Imam "Investigation on Aspects of Power Consumption in Routing Protocols of MANET using Energy Traffic Model" in International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN: 2278 – 8875. http://www.ijareeie.com Vol. 2, Issue 1, January 2013. Page: 590 – 598, Impact Factor 1.686.

Chapter 3

POWER & ENERGY SAVING SCHEMES IN WIRELESS SENSOR NETWORKS

This chapter gives brief introduction of different issues of power & energy saving methods in Wireless Sensor Network the work considered for thesis. Here brief review of the contents of chapters is described.

3.1 INTRODUCTION

Wireless network is a system of autonomous mobile nodes that cooperatively route packets for each other. In such a network, nodes other than the packet source and destination participate in the delivery process. This chapter is mainly concerned with wireless networks, where, power and energy consumption is problem, as nodes are battery powered. Battery technology is not improving at a quick rate, so power consumption is likely to remain an issue in wireless networks [107-108].

One important characteristic of wireless sensor networks is that nodes are energy constrained. Because wireless sensor nodes are always very small, battery power and energy management system are critical issues in building these networks. Nodes are battery operated and frequent recharging or replacement of batteries may be undesirable or even impossible. This makes energy efficiency another important metric in wireless protocols. Since power is often an important issue in many wireless sensor network as well as ad hoc networks, there have been many ideas to propose to different energy saving approaches incorporating power awareness into different routing layers. In this chapter, we describe the different saving methods of power and energy in WSNs for maximize the lifetime of the whole network by consistently consuming the energy of each node [109].

Factors affecting of routing protocols to consume maximum power in WSN

- The topology of the network changes rapidly, which will leads to the loss of packets [110].
- Modifying every node’s routing table, within the communication distance of the fast passing nodes that will consume a lot of the bandwidth.
- Average Delay in the data sending to the quick moving node in the network.

- Transmission between two hosts over a wireless network does not always work equally well in both directions so consumes maximum power.
- Increase the whole networks overhead decreasing of the routing updates so data loss.
- Periodically sending routing tables will waste network bandwidth [111].

3.2 ENERGY MANAGEMENT

This is the process of managing the sources and consumers of energy in a node or in a network as a whole for enhancing the life time of the network**. Energy management can be classified into transmission power management, processor power management, battery energy management and devices power management** [112].

3.3 ENERGY CONSERVATION SCHEMES

Periodically sending routing tables update also waste the battery power and energy in the network. Energy consumption is also an important issue which prevents (WSN) Wireless Sensor Networks to be a non-flowed architecture.

The power breakdown in wireless network primarily depends on their specific node in the network. In [113] it was shown that the energy characteristics of a micro mote class type node are completely dissimilar from those of a star gate energy node in the specific network. However, the following remarks generally hold [112-113].

1. The energy consumption in communication subsystem has much higher than the computation subsystem, when nodes are transmitting one bit or more bits this may be consumes more energy and execute few millions of instructions [90].
2. The sensing subsystem may be a different significant source of energy consumption depending on the particular application; therefore the power consumption reduced.
3. The radio energy consumption is the similar arrangements of magnitude level in the transmission, reception and idle states in the network, while the power consumption drops at least one order of magnitude during the sleep state. Therefore, the radio energy may suppose to be put to sleep or turned on-off whenever possible.

Based on the above parameters of power breakdown, numerous approaches were exploiting for reducing the power consumption in sensor networks.

3.3.1 Duty Cycling Approaches

Duty cycling	Data driven	Mobility based
i)Topology control	**i) Data reduction**	**i) Mobile –sink**
a) location -driven	a) In -network processing	**ii) Mobile-relay**
b) connection - driven	b) Data compression	
ii)Power Management	c) Data prediction	
a)Sleep/wakeup protocol	**ii) Energy-efficient data acquisition**	
• on demand	a) Adaptive Sampling	
• scheduled rendezvous	b) Hierarchical Sampling	
• Asynchronous	c) Model-driven active Sampling	
b) MAC Protocol		
• TDMA		
• Contention based		
• Hybrid		

Fig. 3.1 Different Energy Conservation Schemes in Wireless Sensor Networks

We identify three most important techniques namely duty cycling, data-driven and mobility based approaches. Duty cycling approaches is based on topology control and power management. It is defined as fraction of time nodes are dynamic during their lifetime. Duty cycling is mainly focused on the networks subsystem. When sensor nodes realize a cooperative assignment, the node needs to be synchronizing their wakeup and sleep times. Therefore, the most efficient energy conserving process is using the radio transceiver of low power.

3.3.1.1 Topology Control Protocols

This concept of topology control is exactingly associated with network redundancy. Dense wireless sensor networks characteristically degree of redundancy. In many cases wireless network exploitation is completed at random movement, because of dropping the large number of sensor nodes from an air [104].

Therefore, this may be opportune to arrange a number of nodes larger than that are necessary to manage with possible node failures consumes more energy. Topology control protocols are dynamically adapting the wireless network topology, which is based on the applications, so this topology allow network operations to minimizing the number of dynamic nodes and, therefore, increasing the network life time of node. The topology control protocols classified two sub categories (Fig 3.1).

Location driven protocols: It is define that which node to be turn on and when off based on the location of wireless sensor node which may assumed to be known.

Connectivity driven protocols: It is dynamically activate or deactivate of wireless sensor nodes so that network connectivity of the whole sensing coverage is fulfilled [114].

3.3.1.2 Power Management

The techniques of power management are further divided into two extensive categories depending on the network layer and architecture where are implemented. Power management protocols can be use to implemented either as independent, sleep and wakeup protocols which are running on top of a MAC layer protocol. Power management approach permits to optimize MAC layer protocol medium access functions are based on the particular sleep and wakeup patterns. Sleep and wakeup schemes can be defined for a specified radio subsystem component of the sensor network node. Sleep and wakeup protocols further subdivided into three main categories as given below [117];

(1) On-demand scheme

(2) Scheduled Rendezvous Schemes

(3) Asynchronous Schemes

3.3.1.2.1 On-demand scheme

On-demand schemes which are based on the node should be wake up just when receives a data packets from the neighboring node. This scheme minimizes the energy consumption during receiving and transmitting of nodes in the network and, therefore, makes on- demand schemes mainly suitable designed for large sensor networks applications for low duty cycle. On-demand sleep and wakeup schemes are designed for reducing energy consumption in the desired dense network.

Radio Triggered Power Management (RTPM)

This scheme was investigated in [119]. The fundamental scheme is in the direction of utilization of energy contained in wakeup and sleep time and message to trigger the activation of the wireless sensor node. This approach is similar to that used in active

Radio Frequency Identification and detection (RFID) systems [118]. The radio triggered power management scheme is illustrated in Fig 3.2.

A particular hardware component for the radio triggered circuit is used the energy contained with wakeup message or signal which are uses such type of energy to trigger an interrupt for wake up the sensor node. The radio-triggered approach is broadly different to stand by radio to listen toward possible wakeup messages from the neighboring wireless network nodes.

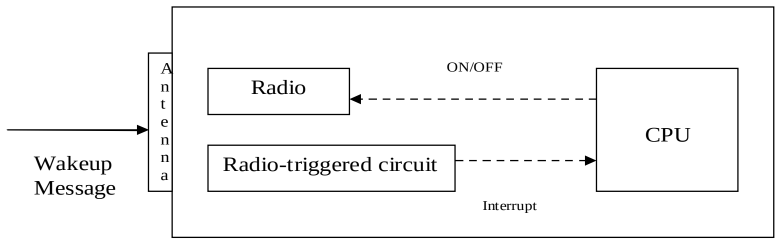


Fig. 3.2 Radio triggered power management

3.3.1.2.2 Scheduled Rendezvous Schemes

In this scheme wireless sensor network is requires to that all neighboring wireless nodes awaken at the matching time. Normally, nodes wake up sometimes to check in favor of possible communications between source and destination. Then, the nodes return to sleep mode until the next rendezvous time come. The most important advantage of such schemes is that when node is awakened it is sure that all of destination nodes or neighbor's nodes are also awake as well. This process is allowed for sending the broadcast messages to all neighbors in network area [120].

On the further way the scheduled rendezvous get-together schemes requires nodes to be corresponding wake up at the same time different scheduled rendezvous protocol associated and differs in such a way that the network sleep and wake up during their life time.

In [120] the authors also recommend a multiple user-parent scheme that is able to combine the above sleep and wakeup patterns. This scheme is shifted even and odd model and resulting from the fully corresponding samples are shifting by wakeup times of nodes in even levels of by $T_{wakeup}/2$ [120].

3.3.1.2.3 Asynchronous Schemes

In Asynchronous Scheme the every source to destination nodes are allocate the wake up time independently of the others neighbors until the end of time have overlapped dynamic periods contained by particular number of cycles in Random Asynchronous Wakeup (RAW) [121]. The different approach which allows the existence of several paths between source nodes to destination node in sensor network established and, therefore, many packets can be forwarded to such available paths. In fact, the Random Asynchronous Wakeup (RAW) protocol consists of routing protocols which is combined with a random wakeup scheme. The proposal for random wake up scheme is that a nodes wakes up randomly one time in every time interval for set duration T, remains active for a pre-defined time T_a ($T_a \leq T$), and then sleep for another time in the network. Once awakes, a network node looks for dynamic neighbors by running a neighbor route discovery practice. Suppose the source node transmit a packet to destination node, than forwarding set of packets to their neighbors as possible forwarders towards to destination. Then, Probability of these neighbors is awake along with source is given by

$$P = 1 - \left(1 - \frac{2.T_a}{T}\right)^m \qquad \text{……..…..……………… (3.1)}$$

If the sensor network is congested or dense, than the numbers of (m) of neighbors in the forward the data packets large but some of them dead therefore [118] the probability P to locate as active neighbors to which forward path the packet is large as well. The random wakeup scheme is particularly simple and relies only happened on local decisions. This technique makes it well studied for networks with frequent topology changes.

3.3.1.2.4 Mac Protocol

Several MAC protocols for wireless sensor networks have been proposed and many surveys and introductory papers on MAC and other protocols are available in the literature [121]. We conclude from the surveys on the most common MAC protocols by classifying according to the taxonomy illustrated in Fig.3.1: TDMA based, contention based and hybrid protocol.

3.3.1.2.5 Time Division Multiple Access (TDMA)

Time Division Multiple Access (TDMA) schemes enables a duty cycle of sensor nodes on the channel access is done for slot-by-slot basis. A node is needed to rotate on their radio only during their own slots; the power consumption is ideally reduced to the minimum required for transmitting or receiving the data. In TDMA based MAC protocols time is divided in (periodic) frames and each frame consist of a certain number of time slots. Every node is assigned to one or more slots per frame, according to certain scheduling algorithm, and uses such slots for transmitting or receiving packets to/from other nodes. In many cases nodes are grouped to form clusters with clusters head which is in charge to assign slots to nodes in cluster as in Bluetooth, LEACH, RIP, $OSPF_{V2}$ [33], and Energy-aware TDMA-based MAC protocol [122].

3.3.1.2.6 Contention Based Protocols

Contention based protocols are the most popular class of MAC protocol for wireless sensor networks (WSN). They achieve duty cycling approach by integrating channel access functionalities for a sleep/wakeup time scheme similar to those describe above. The only difference is that in this case the sleep/wakeup algorithm is not a protocol independent of MAC protocol, but is tightly coupled with it. One of the most popular contention based MAC protocols is B-MAC (Berkeley-MAC) [121], a low complexity and low power MAC protocol which is shipped with the TinyOS operating system. The goal of B-MAC is to provide a few core functionalities and energy efficient mechanism for channel access. First, B-MAC implements basic channel access control features: a back off scheme, an accurate channel estimation facility and optional acknowledgements. Second, to achieve a low duty cycle B-MAC uses an asynchronous sleep/wakeup scheme based on periodic listening called Low Power Listening (LPL). Nodes periodically wake up to check the channel for activity. This periodically wake up between consecutive wakeup is called check interval. After waking up, nodes remain active for a wakeup time, in order to properly detect eventual ongoing transmissions. While the wakeup time is fixed, the check interval can be specified by the application. B-MAC packets are made up of a long preamble and a payload. The preamble duration is at least equal to the check interval so that each node can always detect an ongoing transmission during its check interval. This approach does not require node to be synchronized. In fact, when node detects channel activity, it just remains active and receives first preamble and then payload.

IEEE 802.15.4 is a standard for low-rate, low- power Personal Area Networks (PAN). IEEE 802.15.4 beacon-enabled mode is suitable for single-hop scenarios. However, the beacon-based duty-cycle scheme has to be extended for multi-hop network. In [38] the authors propose a maximum delay bound wakeup scheduling specifically tailored to IEEE 802.15.4 networks. The sensor network is assumed to be organized as a cluster tree. An optimization problem is formulated in order to maximize network life time while satisfying latency constraints. A well-known MAC protocol for multi-hop sensor networks is S-MAC (Sensor-MAC), which adopts a programmed rendezvous communication scheme. Nodes exchange sync packets to coordinate their sleep/ wakeup period. Every node can establish its own programming schedule or follow the schedule of neighbor by means of a random distributed algorithm. To this S-MAC routing protocol end, the authors of propose an enhanced version of S-MAC called Timeout MAC (T-MAC) and specifically designed for variable traffic load. D-MAC [123] is an adaptive duty cycle protocol optimized for data gathering in sensor networks wherever a tree organization has been established at the network layer. In D-MAC the node's schedules are staggered their position for the data gathering tree, because of the nodes active periods along the multi-hop path are adjacent in order to minimize the latency.

3.3.1.2.7 Hybrid Protocols

Hybrid protocols adapt the topology is the combination of reactive and proactive protocol behavior and the level of argument in the network. Hybrid protocol behaves as a contention based protocol (CBP) its level of contention is low, and switch for TDMA scheme level contention is high. The fundamental idea behind hybrid MAC layer protocols is switching between (TDMA and CSMA) depending on the level of contention.

In the specific context of wireless sensor networks, one of the interesting hybrid protocols is Z-MAC (e.g. Zone Routing Protocol (ZRP),Zone-based Hierarchical Link State routing (ZHLS) and LANMAR).

3.3.2 Data-Driven Approaches

The Data driven approaches is basically based on data reduction as well as energy-efficient data acquisition arrangement system. This approaches basically designed toward reducing the amount of sampled data by maintaining the sensing accuracy of nodes in the network inside the acceptable level for application. Sampled data are generally having physically powerful so no need to communicate the redundant information for sink node. Energy-efficient data acquisition schemes are mainly intended to reducing the energy exhausted by the sensing system shown in Fig. 3.3.

3.3.2.1 Data Prediction

This technique is building a model describing the sensed happening between sources to destination nodes in the network, so queries can be answered using the desired model in place of the actual data. There are two is model in the network, one residing at their sink node and another at source nodes.

In this model the sink can be used to answer queries without requirement of any communication between source and destination in the network, therefore reducing the power consumption. A sensor node just samples the data as usual and compares the actual data against the prediction in the network. If sensed the data value falls within an application dependent tolerance, then the model is considered valid. Otherwise, the source node may transmit the sampled data and/or start model update procedure involving the sink as well.

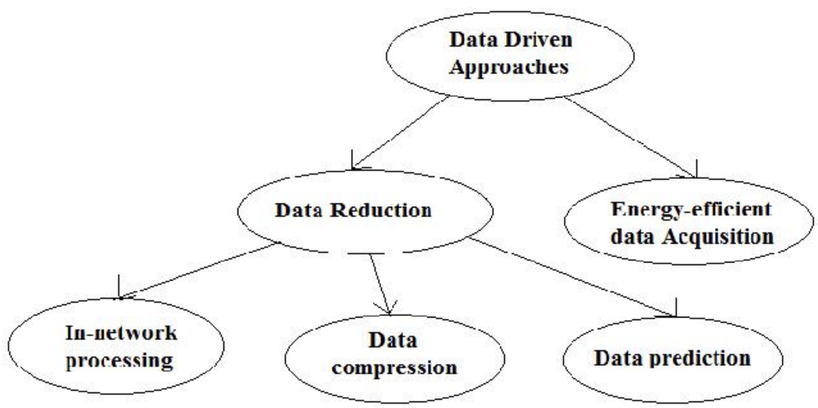


Fig. 3.3 Taxonomy of Data driven approaches

3.3.2.2 Energy-Efficient Data Acquisition

Energy consumption in energy efficient data acquisition is a subsystem or may be relevant to each other, but it can be greater than the power consumption of radio or even greater than energy consumption of the rest of sensor node. This system has many different factors some of factors are given below [103,107].

- **Power Hungry Transducers:** some sensors basically required high power resources to perform their sampling, for example, sensing array such as CCDs or CMOS image sensors or even multimedia sensors generally require a lot of power [125].
- **Power Hungry A/D Converters:** Sensors like seismic and acoustic transducers generally need of high resolution and high rate of A/D converters.

The power consumption of these converters can account for the large amount significant power consumption of the sensing subsystem of desired network [115,126].

- **Active Sensors:** Another class of sensors can get data about the sensed phenomenon by using active transducers for example sonar, radar or laser rangers. In the case of active sensor they have to send out a probing signal in order to obtain information about the observed quantity [127].
- **Long Acquisition Time:** The long acquisition time subsystem the data transfer arrangement of hundreds, milliseconds or even seconds, as a result the energy consumed by the sensing subsystem may be high, even if the sensor power consumption is moderate [128].

3.3.3 Mobility Based Approaches

In this approach if some of nodes are mobile, then traffic flow can be distorted, if mobile devices are dependable in the favor of data collection directly from static nodes than reduces the energy consumption. Mobility is also useful for reducing energy consumption. The packet comes from sensor node to pass through the network towards the sink by the multihop path [129-130].

3.3.3.1 Mobile Sink Based Approaches

Many approaches was proposed in the literature regarding wireless sensor networks or mobile ad-hoc network with mobile sinks nodes (MSN) rely on a linear programming formulation This (LPF) is used for optimizing parameters of the network lifetime [130].

3.3.3.2 Mobile Relay Based Approaches

The Mobile Relay (MR) model based on the approach of data collection in multihop mobile ad hoc networks (MANET) explored in the environment of opportunistic networks. The message ferrying approach is well known for mobile relay based scheme. [131].

3.4 ENERGY OPTIMIZATION METHODS

The Energy optimization classified below two methods:

1. Device Level: Hardware module assortment and their configuration are to realize low energy consumption in a wireless sensor network node.

2. Network Level: selection of communication methods and different protocols to minimize energy consumption and maximize lifetime of network node.

In a WSN sensor node have four essential parts: power, sensing, processing and transceiver unit. Processing unit is the part of microcontroller unit which will able to read sensor data and perform some minimal computations and make ready to packet transfer in the wireless channel for communication [70]. The local memory requirements determination not is high and importance will be placed on the energy saving at destination node and level modes of operation to make possible for low power operation. The communication module / unit are typically an Radio Frequency transceiver that support the IEEE 802.15.4. This unit is collecting the information and to delivered to control data acquisition system. The max. amount of power is used for communication module when compared to other modules. Sharing the data information among sensor nodes consumes more amount of power than implemented individual node.

Hence, need a requirement of to choose a power efficient hardware for various power efficient operating modes to make sure the network system more power efficient. Fig. 3.4 produces power consumption of WSN in various states.

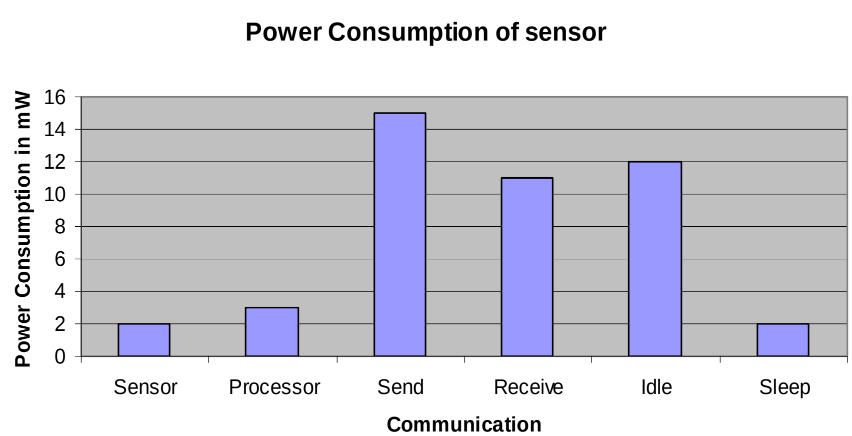


Fig.3.4 Power consumption of WSN in various states

3.5 COMPARISON OF DIFFERENT LIFE SAVING TECHNIQUES

Compared to wired networks to wireless networks such as ad-hoc network, mobile ad-hoc network and cellular networks, Wireless Sensor Networks are near the beginning phase of development and need lot of work in this area for design at different development level. Then we conclude the methodical and comprehensive taxonomy of the life saving and power economy in WSNs [140].

Table 3.1 classification and comparison of different life saving techniques of WSNs.

Characteristics Techniques	**Network Power Usage**	**QoS**	**Power Economy**
Time Synchronization	Low	High	"Power saving is secure due to reduction of communication delays".
Neural Network Approach	Low	Low	"Good compatibility with Wireless Sensor Network's characteristics and therefore energy conservation is achieved".
Real Time Support	High	Low	"A routing of MAC protocol is accepted in this technique which focus is going on the energy conserving by their actual time support".
Transmission Power Control	Low	Low	"The controlling of transmission power according to link quality is an efficient approach as it provides the minimum power required for transmission".
Encryption Schemes	High	High	"The Cryptographic arrangement are using for feedback mode enhancing performance for a wide range of channel qualities and provides significant development in power and energy efficiency".
Data Management	Low	High	"The data management algorithms schemes are increase the network traffic efficiently hence data management schemes are power efficient".
Dynamic Duty Cycle Control	Low	Low	"Dynamic Duty Cycle Controlthe energy level balancingand increase the network lifetime".

3.6 BATTERY

Generally sensor nodes are designed to run on ordinary AA batteries. It is necessary to approximate the power consumption needs of the sensor node. Appropriate selection in the design phase of the transceiver and microcontroller will make sure that the hardware platform on which the sensor node is built is power conscious, and this will be useful in managing the power of the system. We can differentiate batteries in two categories, chargeable and rechargeable [142]. It can be also evaluate according to their different properties like,

- Electro material (such as NiCd, AgZn, NiMH etc).
- Capacity (how much mili-amp-hours (mAh) of current the cell can store).
- Energy density (how much energy can be store in the cell per unit volume).
- Battery Mechanical specifications.
- Battery Environment specifications.

There are many commercial batteries available in the market. However it is preferable that batteries are chosen by the three approaches described [144].

1. Specification of a single, aggregate power supply, resulting in a single battery electrochemistry and cell size.
2. Specification of several power supplies, by a priori division of power sources by power range.
3. Specification of an arbitrary number of power "bundles", based on available space in the device.

This approach which is helps to select the commercial batteries that are available in the market. A comparison of different commercial batteries is shown in the table 3.2.If the sampling period or duty cycle is 1% using TDMA or Low power listing then,

Average drain current = 0.1* (active current) + 0.99*(sleep current) …. (3.2)

Lifetime = capacity / average Drain current ………………………… (3.3)

The life time of Telos, MicaZ and Mica2is the wireless sensor motes are shown in the Fig. 3.5 [144], where vertical axis represents number of days and horizontal axis represents different motes. In some cases battery life can be increase by reducing duty cycle, like if wireless sensor motes (WSM) read the data every 3 minutes it means that if the duty cycle is 0.5% then same battery will give more life time [145].

The comparison of energy requirements by different WSM is shown in table 3.1 Cycle duration arbitrates the length of the sleep stage. In the meantime the value of threshold has an impact on the amount of network transmissions. These two have an impact on the energy consumption and the equivalent battery lifetime of a node running this simple application. The application could obtain the energy descriptions at run-time and if required be adapted.

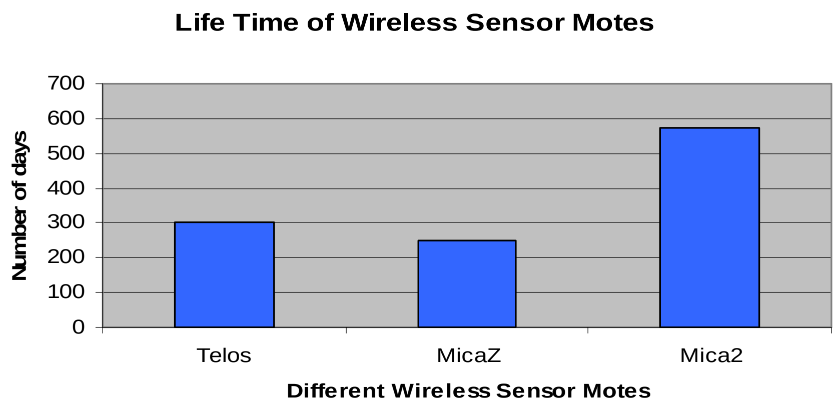


Fig. 3.5 Life times of Telos, MicaZ and Mica2 wireless sensor motes

Table 3.2 Comparison of energy requirement by different WSM

Motes	**Mica2**	**MicaZ**	**Telos**
Wake up Time	0.2 ms	0.2ms	0.006 ms
Sleep Time	30 Mw	30 mW	2 mW
Active Power	33 mW	33 mW	3 mW
Radio Power	21 mW	45 mW	45 mW
Throughput	19 kbps	250 kbps	250 kbps
Voltage	2.5V min	2.5 V min	1.8 V min

In the instance above, two parameters from cycle period and threshold can be altered in the system where the lifetime of network nodes does not reach their destination [134].

3.7 CONCLUSION

In this chapter, we surveyed the main approaches to energy consumption and saving scheme methods in Wireless Sensor Network. These energy saving schemes are essentially used for increasing the lifetime of sensor nodes in WSNs. In addition that we stressed the significance of different energy consumption design issues of WSNs such as fault tolerance, power consumption, hardware constraints etc.

We have surveyed in this chapter on three different categories: (1) Duty-cycling Approaches (2) Data-driven Approaches (3) Mobility-based Approaches. We have summarized and compared different proposed designs, algorithms, and protocols for energy management in wireless sensor networks. Moreover, we have highlighted possible improvements and research in the area of energy optimization methods in wireless sensor networks. There are many issues to be resolved by energy management technique in order to increase the life time sensor nodes such as data aggregation, and data management.

A methodical study of the relation between energy efficiency and system lifetime is an avenue of future research. Analytical results on the bounds of lifetime of sensor networks are another area worth exploring. The sensor data are usually highly correlated and energy efficiency can be achieved by joint source coding and data compression.

Two papers are produced out of research work carried in this section of thesis.

[1] Dharam Vir, S.K.Agarwal, S. A. Imam "Analyses and Evaluation of MANET Routing Protocol for Varying Mobility Model using QualNet Simulator 5.0" in WNTES 2012 at YMCA University of Science and Technology, sector -6, Faridabad On July 2012.

[2] Dharam Vir, S.K.Agarwal, S. A. Imam "Energy consumption between Gateways of Ad-hoc and other Networks " in International Journal of Application or Innovation in Engineering & Management (IJAIEM), ISSN 2319-4847, www.ijaiem.org Volume 2 Issue 3, April 2013, PP. 176-186.

Chapter 4

QoS BASED PERFORMANCE ANALYSIS OF VARIOUS ROUTING PROTOCOLS

Overview of Area: *This chapter gives Quality of Service (QoS) conditions and management in an ad hoc protocol remains a challenging task to support real time applications, due to mobility of nodes, antenna and energy models. Providing optimum performance requires a QoS routing protocol and a resource reservation scheme. Real time application traffic requires reservation of bandwidth, a low delay and a high reliability routing protocol. Brief experimental design and investigation the work considered for thesis.*

4.1 PERFORMANCE ANALYSIS OF MANET ROUTING PROTOCOLS IN EFFECT OF MOBILITY MODELS AND VARYING NETWORK NODES

Mobile Ad hoc Network (MANET) is the collection of the mobile nodes without the aid of fixed infrastructure. The communication in MANET is therefore completely dependent on the nodes of the network. For the efficient working of the network various routing protocols have been developed. These protocols improve the efficiency of MANET by providing the path between distant nodes through multi-hop links. The performance of the protocols is affected by the various factors. One such factor is the mobility of the nodes. This chapter provides comparative QoS based performance analysis of various routing protocols used in day to day scenario under the effect of various mobility models: File, Group and Random Way Point Mobility Model.

The executions was achieved over a real world considering some fundamental metrics with MAC layer and physical layer of stack model and also define the performance effectiveness of wireless routing protocols. The performance was analyzed and compared on metrics like Throughput, Packet Delivery Ratio (PDR), E2E Delay, Average Jitter, RTS Sent, CTS Sent, ACK Sent etc at various mobility models with constant CBR traffic load and varying network nodes.

4.1.1 Introduction

MANET [146] is a robust and decentralized network formed by mobile nodes communicating with each other through wireless links without the support of an existing infrastructure. MANET can be installed quickly due to non dependence on the fixed infrastructure [147]. It is suitable for the areas where fixed infrastructure cannot be installed or in disaster situations or in military operations [148]. The MANET is characterized as dynamic topology, low bandwidth, limited battery power and security.

In these networks the communication between the nodes is multi-hop type i.e. the nodes act as router as well as transceiver enabling the cooperation between them. To facilitate communication between the nodes of MANET various routing protocols [148] were proposed. These protocols improve the performance of MANET in comparison to the conventional protocols but there are several constraints which affects their performance as:

Bandwidth: The wireless networks are having limited bandwidth hence the data rates it can propose are much less than a wired network. This is essential for routing protocols use the bandwidth optimally by keeping the operating cost as low as possible [148].

Broadcast radio channel: The radio channel is shared by the networks which may results in collisions of data and control packets. Another factor which affects the performance of the routing protocols to a great extent is the mobility of the nodes. Due to the mobile nature the nodes move randomly and organize themselves arbitrarily within the network. This random nature affects the protocol performance to a great extent. To improve the performance, various mobility models have been proposed. The protocol performance, is also dependent on the mobility model used [149].

4.1.2 Related Work

Several researchers have done the qualitative and quantitative analysis of Ad Hoc Routing Protocols by means of different performance metrics. They have used different simulators for this purpose.

J. Broch et al.,	"Compared the DSDV, TORA, DSR and AODV Protocols using ns-2 simulator. The simulation was done with 50 nodes with varying pause times. The results were obtained for the metrics: Packet delivery ratio, Routing overhead, Number of hops taken by the packet to reach the destination" [150-151].
Samir R. Dass et al.	"Evaluated the performance of routing protocols with respect to fraction of packets delivered, end-to-end delay, and routing load by varying the number of conversation per node. The evaluation was done with 30 and 60 nodes using Maryland Routing Simulator. The protocols used in the simulation are SPF, DSDV, TORA, DSR and AODV" [152].
Samir R. Das, Charles E. Perkins et al.	"Evaluated the DSR and AODV on-demand routing protocols with three performance metrics: Packet delivery fraction, Average End-End Delay and Normalized routing load with varying pause times. They have used ns-2 simulator. Based on the observations, recommendations were made as to how the performance of either protocol can be improved" [153].
Jyoti Raju and Garcia-Luna-Aceves,	"Compared WRP-Lite a revised version of Wireless Routing Protocol with DSR. The performance parameters used are end-end delay, control overhead; percentage of packets delivered and hops distribution. The evaluation of the performance metrics was done with respect to varying pause time. It was observed that WRP-lite has much better delay and hop performance while having comparable overhead to DSR" [154-155].
Azzedine Boukerche	"The performance comparison of AODV, CBRP and DSR Ad Hoc routing protocols using NS-2 simulator. The key performance metrics evaluated in his experiments are Throughput, Average End-to-end delay of data packets and Normalized routing overhead for different data sources and varying pause times of mobile nodes. As per his observation DSR and CBRP has high throughput than in comparison with

	AODV, CBRP has high routing overhead than DSR" [156].
Y-C. Hu and D. Johnson	"This paper having performance evaluation of on-demand protocols AODV and DSR is undertaken using the GloMoSim simulator. The authors provide an interesting conclusion on the performance of the protocols. They conclude that with sources sending data to different destinations, AODV outperforms DSR. However, when the sources send the traffic to a common destination, they conclude that AODV suffers massive degradation in the average packet delivery rate" [157].

4.1.3 Experimental Study and Analysis

- Performance analysis of MANET routing protocols of various mobility models and varying network nodes.
- Performance analysis of MANET routing protocols various energy models with varying network nodes.
- Analysis and effect of Directional Antennas on energy in routing protocol

4.1.4 Proposed Protocols

As mentioned in previous chapter Ad hoc routing protocols are mainly categories in three categories. It is not possible to analyze the performance of all the protocols proposed till now. So, we have taken 6 protocols under consideration which are explained in chapter 2 [47-48].

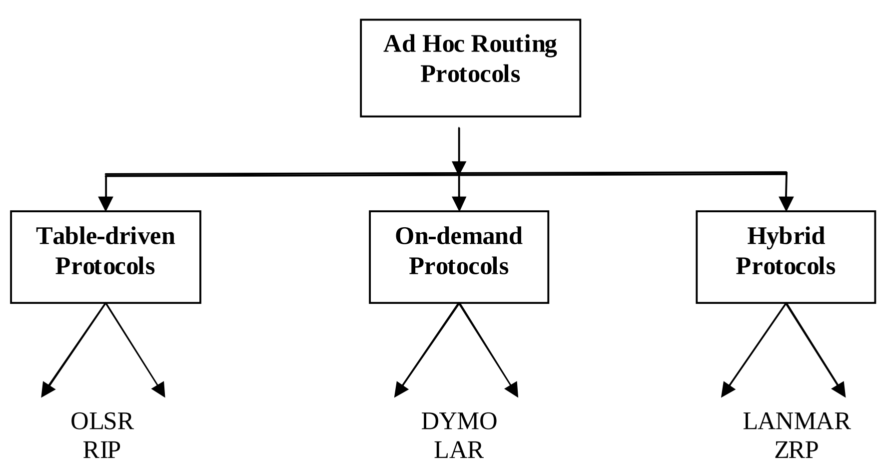


Fig. 4.1 Proposed Routing Protocols

4.1.5 Simulation Setup

For implementing the proposed protocols and setup had to be created with certain variable and fixed parameters was chosen. These parameters were suitably selected for carrying out the simulation process and the proposed investigation on different protocol to implement for check the outcome. A detailed list of simulation setup parameters chosen is shown in Table 4.1 [47].

4.1.5.1 Simulation Setup Parameter

Table 4.1 Simulation Setup Parameters

Parameter	Value
Simulator	QUALNET 5.01
Number of Nodes	40 and 100
Simulation Time Simulation Area	30s 1500 X 1500m^2
Mobility Model	File Mobility Group Mobility Random Waypoint Mobility
Energy Model	Mica-Motes
Traffic Type	Constant-Bit Rate
Node Placement Model	Random
Battery Model	Linear Model
Antenna Model	Omni direction
Total packet sent	24
Packet Size	12288 Bytes

The outcomes of the simulation process have been shown in Fig 4.1(a) and Fig. 4.1 (b).

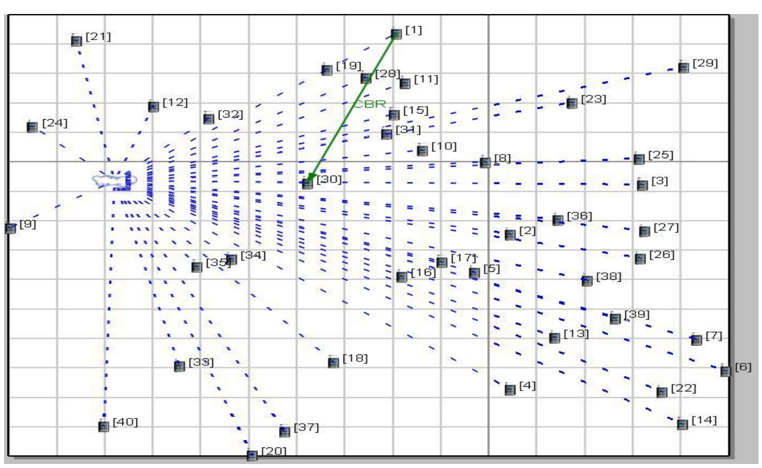


Fig. 4.2(a) Network with 40 nodes

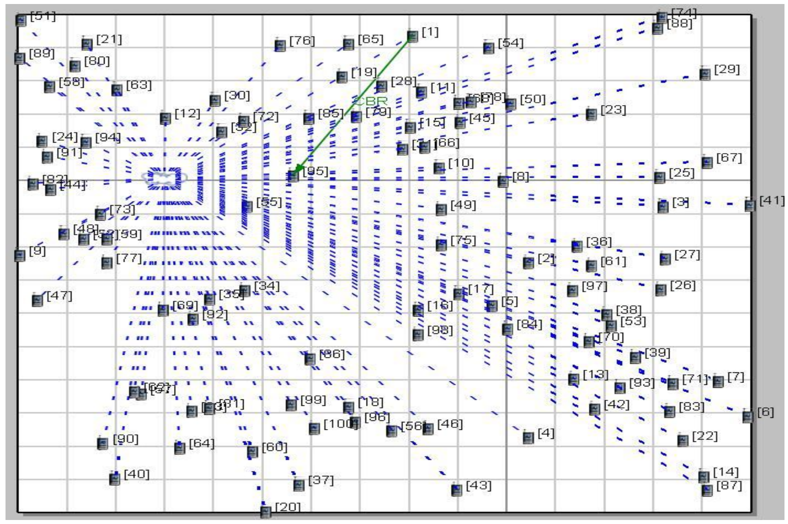


Fig. 4.2(b) Network with 100 nodes

4.1.5.2 Description of Parameters Chosen

- **Examined Protocols:** We chose the standard Table Driven (OLSR, RIP) On demand (DYMO, LAR) and Hybrid (LANMAR, ZRP) protocols from the QualNet-5.0 software and simulated it to collect the data about various parameters [47].
- **Simulation Space:** Our investigation and evaluation comparisons are based on the simulation of varying number of nodes (10-100) with their random positions over a rectangular (1500m*1500m) flat area. In our simulation we choose rectangular space because of order to force the use of longer routes between nodes than would occur in a square space with equal node density [49].
- **Mobility of Nodes:** Mobility support is one of important characteristics for our investigation. Mobile node is the basic object with added functionalities, which can formulate movement, receive, and transmit on a channel. Mobility features consist of node movement intermittent position updates, and maintenance of topology boundary [49].
- **Traffic Pattern:** In the simulation, we use 1 CBR sources and 40-100 connection nodes with a sending rate of four packets per second. In the traffic pattern, we set each packet with different size, from 64 bytes per packet to 1024 bytes per packet [94].

- **Media Access Control Protocols:** The IEEE distributed coordination function (DCF) MAC protocol is used in the simulation of QualNet. MAC layer handles collision detection, fragmentation and acknowledgements. This protocol may be used to detect the transmission error. The QualNet simulator uses the "RTS/CTS/Data/ACK" pattern for unicast packets and a "Data" pattern for broadcasting packets. 802.11 avoid collision by checking the channel before using it. If the channel is available, it can begin to transmit the packets. Otherwise it must wait a random amount of time before resending [48, 94].
- **Radio Propagation Models:** Propagation models are used to determine if the data transmitted through the air has been successfully received. These models also consider propagation delay and Capture effect and carrier sense [47] [108].
- **Energy Model**: The energy dissipation is due to the various activities and the idle and sleep based scenario the energy model chosen Mica-Motes energy model is used conveyed the energy convergence [106].
- **Battery model**: The battery power dissipation model was taken to be linear to consider the consistent decay of power with time when the practical environment is not changing. The default battery, data rate and load size were taken as per the standards given in the text and are available on the QualNet-5.0 software [47].
- **Performance Evaluation Model:** Common standard group for performance measuring of various wireless sensor network investigation and optimization methods would make possible to have universal and systematic methodology for collecting, comparing and evaluating optimization methods for wireless sensor networks. General benchmark group should operate across all simulation platforms and it should be applicable on all types of wireless sensor networks [156].
- **Communications Model**: The MAC layer routing protocol uses the IEEE standard 802.11 Distributed Coordination Function (DCF) [131], MAC layer protocol was used as the All *Route Request* and *Query packets* were broadcasted using the un-slotted Carrier Sense Multiple Access protocol with Collision Avoidance (CSMA/CA).

4.1.6 Assumptions and Limitations

The assumptions for nodes were made for simulation following are given below:

- Each node has their residual battery limitation and position correctly.
- The whole of nodes works in individual approach and there is no such cluster.
- The selected nodes are not in a arrangement to modify their contents of control packets.

4.1.7 Performance Metrics Used

A metric is a standard measurement used in a routing algorithm to determine the best possible, effective and efficient route to a destination. To investigate the analysis and performance evaluation of MANET routing protocols in result of various Mobility models with varying Network nodes size the following metrics were used:

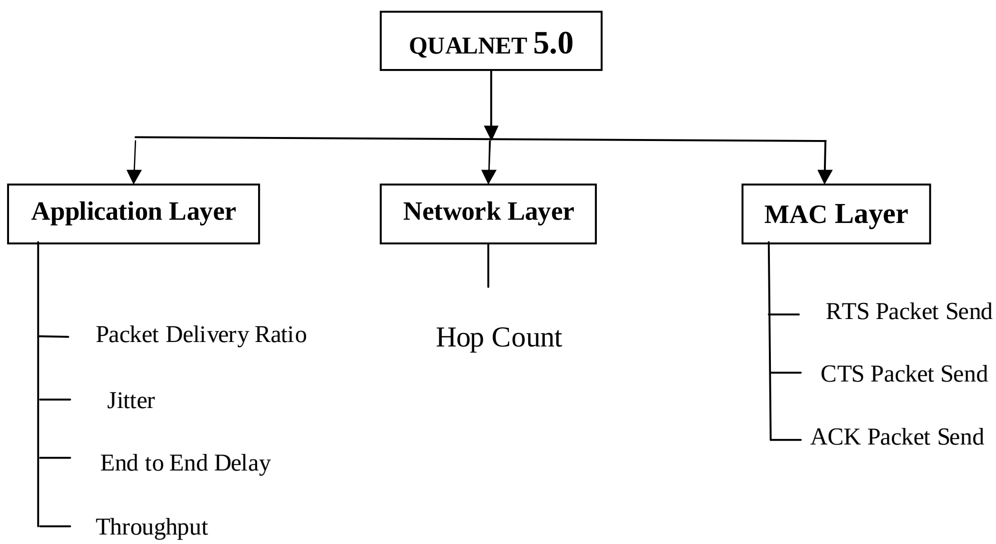


Fig. 4.3 Performance metric of application, network and MAC layers

<u>Packet Delivery Ratio (PDR)</u>: It is the ratio of number of data packets received by source to destination during communication, the number of packets originated by the application layer of the source. It also specifies the packet loss rate that data rate limits the maximum throughput of the network. Better the delivery ratio, more the complete and correct the routing protocol [94].

<u>Jitter</u>: when in a design transmission scenario run then different packets obtain different packet amount of time is reaching from source to destination. Jitter can be measured by using the standard departure of packet delay. Any wireless network communication system having large amount of jitter subsequently the signal quality is very poor [94].

<u>Average End To End Delay</u>: It is defined the time taken by the first data packet to reach its destination sent by the source node [94].

<u>Throughput</u>: The average rate of successful packet message delivered over a communication channel in the network. The number of bits per second should be high for enhanced system performance. The number of bits passing through the network in one second in our designed scenario [154]

<u>Hop Count</u>: Defined as the total number of intermediate nodes to reach from source to destination node [154].

<u>RTS Packet Sent</u>: RTS stands for Right to Send. It is a kind of message packet which is used in “Multiple access with collision avoidance” (MACA) solve the problems like “hidden terminal problem” and “Exposed terminal problem” [155].

<u>CTS Packet Sent</u>: CTS is clear to send. It is also a message packet which is used in “Multiple access with collision avoidance” (MACA) solve the problems like “hidden terminal problem” and “Exposed terminal problem” [156].

<u>ACK Packet Send</u>: Defined as an acknowledgement packet send by the receiver after receiving the correct data packet. The sender is idle until a user requests the transmission of a data packet [156].

4.1.7.1 Successful Route Formation through Simulation

This simulation has been accomplished using the Network Simulator QualNet version 5.0. The QualNet simulation uses the OLSR, RIP, DYMO, LAR, LANMAR, and ZRP as a different routing protocol to discover and maintain routes between the source and the destination nodes. Moreover, this simulation uses IEEE 802.15.4 as a Medium Access Control (MAC) protocol. IEEE 802.15.4 is a standard definition for the Physical layer (PHY) and the MAC layer of the low rate wireless networks. Fig. 4.2(a), Fig. 4.2(b) and Fig 4.2(c) shows success route formation results for different routing protocols and nodes varying from 0 to 60% of the total node strength. The experimental scenario shows successful route formation was almost verified and presented as shown in Figures.

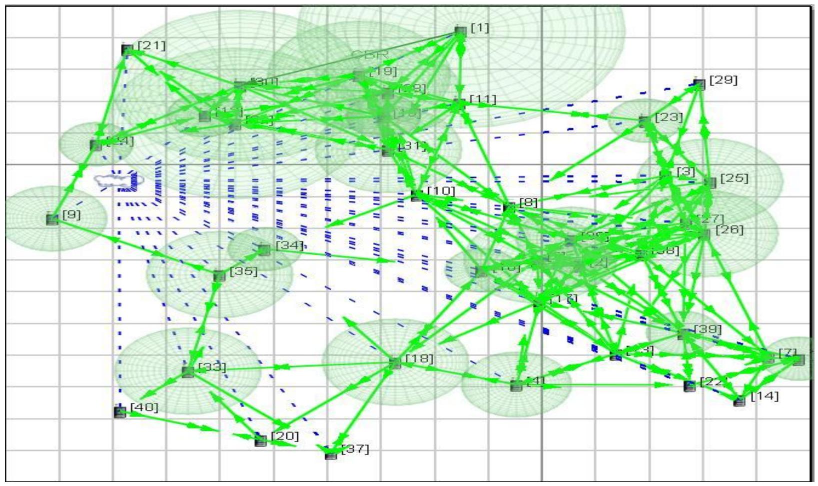


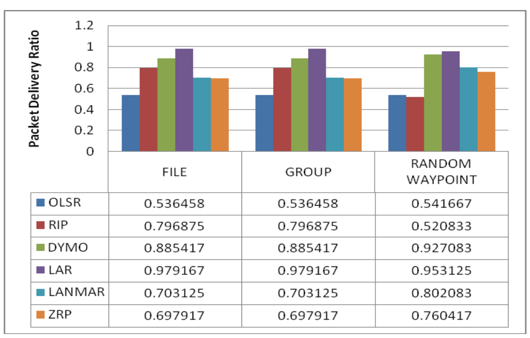
Fig. 4.4 Animation view for 40 nodes, when progress of simulation is 60%

4.1.8 RESULTS AND DISCUSSIONS

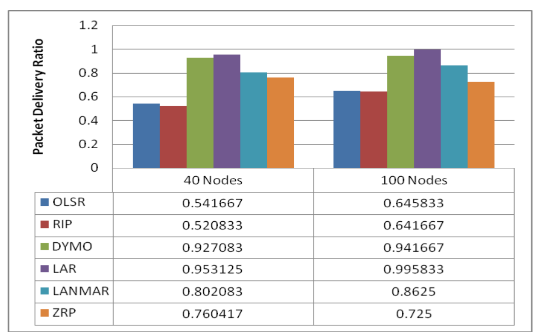
4.1.8.1 <u>Packet Delivery Ratio</u>

Fig. 4.5 (a) shows the impact of mobility on the packet delivery ratio taking routing protocol as parameter. Following inference can be made:

- The LAR routing protocol presents highest value of packet delivery ratio for each mobility model.
- The OLSR routing protocol shows least value for the file and group mobility.



	FILE	GROUP	RANDOM WAYPOINT
OLSR	0.536458	0.536458	0.541667
RIP	0.796875	0.796875	0.520833
DYMO	0.885417	0.885417	0.927083
LAR	0.979167	0.979167	0.953125
LANMAR	0.703125	0.703125	0.802083
ZRP	0.697917	0.697917	0.760417



	40 Nodes	100 Nodes
OLSR	0.541667	0.645833
RIP	0.520833	0.641667
DYMO	0.927083	0.941667
LAR	0.953125	0.995833
LANMAR	0.802083	0.8625
ZRP	0.760417	0.725

Fig. 4.5(a)Packet Delivery Ratio vs Mobility Fig.4.5(b) Packet Delivery Ratio vs No. of Model Nodes

- The RIP shows least value of Packet Delivery Ratio for Random Way Point Mobility.

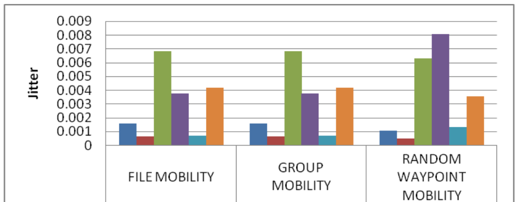
Fig. 4.5 (b) shows the impact on number of nodes of the packet delivery ratio taking routing protocol as parameter. Following inference can be made:

- At varying network size the LAR routing protocol presents highest value of packet delivery ratio.
- The OLSR routing protocol shows least value for the variation in nodes
- OLSR and RIP provide least efficient packet delivery ratio from all routing protocols.

4.1.8.2 Jitter

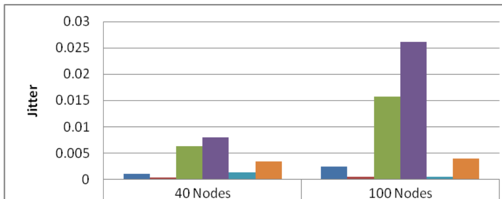
Fig. 4.6(a) shows the impact of mobility on the Jitter taking routing protocol as parameter. Following inference can be made:

- The DYMO presents highest values of Jitter for file and group mobility.
- The LAR shows highest value of Average Jitter for Random Way Point Mobility.
- The RIP presents smallest amount of value of the average jitter for the three mobility models.



	FILE MOBILITY	GROUP MOBILITY	RANDOM WAYPOINT MOBILITY
OLSR	0.001571016	0.001571016	0.001061344
RIP	0.000635662	0.000635662	0.000470926
DYMO	0.006814079	0.006814079	0.006314173
LAR	0.003733734	0.003733734	0.008084512
LANMAR	0.000654067	0.000654067	0.001317213
ZRP	0.004139232	0.004139232	0.003521075

Fig. 4.6 (a) Jitter vs Mobility Model



	40 Nodes	100 Nodes
OLSR	0.001061344	0.002454481
RIP	0.000470926	0.000503492
DYMO	0.006314173	0.015733069
LAR	0.008084512	0.026169762
LANMAR	0.001317213	0.000617576
ZRP	0.003521075	0.004055974

Fig. 4.6 (b) Jitter vs No. of Nodes size

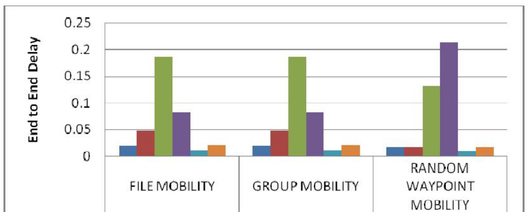
Fig. 4.6(b) shows the impact on number of nodes size on the Jitter taking routing protocol as parameter. Following inference can be made:

- RIP shows the constant least jitter and most efficient in terms of jitter.
- OLSR and LANMAR show the very low amount of jitter.
- ZRP gives an average amount of jitter.
- At DYMO and LAR value of jitter increases abruptly when number of nodes increases.

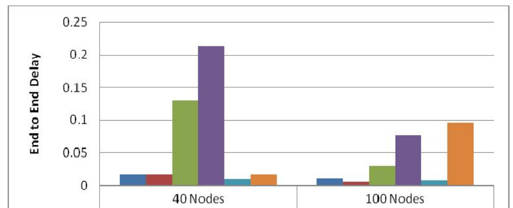
4.1.8.3 Average End to End Delay

Fig. 4.7 (a) shows the impact of mobility on the Average E2E Delay taking routing protocol as constraint. Following inference can be made:

- The DYMO protocol shows highest value for average end to end delay for file and group mobility.
- LAR shows highest value in the case of (RWP) Random Way Point Mobility Model.
- LANMAR shows least value of average E2E delay in case of all the three mobility models.



	FILE MOBILITY	GROUP MOBILITY	RANDOM WAYPOINT MOBILITY
OLSR	0.02007874	0.02007874	0.017530111
RIP	0.047233879	0.047233879	0.017195033
DYMO	0.186451264	0.186451264	0.130537863
LAR	0.08170942	0.08170942	0.213357784
LANMAR	0.012263549	0.012263549	0.010514929
ZRP	0.022003206	0.022003206	0.016727268



	40 Nodes	100 Nodes
OLSR	0.017530111	0.012049447
RIP	0.017195033	0.00683758
DYMO	0.130537863	0.030018644
LAR	0.213357784	0.078237629
LANMAR	0.010514929	0.008128701
ZRP	0.016727268	0.096230006

Fig. 4.7 (a) Average End to End Delay vs Mobility Model

Fig. 4.7 (b) Average End to End Delay vs No. of Nodes

Fig. 4.7(b) shows the impact of No. of Nodes on the Average end to end delay taking routing protocol as parameter. Following inference can be made:

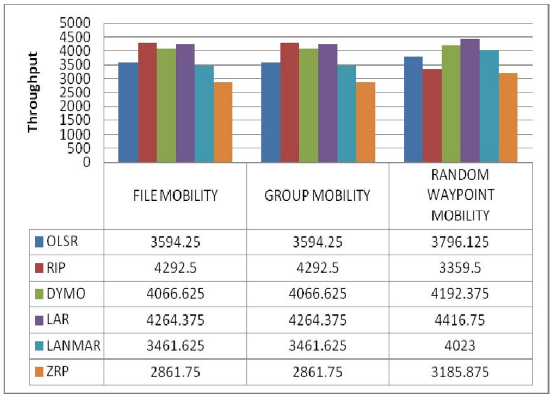
- DYMO and LAR protocols value of delay is higher at 40 nodes but ad the number of nodes increases the value decreases.
- The value of delay for ZRP increase when number of nodes increases.
- LANMAR shows the consistent least value at all networks sizes. OLSR and RIP's efficiency is also good.

4.1.8.4 Throughput

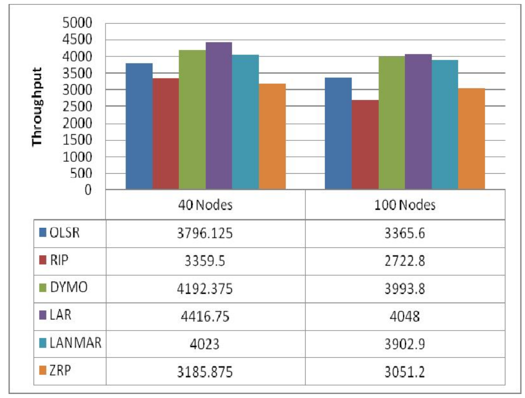
Fig. 4.8(a) shows the impact of mobility on the throughput is taking routing protocol as constraint. Following inference can be made:

- RIP shows highest value of throughput for the File and Group Mobility followed LAR.
- LAR shows highest value for Random Way Point Mobility followed by DYMO.
- ZRP shows least value for each mobility model.

Fig. 4.8(b) shows the impact of Number of Nodes on the throughput taking routing protocol as constraint. Following inference can be made:



	FILE MOBILITY	GROUP MOBILITY	RANDOM WAYPOINT MOBILITY
OLSR	3594.25	3594.25	3796.125
RIP	4292.5	4292.5	3359.5
DYMO	4066.625	4066.625	4192.375
LAR	4264.375	4264.375	4416.75
LANMAR	3461.625	3461.625	4023
ZRP	2861.75	2861.75	3185.875



	40 Nodes	100 Nodes
OLSR	3796.125	3365.6
RIP	3359.5	2722.8
DYMO	4192.375	3993.8
LAR	4416.75	4048
LANMAR	4023	3902.9
ZRP	3185.875	3051.2

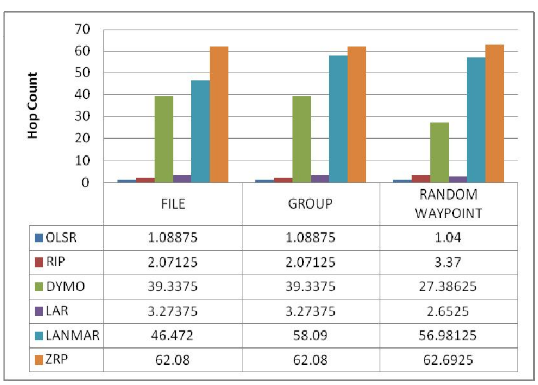
Fig. 4.8 (a) Throughput vs Mobility Model   Fig. 4.8 (b)Throughput vs Number of Nodes

- Throughput of all protocols decreases when the no. of nodes increases.
- OLSR, DYMO, LAR, LANMAR and ZRP are having very minor degradation.
- But at RIP protocol decrease in the performance is countable.

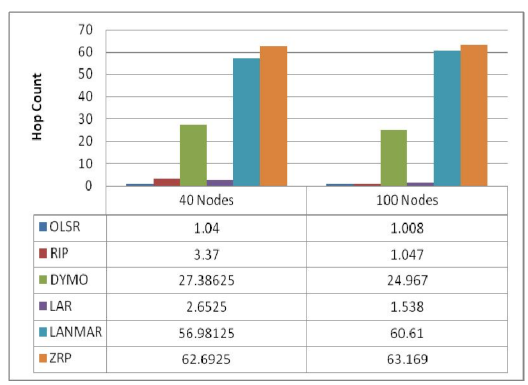
4.1.8.5 Hop Count

Fig. 4.9(a) shows the impact of mobility on the Hop count taking routing protocol as parameter. Following inference can be made:

- ZRP shows highest value of the hop count for each mobility model followed by LANMAR.
- OLSR is having least value of the hop count for each mobility model.



	FILE	GROUP	RANDOM WAYPOINT
OLSR	1.08875	1.08875	1.04
RIP	2.07125	2.07125	3.37
DYMO	39.3375	39.3375	27.38625
LAR	3.27375	3.27375	2.6525
LANMAR	46.472	58.09	56.98125
ZRP	62.08	62.08	62.6925



	40 Nodes	100 Nodes
OLSR	1.04	1.008
RIP	3.37	1.047
DYMO	27.38625	24.967
LAR	2.6525	1.538
LANMAR	56.98125	60.61
ZRP	62.6925	63.169

Fig. 4.9(a) Hop Count vs Mobility modelFig. 4.9(b) Hop Count vs No. of Nodes

Fig. 4.9(b) shows the impact of No. of Nodes on the Hop count taking routing protocol as parameter. Following inference can be made:

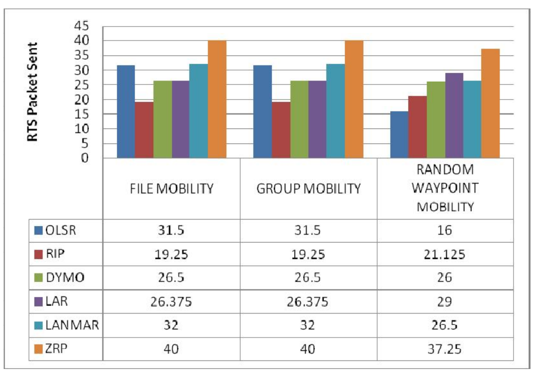
- Hybrid protocols LANMAR and ZRP have worst value of hop count.

- OLSR shows the constant least value of hop count of all increased nodes.
- In case of RIP and LAR value of hop count decreases when number of nodes decrease.

4.1.8.6 RTS Packet Sent

Fig. 4.10(a) shows the impact of mobility on the RTS packet sent taking routing protocol as parameter. Following inference can be made:

- ZRP shows highest value of RTS packet sent for each mobility model and is having highest value in File and Group mobility.
- The RIP shows least value for the File and Group Mobility.
- The OLSR is having least value in case of Random Way Point mobility Model.



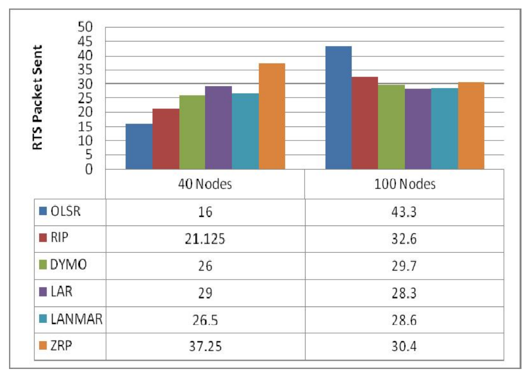


Fig. 4.10(a) RTS Packet Sent vs Mobility Fig. 4.10(b) RTS Packet Sent vs No. of
Model Nodes

Fig. 4.10(b) shows the impact of No. of Nodes on the RTS packet sent taking routing protocol as parameter. Following inference can be made:

- OLSR have the least count of RTS at 40 nodes but having highest count at 100 nodes.
- Only value of LAR and ZRP has decreased with increase in nodes.

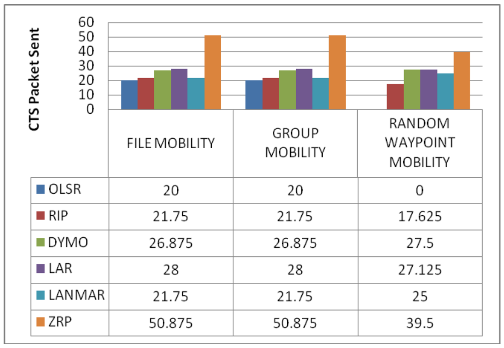
4.1.8.7 CTS Packet Sent

Fig. 4.11(a) shows the impact of mobility on the CTS packet sent taking routing protocol as parameter. Following inference can be made:

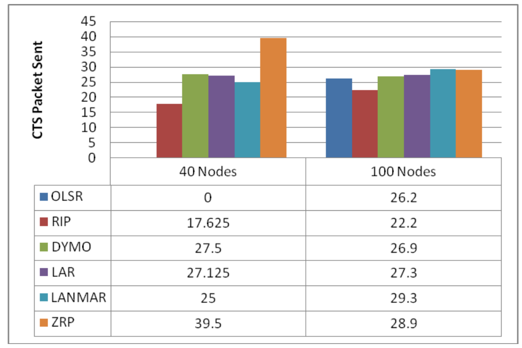
- ZRP shows highest value of CTS packet sent for each mobility model followed by LAR.

- OLSR shows least value for each mobility model and zero in container of (RWP) random way point mobility model.

Fig. 4.11(b) shows the impact of network size on the CTS packet sent taking routing protocol as parameter. Following inference can be made:



	FILE MOBILITY	GROUP MOBILITY	RANDOM WAYPOINT MOBILITY
OLSR	20	20	0
RIP	21.75	21.75	17.625
DYMO	26.875	26.875	27.5
LAR	28	28	27.125
LANMAR	21.75	21.75	25
ZRP	50.875	50.875	39.5



	40 Nodes	100 Nodes
OLSR	0	26.2
RIP	17.625	22.2
DYMO	27.5	26.9
LAR	27.125	27.3
LANMAR	25	29.3
ZRP	39.5	28.9

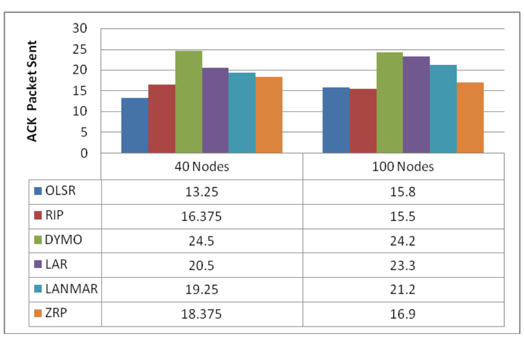
Fig. 4.11(a) CTS Packet Sent vs Mobility Fig. 4.11(b) CTS Packet Sent vs No. of

Model Nodes

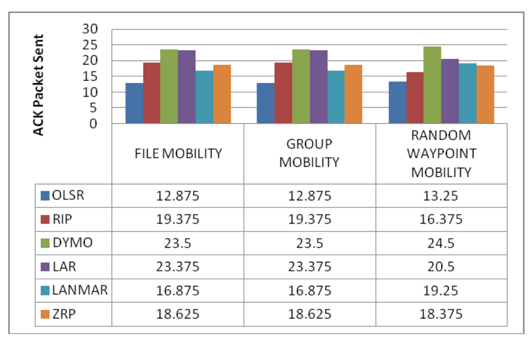
- OLSR does not sent packet when number of nodes size less but when the number of nodes increase its value increase.
- Whereas the value of CTS at ZRP decrease when the number of nodes increases.
- RIP is having the least value of CTS packet sent. DYMO, LAR and LANMAR show the average efficiency.
- OLSR shows least value for each mobility model.

4.1.8.8 <u>ACK Packet Sent</u>

Fig. 4.12(a) shows the impact of mobility and number of nodes on the ACK packet sent taking routing protocol as parameter. Following inference can be made:



	40 Nodes	100 Nodes
OLSR	13.25	15.8
RIP	16.375	15.5
DYMO	24.5	24.2
LAR	20.5	23.3
LANMAR	19.25	21.2
ZRP	18.375	16.9



	FILE MOBILITY	GROUP MOBILITY	RANDOM WAYPOINT MOBILITY
OLSR	12.875	12.875	13.25
RIP	19.375	19.375	16.375
DYMO	23.5	23.5	24.5
LAR	23.375	23.375	20.5
LANMAR	16.875	16.875	19.25
ZRP	18.625	18.625	18.375

Fig. 4.12 (a) ACK Packet Sent vs Mobility Fig. 4.12(b) ACK Packet Sent vs No. of

Model Nodes

- DYMO shows highest value of ACK packet sent for the three mobility models followed by LAR.

- OLSR shows least value for each mobility model.

Fig. 4.12(b) shows the impact of mobility and number of nodes on the ACK packet sent taking routing protocol as parameter. Following inference can be made:

- DYMO shows the consistently worst value of ACK of all number of nodes.
- In case of OLSR, LAR and LARMAR value of ACK increases when the number of nodes.
- Whereas in case RIP and ZRP value decreases when the number of nodes decreases

4.1.9 Conclusion

In our simulation work, performance compassion of different protocols is done. Comparison of different kind protocols proactive, reactive and hybrid is done and presented in the function of varying mobility model and network size. We have take six protocols under consideration proactive protocols: OLSR, RIP; Reactive protocols: DYMO, LAR; Hybrid Protocols: LANMAR, ZRP. In last few years, there were several performance examinations of such routing protocols, although the performance was almost evaluated as a function of mobility rate, speed, and pause time and network size but not by the function of by the mobility model and network size.

As in the Mobile Ad Hoc Network devices are not fixed and they move their position very rapidly. The network topology in such a network keeps changing randomly. On the other hand Scalability is a very important factor for mobile ad-hoc network, as it determines if a protocol will function or fail when the number of mobile users increases.

Table 4.2 Performance in effect of varying mobility model

	OLSR	**RIP**	**DYMO**	**LAR**	**LANMAR**	**ZRP**
Packet Delivery Ratio	Worst	Good at File & group mobility but very low at random way point	Best small difference with LAR	Most efficient Constantly high	Good	Good
Jitter	Good	Efficient consistently low	Worst Constantly High	God at file & group but higher	Most efficient	Good

				at random way point		
Delay	Constantly Good	Efficient Decreases At random way point	Good	Most efficient	Good increases At random way point	Good
Throughput	Constantly Good	Efficient But decreases at random way point	Good	Most efficient	Good increases at random way point	Increases at random waypoint
Hop Count	Most efficient	Good	Average	Good	Average at file increase at group and random way point	Worst constantly very high
RTS Packet Sent	Good at random way point very high at file & group mobility	Efficient	Average	Average	Higher at file & group mobility	Worst
CTS Packet Sent	Efficient at random way point only	Efficient	Average	Average	Good	Worst
ACK Packet Sent	Efficient	Higher at file & group	Worst constantly high	Decreases at Random way point	Average	Average

Table 4.3 Performance in effect of varying network nodes size

	OLSR	**RIP**	**DYMO**	**LAR**	**LANMAR**	**ZRP**
Packet Delivery Ratio	Increase with size of network size	Worst	Good	Best constantly high	Good	Decreases with size of network
Jitter	Good but increase with size of network	Efficient consistently low	Good at small Network but increase at large	Average at small network but increase at large network	Good but little high at small network	Average

			network			
Delay	Good	Most efficient	Worst	Worst	Good	Increase with size of network
Throughput	Good	Decrease at higher rate with increase in network size	Efficient	Most efficient	Better	Good
Hop Count	Most Efficient	Good	Average	Good	Increase with size of network	Worst
RTS Packet Sent	Average at small network rapidly increase with size of network	Good at small network	Most efficient	Efficient	Average	Decreases with increase in network size
CTS Packet Sent	Efficient at small network only	Good	Average	Average	Increase with size of network	Worst
ACK Packet Sent	Efficient	Average	Worst	Increase with size of network	Increase with size of network	Average

4.2 PERFORMANCE ANALYSIS OF MANET ROUTING PROTOCOLS OF VARIOUS ENERGY MODELS WITH VARYING NETWORK NODES

Mobile Ad hoc Network (MANET) is the collection of the mobile nodes without the aid of fixed infrastructure. Therefore the communication in MANET is completely depending on the nodes of the network. For efficient working of the network various routing protocols have been developed. These protocols improve the E^2 (Efficiency and Energy consumption) of MANET by providing the path between distant nodes through multi-hop links. Performance of the protocols is affected by the various factors. One such factor is the energy of the nodes. In this chapter an effort to evolving the performance of five routing protocols Table Driven (OLSR & FISHEYE), Hybrid (ZRP) and On Demand (DYMO & LAR) are used to analyze and compared by using QualNet 5.0 simulator on different energy models like as Generic, MicaZ and Mica-motes to perform Throughput, Average E2E Delay, Jitter, PDF, Energy consumption in transmit , receive, and idle modes .The proportional results was analyzed to test the efficiency of five routing protocols using different energy models. From the analysis it has been analyzed that hybrid routing protocol consumes maximum energy whereas other protocols show comparable consumption with Generic energy model as the maximum energy consuming mode in transmits receive and idle modes. Mica-Motes consume smallest amount of energy consumption in transmit and receive mode for all the five protocols. Finally Mica-motes seem to be more capable of efficiency and energy model as compared to generic and MicaZ.

4.2.1 Introduction

A wireless sensor network is collection of a hundreds and thousands of small sensors called nodes expand across a geographical area, where each sensor functioning separately has the capability for wireless communication, networking, and signal processing of the data and these nodes communicating with each other [151]. Signals can be transmitted without any centralized control and predefined link. Small physical size of nodes has put on processing power which further limits the capacity of size of battery. Routing topology is to decide certain position of the transmission power at nodes and node's location. There are so many routing protocols for comparing E^2 (efficiency and energy) models we are taking five routing protocols for analysis [156]. The MANET routing protocol which is most efficient in enhancing QoS and which may lead to optimal increase in performance. These techniques analyze the network nodes distribution to set the energy of transmitting over the link between two nodes and select an algorithm to calculate the minimum and maximum efficiency. There are many aspects to consider about the energy efficiency awareness of the nodes [144];

- Minimize energy per packet [144]
- Set routes according to the remaining energy [144]
- Maximize network's lifetime [153]
- Minimize the amount of transmission [153]

4.2.2 Related Work

In order to optimize energy consumption utility, the well-designed architectures on all layers, form PHY layer up to Application layer, jointly contribute to energy consumption utility. We indicate the fact that the node in MANET often uses most of its energy to forward the others' traffic, but not its self traffic. It is due to the nature of multi-hop routing and cannot be averted. That is the most important motivation of this chapter. We build the routing architecture on Network layer to fully utilize the energy consumption in MANET. The energy efficient routing not only can be applied to sensor networks, but also on the networks among which energy and battery are critical resources, e.g. ad-hoc networks. The proposed Network layer framework is composite by two components which are sensor deployment and energy efficient routing algorithm. The sensor deployment component is for topology determination [153] [159]. Note that the sensor network topology is non-regular and usually randomly spread as [160-161]. The analytical model presented for energy consumption in IEEE 802.11 single-hop wireless networks is compared to the accounting provided by QualNet with our energy consumption instrumentation. The results match quite closely differing by at most 15%.

Following are the types of energy consumption that have been identified [161]:

- Energy consumed while sending a packet data
- Energy consumed while receiving a packet data
- Energy consumed while in idle mode data
- Energy consumed while in sleep mode

Sleep mode occurs when the wireless interface of the Mobile node is turned off. It should be noted that the energy consumed during sending a packet data is the largest source of energy consumption of all modes. This is followed by the energy consumption during receiving a packet. In the face of the fact that when in idle mode the node does not actually handle data communication operations, it was found that the wireless interface consumes an extensive amount of energy. Idle energy is a wasted energy that should be eliminated or reduced through energy-efficient schemes [161].

4.2.3 Simulation Models and Performance Metrics

This methodology is used in order to isolate the impact on network performance. The performance has been evaluated in three phases OLSR, FISHEYE, LAR ,DYMO and ZRP routing protocols of Mobile Ad-Hoc networks and over it CBR traffic is applied and comparison is done using different energy models (Generic, MicaZ, Mica-motes). The simulations are carried out on a network of 50 nodes placed randomly in the area of 1500m X 1500m, CBR applications are applied between source node (1-10, 1-20, 1-30, 1-40, and 1-50) and destination node respectively. Simulations are configured for the performance evaluation of different routing protocols with the metrics like Total Packets Received ,Throughput, Average E2E Delay, Average Jitter, Packet Delivery Ratio, Energy consumption in transmit mode, receive mode, and idle mode.

4.2.4 Simulation Platform, Models and Attributes

The QualNet 5.0 simulator, including the wireless module to enable mobility of the wireless nodes and support more accurate wireless models for propagation, path loss, multipath fading and reception on wireless networks. The simulations were carried out in three phases [47]:

- 1st phase change energy models (Generic, MicaZ, Mica-motes)
- 2nd phase network sizes changes from 10, 20, 30, 40, and 50 respectively.
- 3rd phase is applied for different routing protocols over three energy models.

For the entire above specified network sizes of the node placement selection was random node placement and random way point (RWP) mobility model used [49].

4.2.4.1 Traffic and Mobility Models

The traffic sources are continuous bit rate (CBR). The data packet is chosen to be 256 bytes in length and the channel bandwidth is 2 Mbps. The mobility model is random waypoint model. In this model, a node moves with a randomly chosen speed uniformly distributed between 0-30 m/s [47].

4.2.4.2 Simulation Parameters

Table 4.4 Simulation setup parameters energy models with variation in no. of nodes

Parameters	**Values**
Routing Protocols	OLSR, FISHEYE, ZRP, DYMO, LAR
Area	1500*1500
No of nodes	10, 20, 30, 40, 50
Fading Model	Raleigh
Channel Frequency	2.4 GHz
Shadowing Model	Constant
Path loss Model	Two ray model
Energy Model	Simple Linear
Battery Model	Simple linear
Mobility	Random waypoint model
Mobility Speeds	1 to 8 meters per sec
Energy Model	1.Generic, 2.Mica- motes, 3.MicaZ
Traffic source	CBR
PHY-Model	PHY802.11b
Data rate	2 Mbps
Antenna-model	Omni directional
Packet size	1024
Radio type	802.15.4
Full Battery Capacity	1200 (mA,h)
Node movement model	Random
Node Speed	10m/s
Energy Supply Voltage	6.5 Volt
Initial Energy (mJoules)	15
Transmission Power (mWatt)	1.4
Receiving Power (mWatt)	1.0
Idle Power (mWatt)	0.0

4.2.5Metrics Used

To evaluate and analyzes the performance of routing protocols, different quantitative metrics are used to compare the performances of DYMO, Fisheye, ZRP, OLSR, and LAR routing protocol. Quantitative metrics are total packet received, throughput client (bits/s), Packet Delivery Fraction, Jitter, Average End-to-End Delay (AE2ED), energy consumed in transmit mode, energy consumed in received mode, energy consumed in idle modes [161].

4.2.6Flow Chart for Design of Scenarios Model

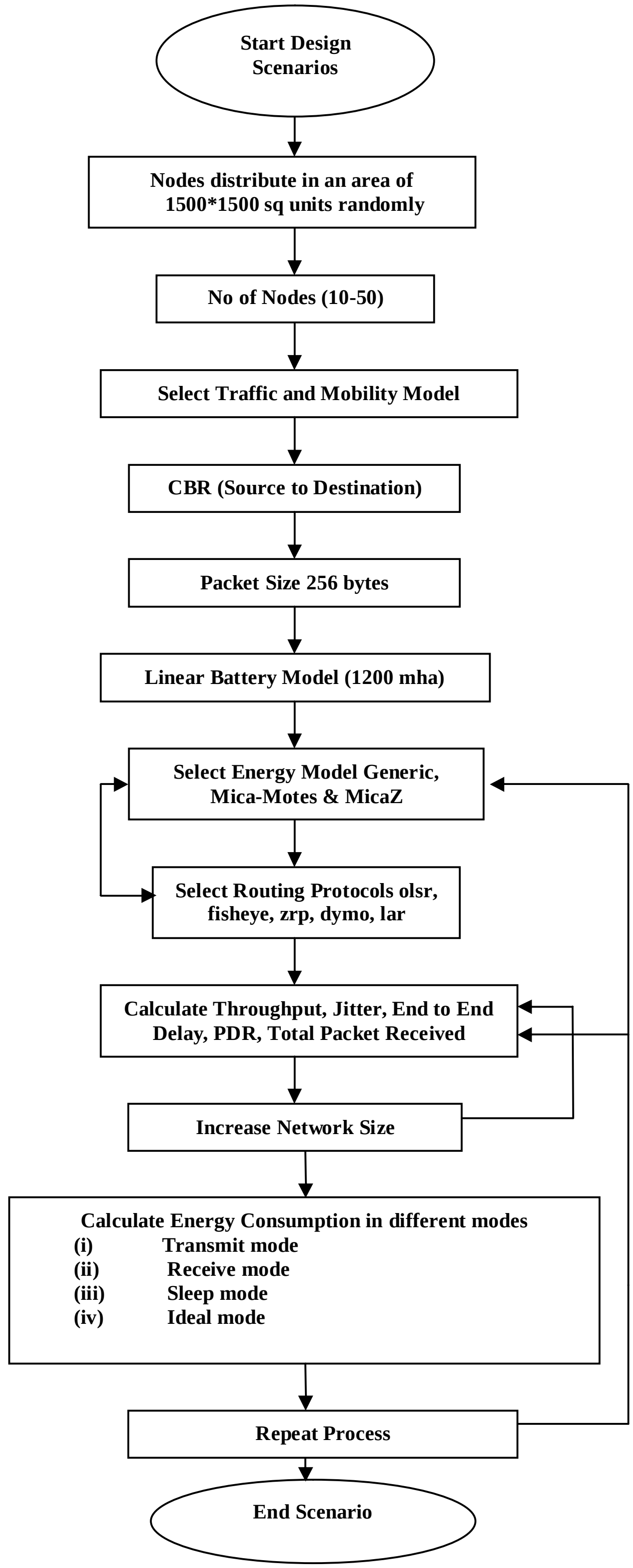


Fig. 4.13 Flow Chart Design of Scenarios Model

4.2.7 System Model

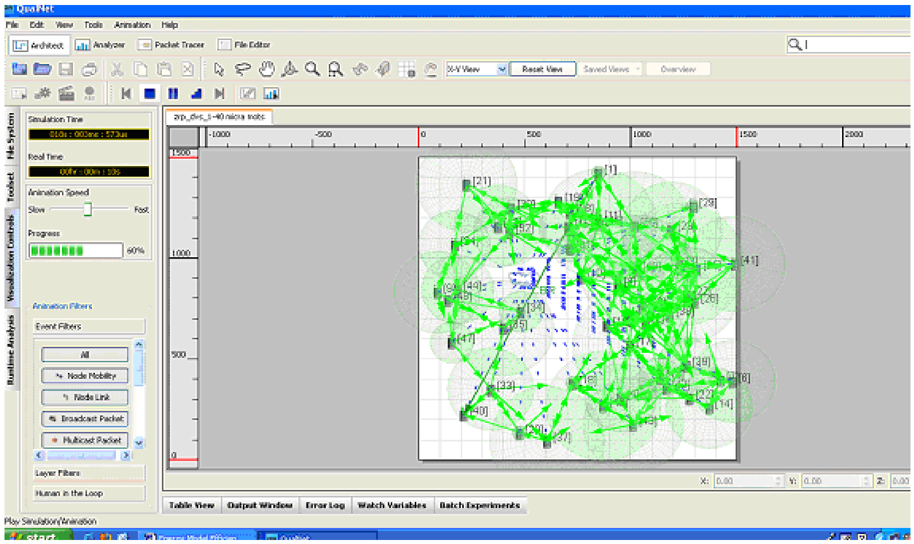


Fig. 4.14 Snapshot of running scenario ZRP routing protocol using 40 network nodes.

4.2.8 Simulation Results and Analysis

Constant bit rate (1-10, 1-20, 1-30, 1-40, and 1-50) is a traffic generator. This UDP-based client-server application sends data from a client to a server at a constant bit rate. Random waypoint mobility model used for simulation the nodes randomly selects a position, moves towards it in a straight line at a constant speed that is randomly selected from a range, and pauses at that destination. The node repeats this, throughout the simulation. The design of scenarios process is simulated in QualNet as shown in Fig. 4.13 and running scenario of ZRP routing protocol using 40 network nodes is shown in Fig. 4.14.

4.2.8.1 <u>Total Packet Received</u>

The total packet received by any client from server per second determines the efficiency of the network for delivering the packet without loss. More is the number of packets received per unit time more will be the efficiency of the network [158].

Fig. 4.15 shows the impact variation of total packet received from server to client the various routing protocols as parameter and also considered for different energy models. Following inference can be made:

- By observation from graph the total packet receiving by DYMO (Generic) is maximum which is followed by LAR, Fisheye, OLSR then ZRP. ZRP having the minimum packet receiving capability for generic energy model.

- The total packet receive (TPR) is maximum for LAR (Mica-motes) which is tailed by DYMO, Fisheye, OLSR then ZRP. ZRP gives the minimum receiving capability of packets for Mica-motes energy model.

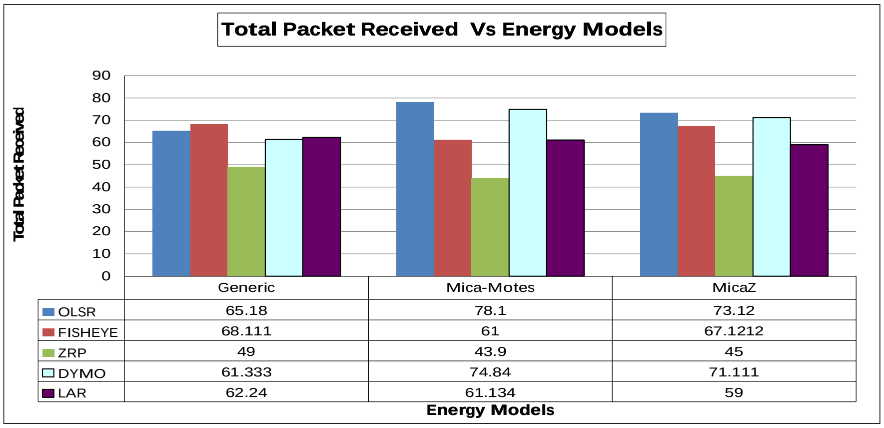


Fig. 4.15 Total packets received for multiple runs with different routing protocols and energy models.

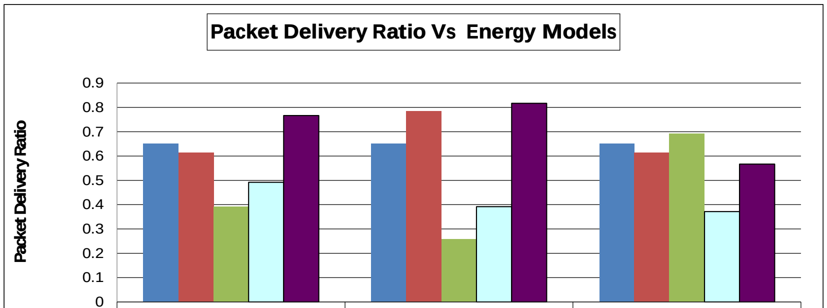
- By observation the TPR is maximum for LAR (MicaZ) which is respectively by DYMO, Fisheye, OLSR then ZRP. ZRP gives the minimum total packet receive (TPR) for MicaZ energy model.

4.2.8.2 **Packet Delivery Ratio**

Defined as the ratio of number of data packets received at the destinations over the number of data packets sent by the sources. Packet delivery fraction is used to determine the efficiency and accuracy of MANET‘s routing protocols [158].

Fig. 4.16 shows the impact variation of Packet delivery ratio of various routing protocols as parameter and also considered for different energy models. Following inference can be made:

- By observation graph the packet delivery ratio (PDR) is maximum for DYMO (Generic) which is followed by LAR, OLSR, Fisheye then ZRP. ZRP having the minimum PDR for generic energy model.
- The packet delivery ratio (PDR) is maximum for DYMO (Mica-motes) which is tailed by LAR, Fisheye, OLSR then ZRP. ZRP gives the minimum PDR for Mica-motes energy model.
- By observation the PDR is maximum for DYMO (MicaZ) which is respectively by OLSR, Fisheye.



	Generic	Mica-Motes	MicaZ
OLSR	0.65	0.65	0.65
FISHEYE	0.612333333	0.783333333	0.613333333
ZRP	0.391666667	0.258333333	0.691666667
DYMO	0.491666667	0.391666667	0.371666667
LAR	0.766666667	0.816666667	0.566666667

Fig. 4.16 Packet delivery ratio for different energy model and no of nodes

- LAR then ZRP. ZRP gives the minimum PDR for MicaZ energy model.
- The above graph it is depicted that maximum number of packets has been sent in DYMO in all the three energy models (Generic, Mica-Motes, MicaZ) while packet delivery is same in LAR, Fisheye, OLSR and ZRP.

4.2.8.3 <u>Throughput</u>

The successful average rate of data packets received at its destination where it may be transported over a certain network node. Throughput is intermittently as data packets per second. Throughput of all protocols decreases when the size of number of nodes increases [158].

Fig. 4.17 shows the impact variation of Throughput of various routing protocols as parameter and also considered for different energy models. Following inference can be made:

- OLSR, DYMO, Fisheye, LAR, ZRP are having very minor degradation.
- By observation the throughput is maximum for OLSR (Generic) which is respectively by DYMO, Fisheye, ZRP then LAR. LAR gives the minimum throughput for generic energy model.
- The throughput is maximum for DYMO (Mica-motes) which is tailed by Fisheye, LAR, ZRP then OLSR. OLSR gives the minimum throughput for Mica-motes energy model.

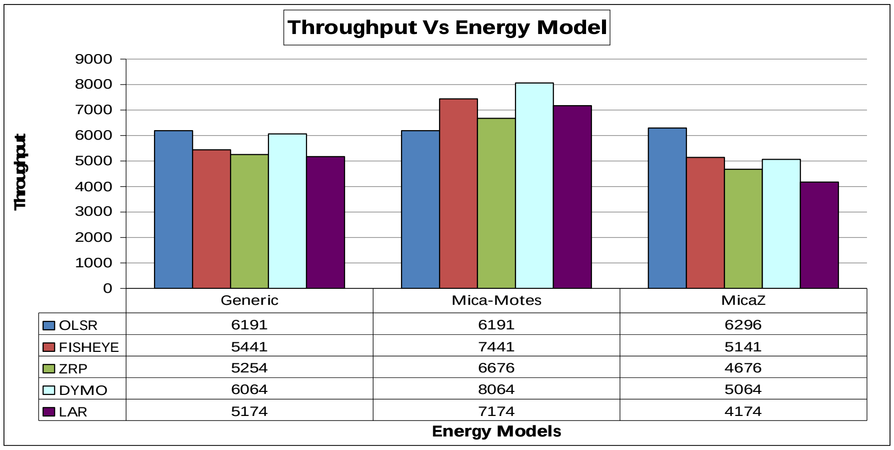


Fig. 4.17 Throughput (s) obtained for different energy model and no of nodes

- By observation the throughput is maximum for OLSR (MicaZ) which is respectively by Fisheye, ZRP, DYMO then LAR. LAR gives the minimum throughput for MicaZ energy model.

4.2.8.4 Jitter

The variation in average Jitter which is caused due to congestion and topology change in network. The value is jitter to be as low as possible for the better performance of any protocol [158].

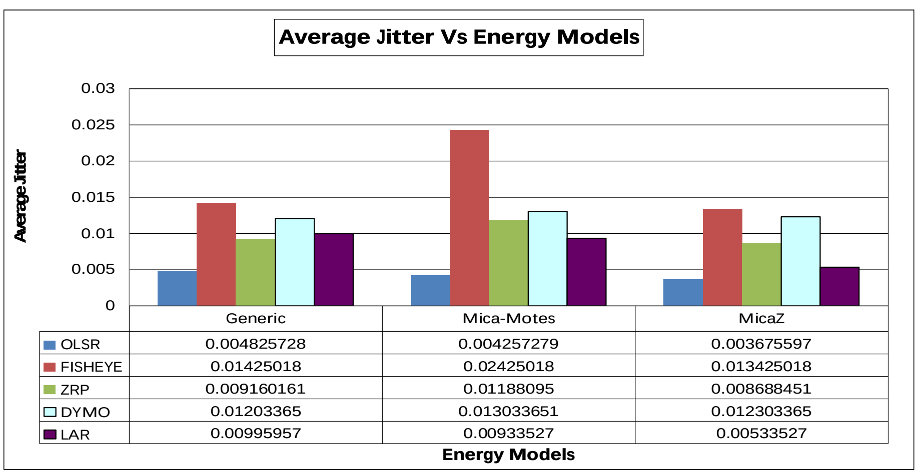


Fig. 4.18 Impact graph of Jitter obtained for different energy model and no. of nodes

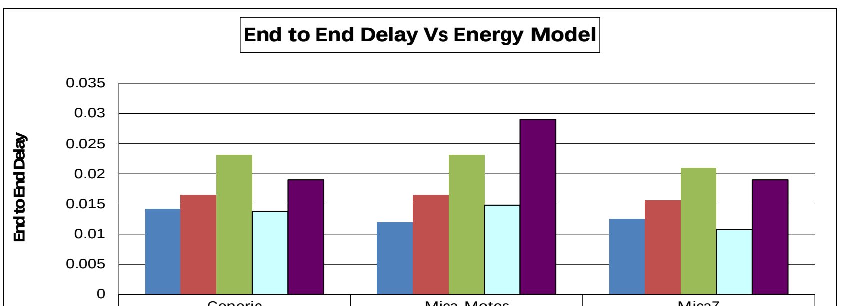
Fig. 4.18 shows the impact variation of average jitter for various routing protocols which considered for different energy models as parameter.

- OLSR shows the constant least jitter.

- By observation the Jitter is maximum for DYMO (Generic) which is followed by Fisheye, ZRP, LAR then OLSR. OLSR gives the minimum jitter for generic energy model.
- The Jitter is maximum for DYMO (Mica-motes) which is tailed by Fisheye, ZRP, OLSR, and then LAR. LAR gives the minimum throughput for Mica-motes energy model.
- By observation the Jitter is maximum for Fisheye (MicaZ) which is respectively by DYMO, ZRP, LAR then OLSR. OLSR gives the minimum throughput for MicaZ energy model.
- ZRP gives an average amount of jitter.

4.2.8.5 Average End-to-End Delay (AE2ED)

The average time drawn in delivery of data packets from the source to destination nodes. The successful data packet delivery and divide that sum by the number of successfully received data [158].



	Generic	Mica-Motes	MicaZ
OLSR	0.014168108	0.012024814	0.012485691
FISHEYE	0.016558474	0.016558469	0.015634823
ZRP	0.023140782	0.023140782	0.020985174
DYMO	0.01379298	0.01479298	0.01079298
LAR	0.018999767	0.028999767	0.018999767

Fig. 4.19 Average End to End delay (s) for different energy model and no. of nodes

Fig. 4.19 shows the impact variation of Average End to End Delay for various routing protocol as parameter and considered for different energy models. Following inference can be made:

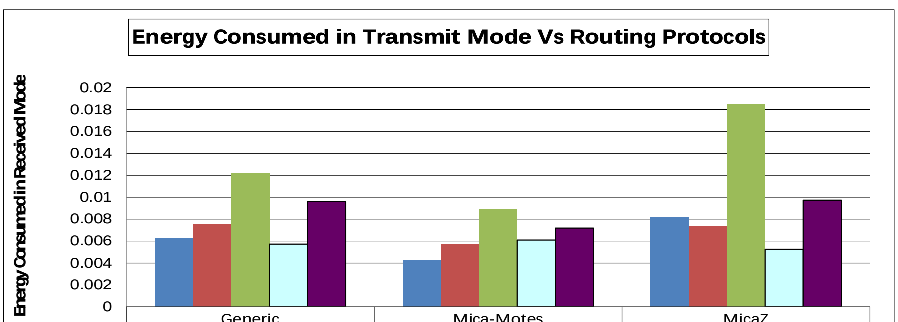
- By observation the Average End to End Delay is maximum for LAR (Generic) which is followed by OLSR, Fisheye, DYMO then ZRP. ZRP gives the minimum jitter for generic energy model.

- The Average End to End Delay is maximum for LAR (Mica-motes) which is tailed by Fisheye, OLSR, DYMO then ZRP. ZRP gives the minimum throughput for Mica-motes energy model.
- By observation the Jitter is maximum for LAR (MicaZ) which is respectively by Fisheye, OLSR, ZRP then OLSR. OLSR gives the minimum throughput for MicaZ energy model.
- ZRP shows the consistent least value at all networks sizes. OLSR and Fisheye's efficiency is also good.

4.2.8.6 <u>Energy consumed in Transmit Mode</u>

The scalability, lifetime of nodes, response time of nodes, mobility, efficiency and effective sampling frequency, all these parameters of the MANET depend upon the power. In case of power failure the network goes down break therefore energy is required for maintaining the individual health of the nodes in the network, during receiving the packets and transmitting the data as well [158].

Fig. 4.20 shows the impact variation of Energy consumption in transmit mode with different routing protocols as parameter and also considered for different energy models. Following inference can be made:



	Generic	Mica-Motes	MicaZ
OLSR	0.0062614	0.004193	0.008144
FISHEYE	0.0075009	0.005643	0.0073202
ZRP	0.0121522	0.008937	0.018423
DYMO	0.0057249	0.006088	0.00525023
LAR	0.0095924	0.007187	0.00972266

Routing Protocol

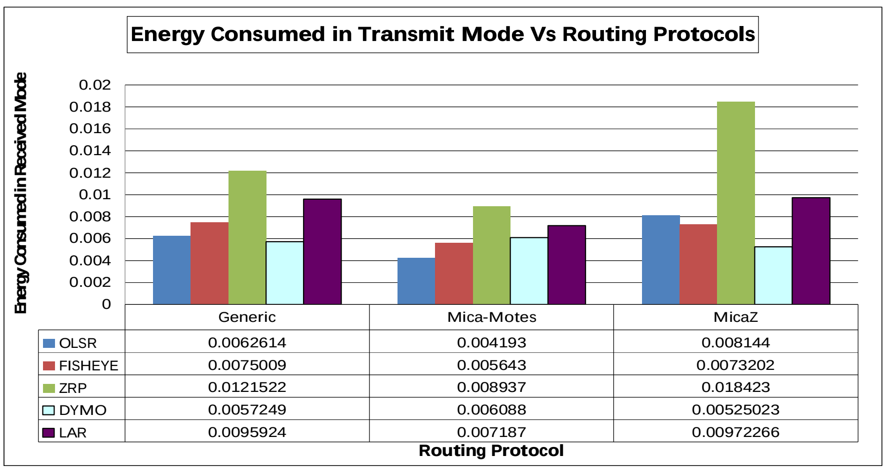
Fig. 4.20 Energy consumption in Received mode with different routing protocols and energy models.

- By observation from graph the maximum energy consumes by OLSR (Generic) is maximum which is followed by ZRP, LAR, Fisheye then DYMO. DYMO having the minimum power consumption in transmit mode for generic energy model.

- The maximum energy consumes by ZRP (Mica-motes) which is tailed by LAR, DYMO, Fisheye, and OLSR. OLSR gives the minimum power consumption for Mica-motes energy model.
- By observation the maximum energy consumes for ZRP (MicaZ) which is respectively by LAR, OLSR, Fisheye, than DYMO. DYMO gives the minimum power consumption for MicaZ energy model.

4.2.8.7 <u>Energy consumed in Received Mode</u>

Fig. 4.21 shows the impact variation of Energy consumption in receive mode with different routing protocols.



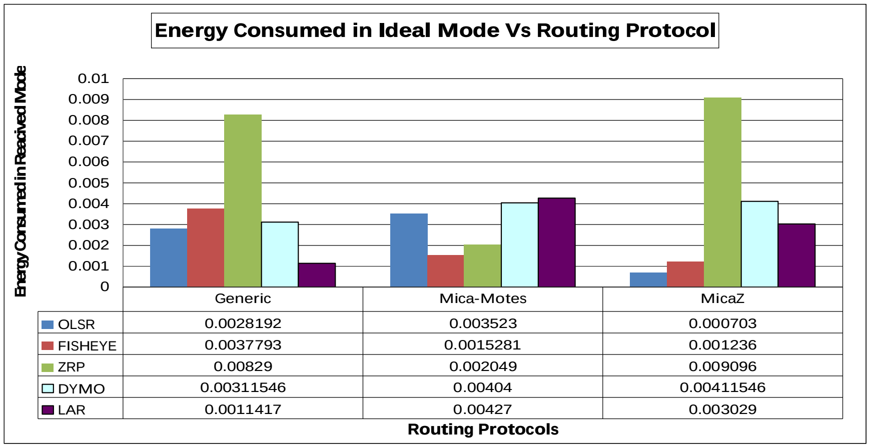
	Generic	Mica-Motes	MicaZ
OLSR	0.0062614	0.004193	0.008144
FISHEYE	0.0075009	0.005643	0.0073202
ZRP	0.0121522	0.008937	0.018423
DYMO	0.0057249	0.006088	0.00525023
LAR	0.0095924	0.007187	0.00972266

Fig. 4.21 Energy consumption in Received mode with different routing protocols and energy models.

- By observation from graph the maximum energy received by OLSR (Generic) which is followed by DYMO, Fisheye, ZRP then LAR.
- The maximum energy received by OLSR (Mica-motes) which is tailed by DYMO, Fisheye, ZRP then LAR.
- The maximum energy received by DYMO (MicaZ) which is respectively by Fisheye, OLSR, LAR, than ZRP.

4.2.8.8 <u>Energy consumed in Ideal Mode</u>

The energy consumption in idle mode is that there is minimum consumption in MicaZ followed by Mica motes and maximum in Generic.



	Generic	Mica-Motes	MicaZ
OLSR	0.0028192	0.003523	0.000703
FISHEYE	0.0037793	0.0015281	0.001236
ZRP	0.00829	0.002049	0.009096
DYMO	0.00311546	0.00404	0.00411546
LAR	0.0011417	0.00427	0.003029

Fig. 4.22 Energy consumption in Ideal mode with different routing Protocols and energy models

- The maximum energy consumes in ideal mode by ZRP (Generic) which is followed by OLSR, DYMO LAR and then Fisheye.
- The maximum energy consumes in ideal mode by Fisheye (Mica-motes) which is tailed by OLSR, ZRP, DYMO, and then LAR. LAR consumes minimum power in ideal mode for Mica-motes energy model.
- By observation the maximum energy consumes in ideal mode DYMO (MicaZ) which is respectively by Fisheye, ZRP, LAR, and then OLSR.

4.2.9 Conclusion

The data obtained from scenario designed using QualNet 5.0 simulator, the throughput is maximum for DYMO (Mica-motes) tailed by Fisheye, LAR, ZRP and minimum for OLSR. ZRP gives the least throughput for all three proposed energy models. Jitter is maximum for DYMO (Mica-motes) followed by Fisheye, OLSR, ZRP then OLSR. OLSR had given least Average Jitter value. Average E2E End delay is least for ZRP (Mica-motes) respectively Fisheye, OLSR, DYMO, and ZRP gives minimum average end to end delay. PDF Maximum for DYMO (Mica-mote) Maximum which is tailed by LAR, Fisheye, OLSR then ZRP. Number of packets received by LAR was minimum all the three energy models while packet received is almost same in DYMO, Fisheye, OLSR and ZRP. For energy consumed in transmit, receive mode it has been concluded that ZRP consumed maximum energy .Generic energy model is the maximum energy consuming mode for all routing protocols. Mica- motes energy model has good for all the routing protocols in all modes with ZRP shows the minimum consumption for all three modes of energy model. Mica-motes model consumes minimum amount of energy in receive and transmit mode for all the proposed protocols.

The maximum Energy efficiency consumption in transmit mode, receive and ideal mode for OLSR for small network size of 10 nodes. The network size increases to 20, energy consumption also increases for all the protocols (OLSR, Fisheye, ZRP, DYMO and LAR) when nodes size increases 50 and above nodes, transmitting energy reduces. Further we can improve our simulation increase number of nodes and tiring to modified the existing routing protocol to give better performance even in high demanding conditions i.e., reduce the energy consumption and increasing the efficiency of nodes in a large network.

4.3 Analysis and effect of Directional Antennas on energy in routing protocol

Mobile ad hoc network is also known as the "networks without network". In mobile ad hoc network, directional antenna plays a vital role. Directional antenna has many advantages such as increased transmission range, higher gain and reduced interference. Directional antenna uses a set of elements with fixed beam nature and to radiate the frequency in all directions and also at a specific angle. In this chapter the performance of different directional antennas for different routing protocols such as AODV, LANMAR and RIP is analyzed. The performance analysis is based on different metrics of the application layer such as average jitter, average end to end delay and the basis of physical layer metrics such as power consumed in transmit, receive and idle mode using QualNet 5.0.

4.3.1Introduction

Directional antenna [8] can radiate the frequency in all directions and also provide the great area of coverage and reduction in power consumption. With these features Directional antenna has been used in mobile ad hoc network. MANET is a network without infrastructure. Mobile ad hoc network has a new structure in the field of communication network. They do not require any fixed infrastructure for instance a base station to work. The nodes change address topology themselves due to the mobility, the entrance or exit of nodes. These nodes use a radio medium [162-163]. In the infrastructure less networks the nodes can freely move within the range but in an infrastructure mode all the nodes are stationary. Due to the mobility of nodes and increasing number of nodes/users, the transformation of information will consume most of the bandwidth. To transmit the data from one node to another node we use different types of protocols such as reactive, proactive and hybrid [164].

Established wireless communication systems employ directional antennas provide large coverage area and lower power consumption, because of this advantage directional antennas have been adopted in Mobile ad hoc networks, cellular network system 2G and 3G. Complexities of routing between nodes are increasing day by day, because of highly dynamic nature and bandwidth of the mobile ad hoc network which results in regular change in network topology. If the networks have a large number of nodes, the transmission of routing information will consume most of the bandwidth. Nodes in mobile ad-hoc network sharing same random access wireless channel and each node function not only as a host but also as a router that maintains routes to end forwards data for the other nodes in the networks that may not be within wireless transmission range. Routing in the mobile ad hoc networks faces challenges due to mobility of the nodes, a large number of nodes, and communication between node resources, constrains like energy and bandwidth [156, 166]. This requires the ad hoc network to have high capability of self-organization and maintenance which is fulfilled by utilizing intellectual routing protocol and efficient resource management in a distributed manner. The routing protocol may generally be categorized as: Reactive, Proactive and Hybrid routing protocol. Reactive type of routing creates routes only when desired by the source node for example AODV, DSR and DYMO [167]. Table driven routing protocols attempt to maintain up to date routing information from each node to every other node in the network for example OLSR, LANMAR[168]. Hybrid routing is a combination of proactive and reactive for example ZRP [169]. Both reactive and proactive routing protocols have their advantages and disadvantages in conditions of routing power consumption and table size. In this chapter we compared and analysis the reactive proactive and hybrid routing protocols like: DSR,OLSR and ZRP on the basis of average jitter, average end to end delay, throughput and power consumption in receive transmit and ideal mode using Omni-directional, steerable and switched mode directional antennas.

4.3.2 Related Work

In these papers (166-168) authors have evaluated to find out which directional antennas are more supportive for wireless sensor network and which directional is best for network. Omni-directional, steerable and switched beam to ad hoc network and are essential to evaluate the effects of directional antennas on the performance of various routing protocols DSR, OLSR and ZRP. In this paper, the performance of DSR, OLSR and ZRP using different directional antenna and all parameters selected by simulator. In the ad hoc wireless networks, battery power is a very critical resource in sensor networks. One such aspect is that nodes are operated normally and power is provided by batteries. Therefore energy conserving has become a very important goal. For energy conservation different algorithms have been proposed to realize power efficiency during the routing process. Directional antennas have been used to reduce transmission power as well as to decrease obstruction in the networks. Author proposed design an energy model for the use of different directional antenna based scenario in QualNet to find out energy consumption on each node when data is transmit or receive.

This chapter can be concluded from the following aspects:

- The summary of directional antennas (Omni-directional, steerable and switched beam) technology starting from very essential elements which is presented, gives a general overview of operating principle [170-174].
- The current ad hoc MAC protocols (IEEE 802.11 family protocols) and three categories of ad hoc routing protocols (reactive, proactive and hybrid routing protocols) in detail have been presented one popular routing protocols for each category is chosen at a time. The three routing protocols are dynamic source routing (DSR), Optimized Link State Routing (OLSR) and Zone Routing Protocol (ZRP) [172].
- The result in the application and physical layer when utilizing directional antennas is obtained and several proposed performance metrics like as average jitter, average end to end delay, total packet receive, and throughput for a comparison of these proposals from technical point of views are reviewed [171].
- We investigate the improvement in ad hoc routing and network performance with directional antennas in power consumption mode routing protocols compared with Omni-directional antenna, steerable and switched beam antenna for static and mobility scenarios through case study which is done with the QualNet simulator [47, 173].
- The Random way point mobility model metric and node pause time in this paper covers the classes of routing protocols like proactive, reactive and hybrid, which provides valuable direction for the performance of all routing protocols under various network conditions [171, 174].

4.3.3 Simulation Setup

4.3.3.1 Simulation Tool Used QualNet 5.0

The simulator used in this chapter is QualNet 5.0, [47] which is developed by Scalable Network Technologies. The simulation is running based on discrete event scheduler. So as to means the simulation is not performed in a constant time flow, but at specific points of time when events occur. QualNet is a predictive high-fidelity modeling tool for wired and wireless networks of tens of thousands of nodes. It employs computational resources of mobility models in large-scale networks with heavy traffic load for reasonable simulation times.

QualNet (Quality Networks) work from Scalable Network Technologies is a commercial product that is an improved modeling tool derived from GloMoSim. It has a dedicated and fully implemented protocols and modules for both the wired and wireless scenarios including ad hoc, cellular and satellite models. The Simulator, this component is designed to include elevated reliability models of a network of tens and thousands of nodes with high mobility and heavy traffic [48].

The default values for all parameters in the configuration file of QualNet were used, i.e., the transmission rate is set at 11 Mbps, and the power consumption is 900 mW for both receiving/idle and transmitting states. The transmission range for each node is 100m (receiver threshold is -75dB). CBR traffic is generated from node 1 to 30 times with 5 second interval; the data size is 512 bytes and simulation time is 300 seconds [48].

4.3.3.2 Flow Chart of QualNet Implemented Model

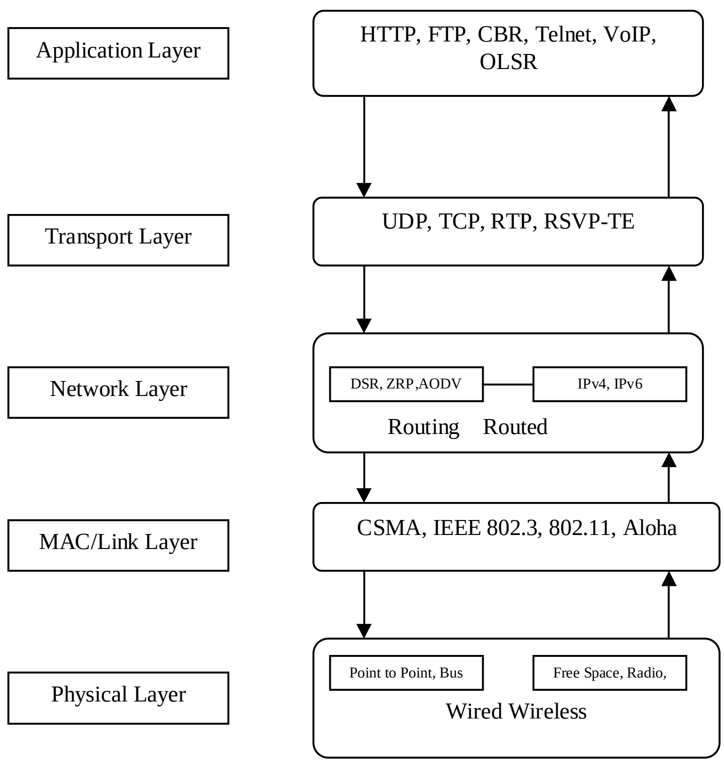


Fig. 4.23 QualNet Implemented Model

4.3.3.3 QualNet Implemented Models

QualNet is implemented using a TCP/IP network model which is similar to layered architecture as shown in Fig. 4.23. The application layer takes place of traffic generation and application level routing. Numerous traffic generator models and application level routing protocols have been implemented in QualNet. Different Traffic generators supported inc1ude HTTP, MCBR, CBR, FTP, VoIP, TELNET, VBR etc. FTP (File Transfer Protocol) is often used to simulate transferring files between server and client, CBR (Constant Bit Rate) is often used to simulate fixed-rate uncompressed multimedia traffic. The (VoIP) Voice over Internet Protocol is used to simulate the routing of voice conversations over the internet or through any other IP based network. In PHY layer, QualNet supports three propagation models path loss free space, two ray and irregular terrain. It offers two fading models: Ricean and Rayleigh model. QualNet provides three antenna models: Omni-directional, switched-beam and steerable antenna [48].

4.3.3.4 Simulation Methodology

In this topic the simulation is performed by increasing the no. of node 10 to 100 linearly within the simulation area 1500x1500. The nodes are deployed randomly in the specified area and node follows the random way point mobility model. These source nodes transmit 1000 byte data packets per second at a constant bit rate (CBR) across the established route for the entire simulation time 30 second.

4.3.4 System Model

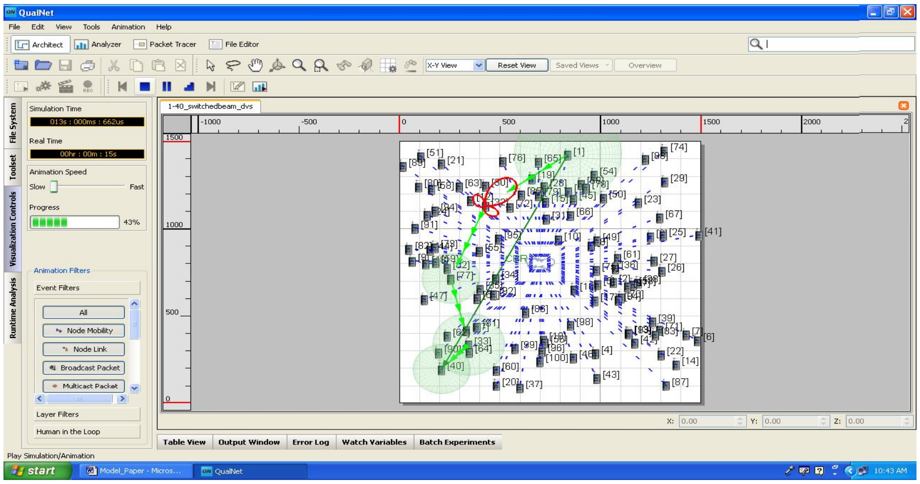


Fig. 4.24 Snapshot of simulation scenario representing route discovery mechanism of 100 nodes for DSR routing.

Table 4.5 Parameters Consideration for Simulation Setup

Parameter	**Value**
Simulator	QUALNET 5.01
Routing Protocols	OLSR, DSR, ZRP
Mac Type	IEEE 802.11
Number of Nodes	100
Transmission range	600m
Simulation Time	30s
Simulation Area	1500 X 1500
Mobility Model	Random Waypoint Mobility
Energy Model	Mica-Motes
Traffic Type	Constant-Bit Rate
Node Placement Model	Random
Battery Model	Linear Model
Full Battery Capacity	1000 (mA,h)
Battery Charge Monitoring Interval	30 Sec.
Antenna Models	Omni direction Steerable Switched Mode
Total packet sent	24
Packet Size	12288 Bytes
Throughput	4274
Channel Frequency	2.4 GHz

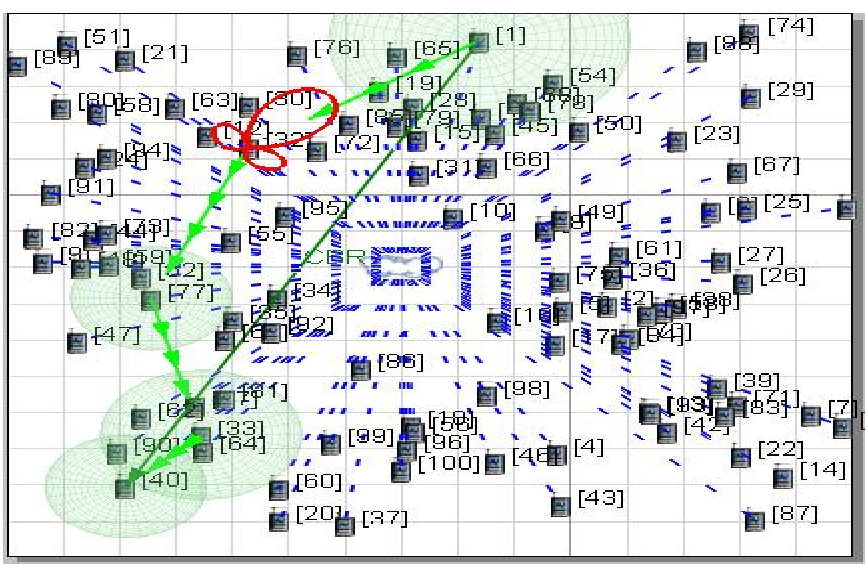


Fig. 4.25Snapshot of simulation scenario representing

CBR between nodes 1 to node 40

4.3.5 Result and Discussion

4.3.5.1 <u>Average Jitter</u>

Average Jitter: It is the alteration in arrival time of the packets and caused due obstruction, topology changes. It is measured in second.

Fig. 4.26 shows the impact of directional antennas on the Average Jitter taking routing protocol as parameter. Following assumption can be made:

- The DSR presents highest values of Average Jitter for Omni and switched beam antennas.
- The OLSR shows highest value of Average Jitter for steerable antenna.
- The ZRP presents least value of the average jitter for all three directional antennas.

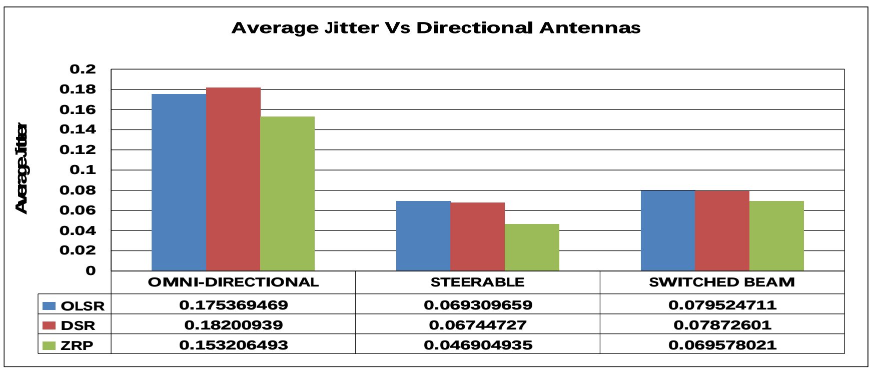


Fig. 4.26 Average jitter for different routing protocols Vs using Directional Antennas

4.3.5.2 <u>Average End to End Delay</u>

End-to-End Delay: Delays due to buffering during the interface queues, route discovery process, and transfer the channel. It measured in second.

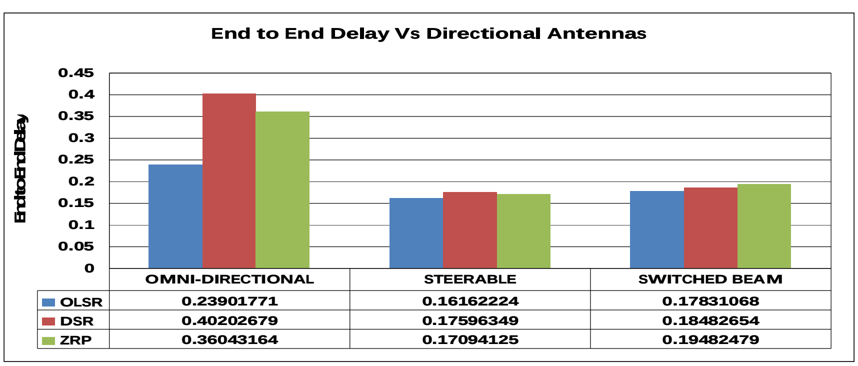


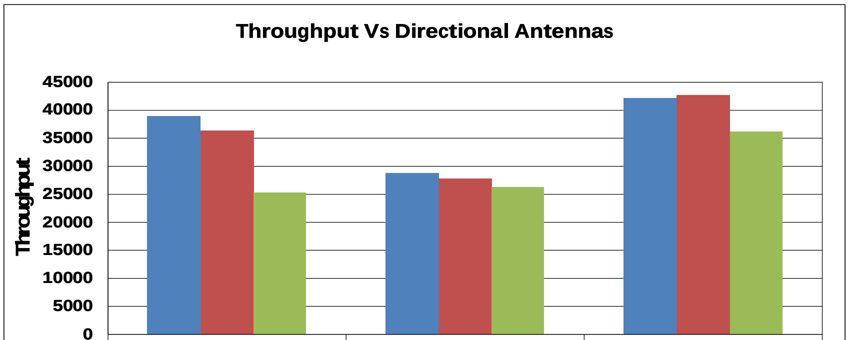
Fig. 4.27 End to End delay for different routing protocols Vs using Directional Antennas

Fig. 4.27 shows the impact of directional antennas on the End to End Delay taking routing protocol as parameter. Following assumption can be made:

- The DSR presents highest values of End to End Delay for Omni-directional and steerable antennas.
- The OLSR presents least value of End to End Delay for all three directional antennas.

4.3.5.3 <u>Throughput</u>

Throughput: Average rate of successful data packets received at destination is called throughput. It is genuine output and precise in bps (bit/s)



	OMNI-DIRECTIONAL	STEERABLE	SWITCHED BEAM
OLSR	38940.2222	28787.2342	42191.1111
DSR	36355.3333	27787.5555	42726.2222
ZRP	25319.1234	26270.2222	36262.9999

Fig. 4.28 Throughput for different routing protocols Vs using Directional Antennas

Fig. 4.28 shows the impact of directional antennas on the Throughput taking routing protocol as parameter. Following statement can be made:

- The DSR presents highest values of Throughput for switched beam antenna.
- The OLSR shows highest value of Throughput for Omni-directional antenna.
- The ZRP presents least value of the average jitter for all three directional antennas.

4.3.5.4 <u>Energy Consumed in Transmit Mode</u>

The mobility, scalability, efficiency, lifetime, effective sampling frequency and response time of nodes, all these parameters of the MANET depend upon the power.

In case of power failure the network goes down break therefore energy is required for maintaining the individual health of the nodes in the network, during receiving the packets and transmitting the data as well.

Fig. 4.29 shows the impact of directional antennas on the Energy Consumed in Transmit Mode taking routing protocol as parameter. Following interference can be made:

- The ZRP presents highest energy consumed in all directional antennas.
- The DSR consumes moderate energy for all three directional antennas.
- The OLSR consumes least energy in Omni directional antenna.

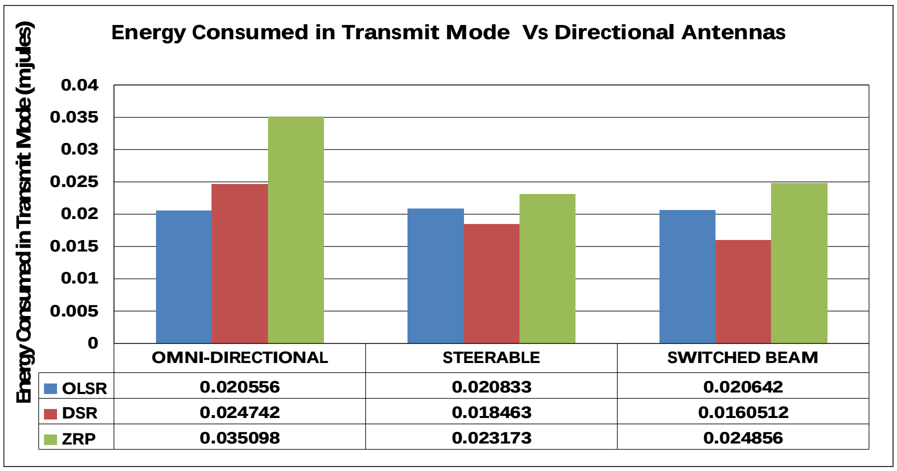


Fig. 4.29 Energy consumed in transmit mode for different routing protocols using Directional Antennas

4.3.5.5 Energy Consumed in Received Mode

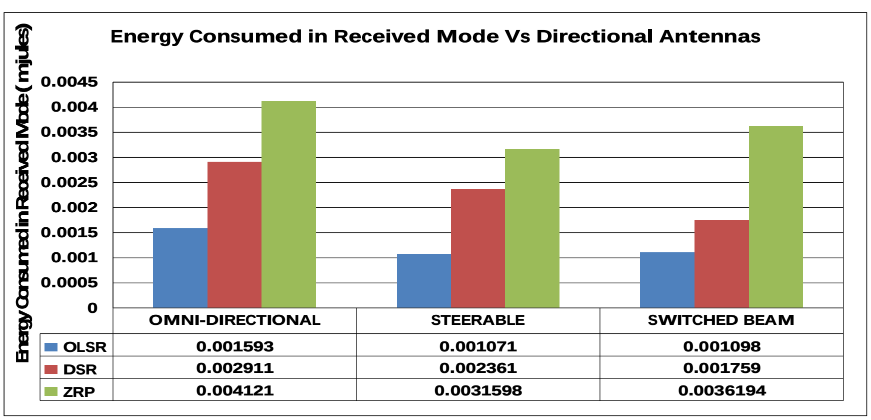


Fig. 4.30 Energy consumed in received mode for different routing protocols using Directional Antennas

Fig. 4.30 shows the impact of directional antennas on the Energy Consumed in Received Mode taking routing protocol as parameter. Following interference can be made:

- The ZRP presents highest energy consumed in received mode in all directional antennas.
- The DSR consumes moderate energy for all three directional antennas.
- The OLSR consumes least energy in switched beam directional antenna.

4.3.5.6 Energy consumed in Ideal Mode

Fig. 4.31 shows the impact of directional antennas on the Energy Consumed in Ideal Mode taking routing protocol as parameter. Following interference can be made:

- The ZRP presents highest energy consumed in Ideal mode in all directional antennas.
- The DSR consumes moderate energy for all three directional antennas.
- The OLSR consumes least energy in all directional antennas.

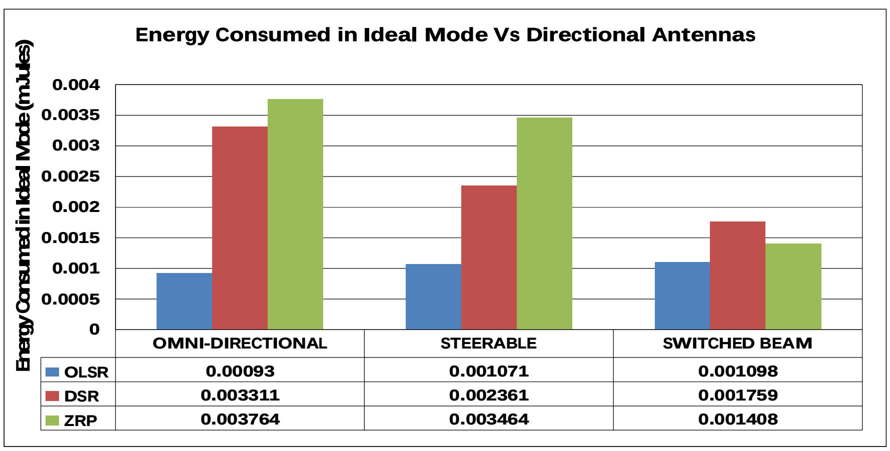


Fig. 4.31 Energy Consumed in Ideal Mode for different routing protocols using Directional Antennas

4.3.6 Conclusion

The use of directional antennas inside Mobile Ad-hoc network can extensively improve the performance of wireless networks. Less interference and higher data rates can be achieved due to narrow directional beams using directional antennas. In this chapter, we have simulated and analyzed the impact of directional antennas on reactive proactive and hybrid routing protocols (OLSR, DSR and ZRP) in mobile ad-hoc networks using Omni, steerable and switched beam directional antennas. These routing protocols performed throughput, delay, jitter in application layer and energy consumption in physical layer of TCP/IP and simulation results of all protocols are shown above. All these parameters of the MANET depend upon the power. In case of power failure the network goes down break therefore energy is required for maintaining the individual health of the nodes in the network, during receiving the packets and transmitting the data. Simulation results show that by using directional antennas, ad hoc networks may achieve better performance. However, scenarios exist in which Omni-directional antennas may be suitable. With the fast development of directional antenna technology, the size of a directional antenna becomes smaller and the cost of it reduces also. The nature of radiating radio energy only towards a certain direction makes directional antennas save more power, increase transmission range and reduce neighborhood interference compared with Omni-directional antennas.

Seven papers are produced out of research work carried in this section of thesis.

[1] Dharam Vir, S.K.Agarwal, S. A. Imam " Quantitative Analyses and Evaluation of MANET Routing Protocol in Effect of Varying Mobility Model using QualNet Simulator" in 2012 world Congress on Information and Communication Technologies, 978-1-4673-4805-8/12/$31.00@2012 IEEE Xplore, October 2012, PP. 915-921.

[2] Dharam Vir, S.K.Agarwal, S. A. Imam "A Simulation Study on Node Energy Constraints of Routing Protocols of Mobile Ad hoc Networks use of QualNet Simulator" in International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN: 2278 – 8875, www. http://www.ijareeie.com Vol. 1, Issue 5, November 2012. Page: 401 – 410.

[3] Dharam Vir, S.K.Agarwal, S. A. Imam "Performance Analysis Of Effect Of Directional Antennas On Energy In Routing Protocol" in International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, www.ijera.com Vol. 3, Issue 1, January -February 2013, pp.238-244

[4] Dharam Vir, S.K.Agarwal, S.A.Imam "Power Control and Performance Improvement of Reactive Routing Protocols using QualNet Simulator" in International Journal of Application or Innovation in Engineering & Management Web Site: www.ijaiem .org Email: editor@ijaiem.org, editorijaiem@gmail.com, ISSN: 2319-4847, Volume 2, Issue 4, April 2013 pp, 175-184.

[5] Dharam Vir, S.K.Agarwal , S.A.Imam "Performance Evaluation and Investigation of Energy in AODV, OLSR Protocols through Simulation" in International Journal of Application or Innovation in Engineering & Management (IJAIEM) Web Site: www.ijaiem .org Email: editor@ijaiem.org, editorijaiem@gmail.com, ISSN: 2319-4847, Volume 2, Issue 7, July 2013 pp, 80-87.

[6] Dharam Vir, S.K.Agarwal, S. A. Imam "Impact of Mobility Model on Table Driven Routing Protocols of MANET" in 8th IEEE conference on Industrial Electronics and Application, (ICIEA 2013), Melbourne, Australia (Accepted). 17-1-2013.

[7] Dharam Vir, S.K.Agarwal, S. A. Imam "A simulation based performance analysis of MANET routing protocol in effect of RWP mobility model and network size" in 25th IEEE Chinese Control and Decison Conference, (2013CCDC), China (Accepted). 22-10-2012.

Chapter 5

PROTOCOLS BASED ON POWER SAVING SCHEMES IN WIRELESS SENSOR NETWORK

This chapter gives an Investigations and optimization of power saving schemes based protocols in Wireless Sensor Network. The brief overview of the contents of chapters is described below.

5.1 INTRODUCTION

MANETs [175] consists of mobile nodes that communicate with each other through either direct link or multi-hop wireless links in the absence of fixed infrastructure. The nodes of these networks have several constraints such as limited bandwidth, transmission range and processing capability due to which the network working has to be fully decentralized i.e. message processing or message passing must be done by nodes themselves using certain routing protocols [176-177].

Several power aware routing protocols that are used for to extending the battery lifetime these are Minimum Total Power Routing Protocol (MTPR), Minimum Battery Cost Routing Protocol (MBCR), Power-Aware Source Routing Protocol, Localized Energy Aware Protocol, Online Power Routing Protocol, Power Aware Localized Routing Protocol and Power Aware Routing Protocol. All of above routing protocols are used to extending battery life and also increase the lifetime of the mobile nodes in desired network [178].

There are number of power routing protocols that are used for to extending the battery lifetime, these are Minimum Battery Cost Routing Protocol [MBCR], Minimum Total Power Routing Protocol (MTPR), Power Aware Source Routing Protocol [PASR], Localized Energy Aware Protocol [LEAR]. All of above routing protocols are used to extending battery life of the mobile nodes [180, 182].

In power aware routing, the protocol doesn’t prioritize short routes anymore, but rather it tries to select those routes which will optimize battery using up to network. If a route contains nodes with low down the battery levels, a longer route is chosen if available. The Minimum Total Transmission Power Routing (MTPR) protocol for instance, chooses routes either with more or shorter hops rather than fewer hops & longer transmission ranges [180-181].

Each node in MANET utilizes its limited residual battery power for its network operations. There are some basic problems related to battery power like difficulties in replacing the batteries in the field, recharging of the batteries, selection of optimal transmission power etc. Due to all these problems power management [182] is an important issue in MANET. Efficient utilization of battery power increases the network lifetime hence is critical in enhancing the network capacity [182].

Power conservation in Wireless Sensor Network and Mobile Ad hoc Network (WANET) is a major challenge even today for researchers. To conserve it various power aware routing protocols have been proposed. These protocols do not take into consideration the residual power left in nodes. To ensure the success of WANET in such scenarios designed in QualNet simulator software in last chapters, it is necessary that the routes be established between every possible pair of nodes at any instant of time irrespective of the shape of the area and the mobility pattern of the nodes. Such an idealistic situation can be created by high density of nodes, high transmission range and very high battery powers [183]. This chapter presents some of our own experimental work performed on the MATLAB tool to study the impact of various parameters on path optimality, throughput and hop count were recorded in presence and absence of power scarce node.

Need for a new energy saving routing protocol

A comparative study of existing power routing protocols indicate that these Protocols suffer from the following drawbacks:

- Unwanted wastage of power when no transmission and receiving process is done.
- All the existing power routing protocols select a gateway which is not done in an intelligent way.
- Most of the power aware routing protocols are not conserving power.
- In all of the existing routing protocols congestion is high.

Assumptions for new energy saving routing protocol

Energy saving routing protocol makes three basic assumptions, which are as follows:

- All nodes are located with in the maximum transmission rage of each other.

- Radios are capable of dynamically adjusting their transmission power on a per-packet basis.
- Energy aware routing protocol (EAR) comprises of two core algorithms that support overhearing and redirecting

5.2 LITERATURE SURVEY ON ENERGY SAVING SCHEMES

Azimet.al	“Proposed power efficient routing protocol for sensor networks. Here, scheme consists of short range and non distance communication between the sensor nodes. Here the author did not focus on the outside of the transmission region. The node occupies high power consumption with limited distance”[186].
Ouadoudiet.al	“The author explored a power efficient clustering protocol based on decentralized clustering algorithm. Here, the power is distributed to all sensor nodes in the network in order to prolong the network life time. In case if the un-authenticated node is entering in to a cluster, the retransmission of packet will occur which leads to the high power consumption. So the network connectivity may be damaged. Here they have focused only on increasing the network life time. But due to clustering the network vulnerability may be induced” [187].
Sujathaet.al	“The author developed a load balancing mechanism for improving energy efficiency based on traffic interference between the neighboring nodes. Here, the energy efficiency of the protocol is evaluated using energy metrics average energy consumed variance and network lifetime”[188].
Li et.al	“The author explored a distributed protocol to construct a minimum power topology and also developed an algorithm to find the shortest path. The length of the path is measured in term of energy consumption. This proposed algorithm used only local information between the neighboring nodes”[189].

5.3 ROUTING PROTOCOLS BASED ON ENERGY SAVING SCHEMES

This process continues at each and every intermediate nodes till the packet reaches to a destination node. The diagram of routing protocol and path matrix is given below [179,180]

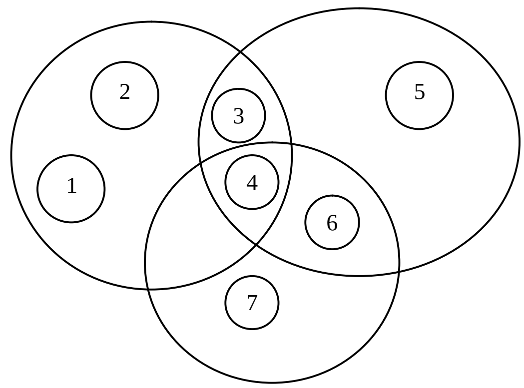


Fig. 5.1 Diagram of routing protocol

The destination node receives RREQs from various nodes but selects the path with minimum total transmission power. It should be noted here that the total transmission power scales with transmitted distance as $d^2$to d^4depending on environmental conditions. This routing approach will in most cases tend to select routes with more hops than others [182,188].

The above protocol can made clearer with the help of an example network as shown in Fig. 5.2. The distances between various pairs of nodes are shown in path matrix (see Table- 5.1). Let us suppose 1 as the source and 7 as the destination. The paths selected from source to destination may be as follows:

- The path (1-2-3-4-6-7) has total transmission loss = k (15 * 15 + 10 * 10 + 10 * 10 + 5 * 5 + 10 *10) =550k units (Here total transmission loss is taken as kd2).
- The paths (1-3-4-6-7) has total transmission loss = k (20 * 20 + 10 * 10 + 5 * 5 + 10 * 10) = 625k.
- Similarly total transmission power loss in path (1-4-6-7) = k (2 5* 25 + 5 * 5 + 10 * 10) = 750k.
- The path (1-2-3-4-6-7) has minimum total transmission power loss. Therefore the same is selected as shown in Fig. 5.2. The limitations of this approach can be summarized as under:

1. The network will be congested as the packets has to routed from multiple nodes
2. More number of nodes has to participate in forming a routing path
3. It will always select its nearest neighboring node.

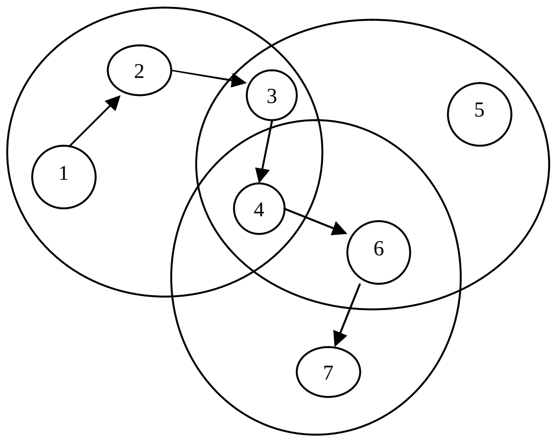


Fig. 5.2 Packet move from source node 1 to destination node 7 using MTPR

Path Matrix

Table 5.1 Show the path matrix of source node to destination nodes with distance between them

Node →	1	2	3	4	5	6	7
	Distance between Nodes						
1	0	15	20	25	----	----	----
2	15	0	10	20	----	----	----
3	----	----	----	10	----	----	----
4	----	----	----	----	----	----	----
5	----	----	----	----	----	----	----
6	----	----	----	----	----	----	10
7	----	----	----	----	----	----	----

5.4 PERFORMANCE ANALYSISOF MINIMUM TOTAL TRANSMISSION POWER ROUTING (MTPR) PROTOCOL IN POWER DEFICIENT NODE

5.4.1 Introduction

This work is based on the performance analysis of low bandwidth and power constraints of nodes, being used in the mobile ad hoc network and design its basic structure and evaluates the outcome of same; minimum hop path, minimum transmitted energy path, residual energy, bandwidth, throughput and power to be adequate so that a reliable and trustful connection between participating nodes is maintained.

This chapter considers MTPR routing protocol and tries to avoid those nodes whose residual power is too low. In addition to this chapter compares the performance of both these protocols on various performance metrics such as throughput, hop count etc. The result shows a significant improvement when nodes with residual energy are avoided from path [183].

We conducted two experimental investigations to study the impact of various parameters such as path optimality, throughput and hop count, shape of the network, size of the network, mobility of nodes, minimum hop path, minimum transmitted energy path, residual energy, bandwidth, throughput and power and other aspects related to MANET performance.

5.4.2 Simulator Design Setup

To perform this experiment, an area of the size 1500 sq. units was chosen and N number of nodes were uniformly distributed using *randint()* function. Each node was assigned a transmission range. There after routes from all source nodes to all destination nodes were explored using Dijkstra’s shortest path algorithm.

5.4.3 Simulation Set up Parameters

Table 5.2: Simulation set up parameters

Parameter	Value
Routing Protocol used	MTPR
Transmission Range	320 units
Number of Nodes	40

Nodes Placement Strategy	Random
Number of iteration	25
Percentage of nodes	0 to 100%step size of 10 %

One routing strategies named as Minimum Total Power Routing (MTPR) was implemented using Dijkstra's shortest path algorithm. Table 5.2 provides the simulation parameters.

5.4.3.1 Proposed Metrics

The metric used for the performance evaluation are as follows:

MTPR_Hop Count: It is defined as number of at the instance of path formation by route from source to destination for successful transmissions.

MTPR_Throughput: It is defined as number successful data packets received at receiver to the total no of data packets sent by transmitter. Higher value of the throughput indicates higher stability of the route.

MTPR_Path Optimality: It is defined as ratio of path length under presence realistic environment and absence idealistic environment.

5.4.4 Snapshot of Simulator

The figures 5.3 to 5.6 show the snapshot of simulation process. Fig 5.4 shows that the yellow line in the figures shows the path created by using MTPR routing algorithms. The path measure the impact of variable transmission range on the network performance, the energy consumed for a route is calculated by taking fixed and variable transmission range of nodes.

Shortest path when no node is selfish and the black lines shows the shortest path after the avoidance of selfish nodes. At low concentration of selfish nodes it is more likely yellow and black lines will be same and as the concentration increases they are likely to be different. Thus at 0% concentration of selfish nodes the route found between a pair of source and destination is shortest and at k% concentration the route found is shortest as if no selfish nodes were present. Thus with the increase in concentration of selfish nodes

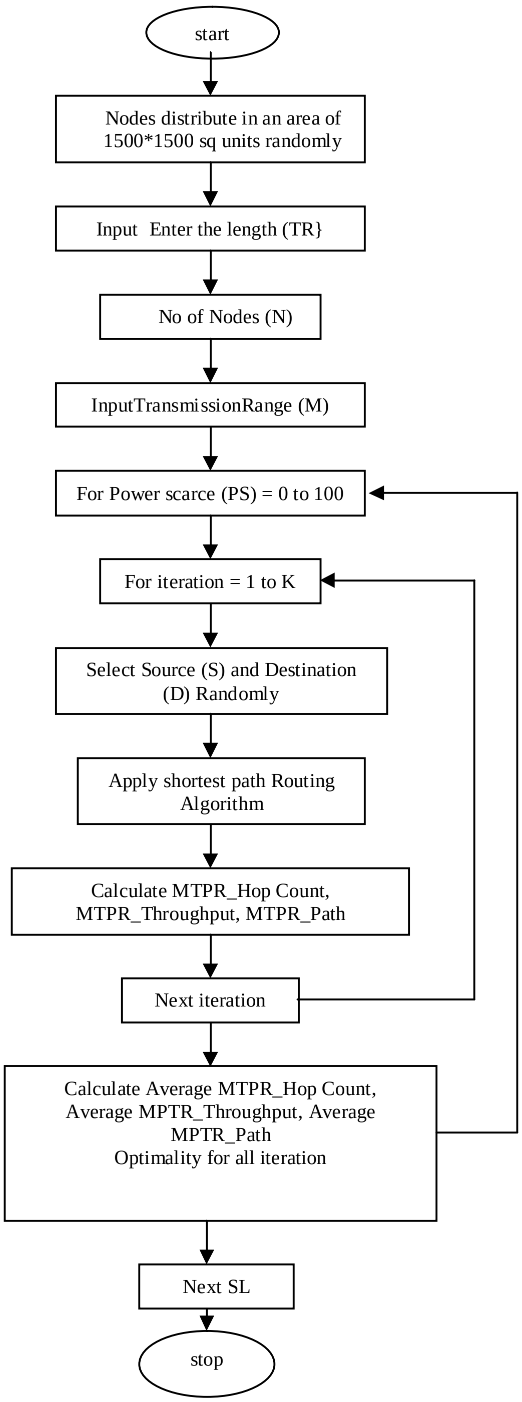


Fig. 5.3 Flow chart of design simulator

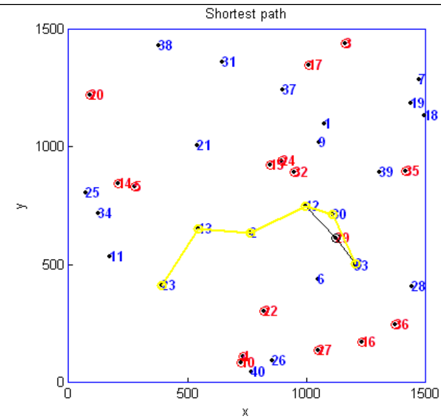


Fig. 5.4 Snapshot to study the effect of MTPR_Path Optimality

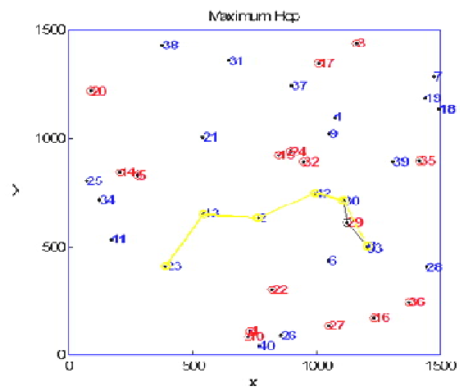


Fig. 5.5 Snapshot to study the effect of MTPR_Throughput

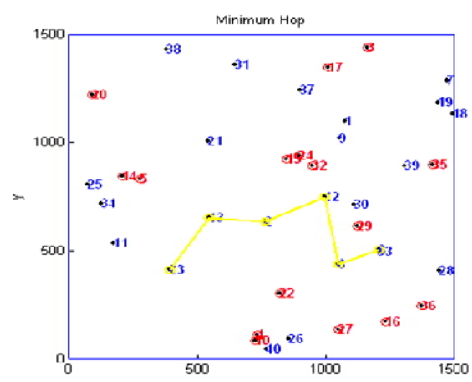


Fig. 5.6 Snapshot to study the effect of MTPR_Hop Count

5.4.5 Simulation Results

5.4.5.1 MTPR_Throughput

Throughput [15] is the ratio of number of data packets received by the destination upon the total number of data packets delivered by source. Throughput is shown in Fig 5.7the throughput rate maximum value when 40% then decrease from 40% proportionate to decreasing percentage level 0 with 90%.packets dropped.

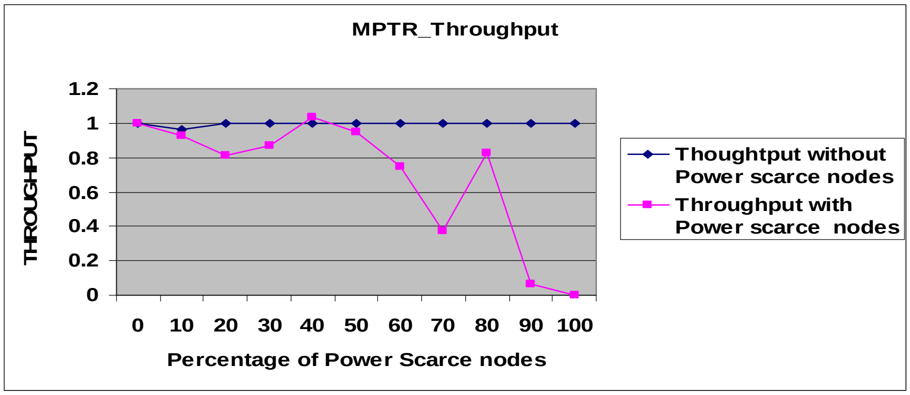


Fig. 5.7 MPTR_Throughput v/s with or without Power scarce

5.4.5.2 MTPR_ Hop Count

Fig 5.8 shows the impact of increase in hop count as the concentration of power scarce nodes increases. The average hop count is almost same when the selfish nodes are up to 10% of the total number of nodes. The maximum hop count occurs at 50%. The average hop count slightly decreases up to 70% and 0 when it reaches 100%. If the route formation does not occur, then in that the maximum hop count (16) was taken.

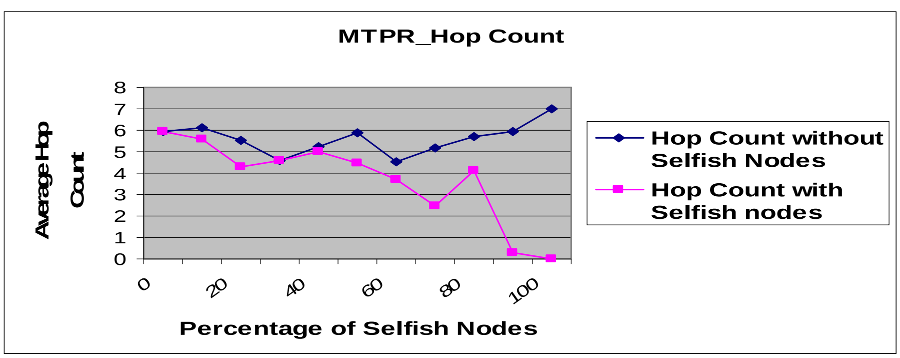


Fig. 5.8 MPTR_Hop Count v/s with or without power scarce

5.4.5.3 MTPR_ Path Optimality

Fig. 5.9 shows the impact of simulation of path optimality of selfish nodes path length on the percentage of packets dropped. There is no remarkable change in the percentage packet dropped when the selfish node concentration is up to 15%. It reaches to a maximum value of nearly 45% then the selfish node decreasing percentage level 0 with 100% packet dropped.

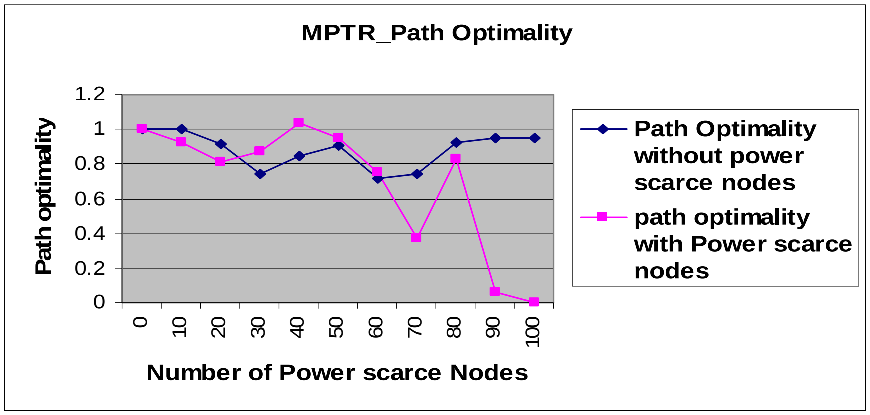


Fig. 5.9 MPTR_Path Optimality v/s with or without Power scarce

5.4.6 Conclusion

The problem of power scarce nodes is very common in ad hoc networks. The major reason for it is cooperation among nodes in routing data packets. As the time passes away the nodes loose their battery power .The effect of environment is also pronounced. The following inference can be made from above results as follows:

- There is almost 45% decrease in values of hop count, throughput, and path optimality in the presence and absence of power scarce nodes.
- Nearly 10%, power scarce nodes do not have any negative effect on the network activities.
- The network never comes to halt position where as the power scarce node reaches to nearly 100%.

The average hop count reaches to a maximum 3.4 times, Probability of percentage of power scarce nodes and throughput comes down to nearly 45% at its peak and percentage of packet drop goes up to nearly 55% at the most.

5.5ANALYSIS OF MANET WITH LOW BANDWIDTH ESTIMATION

A Mobile Ad-hoc network (MANET) is a self organizing and adaptive in environment. A MANET consists of a set of mobile nodes that have to collaborate, interact and communicate to complete an assigned operation. These applications have need of Quality of Service (QoS) parameters such as: minimum hop path, minimum transmitted energy path, residual energy, bandwidth, throughput and power to be adequate so that a reliable and trustful connection between participating nodes is maintained. The proposed work on the performance analysis of low bandwidth and power constraints of nodes, being used in the mobile ad hoc network and design its basic structure and evaluates the outcome of same; on a designed simulator in MATLAB -7.0 and studies its performance on various inputs, like as number of nodes, transmission range, transmission radius of each node throughput and number of iterations. Simulation results show that the number of hop-counts decreases as we increase the percentage of low down bandwidth nodes in the network, it was also concluded that the throughput rate decreases as we increase the number of low down bandwidth nodes in the network.

5.5.1 Introduction

The bandwidth estimation is a basic function that is required to provide QoS in Mobile Ad-hoc Networks [179]. It is a way to determine the data rate accessible on a network path. It is of curiosity to users wishing to optimize end-to-end transport performance, overlay network routing, and peer-to-peer file distribution [190].

Techniques for accurate bandwidth estimation are also necessary for traffic engineering and capacity development support. Because of an Ad-Hoc network is a collection of wireless mobile hosts forming a temporary network without aid of any centralized administration. Mobile Ad- Hoc Networks has a new structure in the field of wireless Communication network. They do not require any fixed infrastructure for instance a base station to work. The nodes themselves address topology changes due to the mobility, the entrance or the exits of nodes. These networks use a radio medium. The technology gives the user a freedom to move freely any were in the communication range and it has become independent of its infrastructure [189]. This freedom from existing infrastructure has made Mobile Ad-Hoc Networks more flexible, affordable and easily deployable in all environments including military and rescue operations. There are two types of mobile network namely Mobile IP and MANET [190].

MANET consists of nodes that are capable to communicate wirelessly among them. MANETs consist of a group of wireless mobile nodes which dynamically exchange data among themselves without the reliance on a fixed base station or a wired backbone network [191].

MANET nodes are typically differentiated by their limited power, processing, and memory resources as well as high degree of mobility. In MANETs, the wireless mobile nodes may dynamically enter in the network as well as leave the network. Because of the limited transmission range, minimum hop path, minimum transmitted energy path, minimum normalized residual energy used, minimum absolute residual energy used, bandwidth, throughput, hop-count and power to be adequate so that a reliable and trustful connection between participating nodes is maintained of wireless network nodes, multiple hops are generally required for a node to exchange information with any other node in the network [79]. Multi-path routing permits the formation of multiple paths between one source node and one destination node. We have used the means of simulation using MATLAB (7.0), a simulator is being designed in MATLAB 7.0. It gathers data about number of hop-count (number of nodes between source and destination for successful routes) and throughput rate (total number of packets received by the destination to the total number of packets send by source). The simulator uses dijkstra algorithm to implement shortest path routing. To evaluate the effectiveness of MANET for nodes having lower bandwidth, the nodes were made unreachable by assigning low bandwidth to a group of some specified percentage nodes in the network [191].

5.5.2 Related Work

Earlier works on throughput constrained routing for MANETs [189-192] has already considered many of the aspects of the problem by estimating achievable throughput. Some of the researchers shared knowledge in the techniques on MTPR proposed and given below;

Abdullah	"Proposed a technique implemented in a sniffing based tool (called wimeter) which captures and analyzes on real-time the frames sent in a preconfigured WLAN. The analysis of captured frames consists on determining the portion of time when the

	channel is free and then to estimate the available bandwidth in function of the packet size of expected frames to be transmitted and the link-layer rate of the sender and the receiver stations. They went ahead to implement a Call Admission Control Framework that uses the wimeter as a basis for bandwidth estimation" [193].
Cheikh Sarr and Heinzelman	"Modified the hello messages in the AODV routing protocol so that it carried bandwidth information of each node and its immediate neighbors. This information was then used to calculate the residual bandwidth due to second hop neighborhood interference" [192].
C-K. Tohet al	"Implemented a load balancing technique based on a probing available bandwidth measuring technique" [194].
Xiang-Yang Liet al	"Proposed an admission control method they called Perceptive Admission Control (PAC). In the method the used a band width estimation method based on listening for the idle time for channel and calculated the available bandwidth as a ratio of idle time to total time multiplied by the channel capacity" [189].
Sujatha P Terdal, et al.	"Proposed a MAC layer based estimation method. It is based on the bandwidth of a link in discrete time intervals by averaging the throughputs of the recent packets in the past time window and use it to estimate the bandwidth in the current time window. Obviously, this estimation may not be accurate because the channel condition may have changed. Greedy Perimeter State-less Routing (GPSR) is used to discover a route to the destination of a new flow. This is a location based protocol which is characterized by their scalability and efficient bandwidth utilization as they do not flood the net-work to find the destination" [188].
Quadoudi Zytoune et al.	"Proposed a new approach based on Multipath Routing Backbone (MRB) for supporting enhanced QoS in MANETS. It improves throughput and minimizes overall end-to-end delay.

	This protocol is designed for highly dynamic ad hoc networks where link failures and route breaks occur frequently. This protocol finds multiple disjoint paths from source to destination where each path satisfies the conditions for QoS. Many other methods have been proposed varying from numerical calculations to probing methods" [189].
C.R. Lin	"Based Backup Routing Protocol considers both route length and link lifetime to achieve high route stability. Primary route for forwarding data packets is formed primarily based on greedy forwarding mechanism, whereas local backup path is established according to link lifetime" [197].
Deepak Vidhateet al.	"Proposed a Multipath Optimized Link State Routing (MP-OLSR) which is a multipath routing protocol. This protocol gives great flexibility by employing different route metrics and cost functions. A modified route recovery and loop detection mechanisms are also implemented in MP-OLSR in order to improve QoS" [198].
R.D. Haanet al.	"Proposed that the discovery of the route operation for path reconstruction should be done from the source itself. It has also given a new mechanism to determine multiple disjoint paths for forwarding the packets from source to destination" [199].

5.5.3 Bandwidth

5.5.3.1 Limited Network Capacity (Bandwidth)

Unlike wired networks with abundant bandwidth, MANETs are limited in radio bandwidths therefore data transfer rates are less than those of wired networks. This raised the need for a routing protocol to optimally use the bandwidth. Furthermore, limited bandwidth results in less stored topology information. Complete topology information is required for an efficient routing protocol, however this cannot to be the case in MANET routing protocol as this will cause an increase in node control messages and overheads which wastes more bandwidth. Control message are messages send over the network enabling nodes to establish connections before packet messages are transfer. An efficient routing protocol is required for a balanced usage of the limited bandwidth [188, 195].

5.5.4 Bandwidth Constraints

The purpose of the MANET is to homogenize IP routing protocol functionality is appropriate for the wireless routing application within both dynamic and static topologies with raised dynamics because of node motion and other factors [192, 200]:

- **Dynamicity:** Every host can randomly change position. The topology is generally unpredictable, and the network position is inaccurate.
- **Non-centralization:** There is no centralized organization in the network and, therefore, network possessions cannot be assigned in a predetermined approach.
- **Radio properties:** The wireless channel can suffer from multi-path effects, fading and time variation, etc.

5.5.4.1 Bandwidth Estimation Methods

Estimating precise available bandwidth allows a node to make optimal decision before transmitting a packet in networks. It is therefore clear that the available bandwidth estimation enhances the QoS in wired and wireless Networks [201]. Measuring available bandwidth in ad hoc networks is challenging issue in MANET and calculating the residual bandwidth using the IEEE 802.11 MAC is still a challenging problem, because the bandwidth is shared among neighboring hosts, and an individual host has no knowledge about other neighboring hosts' traffic status and battery power. Two methods for estimating bandwidth are used below [201]:

Intrusive Bandwidth Estimation Method

The intrusive approaches techniques are based on end-to-end probe packets to estimate the available bandwidth along the length of a path [201].

Passive Bandwidth Estimation Method

The passive approaches techniques uses local information on the used bandwidth and that may exchange this information via neighborhood broadcast [197].

5.5.5 Bandwidth Allocation Algorithm for MANET

Bandwidth estimation in a cross-layer design of the routing and MAC layers and the available bandwidth is estimated in the MAC layer and is sent to the routing layer for admission control. Therefore, bandwidth estimation can be carried out in various network layers [198].

All the information of MANET which include the History of ad hoc, wireless ad hoc, wireless mobile approaches and types of MANETs, and then they present more than 13 types of the routing Ad Hoc Networks protocols were proposed. They give description of routing protocols, analysis of individual characteristics and advantage and disadvantages to collect and compare, and present all the applications or the Possible Service of Ad Hoc Networks [199].

Present bandwidth estimation tools measure more than three related metrics: capacity, available bandwidth, hop count, throughput, and bulk transfer capacity etc. Currently available bandwidth estimation tools utilize a various strategies to measure these metrics. These issues of multipath routing in MANETs were particularly examined. They also discuss the application of multipath routing to support application constraints such as reliability, load-balancing, energy-conservation and QoS [196].

An improved mechanism was proposed to estimate the available bandwidth in IEEE 802.11-based ad hoc networks. In 802.11-based ad hoc networks, few works deal with solutions for bandwidth estimation.

.The hitch is present in bandwidth estimation was reorganized by IEEE 802.11 based ad hoc networks. According to them estimation accuracy is increased by improving the calculation accuracy of the prospect for two adjacent nodes idle period to overlap [195].

In a scattered ad hoc network, a host’s available bandwidth cannot decided only by the unprocessed channel bandwidth, but also by its neighbour’s bandwidth usage and interference caused by other sources, each of which reduces a host’s available bandwidth for transmitting data. Therefore, applications cannot properly optimize their coding rate without awareness of the status of the entire network. The problem in available bandwidth estimation was reorganize in IEEE 802.11 based ad hoc networks [202]. According to them estimation precision is increased by improving the calculation accuracy of the prospect for two neighboring nodes inactive period to overlap.

5.5.6 Experimental Setup and Design Simulator

5.5.6.1 Simulation Model

We have used a comprehensive simulation model based on MATLAB 7.0, for system protocol modeling. MATLAB is a high-performance language for technological computing. It integrates computation, visualization, and programming in an easy-to-use environment, where problems and solutions are expressed in familiar mathematical notation. Typical uses include math and computation algorithm development data acquisition modeling etc.

5.5.6.2 Simulation Design Parameters

We have primarily selected the design parameters

- Number of hop-count
- Throughput
- Number of nodes between source to destination
- Total number of packets received by the source to destination

The flow chart of Table 5.3 is given below which gives us the setup parameters for the developed simulator.

5.5.6.3SimulationSetup Parameters

Table 5.3 Simulation set up parameters for impact on Low bandwidth consideration

Parameters	Values
Area	1500*1500
Number of Nodes	50
Transmission Range (TR)	300m
Battery status	High
Nodes Placement Strategy	Random
Number of iteration	25
Percentage of nodes having low bandwidth	Varies from 0 to 100 percentage (with a interval of 10)

5.5.6.4 Flow Chart for Design Simulator

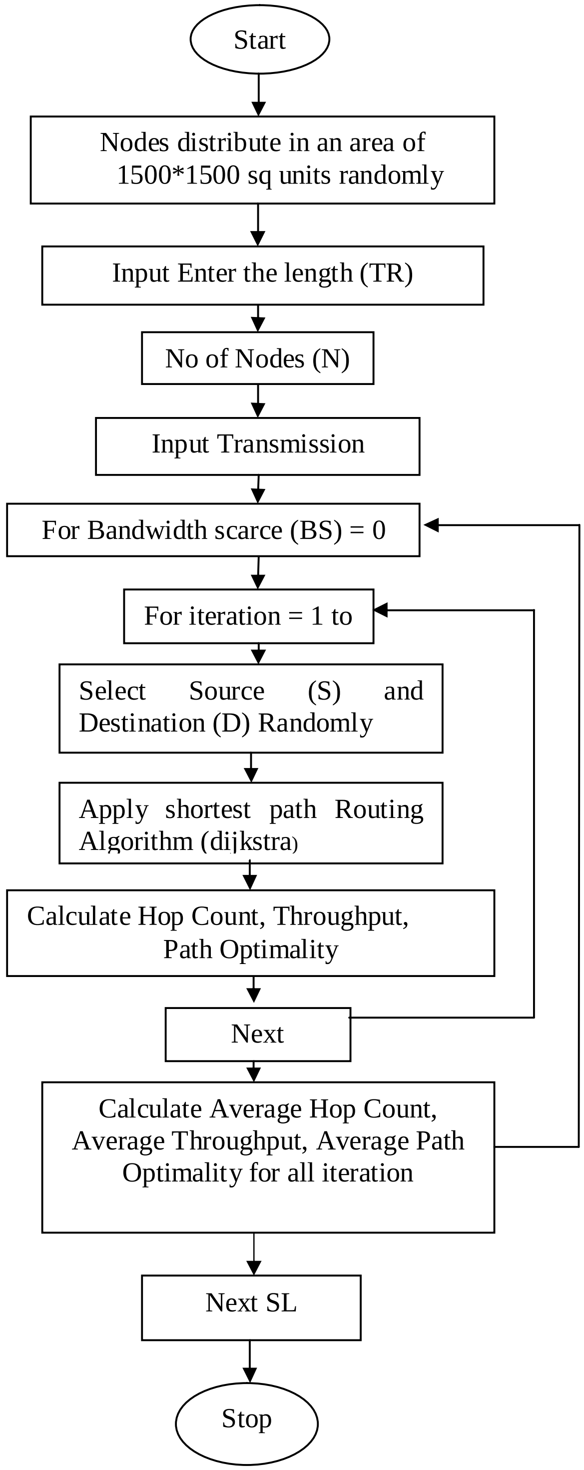


Fig. 5.10 Flow chart for design simulator

5.5.7 Snapshots

The figures mentioned below are the variety of outcomes which came during the simulation running process.

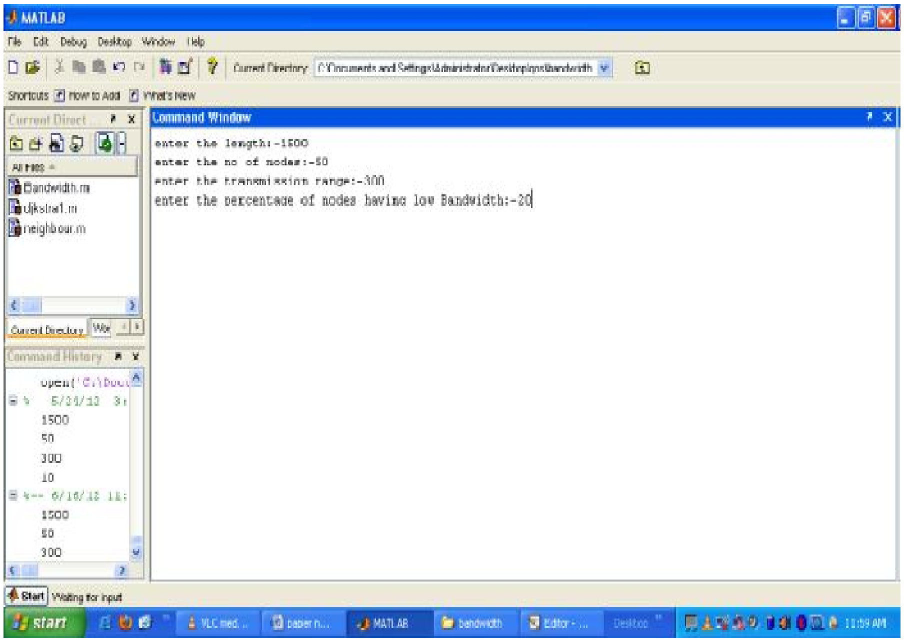


Fig. 5.11 Snapshots of simulator producing input data.

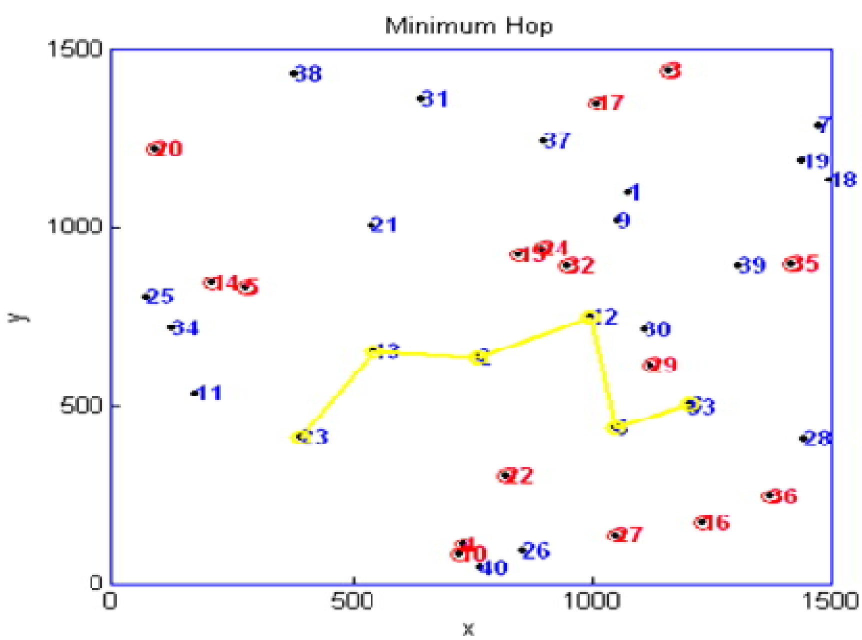


Fig. 5.12 Number of minimum hop in a shortest path

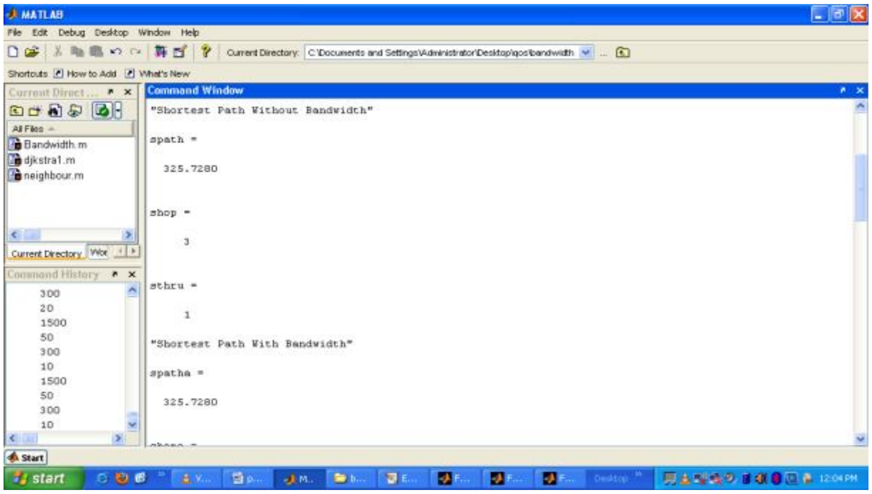


Fig. 5.13 Snapshots of simulator producing output data.

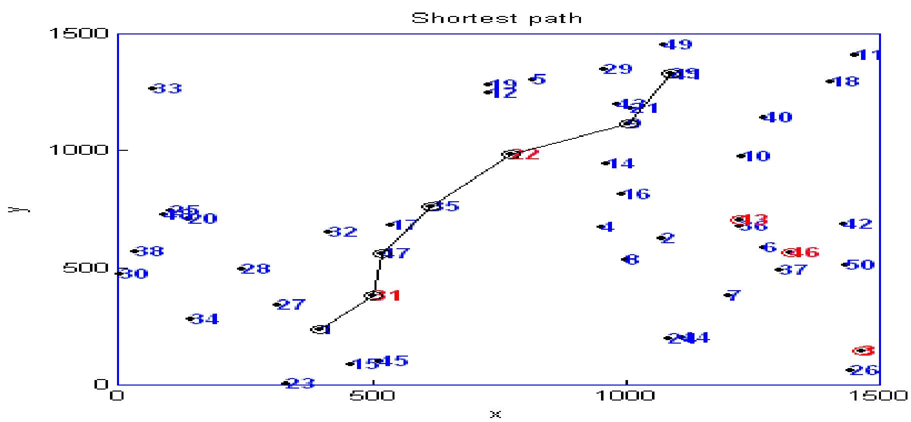


Fig. 5.14 Hop-count in the shortest path

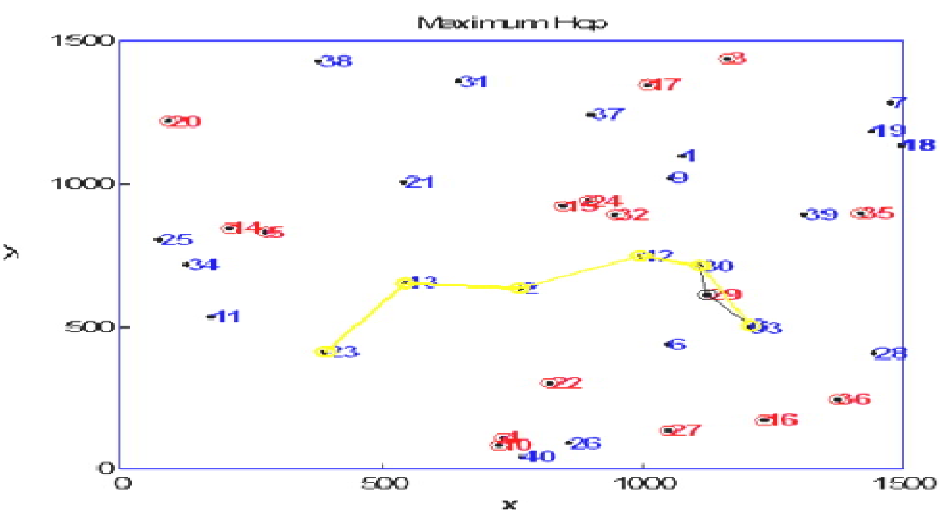


Fig. 5.15 Number of maximum hop in a shortest path

5.5.8 Simulation Results

5.5.8.1 Impact of Low Bandwidth on Hop-Count

The Fig. 5.16 shows that as we gradually increases the percentage of low bandwidth nodes form 10 to 40 number of nodes and then on going up to 100, then hop-count decreases; It shows that the routes which required more intermediate nodes are not forming in the network. Simply longer routes were not being established with the growth of low bandwidth nodes.

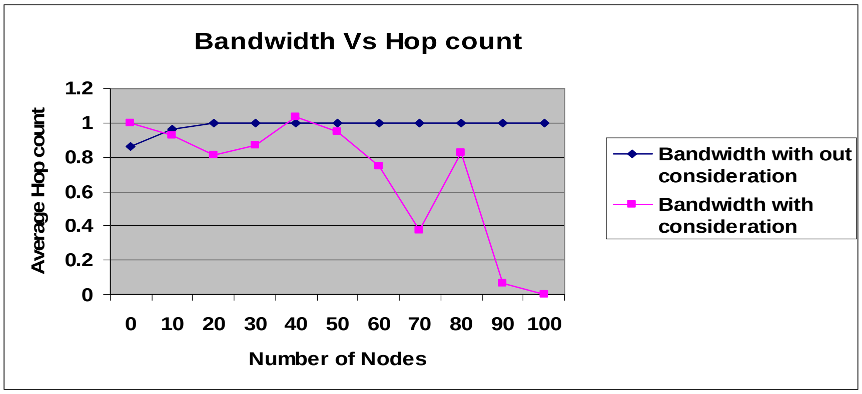


Fig. 5.16 Bandwidth V/s Hop-Counts

5.5.8.2 Low Bandwidth on Throughput

Throughput is the ratio of number of packets received by the destination uponthe total number of packets delivered by the source. The outcome shown in Fig 5.17.

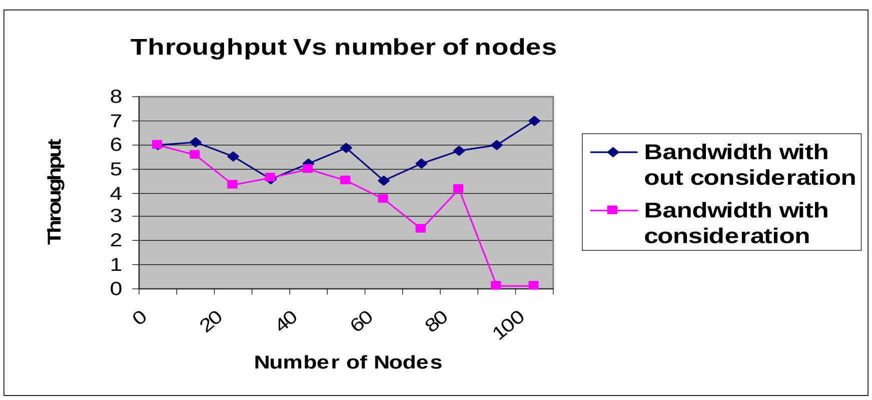


Fig. 5.17 Throughput V/s Number of hop-counts in a shortest path

The throughput rate is going to decrease from level of 50 nodes to the level 100 in proportionate to increasing percentage of low bandwidth nodes in the network and it reaches to level 0 to 100% for low bandwidth estimated nodes.

5.5.8.3 Impact of Low Bandwidth on Path Optimality

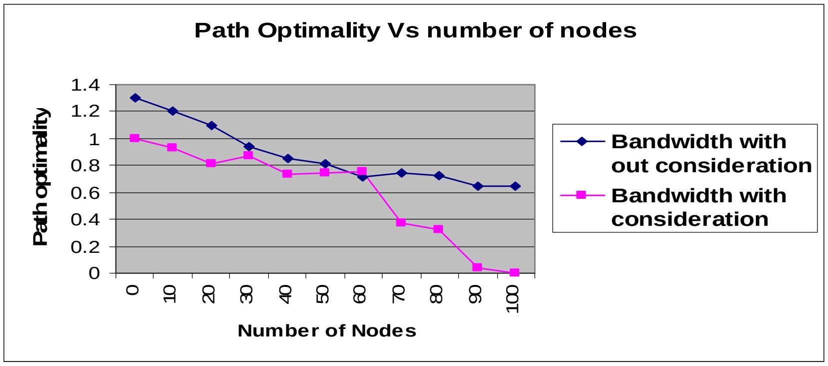


Fig. 5.18 Path Optimality V/s Number of hop-counts in a shortest path

Fig. 5.18 shows the impact of simulation of path optimality of nodes path length on the percentage of packets dropped. There is no remarkable change in the percentage packet dropped in between 0 to 50, when the node concentration is up to 30. It reaches to a maximum value of nearly 60 nodes then the bandwidth decreased.

5.5.9 Conclusion

MANET consists of autonomous, self-organizing and self-operating nodes. It is characterized by links with less bandwidth, nodes with energy constraints, nodes with less memory and processing power and more flat to security intimidation than the fixed networks. However, it has many advantages and different application areas, different assumptions such as location information availability and transmission power control. In this paper, we designed a simulator which is intended in MATLAB-7.0. The simulator uses dijkstra algorithm to implement shortest path routing. To evaluate the effectiveness of MANET for nodes having lower bandwidth, the nodes were made unreachable by assigning a distinct bandwidth to divergent nodes. We conclude performance of three QoS factors (hop count throughput and path optimality) on the basis of varying percentage of low bandwidth nodes in the network. The simulator designed in MATLAB 7.0 gathers data about number of hop-count (number of nodes between source and destination for successful routes). There is almost 45% decrease in values of hop count, throughput, and path optimality in the varying number of nodes.

Two papers are produced out of research work carried in this section of thesis.

[1] **Dharam Vir**, S.K.Agarwal, S. A. Imam "Performance Analysis of MTPR Routing Protocol in Power Deficient Node" in International Journal on Ad-Hoc Networking Systems (IJANS), www. http://airccse.org Vol. 2, No. 4, October 2012, DOI : 10.5121/ijans.2012.2407, pp.67-75.

[2] **Dharam Vir**, S.K.Agarwal, S. A. Imam "Performance Analysis of MANET with Low Bandwidth Estimation" in International Journal of Scientific and Research Publications, www.ijsr.net Volume 3, Issue 3, March 2013 ISSN 2250-3153, pp. 1-5.

Chapter 6

DYNAMIC APPROACH FOR OPTIMIZATION OF ENERGY CONSUMPTION AND POWER AWARENESS IN ROUTING PROTOCOL

This chapter describes the simulation environment, and experimental design aspects of the proposed approach of power consumption distribution based on flat network, hierarchical network, and location-based network routing protocols.

Energy optimization is an essential issue in wireless sensor network that consumes less energy to give optimum performance under low battery power, limited bandwidth and network life time of each node. In this chapter, first we investigate and analyze the impact of receiving energy on nodes and remaining energy in the networks. Analysis and simulation results show that changing receiving energy affects the network life time. This chapter proposes a new approach for optimizing energy consumption in wireless sensor networks (WSNs) that consents to maximum life time of nodes while transmitting a packet from the source to destination. It can be implemented by avoiding nodes which has a minimum residual battery power [187]. The proposed approach is implemented by introducing a threshold value on each node and transmitting the equal length of packet on the route. This threshold indicates whether the node should be included in making routing decisions for a packet and length of the packet considered for equal energy consumption. Extensive simulation results are presented to verify the effectiveness of the proposed approach. Considering this importance we made an attempt to study the behavior of three routing protocols in wireless sensor network. Extensive simulations are done on RIP, OLSR and LAR to determine the network lifetime at different node mobility and at different network load. Simulation results suggest that OLSR is the most energy efficient protocol as compared to other [203].Finally, by the observations we compare that the impact of energy constraints on a nodes in application layer of the networks that OLSR offers the best combination of energy consumption and throughput performance. RIP gives better throughput, packet delivery fraction and delay performance compared to LAR ina more stressful conditions i.e., more number of nodes applied for simulation.

6.1 DYNAMIC APPROACH TO OPTIMIZE ENERGY CONSUMPTION IN RIP, OLSR AND FISHEYE ROUTING PROTOCOLS USING SIMULATOR

6.1.1 Introduction

A Wireless Sensor Network is an infrastructure comprised of sensing, computing, and communication elements that gives an administrator the ability to observe, and respond to events and phenomena in a specified environment. Wireless technology has strongly influenced our personal and professional lives in the recent times due to its applicability and adaptability in different fields. It enhanced our computing, communication skills and information accessing capabilities through many modern types of equipments. Numerous wireless technologies in form of PDA, cellular phones, blue-tooth devices, and many hand-held computers, are extending the wireless communication to a fully all-encompassing computing environment as a result this is emerging as one of the most enveloping computing technologies [110, 200]. Wireless networks can be classified to infrastructure supported network or infrastructure independent networks. The former requires specific network backbone in form of access points or base stations to support communication, while the latter doesn't need such for its operation and popularly known as wireless ad hoc network. Multi hop wireless networks in all their different forms such as mobile ad hoc network (MANET) and vehicular ad hoc network (VANET), wireless sensor network(WSN), wireless mesh network(WMN) [204], etc are coming under this category. In multi-hop ad hoc network destination nodes may be multiple hops away from the source node. This approach provides a number of advantages as compared to single-hop networking solution. Some of its advantages are (i) support for self configuration and adaption at low cost, (ii) support of load balancing for increasing network life, (iii) greater network flexibility, connectivity, etc. However irrespective of these advantages it also suffers with many obstacles associated with constrained battery competence, irregular mobility, routing, etc. The basic necessity in MANET is how to transport packets resourcefully amongst mobile nodes. Since node topology changes frequently which makes routing very cumbersome, moreover low bandwidth, limited battery capacity & error prone medium further adds difficulty in designing a well-organized routing protocol. Further power management is very much essential to nodes which are battery operated & it had always been a cumbersome task to revitalize or swap the battery because the network is working in such harsh conditions and environment where it is neither economical nor feasible to perform that task. Ghastly carrier sensing, retransmission because of collision between packets, exchange of huge number of control messages to find new paths are a couple of major causes for energy consumption[205,116]. In literature different types of techniques are introduced to calculate the energy efficiency of different routing protocols, but the network lifetime is not orderly addressed at unlike network traffic, load and mobility. By focusing on these parameters we have commutated an approach to determine the network lifetime of RIP, OLSR and Fisheye at variable speed and load. RIP and OLSR represent the reactive category of routing mechanism and Fisheye represent the hybrid approach of routings routing in ad hoc network [206].

There are four basic components in a wireless sensor network:

An assembly of distributed or localized sensors,

- An interconnecting network (usually, but not always, wireless-based),
- A central point of information clustering,
- A set of computing resources at the central point to handle data mining, data correlation, event trending, and status querying [206].

Due to advances in wireless communications and electronics over the last few years, the development of networks of low-cost, low-power, multifunctional sensors has received increasing attention. These sensors are small in size and able to sense, process data, and communicate with each other, typically over the radio frequency(RF) channel [198, 207].

6.1.2 Different Power Optimization Issues in Wireless Sensor Networks

Energy Efficiency: In sensor networks, it is of vital importance to consume nodes' energy wisely and efficiently. Since wireless sensor nodes are normally equipped with non-chargeable batteries with limited energy supply, a sensor network cannot function well after a fraction of nodes run out of energy [6].

Network Scalability: In many large scale wireless network applications, the number of sensor nodes in a sensor network may be in the order of thousands, tens of thousands, or even millions. In such large-scale networks, scalability is a critical factor, so that the network performance does not significantly get corrupt as the network size increases [20].

Fault Tolerance: Node failure rate may be very high if they are deployed in friendly environments. Fault tolerance should be included in the design and implementation of algorithms for sensor networks such that the network performance is not sensitive to individual node failures [14].

Data Accuracy: Obtaining accurate information is the main task of sensor networks. Accuracy can be improved through joint signal processing by cooperative sensors [17].

Network Autonomy: Sensor nodes can be either deterministic placed or randomly scattered into a field of interests. In such cases, the untended nodes should self-organize into an autonomous network to decide the structure and topology of the network. Such an autonomous network should be able to schedule sensing tasks and to arrange delivery routes all by itself [6].

Information Security: Information security, which is a common requirement in almost all types of networks, requires that sensing data should be accessed, transmitted, and processed securely [15].

6.1.3 Related Work

In this section we discussed some existing approaches for optimizing power consumption as well as to maximize the network lifetime. In WSN while creating correct and efficient routes between pair of nodes, one important purpose of a routing protocol is to maximize the lifetime of network [183]. As discussed in the introduction, this objective can be proficient by optimizing the energy of mobile nodes not only when they are inactive but also when they are in active communication. Transmission power control, power management and load distribution are the approaches to minimize the active communication energy and sleep/power-down mode is used to minimize energy during immobility.

Saleh Ali et al, (2010)	"Suggested an approach to minimize power consumption in idle mode of mobile nodes. They proposed an idea to change mode of the mobile nodes from Idle to Sleep, i.e. nodes neither transmit nor receive data packets, but in Idle mode the node can consume power as consume in receiving mode. They take two ad hoc on-demands routing protocols and implemented this approach and concluded the power consumed by these routing protocols, with this mechanism is

	less than power consumed” [208].
Amulya Ratna Swain (2010)	“The authors proposed an analytical model for the IEEE 802.11 DCF in multi-hop wireless networks that they considers hidden terminals and accurately works for a large range of traffic load that are used to analyze the energy consumption of various relaying strategies. They gave fact of the existing analytical models of IEEE 802.11 DCF systems were insufficient for an energy efficiency analysis in wireless multi-hop networks. They concluded that this analytical model is accurate in predicting the energy-efficiency over a wide range of scenarios. The given results show that the energy efficient routing strategy depends not only on the processing power but also depends on the traffic load” [209].
Misra et al, (2012),	“Author projected an energy efficient power Control mechanism for base station in mobile communication systems and an efficient sector power control based on distance between base station and mobile node. They also proposed a sleep mode energy control mechanism. In sleep mode energy saving protocol, each sector monitors the number of user in sector cell. They proposed, if number of mobile node falls down a given threshold in sector cell, base station shuts down power. They also proposed an algorithm and demonstrated the tradeoff between energy saving and cell coverage in order to enhance efficient use of base station Transmission power” [210].
Shiva Prakash, (2013)	“The PAMAS (Power Aware Multi-Access protocol with Signaling), protocol consent to a host to sleep mode when it has no packet to transmit/receive or any of its neighbors’ is receiving packets, but it required a separate signaling channel to inquire the status of neighboring hosts. Hence this protocol provides best results in dense networks but the power saving is low in small network” [211].

C.K Toh (1996)	“MTPR (Minimum Total Transmission Power Routing) is an approach to minimize total transmission power consumption by all nodes. MTPR calculates the total transmission power for all routes between source and destination. Among all routes it will select the route with minimum total transmission power. The total transmission power of route is calculated using the formula $$P(R)=\sum_{i=0}^{D-1} T(n_i, n_{i+1})$$ Where i refer the number of nodes appears in the route from source to destination. But this decision increases the end-end delay in the transmission. This approach also increases the number of hops in the route. The lifetime of the network also not considered in this approach because the selected routes are via specific host, the battery of this host will be exhausted quickly” [194].
Murthy (1996)	“MMBCR (Min-Max Battery Cost Routing) suggested by is an approach by selecting nodes with more residual-battery capacities in a route. With the intention that in this approach the battery of each host will be used more fairly than in previous scheme. But it can consume more power to transmit user traffic and there is no guarantee that minimum total transmission path will be selected always. This approach is not paying attention to maximize the lifetime of all nodes” [202].
Uma Sharma et al. (2012)	“The author has described that dynamic selection of the nodes to consume less power and the network never fails” [178].
L. Bao et al. (2002)	“The have proposed new scheme which is based on reducing transmission power to save power” [177].
Tao Yang et al. (2009)	“They are proposed power consumption control protocol, which uses one control channel and multiple data channels”[166].

J. Broch (1998) et al	"They are presented the minimal achievable broadcast energy consumption scheme to save energy in network" [151].

6.1.4 Optimal Power Consumption

Our algorithm transmits the message as an equal length of packets in favor of equal power consumption by all the nodes in the route. Periodical invigilation is carried out to make sure the residual energy of each node is not away from the required level. If the node goes beyond the threshold value, revolutionized it into sleep mode and selects an alternate node for transmission [146, 163].

The key point in the above discussion is to minimize power consumption and maximize lifetime of the entire network. The proposed algorithm is as follows [177, 202]:

1. At the source node, Divide the message into equal length of packets and select a node i where, min (Ei > Thi) from the entire neighboring node.
2. Establish a route to destination where in the energy level of all the nodes is greater than its threshold value.
3. Repeat the following steps in periodical interval t
4. Calculate the residual energy of each node in the route with the equation

   E Res = E – Ec (t)

   Where E, the initial energy of a node,

   Ec (t), energy consumed in periodical interval t and

   E Res, Residual energy of a node.
5. Energy consumption of a node after time t is calculated using the following equation

   $E_c(t) = N_t *a + N_r * b$

   Where $E_c(t)$,energy consumed by a node after time t, N_t , number of packets transmitted by the node after time t and N_r , number of packets received by the node after time t. a and b are constant factors having a value between 0 and 1.
6. If E Res > Threshold value Continue the transmission through the same node
7. Else dynamically find an alternate route for further transmission which satisfies the constraint outlined in our approach.

6.1.5 Proposed Routing Protocols

A wireless sensor network consists of a set of mobile node that is connected by wireless links.

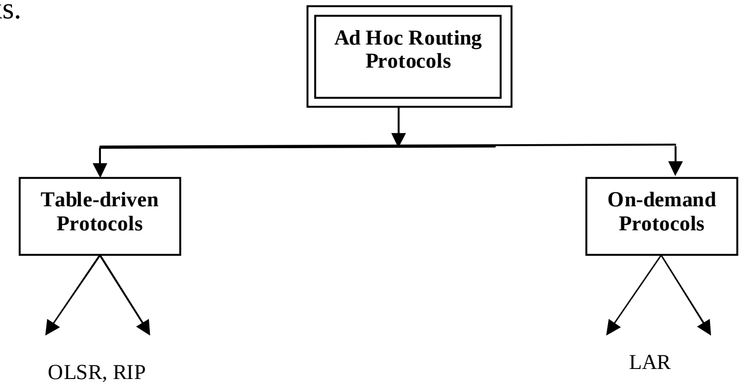


Fig.6.1 Proposed Routing Protocol

The network topology in such a network may keep changing randomly. Routing protocols that find a path to be followed by data packets from a source node to a destination node used in traditional wired networks cannot be directly applied in ad hoc wireless networks due to their higher dynamic topology, absence of established infrastructure for centralized administration.

6.1.5.1 Optimized Link State Protocol (OLSR)

The Optimized Link State Routing (OLSR) protocol, developed by the French National Institute for Research in Computer Science and Control (INRIA), was developed for mobile ad-hoc networks. It operates in a table-driven and proactive manner, i.e., topology information is exchanged between the nodes on periodic basis. Its main objective is to minimize the control traffic by selecting a small number of nodes, known as Multi Point Relays (MPR) for flooding topological information. In route calculation, these MPR nodes are used to form an optimal route from a given node to any destination in the network. This routing protocol is particularly suited for a large and dense network. OLSR generally proposes four types of periodic control messages, namely [207]:

- Hello messages
- Topology Control (TC) messages
- Multiple Interface Declaration (MID) messages, and
- Host and Network Association (HNA) messages.

Hello messages are periodically exchanged within the one-hop neighborhood to obtain the neighborhood information. Using this neighborhood information, each node in the network selects a subset of one-hop away neighbors known as the MPR set. In the MPR set, all two-hop away neighbors are reachable through any member of the MPR set [95].

TC messages are generated and retransmitted for flooding topological information in the whole network only through MPR nodes. Also, MID and HNA messages are relayed only by MPR nodes. Therefore, OLSR optimizes the control traffic overhead by minimizing the size of the MPR set. An MPR member generates and retransmits TC messages.

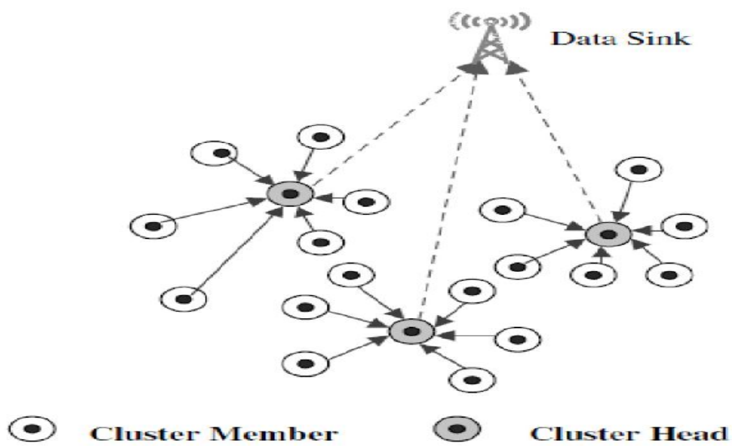


Fig. 6.2 Network model for RIP protocol

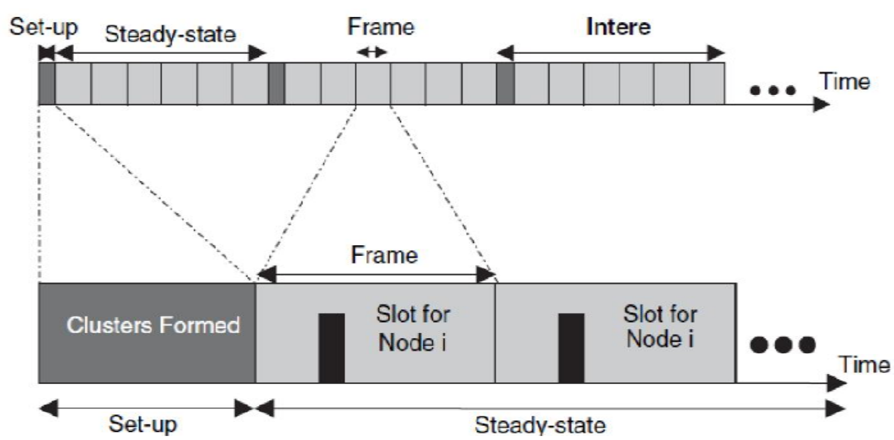


Fig. 6.3 TDMA / CDMA schedule for RIP protocol

These messages offer each node within the network with enough link-state routing information to permit route calculation. MID messages are optimized by an OLSR node protocol with multiple OLSR interfaces so as to inform other OLSR nodes about its interfaces taking part in the OLSR routing defined area [156].

6.1.5.2 Routing Information Protocol (RIP)

RIP or $RIPv_2$ are internet standard implementations of the Bellman-Ford (a.k.a. Ford Fulkerson) routing algorithm. It is a distance vector routing algorithm using the User Datagram Protocol (UDP) protocol for control packet transmission. Routing Information Protocol (RIP) is an Interior Gateway Protocol used to exchange routing information within a domain or autonomous system. RIP lets routers exchange information about destinations for the purpose of computing routes throughout the network. Destinations may be individual hosts, networks, or special destinations used to convey a default route. RIP is based on the Bellman-Ford or the distance-vector algorithm. This means RIP makes routing decisions based on the hop count between a router and a destination. RIP does not alter IP packets; it routes them based on destination address only. The router makes this decision by consulting a forwarding table. The fundamental problem of routing is:

How do routers acquire the information in their forwarding tables?

Routing algorithms are required to build the routing tables and hence forwarding tables. The basic problem of routing is to find the lowest-cost path between any two nodes, where the cost of a path equals the sum of the costs of all the edges that make up the path. Routing is achieved in most practical networks by running routing protocols among the nodes. The protocols provide a distributed, dynamic way to solve the problem of finding the lowest-cost path in the presence of link and node failures and changing edge costs [153,156].

6.1.5.3 Location Aided Routing (LAR)

Location-Aided Routing (LAR) is an on-demand routing protocol that exploits location information. It is similar to DSR, but with the additional requirement of GPS information. In scheme 1 (which is implemented here), the source defines a circular area in which the destination may be located and determined by the following information [97,129]:

- The destination location known to the source
- The instantaneous time when the destination was to be found at that position
- The average moving velocity of the given destination.

Most on-demand methods, including DSR and AODV use flooding to obtain a route to the destination. LAR aims to reduce the overhead to send the route requests only into a specific area, which is likely to contain the destination [97,207].

6.1.6 Proposed Energy Optimization Model

Energy management is required to determine energy consumption of nodes in a mobile ad-hoc network. Ad-hoc on demand distant vector protocol is used for routing between source and destination. Route Request (RREQ), Route Reply (RREP) and Route Error (RRER) messages are used for route discovery and maintenance in network. Link distance is adjusted according to the transmission power and remaining energy. A node broadcasts RRER packets when a link to the next hop is broken. Node’s energy management mode is decided by the control header of medium access control layer data units. The state switching functions are shown in Fig.6.4. Mobile node has two mode of operation like active mode or power-save mode. In active mode, a node is awake and may receive data at any time. In power-save mode, a node is sleeping most of the time and wakes up periodically to check for pending messages.

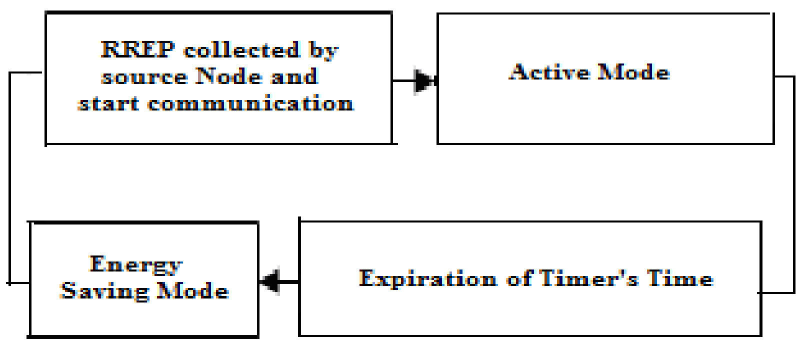


Fig. 6.4 Energy Management Model

Controls messages like route reply messages are used to switch to active mode. RREPs are collected by the source node and start a timer as shown in Fig. 6.4. Protocol adjusts transmission power for per-hop and selects the feasible routes based on remaining energy and transmission power of nodes so as to improve the overall performance of network [17].

Transmission Energy Etx, receive energy Erx, and remaining energy of node Re are added in RREQ. Node is able to estimate the link attenuation with the knowledge of Etx and Erx [17].

6.1.7 Simulation Setup

This section provides the simulation setup and shows the effectiveness of the proposed algorithm compared to the existing algorithms like, MTPR and MMBCR. The proposed scheme is simulated using network simulator QualNet 5.0. Network scenarios have been setup for 25, 45, 65, 85 and 100 nodes in an area of 1500 * 1500 m2. In the different scenarios, value for packet delivery ratio has been observed by varying pause times from 0 to 100 seconds. Fig. 6.4 depicts the simulation scenario for implementing proposed algorithm with 45 numbers of nodes. Experiment has been performed for different set of mobile nodes with different speed to check Energy Consumption in three modes Transmit, Receive and Idle Modes, average jitter and End to End delay [47].

Equal lengths of packets are sent from source to destination with simulation time of 30sec. and power consumption is calculated for different number of nodes like, 5, 10, 15, 20, 25, 30, 35, 40, and 45. It is clear from Fig. 6.4. That initially the proposed approach MPML and MTPR slightly differs. But when the number of nodes increased, the power consumption is high. This is because the selected routes are via specific host, the battery of this host will be exhausted quickly in MTPR and at the same time the total power consumption is high. But in the case of MMBCR initially it consumes more power to transmit user traffic, however in conclusion the battery of each host will be used more fairly than in previous scheme. It is observed from the graph that energy consumption optimizes in the case of proposed scheme when the number of nodes increases [48].

6.1.8 Assumptions

The assumptions made on experimental investigation are:

- All the nodes in a network are not supposed to generate traffic at any given time.
- Multiple hops are used as required before arriving at the destination;
- All the nodes in a network are moving at a given time.

6.1.9 Simulation Parameters

Table 6.1 Simulation setup parameters

Parameters	**Value**
QualNet	5.0

Antenna Type	Omni-directional Antenna
Network Layer	PHY wireless
MAC protocol	Mac/802.11
Network interface type	Physical/ Wireless Phy
No of Nodes	45
Topological area	1500 x 1500 sq. m
Simulation time	30 sec.
Node Speed	10m/s, 20m/s, 50m/s, 100m/s
Energy Model	Mica-Motes
Transmission range	600m
Radio type	802.11b Radio
Packet Reception Model	PHY 802.11b Reception Model
Data Rate	10 Mbps
Node movement model	Random Way Point
Pause Time	30 sec.
Battery Model	Linear Model
Network (Routing)	OLSR, RIP, LAR
Transmit Circuitry Power Consumption	100.0 mW
Receive Circuitry Power Consumption	130.0 mW
Idle Circuitry Power Consumption	120.0 mW
Sleep Circuitry Power Consumption	0.0 mW

6.1.10 Simulation Results

Simulation scenarios and parameters are given in Table 6.1. Values for transmit, receive and idle power have been used directly as mentioned in energy model proposed by Feeney L.M., Nilsson. M. (2011).

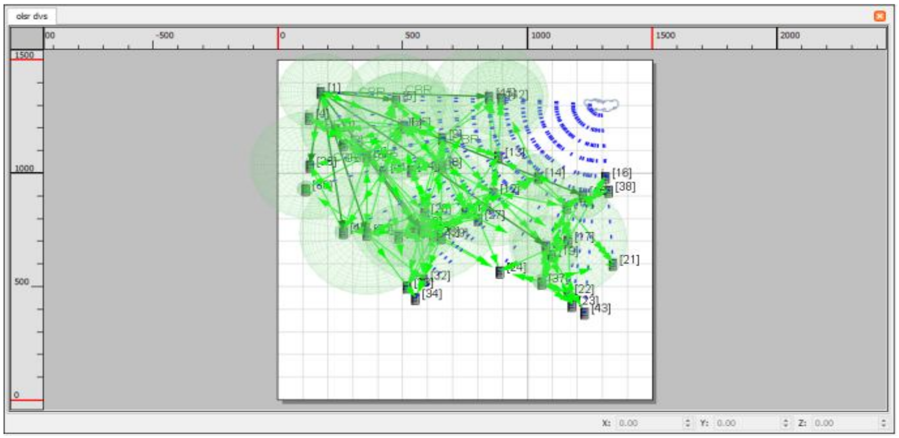


Fig. 6.5 Snapshot of running designed scenario for energy consumed in transmit mode using OLSR routing protocol.

6.1.10.1 Average Jitter

As the packets transmit from source to destination will reach the destination with different delays. A packet's delay varies with its position in the queues of the routers along the path between source and destination.

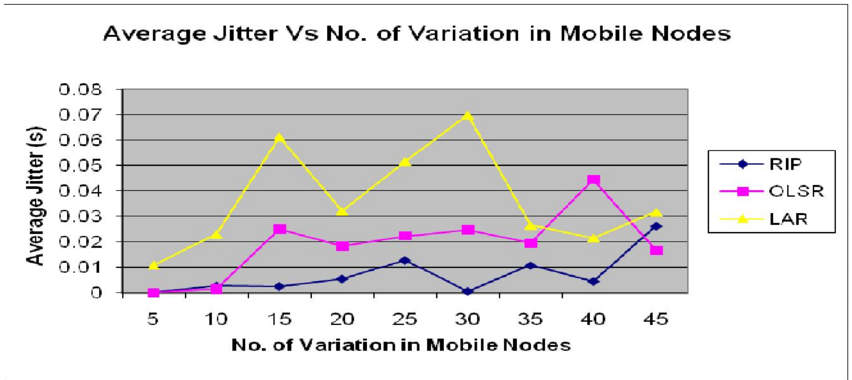


Fig. 6.6 Shows the Average Jitter Vs number of variation in mobile nodes. RIP has better results compared to OLSR and LAR.

The jitter increases at switches along the path of a connection due to many factors, such as conflicts with other packets wishing to use the same links, and non deterministic propagation delay in the data-link layer[17].

6.1.10.2 End-to-end Delay

The average end-to-end specifies the packet is transmitting from source to destination and calculates the difference between send times and received times. Delays due to route discovery, queuing, propagation and transfer time are included in the delay metric [17].

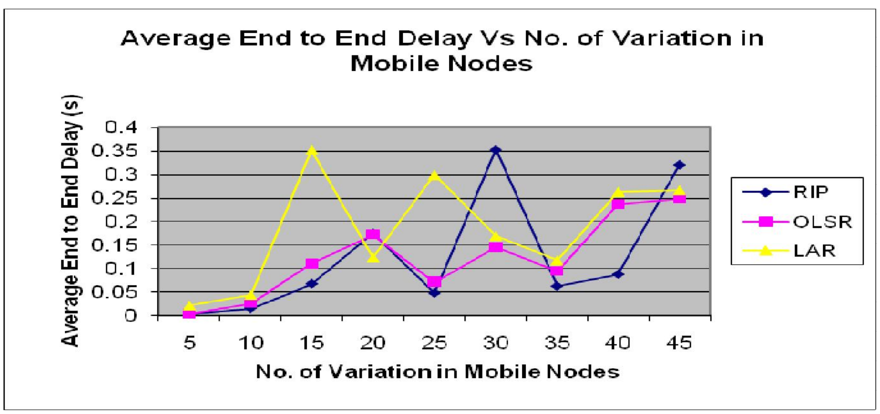


Fig. 6.7 Shows the Average End to End Delay Vs number of variation in mobile Nodes OLSR exhibits better results compared to RIP and LAR.

6.1.10.3 Energy Consumed in Transmit mode

A node is said to be in transmission mode when it sends data packet to other nodes in network. These nodes require energy to transmit data packet, such energy is called Transmission Energy (T_x), of that nodes. Transmission energy depends on size of data packet (in Bits), i.e the size of a data packet is increased the required transmission energy is also increased. The transmission energy can be formulated as:

$$T_x = \frac{330 * P_{length}}{2 * 106}$$

or

$$P_T = \frac{T_x}{T_t}$$

Where T_x is transmission Energy, P_T is Transmission Power, T_t is time taken to transmit data packet and P_{length} is length of data packet in Bits [17].

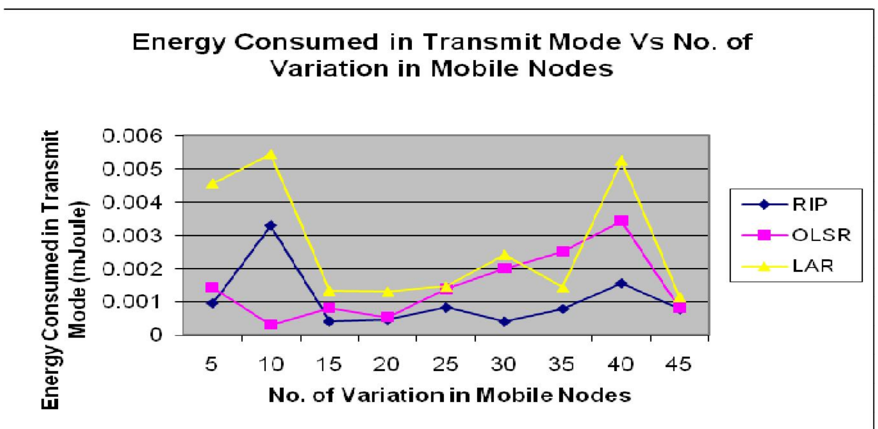


Fig. 6.8 Shows the Energy Consumed in Transmit Mode Vs number of variation in mobile nodes RIP shows better result compare to OLSR and LAR.

6.1.10.4 Energy Consumed in Receive Mode

When a node receives a data packet from other nodes then it said to be in Reception Mode and the energy taken to receive packet is called Reception Energy (R_x), then Reception Energy can be given as:

$$R_x = \frac{230 * P_{length}}{2 * 10^6}$$

or

$$P_R = \frac{R_x}{T_r}$$

Where R_x is a Reception Energy, P_R is a Reception Power, T_r is a time taken to receive data packet, and P_{length} is length of data packet in Bits.

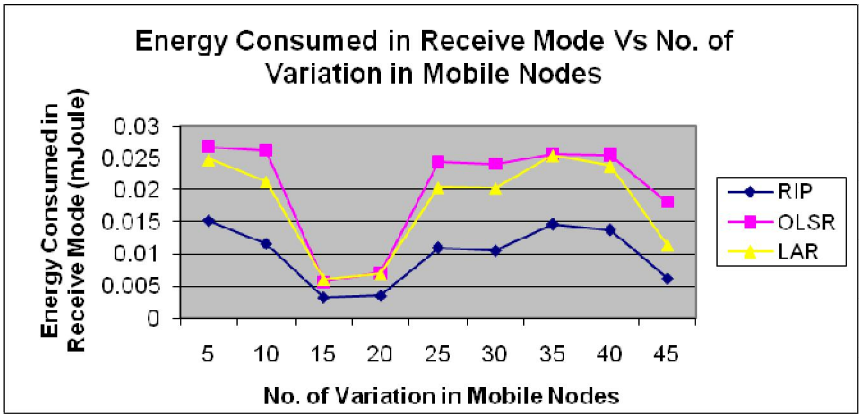


Fig. 6.9 Shows the Energy Consumed in Receive Mode Vs number of variation in mobile nodes RIP shows better result compare to LAR than OLSR.

6.1.10.5 Energy Consumed in Idle Mode

The node is neither transmitting nor receiving any data packets. But this mode consumes power because the nodes have to listen to the wireless medium continuously in order to detect a packet that it should receive, so that the node can then switch into receive mode from idle mode.

$$P_I = P_R$$

Where P_I is power consumed in Idle Mode and P_R is power consumed in Reception Mode.

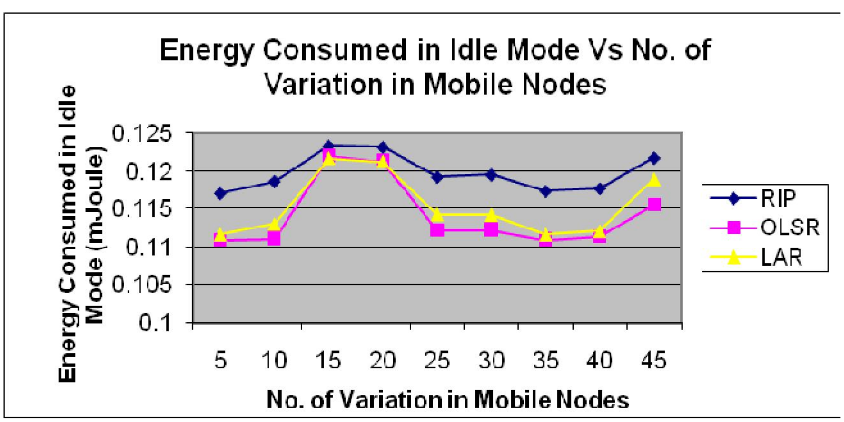


Fig. 6.10 Shows the Energy Consumed in Idle Mode Vs number of variation in mobile nodes. OLSR shows better result compare to LAR than RIP.

6.1.11 Conclusion

In this chapter optimization of energy in RIP, OLSR and LAR routing protocols using QualNet simulator is considered for power management in WSN with characteristics like, unpredictable mobility and multi-hop communication is discussed in detail. It is found that the two important issues, the power optimization and maximize network lifetime can be resolved by introducing a threshold value. The dynamic route discovery forces the node into sleep mode to retain the minimum energy level. Energy optimization model is proposed to estimate the remaining energy due to energy consumption in receiving. Equivalent simulator parameters have been used as inputs to achieve good generalization capability for network. Graphical simulation results have been shown above and proposed approach can save lot of energy with realistic route establishment prospect. The average energy is analyzed and compared with the LEACH protocol and static cluster routing protocol with the given network parameters. Static cluster routing is proposed as better energy efficient than basic protocol. In power saving mode results shows that OLSR is better RIP and LAR routing protocols and also the results from this scheme may be used in prediction of the remaining energy of nodes to control the energy consumption in wireless network.

6.2 POWER AWARE OSPF$_{V2}$ AND RIP$_{V2}$ ROUTING PROTOCOL DESCRIPTION AND IMPLEMENTATION IN QUALNET SIMULATOR

In this experiment we present Power Awareness Routing in OSPF$_{V2}$ and RIP$_{V2}$ protocols using QualNet 5.0 simulator [47]. Two different IGP based routing protocols are used for generating Link State Updates in OSPF$_{V2}$ and distance vector RIP$_{V2}$ routing prototype. For effective performance of these routing protocols we also analyzed their comparison on the basis of measuring metrics like Average jitter, Average end to end delay, Packet delivery ratio, Power consumed (mw) in transmit, received and ideal modes, using random mobility model, varying CBR traffic load and number of nodes can be used to create practical networks that emulate real network scenarios [212].

6.2.1 Introduction

Currently, one of most innovative topics in computer communications is mobile wireless networking. Recent technological advancement in wireless data communication devices and laptops has lead to lower prices and higher data rates. This offer users new applications in mobile computing and has show the way to a rapid growth in the number of wireless networks [208]. Today, wireless networks (WLANs) can increasingly be found in office, education, and industrial environments. The concept of ad hoc networking in computer communications is that users wanting to communicate with each other form a temporary network, without any form of centralized administration. Each node participating in the network acts both as host and router and must therefore is willing to forward packets for other nodes. For this purpose, a routing protocol is needed.

Mobility, potentially very large number of mobile nodes, heterogeneity (terminals can have very different capabilities) and limited resources (like bandwidth and power) make routing in ad hoc networks extremely challenging. The focal objective of this investigation is to cram ad hoc networking with WSN & examine the possibilities for power awareness in routing a mobile ad hoc network. Power consumption of a node is divided on the basis of function into [202]:

- The power consumption in the transmission of a message;
- The power utilization for a message reception;
- The power consumed when the system is in idle mode.

Four corresponding levels on the basis of which power consumption can be introduced by management control in wireless communication are recommended:

- Minimizing power consumption in the idle time by switching over to sleep mode is acknowledged as Power Management [194];
- Minimizing power consumption at the time of communication, i.e. while the system is receiving &transmitting messages is recognized as Power Control [202].
- Calculate a path that minimal o maximizes power consumption; i.e. use of the path that needs the least power to receive &transmit a message [205].
- Compute a path that maximizes the minimal residual power in the network; that is, use a path according to the residual energy of the nodes [205].

Obviously, both of above can not be optimized at the same time, which means there is a tradeoff between these. In the beginning when all the nodes have plenty of energy, the minimum total consumed energy path is better off, whereas towards the end avoiding the small residual energy node becomes more important. Ideally, the link cost function should be such that when the nodes have plenty of residual energy, the power consumption term should be applied, while if the residual energy of a node becomes small the residual energy term should be applied protocol [97-98,106].

6.2.2 OSPF$_{v2}$ and RIP$_{v2}$ Routing Protocols for Power Awareness

6.2.2.1 Open Shortest Path First $_{version2}$ (OSPF$_{V2}$)

The Open Shortest Path First$_{version2}$ (OSPF$_{V2}$) protocol is a link-state Interior Gateway Protocol (IGP) at first was designed to contend with RIP$_{V2}$. It wishes to each OSPF$_{V2}$ router as to maintain a database of internal topology of the AS area [214].

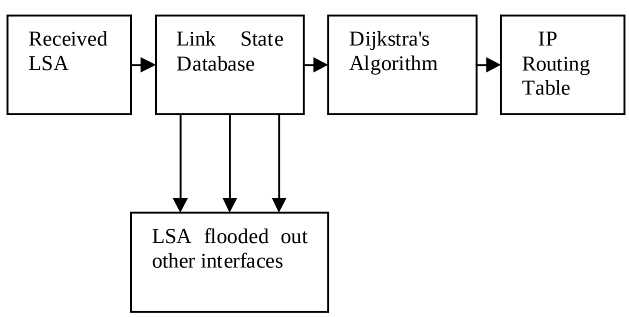


Fig. 6.11 schematically diagram for OSPF$_{V2}$ operation.

Fig. 6.11 shows operation of the $OSPF_{V2}$ protocol. $OSPF_{V2}$ LSAs received on one interface are installed in the link-state database and flooded out the router's other interfaces. From the link-state database, an $OSPF_{V2}$ router calculates its routing table, using Dijkstra's Shortest Path First (SPF) algorithm.

6.2.2.2 $OSPF_{V2}$ Routing Protocol Packets

The $OSPF_{V2}$ protocol runs unswervingly over Internet Protocol (IP) and breakdown is used. These protocol packets were designed so that large protocol packets can be split into numerous small protocol packets [97].

Table 6.2 Packet types $OSPF_{V2}$ are listed below

	Type Packet name	**Protocol function**
1	Hello Packets Sent / Received	"Number of Hello packets sent and received by nodes".
2	Link State Update Packets Sent / Received	"Number of Link State Update packets sent/received by nodes".
3	Link State Update Packets Sent / Received	"Number of Link State Update packets sent/received by nodes".
4	Link State ACK Packets Sent/Received	"Number of Acknowledge packets sent / received by nodes".
5	Link State Request Packets Sent/ Received	"Number of Link State Request packets sent/received by a node".
6	Network LSA Originated	"Number of network LSA originated by a node."
7	Number of LSA Refreshed	"Number of LSA refreshed by a node".

6.2.2.3 Routing Information Protocol $_{\text{Version 2}}$ (RIP_{V2})

The oldest distance vector protocol is still in utilized: RIP (Routing Information Protocol) exists in two versions. This work is based in the newest version, which is RIP_{V2}. RIP_{V2} is internet standard implementations of the Bellman-Ford routing algorithm. Routing Information Protocol (RIP) is an Interior Gateway Protocol (IGP) used to exchange routing information within a domain or autonomous system. RIP_{V2} lets routers exchange information about destinations for the purpose of computing routes throughout the network. Destinations may be individual hosts, networks, or special destinations used to convey a default route. RIP_{V2} does not alter IP packets; it routes them based on destination address only. It is a distance vector routing algorithm using the User Datagram Protocol (UDP) protocol for control packet transmission [97].

6.2.3 Comparison between Distance Vector and Link State Protocols

The main difference between distance vector and link state protocols is the algorithm in which they are based. A distance vector protocol learns routes and sends them to directly connected neighbors. By contrast, link state protocols advertise the state of all links (through packages known as LSAs) that participate in the routing process, so that the other routers in the area can build the topology database [215].

Table 6.3 Differences between distance vector and link state protocols are summarized

Parameters	**RIPV2 (DISTANCE VECTOR)**	**OSPFV2 (LINK STATE)**
Algorithm	Bellman-Ford	Dijsktra
Network view	Topology knowledge from the neighbor point of view	Common and complete knowledge of the N/W topology
Best Path Calculation	Based on the fewest number of hops	Based on the cost (hops, BW, delay)
Updates	Full routing table	Link State Updates
Updates Frequency	Frequently periodic updates	Triggered updates
Routing Loops	Needs additional procedures to avoid them	By construction, routing loops cannot happened
CPU and Memory	Low utilization	Intensive
Simplicity	High simplicity	Requires a trained network administrator

6.2.4 Assumptions and Limitations

The assumptions made on experimental investigation are:

- All the nodes in a network are not supposed to generate traffic at any given time;
- All the nodes in a network are moving at a given time.

6.2.5 Simulation Setup and Models

We have used a simulation model based on QualNet 5.0 Simulator, with Graphical User Interface tools for performance analysis comparison [47-48]. The simulator contains standard API for composition of protocols across different layers. The simulation parameters for design a scenario for power aware are given below in Table 6.4. The scenario is designed for power aware routing protocol using $OSPF_{V2}$ and RIP_{V2} protocols, after running the scenario program snapshot is obtained shown in Fig. 6.12.

Table 6.4 Power and Mobility traffic model parameters for $OSPF_{V2}$ and RIP_{V2} routing protocol

Parameters	**Values**
Simulator	QualNet 5.0
Routing Protocols	$OSPF_{V2}$ and RIP_{V2}
Mac Type	IEEE 802.11
Number of Nodes	80
Variation of Nodes	10 equal numbers
Transmission range	300m
Simulation Area	1500*1500
Mobility Model	Random Waypoint Mobility
Energy Model	Mica-Motes
Traffic Type	Constant-Bit Rate
Node Speed	20m/s, 40m/s, 60m/s, 100m/s
Propagation model	Two Ray Ground
Channel Frequency	2.4 GHz
Transmission range	600m
Item Size bytes	512
Simulation time	300 Sec.
Energy Supply Voltage	6.5 V
Battery Charge Monitoring Interval	60 Sec.
Battery Model	Linear Model
Full Battery Capacity	1200 (mA,h)
Performance Matrices in Physical Layer	Energy consumed (in mjules) in transmit mode Energy consumed (in mjules) in received mode Energy Consumed (in mjules) in ideal mode
Transport	TCP, UDP
Application	VBR, FTP and CBR
Transmit Circuitry Power Consumption	100.0 mW
Receive Circuitry Power Consumption	130.0 mW
Idle Circuitry Power Consumption	120.0 mW
Sleep Circuitry Power Consumption	0.0 mW

6.2.6Scenario for $OSPF_{v2}$ and RIP_{v2}

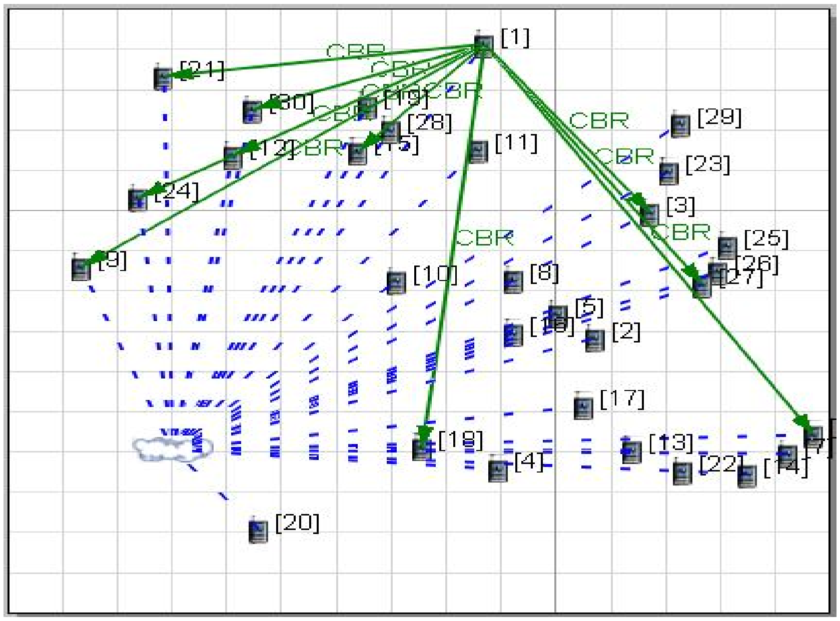


Fig. 6.12 Scenario for $OSPF_{V2}$ and RIP_{V2} for showing random nodes with CBR

6.2.7 System Model

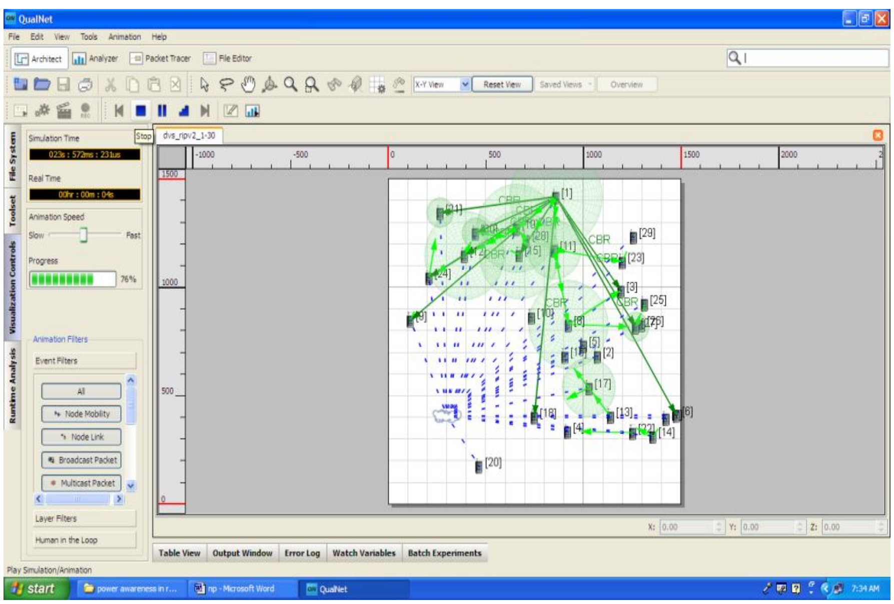


Fig. 6.13 The result of the designed scenario for $OSPF_{V2}$ routing protocol with numbers of CBR and nodes.

6.2.8 Performance Metrics

Now we are conducted extensive calculation on metrics based on terrain size. If terrain size varies; then corresponding metric rapidly changes while numbers of nodes are fixed. Here we perform thorough experimental scenarios are simulated in QualNet simulator to generate graphs in terms of metrics. The following metrics are applied to current scenarios as shown in table 6.4 and Fig.'s6.12 and 6.13.

6.2.9 Simulations Results

6.2.9.1 Average Jitter

The jitter variation is the variation in time taken for packet to reach its destination, computed as:

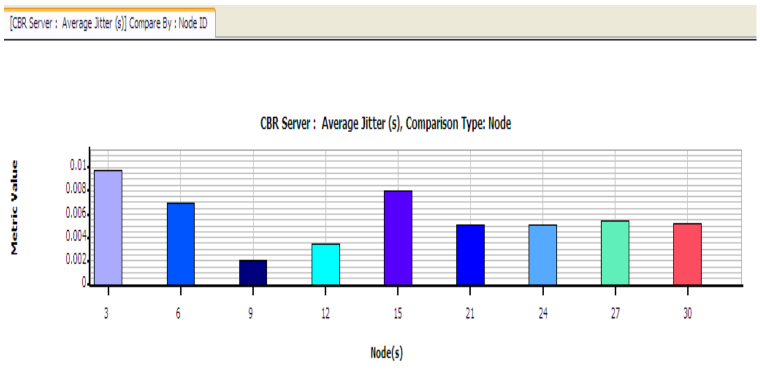


Fig. 6.14 Average Jitter for $OSPF_{V2}$ routing protocol with numbers of CBR and nodes.

In terms of delay variation, it is observed that RIP_{V2} have lower jitter than $OSPF_{V2}$ due to the complex operations that $OSPF_{V2}$ has to carry out.

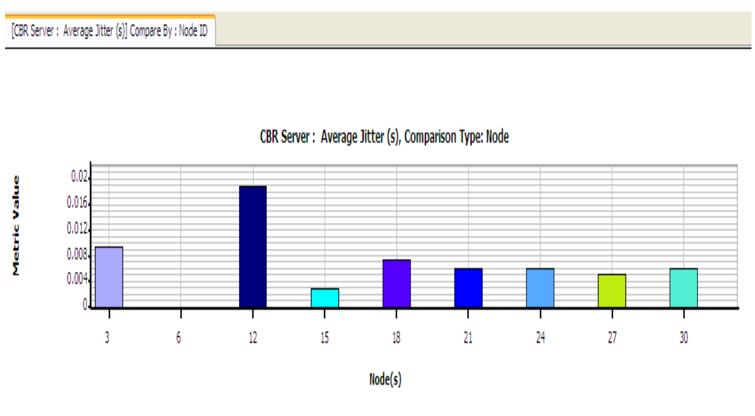


Fig. 6.15 Average Jitter for RIPv2 routing protocol with numbers of CBR and nodes.

Fig. 6.14 and Fig. 6.15 demonstrate impact of varying load and size on jitter. Here, again RIP_{V2} comes up as best performer from $OSPF_{V2}$ protocol. It can be observed that after scaling network up to 30 nodes, there is instant rise in jitter for both protocols. This is due to that fact that as network size increases, its control overhead of Query messages consumes more time to reconfigure the route.

6.2.9.2 Average End to End Delay

The delay is the time (seconds) taken for the packet to reach its destination. It is measured as the difference between the time a packet arrives at its destination and the creation time of the packet.

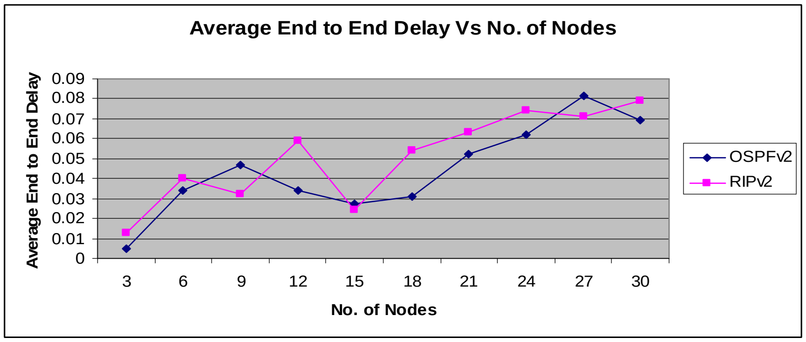


Fig. 6.16 Comparison of average end to end delay with varying nodes at $OSPF_{V2}$ and RIP_{V2} routing protocols.

Fig. 6.16 illustrates average end to end delay by varying number of nodes and traffic sources. Simulation result demonstrates end to end delay remains negligible for small number of nodes. Nodes rises of nodes to 15, drives significant increase in delay, even increase of CBR sources is ineffective.

6.2.9.3 Packet Delivery Ratio

It is the ratio between the amount of incoming data packets and actually received data packets.

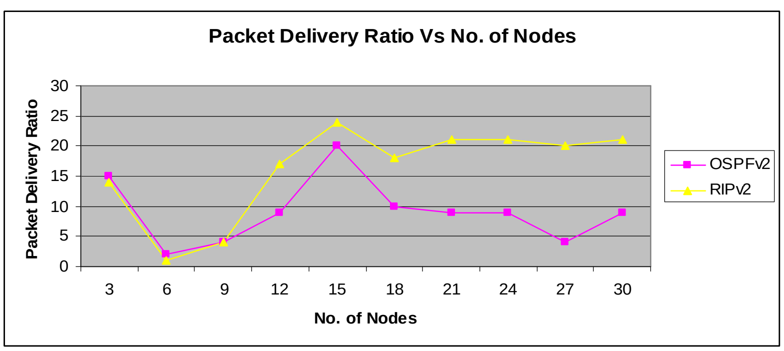


Fig. 6.17 Comparison of packet delivery ratio with varying nodes at $OSPF_{V2}$ and RIP_{V2} routing protocols.

Fig. 6.17 demonstrate packet delivery ratio by varying number of nodes and data packets. Simulation result shows that delivery of packets remains same for small number of nodes. When the nodes rise to 15, there is significant increase in packet delivery ratio. RIP_{V2} performs better than $OSPF_{V2}$.

6.2.9.4 Power Consumption in Transmit Mode

Fig. 6.18 illustrates a graph between power consumption in transmit mode by varying number of nodes. Simulation result shows that $OSPF_{V2}$ consumes more power compared RIP_{V2}. Power consumption for both protocols remains same for less number of nodes. When nodes are raised to 21,thenthe power consumption increases. RIP_{V2} consumes less power in transmit mode when compare to $OSPF_{V2}$.

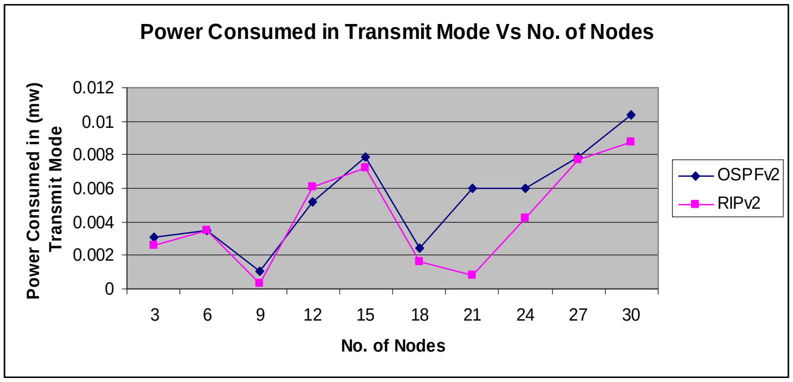


Fig. 6.18 Power consumed in transmit mode with varying nodes $OSPF_{V2}$ and RIP_{V2} routing protocols.

6.2.9.5 Power Consumed in Received Mode:

Fig. 6.19 illustrate power consumption in receive mode by varying number of nodes and consumed power in receive mode. Simulation result shows that $OSPF_{V2}$ consumes more power in receive mode compare to RIP_{V2}.

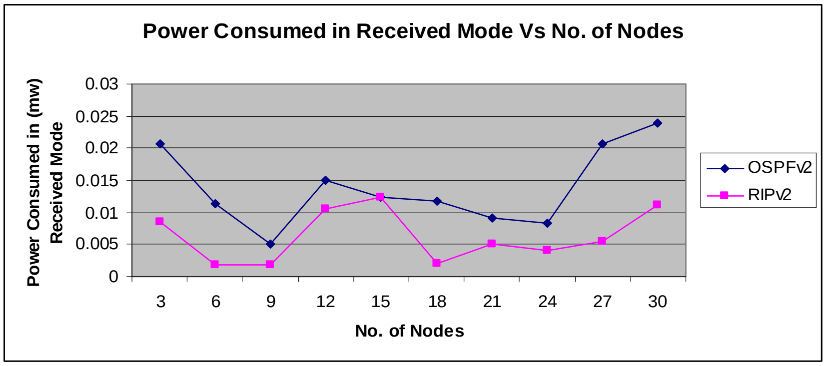


Fig. 6.19 Power consumed in receive mode with varying nodes $OSPF_{V2}$ and RIP_{V2} routing protocols.

6.2.9.6 Power Consumed in Ideal Mode:

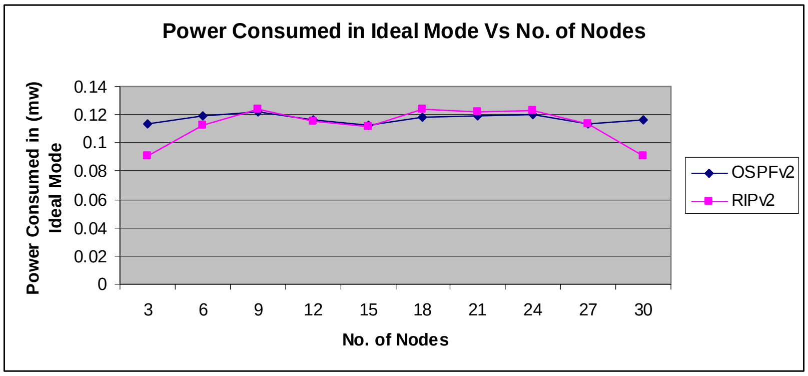


Fig. 6.20 Power consumed in transmit mode with varying nodes $OSPF_{V2}$ and RIP_{V2} routing protocols.

Fig. 6.20 illustrates power consumption with varying number of nodes in ideal mode. Simulation result shows that OSPFV2 consumes more power in ideal mode compare to RIP_{V2}.Power consumption remains almost same between 6 to 27 nodes.

6.2.10 Conclusion

The simulations have exposed the major constraints of RIP_{V2} routing protocol over $OSPF_{V2}$. However, the great advantage of this protocol is its simplicity of configuration and its lower processing consumption. The link state protocols need improvement in some of performance metric compared to distance vector protocols. Efforts are to try minimizing power consumption during the idle time by switching to sleep mode, optimizing a new route to increase the life time of the network. The data collected by simulation is very much needful to researcher shown in table 6.5. Regarding this chapter future work on the mobility issues on reliability and power management in $OSPF_{V2}$ and RIP_{V2} routing protocols.

Table 6.5: shows a summarization of the main analyzed attributes of RIP_{V2} and $OSPF_{V2}$ protocols

Parameters	***RIPV2***	***OSPFV2***
Convergence	Slow	Fast
Link utilization	Inefficient	Optimal
Metric	Hop count	Cost based on BW
CPU Utilization	Optimal	Inefficient
Average End to End Delay	Increase when increases number of nodes.	Varies simultaneously with higher range of nodes.

Average Jitter	Lower	Higher
Load balancing	No	No
	Periodic Updates	LSA flooding, adjacencies formed after three-way hand shaking
Power consumed (mw) in Transmit Mode	Remain same for less no of nodes.	More at higher nodes.
Power consumed (mw) in Received Mode	less	more
Energy consumed (mw) in Ideal Mode	Less as compare to OPSFV2	Same as RIPV2, but increases when nodes increases

Two papers are produced out of research work carried in this section of thesis.

[1] Dharam Vir, S.K.Agarwal, S. A. Imam "Performance Simulation of E^2 Analysis for Energy Models of Mobile Ad-Hoc Network using QualNet Simulator" in International Journal of Future Computer and Communication, www.ijfcc.org Vol. 1, No. 2, August 2012, pp. 85-90.

[2] Dharam Vir, S.K.Agarwal, S. A. Imam "Investigation on Power Awareness in $OSPFV_2$ and $RIPV_2$ routing Protocol in Wireless Sensor Networks" in International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064, www.ijsr.net Volume 2 Issue 2, February 2013, PP. 260-265.

Chapter 7

POWER MANAGEMENT APPROACH AND SCHEME FOR OPTIMIZED LINK STATE ROUTING (OLSR) PROTOCOL

This chapter gives brief experimental design based on power management issues OLSR and modified Optimized Link State Routing (OLSR) protocol and it is designed on QualNet 5.0 simulator.

The most revolutionary topics in computer communications are wireless networking. An area in wireless networking is mobile ad hoc networking (MANET). The concept of MANET is based on the principle that the users can converse with each other in the form of network, without any type of centralized administration. Each and Every message can be send and every computation is performed in the drains of battery life. A solution for power conservation in MANET is power management which means that the routing decisions taken by the routing protocol must be decided on the power-status of the nodes i.e. nodes having low batteries will be less preferred for forwarding packets than the nodes with chock-full batteries, thus mounting the life of the nodes. In QualNet scenario is designed in such a way that it undertakes the real traffic conditions. We have chosen 100 fast moving nodes in the region of 1500X1500 m2 with the random way point mobility model. There is also well defined path for some of the nodes. It shows wireless node connectivity of few nodes using CBR application.

7.1 POWER MANAGEMENT IN OPTIMIZED LINK STATE ROUTING (OLSR) PROTOCOL

7.1.1 Introduction

Wireless sensor networks (WSN's) have attracted researchers on an immense deal of research seeking attention because o their wide-range of prospective applications. Applications of wireless sensor networks contain battlefield surveillance, medical monitoring, biological detection, inventory tracking and home security. This type of network consists of collection of nodes and each node has limited battery power capacity. There may be many possible routes available between two nodes over which data can be able to flow. Assume that each node generated some information and this information needs to be delivered to a destination node. Any node in the network can easily transmit their data packet to a distance node, if it has enough battery power. If any node is far from its neighbor node then large amount of transmission power is required to transmit the data from source to destination. After every transmission, remaining power of this node decreases and some amounts of data transmission of this node will be eliminated from the network because of empty battery power and in similar situation there will be a condition that no node is available for data transmission and overall lifetime of network will decreases [209].

Existing power awareness routing protocols can generally classified as a power management or power control protocol. In IEEE 802.11 there is already a type of power management implemented. The implantation of power awareness routing in this task is only focusing on power control management schemes. However, to make power management schemes for mobile ad hoc networks is most effective, an efficient message routing algorithms, coupled with good solutions for optimizing power consumption during the transmit, received and idle modes of data. In power control routing protocols several metrics can be used to optimize power management in routing. Minimizing the energy consumed for each message is an evident solution that optimizes locally the power consumption. An effective routing protocol should not only focus on individual nodes in the system but also focus on the system as a whole. The nodes have high residual power but the system is not connected because some critical nodes have been depleted of power. Different routing schemes can be utilized, but the two most extreme solutions to power awareness routing for a message are [209-210].

- Compute a path that maximizes the minimal power consumption; the path that requires the least power to transmit and receive a message, hereby keeping the power consumption needed to communicate as low as possible [213].
- Compute a path that maximizes the minimal residual power in the network; the path according to the residual energy of the nodes, hereby maximizing the lifetime of all nodes and the lifetime of the network [217].

7.1.2 Related Work

There exist a number of factors contributing to performance of MANET routing protocols. Some such factors are affecting the performance are discussed in Section 2.10. Furthermore, various researches are carried out to improve routing protocols performance. Some of these researches are outlined in Table 2.3.

Various improvements have been proposed to improve MANET routing protocol performance. This section presents a summary of contributions towards improving routing protocols in Table 2.3. The contributions are summarized as: preventing link failures, reducing delay to improve throughput, lengthening the lifetime of a route, controlling broadcast initiated by neighboring nodes, division of parts to allow higher transmission data to follow one while non real time traffic follows the other, utilizing longest path rather than shortest path, identifying easily repairable routes from the density of neighboring nodes, decreasing the number of route requests, choosing two paths from the centre of the network, coping with dynamic situations using hybrid routing of both reactive and proactive protocols, defining and using intra-segments for local repair and intersegments for global repair and ware energy of nodes to determine the best possible routes. These suggested improvements aim to contribute towards better performance and a lowering of the fail or the expire links reducing delay.

Subramanya Bhat.M, et al.	"Proposed a new route maintenance strategy for DSR by utilizing location and adding a node to source list preventing link failures in order to improve packet sending ratios and to minimize delays. Since the route discovery mechanism is associated with great delay in DSR" [212].
Stephen Mueller et al.	"Proposed the change of the DSR route selection mechanism to behave proactively in order to improve throughput and reduce delay. Clustering is also a technique used in reducing route acquisition overhead" [214].
Shibo Wu et al.	"Proposed a new improvement to the DSR protocol called Modified DSR (MDSR). It functions by understanding the data transmission traffic and separating it into two groups. The first group consists of priority transmission of real time application traffic where delays are sensitive. MDSR uses a larger transmission power for the first group. The second group, non-real time traffic, uses less transmission power where delays can be allowed. Having separate transmission ranges for the type of traffic shows a performance increase in MDSR as compared to DSR" [213].

Stephen Mueller et al.	"Proposed stability based clustering (SBC) to improve performance rather than zone routing protocol. Simple ant routing algorithm (SARA)" [214].
S.T. Shen et al.	Proposed by uses of controlled neighbor broadcast route discovery aiming to reduce routing overheads" [215].
Wijaya et al.	"Present a model to predict the lifetime of routing paths. The scheme proposed chooses the longest expected lifetime. DSR and most routing protocols adopt shortest path routing which is not always reliable and is not always the best option as there is a high probability of a route failure under high network density" [220].
Baoxian Zhang et al	"DSR over AODV (DOA), proposed by targeted route maintenance. DOA implements two levels of route repair defined as intra-segment and inter-segment route repair. If a route fails intra-segment tries to fix it by finding alternative routes within one segment. If it succeeds then way point nodes on routes to source nodes are not changed, hence the source node needed not to be notified. However if it fails, inter-segment will try fixing it by finding alternative routes over multiple segments include downstream and broken segments. If intra-segment succeeds the repaired route will be send to source node and packets to be send using this route. However if inter-segment fails an inter-segment error message is sent to the source node which subsequently starts a new global route discovery" [224].
Tao Yang, et al.	"Proposed a new protocol for route discovery aiming to select the most easily reparable route, among other routes, during route discovery, by taking into account the density and availability of neighboring nodes. The availability of neighboring nodes is associated with its repair fitness" [163].
Alexander Klein et al.	"In another research presented the idea of a new multi path in AODV routing called Centre base Distance Multi-path AODV (CDM-AODV). The two paths in this algorithm are

	chosen from the centre of the network. The reason being is that there is a reverse relationship between the distances of the node to the centre of network. When request packets are sent, replay packets have the information about the centre of network and distance between nodes" [94].
Ruchi R et al.	"Improves AODV routing in dense network and decreases the number of route request by limiting the search area by using a quadrilateral with two angles giving global position system (GPS) coordinates passing from a source to a destination" [80]
S.C. Woo, Hass Z et al.	"In a more recent study, A combination of AODV and OLSR for scalable routing is proposed by called scalable ad hoc routing protocol (SARP). SARP considers the whole network as a zone and reacts opposite to those of zone routing protocol (ZRP). MRP nodes are implemented distributing evenly over the network, while other nodes, if not MRP use AODV routing scheme. In so doing hello message establishes routes and forward messages are handled well in small networks. In high network the combination of MRP and AODV is used" [100-101].

The energy consumption in processing power and battery life plays an important role towards the overall performance; however, it may contribute less to routing performance than addressing ways to defeat overheads in the routing algorithm. A poor management strategy in dealing with message packets over the network will consume a lot of network resource like processing power, bandwidth and battery life.

7.1.3 Need for Power Management in WANETs

The nodes in an ad hoc wireless network are power constrained but limited battery power for their operation. Hence, power management is an important issue in wireless sensor network as well as ad hoc networks. Power management is the process of managing power resources by means of controlling the battery recharge, adjusting the transmission power, and scheduling of power sources so as to increase the lifetime of the nodes of an ad hoc wireless network. The power efficiency of a node is defined as the ratio of the amount of data delivered but the node to the total power finished [225-226].

7.1.3.1 Reasons for Power Management in WANETs

There exist a number of reasons for power management to contributing of performance of WANETs. Some of them are given below.

- Increasing gap between the power consumption and requirements of power availability, so need to the power management.
- Difficult to replace or recharge the batteries. Hence, power conservation is necessary in such scenarios.
- The relay traffic allowed through a destination node is more, and then it may leads to a faster depletion of the power source for that node.
- Power control is essential to maintain the required signal to interference ratio at the receiver and to increase the channel capability.
- Power consumption of a wireless radio depends on the operation mode. Four types of operation modes of a radio can be categorized: (i) transmit mode, (ii) receive mode, (iii) idle mode, and (iv) sleep mode.
- Batteries are likely to increase the size and weight of a mobile node, to reduce the size of the battery, power management techniques are necessary to utilize the maximum battery capacity in the best potential way.
- The power level of a battery is finite and limits the lifetime of a node. Every message sent and every computation performed drains the battery.

7.1.3.2 Classification of Power Management Schemes

To increase the life of an ad hoc wireless network, it is required to be aware of the capabilities and limitations of the power resources of the nodes. For longer lifetime of the node can be achieved by increasing the battery capacity. Increasing the capacity of the battery at the nodes can be achieved by either battery management, which concerns the internal characteristics of the battery, or power management, which deals with maximum utilization of battery capacity [78].

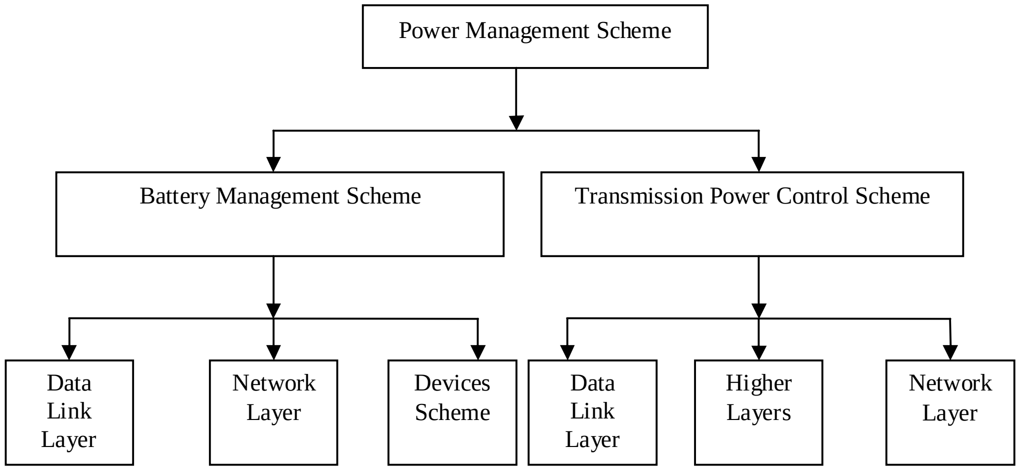


Fig. 7.1 Classifications of Power Management Schemes

The routing protocol must be designed such a way to reduce the amount of information exchanged among the nodes, since communication incurs loss of power. Increase in the number of communication tasks also increases the traffic in the network, which results in loss of data, retransmissions, and hence more energy consumption. The power consumption occurs at the network layer is because of communication and calculation operations. The power conserved in communication operations is due to transmit-receive module present in the source and destination nodes [93,207].

7.1.4 Optimization of Power Consumption

In wireless and mobile ad hoc networking the optimization of power consumption can be divided according to functionality into [161,183,197, 205,211,227];

- The maximum power utilized for the transmission of a message.
- The maximum power utilized for the reception of a message.
- The minimum power utilized while the system is idle.
- Reducing the access amount of data transmitted across the network.
- Lower the transceiver duty cycle range.
- Lower the frequency of data transmission.
- Reduce the frame overhead.
- Implementation of reliable power management techniques.
- Reduce redundant transmission.
- Reduce calculation overhead.

- For powerful routing protocol, reduce the number of retransmission across the network can be controlled effectively.
- Evaluating node density, congestion and network availability.
- For utilizing effective routing algorithm, network life time and energy will be conserved and redundant transmission will be reduced [123].

7.1.5 Proposed Work

We propose two corresponding power management optimization technique for control and manage the power consumption in wireless sensor network as well as ad-hoc networks:

- Optimized minimum power consumption during the idle time by switching to sleep mode this is known as Power Management [167].
- Optimized minimum power consumption during communication, that is, while the system is transmitting and receiving messages; this is known as Power Control [168].

7.1.6 Optimized Link State Protocol

The Optimized Link State Routing (OLSR) protocol, developed and introduced by the French National Institute for Research in Computer Science and Control (INRIA), was invented for mobile ad-hoc networks. It functions in a table-driven and proactive manner, that is, topology information is exchanged between the nodes in a periodic motion. Its main intention is to reduce the control traffic by selecting few nodes, known as Multi Point Relays (MPR) for flooding topological information. In route computation, these MPR nodes are used to integrate an optimal route from a given node to any location in the network. This routing protocol is preferred for a large &dense network. Most of the time OLSR protocol proposes four types of periodic control messages, namely [216-217]:

- Hello messages
- Topology Control (TC) messages
- Multiple Interface Declaration (MID) messages
- Host and Network Association (HNA) messages.

7.1.6.1 Hello Messages

Optimized Link State Routing (OLSR) [218] uses two types of the control messages namely Hello and Topology Control (TC). Hello messages are exchanged periodically within one-hop neighborhood to attain the neighborhood information. By taking the use of this neighborhood information, each and every node in the network selects a subset of one-hop away neighbors recognized as the MPR set. In the MPR set, all the two-hop away neighbors are capable to reach through the subset of the MPR set. With the Hello messages, the Multipoint Relay (MPR) Selector set is constructed which describes its neighbors has chosen this host to act as MPR and from this information the host can calculate its own set of the MPRs. the Hello messages are sent only one hop away but the TC messages are broadcasted throughout the entire network. TC messages are used for broadcasting information about own advertised neighbors which includes at least the MPR Selector list [219].

7.1.6.2 Topology Control (TC) Messages

Topology Control (TC) messages are produced, generated and then retransmitted for flooding topological information in the integrated network only through MPR nodes. Also, MID and HNA messages are carried only for MPR nodes. An MPR member produces and retransmits the TC messages. These TC messages provide each and every node in the network with enough link-state information so as to allow route computation [207, 219].

7.1.6.3 Multiple Interface Declaration (MID) Messages

MID messages are produced by an OLSR node with the help of multiple OLSR interfaces to inform other nodes about its interfaces taking part in the OLSR routing area, Multiple Interface Declaration (MID) messages also which are used to inform other hosts so that the announcing host can have multiple OLSR interface addresses. The MID message is then broadcasted throughout the complete network by the MPRs only [207].

Table 7.1 Description of OLSR parameters

Parameters	**Description**
OLSR-HELLO-INTERVAL	"Specifies the time interval between two consecutive HELLO messages within one-hop neighborhood to obtain the neighborhood information".

OLSR-TC-INTERVAL	"Specifies the time interval between two consecutive TC messages".
OLSR-MID-INTERVAL	"Specifies the time interval between two consecutive MID messages. MID messages will be broadcasted only when an OLSR node has multiple OLSR interfaces"
OLSR-HNA-INTERVAL	"Specifies the time interval between two consecutive HNA messages. HNA messages will be broadcasted only when an OLSR node has non-OLSR interface".

So the topological changes cause the flooding of the topological information to all available hosts in the network. To reduce the possible overhead in the network protocol uses Multipoint Relays (MPR). The idea of MPR is to reduce flooding of broadcasts by reducing the same broadcast in some regions in the network, more details about MPR can be found later in this chapter. Another reduce is to provide the shortest path. The reducing the time interval for the control messages transmission can bring more reactivity to the topological changes [207,221].

7.1.6.4Host and Network Association (HNA) Messages

There is also a "Host and Network Association" (HNA) message which provides the external routing information by giving the possibility for routing to the external addresses. The HNA message provides information about the network- and the net mask addresses, so that OLSR host can consider that the announcing host can act as a gateway to the announcing set of addresses. The HNA is considered as a generalized version of the TC message with only difference that the TC message can inform about route canceling while HNA message information is removed only after expiration time [221].

7.1.6.5 Multipoint Relays Selection

In this section the proposed algorithm for the selection of Multipoint Relay set is described. This algorithm is found from [207, 217]. Hello message can be chosen to act as MPR. The neighbor must be symmetric in order to become an MPR. Proposed algorithm for selecting Multipoint Relay set:

- Take all the symmetric one hop neighbors which are willing to act as an MPR.
- Calculate for every neighbor host a degree, which is a number of the symmetric neighbors, that are two hops way from the calculating source and does not include the source or its one hop neighbors.

- Add the neighbor symmetric host to the MPR set. If it is the only neighbor from which is possible to get to the specific two hop neighbor, then remove the chosen host neighbors from the two hop neighbor set.
- If there are still some hosts in the two hop neighbor set, then calculate the reach ability of the each one hop neighbor, meaning the number of the two hop neighbors, that are yet uncovered by MPR set.
- Repeat previous step until the two hop neighbors set is empty.
- For the optimization, set the hosts in the MPR set in the increasing order basing on the willingness. If one host is taken away and all the two hop neighbors [217].

7.1.6.6 Topology Information

In order to exchange the topological information and build the topology information base the host that were selected as MPR need to sent the topology control (TC) message. The TC messages are broadcasted throughout the network and only MPR are allowed to forward TC messages. The TC messages are generated and broadcasted periodically in the network. The TC message is sent by a host in order to advertise own links in the network. The host must send at least the links of its MPR selector set. The TC message includes the own set of advertised links and the sequence number of each message [221].

7.1.6.7 Control Traffic

All OLSR control traffic is to be transmitted over UDP. This traffic is to be broadcasted when using IPv4, but no broadcast address is specified [222].

7.1.6.8 Routing Table Calculations

The host maintains the routing table, the routing table entries have following information: destination address, next address, number of hops to the destination and local interface address. Next address indicates the next hop host. The information is got from the topological set (from the TC messages) and from the local link information base (from the Hello messages) [222].

7.1.7 Proposal for an Improved Routing Protocol

To find an optimal routing protocol for all situations may not seem viable as it requires vast and substantial research into the behavior of routing algorithms. In this research extensive and simulation experiments have been conducted to find the most suitable and reliable routing algorithms for a given situation. TC Message Received, Hello Message Received , Signal Received but with errors, Signal Received and Forwards to MAC, Power Consumed in Transmit Mode, Power Consumed in receive Mode, Power Consumed in idle / sleep modes with varying Node mobility and number of nodes are contributing factors towards the behavior of a routing protocol.

This research is centered on node mobility and variation in number of nodes therefore recommendations and amendments will focus on OLSR and Modified OLSR. According to the results Modify OLSR performs well in large networks and when node mobility is high. When mobility is low, OLSR delay increases hence the proposed recommendation would be to look at ways of reducing the delay in large network when medium mobility of nodes exists. As network nodes increases some routes are used more frequently than others. Due to limited resources in MANET, the density of node plays an important role in distributing the load over the network. When one route's density becomes very high, the alternative shortest route is used. The risk involved here is that stale routes and longer paths in alternative routes may occur. The advantage is seen in balancing the load so that the shortest and freshest route is not overloaded and becomes expired sooner than its expected lifetime.

When receiving the update information, each node recalculates and updates the route to each known destination [222]. TC message is used to broadcast topological information throughout the network however, only MPR nodes are used to forward the TC messages to nodes in its routing table.

Fig. 7.2 presents the proposed amendments to modified OLSR routing algorithm where a node has a packet to be sent source to a destination. The flow chart shows the use of the alternative shortest path. The paths are considered after the topology is generated. It begins by checking if any route to the destination is available in the routing table. If the route to the destination is not available the source node initiates a broadcast for all possible routes. Should there be a route available, the link is established using a hello message and the sender is ready to send the packet. Once the destination is reached transmission begins. If failure occurs the TC message is sent to update topological changes in MPR nodes. Priority used paths are those with shortest path and freshest route to a destination. If a route expires or is used heavily the alternative route is trigged. Both routes should be capable of establishing connections to send data packets from a source to a destination node. This research only specifies the proposed algorithm in a flow chart. The implementation of the algorithm is proposed in this research as future work [222].

7.1.8 System Model

Computer simulation methodology is used to carry out the proposed research. Usually, the performance of routing protocols is evaluated using computer simulation techniques which, unlike analytical methods, use fewer assumptions and behave more like real systems. The complexity of routing algorithms is another driving force for adopting simulation methodology. In addition, simulation offers more flexibility in model development, validation, and performance evaluation. In QualNet 5.0 [47-48], a precise network topology is referred to as a scenario. A scenario allows the user to denote all the network components and environment under which the network will operate. This includes: terrain details, channel propagation effects including path loss, battery model, fading, and shadowing, wired and wireless subnets, network devices such as hubs, switches and routers, the whole protocol stack selection of standards or user-configured network components, and applications running on the network.

In this work QualNet 5.0 network simulator has been used to design modify OLSR routing protocol or an existing OLSR routing protocol of mobile ad-hoc networks. The physical medium used is 802.11 PHY with a data rate of 2 Mbps. The MAC protocol used is the 802.11 MAC protocol, configured for MANET mode. In this work wireless module of IEEE 802.11b is used to enable mobility of the wireless nodes. IEEE 802.11b support more accurate wireless models for propagation, path loss, multi-path fading and reception on wireless networks.

The simulations are carried out for network densities of 100 nodes respectively in 10 intervals. The area considered for the above network densities are 1500m * 1500m. Simulations scenarios is design for modification in OLSR and existing OLSR routing protocol for power management with the metrics like power consumes in all three modes transmit, received and ideal modes, TC message received, Hello message received, signal received and forward to MAC, signal received but with errors. The parameters and description is given in table1. Fig. 7.3 shows the running designed scenario for modify OLSR routing protocol with number of CBR’s and nodes.

7.1.9 Flow Chart for Modified Proposed OLSR Protocol

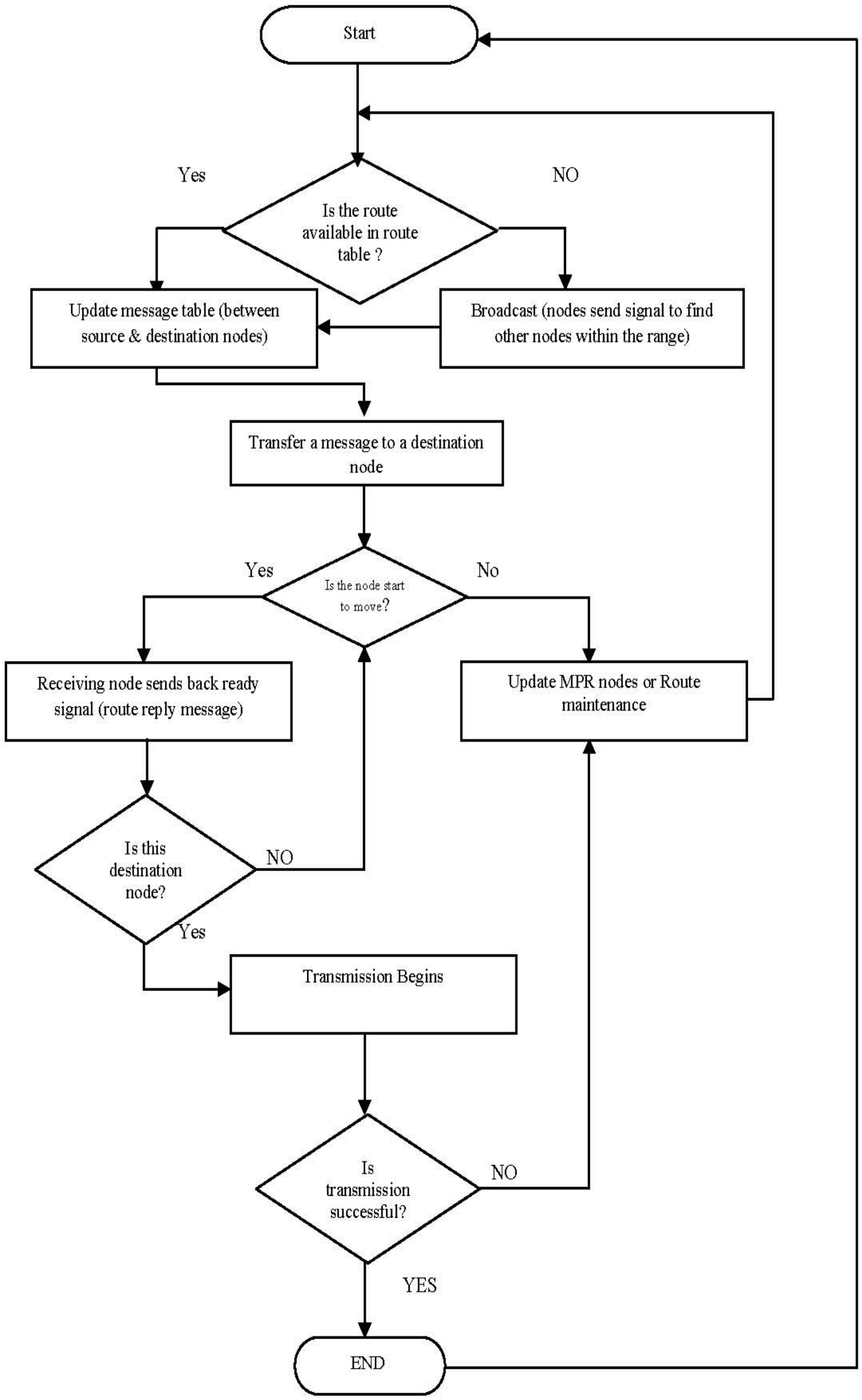


Fig. 7.2 Flow chart diagram for modified proposed OLSR routing protocol

7.1.10 System Model Support and Limitations

We implemented the OLSR routing protocol based on [47], and name this implementation as modified OLSR. OLSR supports most functions included in the specification. For example,

- Attached network management
- Multiple data aggregation to one packet
- Multiple hop TTL control mechanism
- Multiple interface handling
- IPv4 and IPv6
- Address compression

OLSR also supports the QualNet simulator [47]. However, the current modified implementation shown in flow chart of modified OLSR routing protocol, doesn't yet support multiple address handling per interface as given in the specification.

Table 7.2: Description of parameter chosen for traffic and power model parameters of OLSR and modified OLSR routing protocol.

Parameter	**Short Description**	**Value/Type**
Topological Area	"Represents topology or arrangement of mobile nodes. Determined in x & y axis. Also known as network size or dimensional area. Measured in square meter"	1500 *1500 m^2
No. of nodes	"Nodes are communication devices or routers".	1-100
Pause time	"The maximum amount of time, a node stays before a new direction and speed is selected".	10, 20, 40
Max. speed	"Maximum mobility speed of a node. Measured in meter/second".	20 m/s
Transmission range	"Radio transmission range allows a mobile node to send & receive radio signals. Measured in meters".	250 m
Mobility pattern	"Define movement of nodes, which is characterized by speed, direction, and rate of change	Random way point
Application	Denote the traffic type to be used i.e. CBR stands for constant bit rate. Used for real time traffic".	CBR
PHY	"PHY stands for physical layer. 802.11b is basically IEEE wireless standard".	802.11b
Packet size	"Node sends & receives data in the form of packet. Measured in kilobytes".	512 kB

Packet transmission rate	"Every traffic source sends a packet at specific rate that is measured in packet/second".	2 Packets/second
Simulation time	Total duration for which simulation runs.	400 s
No. of CBR	"Total number of CBR connections that can be established among different mobile nodes for communication".	10
Nodes	"Mobile or fixed routers with wireless receivers or wireless transmitters which are free to move arbitrarily"	100
Battery Model	"Battery rate capacity effect: the model which precisely estimates non-linearity effect of rated capacity versus discharge current load".	Linear Model
Start/ End Time	"Time when the conversation ends. If end time is specified as 0, then conversation continue until the end of simulation".	Variable
Simulation time	"Length of simulation and time when scenario complete task".	1800 seconds

7.1.11 Simulation Parameters

For implementing the proposed OLSR and modified OLSR protocol, an environment had to be formed with certain fixed and variable parameters for simulation. These parameters were suitably chosen for carrying out the simulation process and the proposed protocol was implemented to check the effect. A detailed list of simulation parameters chosen is shown in Table 7.3.

7.1.11.1 Set up Parameters for OLSR and Modified OLSR Routing Protocol

Table 7.3 Setup parameters for modified OLSR routing protocol

Simulator	QualNet 5.0
Examined proposed Protocols	OLSR, Modified OLSR
Simulation Period	30 sec
Simulation Area	1500 X 1500m2
Number of Nodes	Variable 10-100
Energy Model	Mica- Motes
Communication Model	IEEE 802.11
Battery Model	Linear
Default Battery	1200
load size	512 byte
Node Placement Model	Random

Antenna Model	Omni direction
Network Layer	PHY wireless
Packet Reception Model	PHY 802.11b Reception Model

7.1.12 Limitation and Assumptions

The following limitation and assumptions are considered for the simulation purpose:

- Every node in the network is stationary.
- All nodes have similar capabilities, and equal significance.
- Each of the nodes is battery operated in simulation process
- Nodes are left unattended after deployment.

7.13 Outcome Snapshot of Modified OLSR Protocol

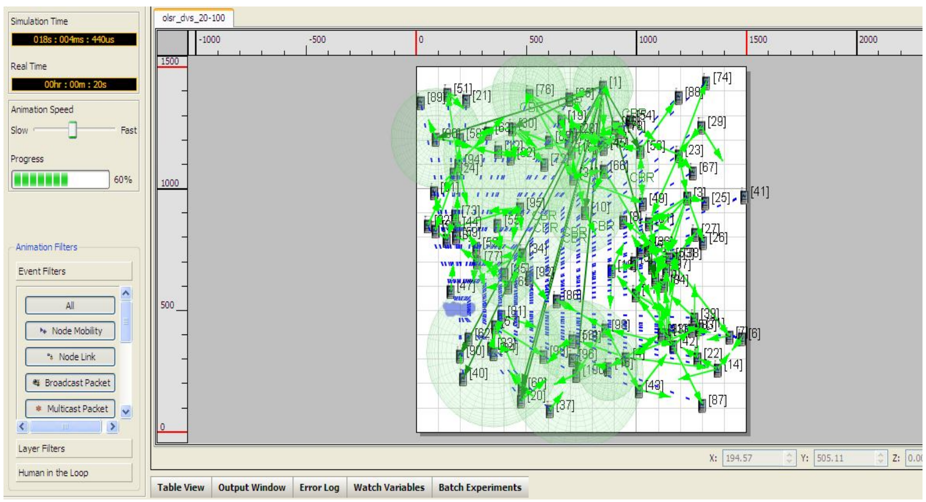


Fig.7.3 Snapshot of running designed scenario for modifies OLSR routing protocol with number of CBR's and nodes

7.1.14 Metrics Used

7.1.14.1 TC Message Received

It is specifies the time interval between two consecutive TC messages. The TC messages are broadcasted throughout the network and only MPR are allowed to forward TC messages. The TC messages are generated and broadcasted periodically in the network. Host can increase its transmission rate to become more sensible to the possible link failures. When the change in the MPR Selector set is noticed, it indicates that the link failure has happened and the host must transmit the new TC message as soon as possible

7.1.14.2 Hello Message Received

This is specifies the time interval between two consecutive HELLO messages within one-hop neighborhood to obtain the neighborhood information.

7.1.14.3 Signal Received but with Errors

Number of incoming signals the radio failed to receive. PHY model is a simple radio model that supports either Signal-to-Noise Ratio (SNR) or Bit Error Rate (BER) based reception.

7.1.14.4 Signal Received and Forwards to MAC:

Number of incoming signals successfully received and forwarded to MAC.

7.1.14.5 Power Consumption

This is the ratio of the average power consumed in each node to total power. The lifetime, scalability, response time and effective sampling frequency, all of these parameters of the wireless sensor network depend upon the power. Power failure regularly breaks in the network. Power is required for maintaining the individual health of the nodes, during receiving the packets and transmitting the data as well.

7.1.14.6 Power Consumed in Transmit Mode

A node is said to be in transmission mode when it sends data packet to other nodes in network. These nodes require energy to transmit data packet, such energy is called Transmission Energy (Tx), of that nodes. Transmission energy is depended on size of data packet (in Bits), means when the size of a data packet is increased the required transmission energy is also increased. The transmission energy can be formulated as:

$$Tx = (330*P_{length})/2*10^6$$

or

$$P_T = T_x / T_t$$

Where T_x is transmission Energy, PT is Transmission Power, T_t is time taken to transmit data packet and P_{length} is length of data packet in Bits [8].

7.1.14.7 Power Consumed in Received Mode

When a node receives a data packet from other nodes then it said to be in Reception Mode and the energy taken to receive packet is called Reception Energy (Rx), Then Reception Energy can be given as:

$$R_x = (230 * P_{length})/2*10^6$$

or

$$P_R = R_x / T_r$$

Where R_x is a Reception Energy, P_R is a Reception Power, T_r is a time taken to receive data packet, and P_{length} is length of data packet in Bits.

7.1.14.8 Power Consumed in Idle/Sleep Mode

The node is neither transmitting nor receiving any data packets. But this mode consumes power because the nodes have to listen to the wireless medium continuously in order to detect a packet that it should receive, so that the node can then switch into receive mode from idle mode.

$$P_I = P_R$$

Where P_I is power consumed in Idle Mode and P_R is power consumed in Reception Mode [223].

7.1.15 Simulation Results

7.1.15.1 TC Message Received

- Fig. 7.4 shows the impact variation of TC Message received with in modified OLSR routing protocol as parameter and also variation in no. of nodes. Following inference can be made:

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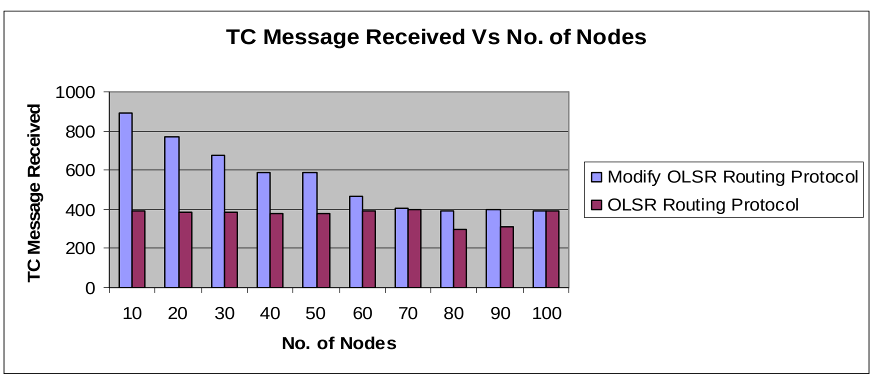

Fig. 7.4 TC Message received with varying nodes and OLSR & Modify OLSR routing protocols

- By observation from graph and analysis of designed scenario observation efforts trying minimize the link failures between nodes, so lifetime of nodes increases, and also saves power consumption. Hence overall performance of power may increases. In modified OLSR link failure less as compare OLSR routing

- The maximum transmission rates also increase in modified OLSR and consume less power by OLSR.

7.1.15.2 Hello Message Received

- Fig. 7.5 shows the impact variation of Hello message received with in modified OLSR routing protocol as parameter and also variation in no. of nodes. Following inference can be made:
- By observation from graph and analysis of designed scenario observation efforts for trying minimize the time interval between the nodes for sending information, so lifetime and scalability of nodes increases, and also saves power consumption. In modified OLSR the message send ratio increases with time and also increases message sending ratio as compare OLSR routing.

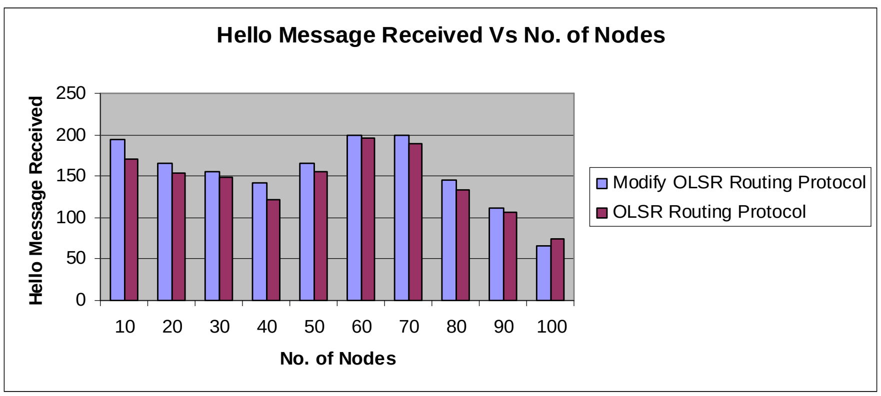

Fig.7.5 Hello Message received with varying nodes and OLSR & Modify OLSR routing protocols

7.1.15.3 Signal Received but with Errors

Fig. 7.6 shows the impact variation of Signal Received but with errors in modified OLSR routing protocol as parameter and also variation in no. of nodes. Following inference can be made:

- By observation from graph and analysis of designed scenario observation efforts for trying minimize the errors when 1 mbps data received from source node to destination. In modified OLSR the errors less then as compare OLSR routing

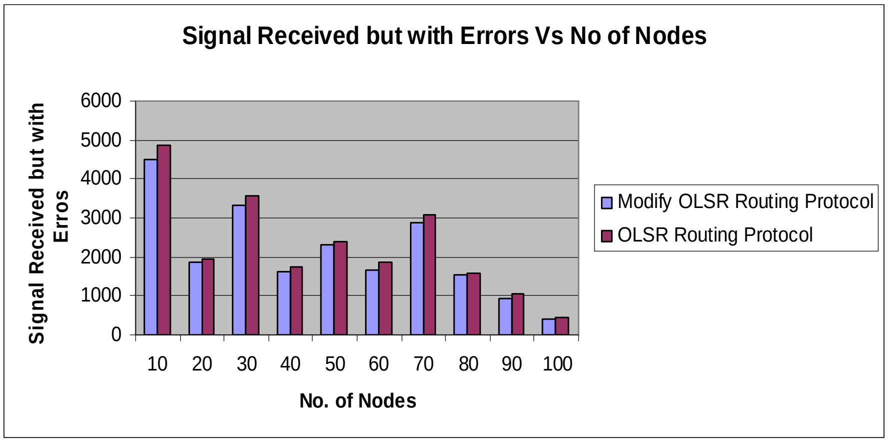

Fig. 7.6 Signal received but with errors with varying nodes and OLSR & Modify OLSR routing protocols.

7.1.15.4 Signal Received and Forwards to MAC

Fig. 7.7 shows the impact variation of Signal received and forwards to MAC in modified OLSR routing protocol as parameter and also variation in no. of nodes. Following inference can be made:

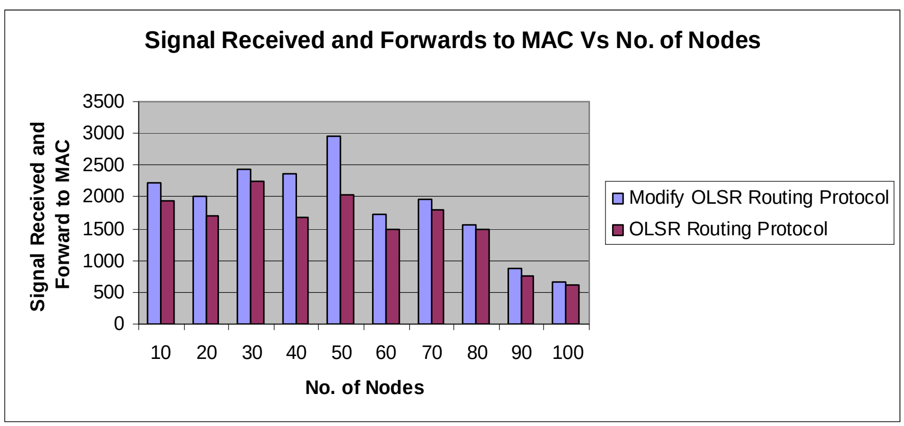

Fig. 7.7 Signal received and forwards to MAC with varying nodes and OLSR &Modify OLSR routing protocols

- By observation from graph and analysis of designed scenario observation efforts for trying incoming signals received from source node to destination
- Nodes are successfully received and forwarded to MAC. In modified OLSR the received signals more then as compare OLSR routing.

7.1.15.5 Power Consumed in Transmit Mode

- Fig. 7.8 shows the impact variation of Power consumption in transmit mode with modified OLSR routing protocol as parameter and also variation in no. of nodes. Following inference can be made:
- By observation from graph and running scenario the maximum power consumed when distance of nodes is longer, hence overall performance of power manage of modified OLSR consumes less power as compare OLSR routing.
- The maximum power consumes by OLSR which is tailed by manage OLSR routing protocol.

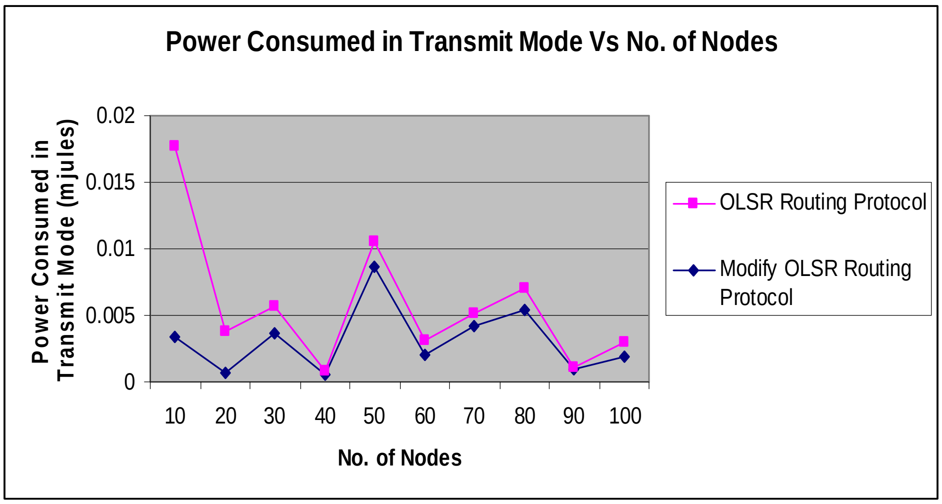

Fig.7.8 Power consumption in transmit mode with varying nodes and OLSR & Modify OLSR routing protocols

7.1.15.6 Power Consumed in Received Mode:

Fig. 7.9 shows the impact variation of Power consumption in receive mode with modified OLSR routing protocol as parameter and also variation in no. of nodes. Following inference can be made:

- On analyzing the results for energy consumption in receive mode it has been concluded that modified OLSR consumes less power as compare to OLSR routing protocol.
- Maximum average power consumes when long distance nodes communicate each other as observing graph and scenario in Fig 7.9

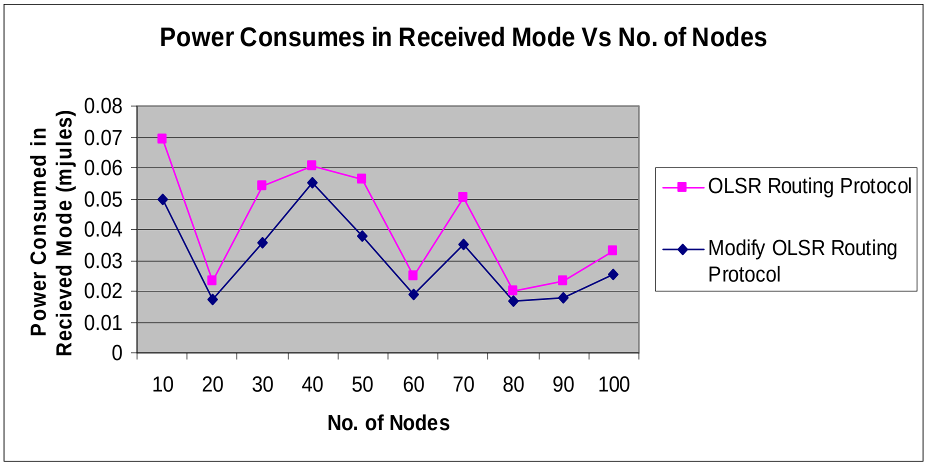

Fig.7.9 Power consumption in received mode with varying nodes in OLSR Modify OLSR routing protocols.

7.1.15.7 Power Consumed in Ideal/Sleep Mode

Fig. 7.10 shows the impact variation of Power consumption in idle/sleep mode with modified OLSR routing protocol as parameter and also variation in no. of nodes. Following inference can be made:

- By observation from graph and running scenario the overall power consumed when distance of nodes is longer, hence overall performance of power manage by modified OLSR consumes less power as compare OLSR routing.
- The maximum power consumes by OLSR which is tailed by manage OLSR routing protocol.

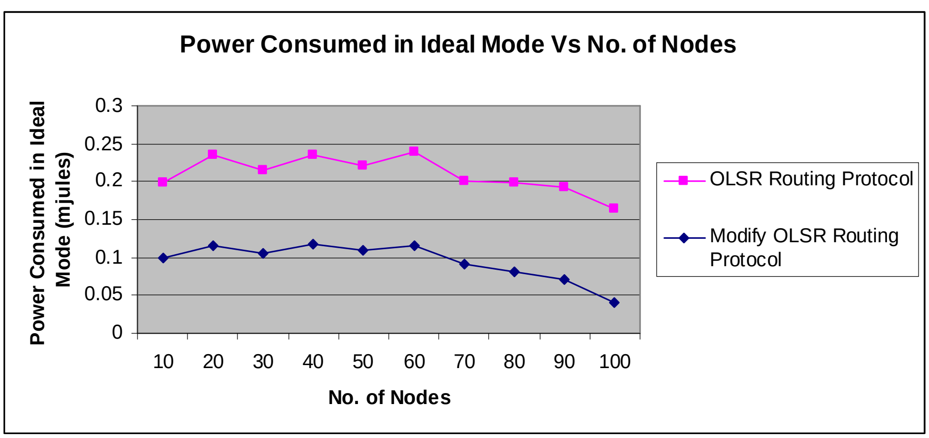

Fig. 7.10 Power consumption in ideal mode with varying nodes and OLSR & Modify OLSR routing protocols

7.1.16 Conclusion

In this chapter, the important issue of power management in Optimized Link State Routing (OLSR), mobile ad-hoc wireless network is discussed. Since mobile nodes have limited battery lives, mobile networks should consume battery power more efficiently to maximize the network life, battery power capacity, transmission power consumption, stability of routes etc. We efforts to solve the problem of reduce the power consumption through power management issues in mobile ad hoc network by modified Optimized Link State Routing (OLSR) protocol and results shown as above. The modified OLSR routing protocol to minimize control traffic, periodic TC messages update, remaining battery power capacity, controlling the battery discharge to improve the power consumption in all modes. The future scope of this protocol is to successfully simulate it for a very large network and implement it with a voice application.

Two papers are produced out of research work carried in this section of thesis.

[1] Dharam Vir, S.K.Agarwal , S.A.Imam "A Dynamic Approach to Optimize Energy in RIP, OLSR and Fisheye Routing Protocols using Simulator" International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) www.ijarcet.org, ISSN: 2278 – 1323, Volume 2 Issue 8, August 2013, pp 2526-2532.

[2] Dharam Vir, S.K.Agarwal, S. A. Imam "Power Management in Optimized Link State Routing (OLSR) Protocol" in International Journal of Modern Engineering Research (IJMER) ISSN: 2249-6645, Volume 3, Issue 1, Jan-Feb. 2013, PP. 275-283.

Chapter 8

CONCLUSION AND FUTURE SCOPE

This chapter gives a conclusion and future scope of WANET for increasing network lifetime of nodes in network. Because reducing power consumption in WANETs has received increased attention among researchers in recent years. Several efficient power aware routing protocols have been developed for mobile networks. To reduce total transmission power and prolong the lifetime of each node. Here conclusion and future scope of all chapters includes in this thesis is described below.

8.1 CONCLUSION

This dissertation work investigates the performance of various categories of routing protocols. It provides an in depth analysis of these categories and provides us with the best routing strategy. In addition, few modifications are done at MAC and network layers in order to improve the network lifetime. The following points can be inferred from the results and analysis as follows:

- The OLSR protocol is the best among all studied in this dissertation. It can be seen that to have better performance Omni-directional antenna and the nodes having mica-motes energy model and RWP mobility reduces power consumption by 15%.
- The communication between power deficient nodes prevails even if we have 10% of selfish nodes.
- The communication never halts even if all the nodes are selfish or power deficient as can be seen from our results.
- The proposed Sleep/Idle Optimized power model and modifications in periodic update messages improves the network lifetime to quite an extent as can be seen from our results.
- The modified OLSR protocol saves about 12-15% battery power in comparison to OLSR protocol. Not only this, it provides better result in comparison to LEACH protocol. The modified OLSR also provides better throughput also.

- The two commonly used protocols RIP_{V2} and $OSPF_{V2}$ are compared and analyzed. The result shows that the RIP_{V2} protocol consumes lesser power in receive and transmit mode in comparison to $OSPF_{V2}$.

These results can be very fruitful for researchers working in this direction.

8.2 FUTURE RESEARCH

In the future, we will try to investigate practical power aware traffic engineering and network design methods, and to modifications in network protocols that will reduce power consumption. The future scope of the proposed work can be to implement this protocol in real environment and to confirm the simulation results. The proposed protocol has been an extension to the conventional RIP_{V3} and $OSPF_{V3}$ protocols, the power model and other proposed strategies can also be incorporated in the other routing protocols such as LEACH, LANMAR, $OLSR_{V2}$ etc. While these protocols performing the experimental studies in the MATLAB and QualNet simulation software environment.

In this research work various categories of routing have been investigated. In addition, modifications in current routing strategies have been proposed in order to improve network lifetime. Still there are areas that need to be taken care of as follows:

- The protocols are only tested on QualNet Simulator. The protocol needs to be tested in realistic conditions.
- Major overhead in network layer protocols is of control messages. If these packets are kept to minimal in number, the power consumption can be further reduced.
- A very important issue that has to be addressed is the security and trust in Ad-hoc networks. Applications like Military and Confidential Meetings require high degree of security and trust against enemies and active /passive eavesdropping attackers.
- An important issue that needs to be addressed is QoS routing. Work needs to be done in this direction.
- Battery power is a major constraint in nodes of MANET. Work needs to be done in order to have battery with longer lifetime.
- Newer operational demands on WANETs (wireless sensor network and ad-hoc network) are going to bring in new trends and information in the research field

towards designing robust protocols, and Wireless Communication keeps on developing forever making the research an endless paradigm.

- Routing overhead reduces to utilize most of the precious bandwidth of Ad hoc networks a new protocol has to be devised to reduce the routing overhead.
- A routing protocol must work with robust scenarios where the amount of traffic is more, mobility is high, nodes are dense and area is large.

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BRIEF PROFILE OF THE RESEARCH SCHOLAR

The content of this page gives the brief introduction of the author is presented.

DharamVir (dvstanwar@gmail.com) received the M.Tech Degree form MDU Rothak (Haryana) and B.E Degree in Electronics and Communication Engineering from Jamia Millia Islamia, Central University, New Delhi 2008, 2004 respectively. He started his carrier as R&D Engineer in the field of computers and networking, since 1992, he is the part of YMCA University of Science & Technology as Head of Section (Electronics Inst. & Control) in the Department of Electronics Engineering. He is pursuing Ph.D in the field of Power aware routing in Mobile Ad hoc Networks. Presently he is working in the field of performance improvement in MANET routing (Power aware routing protocol), his current interest in power control in wireless network system, wireless communication, computer networks.

LIST OF PUBLICATIONS

Paper Published In International Journals: 38

International IEEE Conference: 4

Communicated Papers: 5

List of Published Papers

Sl. No.	Title of Paper	Name of Journal where published	ISBN /ISSN No.	Volume & Issue	Year	Pages
1.	Analysis and Evaluation of MANET Routing Protocol for Varying Mobility Model using QualNet Simulator 5.0	WNTES 2012		1 & 1	July 2012	
2.	Performance Simulation of E^2 Analysis for Energy Models of Mobile Ad-Hoc Network using QualNet Simulator	International Journal of Future Computer and Communication (IJFCC) www.ijfcc.org& DOJ Indexed	ISSN: 2010-3751 DOI: 10.7763/IJFCC.2013.V2.141	1& 2	August 2012	85-90
3.	Performance Analysis of MTPR Routing Protocol in Power Deficient Node	International Journal on Ad Hoc Networking Systems (IJANS) http://airccse.org& DOJ Indexed	DOI : 10.5121/ijans.2012.2407	2 & 4	October 2012	67-75
4.	Evolving energy and efficiency of protocols node in given RWP mobility in MANET	International Journal of Computer Science and Information Security (IJCSIS) https://sites.google.com/site/ijcsis	ISSN: 2276–8775	9 & 11	November 2012	125-134
5	Quantitative Analyses and Evaluation of MANET Routing Protocol in Effect of Varying Mobility Model using QualNet Simulator	2012 world Congress on Information and Communication Technologies, IEEE Xplore	978-1-4673-4805-8/12/$31.00@2012		October 2012	915-921

6	A Simulation Study on Node Energy Constraints of Routing Protocols of Mobile Ad hoc Networks use of QualNet Simulator	International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering http://www.ijareeie.com& DOJ Indexed ISO : 3297-2007	ISSN: 2278–8875	1 & 5	November 2012	401-410
7	Performance Evaluation of Energy Traffic In Ipv6 Networks	International Journal Of Computational Engineering Research (IJCER) www.ijceronline.com & DOJ Indexed	ISSN: 2250-3005	2 & 8	December 2012	222-231
8	Traffic based Energy Consumption Simulation of Reactive, Proactive and Hybrid protocols for Mobile Ad hoc Network	International Journal of Computer Networks (IJCN), http://www.cscjournals.org& DOJ Indexed	ISSN: 2180-1223	4 & 6	December 2012	431-442
9	Simulation of energy consumption analysis of multi-hop 802.11 wireless ad-hoc networks on reactive routing protocols	International Journal of Engineering Research and Applications (IJERA) www.ijera.com& DOJ Indexed ISO : 3297-2007	ISSN: 2248-9622	3 & 1	January 2013	1213-1218
10	Investigation on Aspects of Power Consumption in Routing Protocols of MANET using Energy Traffic Model	International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering http://www.ijareeie.com& DOJ Indexed ISO : 3297-2007	ISSN: 2278-8875	2 & 1	January 2013	590 - 598

11	Performance Analysis Of Effect Of Directional Antennas On Energy In Routing Protocol	International Journal of Engineering Research and Applications (IJERA) www.ijera.com& DOJ Indexed ISO : 3297-2007	ISSN: 2248-9622	3 & 1	February 2013	238-244
12	Investigation on Power Awareness in $OSPFV_2$ and $RIPV_2$ routing Protocol in Wireless Sensor Networks	International Journal of Science and Research (IJSR) www.ijsr.net & DOJ Indexed	ISSN: 2319-7064	2 & 2	February 2013	260-265
13	Power Management in Optimized Link State Routing (OLSR) Protocol	International Journal of Modern Engineering Research (IJMER) http://www.ijmer.com & DOJ Indexed	ISSN: 2319-7064	2 & 2	February 2013	260-265
14	An Intelligent Gateway Scheme for Power Aware Routing in Mobile Ad Hoc Network	International Journal of Science and Research (IJSR) www.ijsr.net & DOJ Indexed	ISSN: 2319-7064	2 & 2	February 2013	564-570
15	Analysis of Power Control Mechanisms of MAC Protocol for wireless Sensor Networks	International Journal of Science and Research (IJSR) www.ijsr.net & DOJ Indexed	ISSN: 2319-7064	2 & 3	March 2013	450 – 456
16	Performance Analysis of MANET with Low Bandwidth Estimation	International Journal of Scientific and Research Publications (IJSR) www.ijsr.net & DOJ Indexed	ISSN: 2319-7064	3 & 3	March 2013	1-5
17	Simulation Analysis of AODV, DSR and ZRP Routing Protocols in MANET using QualNet 5.0 Simulator	International Journal of Scientific and Research Publications (IJSRP) www.ijsrp.org&DOJ	ISSN: 2250-3153	3 & 3	March 2013	1-6

		Indexed				
18	Investigation on Performance of Trust Based Model and Trust Evaluation of Reactive Routing Protocols in MANET	International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) www.ijarcet.org& DOJ Indexed	ISSN: 2278-1323	2 & 3	March 2013	875-880
19	Performance Comparison on Trust Based Power Aware Reliable On Demand Routing Protocol	IOSR Journal of Computer Engineering (IOSR-JCE) www.iosrjournals.org & DOJ Indexed	e-ISSN: 2278-0661, p-ISSN: 2278-8727	9 & 4	April 2013	37-45
20	Energy consumption between Gateways of Ad-hoc and other Networks	International Journal of Application or Innovation in Engineering & Management (IJAIEM) www.ijaiem.org& DOJ Indexed	ISSN: 2319-4847	2 & 3	April 2013	176-186
21	Analysis Design Performance of Microprocessor based Multilevel Inverter	International Journal of Science and Research (IJSR) www.ijsr.net & DOJ Indexed	ISSN: 2319-7064	2 & 4	April 2013	6-12
22	Simulation Aspects of Thyristor Controlled Series Compensator in Power System	IOSR Journal of Engineering (IOSRJEN) www.iosrjen.org& DOJ Indexed	e-ISSN: 2250-3021, p-ISSN: 2278-8719	3 & 4	April 2013	17-26
23	Power Control and Performance Improvement of Reactive Routing Protocols using QualNet Simulator	International Journal of Application or Innovation in Engineering	ISSN: 2319-4847	2 & 4	April 2013	175-184

		&Management www.ijaiem.org& DOJ Indexed				
24	Traffic based energy consumption analysis and improve the lifetime and performance of MAC protocols in ad hoc wireless sensor networks	International Journal of Engineering Research and Applications (IJERA) www.ijera.com& DOJ Indexed ISO : 3297-2007	ISSN: 2248-9622	3 & 3	May 2013	335-340
25	Analysis of Power Flow Control in Power System Model using Thyristor Controlled Series Capacitor (TCSC)	International Journal of Engineering Research and Applications (IJERA) www.ijera.com& DOJ Indexed ISO : 3297-2007	ISSN: 2248-9622	3 & 3	May 2013	821-826
26	Modulation and Control design aspects of Microprocessor Based Multilevel Inverter	International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE) http://www.ijareeie.com& DOJ Indexed	ISSN: 2278-8875	2 & 5	May 2013	1713-1723
27	Analysis on Open-Source Networks of MAC, Energy Model for IEEE 802.11 standards using QualNet Simulator	International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE) http://www.ijareeie.com& DOJ Indexed ISO : 3297-2007	ISSN: 2278-8875	2 & 5	May 2013	1781-1792

28	Productivity Analysis of Reactive Routing Protocol for IEEE 802.11e standard using QualNet Simulator	International Journal of Engineering Research and Applications (IJERA) www.ijera.com& DOJ Indexed ISO : 3297-2007	ISSN: 2248-9622	3 & 3	May-Jun2013	1190-1196
29	The Performance Evaluation of Bellman-Ford and ZRP Routing Protocols in MANETs using QualNet 5.0 Simulator	International Journal of Computer Science And Technology (IJCST) www.ijcst.com& DOJ Indexed	ISSN: 0976-8491	4 & 2	June 2013	70-81
30	Power Analysis and Comparison of Reactive Routing Protocols for Cognitive Radio Ad Hoc Networks	International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE) http://www.ijareeie.com& DOJ Indexed ISO : 3297-2007	ISSN: 2278-8875	2 & 7	July 2013	3083-3095
31	Performance Evaluation and Investigation of Energy in AODV, OLSR Protocols through Simulation	International Journal of Application or Innovation in Engineering & Management www.ijaiem.org& DOJ Indexed	ISSN: 2319-4847	2 & 7	August 2013	80-87
32	Traffic Generator Based Power Analysis of Different Routing Protocol For Mobile Nodes in Wireless Sensor Network Using QualNet	International Journal of Engineering Research and Applications (IJERA) www.ijera.com& DOJ Indexed	ISSN: 2248-9622	3 & 4	August 2013	2548-2554

		ISO : 3297-2007				
33	A Dynamic Approach to Optimize Energy in RIP, OLSR and Fisheye Routing Protocols using Simulator	International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) www.ijarcet.org& DOJ Indexed	ISSN: 2278-1323	2 & 8	August 2013	2278–1323
34	A Novel Approach of Power Management in Zone Routing Protocol (ZRP) Through Simulation	International Journal of Application or Innovation in Engineering & Management www.ijaiem.org& DOJ Indexed	ISSN: 2319-4847	2 & 11	November 2013	47-56
35	WSN Performance Evaluation of Power Consumption Analysis of DSR, OLSR, LAR and Fisheye in Energy Model through QualNet	International Journal of Scientific and Research Publications (IJSRP) www.ijsrp.org& DOJ Indexed	ISSN: 2250-3153	3 & 12	December 2013	1-6
36	Investigation Energy Aspects of AODV, STAR, RIP and ZRP Routing Protocols of WSN using Transmission Traffic Mode CBR and VBR	International Journal of Advanced Communication Technology (IJACT) www.ijact.org	ISSN: 2278-1323	3 & 5	jan 2014	31-41
37	Simulation Analysis of Different Routing Protocols Using Directional Antenna in QualNet 6.1	International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, http://www.ijareeie.com,	ISSN: 2278-8875	3 & 5	May 2014	9408-9414

38	Maximizing the Lifetime of Energy-Efficient Hierarchical Cluster-Based Routing in Wireless Sensor Networks	International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, http://www.ijareeie.com	ISSN: 2278-8875		Nov. 2014	

List of Accepted Papers

Sl. No.	Title of Paper	Name of Journal where accepted	No.	Volume/ Issue Present Status	Year
1.	A simulation based performance analysis of MANET routing protocol in effect of RWP mobility model and network size	25th IEEE Chinese Control and Decision Conference, (2013CCDC), China		Paper Accepted	October 2012
2	Impact of Mobility Model on Table Driven Routing Protocols of MANET	8th IEEE conference on Industrial Electronics and Application, (ICIEA 2013) Melbourne, Australia		Paper Accepted	January 2013
3	Power Saving and Energy optimization Techniques in 802.11 MAC Protocol in WSN using Simulator	26th IEEE Chinese Control and Decision Conference, (2014CCDC), China		Paper Accepted	May 2014
4	Maximizing the Lifetime of Energy-Efficient Hierarchical Cluster-Based Routing in Wireless Sensor Networks	International Journal of Advanced Research in Computer Science and Software Engineering (IJARCSSE).	ISSN 2277-128X	Paper under Print	February 2014

List of Communicated Papers

Sl. No.	Title of the Paper	Name of Journal	Present Status	Year
1	Investigation on Performance Effect of Inter Packet Delay in Coexistence Diverse Wireless Network	27th Chinese Control and Decision Conference (2015CCDC) http://www.ccdc.neu.edu.cn	Under Review process	Papers send on 2-8-2014.
3	A Novel Approach for Improving Link Stability of Hybrid Multicasting Mesh Networks Routing Protocols in Manets	I.J.Computer Network and Information Security, Published Online MECS (http://www.mecs-press.org/) DOI: 10.5815/ijcnis.	Under Review process	Papers send on 18-9-2014.
4	Energy Efficient Cluster Based Multihop Routing For Wireless Sensor Network	International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, http://www.ijareeie.com	Under Review process	Papers send on 2-10-2014
5	Performance Evaluation & Investigation of Remote Controlled Actuators of a Petroleum Pipe Line	Springer	Under process	Papers send on 24-10-2014