Neural Network Based Power Control Algorithms for Mobile Ad-hoc Networks

A Thesis
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DOCTOR OF PHILOSOPHY

Submitted by

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CERTIFICATE

Certified that the thesis entitled "NEURAL NETWORK BASED POWER CONTROL ALGORITHMS FOR MOBILE AD-HOC NETWORKS", which is being submitted by Mr. Krishan Kumar (Registration Number-950803003), to the computer Science and Engineering Department, Thapar University, Patiala, in fulfillment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY, is a record of bonafide research work carried out by him under my guidance and supervision. The matter presented in this thesis has not been submitted either in part or full to any other University or institute for award of any degree.

(Dr. V.P. Singh)
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Supervisor

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Dated: March 26, 2014

Place: Thapar University, Patiala

(Krishan Kumar)

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NOTATIONS AND ABBREVIATIONS

ABR	Associatively Based Routing
AODV	Ad hoc On Demand Distance Vector
CBRP	Cluster Based Routing Protocol
CGSR	Clusterhead Gateway Switch Routing
DSDV	Destination Sequenced Distance Vector
DSR	Dynamic Source Routing
GMIS	Global Mobile Information System
IE	Initial Energy
MANET	Mobile Ad-hoc Network
NTDR	Near-Term Digital Radio
PDR	Packet Delivery Ratio
RDMAR	Relative Distance Micro-discovery Ad-Hoc Routing
Re	Remaining Energy
Rp	Routing Protocol
RTR	Request To Receive Message
Rxe	Receiving Energy
TCP	Transmission Control Protocol
Te	Transition Energy
TORA	Temporally Ordered Routing Algorithm
Txe	Transmission Energy
WRP	Wireless Routing Protocol
ZRP	Zone Routing Protocol
NN	Neural Network
RBFNN	Radial Basis Function Neural Network

ABSTRACT

This research work presents the ability of simulators in analysis and determination of energy consumption for mobile ad-hoc network. New energy computation methods are developed with neural network. Proposed neural network models are used to overcome the problem of simulator for energy computing due to its complex procedure in measurement of energy consumption values for mobile ad-hoc networks.

Mobile ad-hoc network is a special type of wireless ad-hoc network due to its infrastructure and nature of operation. Nodes or devices are moving or changing positions frequently and act as routers in the mobile ad-hoc network. Nodes are communicating with each other through wireless mode without any physical hardware support while moving. Network's topology is changing rapidly and unpredictably and nodes are operated with limited battery in the mobile ad-hoc network. Power control is the necessity for ad-hoc network to run mobile nodes for long periods. Energy optimization is possible by power saving and power control in mobile ad-hoc network. Power saving means to reduce power consumption and power control means to adjust transmission power of mobile nodes to minimize energy consumption in mobile ad-hoc network. Power control reduces data retransmission probability with a good assignment of transmission power and node guarantees it transmission in a low number of attempts. Main focus on the energy consumption not only because that it is the key issue in the mobile ad-hoc network, but also, it is observed from practical experiments that energy consumption problem also affects network performance metrics for the mobile ad-hoc network. Power is consumed even if the frame is not used by the nodes because it was intended for another destination in network. Nodes have consumed energy even if intermediate nodes are not in the communication radio range of each other and need to rely on multi hop transmissions in network. Transmission with optimum transmission energy of nodes is used to reduce the energy consumption of nodes in mobile ad-hoc network. Transmission energy is inversely proportional to remaining energy of nodes in the network. Remaining energy is the energy of the nodes after transreceiving data in mobile ad-hoc network. Simulators are used for analysis of energy consumption among

nodes in the network. Simulator is more time consuming and complex procedure to test data for any unknown value, once program run in the simulation environment.

Neural network model is a mathematical model to determine the node energy consumption for any unknown value in an ad-hoc network. This model is alternative solution of simulator for energy computation in ad-hoc network. A neural network concept is approaching to estimate the energy consumption and reduce the complexity in computation of power consumption with simulator for mobile ad-hoc network.

The main contributions of this study are as follows:

Energy management model is developed with simulator to identify the parameters that affect the energy consumption and determine the remaining energy of mobile nodes in mobile ad-hoc network. Network density, transition energy and time are the factors to maintain remaining energy of nodes in mobile ad-hoc network.

Power control model with slots scheduling is developed. Simulator is used to know the battery power consumption of nodes during transmission of slots in mobile ad-hoc network. Data packets are transmitted with scheduling function due to multi-hops communication in the mobile ad-hoc network. Node transmits frames using the pre-assigned time slots to avoid the collision and retransmission of data packets in mobile ad-hoc network. Node battery power consumption is reduced and network performance is increased with this proposed power control model. Slot based scheduling is better due to better performance as compared to other model in case of packet delivery ratio, end to end delay and network density.

Power control model with simulator is developed on the basis of variable transmission range among the nodes for mobile ad-hoc network. This model is developed to know the relation between transmission power and remaining energy. Near optimal transmission radius is used by each node in the mobile ad-hoc network. Packets are transmitted with optimum transmission power in the network. The communication range affects the energy consumption in mobile ad-hoc networks.

Neural network models are developed with radial basis function neural network to compute the energy consumption for the mobile ad-hoc network. Models are developed on the basis of ad-hoc network parameters that affect energy consumption in the mobile ad-hoc network. **N**etwork density, receiving energy and transition energy are identified as main parameters affects energy consumption and considered as input value. First model is developed on the basis on network density. Network density is the parameter that affects energy consumption in the network. Second model is developed on the basis of receiving energy. Receiving energy is the factor that affects remaining energy of nodes in the network.

Third model is developed on the basis of transition energy. Transition energy is important factor due to switching by nodes to save power in the network. Remaining energy of nodes is considered as main target in three network model.

The Summary of thesis is as follows:

This thesis is divided in to seven chapters. First chapter is about the introduction of mobile ad-hoc network in this thesis. Importance of power control schemes is explained to know about the optimization of energy for mobile ad-hoc network in this research work. Second chapter is focus on literature survey and divided into seven sections. Each section described the survey on power control related to energy consumption in mobile ad-hoc network. Third chapter presents the energy management model. Energy saving factors are identified with this model for mobile ad-hoc network. Fourth chapter is based on power consumption based simulation model for mobile ad-hoc network. Fifth chapter is focus on energy management with variable transmission energy of nodes in network. Sixth chapter presents the neural network model for computation of energy consumption among nodes based on energy management model in mobile ad-hoc network. This model is developed based on the results of simulation model for mobile ad-hoc network. Seventh chapter conclude and provide the future scope of this research work.

CHAPTER 1

MOBILE AD-HOC NETWORKS

CHAPTER 1

MOBILE AD-HOC NETWORKS

1.1 Introduction

Wireless ad-hoc network is unique type of network due to lack of its fixed infrastructure. Nodes itself act as router and link with other without any central transmitter and receiver points, in an ad-hoc network. Mobile ad-hoc network is a mobile type of network. Nodes in mobile ad-hoc network are communicating with each other through wireless mode while moving. This network is a self-configuring network of router connected by wireless link. The nodes are free to move and keep organizing in a dynamic fashion. Network's topology is getting changed unpredictably in the network.

Ad-hoc networks are designed with any wireless technology like infrared and Bluetooth etc. Multilayer’s functions are maintained by ad-hoc network. A fast change in link characteristics is adapted by physical layer in mobile ad-hoc network. Collisions are avoided by multiple access control layer. It is used to allow fair access over the shared wireless links in the mobile ad-hoc network. Network layer is used to distribute the information in the network. It is used to perform task such as self configuration in changing environment. The transport layer is used to control delay that is different than infrastructure networks and sharply delink or link with nodes are maintained by application layer. This layer also deals with widely varying delay and packet loss characteristics in the mobile ad-hoc networks. Mobile Ad-hoc networks are mostly used where network deployment is not available [95].

Mobile ad-hoc networks are future network due to bandwidth based applications and the architectures. Higher bandwidth is the main factor for accountability of any ad-hoc network. The main demand of mobile ad-hoc networks arises from the fast developments and expectations from wireless communications in the world. It is observed that sizes of mobile nodes are getting smaller and cheaper in the ad-hoc network. New research or idea in mobile ad-hoc network is coming from exploitation of wireless communication network for better design and development in future. Smart antennas are being used for discovery of neighbor nodes in ad-hoc network. An advance digital modulation scheme and spectrum code used at higher layer is a great achievement in mobile ad-hoc network.

1.1.1 Development in Wireless Ad-hoc Network

The concept of ad-hoc network was discussed in the year 1980s with the packet radio network. The objective of this program was to use packet switching type communication network for mobile battlefield elements in an infrastructure less, hostile environment for examples soldiers, tanks etc. The packet radio network is based on carrier sense multiple access methods for medium access and routing. The initially designed and developed routing protocols were highly scalable. Ad-hoc network was started in the year 1990s. The ad-hoc networking had further increased the demand of network communication in the world.

Other fields and protocols were used for development of mobile ad-hoc network. Global Mobile Information Systems and the Near-Term Digital Radio were started by department of defense in United States of America. The objective of Global Mobile Information Systems was to provide services with handheld devices anytime, anywhere. Clustering and link state routing are used by Near-Term Digital Radio in an ad-hoc network. Near Term Digital Radio is used by the United State army. Commercial standards were required with the growing interest in ad-hoc networking in the mid to late 1990s. Mobile ad-hoc networking group got instantiated and tried to standardize routing protocols for networks. Researchers are working on ad-hoc routing protocols for the development of ad-hoc network [120].

1.2 Wireless Ad-hoc Networks Classification

Wireless nodes are used to forward packets in the wireless ad-hoc networks. The ad-hoc networks do not require any special infrastructure or hardware. Important classes of Ad-hoc network can be categorized as Mobile Ad-hoc Networks**,** Mesh Ad-hoc Networks and Sensor Ad-hoc Networks. Mobile ad-hoc network is group of mobile nodes and linked with each other by wireless links. The mobile nodes are free to move randomly and structure getting changed at high speed as shown in Figure 1.1. Such networks operate in an independent fashion in the absence of any centrally controlling node.

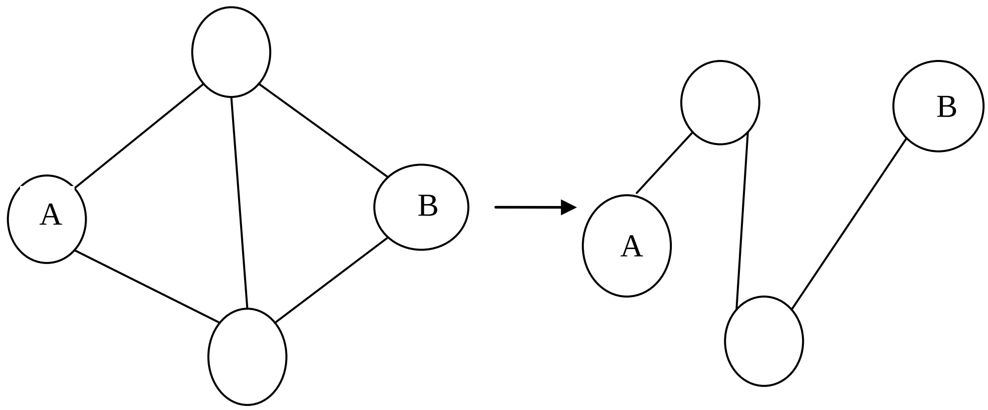


Figure 1.1: Mobile Ad-hoc Network

Mobile ad-hoc network do not depend on the fixed architecture and are lesser in size comparison to wired media. Networks have limited physical security, time varying channels and interferences. Mobile ad-hoc networks have many advantages with many design constraints. Ad-hoc networks are easily deployed. Planning of installation or wiring is not required in mobile ad-hoc network.

Wireless mesh ad-hoc network is more effective when a node connection goes failure. This network is self-healing in nature and reliable as compare to other networks. Network is made up of radio nodes and organized in a mesh structure as shown in Figure1.2. Network communication is possible in case of single node fails. This is possible with intermediate nodes in wireless mesh ad-hoc networks. This network was designed for military applications but has undergone significant evolution in the last few years. Radios with smart antennas are providing functions like client access for high speed handover in wireless mesh ad-hoc network.

Wireless mesh ad-hoc network technology is used to connect different networks and bring the dream of a connected world into reality. Nodes are interconnected with each other with the help of software in larger network. Packets are transmitted from source node to destination node with wireless link from one node to the next in mesh ad-hoc network. The nodes are used to select the best path using dynamic routing algorithms.

Wireless ad-hoc sensor network used sensors to cover geographical area as shown in Figure 1.3.

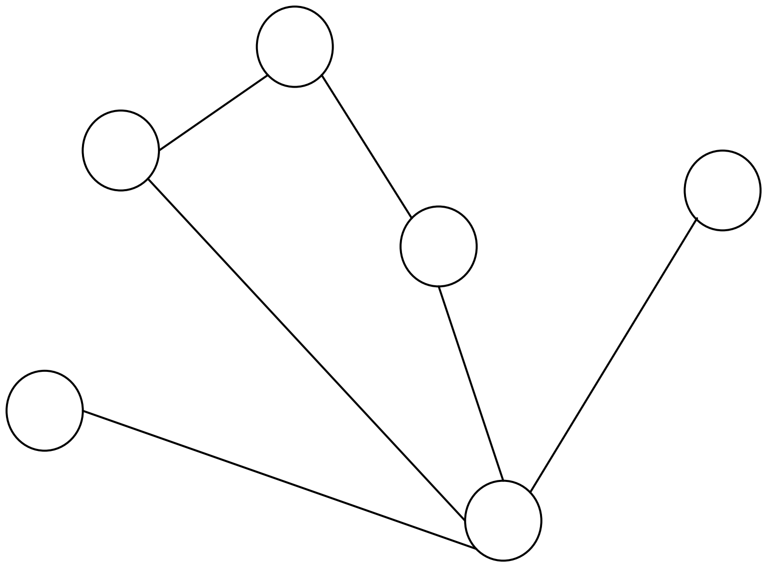


Figure 1.2: Wireless Mesh Ad-hoc Network

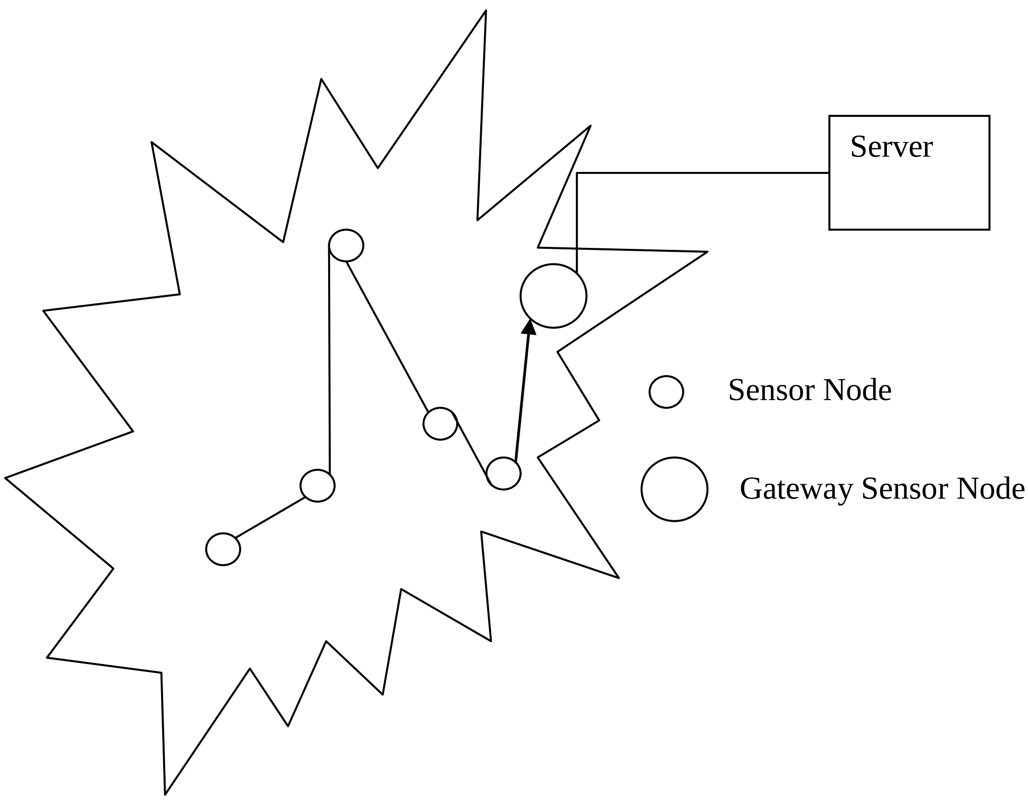


Figure 1.3: Wireless Sensor Ad-hoc Network

Sensor nodes are capable to setup communication and data networking in the network.

1.3 Energy Conservation

Mobile nodes are operated with batteries in mobile ad-hoc network. Limited power is an important factor to develop power control algorithms for ad-hoc network. A survey on improvements in battery technology shows that very little growth in the battery capacity is possible in future. It is more important to control power utilization, by node in the network. Energy saving is main target in ad-hoc networking, due to limited network life time and the extra energy requirements for other network operations inside nodes in the network. The importance of energy saving has increased the demand of research to extend the life time of nodes in ad-hoc networks. Energy saving is possible at different levels of a mobile nodes including mechanism at physical layer. Nodes functions are an important to control energy consumption in the network. Local strategies and global strategies may energy saving in ad-hoc networks.

Local strategies are used by nodes and transfer to power saving mode with negligible impact on the operations in the network. Power saving in carrier sense multiple access based protocols is achieved by applying local policies to the medium access control protocol. This scheme is used to control synchronization among the nodes in the network. Media access control protocol is used to identify intervals when network does not need to be in listening mode. Energy consumption is optimized with the help of medium access control. Main objective of this scheme was to increase the node lifetime without impact on the behavior of the protocols. Physical and medium access control layer are used to deals local policies in the network. This policy is efficient to control energy consumption and transmit the packet.

Global strategy is used to maximize the mobile ad-hoc network life time. Strategy is handling the network approach to save energy, when a network density is high, in term of nodes. A larger group of nodes is selected for this purpose and rest of the nodes is in the sleep state to increase the energy saving in the network. Nodes are participating in packet forwarding and compromising the connectivity among nodes in network. Communication among the nodes depends on the transmission power. Energy consumption gets increased by increasing the transmission power in ad-hoc network. This transmission power impacts energy consumption in mobile ad-hoc network. Nodes energy and links for each transmission are decided with transmission power in the network.

Transmission cost per packet is improved with improvement in data transmission power among of nodes in the network. It is necessary to decrease the number of links to reach the destination due to more number of links in mobile ad-hoc networks. Since nodes in network are limited battery powered. Battery power is a resource that is used effectively in order to avoid the early termination of nodes in ad-hoc network. Power management is associated with the selection of resources and controlling the transmission power to increase the life time of the networks [107].

1.4 Architecture

Structure of the network is changing dynamically in mobile ad-hoc network. Dynamic behavior is possible due to the mobility of the nodes in mobile ad-hoc networks. This network is used in random access wireless channel and cooperating in such fashion to engaging mobile nodes in multi-hop forwarding. Networks are capable of handling configuration very rapidly. Wireless ad-hoc networks take benefit of the independent characteristics of the wireless communication network.

1.4.1 Mobile Ad-hoc Network Architecture

Mobile ad-hoc network does not have any central access point. In this architecture, communication is done directly between the nodes in ad-hoc network. This type of network may be the only solutions where instant infrastructure is required and there is no central backbone system and administration do not exists. Interference and noise easily affects the communication between the nodes in the network. Networks do not require much maintenance. The transmission is not very secure but offers good speed and serves the requirement for communication among nodes in network. Mobile ad-hoc network does not have infrastructure support. Nodes communicating with each other may be come out of range in network. Routing procedure is required to select a path so as to transmit the packets appropriately between the nodes in network.

The nodes in the mobile ad-hoc network not only act as nodes but also as routers that route data to and fro other nodes in network. Figure 1.4 shows a mobile ad-hoc network of three nodes. Node 2 can directly communicate with node1 and node 3, but any communication between nodes 1 and 3 must be routed through node 2.

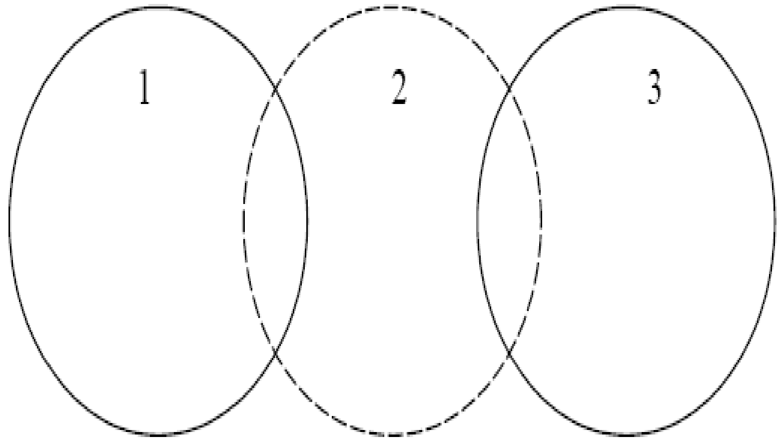


Figure 1.4: Ad-hoc Network with Three Nodes

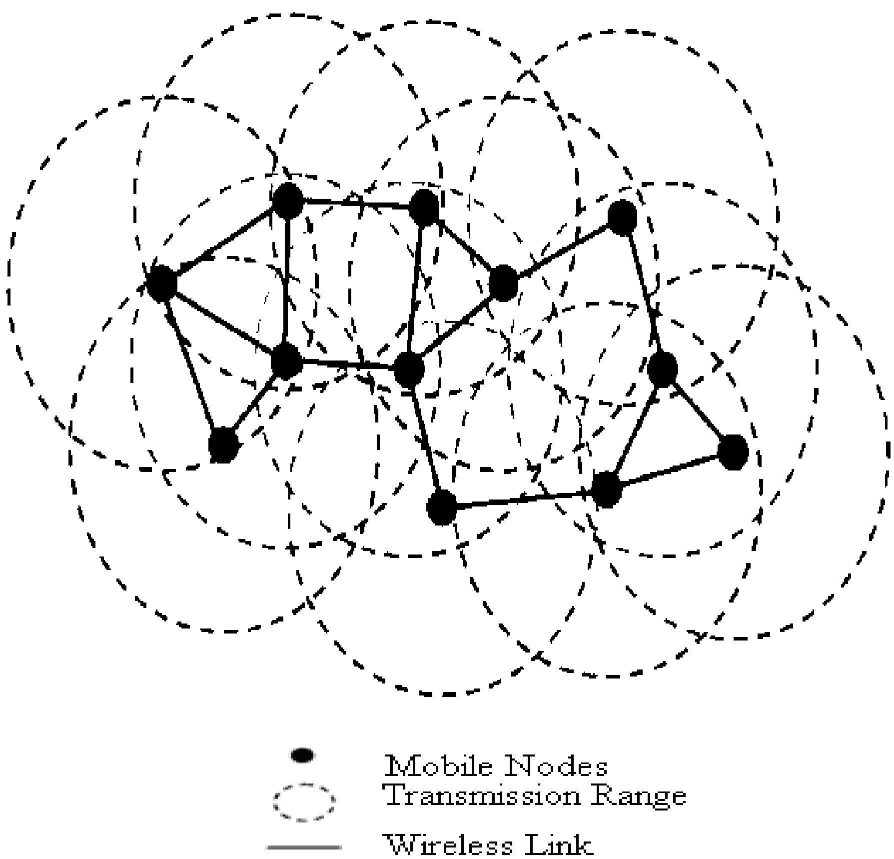


Figure 1.5: Network Topology

The communication among mobile nodes is possible with multi hops in the mobile ad-hoc network as shown in Figure 1.5. Mobile ad-hoc network is a group of two or more mobile nodes linked with wireless communications. This network is capable to create a link among nodes on the fly without any network infrastructure.

1.4.2 Routing Layout

A message flows through the layers in the following order:

Starting from the top layer, Application layer is used to provide information related to user interface to Routing Environment layer for selection of path and transfer information to Reliable Message Delivery for delivery layer of message and information flow to Routing Protocol and then information flow in reverse order from Reliable Message Delivery layer to Ad-hoc network through Routing Environment, Architecture is shown in Figure 1.6.

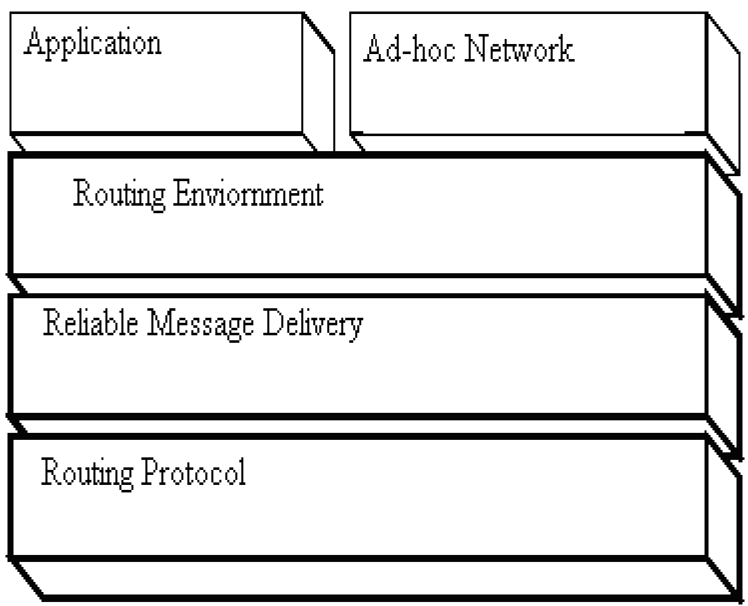


Figure 1.6: Routing Layout

Network layer is decides the routing of the packet through a communication network. Applications are placed on the top of all the layers and support for adaptive application that can control the variation in communication network characteristics**.** The main task of this layer includes data path decision and links between networks. Data link layer is used to provide a point to point communication or point to multipoint communication in the network. Physical layer of the receiver transforms the signals in to bits streams. The routes are decided based on links as well as delay in the network.

A network is a group of nodes connected by a wireless link. Figure 1.7 shows a network with three nodes. Information is transmitted with shared communication channel when a communicating node wants to transmit data to other node in the network.

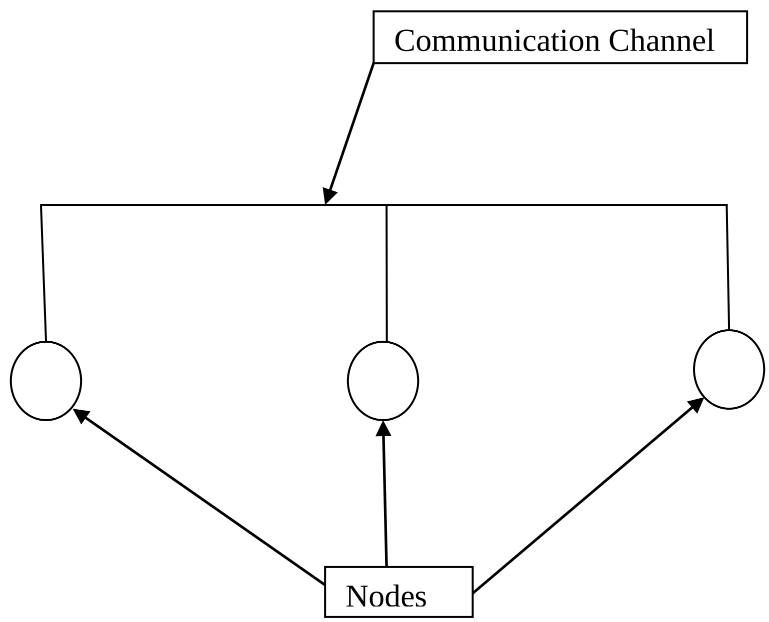


Figure 1.7: Three Nodes Network

Node is a computing device in the network. Information is transferred among nodes in the form of discrete chunks of information blocks.

A Single shared link among nodes is shown in Figure 1.8. Extra links are not required for nodes in the network to exchange information. For example, IF node-1 want to send data to node-9 as shown in Figure 1.8. Initially the data is transmitted to node-4 and subsequently the data is forwarded to node-9 in the network. Data is transferred from source node to destination nodes through intermediate links. Node in the current example, when data is transferred from node 1 to node 3 required one hop and when data is transferred from node-1 to node-9, it requires two intermediate hops for communication.

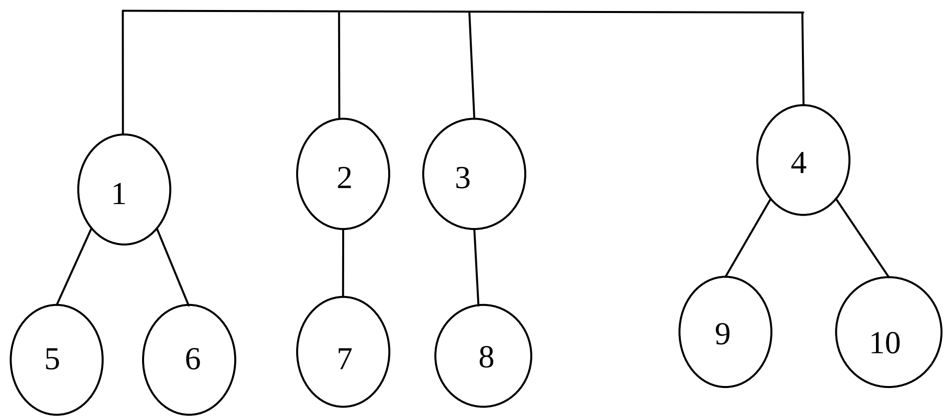


Figure 1.8: Ten Nodes Network

The process of data transfer through decided path is calculated in the network.

1.5 Mobile Ad-Hoc Routing Characteristics

Mobile nodes are used to form temporary network without the support of any centralized control. Routing protocol is required in mobile ad-hoc networks when two nodes are interested to exchange packets and not be able to communicate directly. For example Figure1.9 presents mobile ad-hoc network with three nodes. Node-3 is not within coverage area of node-1. Node-1 and Node-3 want to communicate with each other. Communication is not possible without the support of intermediate node-2 in the network.

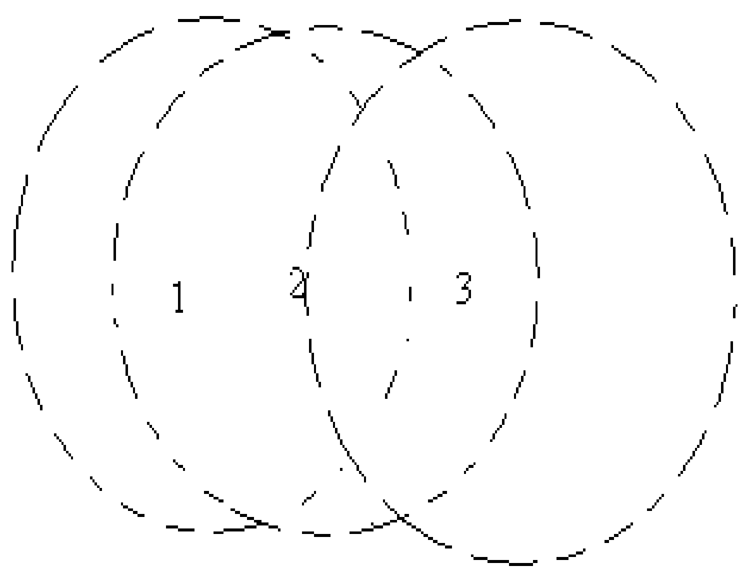


Figure 1.9: Three Mobile Nodes Network

When added more nodes in a network, the situation depicted in Figure 1.10 became more complicated. Routing protocol is used to decide the best path between any two nodes in the network. The addition of just one node makes different paths available between nodes-1 and node-3 possible in the available network.

Another unique situation to mobile ad-hoc networks is illustrated in Figure 1.11. In this case, node1has a larger area for communication and directly communicate with node 3 in network. Node 3 has a smaller coverage area. Node-1 used node-2 in transmission of data to node 3 in this network. One-way link is available between node-1 and node-3**.**

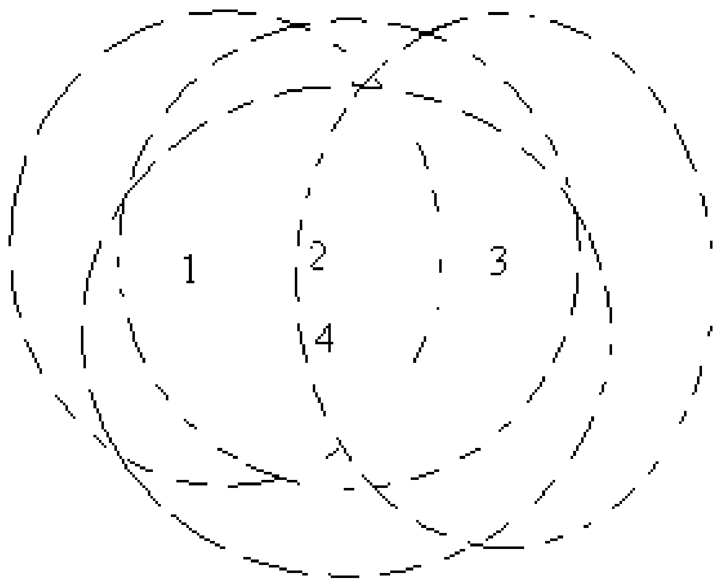


Figure 1.10: Four Nodes Network

Protocols in mobile ad-hoc networks are used to operate mobile nodes at slower bit rates than wired network. Large portion of bandwidth is consumed by flooding of packets in mobile ad-hoc network. Bandwidth is minimized with ad-hoc routing protocols in the network.

1.6 Ad-hoc Routing Protocols

Routing protocols are used to transfer data among nodes anytime and anywhere in the world. Mobile ad-hoc network has a limited bandwidth. Routing protocols has been an extensive research area in mobile ad-hoc network.

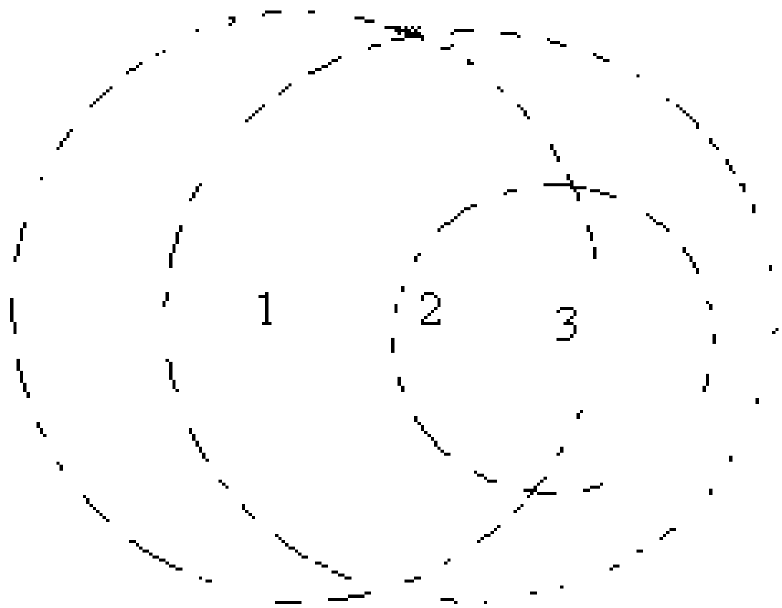


Figure 1.11: One Way Link

Mobile ad-hoc network is an emerging new technology, regardless of their geographic position and allow users to access information. Existing routing protocols fall in to three categories as shown in Figure 1.12:

1. Table Driven Protocols
2. On Demand Protocols
3. Hybrid Protocols

1. Table Driven Routing Protocols

Table driven routing protocols are also called as proactive protocols. Each node uses routing table to manage the information of other nodes in the ad-hoc network. Routing table is used to establish link among nodes in the network. Protocols used limited resources and bandwidth in a network.

2. On Demand Routing Protocols

On demand routing protocols are known as reactive protocols. Mobile nodes are using route discovery process in the ad-hoc network. This protocol is most suitable for such discovery process to find out the route in the network. Protocol is used to maintain the routes between nodes only when nodes want to route data packets in network. This protocol is not updating of every possible route in the network.

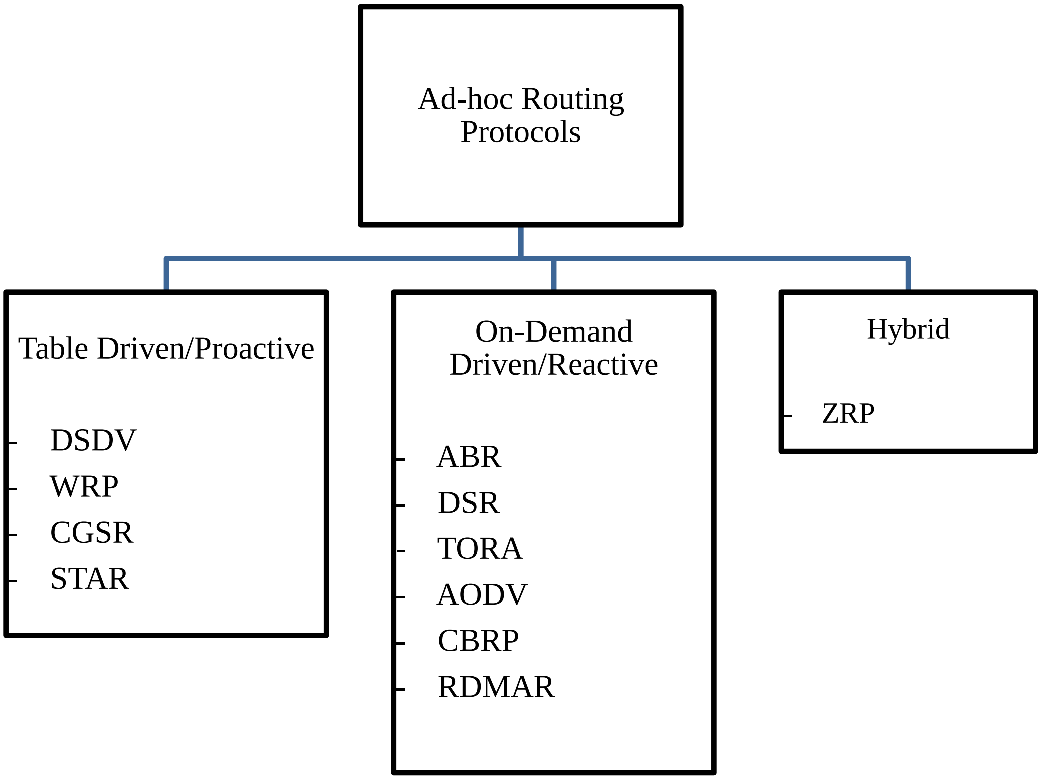


Figure 1.12: Mobile Ad-hoc Routing Protocols

3. Hybrid Routing Protocols

Protocol uses distance vectors to establish the best paths in the networks. Hybrid routing protocols is the combination of table based routing protocols with on demand routing protocols Each node has its self independent routing area and maintain a record of routing information in network.

1.7 Power Control

Power control means to select the signal power of node in the data transfer for mobile ad-hoc network. Ad-hoc networks are used in situation where the infrastructure is not possible. The size of the mobile nodes size is very small. Node has limited battery power and power saving capacity. It is most important to develop new scheme that reduce the power consumption for mobile ad-hoc network. Power control in ad-hoc networks has been the focus of research due to limited battery power of nodes in the mobile ad-hoc network. Power control technique is most effective to reduce power consumption and increase the life time of mobile ad-hoc network.

Power control also depends on the medium access layer to selects the minimum amount of transmit energy. Power control is effective to reduce energy consumption and increase throughput. Network density impacts the transmit power level of node in network. Transmit power control are affected by different layer. Transmission is affected by interference due to the shared nature of the wireless link in the network. Signal Interference is controlled by reducing the transmission range in the network. Energy consumption pattern of the node hardware is useful to analysis the total energy consumption of nodes in a mobile ad-hoc network. Transmission power of node is important to maintain the quality and throughput in the network. A decrease in the transmission power can have the opposite effects.

1.8 Application and Challenges

A mobile ad-hoc network is an independent wireless ad-hoc network and has no dedicated routers, servers and access points. Mobile ad-hoc network is growing rapidly with the increasing number of widespread applications due to progress in wireless communication and the increase of mobile devices. Ad-hoc networking is used anywhere, where infrastructure is impossible. Mobile ad-hoc networks are very flexible to controlling the connections and devices in the network. Mobile ad-hoc network has many applications. But the network is constrained by power sources. Mobile ad-hoc network has applications in the following areas:

1. Commercial

   Mobile ad-hoc network is used in emergency operations like disaster and rescue operations.

2. Military Battlefield

   Military equipments are lack of smart communication. Ad-hoc networking is used to maintain an information network between the soldiers and military information headquarters.

3. Instant Deployment

Mobile ad-hoc networks are used to provide autonomously link on the spot without any support.

4. Short Range Network

Short-range ad-hoc networks are used to provide the intercommunication between various mobile devices. The personal area network has many applications in the future pervasive computing context.

Challenges

Mobile ad-hoc network has many challenges like wireless medium challenges, portability challenges, heterogeneity, routing challenges, security and scalability. Mobile node can move in any direction with any speed in the ad-hoc network. Challenges of mobile ad-hoc network is divided into four main areas such as:

1. Topology

Mobile nodes are free to move and network topologies are changing very rapidly in mobile ad-hoc network.

2. Power

Nodes are operated with battery in mobile ad-hoc networks. Energy saving scheme is used to increase the life time of nodes in mobile ad-hoc network.

3. Security

Security control in the mobile ad hoc network is more difficult as compare to wired network. Vulnerability is possible due to the nature of the mobile ad hoc network.

4. Bandwidth

The bandwidth in mobile ad-hoc network is much lower as compare to wired based network due to interference in wireless communication network.

1.9 Advantages and Disadvantages

There are many factors which force us to use a mobile ad-hoc network other than the infrastructure based network. The biggest ad-hoc's positive point is its independence from any infrastructure. Therefore, it is possible to establish mobile ad-hoc network in any difficult situations. There are several advantages of using mobile ad-hoc networks.

Advantages

1. Infrastructure-less and Reliable

There are situations, with which a user of a communication system cannot rely on an infrastructure. Infrastructure based network are more expensive for specific applications. In an area with very low density like desert, mountain, it is difficult to establish an Infrastructure type network. It is difficult to use service of infrastructure. Cost of installation, maintenance and repair is more expensive in such fixed networks. Military network has same set of problems. It is obviously very useless to build an infrastructure in a battlefield. Aside from cost of installation, the enemy can destroy the infrastructure in short time. An independent from infrastructure network is needed for both cases.

2. Mobility

Mobile ad-hoc networks have mobile nodes to provide better service for different type of applications. In future, there will be requirement for the fast deployment of independent mobile users in wireless communication network. Military network is the best example includes emergency and rescue operations. In these conditions user can not rely on centralized connectivity.

3. Robust

Mobile ad-hoc networks are very robust. Imagine that for some reason one of the node is not working in infrastructure network. All nodes will lose connectivity to other networks. In the mobile ad-hoc networks, such problems are solved. If one node leaves the network or is not working, network is connected to other nodes.

4. Easy to Use

It is difficult to repair the malfunction in short time for infrastructure type network. Mobile ad-hoc network is performing well in such condition [120].

Disadvantages

The mobile ad-hoc network demand is very high nowadays, using ad-hoc network can make rooms look better, because fewer cables are used. Mobile ad-hoc network has lower data rate, security. Medium access control issue is not avoidable in the mobile ad-hoc network. The following are the disadvantages of mobile ad-hoc networks:

1. Lower Data Rate

One of major issue of mobile ad-hoc networks is lower data rates. The characteristic of electromagnetic wave, which is used for wireless communication, prevents ad-hoc network to transmit data better than wired communication. A higher frequency can transmit more data, but it is more vulnerable to interference and performs well in short range.

2. Scalability and Topology

Ad-hoc networks are vulnerable to scalability problem. Since the mobile ad-hoc network nodes are mobile, the routing changes as the nodes move. Current connectivity information must be propagated to all network's nodes. Control messages are used to send around the network frequently. The increased number of control messages burdens the available bandwidth. Mobile ad-hoc protocols are basically designed to minimize the number of control signal, such as by keeping the current information. Algorithm is required for mobile ad-hoc network to evaluate and compare networks' relative scalability in the face of increased number of nodes and its mobility.

3. Security

Mobile ad-hoc networks are vulnerable due to lack of centralized control. Mobile ad-hoc networks are affected by the different types of attacks.

4. Power Consumption

Mobile ad-hoc network has limited power and computation capabilities. A mobile ad-hoc network allows mobile nodes to communicate in the absence of a fixed infrastructure. Ad-hoc networks are operated with battery power. Because of these limitations, network must have algorithms which are energy-efficient as well as operating with limited processing and memory resources. Therefore a mobile ad-hoc network is not suitable for a permanent network. Wired network are fixed network and rely on the symmetric links. Mobile nodes are changing their position in mobile ad-hoc networks.

1.10 Organization of Thesis

The current research work is presented in the thesis is divided in seven chapters. A brief outline of each chapter is given in the succeeding paragraphs.

Introduction of mobile ad-hoc network is first chapter in this thesis. This chapter introduces the development and architecture of mobile ad-hoc network. We have discussed the classification of ad-hoc network and focus on energy conservation in mobile ad-hoc network. Power control schemes are described to highlight the necessity of power control for mobile ad-hoc network in this research work. Application and challenges of mobile ad-hoc network have also been presented in this chapter

Research paper based on study of power control scheme was published in proceeding of National Conferences at ITS Ghaziabad, India

Second chapter is focuses on literature survey. This survey is carried out emphasizing power consumption in mobile ad-hoc network. This chapter is divided into seven sections. First section describes the literature survey on power control algorithms, Second section explains the research gap in distributed power control scheme and power scheduling, Third section illustrates issues with software and hardware of the nodes in mobile ad-hoc network, Fourth section presents the issues related to transmission power control scheme, Fifth section describes the problems with power management in mobile ad-hoc network, Sixth section presents the issues related to energy management to improve remaining energy of nodes in the network and last section is focused on factors affected transmission energy for energy conservation in the mobile ad-hoc network and seventh section presents computation techniques with neural network approach.

Research paper based on this literature survey was published in a Journal (Springer).

The third chapter demonstrates the energy management model. This model is based on the energy management schemes that make decisions when to activate or shut the nodes so as to minimize energy consumption within the network. In this chapter, it has also been focused on the operation modes of node in the network. It has also discussed the classification of energy management scheme for mobile ad-hoc network. Ad-hoc on demand routing protocol is explained & implemented to understand the routing in network. Implementation issues in energy management are also explained in this chapter.

One Research paper based on energy management is accepted for IEEE International conference held at Manav Rachna International University, Faridabad, India.

In fourth chapter, the power consumption based simulation model has been presented for mobile ad-hoc network, in this the power consumption is controlled with slot transmission time. Power management scheme has been discussed and medium access control architecture. Scheduling policy, energy depletion control and flow chart are presented for transmission in ad-hoc network. OMNET++ simulator is described to simulate mesh topology based network. In this chapter, power consumption measurement and analyses the simulation results have been central focus of the work in this chapter.

Research paper based on power consumption based simulation model was published in a Journal (Springer).

In chapter5, Power control with transmission energy is discussed. A novel optimal radius selection scheme is introduced to determine remaining energy corresponding to the optimum transmission energy of nodes in network. Power control models and protocols have been discussed. Main focus of this chapter is energy management with variable transmission energy of nodes in network. Simulation parameters and results for analysis of power control for mobile ad-hoc network has been discussed in the last.

Research paper based on power control flow chart was published in proceeding of National conference at Lingaya's University, Faridabad, India.

Chapter 6 introduces the neural network model. There is discussion about energy management based simulation model to develop this neural network model. It was not possible to design and develop this model without the functioning knowledge of simulation model for mobile ad-hoc network. Neural network model is developed to know status of remaining energy at any time with respect to transition energy (Te), receiving energy (Rxe) and network load (Nodes). Te, Rxe and Nodes are used as input value and Re (remaining energy) act as output value to train the neural network. The effectiveness of the neural network model has been discussed in this chapter. Neural network model results are used to describe the analogous relationship of target mean remaining energy value with respect to input value mean ad-hoc network parameters value. It is proved that neural network model is an alternative solution of simulation model for mobile ad-hoc network.

Research paper based on neural network model study was published in proceeding of International conference, Ghaziabad, India.

In chapter7, the work is providing the summarizations and discusses the future scope of this research work.

CHAPTER 2

LITERATURE SURVEY

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

Power control is a difficult problem due to architecture of mobile ad-hoc networks. One node at a time can be both a data source and a router which forwards data on behalf of other nodes in ad-hoc networks. In such a scenario, the existence of a centralized entity is missing, which can maintain and control, the power control mode of each node in the networks.

Ad-hoc networks were introduced first in military applications. Such a Network is based on a set of nodes capable of communicating each other through wireless link. A mobile ad-hoc network is an arbitrary number of autonomous mobile nodes which communicate over wireless links with bandwidth constraints [18]. Source node can transmit the message to destination node when both communication nodes are in communication range for data transfer otherwise source can send data through intermediate node in the network. Wireless hosts are powered by batteries, capable of providing only a limited amount of energy. One way to conserve energy is to use power control mechanisms. Ad-hoc networks are dependent on the support from multi-hop communication schemes so that networks can relay massages through other hosts in the absence of direct route between the sending and receiving nodes. Nodes battery is an important factor to determine the life of network. Energy consumption issues in ad-hoc network can be reduced with the help of hardware and software techniques. Remaining energy of node is a key design consideration in the mobile ad-hoc network. Efficient utilization of the battery energy can greatly influence the overall performance of the network. Proper distribution of energy resources is required to increase the life time of nodes in the network. Power control mechanism is a serious issue in mobile ad-hoc networks [19]. Ad-hoc networks are not supported from any special communication link or access point so that networks transfer the data through mobile nodes in the mobile ad-hoc network.

2.2 Literature Survey on Existing Work Related to Power Control

Literature review is focused on distributed power control scheme, power control algorithm and power scheduling, software and hardware effect on power consumption, transmission power control protocol, power control with energy management, power control by power saving and power control with neural network model.

2.2.1 Power Control Algorithms

The Reinforcement learning algorithm was suggested by *Long et al.* to minimize transmission power of nodes in mobile ad-hoc network. The power level is consumed by signal to noise ratio of ongoing connections by maintaining the threshold power level among the nodes in the network. The concept of power is not successful with coding scheme in the network [23]. *Xiang et al.* have concentrated on generic algorithm, for solving the issue of optimum energy consumption, associated with nodes in wireless ad-hoc networks. In a network, the secure transmission with the help of permutation encoding is very effective. This scheme is also employed to search for the best and effective mobile node sequence to solve minimum power level problem. Permutation-encoded scheme is not effective in interference-based link scheduling process for mobile ad-hoc networks [136]. *Zheng et al.* have presented a joint power control, link scheduling and rate control algorithm. This was done using the convex optimization theory. The suggested algorithm practically considers the power management in interference based link scheduling process and suggests a congestion control at the transport layer. But the suggested algorithm is ineffective for larger networks [128]. For handling the larger networks, heuristic algorithms have been suggested by *SongUuo et al.* The suggested algorithm suggests the transmission of data with minimum transmission energy among all the users in a network. But in case of a larger network, the heuristic algorithm is ineffective in maintaining the node power level, especially for interference-based link scheduling [110].

2.2.1.1 Research Gaps

In this section, it has been observed from the literature study that the transmission power in a network is minimized; using an algorithm to determine the set of powers for scheduled users. It was impossible to decide the individual power of node in a network. The individual node power can be determined or estimated using Reinforcement learning algorithm. Results of this algorithm are not positive due to improper interfacing with encoded schemes in the network. Link scheduling with control of power consumption among nodes is effective to solve the energy consumption issue in the network.

2.2.2 Distributed Power Control Scheme and Power Scheduling

Network performance is improved with optimum power consumption among nodes and maintained by power control medium access protocol. *Zawodniok et al.* have suggested using lesser transmitter power per bit, to save the energy and thus the life-time of wireless nodes is extended. But at the high transmission rate, due to less transmitter power per bit, the Power control medium access protocol scheme becomes ineffective [76]. In order to maintain power efficiently at a given data transfer rate, *YanChen et al.* have suggested effective power allocation, between the source node and intermediate nodes in the network. Here networks are not considered to be reliable because of the congestion problems [142]. *Pimentel et al.* have focused on dynamical behavior of ad-hoc networks, where the introduction of extra link increases the performance of the network as well as its energy saving due to solve the congestion issue in the network. Gateways are not sufficient enough to improve network efficiency alone [42]. Network performance is improved with assigning an optimum power for each link and maintain minimum communication rate among nodes in the network. *Lee et al.* have identified power scheduling and communication control scheme for the ad-hoc network. In this scheme, it is observed that nodes consume more energy in the network [57]. *Charya et al*. have proposed a scheme, randomly selection of the mobile nodes consumes less energy in data transmission and the network never goes down. But the network performances start degrading at high data transfer rate in the network [123].

2.2.2.2 Research Gaps

In this section, it is observed from the literature review that power consumption by nodes is affected by data transfer rate. Nodes consume more power at high data transfer rate. It is difficult to maintain high transmission power. Joint opportunistic power scheduling and Gateway are not effective due to congestion problem in the network. Network efficiency is directly affected by transmission rate in the network.

2.2.3 Layer and Hardware effect on Power Consumption

The optimization of power in the ad-hoc network is maintained by the energy consumption control of the hardware circuitry in the network. Node has its own communication link for data transfer in mobile ad-hoc network. *Kawadia et al.* have suggested a basic cross layer design method affecting all layers from physical to transport layer. The node architecture has different types of layer. Here each layer has a specific function. The Layers protocols are affecting energy consumption, delay and throughput. Because of the more power consumption of nodes, the Layer protocols are ineffective in fast random selection of nodes in the network [127]. *Campbell et al.* have explored the optimization of power consumption is possible with help of physical as well as network layer, affecting the performance of data communication network. Data transmission rate is directly affected with power control in the ad-hoc network. Communication link among nodes are improved with transmission power and direct communication among nodes is possible by adjustment of transmission power in the ad-hoc network. In case of high traffic mobile ad-hoc networks, the transport layer is ineffective [56].

Kumar et al. have focused on the protocol for reliable delivery of data over unreliable link in the networks [40]. *Das et al.* have suggested r-shrink procedure, a heuristic for improving the solutions based on fast sub-optimal algorithms. Wireless networks based broadcasting, inherently reaches several nodes with a single transmission. This procedure can be utilized in computation of the routing trees to minimize the sum of the transmitter powers [3]. *Murthy et al.* have stated that channel contention is directly proportional to number of nodes in ad-hoc network [20]. *Anagnostou et al.* have suggested the different reconfigurable components to be used in antenna for modifying its structure and functionality. The reconfigurable antennas, with capability to radiate more than a single pattern at different frequencies and polarizations are necessary in modern telecommunication systems [26].

Gesbert et al. have suggested an overview of progress in the area of multiple input and output, space-time coded wireless systems. Authors have highlighted the different classes of techniques and algorithms based on multiple input and output including spatial multiplexing and space-time coding schemes. The derivation and analysis of such algorithms is generally done, under ideal independent fading conditions [27]. *Werner et al.* have explored the recent developments in the rapidly growing field of fractal antenna engineering. This way a new class of antenna element designs have been suggested which are compact and multi-band in size [28]. For efficient coordination of radio communication devices in unlicensed frequency bands, *Raychaudhuri et al.* have suggested a spectrum etiquette protocol. This method enables spectrum coordination between multiple wireless devices using different radio technologies such as IEEE 802.11.x, 802.15.x etc [29]. Based on distributed hashing and prefix hashing, prefix routing over set elements protocol have been suggested by *D. Sampath et al.* for scalable routing in mobile ad-hoc routing. In this routing scheme, the nodes utilize neighbor-to-neighbor signaling, which label themselves with prefix labels. The prefix labels provide implicit routing from any node to any network destination. A distributed hash tables at nodes is implement for storing the mappings between node identifiers and their prefix labels [31].

Orhan et al. have presented a dynamic mobile ad-hoc network management system with the help of controlled network nodes called agents, improves network connectivity. Agents have pre-defined wireless communication capabilities, similar to the other nodes in the network. Further agents are dynamically determined to optimize network connectivity [32]. *Kaplan* has stated that most modern global positioning system receivers have a built-in timepiece that continues to run even when the set is powered down. A critical piece of information is time. Receiver associated with nonvolatile memory that stores the last user position, velocity and time when the set was powered down [33]. *Sheu et al.* have presented a novel priority medium access control protocol to support multimedia traffic in wireless ad-hoc networks. Nodes transmit their frames in turn according to their identity number [51]. For complex hardware/software systems, *Hollstein et al.* have suggested the network-on-chip based design. Network-on-chip architectures have opened new vistas of re-configurability [124]. *Jakes* has stated that software agents have the ability to monitor progress and acting autonomously when the need arises in network [133]. *Kiess et al.* have stated that simulation is valuable techniques for the evaluating the algorithms and protocols prescribed in mobile ad-hoc networks [135]. *Lin et al.* have described a cost efficient deployment strategy based on random deployment of nodes to search a region of interest [145].

2.2.3.1 Research Gaps

In this section, it is observed from literature review that due to higher power consumption by nodes, the network layer protocols are not very effective in fast dynamic configuration of networks. For light traffic based mobile ad-hoc networks, the Physical and network layers are not effective. Over the unreliable networks, the transmission control protocol is not providing reliable end-to-end-delivery of data.

2.2.4 Transmission Power Control Protocol

The total energy spent for each successful packet transmission is minimized by using the optimal policy. A time-slotted network based wireless network has been suggested by *Adarsh et al. for* controlling the transmission power. But because of the signal losses over long ranges, the transmission power control scheme is not effective for communication [6]. *Muqattash et al,* have suggested transmission power control scheme in which signal is being transmitted over a transmission channel in radio range effectively without any appreciable loss. This scheme is effective in determining the energy consumption and performance of the network [5]. A protocol named power medium access protocol has been suggested by *Krun et al.*, which achieves a significant throughput. An access window is being used while exchanging the information in Power medium access protocol. This Access window is used to allow for a series of request-to-send and clear-to-send messages in simultaneous data packet transmission. But the interference in nodes effects the data transmission [77].

Tae et al. have compared the random vs fixed power controls schemes and observed that randomizing transmission power has positive effect of reducing high interference to the other nodes. This leads to the improvement in network connectivity. For smaller sized local networks, the fixed power control is more suitable. The Random power control is made by randomizing the transmission power for various nodes in a network. But this leads to unreliability in network [122]. In order to increase the link throughput, *Ruffini et al.* have described a transmission control scheme. This scheme utilizes higher transmission rate for increasing the link throughput. But at the same time, this scheme, requires higher transmission power. Besides the suggested scheme is increasing the interference in a network. With the help of the transmission control scheme it was not possible to improve traffic carrying capacity of network [78]. A sort of negotiation is done in the transmission power between source and receiver nodes in the novel medium access protocol suggested by *Zhitang et al.* This mechanism enhances the traffic carrying capacity at the cost of low signal quality in an ad-hoc network [148]. *Kaojung et al.* have studies minimum energy multicast problems where the mean nodes are communicating with multi-cast based messages on different links in a network. Each link is available with minimum energy for transmission of data. To know the shortest path with minimum transmission power, branch and cut or cutting planes techniques are used. The power control problem was not improved due to multicasting in a network [24]. *Kim et al.* have enhanced ad-hoc on-demand distance vector routing protocol. Here the efforts are done to improve the networks lifetime in mobile ad-hoc network [52]. *Cook et al*. have suggested reliability analysis method. This method is based on node mobility and the continuous changes in the network's connectivity. One of the most important measures for the performance of emerging wireless networks is reliability [58]. Wang et al. have stated that transmitter power control protocol and power management algorithms are two power conservative protocols for mobile ad-hoc networks [138]. *Matuszewski et al.* have introduced multiple input multiple output technologies in wideband code division multiple access systems to improve their spectral efficiency [149]. Li et al. have described the distributed protocols to construct minimum energy topology for mobile wireless networks [139].

2.2.4.1 Research Gaps

In this section, it is observed from literature study that for long range communications, transmission power control scheme is not very effective. This is due to the signal loss and low throughput. The interference of nodes affects the access window. With higher transmission power, the transmission control scheme has higher link throughput. But this led to the poor power control and decreased signal strength in a ad-hoc network

2.2.5 Power Control

Rong et al. have presented power management framework to reduce power consumption and improve throughput in the network. Framework is supported by On-demand routing protocol to save energy by switch on and off the radio communication. This frame work is not suitable for large size mobile ad-hoc network [91]. *Sun et al.* have described energy saving algorithm based on structure information of network. This algorithm is adaptable in nature and not used for high data transfer based mobile ad-hoc network [71]. *Sartini et al.* have focused on medium access in mobile ad-hoc network. Ad-hoc medium access is not effective to control the performance metrics in the mobile ad-hoc network [44]. *Liang et al.* have presented communication system to manage power control. It is used with less power to improve the quality of service and network life time in the network [22]. *Chou et al.*

have described that modified medium access control is effective to prolong the network lifetime. It is used with high transmission power for transmission of data in the network [128]. *Lee et al.* have presented algorithm to select path for minimize the transmission power. Network performance is not increased with this algorithm in the network [108]. *Zhu et al* have focused on power saving techniques to increase the efficiency of communication network [55]. Chiasserini et al. have presented power saving model based on power saving mode in the network [16]. *Ziouva et al.* have focused on acknowledgment mechanism for verifying successful transmissions in network [34]. *Rango et al.* have highlighted the power saving issues under a wide variety of networking scenarios [35].

2.2.5.1 Research Gaps

In this section, it has been observed from literature review that power management scheme is not effective for large size network. Power control is possible when nodes are moving with high speed. It is difficult to maintain the quality of services in the mobile ad-hoc network. Medium access layer can not maintain the quality of service with low transmission power in the network. Routing algorithms are efficient to control energy consumption as well as quality of service in the network.

2.2.6 Power Control with Energy Management

Charles et al. have stated that main objective of routing protocol to select shortest path with energy conservation from sender to the receiver in network [15]. *Jun et* al. have described that signal strength is decreasing as noise and interferences are increased and affects the energy consumption in the network [50]. *Tseng et al.* have focused on power control protocol to save power of nodes during communication in the network [140]. *Sungwon et al.* have explained the mobility characteristics of nodes affects energy consumption in ad-hoc network [119]. *Krishnamurthy et al.* have described that transmission based power control is used to improve the throughput in the network [90]. *C. Tuduce et al.* have stated that power control based on distribution of transmission power with transmission rate among nodes is used to control energy consumption in the network [21]. *Charya et al*. have described that node consumes less power in randomly selection of paths and link maintained for long periods [146]. *Chunhua et al.* have presents an algorithm to minimize the rework in selection of path to save energy and improve the quality of service in the ad-hoc network [25]. *Ebert et al.* have implemented scheme to minimize the transmission power to get better performance in mobile ad-hoc network [47]. *Rodoplu et al*. have developed power control scheme to save energy for large size mobile ad-hoc network [125]. *Wu et al.* have presents power control with data channel in the mobile ad-hoc network [105]. Tseng et al. have focused on the node power level with communication range to transreceiving data in the network [104].

Avidor et al. have presented Transmission power control algorithm with different type of topology to know the energy consumption among nodes in the network [30]. *A. K. et al.* have explained the programming models to minimize the power level of nodes in broadcasting of data with wireless communication network [2]. *A. Singh et al.* have described the importance of energy saving protocol to improve the performance of network [10]. *Wieselthie et al.* have developed algorithm for data transfer among nodes and solve the issue of energy consumption in mobile ad-hoc network [48]. *Dowell* has stated that ordinary analytical models are infeasible for complex system [70]. *Andrew et al.* have discussed about the autonomic computing and its effect on energy consumption in network [75]. *Wadhwa et al.* have studied and evaluated the performance of wireless communication network. A result shows that throughput is decreased when numbers of unwanted channels are increased in network [79]. *Min et al.* have presented an algorithm to provide the minimum energy multicasting and link among nodes in wireless ad-hoc networks [80].

Wadhwa et al. have presented the protocol based on communication range and antenna direction for energy saving in the network. This protocol is effective to save a lot of energy to improve the performance of the network [81]. *Wang* has proposed energy management scheme for saving of energy consumption in network [144]. *Wadhwa et al.* have presented spectrum sharing model to increase the throughput in the network [83]. *Havinga et al.* have designed heterogeneous mobile system for efficient energy consumption control in mobile ad-hoc network [88]. *Min et al.* have presented energy consumption control model based on micro sensor hardware for ad-hoc network [94]. *Ramanathan et al.* have stated that energy consumption control is main issue for design and development of the network [95]. *Muraleedharan et al.* have stated that intelligent transportation system with mobile ad-hoc network is associated with many autonomous applications [98]. *Toumpis et al.* have discussed the concept of energy saving in wireless ad-hoc networks and focused on the critical technical challenges [111]. *Guo et al.* have presented an algorithm and described about the research on the energy saving routing to control energy consumption in the network [112]. *Lo et al.* have presented a protocol for power control and maintain high performance in large size ad-hoc networks [113].

2.2.6.1 Research Gaps

In this section, it is observed from literature survey that reactive protocols are used by many researchers to find a shortest path to the end point but link degradation is continue as per nature of mobile ad-hoc network. Transmission power is saved based on bitwise data transfer with distributed power control scheme in the network. On other hand, randomly selection of the path consumes less power in the network. Energy management model is effective for reduce the energy consumption in mobile ad-hoc network. It is not used to improve the overall performance of the network. Intelligent transportation system with mobile ad-hoc network is associated to improve the performance with many autonomous applications. Novel medium access control protocol achieves considerably high performance in ad-hoc networks.

2.2.7 Power Control with Transmission Time and Energy

Banerjee et al. have focused on link distance for power savings in the wireless network [106]. *Avidor et al.* have described topology control algorithms to save power with transmission energy of each node in the network [64]. *Premalatha et al*. have used new metric entropy to minimize the number of path to improve performance in the communication network [62]. *Song et al.* have described the broadcast based energy saving methods for mobile nodes in the network [73]. *Wei et al.* have mentioned that Ring scheduling is not effective to maintain the energy saving with performance in the mobile ad-hoc network [134]. *Li et al* have described that node consumed energy before transmission of data during hold state. Node is used to hold the packet and affect energy consumption in the network [72].

Aksu et al. have measured the minimum cardinality of the co-operation at node to save energy for wireless network [7]. *Wang et al.* have stated that energy control model is not effective to estimate the overall energy consumption by each node in the network. Network life is depends on the energy consumption in wireless communication [144]. *Vijay et al.* have explained that network life time is affected by node mobility and location error in the network [45]. *Kumar et al* have described that proactive protocol is most suitable for large size wireless networks [100]. *Mumtaz et al.* have mentioned that performance and energy saving is possible by efficient path selection in the mobile ad-hoc routing [117]. *Abusalah et al*. have described that performance of the network is decided with standard performance metrics of the mobile ad-hic network [74]. *Wu et al.* have stated that searching routing is used to save power in the network [137].

Chaba et al. have mentioned that performance of On-demand ad-hoc routing protocol is better than other protocols in the mobile ad-hoc network [143]. *Goldsmith* has described that signal propagates through wireless channel and associated with random fluctuation in time due to moving position of sender and receiver [4]. *Hamieh et al.* have proposed method to identify jamming attack and analyses of energy consumption in the network [8]. *A. Baber et al.* have presented data verification approach for transmission of data among mobile nodes in network. It is easy to use in any situation as per characteristics of mobile ad-hoc network [9]. *Awad et al.* have described about the cord protocol to identified failure path and save power in the wireless network [12]. *Meshram et al.* have focused on ad-hoc network factors to save power and prolonging battery life with power conservation techniques at various layers [13]. *Baisakh et al.* have presented an energy saving approach which purpose was to select shortest path in the work [14]. *Piazza et al.* have focused on energy control effect with wireless fidelity network cards to save energy in the network. Transmission power has a marginal effect on the overall energy consumption [36].

Samman et al. have presented the network with multicast routing. It is used to transmit multiple packets with deadlock mechanism of routing protocol. Destination node addresses is maintained by packet header and provide the link among nodes in the network. Deadlocks are controlled with tagging process in the network [37]. *Pei et al.* have presented a Landmark routing protocol to minimize routing overhead and optimize energy consumption in the network. This protocol is most appropriate for large scale ad-hoc network [38]. *Chakrabarti et al.* have described route discovery protocol with error correction mechanism. Route discovery is crucial when a node moves in mobile ad-hoc network [39]. *Chlamtac et al.* have presented a set of challenges and problems requiring further research in the future [43]. *Eriksson et al.* have presented mechanisms to implement dynamic addressing efficiently. This mechanism suggested that random addressing is an effective method for getting shortest routing in large ad-hoc network [59].

Nurminen et al. have stated that most researchers have not done any work on the energy consumption node wise in the network. Mostly research work in this area is based on the total energy consumption of nodes in the network [60]. *Paek et al.* have stated that global positioning system that provides accurate position information while node is spending minimal energy in network [61]. *Abbas* has enhanced Dijkstra's shortest path algorithm to decrease the average time complexity, thus increasing the performance of tiling array. Prior works have developed the minimal tiling path problem for the choice of oligonucleotides using Dijkstra's shortest path algorithm is used to compute universal finest tiling paths from millions of candidate oligonucleotides on computers [85]. *Gaur et al.* presented a detection method to identify collusion attack on nodes and select the route among closet nodes in the network [86]. *Chand et al.* have presented cluster based method for caching in the network. Performance of this scheme is better due to none overlapping of cluster in the network [87]. *Samar et al.* have focused on the independent zone routing frame work, which used adaptable and efficient network parameters to minimum the size of routing area in the network [89]. *Doss et al.* have described a method to maintain privacy or security mechanism and proper routing among nodes in network. Mobile networks are most suitable due to its structure [101].

Singh et al. have developed a novel multi-access protocol for ad-hoc network that conserve power by turning off radios under certain conditions [102]. *Singh et al.* have presented a new power-aware metrics for determining routes in wireless ad-hoc networks. These new metrics can be used in most traditional routing protocols for ad-hoc networks [103]. *Jha et al.* have stated that node mobility in mobile ad-hoc network is a challenge to get better performance with randomly address allocation based address routing [116]. *Ali K et al.* have described the ad-hoc routing protocols and focused on the possible service of ad-hoc networks [120]. *Sesay et al.* have focused on current research issues in mobile ad-hoc networks [107]. *Yousefi et al.* have focused on comprehensive study of challenges in mobile ad-hoc networks. Main focus was on the problems and solutions related to energy consumption issues in mobile ad-hoc networks [109]. *Ramasubramanian et al.* have introduced the hybrid type routing protocol to maintain the gap among reactive and proactive type protocol in the network. Network performance is improved with the hybrid protocol [126].

2.2.7.1 Research Gaps

In this section, it is observed from literature survey that the transmission power of each node is assigned under topology control based algorithms to reduce power consumption of nodes in ad-hoc networks. It is not used to estimate the energy consumption of node in the network. The concept of transmission range is not more effective to save energy in the network. Searching range based routing algorithm is used to maintain shortest link among nodes. Signal propagates through wireless channel is associated with random fluctuation in time due to moving position of sender and receiver in the network. Energy saving approach based on grid is used to select path among the nodes in the network. This approach provides routing for large size mobile ad-hoc networks. Existing energy saving approaches are related to overall energy consumption of network not related to individual energy consumption of node in the network.

2.2.8 Computation Techniques with Neural Network Approach

Rahman et al. have described that neural network had lower error and consequently better precision in locating the target node in wireless networks [82]. *Zooghby et al.* have presented the neural network based multiple sources tracking algorithm, which is based on radial basis function neural networks to detect the incoming signal in wireless network [1]. *Zheng et al.* have stated that the localization accuracy can be significantly improved by using neural network [83]. *Shieh et al.* have developed an algorithm to improve performance better than radial basis function network for different applications [17]. *Rajaee et al.* have explained that probabilistic neural network can estimate the location of unknown nodes and easily reduce calculations [115]. *Min et al.* have stated K-Nearest Neighbor algorithm is one of those algorithms that are very simple to understand makes decision based on the entire training data set [99].

Twome et al. have described the methods of neural network validation as applied to function approximation networks with small sample sizes. This method is performing better than those constructed in the traditional manner [46]. *Singh et al.* have presented network, which is designed according to feed-forward network. Effectiveness and applicability of the network model is verified for different applications [84]. *Setiono et al.*

have explained method to identify symbolic pattern using neural network model. The neural network is used to get the required exact pattern rate for application [92]. *Biswas* has presented a concept to take effective decision, which is based on the measurement of matching among fuzzy bags. Problem is focus on identifying accurate results out of *n* alternatives on the basis of *specified* factors [93]. *Chakraverty et al.* have introduced an algorithm for the neural network training in order to have efficient learning and training of the network. Main objective was to estimate the vibration characteristics of plate structures [114]. *Raj et al.* have presented an advance neural network models with the help of appropriate graph. The network produce a graph discover by randomly nodes to generate a code and used link among nodes [129]. *Bregains et al.* have implemented an artificial neural network to find the excitations of a square planar array. The array is composed of uniformly spaced sub arrays and has a quasi in its radiation diagram. This simulation model includes the reduction of any signal interference in the shaped radiating zone after its position has been determined [49].

2.2.8.1 Research Gaps

In this section, it is observed from literature survey that neural networks are more effective and accurate in locating the single target node with low error rate. Neural network based multiple sources tracking algorithm is not more accurate to get better results. Probabilistic neural network can estimate the location of unknown nodes and easily reduce calculations for small size mobile ad-hoc network. Neighbor algorithm is algorithms that are very simple to understand and makes better decision based on the entire training data set for large size mobile ad-hoc networks. Neural network model based on feed-forward neural network is developed to improve effectiveness and applicability of the wireless network models, not for mobile ad-hoc networks.

2.3 Problem Identification

Literature survey is carried to study the schemes related to power control, main objective was the optimization of energy consumption in the ad-hoc network. Mobile Ad-hoc networks have number of challenges due to limited power resources and structure of the network. Ad-hoc protocols are designed to save energy in the ad-hoc network. Mobile nodes act as routers and used energy in transmission and receiving of data in the network.

Optimization of energy is possible with saving of power or control power in the network. Power control is more effective than saving of power due to characteristics of mobile ad-hoc network. Transmission power is adjusted in power control for optimization of energy consumption in the network. Node consumed more energy in retransmission of data in the mobile ad-hoc network. Retransmission probability of node is reduced by power control. Interference among nodes is controlled by power control to improve the performance in the network. Communication range among nodes is affected by transmission power in mobile ad-hoc network. Remaining energy of nodes also proportional to transmission power and used to increase the life time of ad-hoc network.

Neuron network based power control algorithm is proposed in this research work to estimate the energy consumption in ad-hoc network. Energy computation with neural network technique is more useful as compared to simulator. Performance of the neural network model depends on selection of inputs and output parameters to get accurate results for mobile ad-hoc network. Parameters affect energy consumption in mobile ad-hoc networks are identified with the help of simulation results and neural network model is developed with identified parameters. It is easy to measure remaining energy of nodes with neural network model for mobile ad-hoc networks. Remaining energy is the main parameter to determine the life time of nodes in the network. Remaining energy control is possible with power control in the mobile ad-hoc network.

Power control with neural network algorithm is an effective method for estimation of energy used by nodes in mobile ad-hoc networks. Neural network techniques are preferred over traditional methods due to accurate results. It is easy to get result at any intermediate points once neural network is trained according to input and output parameters for the mobile ad-hoc networks. Simulator is used to get results according to predefined input parameters and not used to get result for any intermediate points once simulation run for particular application.

2.4 Conclusion

Issues are identified in the literature survey related to power control, which was needed to be solved in an effort to optimization of energy consumption for the network. Energy management and neural network based power control model are proposed to measure energy consumption of mobile ad-hoc network. Power control also affects the performance metrics of energy consumptions. Power control is required to increase the lifetime of the networks. Energy management and other power control schemes must fulfill all the issues to give the better results in mobile ad-hoc networks. Energy management is possible by using effective performance metrics for selection of path with efficient node power level in the mobile ad-hoc network. Power control also affects ad-hoc network life time and performance level. Mobile ad-hoc network has unique characteristic such as limited battery level of nodes. The key solution is energy efficient power control model. Latest work in energy saving schemes has targeted ad-hoc networks. Energy management is required for the design and development of mobile ad-hoc network. Power control requires operating knowledge as well as understanding the function of node power consumption of mobile ad-hoc network.

It is observed from the literature survey that power control is possible with software as well as hardware in the mobile ad-hoc network. Different types of studies are recommended for different schemes to control the power in mobile ad-hoc networks. Neural network based energy computation technique is more effective as compare to existing simulation based techniques for mobile ad-hoc network. This technique is most useful for design and development of the mobile ad-hoc network.

CHAPTER 3

ENERGY MANAGEMENT MODEL

CHAPTER 3

ENERGY MANAGEMENT MODEL

3.1 Introduction

Mobile ad-hoc networks are deployed to setup wireless link anywhere and anytime for data transfer. Ad-hoc networks enable users to create a mobile communication system on the fly. The energy utilization in ad-hoc networks is an important ingredient in overall management of networks. It is a general trend toward ad-hoc architectures. Research in multi-node architecture has shown it one of the solutions in the implementation and development of ad-hoc networks. Mobile ad-hoc networks are supposed to play increasingly larger roles in the future. Mobile ad-hoc networks are also increasing interest for a diversified set of applications and response to incidents that failure of the existing communication network. Traditional energy management is based on the schemes that make decisions on when to activate or switch off the nodes so as to minimize the energy consumption within the mobile ad-hoc network [88].

In this chapter, energy control is explained with proposed energy management model, which improves the remaining energy of nodes in mobile ad-hoc networks. Remaining energy is the amount of energy of the nodes left, after sending and receiving data in ad-hoc network. In this energy management model, each node can switch between power saving and active modes to save power. Energy control is also a performance metrics for mobile ad-hoc networks. This factor is directly related to the operational lifetime of nodes in the mobile ad-hoc networks. Mobile nodes have to rely on finite source of energy. The improvements in battery technologies are comparatively less, in comparison to the development in the field of mobile ad-hoc networks. Besides, A battery increases the weight of a node, at that node in ad-hoc network. Power and life time of nodes are decreased with decrease in weight of a battery in a mobile ad-hoc networks.

In the mobile ad-hoc networks, battery replacements are not possible very frequently. Every node operated with a small low power capacity battery as energy sources and specifically this become more difficult, while operating in remote locations. Overall performance is decided with efficient utilization of energy in the network. Energy consumption is one of the most important performance parameter for the designing and development of mobile ad-hoc networks, as it directly affects lifetime of the network. A mobile node with limited energy capacity has brought energy conservation to the forefront of all the concerns for using mobile communications in mobile ad-hoc network. The concern increases, for mobile ad-hoc networks where mobile nodes are expected to be used for longer durations of time, with limited possibility, for recharging batteries. Such needs demand the energy saving in the mobile ad-hoc network to support improvements in the lifetime of nodes. Energy conservation is achieved with energy management during active communication in the networks. Energy saving also determined with relation between the size of data in application and the amount of energy consumed in transmission of that data. An application level technique is used to reduce the amount of data to send in mobile ad-hoc network. Data transmission among nodes is possible after selection of application with energy efficient scheme to save power in the mobile ad-hoc network [90].

3.2 Energy Management

Mobile ad-hoc networks have inherited the issues of the wireless network. The wireless link is still not considered to be reliable than wired media. A communication among nodes is established according to time and asymmetric link in the network. Energy management issues are occurring in wireless network. Wireless communication as media has no limit of coverage area to setup link among nodes in the network. Wireless communication link is not secure due to interference of signal in the network. Besides, the lack of permanent infrastructure, the multi hop communication and characteristics constraints, mobile ad-hoc network is performing well in different applications. Energy control based link among nodes is an emerging research area in mobile ad-hoc networks. The efforts are being done in the direction of improving end-to-end network throughput while reducing energy consumption. This is required, because, with the increase in power and the increase in connectivity range, every node will reach almost all other nodes in a single hop. But the higher powers cause a higher interference level and therefore there will be increase transmission attempts. There are four possibilities to save power from the nodes in mobile ad-hoc networks:

1. Per Packet Reduced Energy Consumption

   The total energy consumption is defined as the sum of powers, consumed on each node in the path from a packet. The power consumption at a node is a function of the load of this node and distance between the neighbors. It is required to select a route where the distance between the nodes is not too long in mobile ad-hoc network. Short path with many hopes is avoided to maintain power level of nodes in the network.

2. Per Packet Increased Network Connection

   This particular metric is required to maintain the load on all the mobile nodes in the mobile ad-hoc networks. This is more important in environment where the network is temporary.

3. Reduced Variance in Node Power Levels

   This particular metric is used to disperse the load among all nodes so that on an average, the power consumption remains uniform on all nodes in a network. The complexity of the problem increases, with the increase in size and rate of data packets, with time, in a network.

4. Minimize Node Cost

   This particular metric minimizes the cost per nodes for a packet after routing a number of packets or after a specific period. Battery power is saved with selection of energy aware routing by nodes in mobile ad-hoc networks [88].

3.3 Energy Management Necessity

The energy efficiency of nodes in mobile ad-hoc network is the ratio of the amount of data transferred to total energy consumed by nodes. Nodes are used to transmit more number of packets in a specified time period to increase the energy efficiency in the network. The requirement of energy management is listed below:

1. Energy Source

   Ad-hoc networks are associated with limited energy resources. The main objective for development of mobile ad-hoc networks is to set up link between nodes where infrastructure is not available.

2. Battery Replacement Impossible

In most of the situations, it is extremely difficult to replace or recharge the batteries in mobile ad-hoc network. In situations such as battlefields, this is almost impossible. Therefore, energy conservation is essential in ad-hoc network.

3. Lack of Central Administration

In the absence of central coordinator, introduces multi-hop routing and it necessitates that intermediate nodes used by nodes in network.

4. Battery Constraints

A battery affects the size and weight of a mobile node in ad-hoc network. Life time of nodes is increased by increasing the size of battery and life time of nodes are decreased by decreasing the size of battery in the network.

5. Optimal Power

The optimal transmission power is used to determine the reach ability of the nodes in ad-hoc network. The consumption of battery charge also directly proportional to the transmission power in the network.

6. Channel Utilization

Power control becomes very important for mobile ad-hoc network where limited bandwidth is used by nodes in the network [13].

3.4 Classification

Five classes of energy management are explained below:

1. Battery Management
2. Data link Layer Management
3. Network Layer Management
4. Transmission Management
5. System Management

1. Battery Management

Battery energy management is most important factor in design and development of the mobile ad-hoc network. Energy saving is used to maximize the energy produced by the node battery in mobile ad-hoc network [16].

2. Data Link Layer Management

This data link layer management deals with the packet transmission time to control the energy consumption in mobile ad-hoc network.

3. Network Layer Management

This management blocks next communication among nodes and allows battery to recover when battery charge level is below threshold in the network. Battery is used to provide service when battery recovers its charges again in the network.

4. Transmission Management

Transmission power management is used to provide link layer solutions such as power save in active mode and time is divided into time slots. Each interval starts with an ad-hoc traffic indication message window if node A wants to transfer packet to node B, node A transmits an ad-hoc traffic indication message to node B during an ad-hoc traffic indication message window. Size of ad-hoc traffic indication message window and slot time affects performance in the network.

5. System Management

Hardware and operating system is used to save power of nodes in the network. This scheme is implemented to use mobile nodes in power saving mode in the networks**.**

3.5 Mobile Ad-hoc Routing

Efficient ad-hoc routing is used to improve remaining energy and the networks lifetime of mobile nodes in ad-hoc networks. On demand distance vector routing protocol is used for routing among the nodes in mobile ad-hoc networks. Routing is used to transfer the data and selection of shortest path among nodes in the mobile ad-hoc network. Routing algorithms are used to select path between nodes in the network. Static routing update routing table written by an administrator when new router is added or deleted from the network as compare to dynamic routing [52].

3.5.1 Ad-hoc On-Demand Distant Vector Routing

Ad-hoc on-demand distant vector routing used a route request and route reply message in the network. Sender node broadcasts a route request packet through the communication network when a sender node find a path to a destination node for which it does not already have a path in the network. Nodes are accepting this packet and maintain their data for the source node in the route tables. Route request is used to update the current sequence number. Route reply message is sent by nodes when receiving the route request and verify the sequence number greater than or equal to number available in route request. In this case, it acknowledge route reply back to the sender node. Otherwise, it rebroadcasts the route request in the network. When sender node receives the route reply message, it starts transmission of data to the destination node in the network.

3.5.2 Issues with Routing

1. Communication links

   Mobile nodes used the asymmetric links and constantly changing position within mobile ad-hoc network.

2. Routing

   Mobile nodes in mobile ad-hoc networks are frequently changing positions in the network. Routes are updated in the routing table and need unnecessary routing overhead.

3. Transmission Interference

   The communication among nodes is interfering with each other and overhears communication of closet nodes in the network. Link interfering is the major problem in the mobile ad-hoc networks.

4. Structure

   Topology is not constant in the mobile ad-hoc network. Routing tables are used to update changes in the topology.

3.6 Proposed Model

Energy saving model is proposed to save energy and calculate the energy consumption of mobile nodes in network. In this model, each mobile node is switched between power saving and active modes in mobile ad-hoc networks. Node is ready to accept data during active mode and not active in sleep mode just wakes up for any pending information at any time in the network. A transition between modes is occurring by arrivals of data in the network. The state transition is shown in Figure 3.1.

On-demand routing protocols have control messages like Route Reply Messages to indicate that subsequent packets are for this route in the network. Control messages are used for node to transition to active mode. The keep-alive timer for this transition is used in mobile ad-hoc network. Nodes in power-save mode cannot hear messages from their neighbor's nodes in the mobile ad-hoc networks.

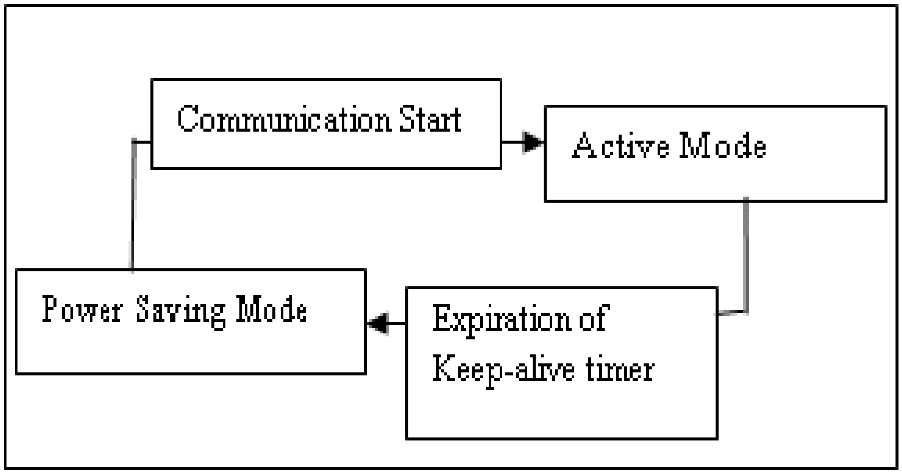


Figure 3.1: State Transition

Entries for unreachable neighbor's nodes will be reused periodically in ad-hoc network.

3.7 Determine Remaining Energy

Energy management model is used to improve the overall remaining energy in the mobile ad-hoc network. Development of the network requires knowledge about the functions and behavior of mobile ad-hoc networks. Energy efficient protocols are used to control remaining energy of nodes in the network. The energy is consumed by a mobile node which depends on its operating mode. Node never consumed energy during the sleep state in the network. Node whenever require switchover to the active mode and ready to send or accept information at any time [94].

Model has important performance factor like transition energy, transition time and network density. Transition energy is the energy consumed by mobile nodes in state transition from power saving mode to active mode. Transition time, is the time, used in state transition from power saving mode to active mode. Ad-hoc on demand distant vector protocol is used to select path with remaining energy for nodes in the network. Transmission energy of nodes is used to improve the remaining energy of nodes in mobile ad-hoc network. Transmission energy is based on transmission power in this energy management model. Transmit power level is used to dynamically adjust transmission power and achieves the maximum remaining energy of nodes for network life time. It is controlled carefully to reduce energy consumption. Receiving energy (Rxe) is the energy, which is consumed by the node in receiving of data during communication in the network.

Remaining energy of node is measured in Joules and calculated from equation (1).

$$\mathrm{Re} = \mathrm{Ie} - \mathrm{Txe} + \mathrm{Te} + \mathrm{Rxe} \qquad (1)$$

Remaining Energy (Re) is calculated with Initial Energy (Ie), Transmission Energy (Txe), Transition Energy (Te) and Receiving Energy (Rxe)

Remaining energy is decided with the transmission power of nodes in mobile ad-hoc network. Network life is depends on the remaining energy of nodes in the network.

3.8 Simulation Environment

Mobile nodes are changing position continuously in mobile ad-hoc networks. It is challenge for ad-hoc networks protocols to correctly behave in this dynamic environment. Therefore, nodes movements is an important aspect in mobile ad-hoc network simulation. Selection of mobility model, average speed and node distribution is important factors in configuration of mobile ad-hoc network with help of NS2 simulator. Simulation environment is associated with few factors as explained below:

1. Speed

   Average speed is selected with random way point model. It is used to provide an average speed during simulation run for mobile ad-hoc network.

2. Random Waypoint Model

   A pause time of nodes is described with mobility model. Random waypoint mobility model is used in the mobile ad-hoc network. Node speed is determined with pause time when mobile nodes are moving with each other in the network. Mobile nodes used time to stay in a particular area. Nodes used any random location and moving towards new positions at selected speed when time expires in the network.

3. Node Distribution

   Nodes movement is decided with random way point model. Nodes are moving randomly and distribution is not uniform in the mobile ad-hoc network.

3.8.1 Simulation Parameters and Results

Most mobile ad-hoc networks are designed with simulation tools and used libraries for link protocols. Simulation tool is used to get graphical interface for the development of network model. Network simulatorNS2 is used to simulate mobile ad-hoc network with command. The set of commands required to configure a mobile ad-hoc network are explained below-

The command required to configure a mobile node is $ns_ node-config, adhoc Routing is- $val(rp), link layer is -llType $val(ll), mac layer is -macType $val(mac),

for interface queue type is-ifqType $val(ifq), for interface queue length is-ifqLen $val(ifqlen), for antenna is-antType $val(ant), for propagation model is-propType $val(prop), for network interface type is -phyType $val(netif), for topography instance is-topoInstance $topo, for tracing at agent level is-agentTrace ON, for tracing at router level is-routerTraceON,

for tracing at mac level is-macTrace ON, for mobile node movement is-movementTrace ON and for channel is-channel $chan_1_. And mobile nodes are created and channels are assigned:

```
for {set i 0} { val(nn)} {incr i} {
set node_(   ns_ node i) random-motion 0;
}
```

Routing protocols are assigned-

```
set val(rp) ;
```

Simulation network parameters are given below:

Mobility Model-Random way point, Speed-2m/s, Initial Energy-100 J, Transmission Power-100mw to 500mw, Receiving Power-50mw to 250mw, Transition Time-0.005ms, Transition Power-0.02mw, Network Area $= 700\text{m} \times 700\text{m}$.

Packet delivery ratio and transmission delay are the performance metrics to compare the performance of proposed model with existing model for the ad-hoc network. Transition energy, receiving energy and network density are the identified parameters affect energy consumption of mobile nodes in the mobile ad-hoc network.

Packet delivery ratio is the ratio of packets that are transferred to a destination node to the number of packets that have been transferred by the sender node in the mobile ad-hoc network. Transmission delay is the time used by nodes to push the data packets to communication link in the network.

3.8.1.1 Remaining Energy and Transition Energy

In this section, it is observed form simulation results that value of remaining energy in proposed model is higher as compare to existing model as suggested by Wang et al. [144] with respect to transition energy in mobile ad-hoc network. Remaining energy depends on energy consumed by nodes in state switching from power saving mode to active mode during operation in ad-hoc network.

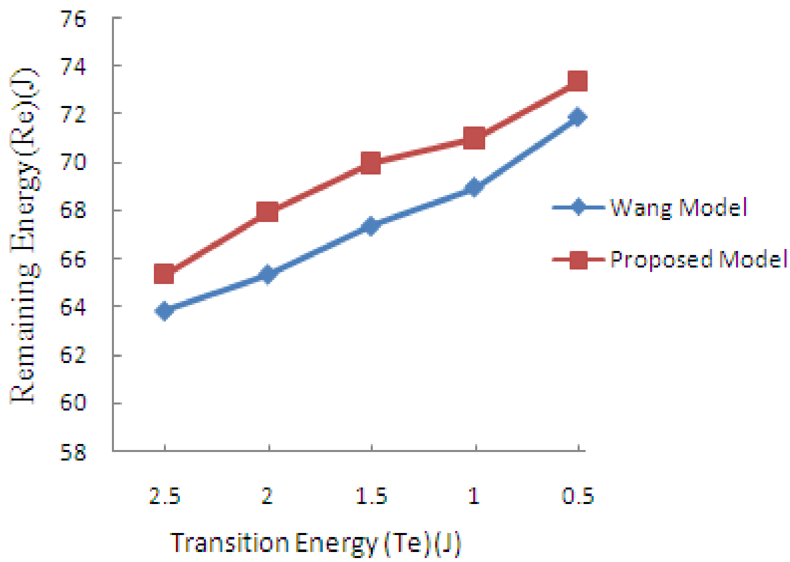


Figure 3.2: Remaining Energy and Transition Energy

Transition energy is important factor to control energy consumption in mobile ad-hoc network. Transition energy depends on switching time between power saving mode and active mode in the network. Transition energy as well as remaining energy is increased with reducing switching time. Remaining energy directly affect transition energy in the mobile ad-hoc network as shown in Figure 3.2.

3.8.1.2 Remaining Energy and Receiving Energy

In this section simulation results prove that proposed model has higher value of remaining energy as compare to existing model as proposed by Wang et al. [144] with respect to receiving energy in mobile ad-hoc network. Nodes remaining energy is estimated with energy consumed by nodes in accepting data.

Receiving energy is associated directly with remaining energy and lifetime of nodes in the network. Remaining energy value in both models is increased as receiving energy value is decreased in mobile ad-hoc network. Receiving energy consumed by nodes in proposed model is also key factor to control energy in mobile ad-hoc networks.

Remaining energy is increased with decreased in receiving energy as shown in Figure 3.3.

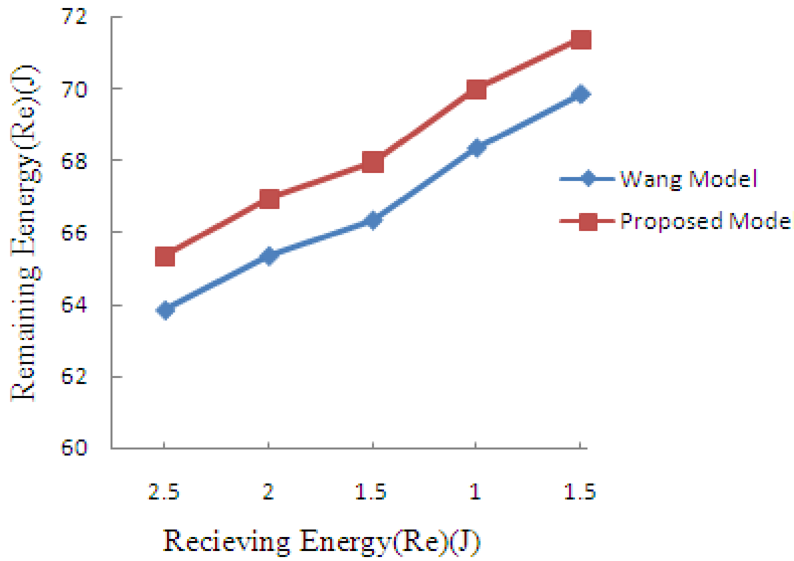


Figure 3.3: Remaining Energy and Receiving Energy

3.8.1.3 Remaining Energy and Network Density

In this section, remaining energy is increased with decrease in network density mean mobile nodes in the network. Remaining energy status in proposed model is better than existing model as suggested by Wang et al. [144]. Figure 3.4 shows the remaining energy status.

. Remaining energy is inversely proportional to network density or communicating nodes in mobile ad-hoc network. Nodes life time is directly proportional to remaining energy of nodes in the network. When the numbers of nodes are increased accordingly more remaining energy is required for nodes in the network. It is clear from Figure 3.4 that network life time is directly affected by network density. It is seen that twenty five nodes used more remaining energy in both models as compared to remaining energy used by five nodes in the networks. Life time of nodes in proposed model is better than Wang model.

3.8.1.4 Packet Delivery Ratio and Node Speed

In this section, packet delivery ratio is decreased with increase in speed of mobile nodes in the network. Packet delivery ration in proposed model is better than existing model as proposed by Wang et al. [144]. Figure 3.5 shows the packet delivery status. It is observed from simulation results that packet delivery ratio depends on node speed in the mobile ad-hoc network. Packet delivery ratio in proposed model is high as compare to Wang model [144] in mobile ad-hoc network.It is observed from Figure 3.5. that packet delivery ratio is affected with respect to mobile node speed in the mobile ad-hoc network. Network performance is determined with packet delivery ratio in the network.

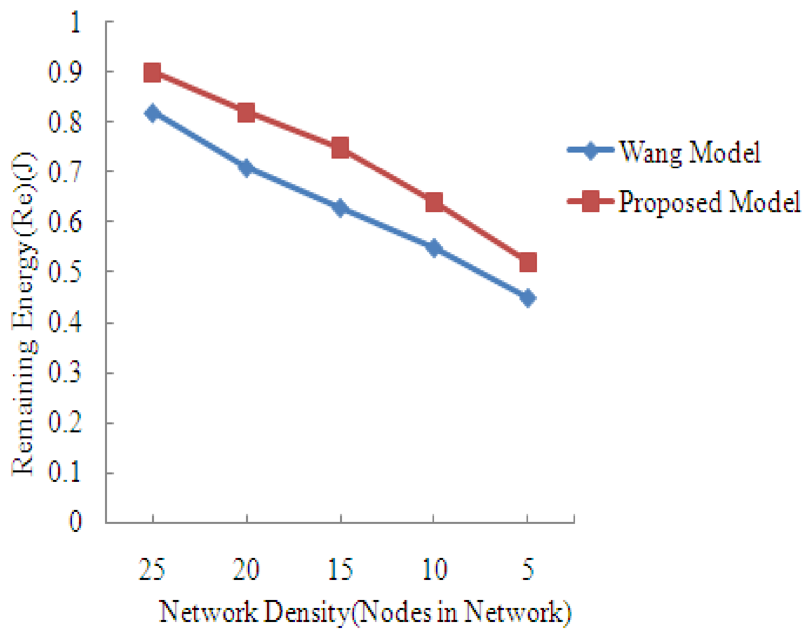


Figure 3.4: Remaining Energy and Network Density

3.8.1.5 Transmission Delay and Network Density

In this section, transmission delay is increased with decrease in network density mean mobile nodes. The status of transmission delay in proposed model is better than existing model as as suggested by Wang et al. [144]. Figure 3.6 shows transmission delay status.

It is observed from the simulation results that transmission delay depends on the network density (nodes) in the networks. Transmission delay in proposed variable transmission range model is low as compare to Wang model in mobile ad-hoc network.

Remaining energy of nodes is directly affected as transmission delay is increased in mobile ad-hoc network. Transmission delay is minimized to improve the remaining energy of nodes in the network.

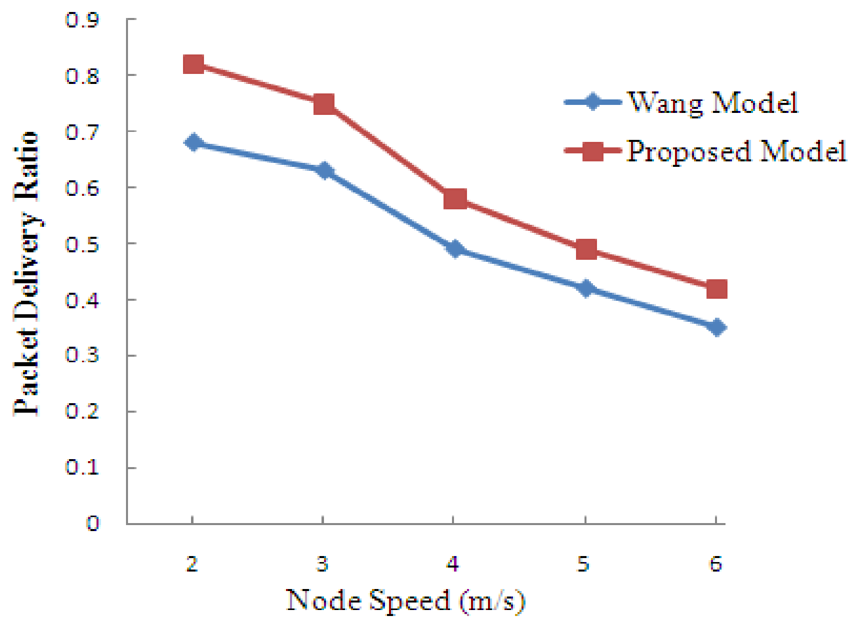


Figure 3.5: Packet Delivery Ratio and Node Speed

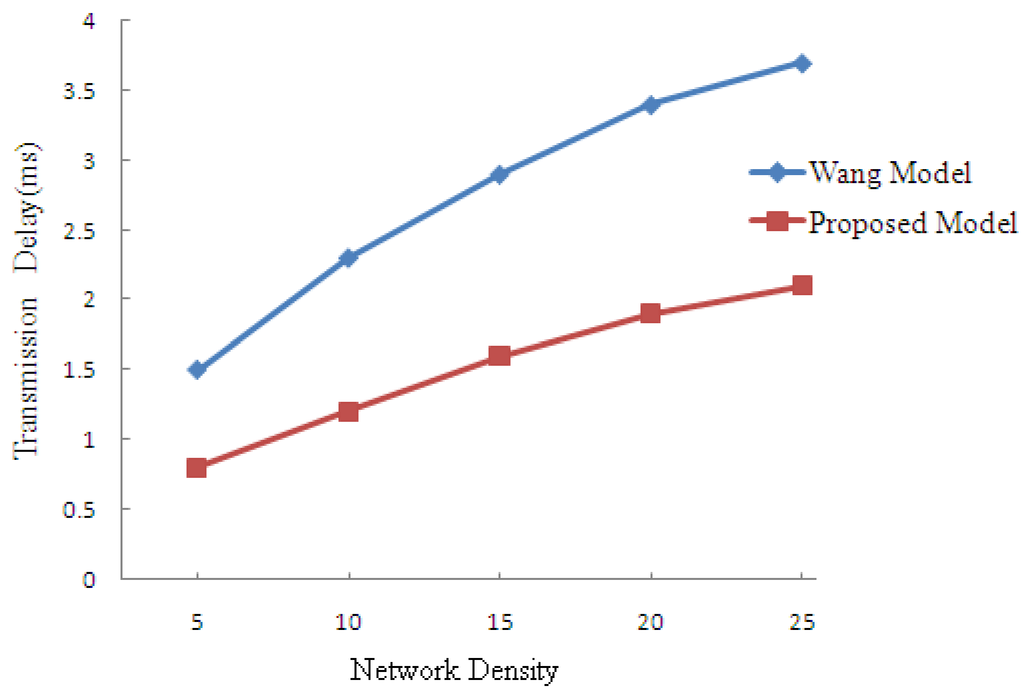


Figure 3.6: Transmission Delay and Network Density

Remaining energy is inversely proportional to network density in the network. It is seen that nodes consumed more energy when increased the network density or nodes in the network. Life time of nodes in proposed model is better than Wang model.

In this section, it is concluded that energy control is possible with network load. Remaining energy is controlled with network density, transition and receiving energy of nodes for mobile ad-hoc networks.

3.9 Conclusion

Energy management is necessary due to limited life time of mobile nodes in mobile ad-hoc network. Remaining energy of mobile node is inversely proportional to transmission energy in the network and lifetime is directly affected by remaining energy in mobile ad-hoc network. Transition energy and time are the factors to maintain remaining energy in mobile ad-hoc network. It is observed that proposed model provides efficient energy management to improve remaining energy in the mobile ad-hoc network. Other performance metrics like packet delivery ratio and transmission delay are better than existing model.

CHAPTER 4

POWER CONTROL WITH SLOTS SCHEDULING

CHAPTER 4

POWER CONTROL WITH SLOTS SCHEDULING

4.1 Introduction

Mobile ad-hoc networks have been a high demand network for many years. Power control is an important factor due to impact on nodes life in the mobile ad-hoc networks. Battery is a limiting factor in successful deployment of a mobile ad-hoc network, since nodes are battery powered. Power based connectivity among nodes is a new concept in mobile ad-hoc networks. Power control with transmission time is used to improve life time of nodes in the network. This is due to the fact that as the power of nodes gets higher and communication among nodes is possible with minimum hops or single hop in ad-hoc network. Nodes consume more power in re-transmission attempts in mobile ad-hoc network. Interference among nodes is reduced by reducing the transmission power levels at each node in the mobile ad-hoc networks. Power conservation is used to minimize the power consumption of nodes and objective like network lifetime is achieved with this procedure in mobile ad-hoc networks. Power saving mechanisms is used to decrease interference by increase the number of transmissions with power control in the mobile ad-hoc networks [51].

The main focus of this chapter is power control with scheduling function and identifies the parameters affect energy consumption in mobile ad-hoc network. Power is managed efficiently among the nodes in mobile ad-hoc networks. Power management among nodes is a critical issue for mobile ad-hoc networks. Different type of networks with data rate and power consumption is shown in Figure 4.1.

Personal area network technology was initially used to allow devices to communicate within smaller coverage area at low data transfer rate. Wireless local area network is used for wireless devices to communicate for long range communication at high data transfer rates. Network with standard IEEE 802.15.3 was designed to send data at high data rates comparable to IEEE 802.11wireless local area network. The communication range among wireless devices is smaller in the network. Power management is used to reduce the power consumption among wireless devices in the network standard 802.15.1.

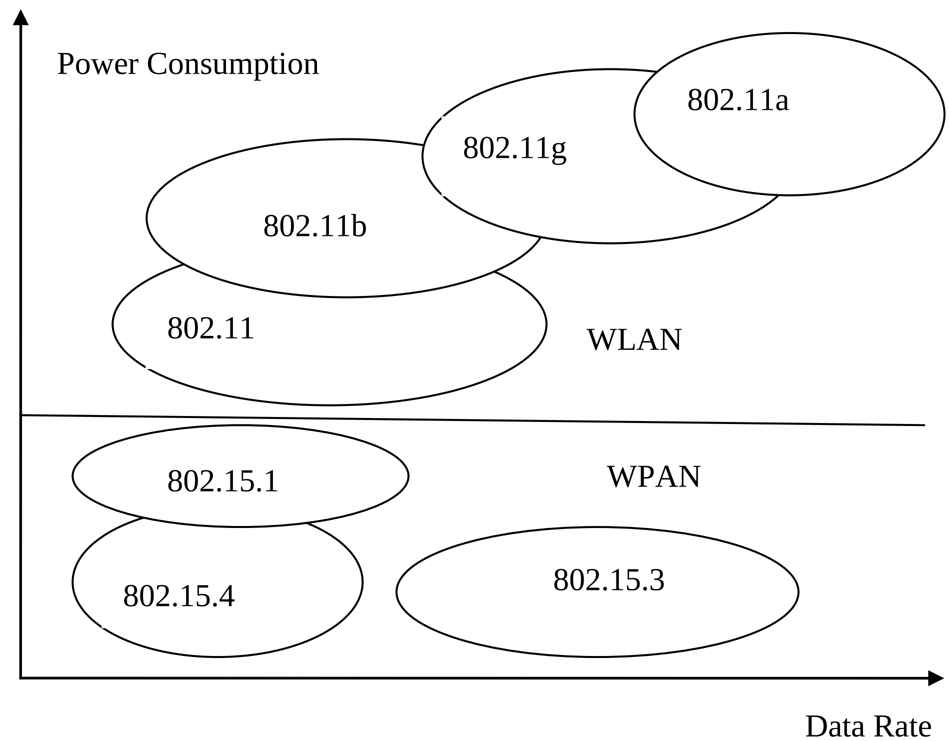


Figure 4.1: Power Consumption and Data Transfer Rate

Most wireless local area networks are operated on the IEEE 802.11 standard as in Figure 4.1. This standard is used for wireless devices to transfer data like traditional wired local area networks. A node consumes more power due to longer communication range in the network. Power saving mode is built into the 802.11 standard to reduce power consumption by nodes in network. IEEE 802.11h type standard of IEEE 802.11 is improving the power management capabilities in the network. Mobile ad-hoc network are robust due to lack of an infrastructure. Responsibility of coordination and control nodes are a critical issues in ad-hoc network [20].

Scheduling is a main aspect that is considered for power control in mobile ad-hoc networks. Energy efficient flowchart is also proposed to decide time slot schedule and control power in the network. Optimal schedule is used to minimize the time delay and provides maximum slots with in specified time. The proposed flowchart is used to minimize the delay in transmission of data in the network. Network is used a communication channel to inter connects nodes and provides communication services among a large number of mobile nodes. Single channel is used by nodes with access protocol in mobile ad-hoc network. Collided packets are increasing the time delay due to retransmission of packets in mobile ad-hoc networks. Scheduled transmission of data is required for each node to avoid any collision in ad-hoc networks. The time division multiple accesses are used to schedule transmission and save power in mobile ad-hoc network. Power control is used with medium access control in order to increase the utilization of radio channel in network. Scheduling function policy is efficient to increase the performance with utilization of the radio channel in the network.

4.2 Power Management

Battery is the main component to provide power supply to nodes in mobile ad-hoc networks. Mobile computing technology is growing rapidly and devices are more efficient. Battery technology is not developed to operate mobile nodes for many days without recharging. Power management depends on the active time of nodes in mobile ad-hoc networks [32].

The transmission power is determined by the reach ability requirement of the ad-hoc network. Routing protocols and the medium access control protocols are used to ensure minimum power consumption among nodes in the mobile ad-hoc network. Adjust transmission power control is required in the transmission of data packet among nodes to save power in the network. In adjust transmission power control, nodes adjust transmission power specifically per node or per link unit in the network. This power control is based on the distance between nodes or depending on radio frequencies. It conserves energy of a network and improves network performance [121].

4.3 Medium Access Control

In mobile ad-hoc networks, power controlled medium access control is becoming the most effective access protocol to provide the use of the radio spectrum in the network. It is difficult to design access scheme for mobile nodes to access the channel without centralized control point in mobile ad-hoc network. The source of energy waste in the networks includes wireless communication and interference. It is observed from radio communication that energy wastage depends on power consumption by communication between nodes in the network. For example, packet length is reduced in data compression techniques to save energy in radio communication. A power-aware medium access control protocol is used to avoid energy wastage from one or all sources in mobile ad-hoc network. To make medium access control protocol energy efficient, minimize random access collision and avoid the retransmission. Longer time delay and unnecessary energy consumption is associated with retransmission of data by nodes in ad-hoc network. An important target of any access protocol is to avoid collisions in the network [29].

Receiver nodes have to be active on all the time to maintain idle listening in the mobile ad-hoc networks. Power is consumed by nodes in idle listening is important factor for the performance of the network. Energy conservation is possible by energy aware medium access control protocols to use mobile nodes in sleep mode during no any communication among nodes in mobile ad-hoc network. Nodes do not perform any task in sleep mode and ready for communication in network. Energy saving is possible to switch node in sleep mode during no any work in mobile ad-hoc network. Mobile nodes used power due to overhearing the transmissions of neighbor nodes in the networks. Power control is the solution of this problem in the network. Energy saving with header compression is also possible by reducing the packet length in data communication for ad-hoc network. Power saving is possible when mobile nodes used multiple transmission slots without reservation packet.

Nodes are turned off when communication media is busy to avoid wastage of energy. It is possible to decrease the channel utilization. Bandwidth is most important factor for mobile ad-hoc networks. Bandwidth efficiency is the ratio of the bandwidth used for actual data transmission to the total available bandwidth in the network. The medium access control protocol used maximum bandwidth for mobile ad-hoc networks.

Medium access control achieves adaptively to both network structure and the quality of service factors for different types of network. Medium access control framework is used to provide the decision flexibility to access networks. Medium access control is developed for reliable data transportation with the view of prolonging the network lifetime. Ad-hoc network is synchronized and communication link time is slotted. The two-way handshake signals are used in the communication. Receiver sends a Request To Receive message. The receiver address is included in the message. A sender that receives a Request To Receive and that has a packet destined to the receiver can transmit data.

Packets have a fixed length, so that the two-way handshake is possible within a time slot as shown in Figure 4.2.

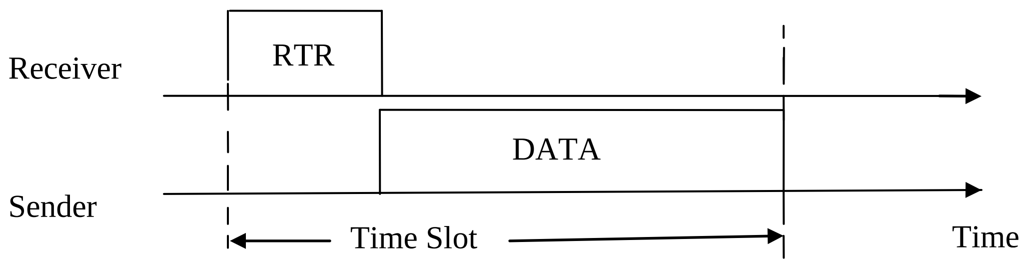


Figure 4.2: Two Way Handshakes

The protocol is used to avoid the collisions among scheduled nodes. It is more difficult to avoid collisions due to unscheduled stations in the network. A collision is occurring when an unscheduled station used to transmit the packet at a slot that is reserved by a scheduled station in the network. The control header of medium access control layer data units decides node's energy management mode.

The 802.11medium access control frame consists of a medium access control header, frame body and check sequence, as shown in the following Figure 4.3. Frame control subfield like Protocol Version presents the current version of the 802.11protocol, Type and Subtype determines the specific function, To DS and From DS indicates whether the frame is going to or exiting from the DS More Fragments presents fragments of the frame, Retry presents whether or not the frame is being retransmitted, Power Management indicates mode whether active mode or power-save mod., More Data indicates more frames, WEP presents encryption and authentication in the frame, Order indicates received data frames order. Frame control field contains control information and used for defining the type of 802.11MAC. It is providing necessary information for the different fields to understand how to process the frame.

4.4 Scheduling

The main objective of scheduling is to decide the time in which waiting data packet for transfer at any point in the network. Packet scheduling and channel access scheduling are the two main scheduling in the network. Packet scheduling is used to select order in which packets are waiting for transmission and channel access scheduling is used to finalize the access of channel by nodes in network.

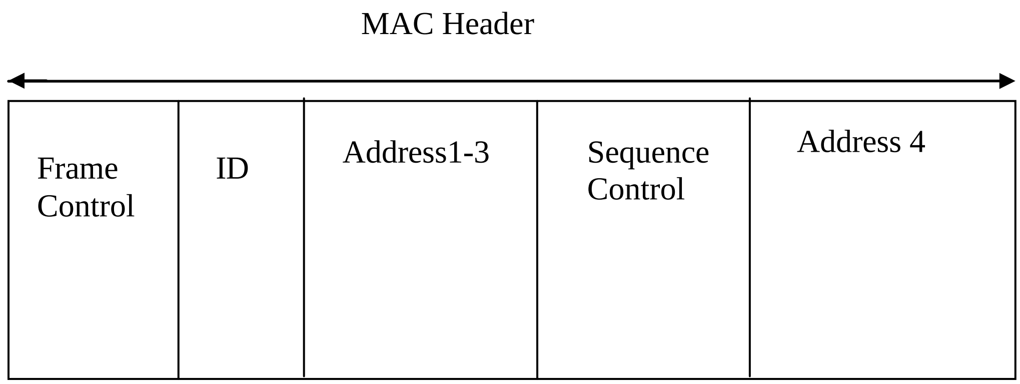


Figure 4.3: Medium Access Control Header

Transmission of data packet is provided by scheduling function due to muti-hops communication in the mobile ad-hoc network. Scheduling algorithm is used to decide which packet to process next, this will have effect in the end to end delay and network density. Slots based scheduling for simulation is proposed to schedule the data in mobile ad-hoc network. There are different scheduling functions for different network environment. Different routing protocols are used with different methods of scheduling and provide support to data packet with smaller number of hops to their destination. It reduced the delay and improve packet delivery ratio in the mobile ad-hoc network.

Time division multiple access is also a scheme to access medium with different node speed and network density in the network. Quality of service is assured with scheduling function and efficiently bandwidth is utilized in the network. Time division multiple access is used to optimize energy consumption in better way as compare to Ring based scheduling for mobile ad-hoc network. Slot based scheduling is better due to better performance in case of packet delivery ratio, end to end delay and network density. In this schedule, data packets are transmitted with time slots as shown in Figure 4.4.

The payloads in one physical block are known as packet and use multiple slots as shown in Figure 4.4. Scheduling function that decides the bandwidth is maintaining link among nodes in the network.

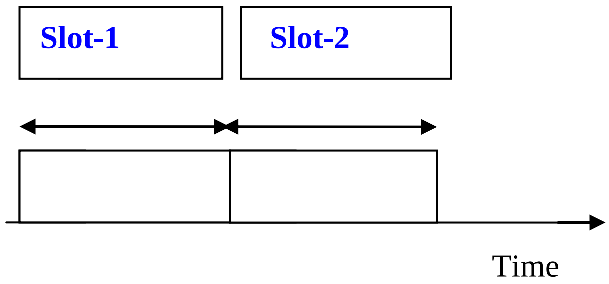


Figure 4.4: Time Slots

Consider packets that arrived at time t_a, x(t_a).

Where t = system time, t_a= packet arrival time,

x(t_a) = no. of packets arrived during (t_a-1, t_a),

t_d= packet deadline,

h_r(t)= scheduling function, $0 \geq h_r(t) \leq 1$.

Transmit all the packets before deadline t_a+t_d. The number of packets to be transmitted is given by equation (1).

$$x(t_a) = \sum_{t=t_a}^{t_a+t_d-1} h_r(t - t_a)x(t_a) \tag{4.1}$$

Where h_r and x(t_a) are vector forms of the scheduling function and packet arrival [69].

4.5 Flow Chart

Energy depletion of nodes is controlled to improve the life time of nodes and overall performance in ad-hoc networks. Directional antenna is used to avoid energy depletion and interference among nodes in the network. Power control is used for reliable data transmission in mobile ad-hoc network. Flow chart is proposed to setup communication and control power in mobile ad-hoc network.

Node transmits frames using the pre-assigned time slots as shown in Figure 4.5. Interference is reduced by using this procedure. Time slots for each user have been pre-determined to avoid the collision in mobile ad-hoc network. The control of communication and interference is very complex, especially when nodes are mobile in ad-hoc network. Packet routing is known as store and forward packet routing. In this routing, a packet can either wait in queue or jump to other queue.

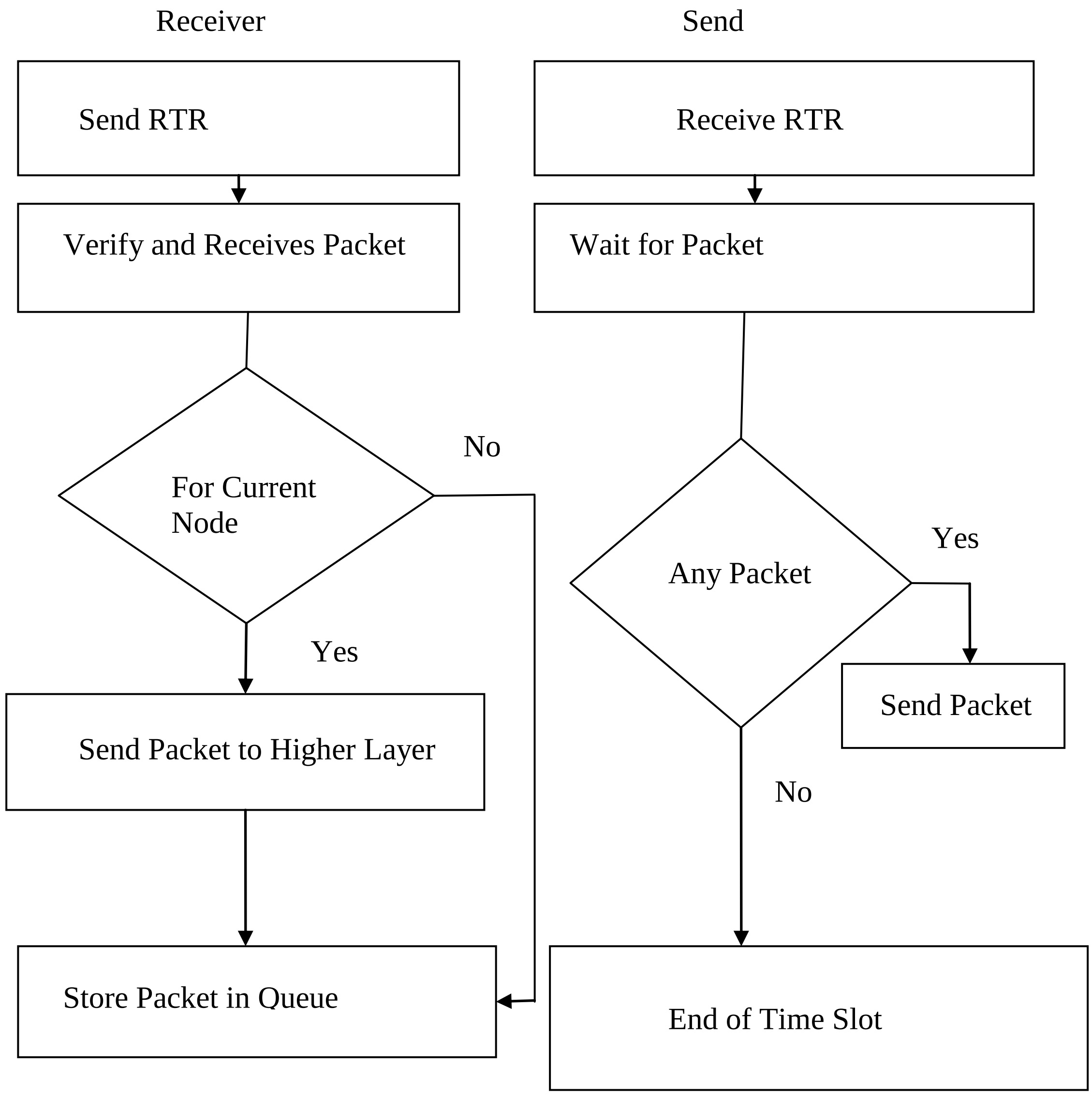


Figure 4.5: Flow Chart

4.6 Simulation Results

OMNET++simulator is used to simulate mesh topology based mobile ad-hoc network. Simulator is effective tool to analysis of energy consumption of mobile nodes in the mobile ad-hoc network. All nodes are in the range of each other to send and receive data in the network. Network parameters are used to measure the node battery power consumption with respect to slot time and number of slots. Five cases are explained to know the relationship between battery power and slot time.

Case1. Slot transmission time t=0.5s, Number of slots=5 to 20 slots

Nodes are interconnected in mesh topology and have fixed slot time. Nodes have used slots for transmission and reception of data in the network. Battery power depends on the slots time used for communication of data among nodes in the network.

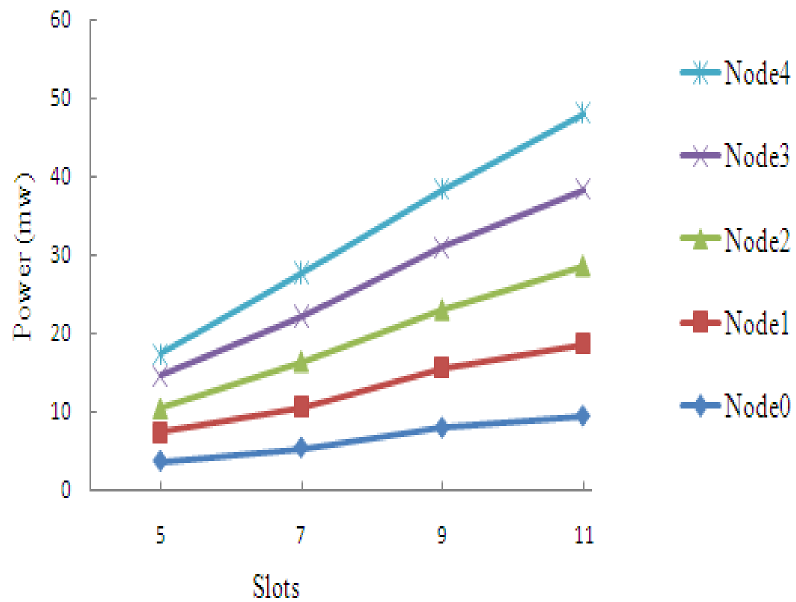


Figure 4.6: Slot and Power (mw) with Time, t=0.5s

It is observed from Figure 4.6 that nodes have consumed less power with five slots as compared to power consumption with twenty slots. Nodes consumed more battery power when numbers of slots are increased in communication network.

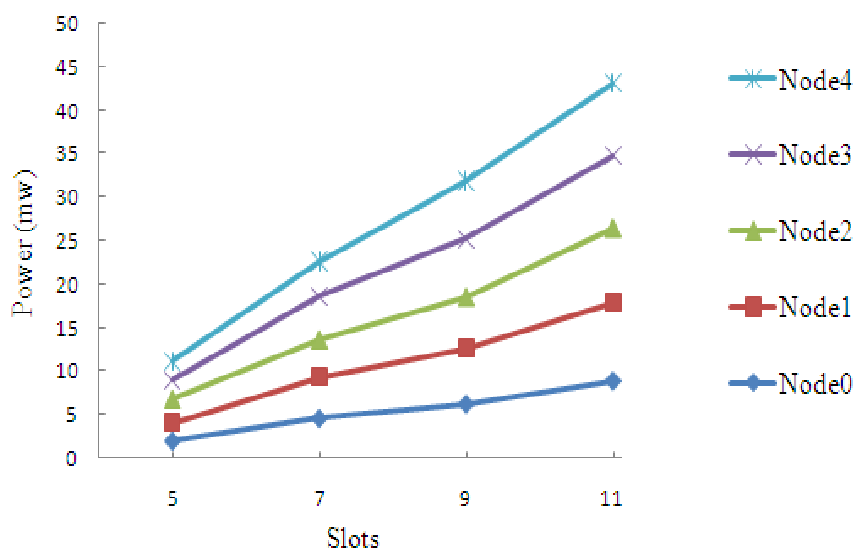


Figure 4.7: Slot and Power (mw) with Time, t=0.4s

Case2. Slot transmission time t=0.4s, Number of slots=5 to 20 slots

It is observed from Figure 4.7 that network consumed less power when slots time is decreased in the network from time t=0.5s to 0.4s with same set of slots in the network.

Case3. Slot transmission time t=0.3s, Number of slots=5 to 20 slots

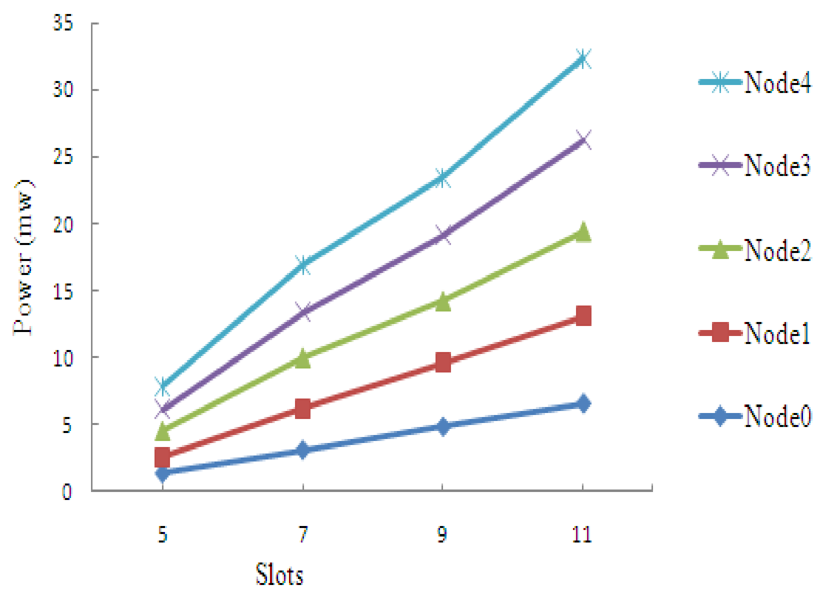


Figure 4.8: Slot and Power (mw) with Time, t=0.3s

Case4. Slot transmission time t=0.2s, Number of slots=5 to 20 slots

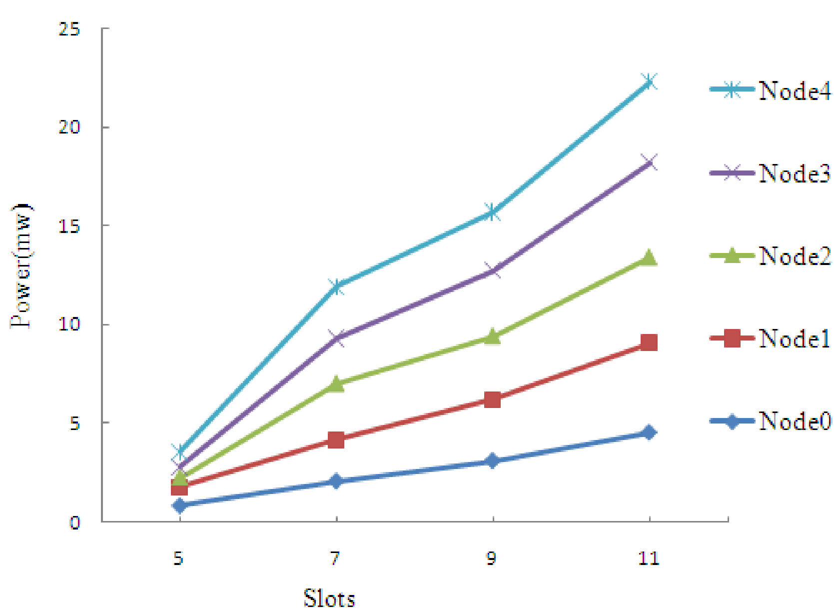


Figure 4.9: Slot and Power (mw) with Time, t=0.3s

It is observed from Figure 4.8 that power consumed by nodes is low as compared to previous results with slots transmission time as t=0.3s in the network.

It is observed from Figure 4.9 that power consumption is decreased as compared to previous results by reducing the transition time of slots in the network.

Case5. Slot transmission time t=0.1s, Number of slots=5 to 20 slots

In this section, it is observed from all the above results that power consumption is controlled with Function scheduling with time. Power consumption is depends on active time of nodes in mobile ad-hoc networks. Network life is increased by decreasing the battery power consumption during active time in the network. Network life time is directly increased perfect scheduling with less slots transmission time in the network. Node battery power consumption is reduced by transmission of more slots in limited periods without any collision in the network.

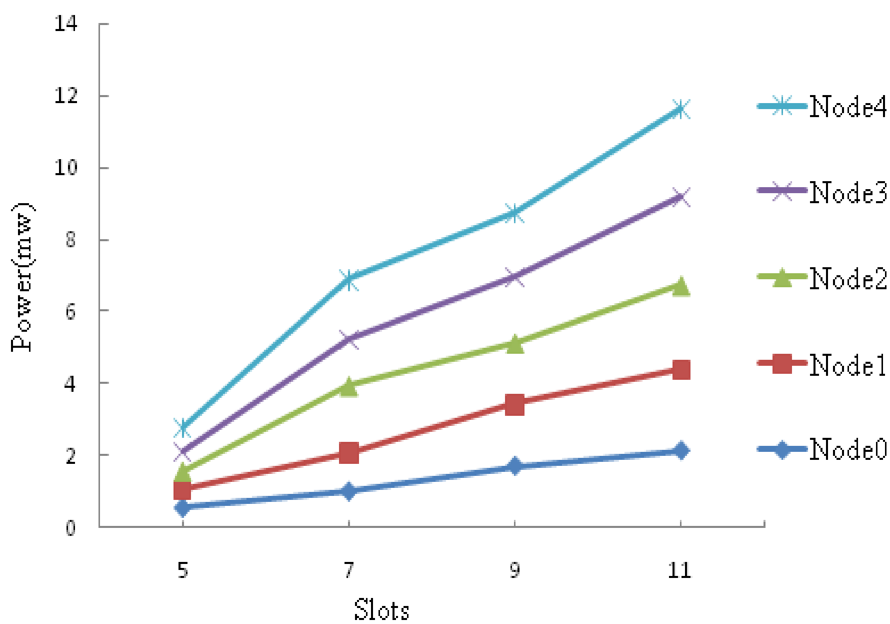


Figure 4.10: Slot and Power (mw) with Time, t=0.1s

It is observed from Figure 4.10 that nodes have consumed very less power with slots transmission time 0.1 s as compared to all previous results.

4.7 Performance Evaluation

Ring schedule based time division multiple access existing scheduling for transmission of data packet is not efficient to save energy and improve delay due to poor quality of service and interference among nodes in the network. Proposed power control scheduling is most effective as compare to existing model based on performance metrics for the network. Packet delivery ratio, End-to-End delay, Mobility factors are used as performance metrics to know the affects of proposed slots based scheduling on the performance in the mobile ad-hoc network. End-to-End-delay is averaged delay over transfer of data packets from the sender node to the destination node in the network. Packet delivery ration is the ratio of the packets received without any collision and the total packets transmitted in the mobile ad-hoc network. Network density is considered as number of nodes or network load for this network. Relationship among various performance factors is explained below:

4.7.1 Packet Delivery Ratio and Network Density

In this section, packet delivery ratio is increased with decrease in network density mean mobile nodes. The status of packet delivery ratio in proposed model is better than existing model as proposed by Wei et al. [134]. Figure 4.11 shows packet delivery status.

It is observed from the simulation results from Figure 4.11 that packet delivery ratio depend on the network density (nodes) in the networks. Remaining energy of nodes is increased as mobile nodes are decreased in the mobile ad-hoc network.

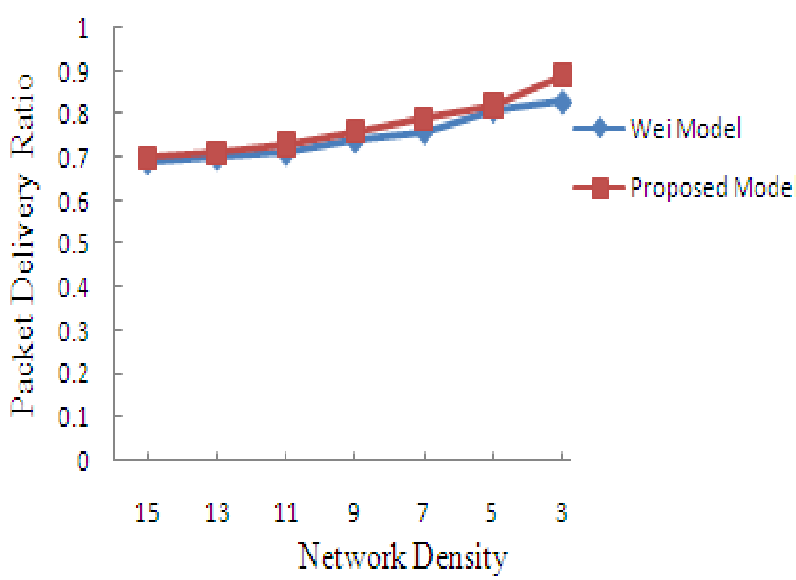


Figure 4.11: Packet Delivery Ratio and Network Density

4.7.2 Packet Delivery Ratio and Node Speed

It is observed that Figure 4.12 that packet delivery ratio is decreased with increase in speed of mobile nodes in the network. Packet delivery ratio in proposed model is better than the existing model as proposed by Wei et al. [134]. Figure 4.12 shows the packet delivery status.

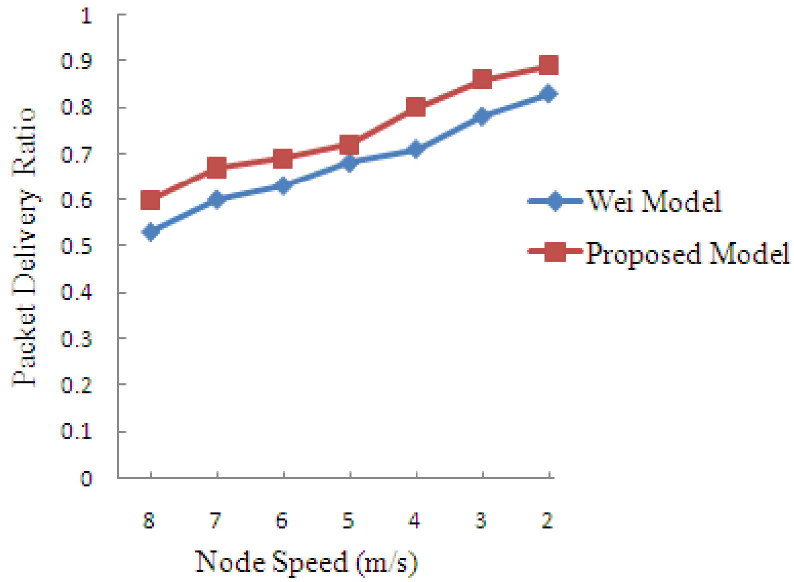


Figure 4.12: Packet Delivery Ratio and Node Speed

4.7.3 End to End Delay and Node Speed

In this section, End-to-End delay is increased with increase in nodes speed for mobile ad-hoc network. The status of delay in proposed model is better than existing model as proposed by Wei et al. [134]. Delay status is shown in the Figure 4.13.

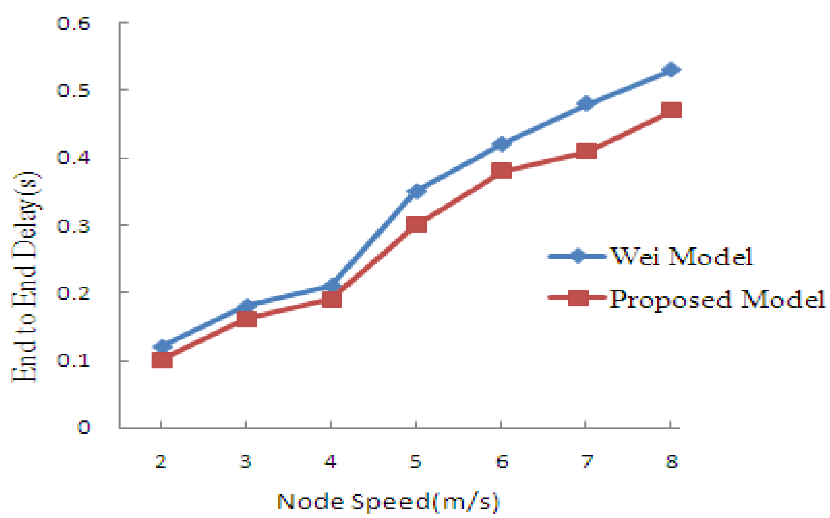


Figure 4.13: End to End Delay and Node Speed

It is observed from the simulation results that delay depends on nodes speed in the networks. End to End delay is minimized to improve the remaining energy of nodes in the network.

4.8 Conclusion

It is observed that power control is possible with adjustment of slots time in mobile ad-hoc network. Power consumption is decreased with transmission of maximum slots in fewer periods in the network. Proposed flow chart is effective for power saving mechanism for ad-hoc network. Simulation results shows optimization of power consumption is possible by saving battery power for mobile ad-hoc network. Performance of proposed model is better as compare to existing model suggested by Wei et al. due to function scheduling with slots time in the mobile ad-hoc network.

CHAPTER 5

POWER CONTROL WITH TRANSMISSION RANGE

CHAPTER 5

POWER CONTROL WITH TRANSMISSION RANGE

5.1 Introduction

Transmission range is the parameter to reduce the overall power consumption in mobile ad-hoc network. Transmission range and power are related to each other in the network. Power of mobile nodes affects energy consumption due to communication range when nodes are not in the range of each other and aspire for data transfer through intermediate nodes in the network. Transmission power is directly proportional to transmission range among nodes in the network. Power control is an issue in the design of mobile ad-hoc networks due to common range transmission. Effective variable transmission range based power control is used to improve the overall network performance in the network. This type of power control increases the connectivity and improves the remaining energy of nodes in mobile ad-hoc networks.

Optimization of energy consumption is a challenge due to limited battery power in mobile ad- hoc networks. There are many power control schemes to save communication related energy. Mobile ad-hoc network is used for node to node communication without any infrastructure. Network has self-configuration ability and used for situations where no infrastructure is possible. Recently software is used to control the transmission power to save energy with optimum transmission range. Transmission range also impacts many other networking performance metrics like network density in the ad-hoc network. It is more difficult to select transmission power levels which maintain a relation among transmission power and network density in the network.

Mobile ad-hoc network consists of nodes with relatively low mobility and short transmission range. Optimization of transmission range is an issue in designing ad-hoc network. Variable transmission range is used in reducing the energy consumption between the nodes and increasing the packet delivery ratio in mobile ad-hoc network. Packet delivery ratio also depends on the transmission range according to mobility speeds of nodes in the mobile ad-hoc network. The network performance is enhanced by variable transmission range in mobile environment. It is expected to select an effective transmission range to control energy consumption in the networks. Power control is necessity for mobile ad-hoc network by adjusting transmission ranges. Data transmission is an important communication factor used in mobile ad-hoc networks. It is required to develop efficient communication range model for optimization of energy consumption in the network.

Transmission range based power control is a new concept in mobile ad-hoc networks. It is used to improve average power consumption. Interference among nodes is reduced by reducing the transmission power levels at each node in network. Energy saving protocols are used to dynamically reach a near optimal transmission power level which is close to the maximum achievable remaining energy of nodes in the network. The major advantage of this approach is power saving. Power is one of the most important resource in the mobile ad-hoc environment. It is used in improving the remaining energy and life time as well. Power control based routing is possible with low range mobile ad-hoc network and used for rescue and emergency disaster relief operations [14].

This chapter is focus on the transmission power and other performance parameters with minimum transmission range in mobile ad-hoc network. Transmission through intermediate nodes is used for the transmission of data to destination point in the network. Transmission range management is used to increase the life time of nodes in ad-hoc network. Transmission powers of nodes decide the throughput in the network and affects network life time. Existing techniques have been based on communication path and used with many intermediate nodes instead of direct transmission.

5.2 Power Control Models

The power control models are categorized into three categories:

1. Transmission Power Based Model

   Transmission power based model is used to add the transmission power of the data packet at each link in the network. Energy efficient routing protocol is used to minimize the total transmission power along the path in the mobile ad-hoc network.

2. Transcieving Power Based Model

This model is used to add power consumed by nodes during transmission and receiving for transfer of data packet at each link in the network. Intermediate nodes consumed energy during forwarding and receiving data packet in the networks.

3. Reliable Transmission Power Based Model

This model is used to add up the energy consumption for new data and retransmitted data in the network [41].

5.3 Transmission Power Control

Effective power control is a great challenge in the development of mobile ad-hoc network. Transmission power protocols are based on common range transmission in mobile ad-hoc networks. Variable communication range instead of common range transmission is used for development of mobile ad-hoc network. The transmission range has an important role on the data transfer rate due to the mobility nature of nodes in the network. The concept of transmitting the numbers of signaling packets with low signal power is used in the mobile ad-hoc networks [65].

Power control affects the performance of mobile ad-hoc networks due to impacts on the traffic carrying capacity and the connectivity in the network. Intermediate nodes are decreased by increasing the transmission power of nodes in the ad-hoc network. Low transmission power is used to reduce the interference and need more intermediate nodes to reach destination in the network. It is possible to use direct communication link and maintain large connectivity among nodes with optimum transmission power of nodes in the network.

In this chapter, variable-range based transmission control is used to improve the link connectivity and performance of the network. Power control also impacts on the packet delivery ratio and transmission delay time in mobile ad-hoc networks.

5.4 Advantages

Transmission range based power control is used to improve the communication links and energy consumption among nodes in the network. Advantages of transmission range based power control are explained below:

1. Reliable Link

Power control techniques are used to maintain reliable link and connectivity in mobile ad-hoc network.

2. Energy Consumption

Transmission power control is used to decrease the transmission power and improve energy consumption in the network. Remaining energy is directly associated with transmission power of nodes in the network.

3. Better Reuse of the Medium

This power control is used to reduce number of collisions by enhance network utilization with lower latency times. Signal range is most important for successful link among nodes in the ad-hoc network [36].

5.5 Transmission Modes

Source to destination transmission mean direct transmission between source and destination another way is node by node transmission. These are the two transmission modes in mobile ad-hoc network. Error recovery is possible through retransmissions by the source node in the network. Individual link is used to provide the reliable transmission to the next node using localized packet retransmissions with node by node transmission in network [54].

Energy efficiency is associated with two factors as explained below:

1. Normalized Energy

Normalized energy is the average energy per data and provides the energy savings in the network.

2. Throughput

This performance metric determine the packets transmitted from the source point to the destination point in the mobile ad-hoc network.

5.6 Issues with Existing Common Transmission Range

Transmission energy is directly associated with transmission range. It is used to control remaining energy to increase the life time of mobile nodes in the network. None of the researchers have approached transmission range and remaining energy to optimize energy consumption in ad-hoc network. Energy management model is used to manage remaining energy in mobile ad-hoc network. It is observed that common transmission range mode could not control energy consumption of nodes to maintain the life time of network. A larger transmission range is achieved at the expense of more energy per transmission. Shorter transmission range is associated with a larger number of intermediate nodes to transmit a packet to destination node in the mobile ad-hoc network. The optimization of transmission range and power is main issue in design a network with relatively high mobility and long range. Remaining energy of mobile nodes in mobile ad-hoc network is controlled with variable range transmission model. It is used to increase the overall performance of the mobile ad-hoc network.

5.7 Proposed Variable Transmission Range Model

Variable transmission range is used to improve the remaining energy of nodes in mobile ad-hoc networks. Variable transmission range model is proposed to capture the relation between transmission power and remaining energy. This model is used for a significant increase in energy and performance over exiting model with variable transmission ranges. Near optimal transmission radius is used by each node in the mobile ad-hoc network. It is used to achieve the same power as well as a second transmission radius if nodes are able to select one of two power levels prior to current communication in mobile ad-hoc network. Transmission energy of nodes is determined by energy management technique and performance is analyzed with remaining energy of nodes in network. Remaining energy is the energy of the nodes after transreceiving data in mobile ad-hoc network. This energy is used to determine the current energy status of nodes in the network. In this model, source node S is placed at the centre of a circle of radius x, where x is the largest path between source point S and destination point D in the network, as shown in Figure 5.1. The destination node D is used to provide the uniform distributed information over the entire circle. Intermediate nodes as M and N are used to transfer the packet from the source point to the destination point due to limited communication range in the mobile ad-hoc network. All nodes are using common transmission radius R. Source node directly transfer data to destination node when both nodes are within distance R in the network. Common transmission range is shown in Figure 5.2.

Transmission is based on following two conditions and cases. In first condition, x must be greater than R and in the second condition, the sending nodes are aware about the positions of all its nearest nodes and position of the destination node. Two cases are considered based on above two conditions in the network. First case, sender node S used to transfer a packet directly to the destination node D, in case D is placed within distance R from S in the network. Second case, Destination node is outside the communication range of the source node when the source node sends the packet to intermediate node through M and N.

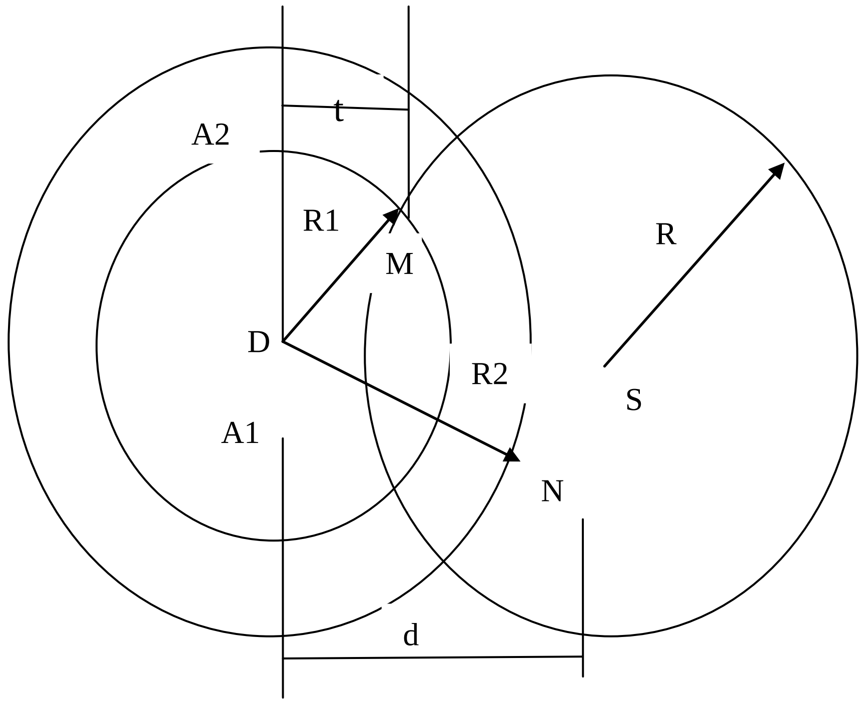


Figure 5.1: Variable Transmission Range

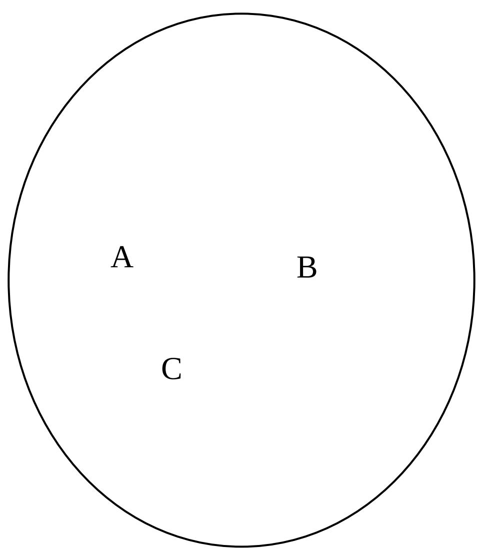


Figure 5.2: Three Nodes in Common Transmission Range

Power control is not effective in common transmission range among mobile nodes in the network.

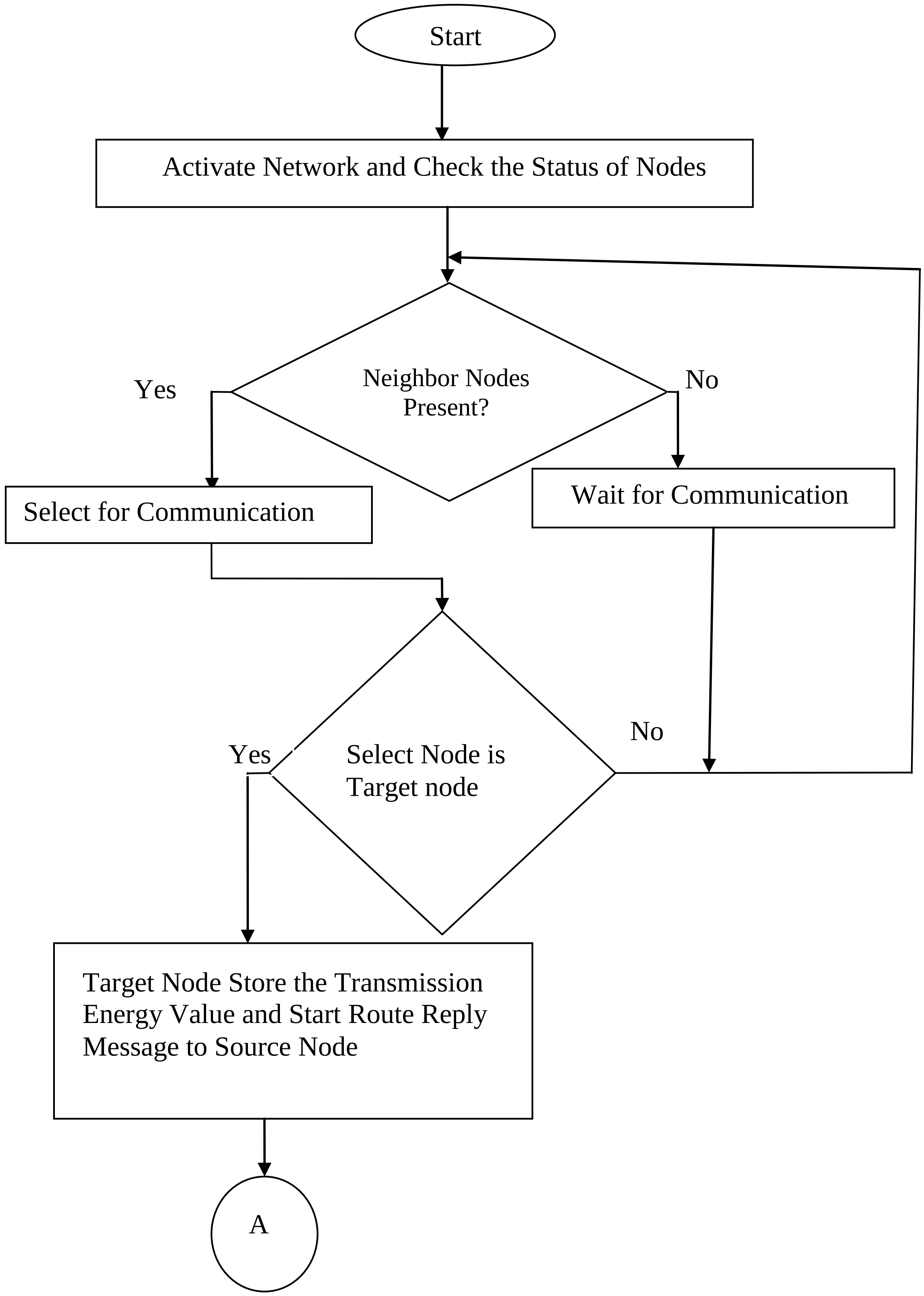
Transmission energy (Txe) is measured with Equation (5.1) as given below:

$$\mathrm{Txe} = \mathrm{K1r\omega} + \mathrm{K2} \qquad (5.1)$$

Where r is the transmission range, ω is the path loss exponent, k1 and k2 are parameters and determined by the characteristic of the transceiver.

Ad-hoc on demand distant vector routing protocol with Route Request, Route Reply and Route Error messages is used for selection of path in mobile ad-hoc network. When a source node transfer data to a destination node and path is not identified in the network. Source node send route request message to closet nodes in the network. The routing table of a mobile node is used to maintain entries for each destination node in the ad-hoc network. Active and power saving modes are used by nodes in mobile ad-hoc network. Control messages like route reply messages are used to switch node to active mode shown in Figure 3.1.

Transmit power with optimum range is used to control energy consumption in the network. It is used to dynamically adjust transmission power and achieves the maximum remaining energy of nodes for network lifetime. Flow chart for Energy management with variable transmission range is shown in Figure 5.3.


Start
Activate Network and Check the Status of Nodes
Neighbor Nodes Present?
Yes
No
Select for Communication
Wait for Communication
Select Node is Target node
Yes
No
Target Node Store the Transmission Energy Value and Start Route Reply Message to Source Node
A

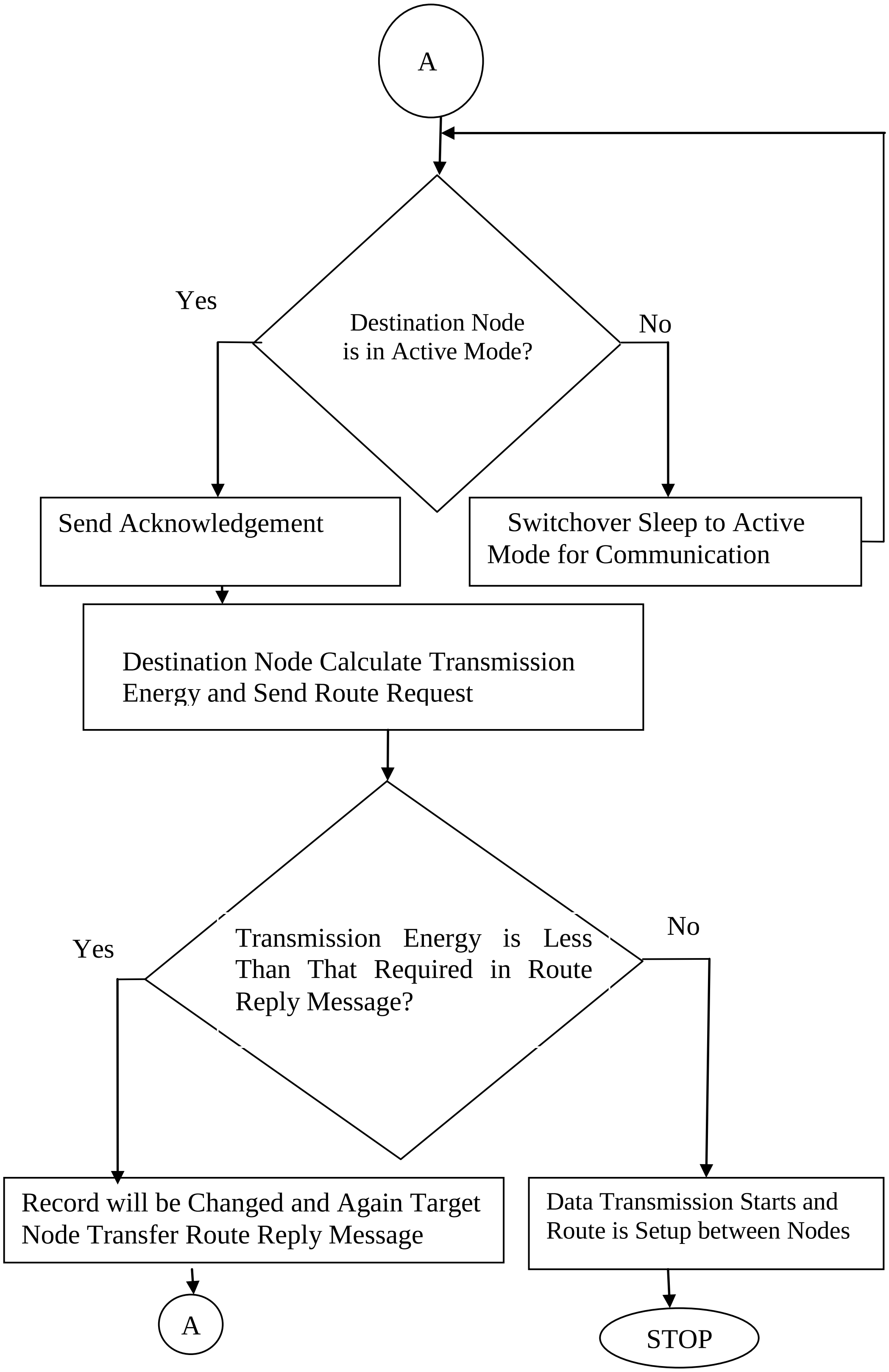


Figure 5.3: Flow Chart

5.8 Simulation Results

Proposed model is simulated with NS2 simulator for analysis of energy consumption. Network coverage area 900 m x 900 m, random waypoint model and 500 seconds simulation time is used for mobile ad-hoc network.

Table 5.1 NS2 Simulation Parameters

Area	900m x 900m
Nodes	30,35,40,45,50 Nodes
Mobility Model	Random Way Point
Node Speed	2m/s,4 m/s,6m/s,8m/s
Transmission Range	5m,10m,15m,20m
Initial Energy	100J
Protocol	AODV

Transmitter power range is from 100mw to 500mw and receiver power range is 50mw to 250 mw with transition time 0.005ms in the network.

Optimization of energy consumption is possible with transmission power and delay. Packet delivery ratio is the important factor to decide the performance of mobile ad-hoc network. Remaining energy or network life is in increased with performance metrics and relationship is explained below:

5.8.1 Remaining Energy and Transmission Power

In this section, it is observed from the simulation results that nodes remaining energy is directly associated with power consumed by nodes in transmission of data. Remaining energy by nodes in proposed variable transmission range model is higher as compare to existing model proposed by Javier et al. [56] in mobile ad-hoc network as shown in Figure 5.4.

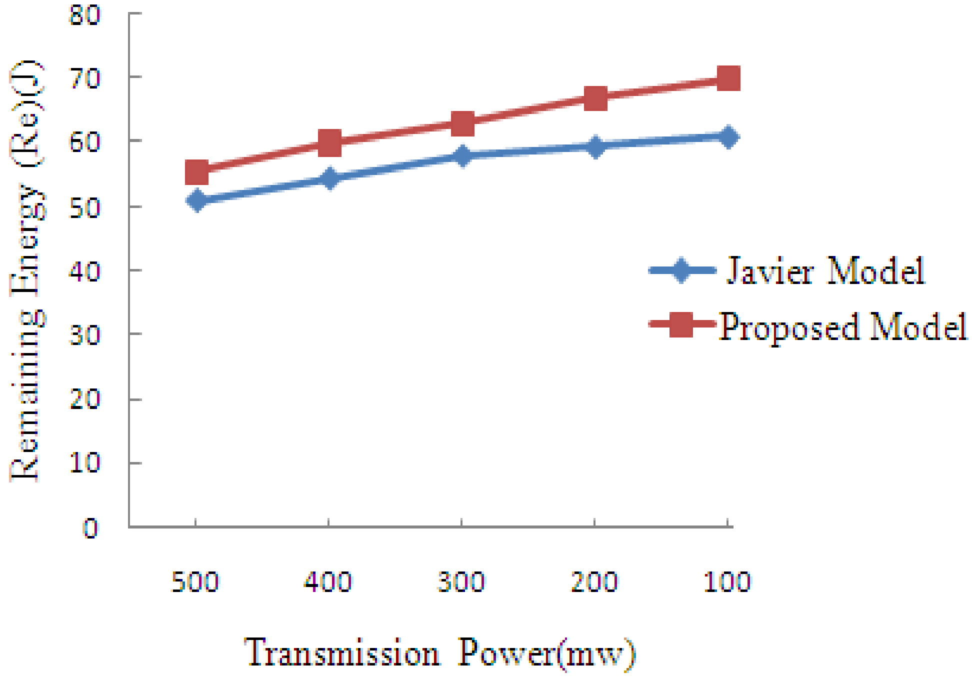


Figure 5.4: Remaining Energy and Transmission Power

Network lifetime is increased with perfect control of transmission power. Remaining energy of nodes is increased with respect to transmission power. Remaining energy of nodes at high power is low in the ad-hoc network. It is required low transmission energy of nodes to maintain high value of remaining energy in the network. Remaining energy is used to decide the life time of nodes in the mobile ad-hoc network.

5.8.2 Transmission Energy and Communication Range

It is observed from simulation results that nodes transmission energy is associated with communication range in mobile ad-hoc network. Transmission energy consumed by nodes in proposed variable transmission range model is low as compare to Javier model [56] in mobile ad-hoc network.

It is observed from Figure 5.5.that network lifetime is increased with perfect control of transmission energy in the network. Remaining energy of nodes is increased with respect to transmission energy. It is required low transmission energy of nodes to maintain high value of remaining energy in the network. Remaining energy is directly affected by communication range to decide the life time of nodes in the mobile ad-hoc network.

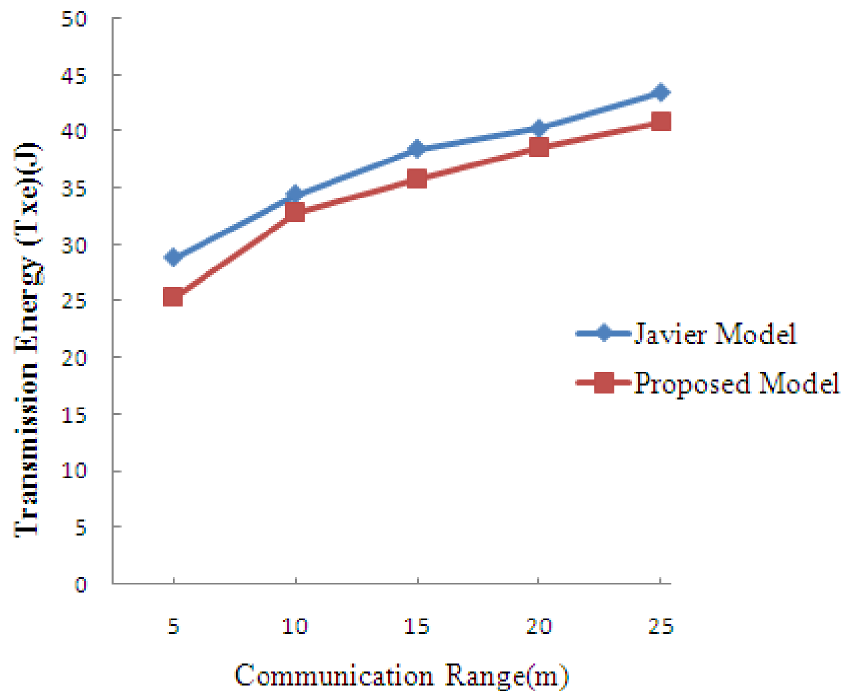


Figure 5.5: Transmission Energy and Communication Range

5.8.3 Transmission Delay and Network Density (Nodes)

It is observed from the simulation results that transmission delay depends on the network density (nodes) in the networks. Transmission delay in proposed variable transmission range model is low as compare to existing model suggested by Javier et al. [56] in mobile ad-hoc network.

It is observed from Figure 5.6 that transmission delay is increased with respect to number of nodes in the mobile ad-hoc network. Remaining energy of nodes is decreased as transmission delay is increased in mobile ad-hoc network. Network life time is directly associated with transmission delay in the network.

Low value of transmission delay is used to maintain high value of remaining energy in the network. Life time of nodes depends on remaining energy in the mobile ad-hoc network.

5.8.4 Packet Delivery Ratio and Node Speed

Packet delivery ratio is the ratio of packets that are transfer to a destination node to the number of packets that have been transferred by the sender node in the mobile ad-hoc network. It is observed from simulation results that packet delivery ratio is directly associated with node speed in transmission of data in the network. Packet delivery ratio in proposed variable transmission range model is high as compare to existing model presented by Javier et al. [56] in mobile ad-hoc network.

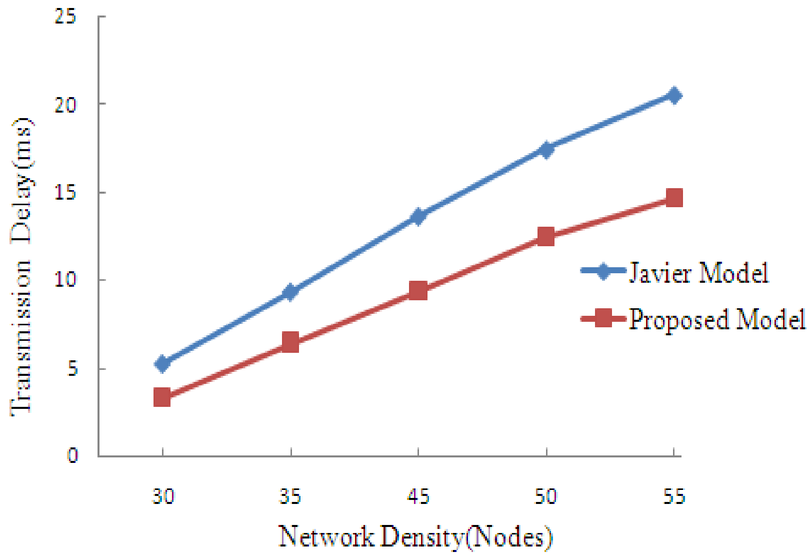


Figure 5.6: Transmission Delay and Network Density

It is observed from Figure 5.7 that packet delivery ratio is varied with respect to mobile node speed in the mobile ad-hoc network. This packet delivery ratio is decreased as node speed is increased in the network. Network performance is associated with packet delivery ratio in the network.

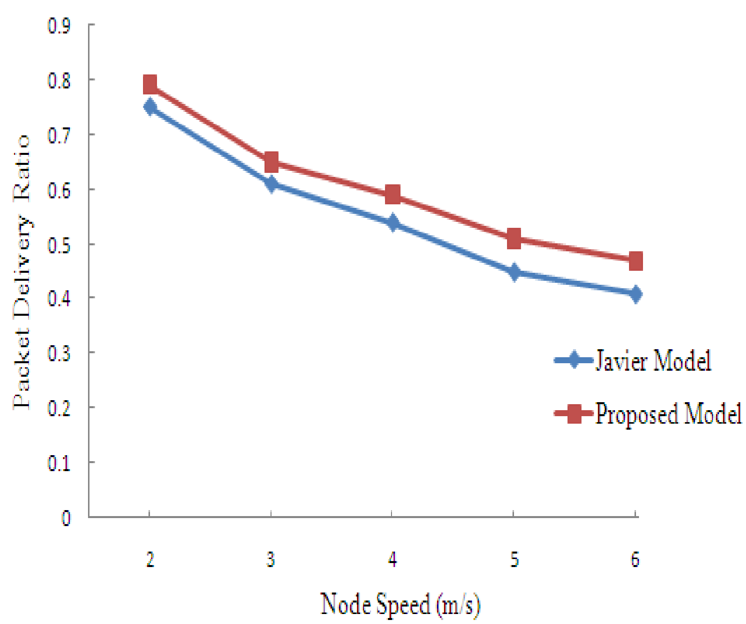


Figure 5.7: Packet Delivery Ratio and Node Speed

5.9 Conclusion

Power control with variable transmission range model is introduced for mobile ad-hoc network. It is observed from simulation results that network improves the remaining energy and network lifetime by optimize transmission range and power in the mobile ad-hoc networks.

In this chapter, optimal radius selection scheme with energy management is used to determine the remaining energy corresponding to the optimal transmission range in the mobile ad-hoc network. Transmission energy and remaining energy are inversely proportional to each other in mobile ad-hoc network. The transmission energy status of all mobile nodes is verified and transfer to destination node in the network. Variable transmission range based power control is of more important in mobile ad-hoc networks due to lack of central control. Packets are transmitted with reduced power consumption in the network. The communication range affects the energy consumption in mobile ad-hoc networks. Simulation results are effective to decide transmission energy of nodes for mobile ad-hoc networks.

CHAPTER 6

NEURAL NETWORK BASED POWER CONTROL

CHAPTER 6

NEURAL NETWORK BASED POWER CONTROL

6.1 Introduction

Neural networks based computing techniques are more effective for different type of applications. Researchers are continually constructing neural networks to solve complicated issues for different applications. Neural network approach is easy to use as compare to simulation network. Power conservation schemes are used for mobile ad-hoc networks. Mostly solutions are based on selection of the shortest path to save energy in the ad-hoc networks. In this chapter, neural networks based models are proposed for energy consumption prediction in mobile ad-hoc networks [129]. Accurate prediction is of great importance for reliable operation of mobile ad-hoc network. Power control has been one of the major research fields. A neural network model is an effective solution to estimate the power consumption by nodes in mobile ad-hoc network. Neural network is capable of representing the relationship between the input parameters of mobile ad-hoc network and results mean outputs [92]. Neural network is one approach for achieving proposed thesis object. Characteristics of neural network (NN) are explained below:

1. Learning Ability

   Neural network has an ability to learn and perform tasks based on the data given for training.

2. Own Organization

   A neural network generates own organization during learning time.

3. Parallel Computation

   A neural network computation is used to carry out operations in parallel computation.

4. Fault Tolerance

   Partial destruction of a network leads to the corresponding degradation of performance. A neural network capability is used to retain even with major network damage [67].

6.2 Requirements of Neural Network

There are basic reasons to building neural networks:

1. Parallel Processing

   Neural network is used to perform many tasks at a time. Neural network is like multiprocessor friendly architecture. Neural network is used in less time with parallel architecture.

2. Function

   Neural networks are used to perform functions via images, pictures and concepts. Computers functions are logically with a set of rules and calculations.

3. Self Programming

   Neural networks are used continuously to adapt function by altering their own programming. Conventional computers are limited by their functions.

4. Speed

   Neural networks are used with multiple chips built for the different applications. The speed of traditional computer is decided with different aspects of the processor.

6.3 Neural Network Architecture

Neural network is configured with Input layer, single hidden layer and output layer as shown in Figure 6.1.The hidden layer of network is non-linear and the output layer is linear. Input layer is made up of input values or data that connect the network to its environment. Single hidden layer consist of function known as Gaussian functions. Network using Gaussian functions construct local approximations to non-linear I/O mapping.

Output layer with linear activation function is given below in Equation 6.1.

$$y = w_1 \emptyset_1(||X - t_1||) + \cdots + w_{m1}\, \emptyset_{m1}(||X - t_{m1}||) \qquad (6.1)$$

Hidden unit contain radial basis function $\emptyset_\sigma||X\text{-}t||$, Where $r=||X\text{-}t_1||$ is distance of input value $X=(X_1,X_1\text{------},X_m)$ from vector t. Where t is known as centre and σ is called spread.

In this research work hidden layer with Gaussian function is used for σ >0, is given below:

$$\emptyset(r) = \exp\left(-\frac{r2}{2\sigma^2}\right) \qquad (6.2)$$

Center and spread are the parameters in this network. In radial basis function output depends on the distance of the input X from t. **N**etwork load (Nodes), receiving energy (Rxe) and transition energy (Te), used as input values. Main target is to get the value of remaining energy (Re) at any time with respect to input value.

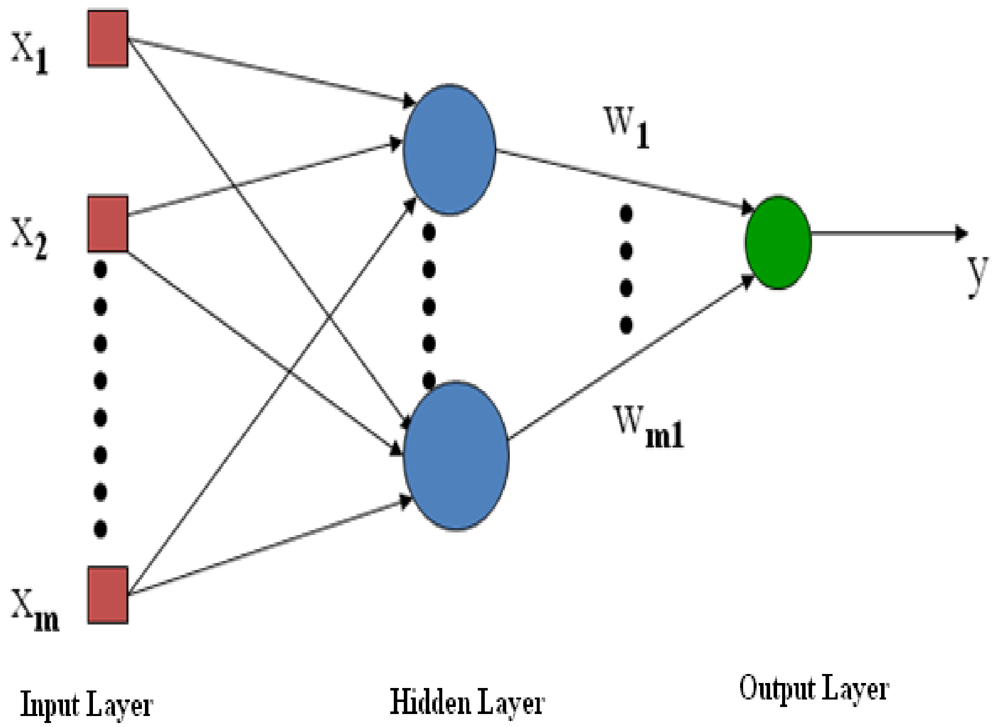


Figure 6.1: Generalized Neural Network Architecture

6.4 Issues with Existing Techniques

This section describes the issues with the existing research on the remaining energy of nodes and network lifetime in the mobile ad-hoc networks. Previous researchers have ignored power control with remaining energy in the mobile ad-hoc networks. Power control is the essential requirement to reduce energy consumption of nodes for effective data transmission with limited remaining energy of nodes in mobile ad-hoc network. Remaining energy is the energy of the nodes after transreceiving data and key parameter to increase the network lifetime in network. Simulator is used to analyze the energy consumption of mobile nodes in the mobile ad-hoc network. Simulation approach is time-consuming. It was not possible with simulator to determine any intermediate value without changing the ad-hoc network parameters value. Using simulator, again set the parameter and executes the program to get new results, according to intermediate value for mobile ad-hoc network. It is difficult and complex to determine any intermediate data value within data limit range. Simulation approach is not suitable for real-time applications during system restoration.

6.5 Energy Management and Routing

Energy management concept is used to know the energy status of nodes in network. Ad-hoc on demand distant vector protocol is used for energy management concept in mobile ad-hoc network. Route Request (RREQ), Route Reply (RREP) and Route Error (RRER) messages are used for route discovery in network. A node broadcasts RRER packets when a link to the next hop is broken. Active mode or powers save mode are two modes of operation in the mobile ad-hoc network. Node is ready to receive data at any time in active mode and sleeping most of the time in power-save mode. Routing protocol is used to generate control messages like route reply messages to switch to active mode.

RREPs messages are collected by the source node and start a timer. Energy management model has main parameters like transition energy and time. Transition energy is the energy consumption in state transition between two modes. Transition time is the time used in state transition from power saving mode to active mode. Transmission energy is decided with transmission power and receiving energy is depending on receiving power in this model. Node initial energy is total energy of node and used for different mode in communication. Remaining energy is calculated with Equation1 as explained in the Chapter3. Power control is directly affected by remaining energy of nodes in mobile ad-hoc network.

6.6 Proposed Neural Network (NN) Model

Neural network model is developed with the minimum energy level of each node in mobile ad-hoc network. This concept is used to solve power control problem in the ad-hoc network. Neural processing presents a different effective way to store and manipulate knowledge. Proposed neural network model is based on energy management model's simulation results. Neural network model is used to determine the remaining energy of nodes in mobile ad-hoc network.

Neural network model is developed to know status of remaining energy (Re) act as ouput value at any time with respect to network load (Nodes), receiving energy (Rxe) and transition energy (Te), used as input [P] values. Neural network results are used to describe the analogous relationship of remaining energy with respect to input parameters. Performance of the neural network model depends on selection of input parameters. Single input value based neural network model is proposed to get the results according to the target values. In this neural network model hidden layer has five neurons to get the results.

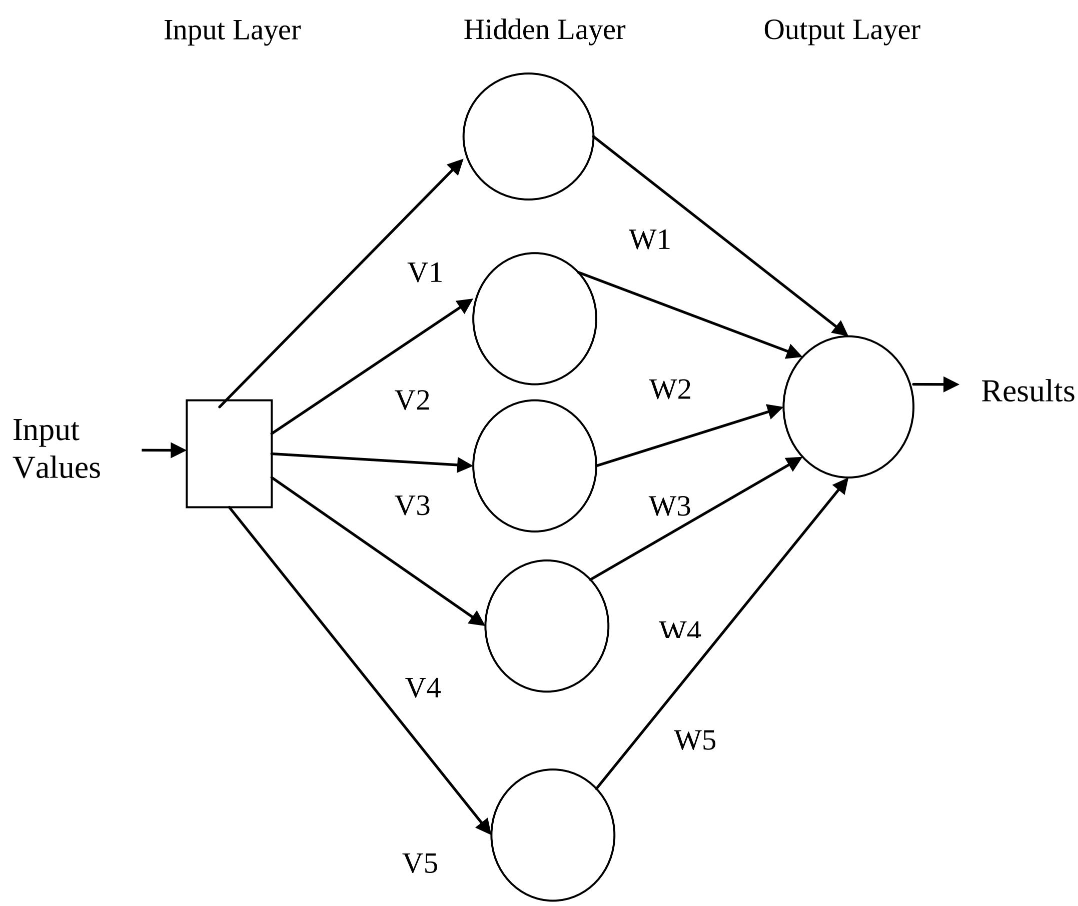


Figure 6.2: Proposed Neural Network Model

Radial basis network function newrbe is used to produce a network result with zero error on training vectors and describe below:

$$\text{net} = \text{newrbe}(\text{P}, \text{T}, \text{SPREAD}) \tag{6.3}$$

The function takes matrices of input vectors P and target vectors T. Spread constant SPREAD is used for the radial basis layer in neural network.

6.7 Experiment

Neural network models are developed with set of weights V1, V2,… V5 at the input layer and weights W1,W2.....W5 at the output layer. Neural network toolbox of MATLAB software is used for the modeling. The results from neural network model are used in validation of data within the range of the training set. This approach is most suitable for real time applications. Neural network toolbox supports learning with radial basis for mobile ad-hoc network. Relationship among network density, receiving energy and transition energy is explained with neural network model.

NS2 simulator is used to simulate existing Wang Models. In the simulation, mobile nodes move in 700 m x 700 m region for 100 seconds simulation time. Initial locations and movements of the nodes are obtained using the random waypoint model. All nodes have the same transmission range of 250 meters. Random Way Point is the mobility model. Nodes are moving speed is 2m/s. Transmission power is used in the range 100mw to 500mw. Receiver power is used in the range 50-250mw. Transition time is 0.005ms.

6.7.1 Experiment1

Neural Network model with network density as input values and remaining energy act as output values is shown in Figure 6.3. Neural network model is developed to know status of remaining energy at any time with respect to network density (Nodes). Neural network model is shown below:

6.7.1.1 Training Phase

Neural network is trained with the values of Network Density as input(s) and Remaining energy(Re) as output(s) as per results of simulator for mobile ad-hoc network called training pattern. Number of nodes in the hidden layer has been reported as five only for this model. The output of the network and the output of the neurons are computed by Gaussian function as mentioned earlier in the architecture of radial basis function network. The activation function and learning rate have been optimized during the training of the network for given training patterns. The input and output patterns are given in Table 6.1.

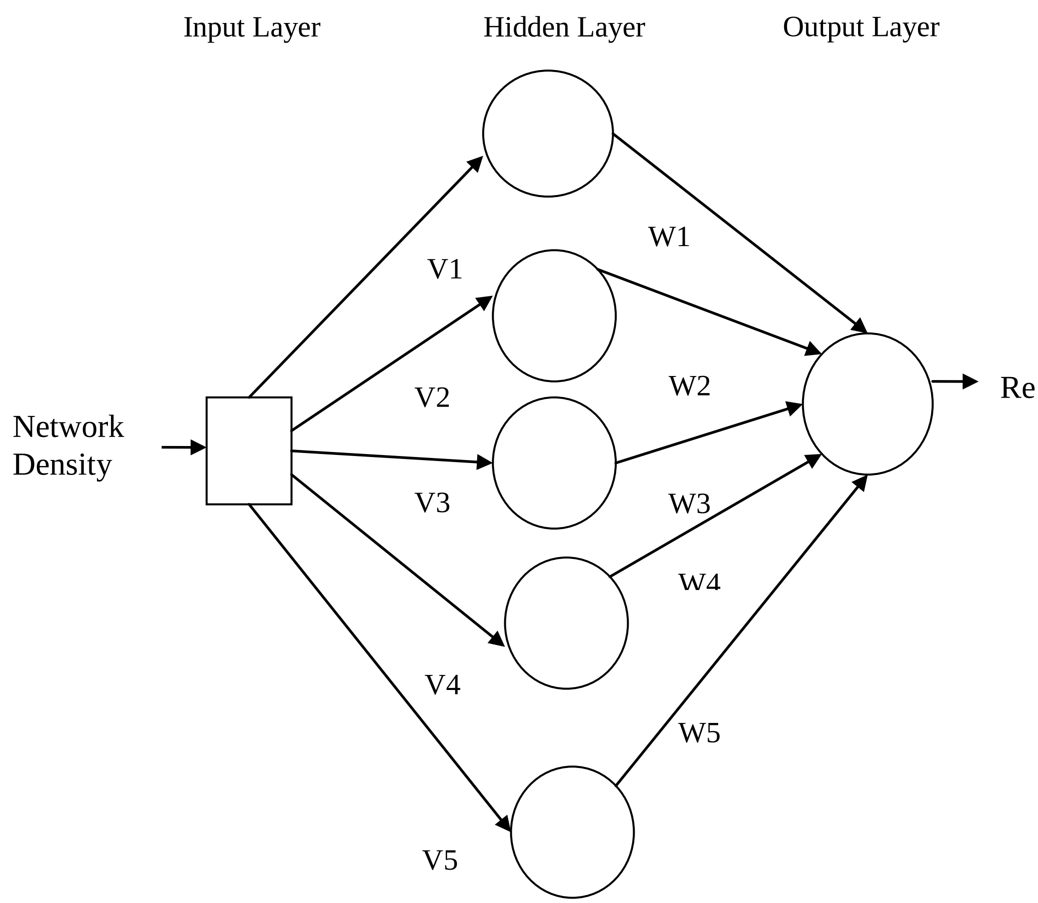


Figure 6.3: Neural Network Architecture to Estimate Re (Remaining Energy) as results or output values with respect to Network Density as Input Value

Table 6.1: Training Results of the Neural Network Using the Input Pattern for Remaining Energy and Network Density

Network Density(Nodes)	5	10	15	10	5
Wang Model	0.735	0.569	0.537	0.569	0.453
Proposed Simulation Model	0.825	0.624	0.620	0.616	0.528
Predicted by Neural Network	0.824	0.643	0.625	0.619	0.521

6.7.1.2 Validation Phase

Validation phase has been under taken to show the ability of neural network model to determine the remaining energy for network density or nodes in the mobile ad-hoc network. These are the new data patterns or unknown data that is not used during the training of the network. This data for validating the network model is given in Table 6.2.

The results from neural network model are used in validation of data within the range of the training set. It is observed from the Figure 6.4 that remaining energy is increased with decrease in network density. Remaining energy has not linear relationship with network load at few points. Neural network results are helpful to describe the exact nature of operation.

Table 6.2: Validated Data for Remaining Energy and Network Density (Nodes)

Network Density as Input Values	Remaining Energy (Re)(J)	
	Prediction by Neural Network (NN) Model	Wang Model [Simulation Results]
5	0.824	0.735
6	0.768	0.689
7	0.724	0.635
8	0.712	0.615
9	0.686	0.598
10	0.643	0.569
11	0.641	0.565
12	0.631	0.538
13	0.585	0.517

Relationship among remaining energy and network density in mobile ad-hoc network is shown in Figure 6.4.

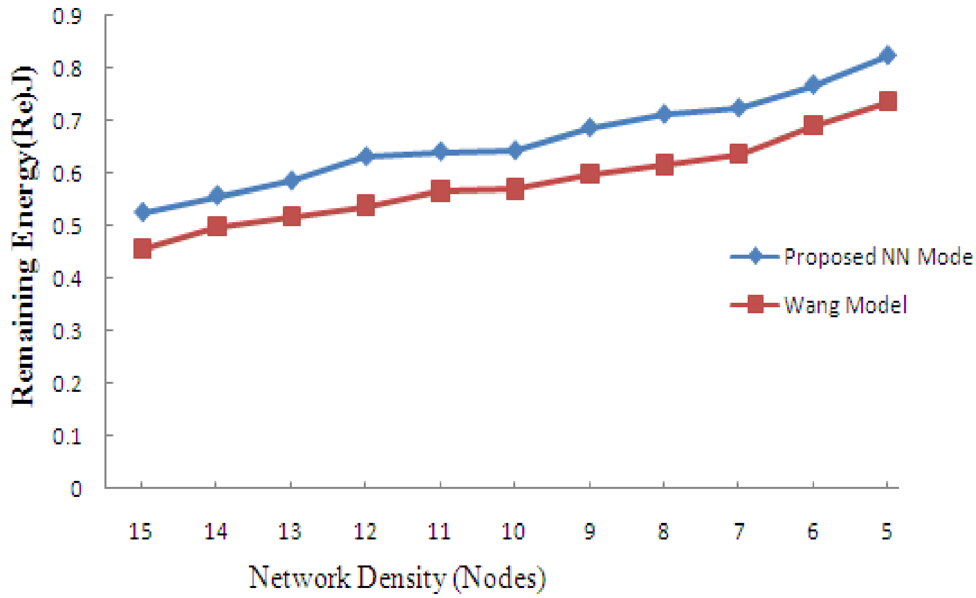


Figure 6.4: Remaining Energy and Network Density (Nodes)

6.7.2 Experiment 2

In this training set of neural network, receiving energy **(**Rxe) act as input value and remaining energy (Re), act as output value.

6.7.2.1 Training Phase

In this training phase, neural network is trained with the values of receiving energy as input(s) and remaining energy (Re) as output(s) as per results of simulator for mobile ad-hoc network called training pattern. Same number of nodes in the hidden layer has been reported as in previous training. Gaussian function is used to determine the output of the network and the neurons are computed. Training of the network for given training patterns depends on the activation function and learning used for this training pattern. The input and output patterns are given in Table 6.3.

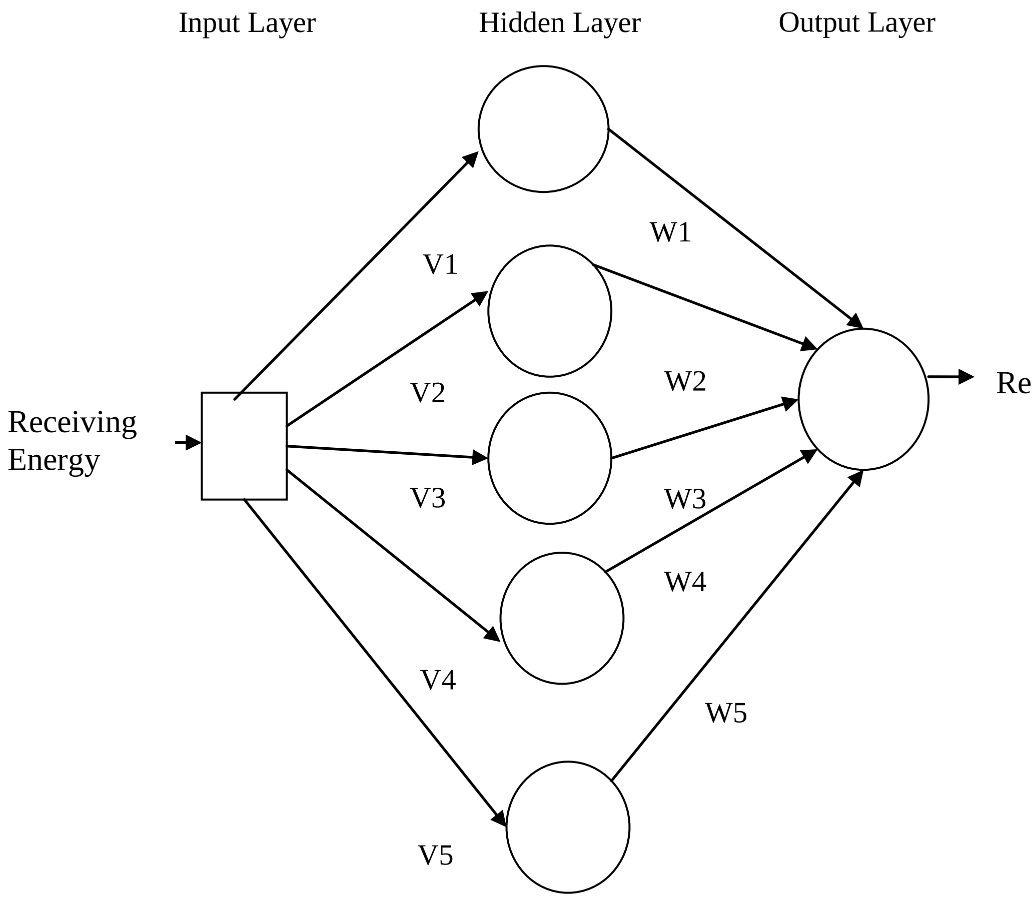


Figure 6.5: Neural Network Architecture to Estimate Re (Remaining Energy) as Results or Output Value with Respect to Receiving as Input Value

Table 6.3: Training Results of the Neural Network Using the Input Pattern for Remaining Energy

Receiving Energy	0.5	1	1.5	2	2.5
Wang Model	66.853	64.353	63.853	62.353	60.853
Proposed Simulation Model	67.855	65.367	67.853	63.993	61.853
Predicted by Neural Network	67.854	65.359	67.858	63.986	61.819

6.7.2.2 Validation Phase

In this section, validation phase has been under taken to show the ability of neural network model to determine the remaining energy for receiving energy as input value. These are the new data patterns or unknown data that is not used during the training of this network. This data for validating the network model is given in Table 6.4.

It is observed from the Table 6.4 that remaining energy is associated with receiving energy in mobile ad-hoc network. It is easy for mobile ad-hoc network operator to know the status of remaining energy and receiving energy at any time. It is seen from the Figure 6.6 that remaining energy is increased with decrease in receiving energy. Remaining energy value in proposed model is better than existed model as Wang model.

Table 6.4: Validated Data for Remaining Energy and Receiving Energy

Receiving Energy As Input Values	Remaining Energy (Re)(J)	
	Prediction by Neural Network(NN)	Wang Model [Simulation Results]
0.5	67.854	66.853
0.6	67.36	66.245
0.7	65.66	65.675
0.8	65.99	65.156
0.9	65.48	64.645
1	65.359	64.353
1.1	65.30	64.193
1.2	65.24	63.975
1.3	65.15	63.586

Relationship among remaining energy and receiving energy in mobile ad-hoc network is shown in Figure 6.6.

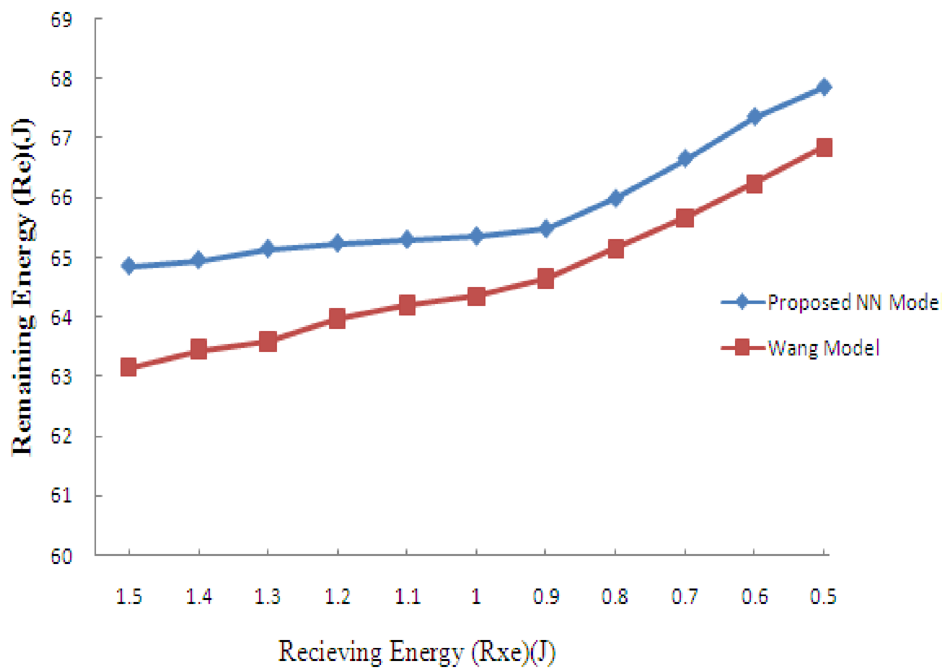


Figure 6.6: Remaining Energy and Receiving Energy

6.7.3 Experiment 3

In this training set of neural network, transition energy (Te) is used as input value and remaining energy (Re) act as output value. Neural network results are used to describe the analogous relationship of transition energy and remaining energy.

6.7.3.1 Training Phase

In this training phase, Neural network is trained with the values of transition energy as input(s) and remaining energy (Re) as output(s) as per results of simulator for mobile ad-hoc network called training pattern. Gaussian function is used to decide the output of the network. Training of the network for given training patterns depends on the activation function and learning rate used for this training pattern. The input and output patterns are given in Table 6.5.

Table 6.5: Training Results of the Neural Network Using the Input Pattern for Remaining Energy and Transition Energy

Transition Energy	0.5	1	1.5	2	2.5
Wang Model	67.853	65.123	62.353	60.35	58.853
Proposed Simulation Model	68.789	65.858	63.958	61.966	62.353
Predicted by Neural Network	68.782	65.850	63.949	61.957	62.356

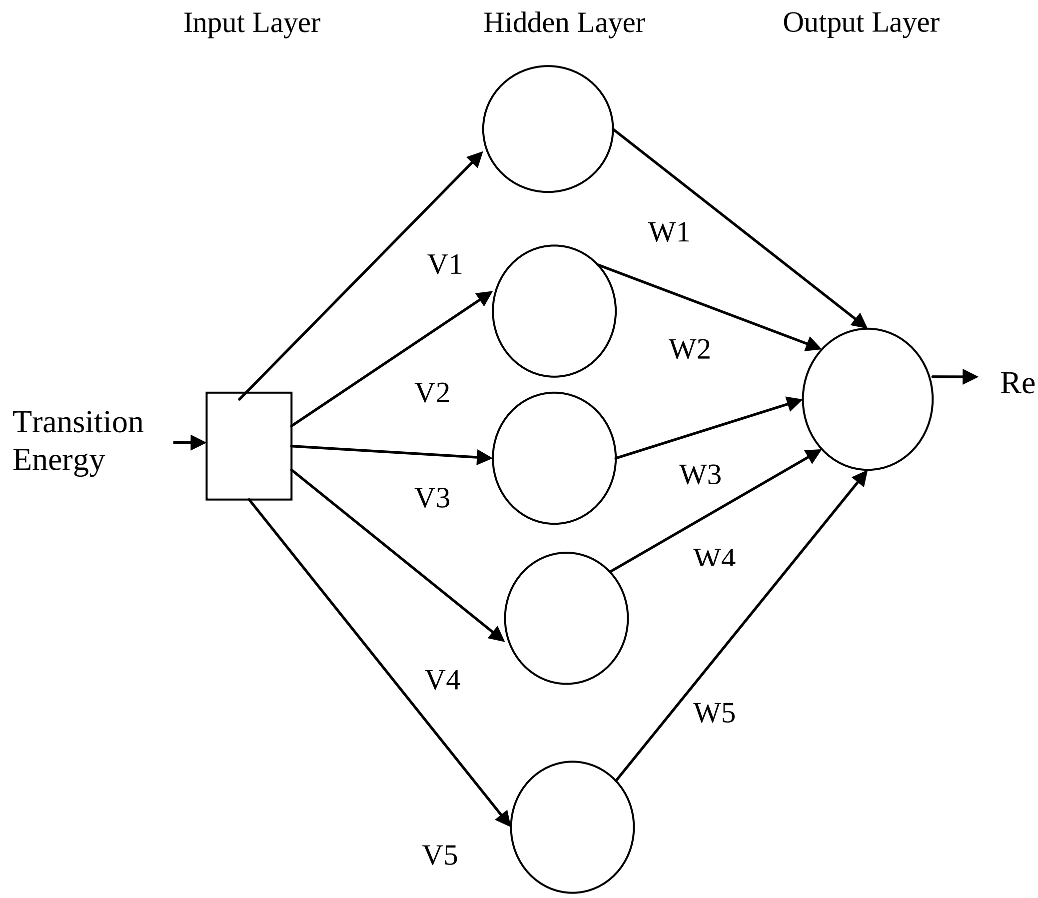


Figure 6.7: Neural Network Architecture to Estimate Re (Remaining Energy) as result with respect to Transition Energy as Input Value

6.7.3.2 Validation Phase

In this validation phase, proposed neural network model is verified to determine the remaining energy as output value for transition energy as input value. These are the new data patterns or unknown data that is not used during the training of the network. This data for validating the network model is given in Table 6.6.

It is observed from the Table 6.6 that remaining energy is associated with transition energy in mobile ad-hoc network. This model is useful for network operator to know the status of remaining energy and transition energy at any time. It is seen from the Figure 6.8 that remaining energy is increased with decrease in transition energy. Remaining energy value with respect to transition energy is higher in proposed neural network model as compared to existed model as Wang model.

Table 6.6: Validation data for Remaining Energy and Transition Energy

Transition Energy as input values	Remaining Energy Re(J)	
	Prediction by Neural Network (NN) Model	Wang Model Simulation Results
0.1	70.7	69.856
0.2	70.75	69.456
0.3	69	68.423
0.4	68.22	67.453
0.5	68.78	67.853
0.6	68.2	67.1
0.7	67.8	66.958
0.8	66.33	66.353
0.9	66.85	65.958
1	65.85	65.123
1.1	65.82	64.926
1.2	65.431	63.987
1.3	65.13	63.945
1.4	63.62	62.245

It is observed that remaining energy is decided with network density, receiving and transition energy of nodes in the network. Neural network model is effective and alternative solution of any simulator or tool for design and development of mobile ad-hoc network.

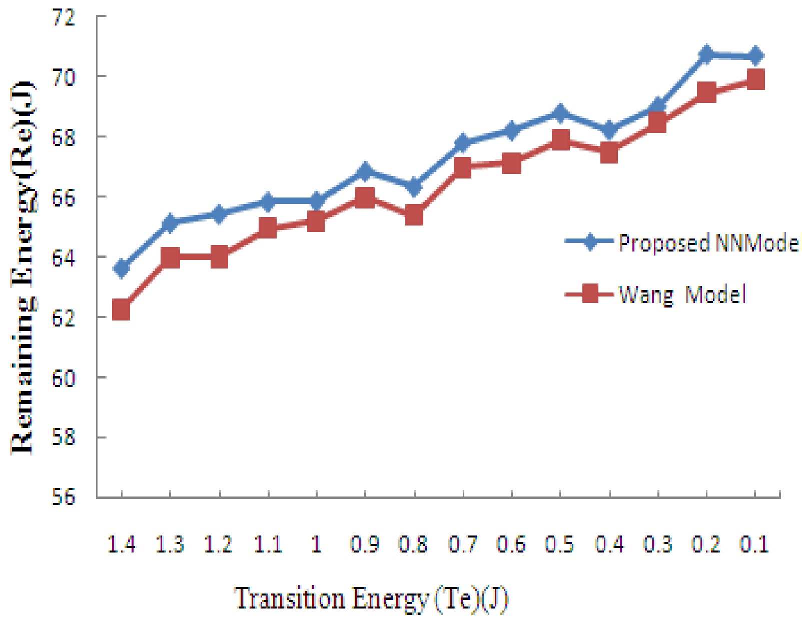


Figure 6.8: Remaining Energy and Transition Energy

6.8 Conclusion

Neural network model is proposed to determine the remaining energy of nodes in mobile ad-hoc networks. The results from this scheme are sufficient in prediction of the remaining energy of nodes within the range of the training set. Neural network approach with energy management technique omits time-consuming simulations and suitable for real time applications. Results are useful for hardware designers to decide the different power settings for the development of mobile ad-hoc networks. This model is developed to know the network life time and nature of network with different network parameters. It is used as a training tool for the mobile ad-hoc network operators. This concept is more helpful to design effective algorithm to solve power control problem in mobile ad-hoc network. Neural network model is a mathematical model and built based on time domain knowledge. This model is most effective for modeling of systems in uncertainty or prediction of data. Neural network model is an effective and alternative solution of simulator to design and development of mobile ad-hoc network.

CHAPTER7

CONCLUSION AND FUTURE SCOPE

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 Conclusion

Power control is one of the central issue in mobile ad-hoc networks. This is due to limited battery power available with each node in the mobile ad-hoc networks. Therefore, the transmission with optimal transmission energy of nodes is carried out, to reduce the energy consumption among nodes in the network. It has been observed that the remaining energy is inversely proportional to transmission energy and directly proportional to life time of mobile nodes in mobile ad-hoc network. In the current research work, the first chapter introduces the basic fundamentals of mobile ad-hoc networks. Literature survey on existing work related to power control is described in second chapter. Energy management model is proposed in third chapter. Fourth chapter explained the power control with slot scheduling in mobile ad-hoc networks. Fifth chapter is focused on power control with variable transmission range and the sixth chapter introduces the neural network model to compute the remaining energy of nodes in mobile ad-hoc network.

It was observed that the existing power control techniques are insufficient to meet the requirements of mobile ad-hoc networks due to the different conflicting constraints. One of the most important constraints is power control in mobile ad-hoc network. Therefore, the power control with different ways is used to reduce the energy consumption of mobile nodes in the mobile ad-hoc network. Simulators are used to analysis of energy consumption in mobile ad-hoc networks. Sometimes simulators are more time consuming to get results with different parameters value for mobile ad-hoc network. In addition to this, it is also comparatively, difficult to get results with simulator, at intermediate inputs in the network. So, it is imperative to have the most efficient neural network model for computation of energy consumption in network. Therefore in the current work, neural networks based model is utilized efficiently to solve problem, which is associated with simulation model for the mobile ad-hoc networks.

In this research, neural network based power control algorithm for efficient power saving in mobile ad-hoc network has been proposed and its performance is compared with the existing model.

It has been observed that suggested model has higher value of the remaining energy with respect to transition energy as compared to existing model proposed by Wang et al. [144], as results are shown in Figure 3.2. The Improvement in the remaining energy with respect to receiving energy when compared results of proposed model with existing model presented by Wang et al.[144] for mobile ad-hoc network as results shown in Figure3.3. Remaining energy value is increased with decrease in network density mean mobile nodes in the network. Remaining energy status in proposed model is better than existing model as proposed by Wang et al. [144]. As shown in Figure 3.4. High value of remaining energy is efficient to prolong the network life time in the suggested model. It was not possible save energy efficiently with existing model for mobile ad-hoc network. Performance metrics also better in current suggested model for ad-hoc network. Packet delivery ratio with respect to node speed in current proposed model is better than existing model as suggested by Wang et al. [144] as results are shown in Figure 3.5. Network performance is determined with packet delivery ratio in the network. The status of transmission delay with respect to network density in proposed model is better than existing model as presented by Wang et al. [144]. Figure 3.6 shows transmission delay status for mobile ad-hoc network.

It has been observed from the current proposed model that battery power consumption is directly affected with data transmission time of packets in mobile ad-hoc network. In first case when Slot transmission time t=0.5s and number of slots are varied from 5 to 20 slots. Nodes have consumed less power with five slots as compared to power consumption with twenty slots. Nodes consumed more battery power when numbers of slots are increased in communication network as results are shown in Figure 4.6. When Slot transmission time t=0.4s and number of slots=5 to 20 slots network consumed less power when slots time is decreased in the network from time t=0.5s to 0.4s,as results are shown in Figure 4.7. Network consumed less power when slots time is decreased in the network from time t=0.4s to 0.3s with same set of slots in the network. Power consumed by nodes is low as compared to previous results with slots transmission time as t=0.3s in the network as results are shown in Figure 4.8.

It is observed from Figure 4.9 that power consumption is decreased as compared to previous results by reducing the transition time of slots in the network, When Slot transmission time t=0.2s and same number of slots=5 to 20 slots used for mobile ad-hoc network. When Slot transmission time t=0.1s, with same number of slots=5 to 20 slots as results are shown in Figure 4.10. Nodes have consumed very less power with slots transmission time 0.1 s as compared to all previous results. Battery power consumption is minimized when slots transmission time is decrease from slot transmission time t=0.5s to 0.1s.

Existing Ring schedule based time division multiple access existing scheduling not efficient to saves energy and maintain the performance metrics in the network. Proposed power control based scheduling is most effective as compare to existing model based on performance metrics and optimization of battery power consumption for the mobile ad-hoc network. Packet delivery ratio with respect to network density in proposed model is better than existing model as suggested by Wei et al. [134], as results are shown in Figure 4.11. Packet delivery ratio is decreased with increase in speed of mobile nodes in the network. Packet delivery ratio in proposed model is better than existing model as presented by Wei Model [134]. Figure 4.12 shows the packet delivery status. End-to-End delay is increased with increase in nodes speed for mobile ad-hoc network. The status of delay in proposed model is improved as compared to existing model suggested by Wei model [134]. Delay status is shown in the Figure 4.13.

It has been observed that remaining energy with respect to transmission power in proposed variable transmission range model is higher as compare to existing model presented by Javier et al.[56] for mobile ad-hoc network as results are shown in Figure5.3. Transmission energy is associated with communication range in mobile ad-hoc network. Transmission energy consumed by nodes in proposed variable transmission range model is low as compare to suggested model by Javier et al. [56] for mobile ad-hoc network, as results are shown in from Figure 5.4. Transmission delay depends on the network density (nodes) in the networks. Transmission delay in proposed variable transmission range model is low as compare to model presented by Javier et al. [56] in mobile ad-hoc network. It is observed from Figure 5.5 that transmission delay is increased with respect to number of nodes in the mobile ad-hoc network. Packet delivery ratio with respect to node speed in proposed variable transmission range model is improved as compare to existing model by Javier et al. [56] in mobile ad-hoc network, as result shown in Figure 5.6

It has been observed from proposed neural network model that computation of energy consumption is better than simulation models. Neural network results are verified with known and unknown results of simulator for mobile ad-hoc network. Neural network model is developed to know status of remaining energy as output value at any time with respect to network density (Nodes) as input value. The input and output patterns are given in Table 6.1. This data for validating the neural network model is given in Table 6.2. Neural network results are helpful to describe the exact nature of operation. Remaining energy and network density (Nodes) relation in shown in Figure 6.4 and indicates that remaining energy is improved as compared to existing simulation model proposed by Wang et al. [144]. When neural network is trained with receiving energy as input value and remaining energy act as output value. Training of the network for given training patterns depends on the activation function and learning used for this training pattern. The input and output patterns are given in Table 6.3. Validation phase has been under taken for new data patterns or unknown data that is not used during the training of this network. This data for validating the network model is given in Table 6.4. It is seen from the Figure 6.6 that remaining energy is increased with decrease in receiving energy. Remaining energy value in proposed neural network model is better than existed model as suggested by Wang et al. [144]. When neural network is trained with transition energy as input value and remaining energy act as output value. Training of the network for given input and output patterns are given in Table 6.5. Proposed neural network model is verified for new data patterns or unknown data that is not used during the training of the network. This data for validating the network model is given in Table 6.6. It is observed from the Figure 6.7 that remaining energy is increased with decrease in transition energy. Remaining energy value with respect to transition energy is higher in proposed neural network model as compared to existed model as presented by Wang et al.[144]. This research also proposes new methods for power control in mobile ad-hoc network.

7.2 Future Scope

From the current trends, in invasive technologies and pervasive computing, it is observed that the mobile ad-hoc networks are here to stay and continue for longer duration. But the related devices are always power hungry. In order to further utilize the available power, some suggestions are

1. The routing algorithms deputed to route/transmit the packets itself can be designed to optimally control the transmission power, in order to have power available to each node for longer duration of time.
2. The computational jobs can be offloaded to the nodes with powerful battery backup or to the clouds.
3. The suggested neural network based model can be used to pre-calculate the energy requirements of the nodes.
4. While each node receives the data through wireless transmission. A mechanism may be worked out where the battery power at each node gets rejuvenated with the reception of the signals/packets. In case of multi-hop transmission of packets, with the reception of each packet, the battery power will get rejuvenated in the sequential manner.
5. The electronic circuits responsible for computations, transmission and reception at each node, can be designed and fabricated using such a material, which requires lesser power for its operations.

There is a lot of scope in the direction of developing the current neural network model taking in to consideration the design and fabrication of electronic circuit, the type of jobs required to be done on each node, kind of QoS required and the amount of battery power depleted and rejuvenated during each transmission and reception.

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