ABSTRACT

In wireless ad-hoc networks, every node performs communication with other nodes directly or through the intermediate nodes because of limited bandwidth (BW). Almost all network nodes are operated on lithium ion rechargeable batteries; these batteries have a limited lifetime (3 to 4 hours only). Hence, power-efficient routing in wireless Ad hoc networks is an important research issue as it determines the network lifetime. This work proposes a novel optimized power efficient routing algorithm (OPERA) considering the network parameters like node density, power consumption, traffic congestion and node status. The proposed work ranks the communication parameters based on different traffic congestion zones like maximum, moderate and minimum, using Analytical Hierarchy Process (AHP) and selects optimal path. The OPERA is an adaptive and Energy efficient technique. A simulation study is performed to compare the performance of OPERA with AODV protocol. Our result indicates that OPERA consumes less energy as compare to AODV.

CHAPTER ONE

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 WIRELESS SENSOR NETWORKS (WSN)

The random deployment of wireless sensor nodes is known as ad-hoc wireless sensor networks and these are the temporary networks. WSNs are an emerging technology that has an extensive range of potential applications including environment observing, smart spaces, medical systems and robotic exploration. Such a network generally consists of a great number of distributed nodes that establish themselves into a multi-hop wireless network. Each node has one or more sensors, embedded processors and low-power radios, and is normally battery operated. Normally, these nodes coordinate to perform a common task.

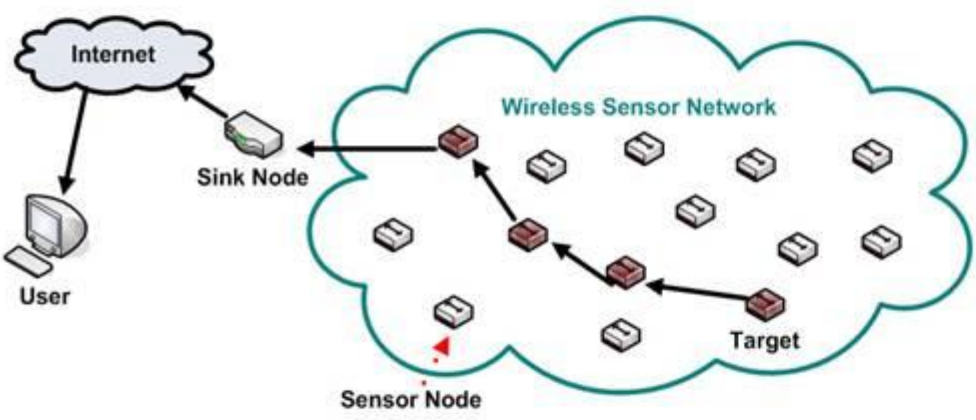


Fig.1 Ad-hoc wireless sensor network

The WSN is made of nodes from a few to quite a lot of hundreds or even thousands, where each node is attached to one (or sometimes quite a lot of) sensors. Each such sensor network node has generally several parts: a radio transceiver with an inner antenna or connection to an outer antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, generally a battery or an embedded form of energy gathering. A sensor node might fluctuate in size from that of a shoebox down to the size of a grain of dust, although operational "motes" of genuine microscopic dimensions have yet to be created. The price of sensor nodes is likewise variable, fluctuating from a few to hundreds of dollars, depending on the complication of the individual sensor nodes. Size and price constraints on sensor nodes result in analogous constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can differ from a simple star network to an advanced multi-hop wireless mesh network.

1.2 Sensor Node

Wireless sensor node is an important part of WSNs and it consists of a radio module, memory, sensor, a controller, communication device and battery. The brief description of parts of wireless node is shown below.

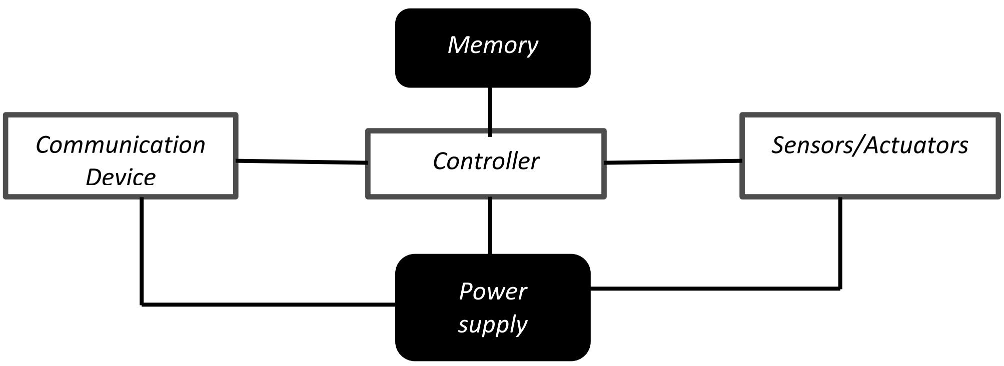


Fig.2 Wireless sensor node

1.2.1 Controller

Controller is a heart of sensor node. Most of the tasks are performed by controller in sensor node for example executing, manipulating and processing data are common tasks of microcontroller. It also controls the task of different parts of sensor node. While the most common controller is a microcontroller, other alternatives that can be used as a controller are: a general purpose desktop microprocessor, digital signal processors, FPGAs and ASICs.

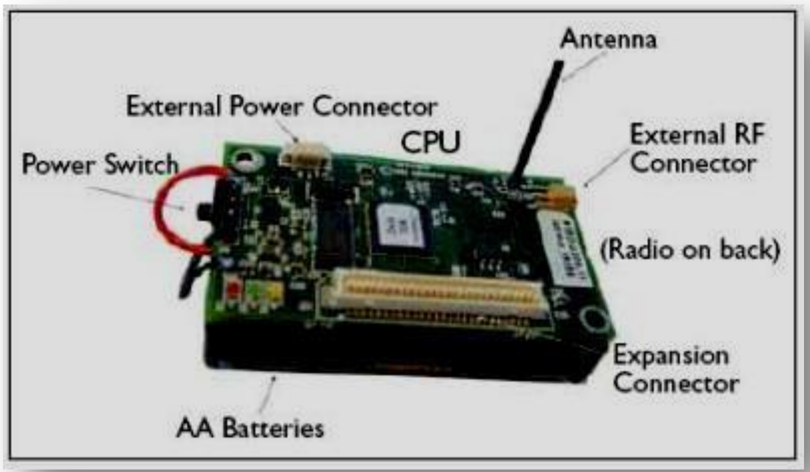


Fig.3 wireless sensor node hardware architecture

1.2.2 Communication Device

The communication device in sensor node is transceiver that is used to both transmit and receive the signals. Transceiver is consisting of both transmitter and receiver. The possible varieties of wireless transmission media are radio frequency, optical communication (using laser) and infrared. Lasers need less energy, but want line-of-sight for communication and are sensitive to atmospheric conditions. Infrared, like lasers, needs no antenna but it is restricted in its broadcasting capacity. Radio frequency-based communication is the most relevant that fits most of the WSN applications. WSNs tend to use license-free communication frequencies: 173, 433, 868, and 915 MHz; and 2.4 GHz. The functionality of both transmitter and receiver are combined into a single device known as a transceiver. Transceivers often lack unique identifiers. The operational states are transmit, receive, idle, and sleep. Current generation transceivers have built-in state machines that perform some operations automatically.

Most transceivers operating in idle mode have a power consumption almost equal to the power consumed in receive mode. Thus, it is superior to completely shut down the transceiver rather than leave it in the idle mode when it is not transmitting or receiving. A significant amount of power is consumed when switching from sleep mode to transmit mode in order to transmit a packet.

1.2.3 External memory

Memory is a collection of registers that is used to store information. The most commonly used memories are RAM (random access memory) and ROM (read only memory).Flash memory is fast access memory. RAM is a main memory in which controller process the data. Memories used for long time storage of data are secondary memory (hard disk).

1.2.4 Power supply

Sensor nodes are battery operated devices, they required an external battery for their operation. Since it is a battery operated device it consumes more power and hence its power consumption is more. A sensor node consumes power in three common modes: Transmit mode, receiving mode and idle mode. Sensor nodes required less power in transmit and receiving mode but it consumes more power in idle mode. In idle mode the sensor node is do not performer any task (transmition and reception) but their radio is ‘on’ and hence it consume more power in in idle mode.

1.3 Characteristics of Wireless Sensor Networks

The chief characteristics of WSNs include:

- Power consumption limits for nodes using batteries or energy gathering
- Ability to handle with node failures
- Mobility of nodes
- Communication failures
- Heterogeneity of nodes
- Scalability to huge scale of placement
- Ability to withstand tough environmental conditions
- Simplicity of use
- Self-organizing proficiencies
- Short-range broadcast communication and multihop routing
- Dense distribution and supportive effort of sensor nodes
- Repeatedly changing topology due to fading and node failures
- Restrictions in energy, transmit power, memory, and computing power

Sensor nodes can be assumed as small computers, particularly basic in terms of their interfaces and their components. They generally contain a processing unit with restricted computational power and restricted memory, sensors or MEMS (including specific conditioning circuitry), a communication device (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery. Other possible inclusions are energy harvesting modules, secondary ASICs, and possibly secondary communication interface (e.g. USB).

The base stations are one or more components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server.

1.4 Application of wireless sensor networks

All these features ensure a wide range of applications for sensor networks. Though the number of areas of application is growing rapidly, some of the key application areas are listed below:

1.4.1 General Engineering

- Automotive telematics: Cars, which comprise a network of dozens of sensors and actuators, are networked into a system of systems to improve the safety and efficiency of traffic.
- Sensing and maintenance in industrial plants: Complex industrial robots are equipped with up to 200 sensors that are usually connected by cables to a main computer. Because cables are expensive and subject to wear and tear caused by the robots

movement, companies are replacing them by wireless connections. By mounting small coils on the sensor nodes, the principle of induction is exploited to solve the power supply problem.

- Aircraft drag reduction: Engineers can achieve this by combining flow sensors and blowing/sucking actuators mounted on the wings of an airplane.
- Smart office spaces: Areas are equipped with light, temperature, and movement sensors, microphones for voice activation, and pressure sensors in chairs. Air flow and temperature can be regulated locally for one room rather than centrally.
- Tracking of goods in retail stores: Tagging facilitates the store and warehouse management.
- Tracking of containers and boxes. Shipping companies are assisted in keeping track of their goods, at least until they move out of range of other goods.
- Commercial and residential security.

1.4.2 Agriculture and Environmental Monitoring

- Remote exploration: Exploration and surveillance in inhospitable environments such as remote geographic regions or toxic locations can take place.
- Geophysical monitoring: Seismic activity can be detected at a much finer scale using a network of sensors equipped with accelerometers.
- Monitoring of freshwater quality: The field of hydrochemistry has a compelling need for sensor networks because of the complex spatio-temporal variability in hydrologic, chemical, and ecological parameters and the difficulty of labour-intensive sampling, particularly in remote locations or under adverse conditions. In addition, buoys along the coast could alert surfers, swimmers, and fishermen to dangerous levels of bacteria.

- Habitat monitoring: Researchers at UC Berkeley and the College of the Atlantic in Bar Harbor deployed sensors on Great Duck Island in Maine to measure humidity, pressure, temperature, infrared radiation, total solar radiation, and photosynthetically active radiation.
- Disaster detection: Forest fire and floods can be detected early and causes can be localized precisely by densely deployed sensor networks.
- Contaminant transport: The assessment of exposure levels requires high spatial and temporal sampling rates, which can be provided by WSNs.

1.4.3 Military Applications

- Asset monitoring and management: Commanders can monitor the status and locations of troops, weapons, and supplies to improve military command, control, communications, and computing.
- Surveillance and battle-space monitoring: Vibration and magnetic sensors can report vehicle and personnel movement, permitting close surveillance of opposing forces.
- Urban warfare: Sensors are deployed in buildings that have been cleared to prevent reoccupation; movements of friend and foe are displayed in PDA like devices carried by soldiers. Snipers can be localized by the collaborative effort of multiple acoustic sensors.
- Protection: Sensitive objects such as atomic plants, bridges, retaining walls, oil and gas pipelines, communication towers, ammunition depots, and military headquarters can be protected by intelligent sensor fields able to discriminate between different classes of intruders. Biological and chemical attacks can be detected early or even prevented by a sensor network acting as a warning system.

1.4.4 Health Monitoring and Surgery

- Medical sensing: Physiological data such as body temperature, blood pressure, and pulse are sensed and automatically transmitted to a computer or physician, where it can be used for health status monitoring and medical exploration.

1.5 Challenges and Constraints

The most common issue in wireless networks are energy consumption, deployment of node, security etc.

1.5.1 Energy

The most common problem in wireless sensor networks is limitation in power supply. Sensor node is battery operated device, if the battery is discharge than charging the battery or replace it with new one is a costlier process. The most common solution of this problem is to charge the battery by using a natural source for example solar energy that is widely available in plenty of quantity in the world. Hence instead of replacing the sensor node with new one we can charged it using solar cell. We can also reduce the energy consumption in wireless networks by using an energy efficient routing protocol for data transmission (e.g. AODV, DSR etc.).Depending upon the shortest path selection for data transmission we can choose the best routing protocol. As the path traced by the routing protocol consist of more number of nodes than the energy consumption is also high.

1.5.2 Self-Management

Most of the wireless networks applications are operate in distant areas and tough environments, without infrastructure support or the possibility for maintenance and repair. Hence, sensor nodes must be self-managing in that they configure themselves, and change in the environmental stimuli without human intervention. For example in ad-hoc wireless networks, they do not require predetermined and engineered location of individual sensor nodes. Hence it is important for networks being deployed in remote or inaccessible areas.

CHAPTER TWO

ROUTING

PROTOCOLS

CHAPTER 2

ROUTING PROTOCOLS

2.1 ROUTING PROTOCOL

Routing protocol is a set of rules that is used to define the path for data transmission between the wireless sensor nodes. Different routing protocols for both wired and wireless sensor networks are available; depending upon the requirement the routing protocols are used.

2.2 CLASSIFICATION OF ROUTING PROTOCOLS

Depending upon their use the routing protocols are dividing into different categories and they are shown below. Wireless routing protocols are divided into three categories:

I. FLAT ROUTE

- **Proactive**: examples are,
    - FSR (Fisheye State Routing),
    - OLSR (Optimized Link State Routing Protocol)
    - TBRPF (Topology broadcast based on reverse-path forwarding)
    - FSLS (Fuzzy Sighted Link State)

- **Reactive**: example are,
    - AODV (Ad hoc On-Demand Distance Vector) and
    - DSR (Dynamic Source Routing).

II. Hierarchical routing

- HSR (Hierarchical state routing)
- ZRP (Zone Routing Protocol)
- CGSR (Cluster head Gateway Switch Routing Protocol)
- LANMAR (Landmark Ad Hoc Routing)

III. Geographic position assisted routing

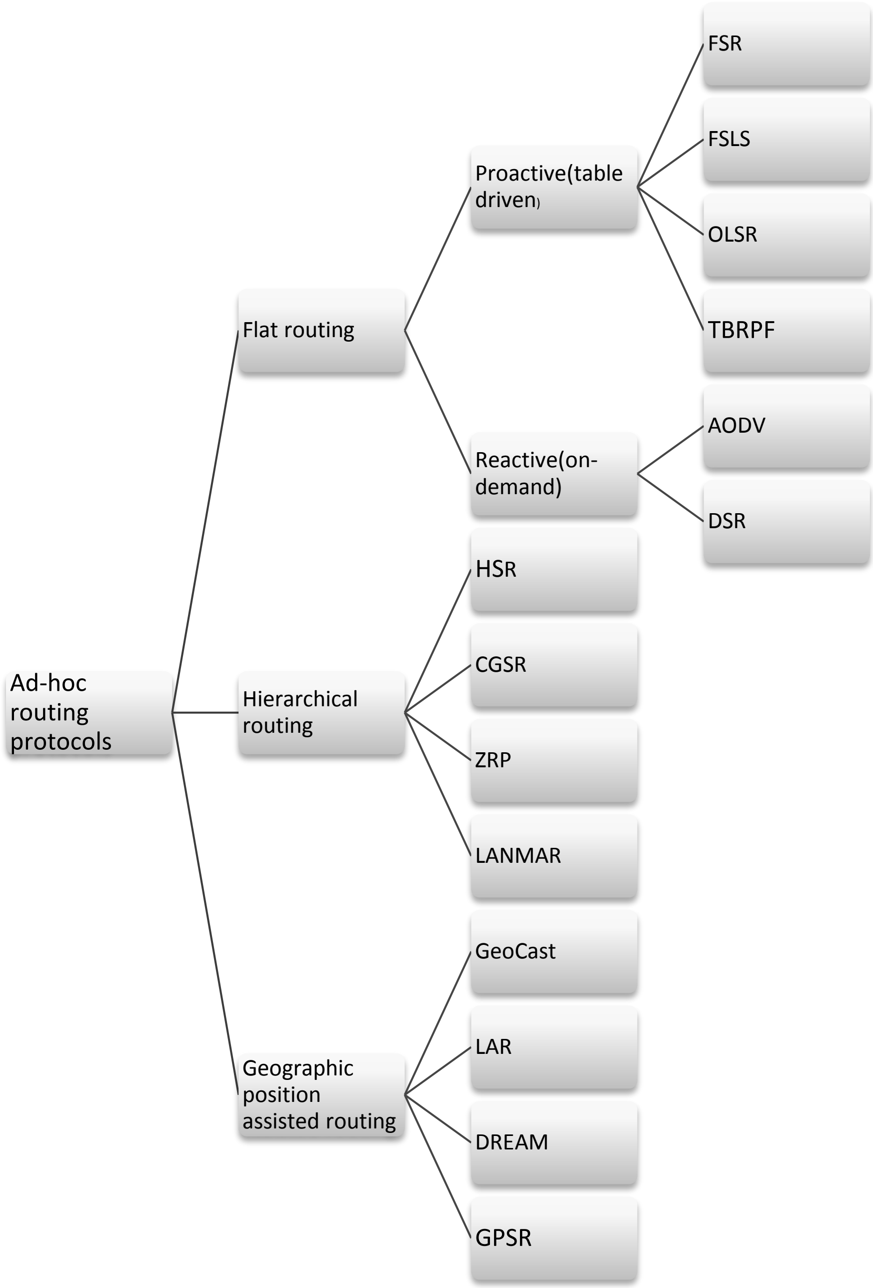
- GEOCAST

  Geocast states the delivery of information to a cluster of destinations in a network recognized by their geographical positions. It is a particular form of multicast addressing used by some routing protocols for mobile ad hoc networks.

- GPSR (Greedy Perimeter Stateless Routing)

2.2.1 Proactive or Table-driven routing protocol

Proactive routing protocols are also named table driven, they are estimate the routes within the network, and so that when a packet wishes to be forwarded the route is already known and can be instantly used. Table driven routing protocols withstand consistent and up to date routing information about each node in the network.


FSR
FSLS
Proactive(table driven)
OLSR
Flat routing
TBRPF
AODV
Reactive(on-demand)
DSR
HSR
CGSR
Ad-hoc routing protocols
Hierarchical routing
ZRP
LANMAR
GeoCast
LAR
Geographic position assisted routing
DREAM
GPSR

These protocols require each node to store their routing information and whenever there is a change in network topology, the updates has to be made throughout the network.

2.2.2 Reactive or On-demand routing protocol

Reactive routing protocols are also named on demand and it invokes a route determination procedure only on demand. A node in order to communicate with another node, it first search for a route in its routing table. If the route is found than it starts the communication directly, otherwise the node initiates a route discovery phase. Once a Route has been recognized, it is maintained until either the destination becomes out-of-the-way (along every path from the source), or until the route is no longer used, or terminated. Examples are

- Ad-Hoc On-demand Distance Vector (AODV)
- Dynamic Source Routing (DSR)

2.3 Ad-Hoc On-Demand Distance Vector routing Protocol

Ad-hoc on demand distant vector is a reactive and on demand routing technique. Aodv uses bi-directional links for data transmission and routing cycle used for route discovery. It maintains active routes and uses sequence number for loop prevention. It provides both unicast and multicast data transmission in wireless sensor networks. Whenever the routes are not used, they get expired or discarded so that the need of route maintenance is reduced. Hence it minimizes the number of active routes between source and destination. It can find multiple routes between sender and receiver but implement only one route for data transmission because it is difficult to manage multiple routes between same sender and receiver. In Aodv if one route is expired than it is difficult to find whether the other route is available or not.

2.3.1 Properties

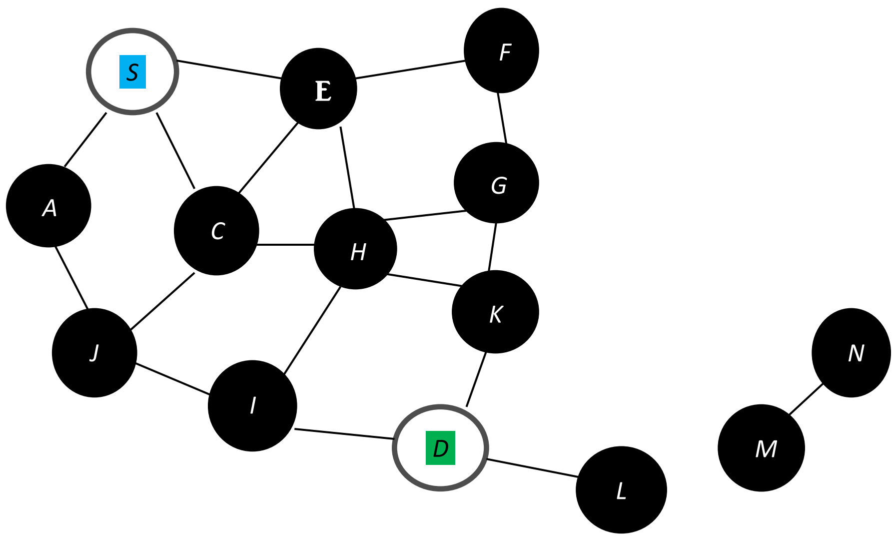
- Aodv discover routes as and when necessary but it does not maintain route from each node to every other nodes
- It maintain route whenever it required
- Each node maintains its sequence number monotonically. This sequence number updated each time when there is change in neighbouring node or topology.
- Aodv use routing table to store routing information for bath unicast and multicast data transmission.
- Route table is used to store
    - Destination address
    - Next hop address
    - Destination sequence number
    - Life time
- For every destination, a node maintains a list of precursor nodes and this precursor node help in route maintenance.

2.3.2 Aodv Route Discovery

When a node is try to send a packet to a destination than first it check its route table for a define route to the required destination. If route is already define in the route table than it sends the packet to the next node or if the route is not defined than it go through the route discovery process. In route discovery process, the source node first generates a route request packet (RREQ). The RREQ consist of source node's IP address, source node's current sequence number, destination IP address and destination sequence number. The RREQ also consist of a Broadcast ID number which is incremented every time when a source node uses REEQ. Broadcast ID and source IP address form a unique identifier to the REEQ and this broadcasting is done through a process known as flooding.

2.3.2.1 Flooding and example

The source node S broadcast a control packet P to all its neighbours and each node receiving packet P are forward it to its further neighbouring nodes and this process is going on. The sequence number is help to avoid re-transmission of same packet P. And finally the control packet P is reaching the destination node D. When control packet P is received by node D than further transmission of packet P is stopped.



S: Source node; D: destination node

Fig.5 (a) Flooding example

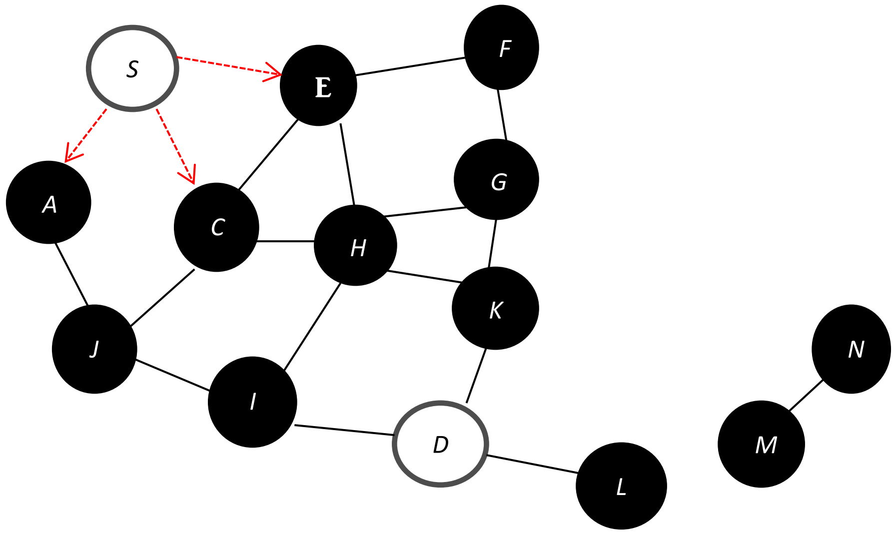


Fig.5 (b) Flooding example

The source node S sends the control packet P to their neighbouring nodes A, C and E as shown fig.5 (b).

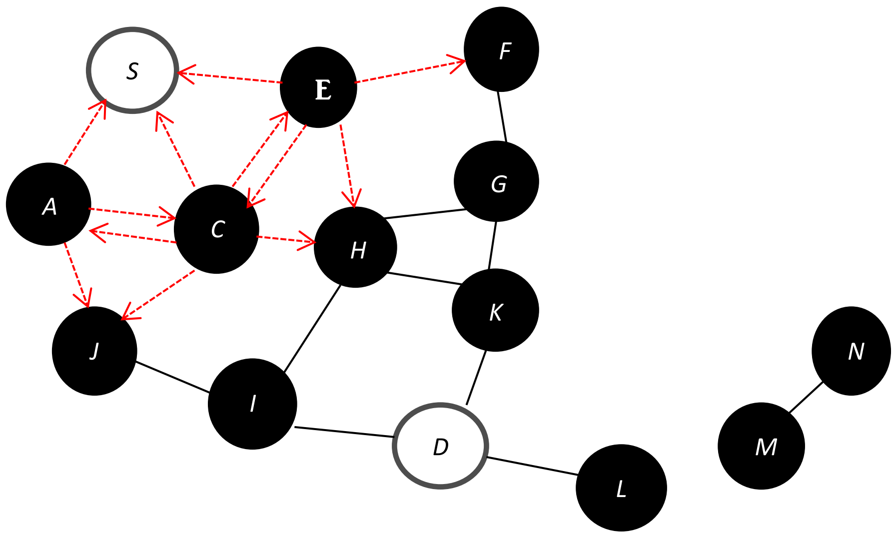


Fig.5(c) Flooding example

Since the neighbouring nodes of S are further transmit the control packet P to its neighbouring nodes and node J received packet from node A and node C at the same time hence there is chance of collision to occur. It is shown in fig.5(c).

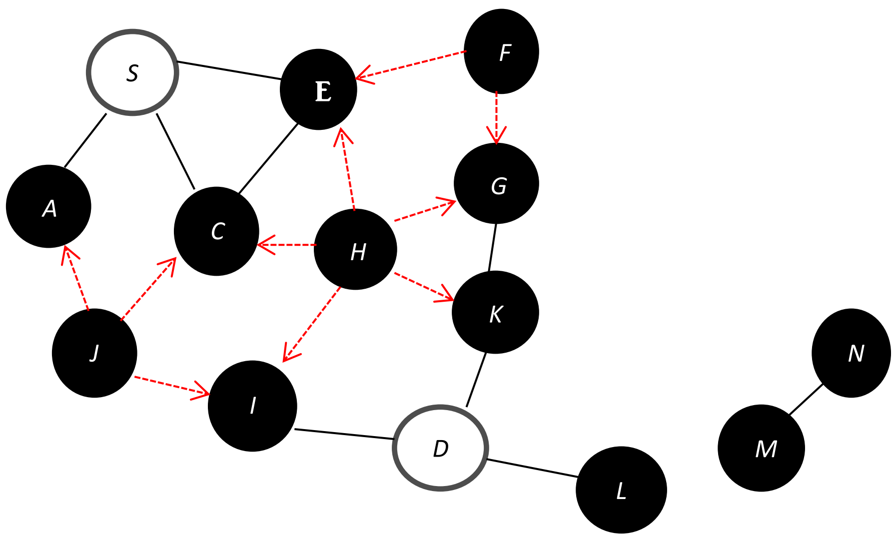


Fig.5 (d) Flooding example

In fig.5 (d), node C does not send the control packet P to node S because it is already sends the packet in the previous step.

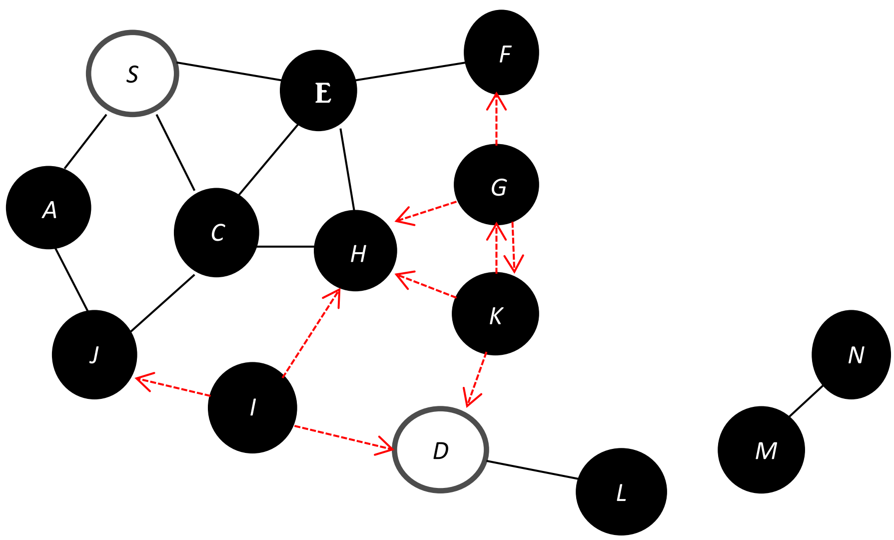


Fig.5 (e) Flooding example

In fig.5 (e), Node D received the packet P from node I and node K at the same time; hence there is a chance of collision because node I and node K are hidden from each other. Without the use of flooding data does not transmit to destination node.

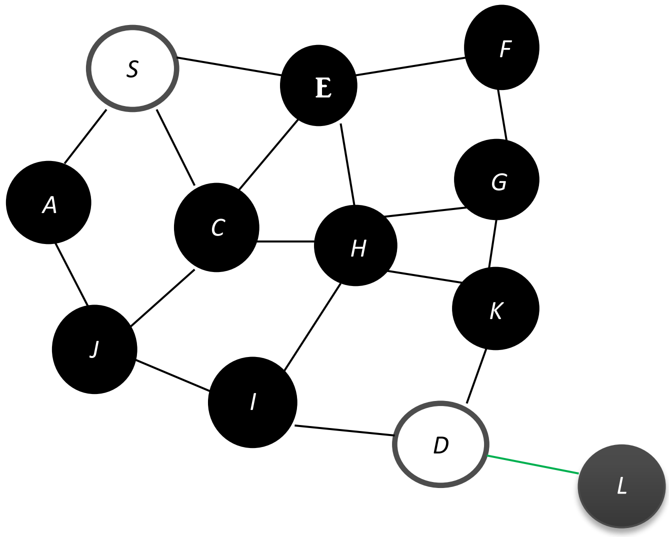


Fig.5 (f) Flooding example

In fig.5 (f), Node D does not send the packet to the node L because the path is traced between source and destination so there is no need of further transmission of control packet P.

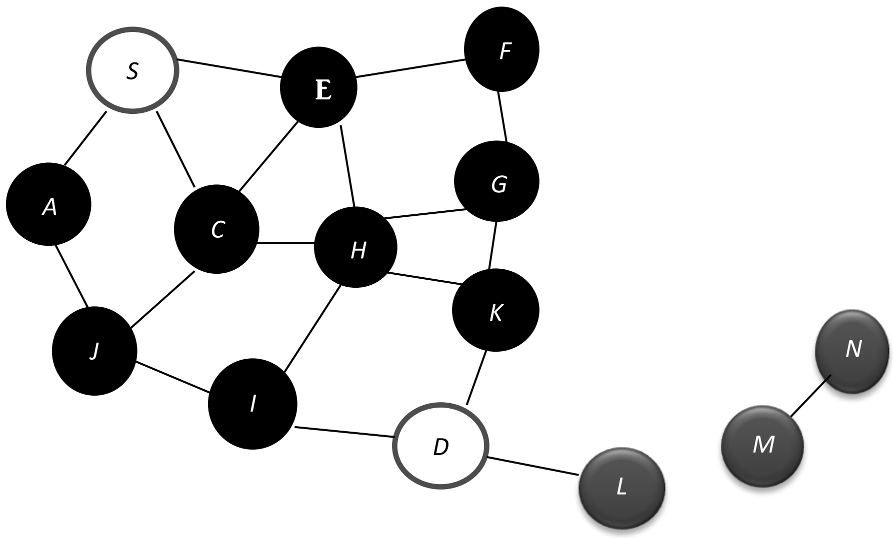


Fig.5 (g) Flooding example

In fig.5 (g), the flooding process is complete and packet P is does not send to node M and node N because they are unreachable nodes of the network.

2.3.2.2 Advantages and Disadvantages of Flooding

Advantages

- Since data is delivered to the destination through multiple paths, hence, there is less chance of data loss.
- May be more efficient than other protocols when rate of information transmission is low enough that the overhead of explicit route discovery and maintenance incurred by other protocols is relatively higher.
- Its simplicity.

Disadvantages

- Very high overload: Data packets P may be delivered to too many nodes that do not require to receive them.
- Lower reliability of data delivery.

2.3.2.3 Route discovery

Once an intermediate node receives a RREQ, the node sets up a reverse route entry for the source node in its route table. The reverse route entry consist of source IP address, number of hop to source node, source sequence number, IP address of node from which RREQ is received and life time. A node can send a RREP (route reply packet) to the source node through the reverse route. When RREQ is received by destination node than it first check that the IP address of destination node is matched with the IP address placed in the RREQ destination IP address field. If they are matched than destination node unicast a RREP message towards the source node through reverse route. If the address is not matched than increment the hop count and broadcast the message to the neighbouring nodes. Finally, the REEQ will reach the destination.

Example of route discovery is shown below:

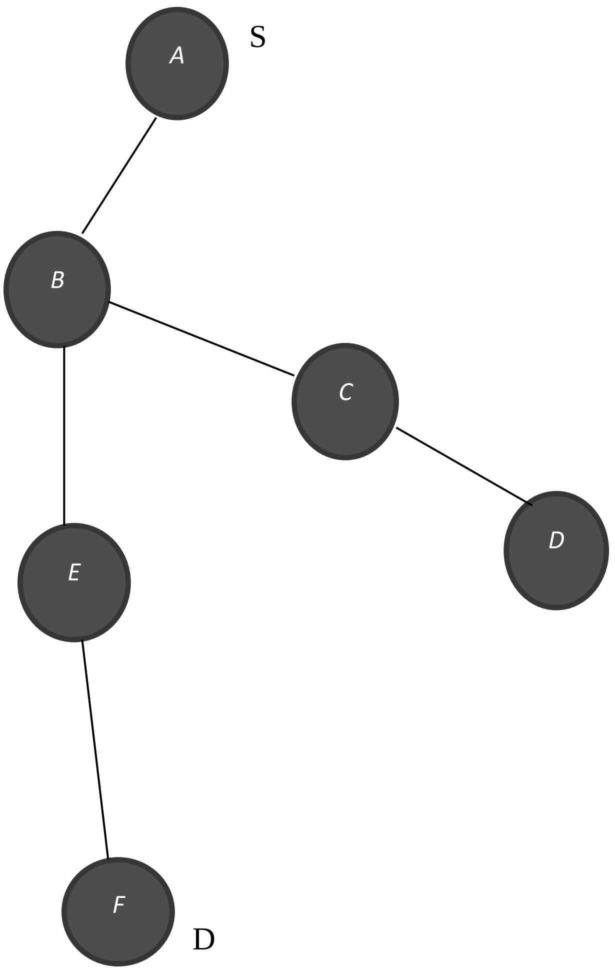


Fig 6(a) Route discovery

In Fig. 6(a), A is the source node and F is the destination node. Hence, before transmitting data from source node to destination node, a route is discovered between them using intermediate nodes. In order to transmit data to the destination node, node A first transmit a RREQ message to the node F.RREQ message contains destination IP address, destination sequence number, source IP address, source sequence number and hop count (initially equal to zero).

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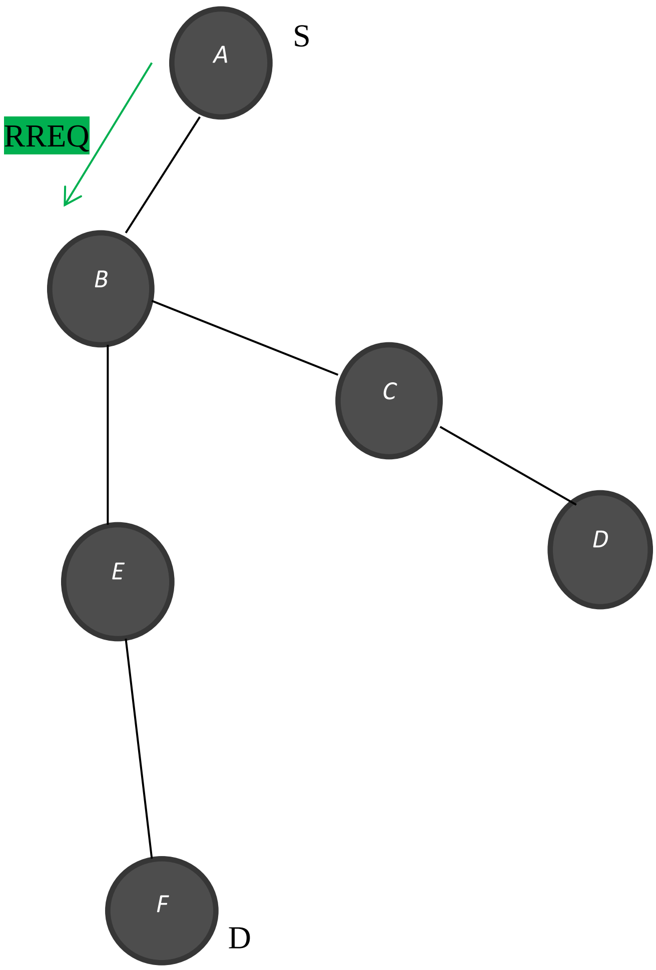


Fig 6(b) Route discovery

In fig. 6(b), Source node A broadcasts the RREQ to its neighbouring nodes .Node B received the RREQ message and make a reverse route entry that contains Destination=A, hop count=1, Next hop=A. Hence it does not reach to the destination so it again broadcast the RREQ message to the neighbouring node as shown in fig 6(c). Similarly the other nodes are broadcasting the RREQ message to their neighbouring nodes until the destination is reached. Also the reverse route entry and hop count are set in the respective entries into RREQ message. The intermediate node are transmit the RREP message to their neighbouring node each time after broadcasting RREQ message in order to set a reverse route to the source node A.

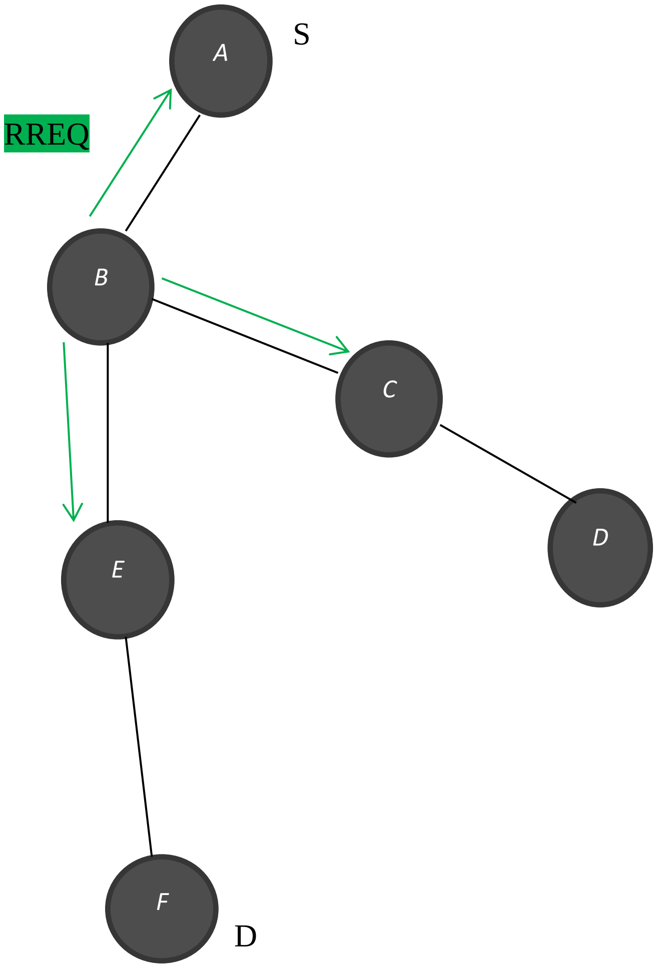


Fig 6(c) Route discovery

To determine whether the path known to an intermediate node is more recent, destination sequence numbers are used.

In fig. 6(d), Node E and C both received the RREQ message but only node E is send RREP message to the source node through node B. Now node E broadcast the REEQ to neighbouring node and the message is finally reached to the destination node F.

The destination node receives RREP message from multiple nodes but it respond to only that node that comes first. Once the RREP receive by the source node A (that is send by the destination node F) after that a forward path is set between source and destination node that is used for data transmition. The forward path is shown in fig 6(e) is used to send data from node A to node F.

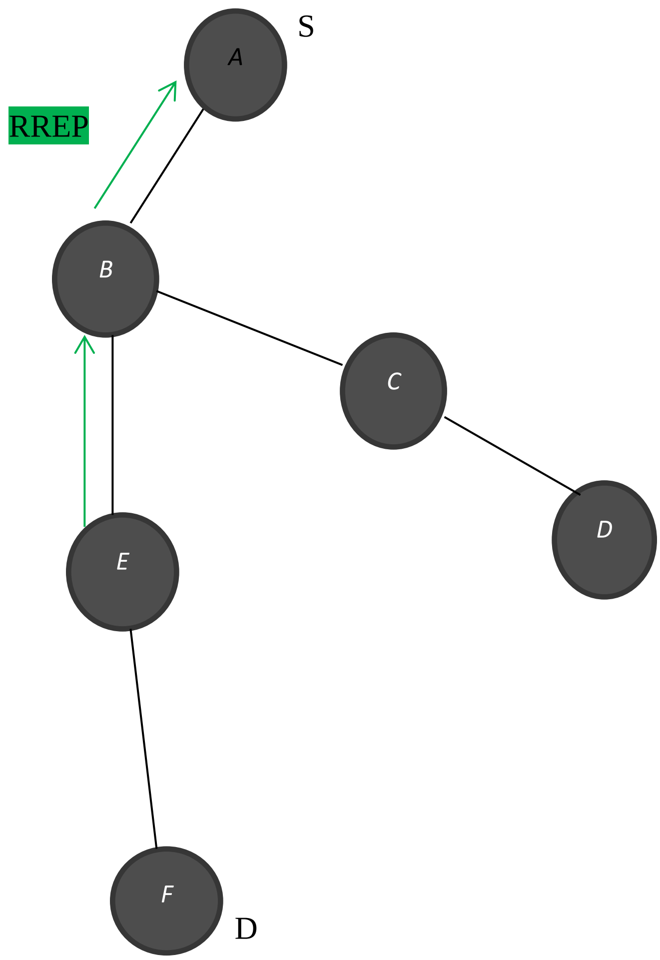


Fig 6(d) Route discovery

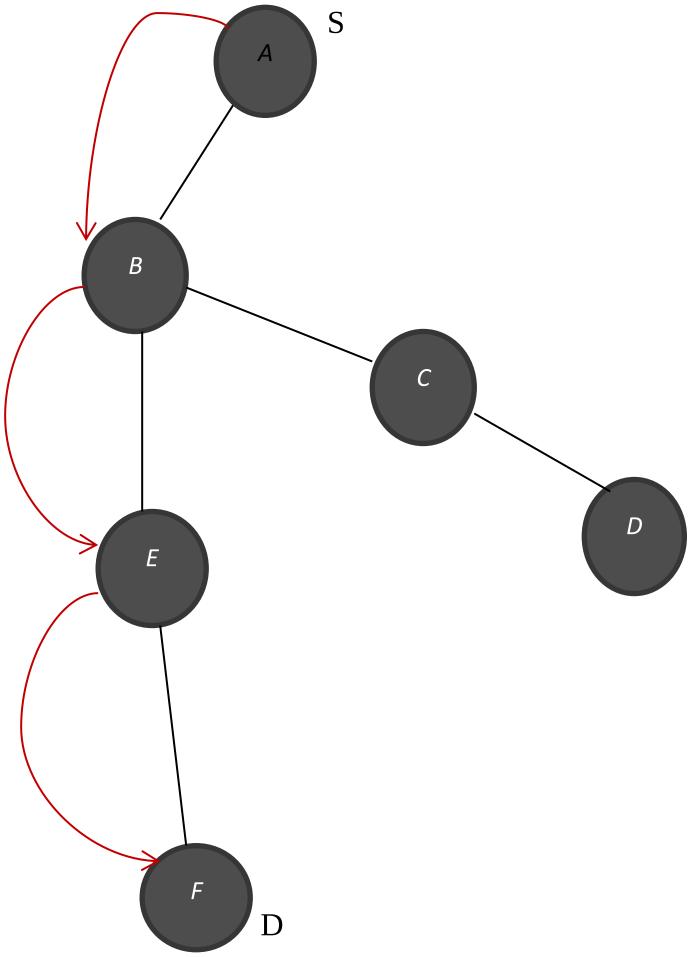


Fig 6(e) Route discovery

CHAPTER THREE

Optimized Power Efficient Routing Algorithm (opera)

Chapter 3

Optimized Power Efficient Routing Algorithm (OPERA)

3.1 Introduction

The ad-hoc network is a collection of nodes/ routers which may be static or dynamic in nature forming a temporary network without the pre-knowledge of any centralized management administration or standard support services, which are regularly available for the conventional wireless networks. The network organization and topologies may change rapidly and spontaneously. Ad-hoc networks do not rely on any pre-established infrastructure and can therefore be deployed in places with no base stations unlike in case of mobile networks. This is useful in disaster recovery situation environments and places with no existing or damaged radio communication system, where quick and fast deployment of a network is needed for communications.

Since most of the nodes and devices in ad hoc network are battery operated, and generally these networks are of large size, saving battery life is an important design issue. Hence designing power efficient protocol for saving the battery life in ad hoc network is challenging design issue .Related work by various researchers focused on the use of low power hard disks, low power analog –to-digital and dig1ital- to -analog converters, high capacity batteries, low power analog or digital ICs, which are adequate to increase the life time of the networked systems.

The existing research in this field, we observe that some of them are based on graph theoretical and computational geometrical techniques, further based on a simplified model. The others are based on building simulation or real system, based on electronics engineering methodologies. However, the power model in the former approaches is too simple and assumes that every node of network must know the power level of all other nodes. Some simulation models even require location information of all the nodes available in the network. However power consumption also depends upon communication parameters like node density, traffic congestion and other network parameters. This work focuses on optimizing energy consumption by considering communications parameters include node density, traffic congestion, power consumption and node status.

Power optimization is a vital design issue in the Ad hoc network; this work is an attempt to use the AHP ranking techniques using real data to select the optimal path with less power consumption.

3.2 RELATED WORK

In ad-hoc networks power can be saved at different levels. Many researcher's' proposed different techniques to reduce power consumption or save the battery life;

GAF [1] is a protocol using location information to bring about node equivalence with the help of GPS is the one protocol that falls under this category. The algorithm involved break up the whole network area into virtual frameworks. Notably, the nodes pervading one virtual network framework are able to communicate to the nodes present in the neighbouring framework. The power management applied in this technique places some nodes into sleep mode and thus conserves energy. These nodes can pertain to various states like discovery, active or sleep. The balance in the lingering is maintained in a distribution manner by applying balancing approach. A node with optimal lingering energy become active node while its neighbouring nodes tends to go into sleep state .this approach sets off more computational delay, extra bandwidth usage , more energy consumption at each participating nodes

In [2] author concluded that battery life dependents upon a) residual power capacity b) transmission power consumption c) reception power consumption and the total power consumed is sum all .The algorithm is finding the optimized route which save the power consumption by guaranteeing the transmission of network data packets depends upon residual power capacity of each node along the route. But the author did not include the main parameters like initial transmission power, range of frequencies, traffic on each node, node density, active or passive node , traffic congestion which are key parameters to select route or to save the battery life as the net nodes are characterized by their limited battery life.

The load distribution approach seeks to balance the energy usage of all nodes. This objective is achieved by selecting a route with intermediate nodes not used much often rather than selecting the shortest path [3]. This technique may involve more intermediate nodes in a route, but data packets are conveyed only through energy comfortable nodes. The protocol may not offer the lower energy path but surely prevents some nodes from being overloaded and ensures for longer network life time.

The power management based protocols obtain the energy efficiency goal through the use of two channels, one for control the other for data. For example, RTS/CTS signals are transmitted via control channels and the data via data channels. The protocol that facilitates this technique is known as Power Aware Multi Access Protocol (PAMAP) [4]. In this the node sends an RTS message over the control channel when it is ready be transmitted, and waits for CTS. If CTS message is not received within a stipulated time, the node enters to the power off mode, and sends a busy tone sign over the control channel to its neighbour. After turning to active state, the node is enabled and the node can now transmit data over the data channel. The converse also applies, i.e. once CTS are received, and the node transmits the data packet over the data channel.

In contrast, there is sleep/power down mode approach which focuses on inactive time of communication [5]. In MANET, the nodes are in sleep mode and packets cannot be delivered to their destination. This problem can be overcome by choosing a special node, known as MASTER, which can manage communication on behalf of the neighbouring nodes called SLAVES. The slave nodes in a sleep mode manage to save battery energy. The slave mode may wake up once in a while and communication with the master node to detect if there is any data to retract. If there is none, it reverts to sleep mode. This is a highly energy saving technique. In a multihop MANET, more than one master mode is used handle all data.

This literature survey giving attention on, how these techniques/ protocols are selecting the energy efficient route and save battery life or increase network life time. In this paper we propose an optimized power efficient routing algorithm considering real network parameters.

3.3 AHP BASED MODELLING

Genetic algorithms are a part of evolutionary computing, which is a rapidly growing area in artificial intelligence. Genetic algorithms are inspired by Darwin's theory of evolution. Problems are solved by an evolutionary process resulting in the best (fittest) solution (survivor). Problem solving by genetic algorithms (GA) uses an evolutionary process. Algorithm begins with a set of solutions (represented by chromosomes) called population. Solutions from any one population are taken and used to form a new population. This is motivated by a hope that the new population will be better than the old one. Solutions, which are then selected to form new solutions (offspring), are selected according to their fitness - the more suitable they are more chances they have to reproduce. This is repeated until some condition, for example number of populations or improvement of the best solution is satisfied.

3.4 Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is a method for comparing a list of objectives or alternatives. When used in the systems engineering process, AHP is a powerful tool for comparing alternative designing concepts. AHP is a comprehensive, logical and structured framework. It allows improvement in the understanding of complex decisions by decomposing the problem in a hierarchical structure. The incorporation of all relevant decision criteria, and their pair-wise comparison allows the decision maker to determine the trade-offs among objectives. This procedure recognizes and incorporates the knowledge and expertise of the participants. It makes use of their subjective judgment, which is a particularly important feature for decision-making based on a poor information base. The AHP is based on three principles:

- Decomposition of the decision problem
- Comparative judgment of the elements
- Synthesis of the priorities.

It can be achieved by the following three steps-

Step 1: Creation of hierarchies to resolve a problem.

Step 2: Comparison of the alternatives and the criteria.

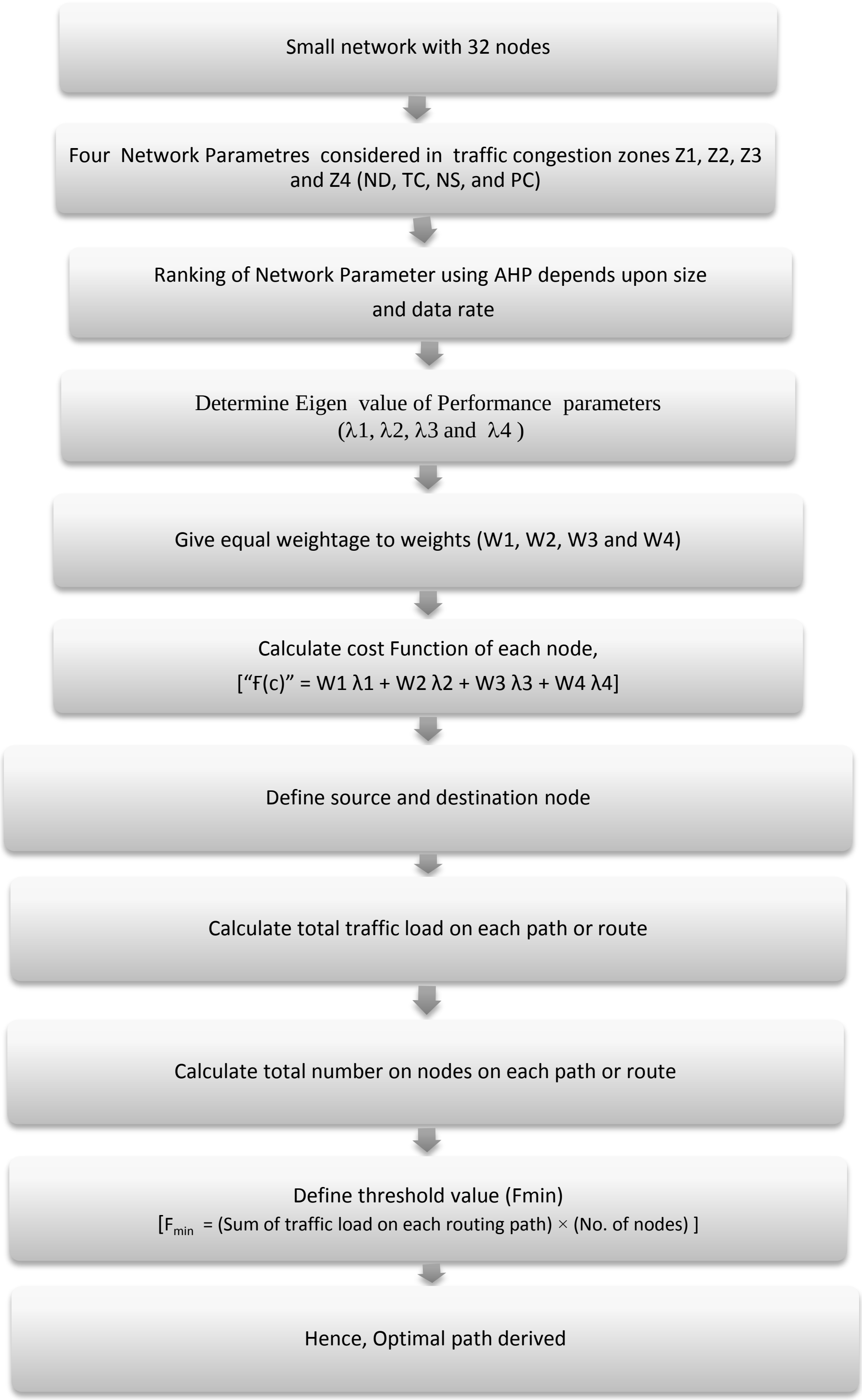
Attributes	Numerical Ranking
Extremely Preferred	9
Very Strongly to Extremely	8
Very Strongly Preferred	7
Strongly to very strongly	6
Strongly Preferred	5
Moderately to strongly	4
Moderately Preferred	3
Equally to moderately	2
Equally Preferred	1

Table 1: attributes and numerical ranking in AHP

Step 3: Synthesize the comparisons to get the priorities of the alternatives with respect to each criterion and the weights of each criterion with respect to the goal. Local priorities are then multiplied by the weights of the respective criterion and finally the results are summed up to get the overall priority of each alternative.

In this work, an attempt has been made to combine these two novel techniques to solve the routing issue to save the battery life in Ad-hoc networks so that the routes may be overused for further communication.

3.5 PROCESS FLOW CHART OF OPERA



3.6 Optimized power efficient routing algorithm (OPERA)

Power optimization is a vital design issue in the Ad-hoc networks. OPERA is AHP (analytical hierarchy process) based approach for optimizing the route to save the power consumption or save the battery life using key network parameters like node density, node status, power consumption and traffic congestion.

This thesis work is time based adaptive and efficient method which select a power optimized route considering real day time data available such as node density, traffic congestion, node status and power consumption. These parameters will be scaled using the Analytical Hieratical Process (AHP) to generate population which may represents real traffic load/ cost on each node, and used in power optimized route detection.

3.7 Problem Formulation

A typical Ad-hoc network can be considered to be made up of n nodes, so as to standardize input for normalization. Qualitative attributes like node density (ND), traffic congestion (TC), node status (NS) and power consumption (PC) have been considered for cost estimation of each node. These network parameters are normalized on a scale of 10 using AHP modeling. We calculate the cost function of each node using the equation 1 below, in which the values of weights W1, W2, W3 and W4 are assumed. They are varies in the range of 0 to 1.The main objective of thesis research work is to minimize the cost of a route by minimizing the Fmin using equation 3.

Cost Function "Ғ(c)" = $W1\ \lambda 1 + W2\ \lambda 2 + W3\ \lambda 3 + W4\ \lambda 4$ ……... (1)

The value of network parameters (ND,TC,NS and PC) are assumed and ranked by AHP in four different standard time zones (6am-12 noon; 12 noon-6pm; 6pm-12 midnight; and 12 midnight-6am). Here, λ1, λ2, λ3 and λ4 are the Eigen values that represent the network parameters and can be used in calculation the cost function of each node by using equation 1. For example at 6am node density is moderate and the numerical value of ND will be taken near to 4 and similarly the numerical values of other network parameters are scaled using AHP modeling.

Table 2: Numerical ranking of various network Parameters (ND, TC, NS and PC)

Extreme valued	Very Strong to Extreme valued	Very Strong valued	Strong to very strong valued	Strong valued	Moderate to strong valued	Moderate valued	Low to moderate valued	Low valued
9	8	7	6	5	4	3	2	1

The different values or characteristics roots (λ1, λ2, λ3, λ4) can be calculated by using performance matrix.

$$\triangle = \begin{bmatrix} \alpha 1 & \beta 1 & \gamma 1 & \Phi 1 \\ \alpha 2 & \beta 2 & \gamma 2 & \Phi 2 \\ \alpha 3 & \beta 3 & \gamma 3 & \Phi 3 \\ \alpha 4 & \beta 4 & \gamma 4 & \Phi 4 \end{bmatrix}$$

Performance matrix

(Here α = ND, β=TC, γ=PC, Φ =NS)

Eigen values can be calculated by using the expression given below

$$|\Delta - \lambda I| = 0 \quad \ldots\ldots\ldots\ldots\ldots\ (2)$$

Where, **I** is the Identity Matrix. By solving equations 2, various values of λ can be obtained to observe the cost function for each node in the network using equation 1.

Further the cost function F(c) represents traffic load on each node and this real traffic load on each of the nodes estimate the power consumed by a route when data packets are transmitted from source to destination. Now, the optimal route is obtained by minimizing the optimum function (Fmin) using equation 3.

Fmin = (Sum of traffic load on each routing path) X (No. of nodes) …… (3)

The values of this cost function is help for selection of the cheapest route for data transmission form source to destination in the define network.

3.7.1 Example

Table 1 shows the performance matrix of a node at 6 a.m. for a particular time zone that contain network parameters ND, NS, PC and TC. These network parameters are taken from TRAI at define time zone. We consider a 4x4 performance matrix and it shown below: -

$$\triangle = \begin{bmatrix} 4.5 & 2.5 & 2.75 & 5 \\ 4.75 & 2.75 & 2.65 & 5.5 \\ 4.95 & 2.45 & 2.55 & 5.25 \\ 4.3 & 2.8 & 2.95 & 5 \end{bmatrix}$$

By solving the performance matrix, equation 2 yields the value for λ1, λ2, λ3 and λ4 as 15.0917, 0.452, 0.2514 and -0.071 respectively and cost function can be calculated using equation 1 (C_1= 15.7441). We assume all the weights equal to unity (W1=W2=W3=W4=1) and the optimized path is obtained by minimizing the minimum function (Fmin) using equation 3.

Similarly, other values of λ can also be obtained by taking different values of network parameters in the same time zone. The cost function for all network nodes has been calculated for the four standard time zones during a particular day. The cost function of each network node represents the traffic load. Further, this real traffic load on each of the network nodes estimate the power consumed by a route when data packets are transmitted from source to destination.

Now, the values of the network parameters (ND, TC, PC and NS) for each node are taken from TRAI and they are shown below in tabular form.

Table 3: Performance of each node in Time Zone (6am –12 noon)

N1

ND	*TC*	*PC*	*NS*
4.5	*2.5*	*2.75*	*5*
4.75	*2.75*	*2.65*	*5.5*
4.95	*2.45*	*2.55*	*5.25*
4.3	*2.8*	*2.95*	*5*

N2

ND	*TC*	*PC*	*NS*
5.5	*3.53*	*4.34*	*5.6*
4.5	*5.35*	*4.12*	*2.54*
4.34	*3.245*	*5.23*	*3.44*
4.45	*3.45*	*4.04*	*3.456*

N3

ND	*TC*	*PC*	*NS*
5.54	*3.67*	*2.98*	*4.456*
2.34	*5.56*	*6.34*	*5.45*
3.4	*4.65*	*4.456*	*4.99*
4.34	*4.45*	*5.32*	*4.45*

N4

ND	*TC*	*PC*	*NS*
6.23	*5.45*	*3.345*	*7.2*
3.45	*5.56*	*6.23*	*5.65*
2.34	*4.567*	*6.345*	*4.34*
5.45	*6.34*	*4.456*	*6.32*

N5

ND	***TC***	***PC***	***NS***
4.5	***3.54***	***5.456***	***5.456***
3.5	***3.45***	***2.78***	***6.34***
3.67	***4.78***	***5.678***	***3.2234***
3.33	***4.234***	***4.347***	***4.567***

N6

ND	*TC*	*PC*	*NS*
2.34	*4.456*	*3.32*	*5.23*
4.234	*5.23*	*4.45*	*3.56*
2.56	*4.98*	*2.67*	*5.45*
4.43	*2.456*	*4.04*	*4.237*

N7

ND	***TC***	***PC***	***NS***
5.45	***4.34***	***4.45***	***6.56***
4.456	***3.34***	***5.456***	***5.12***
4.43	***4.345***	***5.45***	***4.21***
7.23	***3.4***	***4.5***	***6.7***

N8

ND	*TC*	*PC*	*NS*
5.45	*6.23*	*4.34*	*5.66*
4.34	*5.56*	*4.56*	*5.87*
3.456	*6.345*	*4.4547*	*7.45*
5.34	*6.23*	*6.11*	*3.34*

N9

ND	*TC*	*PC*	*NS*
9	*7.77*	*8.65*	*7.7*
8	*6.7*	*5.6*	*6.7*
5.66	*7.55*	*7.7*	*8.35*
8.2	*6.55*	*8.5*	*7.45*

N10

ND	*TC*	*PC*	*NS*
8.88	*8*	*9*	*8.45*
7.88	*7.77*	*6.555*	*7.2*
7.6	*6.79*	*6.89*	*8.66*
5.77	*5.556*	*7.79*	*7.333*

N11

ND	*TC*	*PC*	*NS*
8.45	*7.77*	*8.45*	*7.7*
7.77	*5.99*	*6.6*	*6.7*
6.34	*6.678*	*7.123*	*8.35*
6.678	*7.345*	*8.5*	*7.66*

N12

ND	*TC*	*PC*	*NS*
8.28	*8.12*	*9.45*	*8.35*
7.9	*7.56*	*7.555*	*7.45*
7.678	*6.345*	*6.49*	*8.34*
6.97	*5.556*	*8.79*	*7.67*

N13

ND	*TC*	*PC*	*NS*
8.88	*8.34*	*9.4*	*8.234*
7.78	*7.85*	*7.543*	*7.456*
7.45	*8.23*	*7.324*	*6.789*
6.66	*6.78*	*7.89*	*8.88*

N14

ND	*TC*	*PC*	*NS*
8.76	*8.54*	*8.887*	*9.56*
7.77	*7.45*	*7.456*	*7.3456*
8.2	*8.33*	*7.456*	*6.66*
8.88	*8.334*	*8.88*	*8.43*

N15

ND	*TC*	*PC*	*NS*
7.78	*7.85*	*8.54*	*7.284*
8.88	*7.45*	*8.543*	*6.956*
6.66	*8.23*	*7.724*	*6.7*
7.45	*8.2*	*6.89*	*8.02*

N16

ND	*TC*	*PC*	*NS*
8.654	*8.55*	*8.387*	*7.66*
7.345	*7.65*	*7.656*	*8.3456*
8.09	*8.73*	*7.856*	*8.56*
8.45	*8.384*	*8.28*	*7.7843*

N17

ND	*TC*	*PC*	*NS*
5	*2.5*	*2.75*	*5*
4.75	*2.75*	*2.65*	*5.5*
4.95	*2.45*	*2.55*	*5.25*
4.3	*2.8*	*2.95*	*5*

N18

ND	*TC*	*PC*	*NS*
5.5	*3.53*	*4.34*	*5.6*
4.5	*5.35*	*4.12*	*2.54*
4.34	*3.245*	*5.23*	*3.44*
4.45	*3.45*	*4.04*	*3.456*

N19

ND	*TC*	*PC*	*NS*
5.54	*3.67*	*2.98*	*4.456*
2.34	*5.56*	*6.34*	*5.45*
3.4	*4.65*	*4.456*	*4.99*
4.34	*4.45*	*5.32*	*4.45*

N20

ND	*TC*	*PC*	*NS*
6.23	*5.45*	*3.345*	*7.2*
3.45	*5.56*	*6.23*	*5.65*
2.34	*4.567*	*6.345*	*4.34*
5.45	*6.34*	*4.456*	*6.32*

N21

ND	*TC*	*PC*	*NS*
4.5	*3.54*	*5.456*	*5.456*
3.5	*3.45*	*2.78*	*6.34*
4.8	*4.78*	*5.678*	*3.2234*
3.33	*4.234*	*4.347*	*4.567*

N22

ND	*TC*	*PC*	*NS*
2.34	*4.456*	*3.32*	*5.23*
4.234	*5.23*	*4.45*	*3.56*
2.56	*4.98*	*2.67*	*5.45*
4.43	*2.456*	*4.04*	*4.237*

N23

ND	*TC*	*PC*	*NS*
5.45	*4.34*	*4.45*	*6.56*
4.456	*3.34*	*5.456*	*5.12*
4.43	*4.345*	*5.45*	*4.21*
7.23	*3.4*	*4.5*	*6.7*

N24

ND	*TC*	*PC*	*NS*
5.45	*6.23*	*4.34*	*5.66*
4.34	*5.56*	*4.56*	*5.87*
3.456	*6.345*	*4.4547*	*7.45*
5.34	*6.23*	*6.11*	*3.34*

N25

ND	*TC*	*PC*	*NS*
7.45	*6.43*	*7.43*	*4.34*
6.234	*7.456*	*6.45*	*6.34*
5.32	*8.34*	*6.345*	*5.87*
7.056	*5.34*	*6.34*	*6.83*

N26

ND	*TC*	*PC*	*NS*
6.23	*4.76*	*5.81*	*4.84*
5.23	*6.43*	*5.34*	*6.34*
6.74	*5.456*	*6.21*	*5.43*
7.34	*6.789*	*6.51*	*6.13*

N27

ND	*TC*	*PC*	*NS*
6.32	*7.88*	*5.33*	*5.66*
7.11	*6.934*	*5.92*	*6.49*
5.22	*6.21*	*4.34*	*6.13*
4.45	*6.22*	*5.56*	*4.89*

N28

ND	*TC*	*PC*	*NS*
6.21	*6.67*	*7.54*	*4.67*
4.5	*5.96*	*4.65*	*7.06*
5.76	*4.88*	*7.45*	*4.4*
6.23	*4.4*	*5.4*	*6.66*

N29

ND	*TC*	*PC*	*NS*
7.23	*5.45*	*6.51*	*7.1*
5.66	*7.33*	*6.34*	*5.76*
6.23	*6.23*	*5.72*	*4.23*
7.145	*4.65*	*7.91*	*6.45*

N30

ND	*TC*	*PC*	*NS*
5.45	*6.21*	*6.24*	*6.71*
6.44	*5.1*	*5.98*	*7.27*
4.23	*6.12*	*4.75*	*6.23*
6.23	*5.23*	*5.87*	*8.23*

N31

ND	*TC*	*PC*	*NS*
5.56	*7.11*	*5.87*	*6.34*
7.32	*5.32*	*4.56*	*5.87*
6.23	*6.87*	*5.98*	*7.23*
5.78	*4.56*	*6.78*	*5.12*

N32

ND	*TC*	*PC*	*NS*
5.33	*6.34*	*6.98*	*4.99*
6.239	*4.678*	*6.65*	*5.23*
5	*7.01*	*6.2*	*7*
5.33	*4.55*	*6.87*	*5.76*

3.8 Traffic load on network nodes

The cost of each node is calculated by substituting the values of network parameters into the performance matrix and by solving the performance matrix it will give the Eigen values for each node. These Eigen values are put into the equation 1 in order to find the cost of each node. The cost of 32 nodes at 6 a.m. in a particular time zone is shown below in tabular form.

Table 4: node cost factor for 32 nodes

1) 15.7441	**2) 35.85**	**3) 26.074**	**4) 14.656**
5) 20.119	6) 35.873	7) 23.9561	8) 14.0186
9) 20.959	10) 33.053	11) 27.5182	12) 15.24
13) 14.4771	14) 32.5262	15) 24.9006	16) 14.45
17) 20.006	18) 29.223	19) 27.1547	20) 14.7695
21) 24.455	22) 30.001	23) 24.9709	24) 13.262
25) 22.4993	26) 30.9009	27) 25.9561	28) 14.7858
29) 18.8047	30) 32.5341	31) 23.2704	32) 13.5164

CHAPTER FOUR

RESULTS

AND

DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS

In this work we have obtained the optimized path between source and destination using real traffic load on different nodes for a particular time zones. All the nodes (transmitters/receivers) under ad-hoc network are distributed to cover entire area. Here we have assumed that the network consist of static nodes.

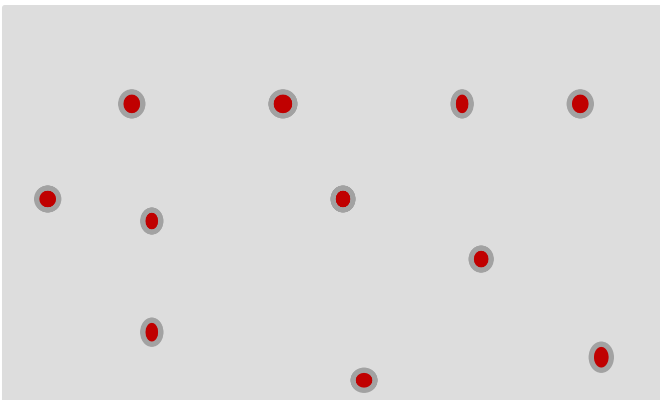


Fig. 7 wireless ad-hoc network

We have optimized the route under the MATLAB tool using the genetic algorithm (GA). In this thesis we have used minimum threshold function (Fmin = Sum of traffic load on each routing path X No. of nodes under a path) to select the optimized path in order to save battery life for further transmission of data packets over the entire network by each node.

4.1.1 Simulation Environment

We have implemented OPERA in MAT LAB –TOOL. For our results we assumed 32 nodes which are randomly distributed cover entire network of area 1500x1500 communicating by IEEE 802.11.The simulation time is 240 seconds. We performed simulation with 10, 20 and 30 number of nodes. Here we have also assumed that the network is static and yet easy allows passage of information since all the nodes of the network are active.

4.1.2 Simulation Results

Case 1:

When source node no. is 1 and destination node no. is 8, than path traced by OPERA consist of node no. 1, 3, 5, 6, and 8.While in case of AODV and DSR path consist of node no. 1, 3, 5, 7, 9 and 8. Hence OPERA give better performance as compare to AODV and DSR.

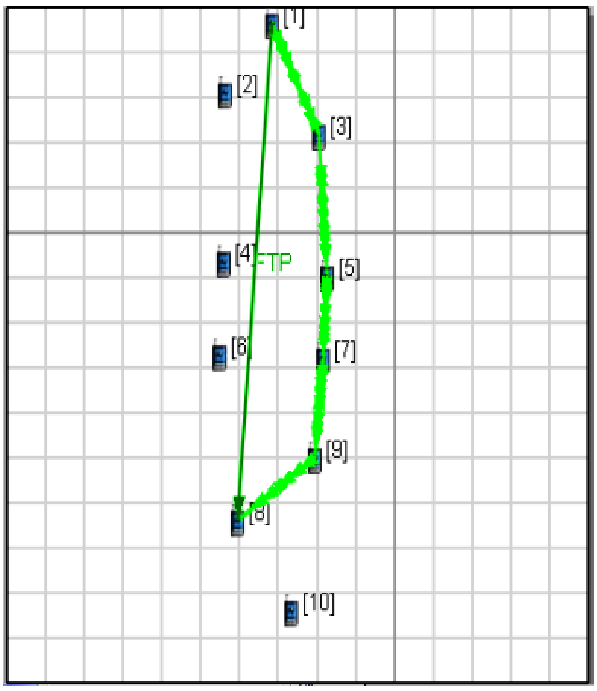


Fig 8 AODV (Path)

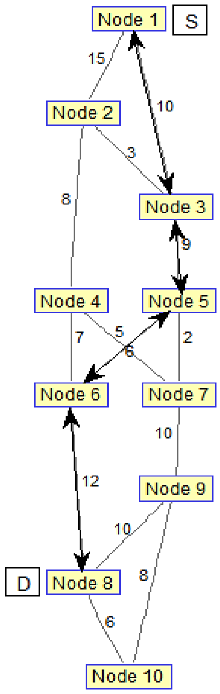
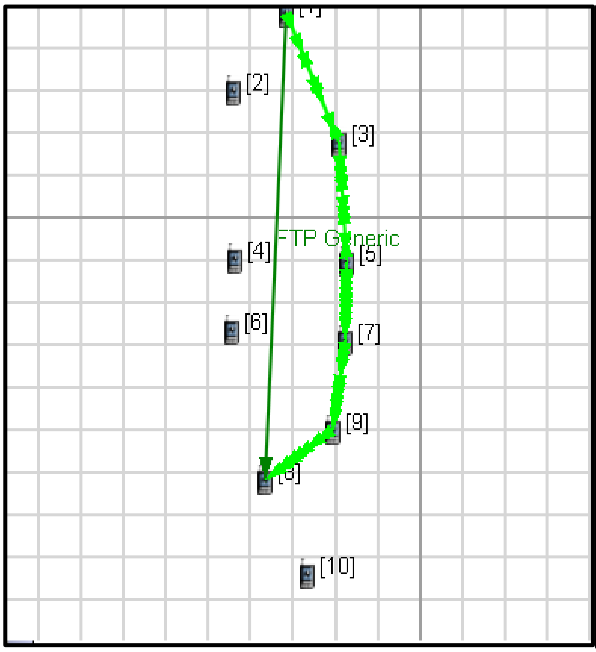


Fig. 9 OPERAN (Path)



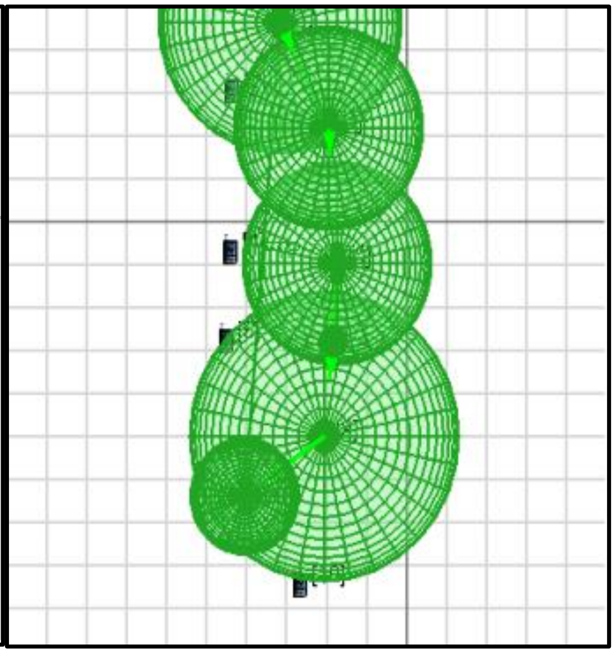


Fig.10 DSR (path)

Fig.11 Simulation top view (AODV)

Case 2:

When considering node 3 as a source node and node 8 as a destination node, than path traced by OPERA consist of node number 3, 5, 6 and 8. While in case of AODV and DSR routing protocols the path traced consist of node number 3, 4, 6, 8 and 3, 5, 7, 9, 8 respectively. Hence in this case the performance of OPERA and AODV routing protocols is almost equal. But DSR is consist more number of node as compare to AODV and OPERA, therefore DSR give less performance as compare to others.

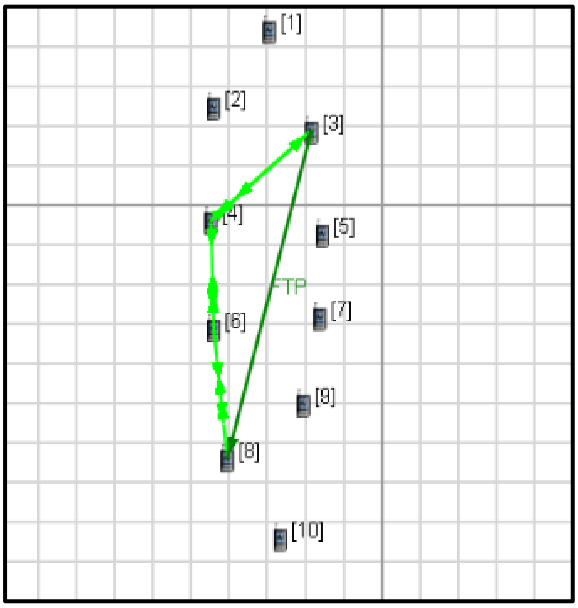


Fig.12 AODV (Path)

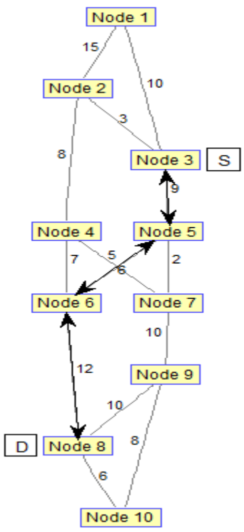


Fig.13 OPERAN (Path)

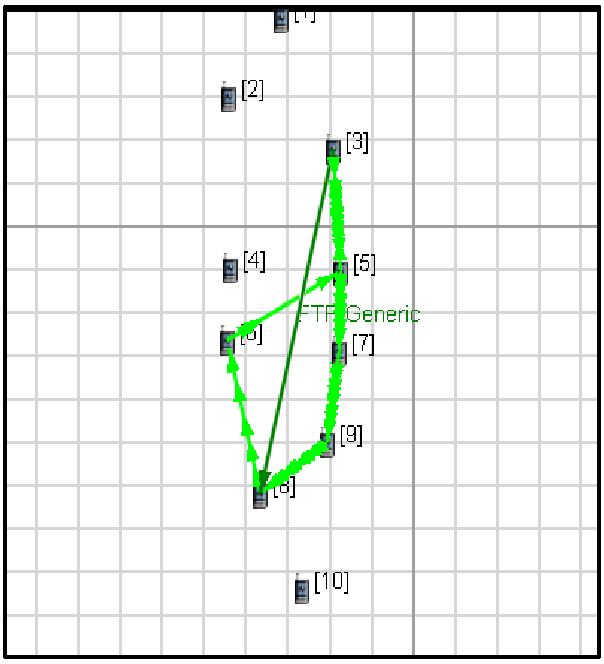


Fig.14 DSR (path)

Case 3:

When considered source node number is 7 and destination node number is 31, than path traced by OPERA consist of node number 7, 26, 9, 28, 13 and 31.While in case of AODV and DSR the path traced consist of node number 7, 25, 8, 26, 9, 27, 10, 29, 13 and 31.Hence it is clear that the performance of OPERA is better as compare to DSR and AODV.

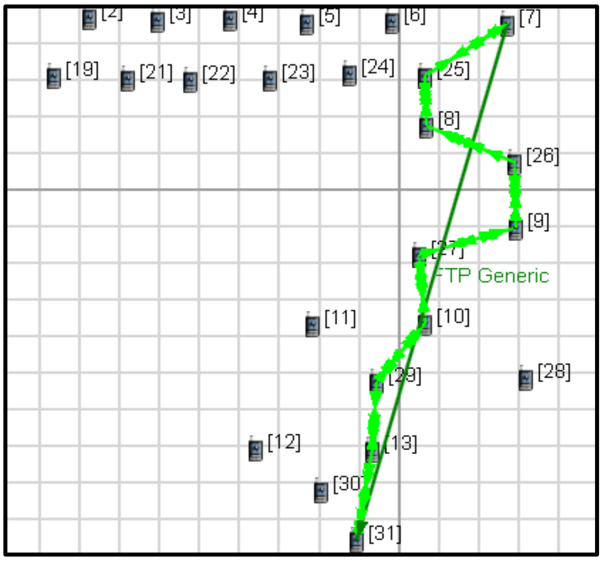


Fig. 15 DSR and AODV (path)

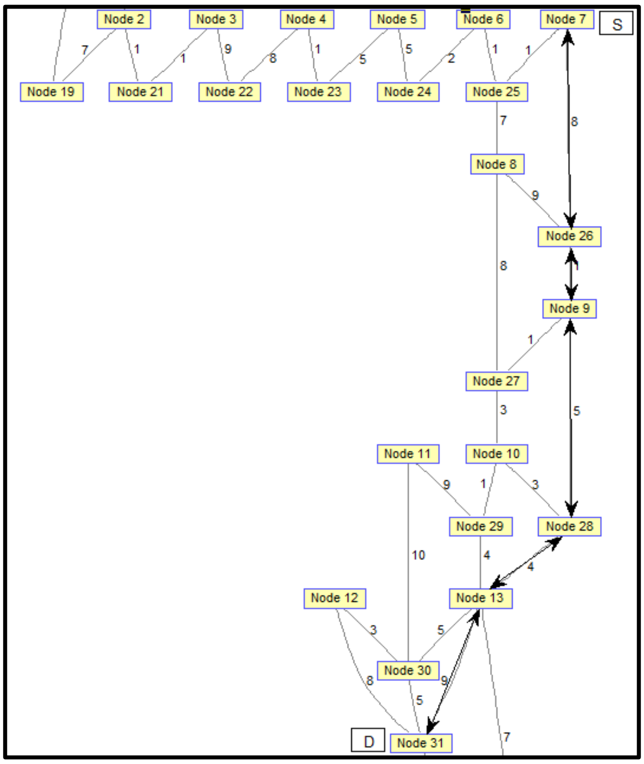


Fig.16 OPERA (Path)

Case 4:

When considered source node number is 9 and destination node number is 31, than path traced by OPERA consist of node number 9, 28, 13 and 31.While in case of AODV and DSR the path traced consist of node number 9, 27, 10, 29, 13 and 31.Hence it is clear that the performance of OPERA is better as compare to DSR and AODV because the path traced by AODV and DSR routing protocols consist of large number of nodes and these nodes are increase with increase in network complexity. It is observed from all the scenarios that OPERA has less average route cost as well as number of hopes. Hence OPERA has less power consumption as compared with AODV and DSR.

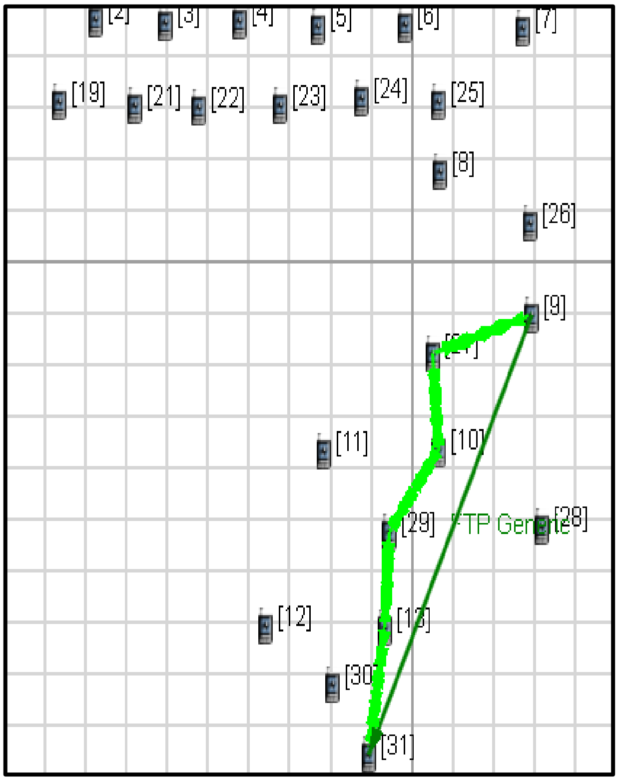


Fig.17 DSR and AODV (Path)

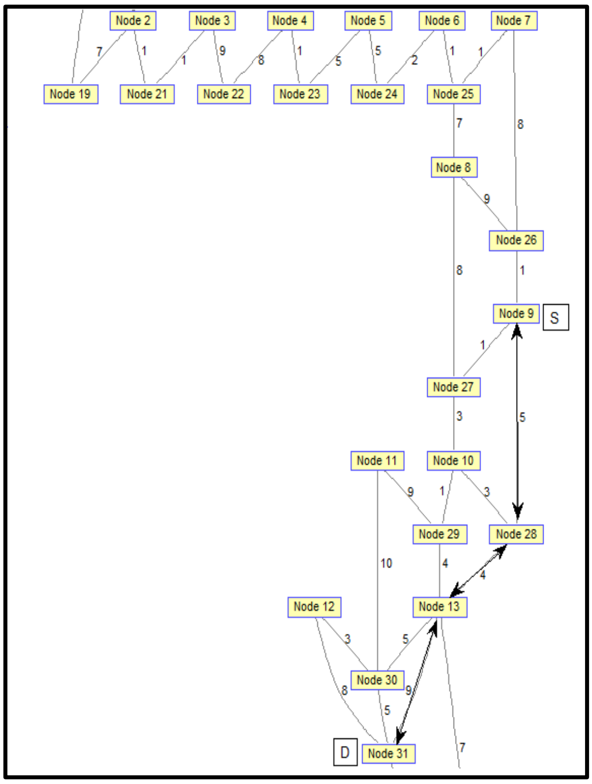


Fig.18 OPERA (Path)

Table 5: Simulation results for OPERA, DSR and AODV

Source node (S)	Destination node (D)	Path traced (OPERA)	No. of hops taken	Average Cost Factor (OPERAN)	Path traced (AODV)	No. of hops taken	Average Cost Factor (AODV)	Path Traced (DSR)	NO. Of hops	Average cost factor (DSR)
1	8	1,3,5,6,8	4	19.993	1,3,5,7,9,8	5	23.012	1,3,5,7,9,8	5	23.012
3	8	3,5,6,8	3	21.056	3,4,6,8	3	19.697	3,5,7,9,8	4	23.621
7	31	7,26,9,28,13,31	5	20.785	7,25,8, 26,9,27,10, 29, 13,31	9	22.91	7,25,8, 26,9, 27,10, 29, 13, 31	9	22.91
9	31	9,28,13, 31	3	23.175	9,27,10,29, 13, 31	5	24.06	9,27, 10,29, 13,31	5	24.06

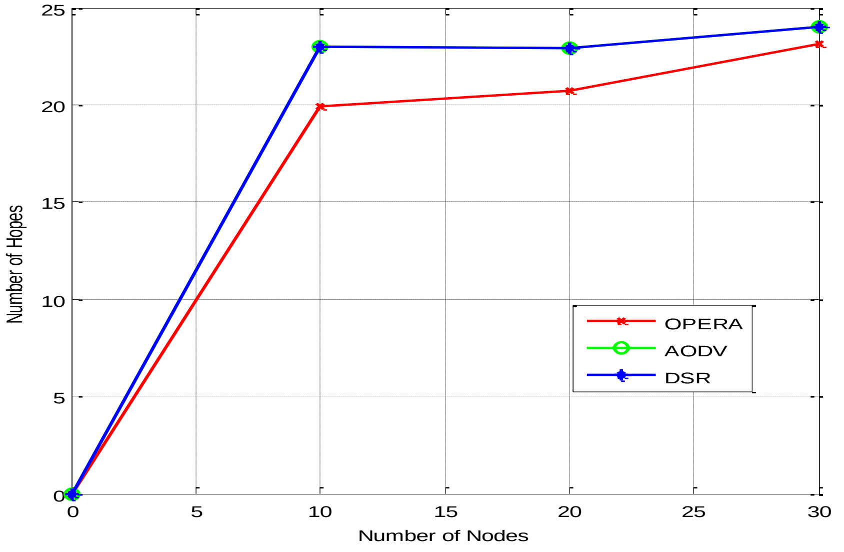


Fig. 19 Route cost versus no. of nodes

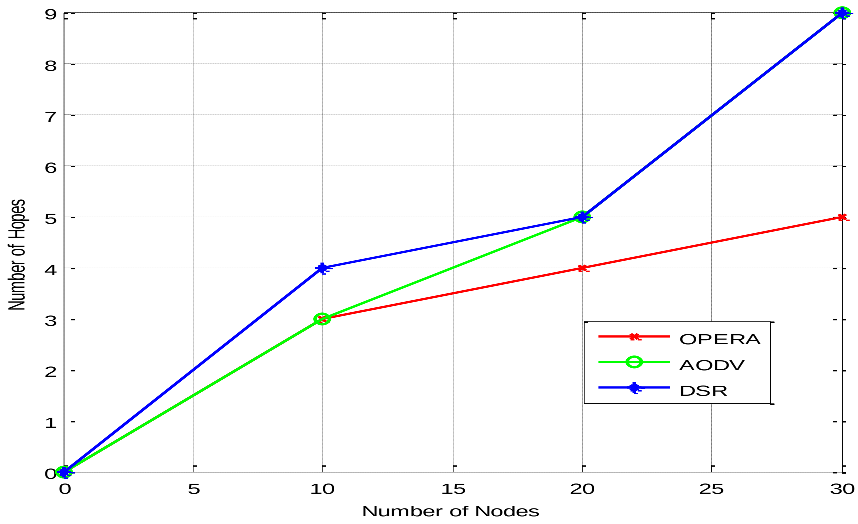


Fig.20 Number of hopes Vs number of node

Figure 19 shows the variation of route cost with respect to node density. It can be seen that as number of nodes increases, results in route cost increases slowly in OPERA as compared with AODV and DSR. It can be also observed from figure 20 as number of nodes increase than number of hop counts also increase in all three protocols but OPERA outperforms AODV and DSR.

On the basis of results of simulations we can say that ‘as the density of nodes is increasing the number of hop count is also increasing in all three approaches but it is less in number in OPERA as compared to AODV and DSR. The high value of hope counts results in high power consumption.

4.1.3 Varying Node Density

By varying the traffic congestion we can minimize our objective function and along with that we can also observed the effects of change in traffic congestion on cost function, no. of hops and average energy consumed. The results are shown below in graphical as well in tabular form.

Fig.21: Energy Consumption V/s Number of Nod (At Maximum Traffic)

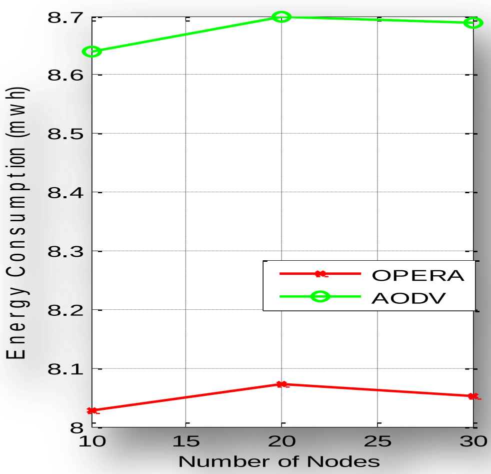
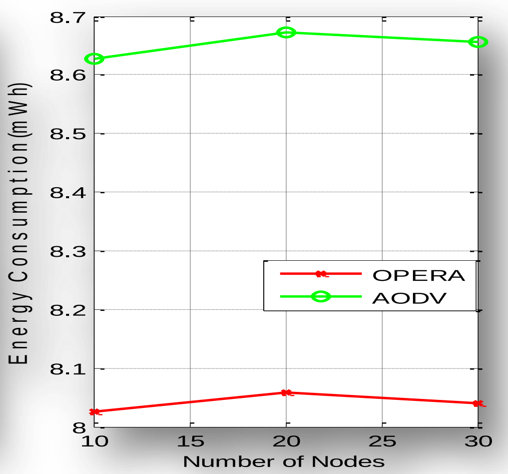


Fig. 22: Energy Consumption V/s Number of Nodes (At Moderate Traffic)



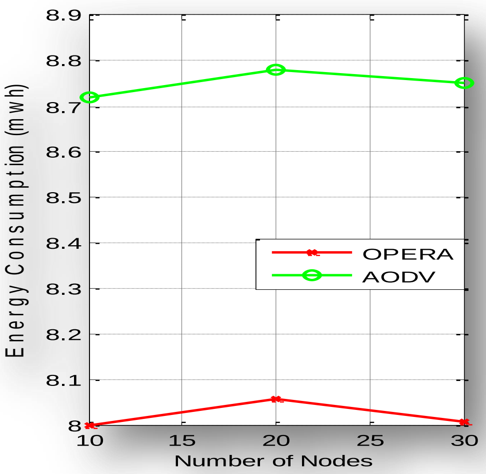


Fig.23: Energy Consumption V/s Number of Nodes (At Minimum Traffic)

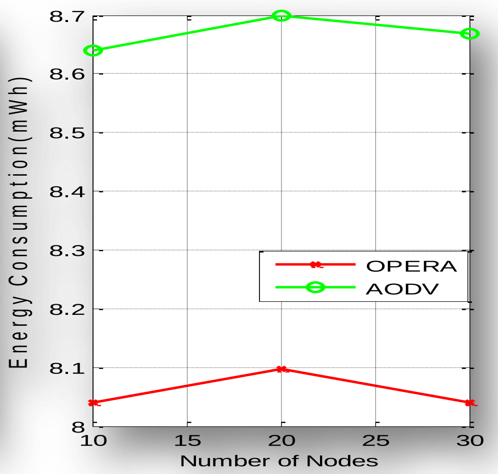


Fig.24: Energy Consumption V/s Number of Nodes (At Open Traffic)

In figure 21, 22, 23 and 24, we have varied the traffic congestion at maximum, moderate, minimum and open data bytes, so as to analyze the impact of the variation of traffic congestion on the total energy consumed. Comparatively, OPERA consumes lesser energy as compare to AODV. Through mathematical analysis, we observe that the average energy saved is about 8.29% per hour at maximum traffic congestion, 7.60% per hour at moderate traffic congestion, 7.30% per hour at minimum traffic congestion and 7.00% per hour at very low or open bit rate.

The results are tabulated in tables 3, 4 and 5. Therefore, it is observed that OPERA has lesser average energy consumption as compared to AODV. The total energy consumed for the routing path can be calculated using,

$$ET = \Sigma Et + \Sigma Er + \Sigma Eint \quad \text{..........................} \quad (4)$$

Where, E_{t} = Transmit mode energy on each node along the route

E_{r} = Receive mode energy on each node along the route

E_{int} = Initial energy on each node along the route in ideal mode

Table 6: Average energy consume in OPERA

S	*D*	*Path*	*At Max Tc*		*E_T At Max Tc (mWh)*	*E_T At Mod Tc (mWh)*	*E_T At Min Tc (mWh)*	*E_T At Open Tc (mWh)*
			No. of hops	*ARC*				
1	*8*	*1,3,5,6,8*	*4*	*27.5*	*8.005*	*8.053*	*8.035*	*8.030*
3	*8*	*3,5,6,8*	*3*	*27.81*	*8.001*	*8.040*	*8.027*	*8.026*

7	31	7,26,9,28,13,31	5	23.71	8.060	8.098	8.072	8.059
9	31	9,28,13, 31	3	23.50	8.009	8.040	8.053	8.040

S= SOURCE NODE; D=DESTINATION NODE; ARC=AVERAGE ROUTE COST, MOD –MODERATE, Tc – TRAFFIC CONGESTION

Table 7*:* Average energy consume in AODV

S	*D*	*Path*	*At Max Tc*		E_T *At Max Tc (mWh)*	E_T *At Mod Tc (mWh)*	E_T *At Min Tc (mWh)*	E_T *At Open Tc (mWh)*
			No. of hops	*ARC*				
1	8	1,3,5,7,9,8	5	28	8.725	8.719	8.665	8.634
3	8	3,4,6,8	3	28.87	8.720	8.704	8.640	8.628
7	31	7,25,8,26,9, 27,10,29,13,31	9	25.12	8.780	8.733	8.700	8.672
9	31	9,27,10,29,13, 31	5	23.68	8.750	8.725	8.688	8.655

Table 8:Energy saved (E_s) in OPERA as compared to AODV

E_s *At Max Tc*	E_s *At Mod Tc*	E_s *At Min Tc*	E_s *At open Tc*
8.29%	7.60%	7.30%	7.00%

CONCLUSIONS

The proposed OPERA performs much better than AODV. However the efficiency of OPERA increases with increase in number of nodes. OPERA is 7.5% more energy efficient than AODV. For networks with smaller number of nodes AODV may be better.

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