

“Design of Simulator for Energy Efficient Clustering in Mobile Ad Hoc Networks”

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In Computer Science and Engineering

By

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Department of Computer Science and Engineering

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Under the Guidance of

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NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA

CERTIFICATE

This is to certify that the thesis entitled, “**Design of Simulator for Energy Efficient Clustering in Mobile Ad Hoc Networks**” by **Amit Kumar and Dheerendra Srivastava** in partial fulfilment of the requirements for the award of Bachelor of Technology Degree in Computer Science and Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any Degree or Diploma.

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Abstract

The research on various issues in Mobile ad hoc networks are getting popularity because of its challenging nature and all time connectivity to communicate. MANET (Mobile Ad-hoc Networks) is a random deployable network where devices are mobile with dynamic topology. In the network topology, each device is termed as a node and the virtual connectivity among each node is termed as the link. Nodes in a network are dynamically organized into virtual partitions called clusters. Network simulators provide the platform to analyse and imitate the working of computer networks along with the typical devices, traffic and other entities.

Cluster heads being the communication hotspots tend to drain its battery power rapidly while serving its member nodes. Further, energy consumption is a key factor that hinders the deploy ability of a real ad hoc and sensor network. It is due to the limited life time of the battery powered devices that motivates intense research into energy efficient design of operating systems, protocols and hardware devices. Clustering is a proven solution to preserve the battery power of certain nodes. In the mechanism of clustering, there exists a cluster head in every cluster that works similar to a base station in the cellular architecture. Cluster heads being the communication hotspots tend to drain its battery power rapidly while serving its member nodes. Further, energy consumption is a key factor that hinders the deploy ability of a real ad hoc and sensor network. It is due to the limited life time of the battery powered devices that motivates intense research into energy efficient design of operating systems, protocols and hardware devices.

The mobile ad hoc network can be modelled as a unidirectional graph $G = (V, L)$ where V is the set of mobile nodes and L is the set of links that exist between the nodes. We assume that there exists a bidirectional link L_{ij} between the nodes i and j when the distance between the nodes $d_{ij} < t_{range}$ (transmission range) of the nodes. In the dynamic network the cardinality of the nodes $|V|$ remains constant, but the cardinality of links $|L|$ changes due to the mobility of the nodes.

Network simulators are used by researchers, developers and engineers to design various kinds of networks, simulate and then analyze the effect of various parameters on the network performance. A typical network simulator encompasses a wide range of networking technologies and can help the users to build complex networks from basic building blocks

such as a variety of nodes and links. The objective of our work is to design a simulator for energy efficient clustering so that the data flow as well as the control flow could be easily handled and maintained.

The proposed energy efficient clustering algorithm is a distributed algorithm that takes into account the consumed battery power of a node and its average transmission power for serving the neighbour nodes as the parameters to decide its suitability to act as a cluster head. These two parameters are added with different weight factors to find the weights of the individual nodes. After the clusters are formed, gateway nodes are selected in the network that help for the inter cluster communication. The graph for the number of cluster heads selected for different number of nodes are also drawn to study the functionality of the simulator.

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List of Abbreviations

ACE	Application Characterization Environment
ALM	Aggregate Local Mobility
API	Application Program Interface
CH	Cluster Head
DMAC	Distributed Mobility Adaptive Algorithm
GPS	Global Positioning System
GUI	Graphical User Interface
GCA	Group Communication Application
MANET	Mobile Ad-hoc Network
MOBIC	Mobility Metric Based Algorithm
OPNET	Optimized Network Engineering Tools
PARSEC	Parallel Simulation Environment for Complex System
PCL	Parallel Calculation Laboratory
PDA	Personal Digital Assistant
QoS	Quality Of Service
RWP	Random Way Point
TACA	Topology Adaptive Clustering Algorithm
TCL	Tool Command Language
WCA	Weighted Clustering Algorithm
WSN	Wireless Sensor Network

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Chapter 1

Introduction

Over past few years there has been a revolutionary change in the area of telecommunication brought by different kinds of new technology and devices. Networking devices i.e. Laptops, cell phones etc. are getting smaller with increasing mobility and connectivity to internet cloud. In this scenario dependency on hard wired network is no longer of our concern. With The exponential growth of wireless devices the number of wireless internet users is going to exceed than that of the wired line internet users within few years. IEEE 802.11x standards have brought a revolutionary change in the field of wireless networks. To obtain connectivity within a network or to communicate with devices across the network, only a wireless interface or access point is required.

Network devices can get connected across the network or they can obtain mutual connectivity by organising themselves into ad-hoc networks. According to IEEE 802.11 “An ad-hoc network is a network composed of communication devices within mutual transmission range of each other via wireless medium “. In modern communication system where there is a requirement of fast and reliable network, devices may be connected via wireless technologies but in some cases wired backbone structure connects several different wireless networks. There are various kinds of wireless network technologies like WPAN, WLAN and MANET etc.

1.1 MANET

A **mobile ad-hoc network (MANET)** is a self-configuring network of mobile devices; i.e. without proper infrastructure and is connected by wireless links. In other words “A MANET is a collection of mobile user that communicate over relatively bandwidth constrained links “. . It is a Random deployable network where nodes are mobile with dynamic topology. In the network topology, each device is termed as a node and the virtual connectivity among each

node is termed as the link. There exists a link among the nodes when they are within the transmission range of each other. The nodes are connected in a decentralise fashion where identifying the topology, delivering the message or execution of any kind of operation is done by each node independently. Nodes organise themselves to send any message or packet to other nodes by creating a multi-hop networking structure. It may be a standalone network or can be connected to external networks. Introduction of new technologies like HyperLAN, Bluetooth etc, have facilitated to evolve MANET outside its earlier and constrained domain.

IEEE 802.11 family has got two main versions that deals with Wireless networks

1. IEEE 802.11a, that works in 5GHz band and provides data rate up to 54Mbps and uses OFDM interface.
2. IEEE 802.11b , operates in 2.4GHz band with data rate 11Mbps. That studied in framework of MANET.

The mobile devices can work in two modes under IEEE 802.11 standards . They are the ad-hoc mode and the Infrastructure mode. Infrastructure mode contains wireless interfaces that further leads to connectivity through wired backbone . wireless access point is necessary for this kind of structure. It supports high scalability and centralised security but in ad-hoc wireless network mobile nodes directly communicate with each other without the help of intermediate access point .Ad hoc network is also calledas the peer to peer network where each node acts as a router along with its normal job as a communicating device. An ad-hoc network can be further connected to internet with the help of gateway nodes.

1.1.1 Application of MANET

Mobile Ad-hoc Networks provide self deployed mode of communication but it leads to the problem of scalability, mobility and energy efficiency . the set of applications of MANET vary from small scale ,static and limited power source network to large scale , highly dynamic and mobile networks. MANET can be deployed in any area where there is requirement of cheap ,fast and direct communication ,such as military service, PDAS ,Group communication etc. In these areas the network can be established or removed on demand without affecting the infrastructure.

- **Military Services:-** This is the basic and common application of MANET . In military services there is requirement of highly mobile network where infrastructure is not necessary , because to setup a highly wired and complex static

network may create problem in battlefield, besides soldiers are highly mobile so in order to broadcast any message we need a dynamic network. But in military scenario there is requirement of security, high latency, reliability and recovery from failures etc. So military networks are designed to establish low probability of detection so nodes in ad-hoc network must not radiate more power and there should be irregularity in message passing that helps with the problem of detection and interference.

- **Disaster management:-** In Disaster situations use of dynamic and peer to peer communication is highly important. MANET provides network with self configuration and minimum overhead . MANET can be set up on any area with minimum or no infrastructure . In situations like earthquake, flood or any manual or natural destruction this kind of network can be implemented as it provides high mobility and requires no central connectivity .
- **Group Communication:-** Any shared application running on current internet based scenario is typically based on client/server communication for ex- Instant messaging ,server gaming etc. But if a group wants to communicate with another group it has to depend on server then message is passed to another client through that central network but MANET provides P2P communication without centralised approach. It is termed as GCA(Group Communication Application) . Now IM services that earlier used to depend on centralise operator has become distributed and can be implemented on a dynamic network . If two group wants to communicate the just have to come close enough to get connected through multi hop paths.
- **Personal Area Network:-** it is a small range of network that connects mobiles phones, PDAS laptops etc. It can be established as a network to communicate among connected nodes or it can be used to connect a back bone network.

1.1.2 Challenges of MANET

So far we have discussed about different benefits and applications of MANET but irrespective of it's characteristics of easy deployment, no need of infrastructure there are certain challenges one has to face while implementing Mobile Ad-hoc Network.

- **Dynamic topology:-** Nodes are mobile and can be connected dynamically in an arbitrary manner. Links of the network vary timely and are based on the proximity of one node to another node.

- **Scalability:-** Scalability can be broadly defined as whether the network is able to provide an acceptable level of service even in the presence of a large number of nodes. In MANET when the network size increases no. Of packets send by node also increases that leads to drainage of limited battery power and network life time gets reduced thus scalability is major challenging issue.
- **Energy Efficiency:-** Energy efficiency is the major challenging issue as it affects the network life time and stability.
- **Security:-** Mobility implies higher security risks such as peer-to- peer network architecture or a shared wireless medium accessible to both legitimate network users and malicious attackers. Eavesdropping, spoofing and denial-of-service attacks are major vulnerabilities.
- **Autonomous:-** No centralized administration entity is available to manage the operation of the different mobile nodes.
- **Device discovery:-** Identifying relevant newly moved in nodes and informing about their existence need dynamic update to facilitate automatic optimal route selection.
- **Topology Maintenance:-** Updating information of dynamic links among nodes in MANETs is a major challenge.
- **Transmission quality:-** This is an inherent problem of wireless communication caused by several error sources that result in degradation of the received signal.

1.2 Clustering

Definition:- Division of network into different virtual groups , based on certain rules in order to differentiate the nodes allocated to other sub-network. Or in simple words we can say that clustering in MANET is defined as virtual partitioning of nodes into sub networks according to geographical area.

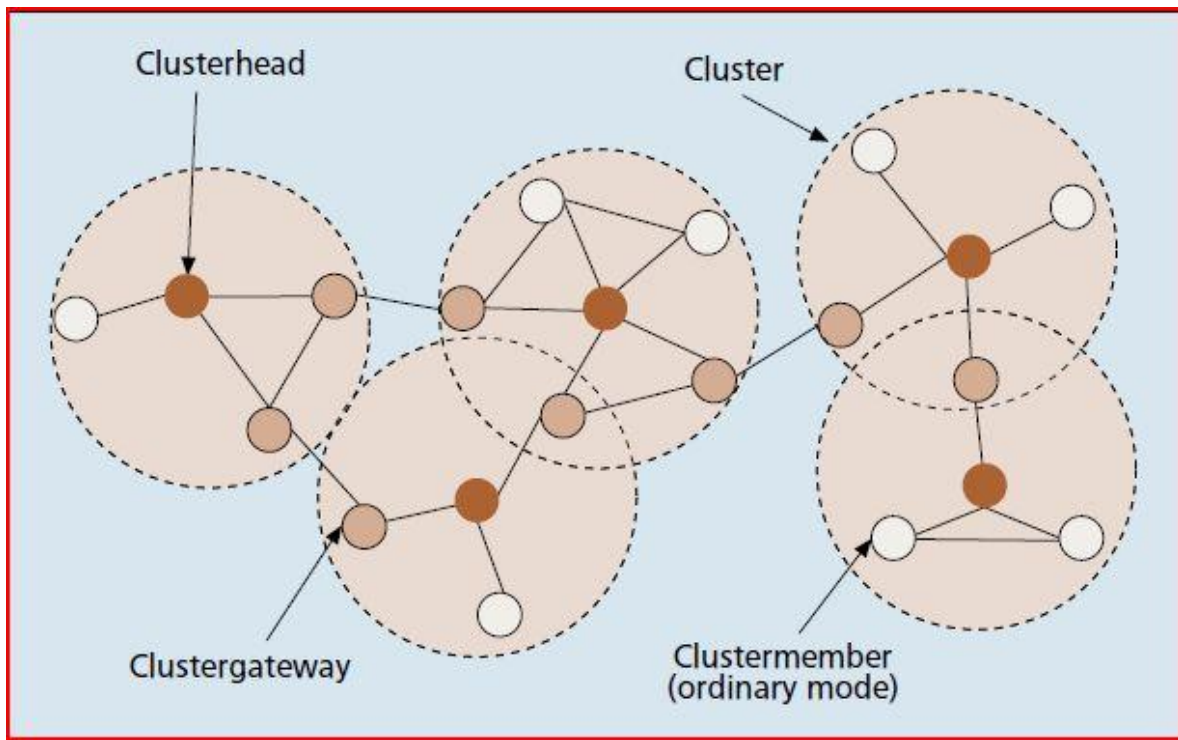


Fig 1- Cluster Structure

A typical cluster structure has shown in figure 1.1. It can be seen that different nodes are grouped to form a structure called as cluster on the basis of closeness and other factors. In any cluster structure there every mobile node is assigned with a status or function .on the basis of there work and status nodes in any structure can be divided into three categories.

- **Cluster head :-** It is a local co-ordinator of a cluster . it performs intra-cluster routing packet forwarding etc. A Cluster head does the resource management for its member nodes and perform inter-cluster and intra-cluster communication. It works similarly as base station. A cluster is shown in the given figure with dark-filled circles.
- **Gateway node:-** A cluster gateway is a non cluster head node with inter-clusters links. it can access neighbouring clusters and exchanges cluster-related information between two clusters. It act as a common or distributed access point between two cluster head. Gateway nodes are of two types
 - (1) **Ordinary gateway node:-** When a node lies within the transmission range of two cluster heads i.e. both cluster heads remain its one hop- neighbour and it facilitates

the transmission between them then this node is called as ordinary gateway node for those two clusters.

(2) **Distributed gateway node:-** When a node is a one-hop neighbour of a cluster head and it is connected to other node that is also immediate neighbour of other cluster head so that both cluster head can communicate with each other via 2-hop neighbours then those two nodes are termed as Distributed gateway node.

- **Ordinary node:-** These are the nodes that exist as immediate neighbour of cluster head. They are cluster member but take part in topology and can act as cluster head or cluster gateway when there is a requirement.

Cluster control architecture:- There are two kind of cluster control architecture one-hop and d-hop depending upon the diameter of the cluster in one-hop control architecture every ordinary node remain at maximum of one hop distance to its cluster head . and in d-hop the distribution of ordinary node may be greater than one and at maximum of d-hop distance from central co-ordinator;

Structure of a cluster:- Nodes in MANET can either be in flat structure or hierarchical structure

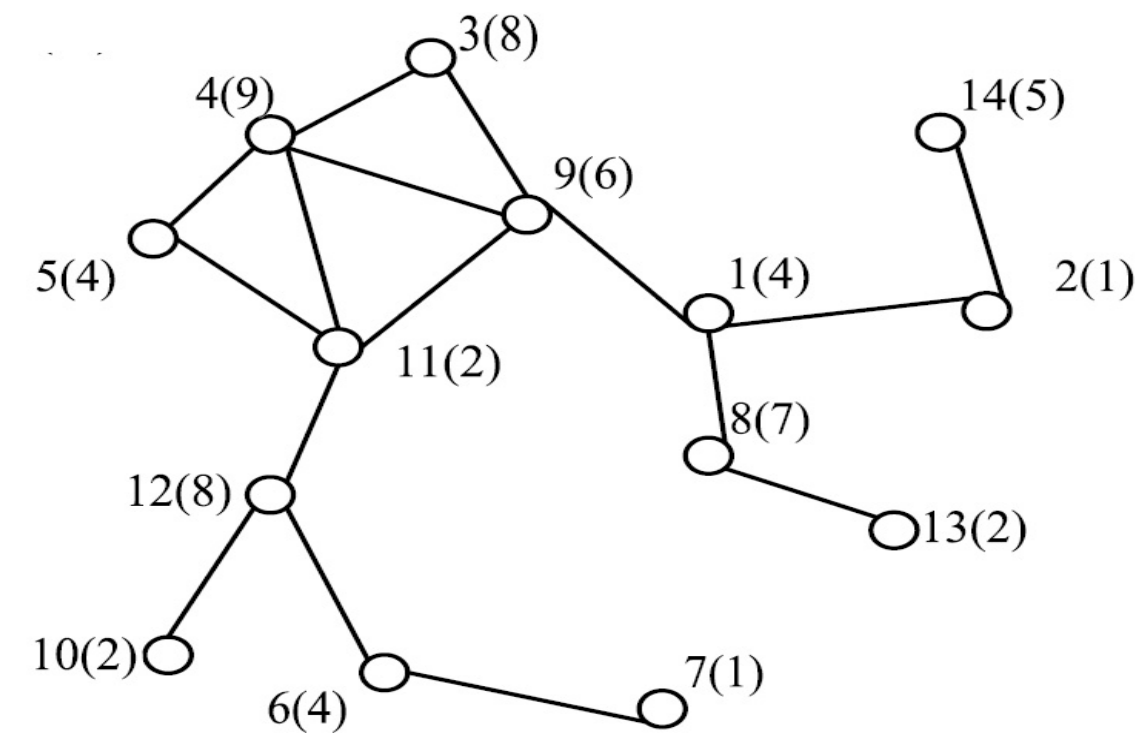


Fig 2- flat structure

In flat structure every node bears equal responsibility to perform any task. It works fine for small networks but for large networks there has been high communication overhead an network will be flooded through data packets.

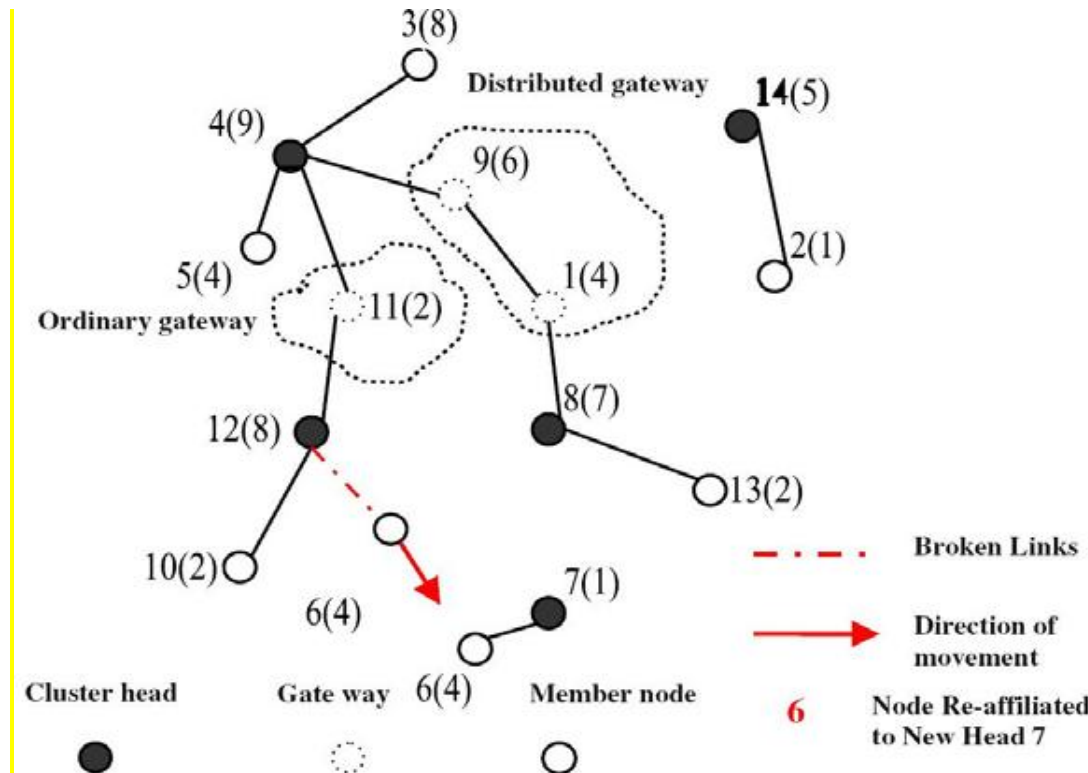


Fig 3- hierarchical structure

In Hierarchical structure every node is assigned with certain task or nodes are divided to act efficiently. Like gateway node is responsible for inter or intra cluster communication, cluster head act as central co-ordinator etc.

Why MANET require Clustering:- It has been already shown that a cluster architecture guarantee basic performance achievement in a network with large no of mobile nodes. There are following reasons for a ad-hoc network that shows the requirement of clustering.

- A cluster structure facilitates the reuse of resources to increase the system capacity. With the non-overlapping multi cluster structure two clusters can deploy the same frequency or code set if they are not neighbouring clusters. A cluster can also put the co-ordination in transmission with the help of other special nodes.

- Other benefit lies in field of routing as the set of cluster heads and cluster gateways can form a virtual backbone for inter-cluster routing thus the routing information can be restricted in this set of nodes.
- A cluster structure makes ad-hoc networks looks smaller and more stable. If a node changes its cluster then only nodes residing in corresponding clusters are need to update the information no need the changes to be seen by entire network.

Chapter 2

Literature Survey

2.1 Clustering

In hierarchical structure nodes in a network are dynamically organized into partitions called clusters. The nodes that are geographically close to each other form a cluster. Then each cluster elects a centralise node called the cluster head which acts as a coordinator for that cluster. Dividing a network into clusters helps maintain a relatively table network topology. Clustering turns any ad-hoc network in such a way that it becomes more manageable. Size of any cluster can be controlled with the help of transmission power of its dynamic node.

There are certain rules and algorithm in order to divide a network into clusters and select a cluster head among them. Any clustering algorithm partitions the network in an optimize way. Several clustering algorithms have been proposed some of them are very plain and simple and some of them are utilizing different parameters of ad-hoc network (i.e. mobility, transmission power, closeness etc.) .

2.1.1 Lowest Id Algorithm:-

Lowest ID algorithm is the simplest clustering algorithm that basically selects cluster head on the basis of unique ID assigned to a node. This algorithm takes following steps .

- every node broadcasts its own ID to all other neighbouring node periodically and in form of any “HELLO” message.
- Nodes that receive messages from its neighbouring node compare their Ids and the node with lowest ID has been selected as a cluster head.
- If a node here broadcast message from two of its neighbouring nodes has become a Gateway node.

Disadvantage:-

- There is no limit of number of nodes in a cluster so overhead may occur.

- No network related parameters are taken into consideration so performance of such network is unpredictable and random.

2.1.2 Highest Degree Algorithm

This is purely based on degree of connectivity . Cluster head selection takes place on the basis of Degree of each node. There are following steps in this algorithm

- each node broadcasts value of its degree (i.e. no. Of neighbours connected to that node).
- A node with highest value of degree in the neighbourhood is selected as cluster head and all other neighbouring nodes join as a cluster member.
- The procedure is repeated until each node is assigned with a cluster head. And any tie is broken with lowest ID.

Disadvantage:-

- There is no bound on no. Of nodes per cluster head so cluster heads become overloaded.
- Does not provide any quantitative measure of stability.
- Due to change in network topology, this approach gives high turnover of cluster heads. This is because when the node with the highest connectivity drops, it will fail to be re-elected as a cluster head.

2.1.3 (α ,t) Cluster Framework

This algorithm is mainly focused on maintaining a topology which allows for optimal routing, In case of low mobility and efficient routing. But if node mobility is high. (α ,t) approach deals with path availability , which is decided by mobility of nodes lie on certain path.

- In this algorithm α determines lower bound on probability that a given cluster path will remain available for time t.
- Each node in the network is given a node's cluster identifier number (CID) and makes use of a timer named α timer. This timer generates the maximum time t for which a node makes sure that paths will be available for each cluster destination with probability α .

- During topological changes such as Node activation, link activation, link failure, deactivation of node and α timer expiration, the algorithm re evaluates (α, t) values.

Disadvantage:-

- It achieves node stability but for a certain time limit.
- During topological changes again values of (α, t) re-evaluates so it becomes a complex process as it takes mobility as a parameter.

2.1.4 MOBIC

It is similar as Lowest ID but here mobility is considered as a base for clustering instead of ID. To compute the cluster head Aggregate Local Mobility(ALM) is used as mobility metric. The steps of algorithm are as follows,

- ALM is calculated as the ratio of received power levels of successive transmissions by transmitting periodically “hello” messages, between a pair of nodes.
- ALM gives relative mobility between neighbouring nodes.
- Each node then calculates aggregate local mobility metric M value by calculating the variance (with respect to zero) of the entire set of relative mobility samples of all its neighbours.
- The node with lowest value of M becomes cluster head.

Disadvantage:-

- It uses signal strength in order to measure mobility but due to noise , obstacles or battery power weight based on signal strength may not be accurate.
- Mobility is considered as measurement of stability of cluster head but there are other factors that also need to be taken into account because single parameter will not give desired stability in all scenarios
- only we are looking at the stability of cluster head alone and not at the entire network. To ensure stability of entire network gateway nodes should be considered.

2.1.5 Mob D-hop

It is a distributed algorithm that partitions ad-hoc network into d-hop clusters based on mobility metric. The objective of framing network into d-hop is to make diameter of cluster more flexible. In this algorithm a node basically calculates its closeness from other nodes and that can be done by measuring send/receive signal strength. This algorithm basically depends upon five terms estimated distance between nodes, the relative mobility between nodes, the variation of estimated distance over time, the local stability, and the estimated mean distance.

Execution of MobDhop takes place in three stages.

- **Discovery stage:** - At the initialization stage two-hop clusters to be formed. Nodes exchanges “hello” message in a periodic way. After a discovery period in which node acquires complete knowledge of all its neighbours, each node computes its local stability value and broadcasts to all its neighbours. Node with the lowest stability value becomes the cluster head and its local stability becomes group stability(GS).
- **Merging stage:** - the two hop clusters in discovery stage can further be expanded by merging process. This process can be initialized by any non-clustered node that wishes to join a cluster or any two neighbouring gateway nodes requests to merge their clusters. First condition of merging is variation of estimated distance between two merging nodes should be less than or equal to the minimum value of group stability of the two clusters. Second condition states that the mean distance between two gateways should be less than or equal to the higher value of estimated mean distance of the two clusters.
- **Cluster maintenance stage:-** A cluster maintenance stage is invoked when topology changes occur due to either arrival of a new node or a node leaving the network. When a node switches on it will begin the merging process as described in order to join a cluster. When a node which is a cluster head switches its immediate neighbours begin the discovery process as described so that a new cluster head can be selected.

Disadvantage:- this algorithm also suffers from drawbacks of MOBIC.

- Only mobility is considered as a stability parameter other factor such as battery power which is an important factor of node stability, is ignored.
- This algorithm is just looking at the stability of cluster head alone not the stability of whole network.

2.1.6 DMAC

It is Distributed and Mobility-Adaptive clustering algorithm provides a general solution for clustering framework. Nodes are assigned weight based on their mobility-related parameter. A node with bigger weight is more suitable for cluster head.

- During the initialization period each node is assigned with a weight (number =0) and unique ID.
- Weight of node represents its mobility parameter.
- Each node sends its weight and ID to one hop neighbour and node that has highest weight among all its neighbours is selected as cluster head.
- If a node joins a cluster it sends JOIN message and if it becomes a cluster head it sends CH message.

Disadvantage:-

DMAC Provides a generalised framework but still the weight metric method is not clearly specified.

2.1.7 WCA

It is also a weight based distributed clustering algorithm like DMAC but here weight is specifically defined . WCA (weighted Clustering Algorithm) selects cluster heads on the basis of number of nodes it can handle, mobility, transmission power and battery power. Steps in algorithm.

- Calculate all the parameters such as battery power, transmission power , mobility and degree difference for each node.
- M_v is the mobility of node. A node with less mobility is always better.

- $T.\Delta V$ is the degree difference i.e. the deviation of actual degree of node to ideal degree.
- D_v is sum of distance from a node to all its neighbours .it is used as energy consumption parameter .
- P_v is total time the node has served as cluster head.
- Weight factors are chosen as $W_1+W_2+W_3+W_4 = 1$
- The node with minimum weight is selected as cluster head.
- A pre-defined threshold is established in order to specify the number of nodes each cluster head can ideally support, in order to avoid overload.

2.1.8 TACA

The aim of TACA is to select minimum number of cluster heads to minimise the number of nodes in the virtual back bone. The features of TACA are

- The nodes in the ad hoc network are capable to increase or decrease their transmission range. But there is a max range R_{max} .
- Battery power and mobility of nodes are taken as weight deciding factor
- A cluster head is selected when the network is first activated.
- As a node drains its battery power completely, it becomes dead and is removed from the network.

Calculating Node Weight:

- Distance covered by a node $D_v = \text{sum}[\text{DIST}_v]$
In 'n' time units from $i=t-n$ to $i=t$ where t is current time.
avg speed of node $S_v = D_v/n$.
- Mobility factor $\Delta M = \delta - S_v$. δ is max permissible speed of node.
- Available battery power is $P_{av} = P_{av} - P_{cons}$.
 P_{av} = Available battery power of the node.
 P_{cons} = Battery power consumed by the node.
- $WT(v) = x_1 * \Delta M + x_2 * P_{av}$.
- x_1 and x_2 are the weight factors that are normalised so that $x_1 + x_2 = 1$.

Disadvantage:-

- TACA selects two kinds of cluster heads volunteer and non volunteer so flooding occurs.
- In is not energy efficient as it does not take transmission power and cardinality of nodes into account while calculating weight factor.

2.2 Simulator

Several methods exist to evaluate the performance of data communication protocols, including live network tests, test-beds, hardware emulation, and mathematical models. Software simulation, however, is often a time efficient and cost effective method.

Researchers around the globe are using software simulation tools because it provides a controlled environment within which performance of any network model can be evaluated easily and effectively.

Nowadays, the popularity of the existing network simulators and in particular that of Ad Hoc networks varies from one simulator to another. Besides, every simulator is based on its own methodology and models to simulate a real network.

While many network simulators are available in the software world but in this topic there will be a comprehensive discussion about performance and functionality provided by the discrete event network simulators like ns-2, QualNet, GlomoSim, NetSim and Opnet.

2.2.1 NS-2

The network simulator ns-2 is another discrete event simulator targeting at networking research. It is the abbreviation of Network simulator version two, which first been developed by 1989 using as the REAL network simulator. Now, NS-2 is supported by Defence Advanced Research Projects Agency (DARPA) and National Science Foundation. In NS-2 there is no graphical options but it has GUI for visualising the simulation run.

Its modules can be written in Scripting language OTcl or in C++. Besides ns-2 already includes a large library of common modules, which are usually sufficient for simulating

common wired- or wireless networks. This simulator is open source and provides online document.

Advantages:-

- NS-2 can support a considerable range of protocols in all layers. For example, the ad-hoc and WSN specific protocols are provided by NS-2.
- Open source model of NS-2 saves the cost of simulation, and online documents allow the users easily to modify and improve the codes.
- It can run on any system having GNU C-compiler gcc as it is written in C++. Thus it can run on UNIX platform as well.

Limitations:-

- people who want to use this simulator need to familiar with writing scripting language and modelling technique, the Tool Command Language(Tcl) is somewhat difficult to understand and write.
- NS-2 is sometimes more complex and time-consuming than other simulators to model a desired job.
- NS-2 provides a poor graphical support, no Graphical User Interface (GUI) ,the users have to directly face to text commands of the electronic devices.
- Due to the continuing changing the code base, the result may not be consistent, and contains bugs.
- NS-2 can not simulate problems of the bandwidth, power consumption or energy saving in WSN., NS-2 has a scalability problem number of nodes can not be exceeded to 100.

2.2.2 Glomo Sim

GloMoSim is a scalable simulation environment for wireless and wired network systems, developed by PCL (Parallel Calculation Laboratory) of UCLA (University of California in Los Angeles). It uses Parallel Simulation Environment for Complex System (PARSEC) that is a C based simulation language for sequential and parallel execution of Discreet event simulation model. Glomosim Supports protocol for purely wireless network.

Advantages:-

- Scalability of network model can be increased up to thousands of nodes.
- GloMo Sim is useful for a network model where nodes are exchanging high amount of information.

Limitations:-

- The updates of GloMoSim are not regular. The last update was in 2003.
- GloMoSim is being designed using the parallel discrete-event simulation capability provided by PARSEC. However, the last version of GloMoSim supports only one sequential simulation.

2.2.3 Qual Net

Qual Net is a commercial derivative of GloMo sim. GloMo Sim was designed for MANET but Qual Net supports wider range of networks and analysis i.e. MANET, QoS, Wired Network, Cellular, Satellite etc. Its modules are written and designed in C++. Qual Net developer toolkit contains following component .

- Qual Net Animator – Graphical component used as animation tool.
- Qual Net Scenario Designer - Graphical , Finite state machine based custom protocol design tool
- Qual Net Analyzer – Statistical Graphic tool used for built in and custom statistic collection
- Qual Net Packet Tracer –packet level tracing and visualisation.

Qual net provides a GUI interface where simulation can be seen by the help of its animator component

Advantages:-

- Qual net provides GUI tools for protocol modelling.
- Scalability increases via parallel execution.
- It provides a clear built in measurement for each layer.
- Contains standard API for composition of protocol across each layer.

Limitations:-

- Difficult installation on Linux, as it has been built for older version of Linux (Fedora core 4).

- slow Java-based User Interface.
- very expensive.

2.2.4 NETSIM

Netsim provides complete model creation and modification capabilities along with graphical animation and data output. Netsim uses the event graph method and object-oriented programming for simulation. Netsim is a world wide web based simulation package written entirely in Java. Netsim allows expandability for complex modelling and integration with other Java-based programs, such as graphing and analysis packages.

Any simulation problem modelled in NETSIM can be viewed as an HTML page like applet in JAVA. It provides traditional procedural based simulation package.

Advantages:-

- it is available in all platforms without recompiling. It can be accessed remotely as modelling is JAVA applet based.
- It provides security by password mechanism for individual access , and protect against unauthorized change and delicacy.
- High maintenance as frequent modification is instantly distributed. All modification and implementation are made on-sever.
- Encourage communication and interaction through java and requires Browser capable of running JAVA programs.

Limitations:-

- For Other traditional simulation model loading time depends on system itself not on the internet. In case of web simulation if there is heavy traffic loading time may exceed and thus simulation.
- It does not have copy of simulation over system, so dependency on internet increases and interruptions in network may cause inconsistency.
- It is not efficient for longer run without updating frequently.

2.2.5 OPNET

OPNET stands for Optimized Network Engineering Tools. The OPNET software provides an ACE (Application Characterization Environment) module which can be used to import packet traces into simulation from different sources including TCPDUMP files., It is a high level event based simulation tool. Simulation operates at packet level. Originally it was built for simulation of fixed networks but now possibilities of wireless simulation are also very rich.

OPNET consist of high level user interface which is designed from C and C++ code blocks, and with a huge library of OPNET specific methods. It provides a hierarchical structure where modelling can be done in three domain

1. Network Domain- Network topologies, sub-networks, mobility etc. Lies in this domain.
2. Node Domain- it deals with single network nodes i.e. router, mobile devices etc.
3. Process Domain- it consists of single module and source code inside a network node.

Advantages:-

- OPNET provides a GUI for the topology design, which allows for realistic simulation of networks.
- It has been used extensively and it provides real scenario including traffic and all so there is possibility of getting results error free.

Limitations:-

- Simulation in OPNET requires A lot of processing and it may be time consuming for a network containing large number of sender and receiver nodes.
- OPNET need parallel processing in order to work effectively so in this environment multiple processors are used to simulate high scalable scenario.

Chapter 3

Proposed Simulator and Algorithm

3.1 Basics of Simulator

The mobile ad hoc network can be modelled as a unidirectional graph $G = (V, L)$ where V is the set of mobile nodes and L is the set of links that exist between the nodes. We assume that there exists a bidirectional link L^{ij} between the nodes i and j when the distance between the nodes $d_{ij} < t_{range}$ (transmission range) of the nodes. In the dynamic network the cardinality of the nodes $|V|$ remains constant, but the cardinality of links $|L|$ changes due to the mobility of the nodes. This modelling of nodes is represented in graphical scenario of java based simulator. Following are the main features of Graphical Scenario of proposed simulator.

Simulation Area:-

Each mobile node is represented as a moving disc and they are randomly deployed in a square of 10X10 which is called as simulation area. Each node is identified with a unique identifier ID . ID is given as a label to each node starting from 0 to Node_number-1. The nodes in the network are allowed to move freely within the network area by following the Random Way Point Mobility model (RWP) and satisfy the boundary conditions. In the RWP the nodes chooses a random speed and random direction and moves towards the destination. After reaching the destination it pauses for a while before selecting another set of speed and direction for the next movement . While moving in the network the nodes establish connectivity with the neighbour nodes that are within their transmission range.

The bidirectional mutual connectivity of nodes are called as links. Links can be established between two nodes when they come close enough such that there mutual distance is less than or equals to their transmission range. Links in the simulation area is represented as a straight line that changes dynamically according to the node movement.

Node:-

In the simulation area each node is represented as a disc and labelled with unique ID, but there are three basic different types of nodes in any mobile ad-hoc network model, Cluster heads, Cluster Gateways, and ordinary nodes. There is a proper discrimination between these nodes on the basis of their function, so that they are distinguishable from each other.

Cluster heads are selected after execution of proposed clustering Algorithm and after evaluation of cluster heads, those nodes are defined as black coloured disc.

Ordinary nodes i.e. neither cluster head nor Gateway, are Red coloured nodes without. Cluster Gateways are either common node for two cluster heads or two nodes that are mutually connected and both of them are at one-hop distance from two different cluster heads. In first case they are ordinary gateway nodes but for later they are distributed gateway nodes. Gateway nodes blue in colour.

Range:-

Range is defined as the length of maximum distance, any node can transmit. It is given in meters with discrete values of 1,2 up to 10. Range can be increased or decreased in side menu of simulator. It is an important measure to display connectivity in simulation area.

Simulation speed:-

Simulation speed gives the speed of mobile nodes in simulation area. Like range ,speed has also measured in discrete values of 1,2 up to 10 meter/sec.

Connectivity matrix:-

It is basically a table that contains all the information of a mobile nodes. It contains 5 columns and number of rows can be changed according to given Node_Number.

Node_id	Degree	Avg_distance	E _{consumed}	CH
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Node_id :- it displays the unique ID of all nodes.

Degree:- this column shows the degree of connectivity(connected neighbouring nodes) for each node.

Avg_distance:- it is calculated for each node by

$$\text{Avg_distance} = \frac{\sum \text{Dist}}{|D_i|}$$

$\sum \text{Dist}$ is sum of distances between a node and all its one-hop neighbours.

D_i is the degree of connectivity of that node.

E_{consumed} :- this column contains the value of energy consumed for each node.

CH:- shows the id of Cluster head for corresponding Node_id.

Statistical Result:-

It shows result graph between

1. no of nodes and no of cluster heads .
2. no of cluster heads and range in meters.

3.2 Selection of Cluster head in the simulator

The proposed work is a modification to the TACA. The energy efficient clustering algorithm is a distributed algorithm. It considers the battery power consumed by a node and its average transmission power utilised for serving its neighbours as the parameters to decide its suitability for a cluster head. These two parameters are added with different weight factors to find the weights of the individual nodes.

The steps for finding the cluster heads in the network are described below:

Step 1: Every node probes its neighbours by broadcasting hello packets and receiving acknowledgements from others. Figure 2 represents the nodes after finding their connectivity in the network.

Step 2: The nodes calculate the number of neighbours from which it receives the acknowledgements. This number represents its degree of connectivity $|D_i|$ or the cardinality of the node in graph theory terminology.

Step 3: Compute the average transmission power utilized by a node as:

$$P_{av} = \frac{\sum Dist}{|D_i|} \quad \text{where}$$

P_{av} = Average Transmission Power.

$Dist$ = Distance between the node and its one hop neighbors.

Step 4: Compute the weight of the node as

$$W_i = \alpha * E_{cons} + \beta * Energy_{P_{av}}$$

Where α and β are the weight factors and

$Energy_{P_{av}}$ = Energy consumed due to the average transmission power utilised.

The algorithm indicates that a node having lowest weight W among its 1-hop neighbours consumes minimum battery power and utilises minimum transmission power to serve the neighbours. So this node is selected as the cluster head and its 1-hop uncovered neighbours (i.e. whose role is not yet decided) become the cluster members of the selected head. The set of covered nodes are exempted from taking part in subsequent selection procedure and this process is repeated till all the nodes are assigned with their role either as a head or a member.

Chapter 4

Snapshots

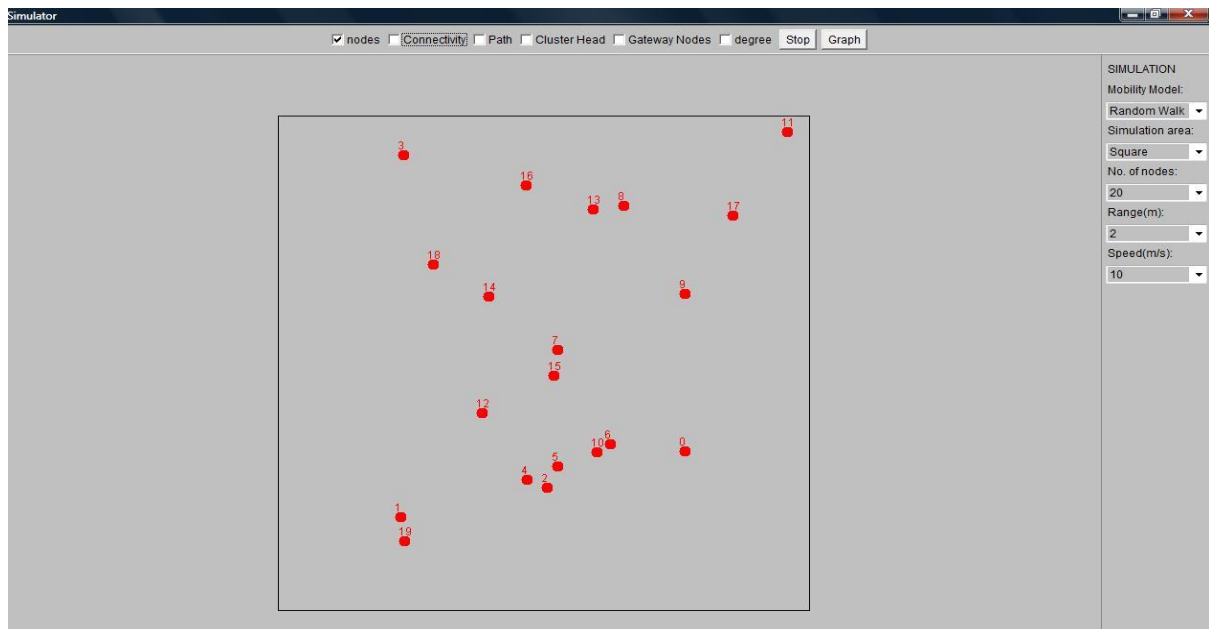


Fig - 4 Simulator for Dynamic Network Showing nodes in simulation area

In fig-4.1 a square simulation area of 10x10 is shown with randomly deployed node. Each node is assigned with unique ID. Default value of node number is given 20. Nodes are visualised in red coloured disk. Nodes are free to move in random walk fashion inside the simulation area. Node selects a random speed and direction and move towards destination.

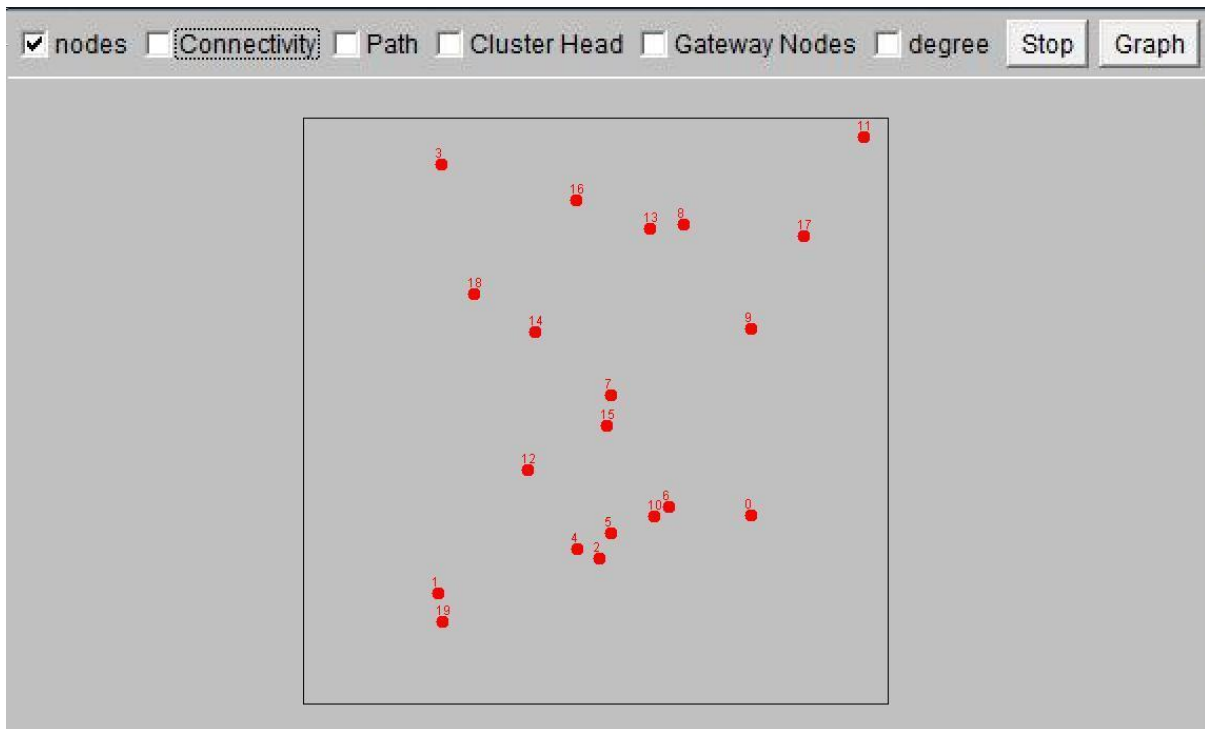


Fig - 5 Top menu of simulator

Top menu has check boxes and buttons by which we can select connectivity , path , cluster head , gateway nodes and degree we can use stop button to stop the nodes and graph button to get the statistical results in form of graphs. By selecting connectivity box virtual links can be viewed inside the simulation area. Path traced by nodes can be seen by checking path box. Cluster heads can be displayed by checking Cluster head box. Gateway nodes is displayed by checking Gateway Nodes box. By checking Degree box Connectivity matrix table is displayed.

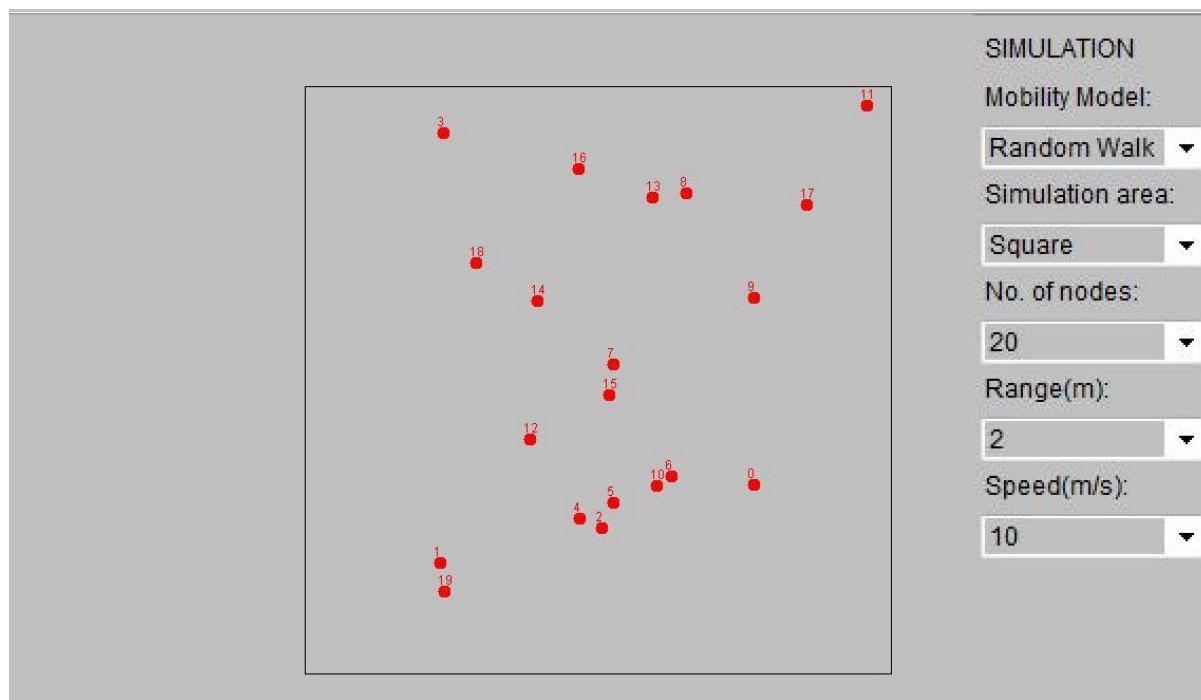


Fig - 6 Side menu of simulator

Side menu has drop down menus for mobility model , simulation area , number of nodes , range and speed. No. of nodes can be changed in the simulation area by selecting appropriate option from no. of nodes drop down menu. Range can be selected in discrete values of 1 to 10 meters so as speed can be changed from 1 to 10m/s.

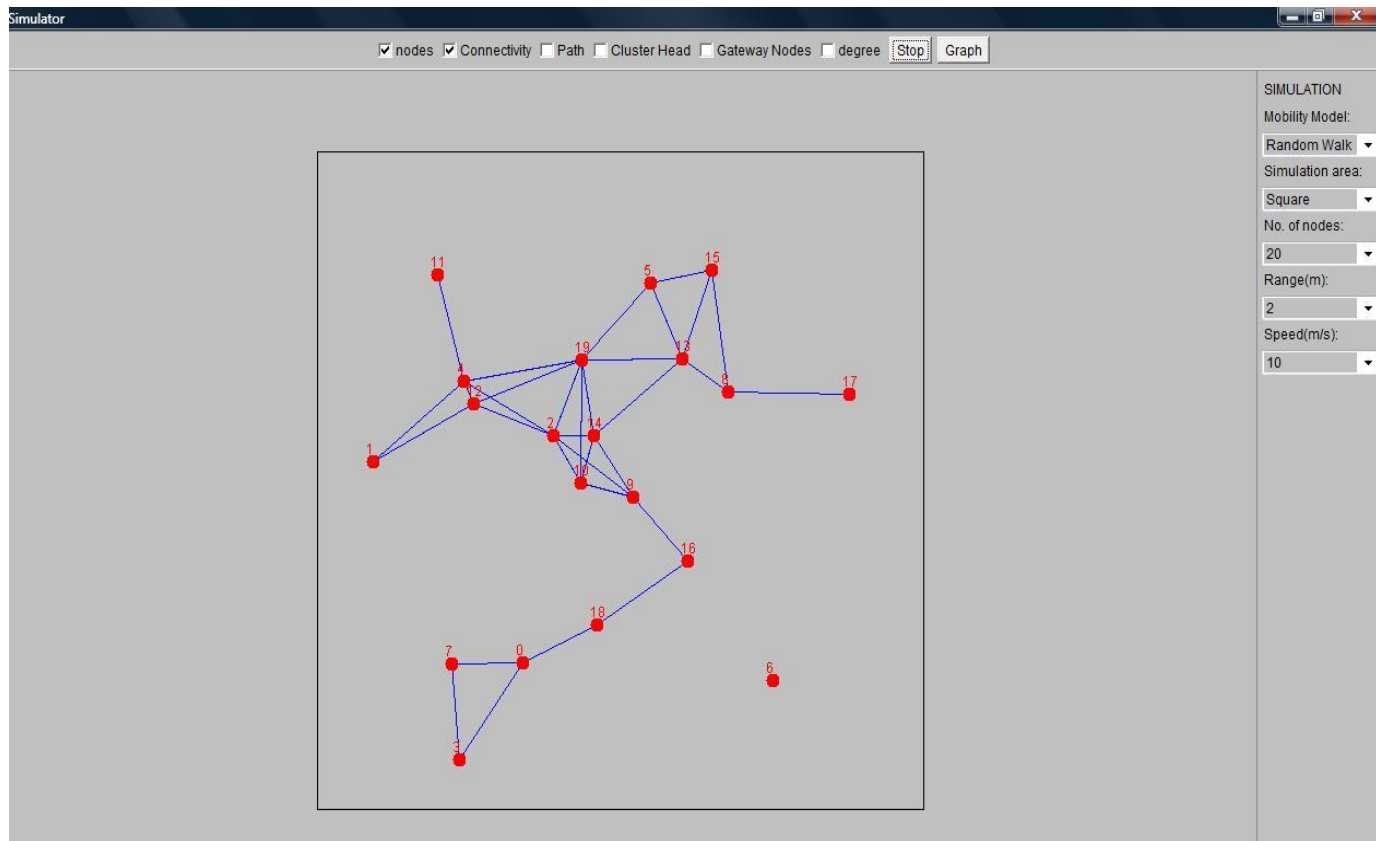


Fig 7 The simulator after the nodes probed their connectivity with the neighbours

Given fig. Shows the simulator where nodes are connected to their neighbours. Connectivity between two neighbouring nodes is displayed by blue coloured straight lines. Nodes that are not connected to any neighbour is called as isolated node for ex. In given scenario node no. 6 is an isolated node .Neighbouring node is decided by comparison between transmission range and relative distance between two nodes.

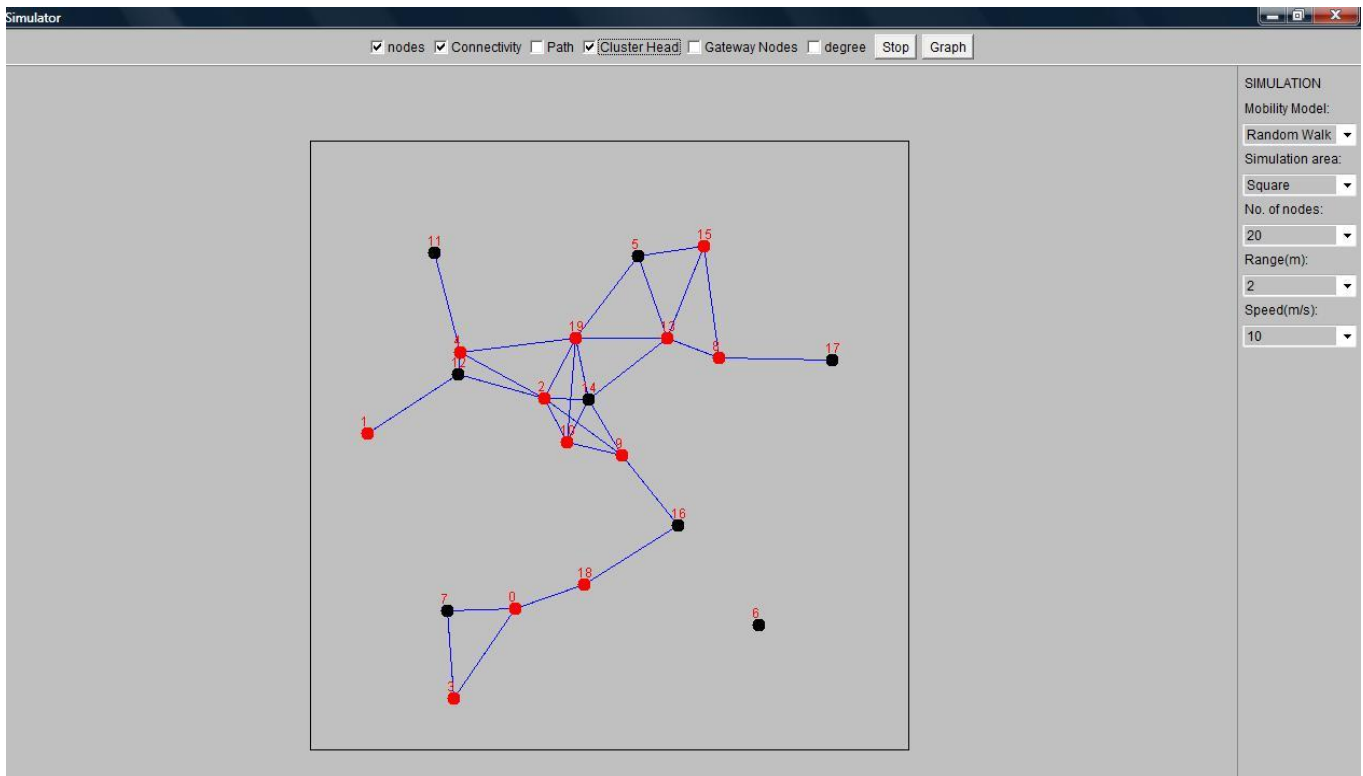


Fig- 8 Cluster Heads are identified in the simulator

In the simulation area cluster heads are shown in black coloured disks. After execution of clustering algorithm cluster heads are selected on the basis of consumed energy. The nodes with less consume energy among its one-hop neighbour are selected as cluster head and displayed in black colour inside the simulation area.

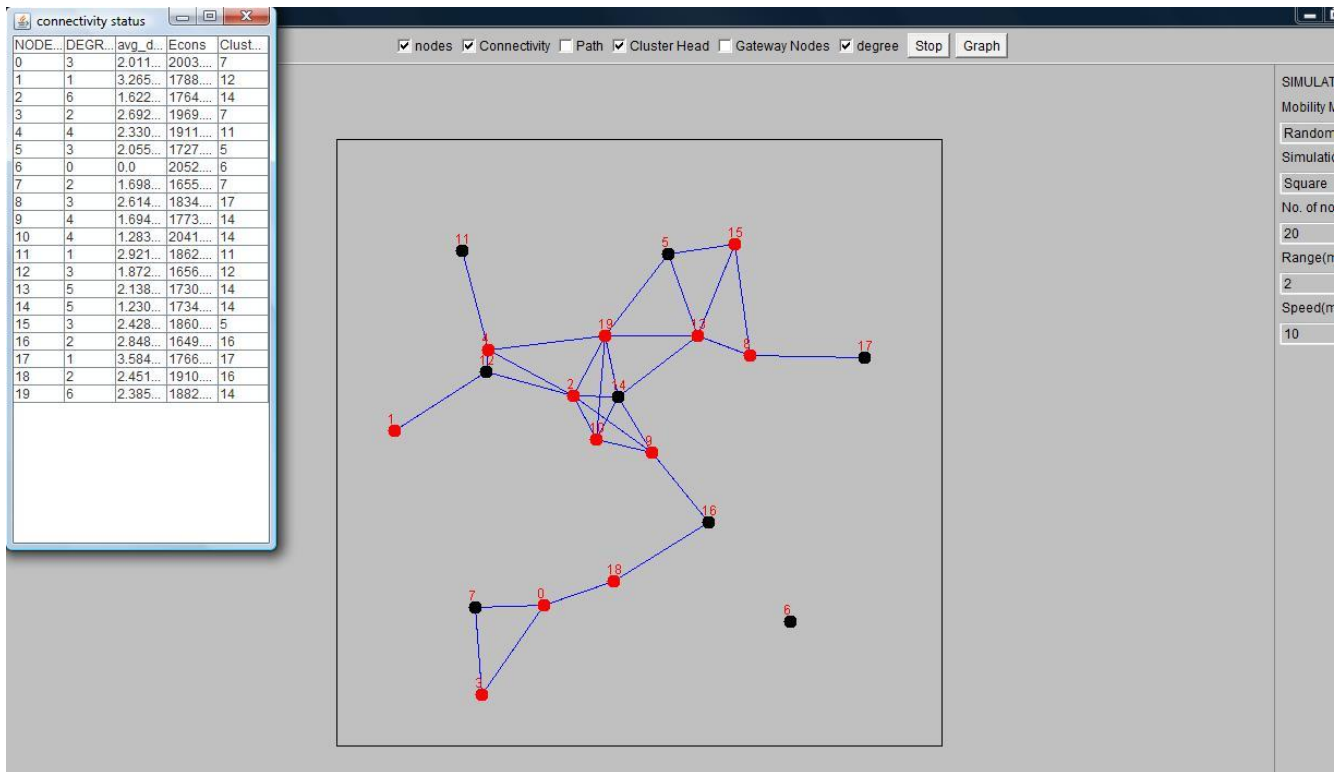


Fig 9 Simulator with connectivity matrix

Upper menu shows checkbox on clicking degree box a connectivity matrix is displayed on the upper left side of simulator. It contains five column that updates dynamically, with the change in topology. First column “Node_ID” contains unique id of all nodes. Second column “degree” contains cardinality of nodes. Third column “avg_dist” contains average transmission power of each nodes. Fourth column “Econs” contain energy consumed by each node and fifth column “CH” contains ID of cluster heads for corresponding nodes. Cluster heads are selected on the basis of these stats.

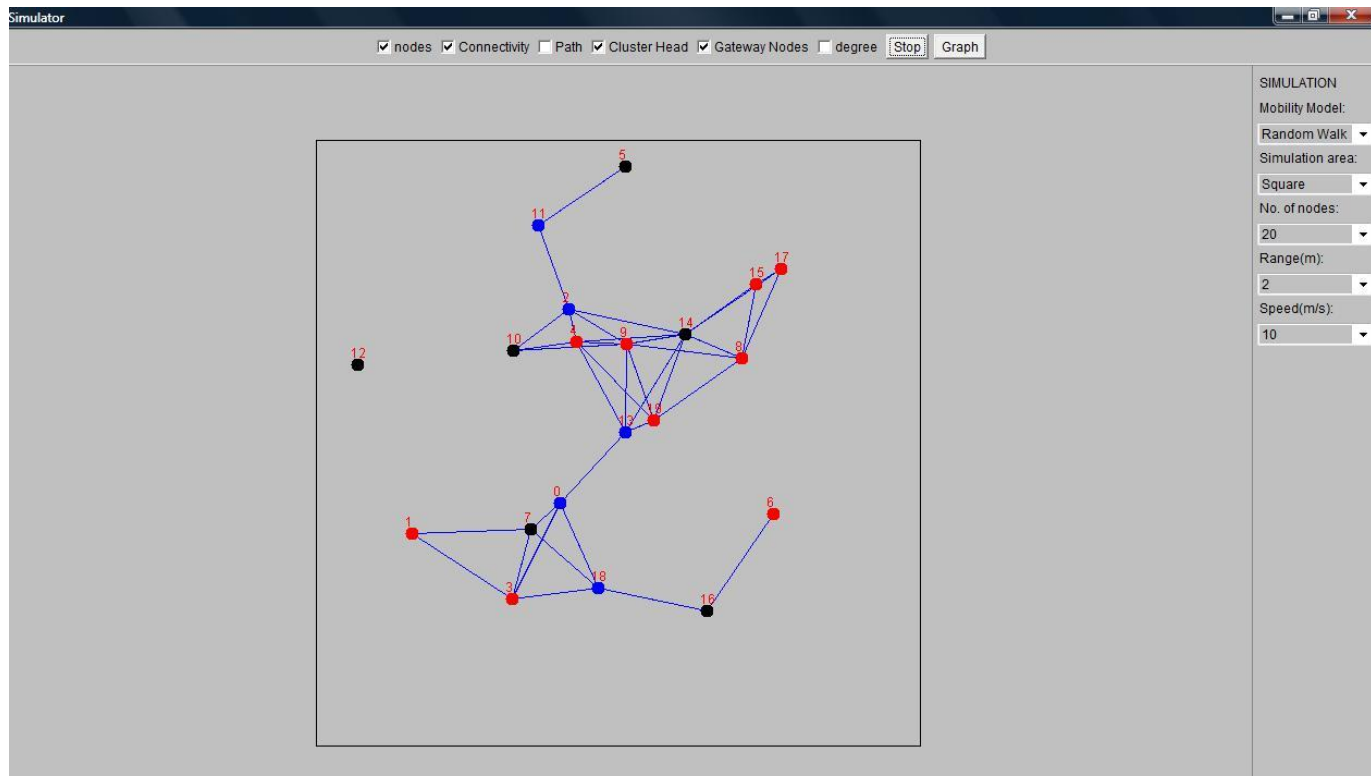


Fig 10 Simulator depicts Gateway Nodes in simulation area

If a node sense transmission from two cluster heads then that node is said to be the gateway node. Here gateway nodes are displayed with blue colour inside the simulation area. If there are two or more than two nodes that posses characteristics of gateway nodes for same cluster heads then tie has been broken by lowest ID algorithm. These gateway nodes provide connectivity extended to internet.

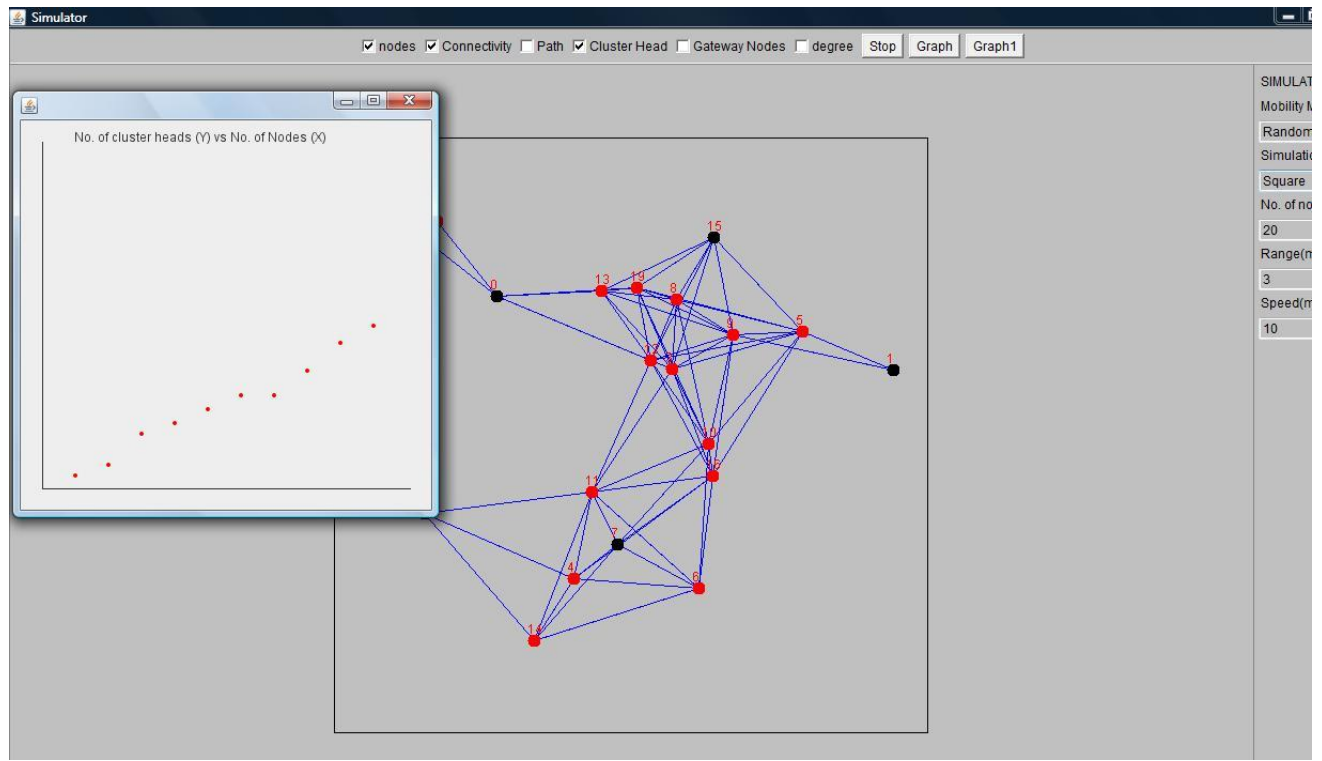


Fig 11 Simulator with graph between number of cluster heads and number of nodes

Here is the graph is plotted between the number of nodes varies from 10 to 100 and between the number of cluster heads. No. of cluster heads are mapped on y-axis while no. of nodes are mapped on x-axis. No. of nodes can be changed from side menu and it varies from discrete values of 10 to 100. With the change of nodes every time no. of cluster heads are calculated and the relation between those values is represented by red dots. Conclusion can be made by analysis of given result that no. of cluster heads increasing subsequently with increase of no. of nodes in the simulation area.

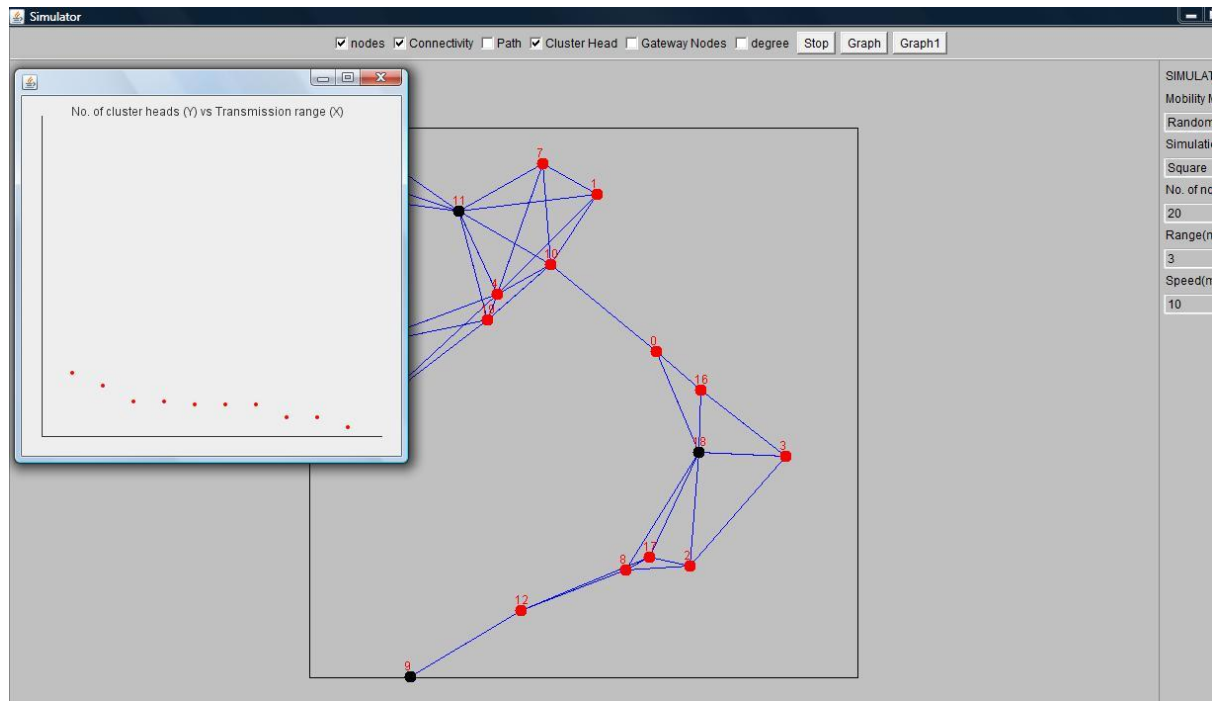


Fig 12 Simulator with graph between number of cluster heads and transmission range

Here the graph is between the number of cluster heads and the transmission range ranging from 1 to 10 (in meters). No. Of cluster heads are mapped to y axis and transmission range is mapped to x axis. By changing the transmission range through side menu different values for range can be plotted on x-axis and correspondingly for each value of transmission range no. Of cluster heads are calculated and can be plotted on y-axis. The analysis of red dots that implies relation of range and no of cluster heads it can be stated that with the increasing value of transmission range, no. of cluster heads are decreasing subsequently.

Chapter 5

Conclusion

A network simulator is a software program that imitates the working of a computer network. In simulators, the computer network is typically modelled with devices, traffic etc and the performance is analysed. Typically, users can then customize the simulator to fulfil their specific analysis needs. The proposed simulator is an extension to the earlier work for designing of a distributed clustering algorithm for ad hoc networks. A node that consumes minimum energy in the network is selected as the cluster head. The energy consumption is considered to be the function of the degree of connectivity of a node along with its average transmission power that is consumed in serving its neighbour nodes. In future routing protocols can also be implemented with further modification.

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Dissemination of Work

Amit Kumar, Dheerendra Srivastava and Prof. Suchismita Chinara, “Design of the simulator for energy efficient clustering in MANET” accepted in International Conference on Computer Science, Engineering and Applications (CCSEA-2012). NEW DELHI, 26-27 May 2012.