Energy Efficient Stable Cluster Scheme for MANET

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Certificate

This is to certify that the work in the thesis entitled *Energy Efficient Stable Cluster Based scheme for MANET* by *Eppa Rahul*, having roll number 213CS1150, is a record of an original research work carried out by him under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of *Master of Technology* in *Computer Science and Engineering Department.* Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

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Abstract

In Mobile Ad-hoc Networks, cluster based routing protocol(CBRP) is robustly used since they combine the advantages of Reactive and Proctive routing protocols. And they have less routing overhead and less end-to-end delay compared to Reactive and Proctive routing protocols respectively. Energy source for a mobile node is limited, and even difficult to recharge. The life time of the network depends on the life time of the nodes. So we propose differnet shemes to have energy efficient stable clusters. By using stable clustering algorithm to avoid frequent reclustering, efficient clustering scheme to minimize overlapping clusters, and allow nodes to save their energy by changing their mode to sleep mode.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Initially tactical networks used follow ad-hoc paradigm. And the commercial MANET development took place from the technologies like Bluetooth, Hyperlan, and IEEE 802.11. Mobile adhoc networks play a very crucial role in the future of wireless technologies. There is much more research and development to come in MANET. The following are the MANET characteristics, applications and capabilities.

1.1 MANET

A mobile ad-hoc network (MANET) is a mobile wireless mesh network. It is developed on sole purpose to have a self configuring network of mobile devices connected by wireless links. The Ad hoc network is a totally different model of traditional mobile networking. Ad hoc networks are capable of existing in the environment where there is no any fixed infrastructure. But they depend on the other nodes to form the network. The operations of MANET are like complex distributed system across the wireless node that helps to dynamically create a network. The connections between the nodes may be temporary, but every time a new arbitrary connection forms a network. So nodes can have a seamless internetwork even in the environment where there is no any prior communication network existing.

The technology of wireless cellular system started in late 1980. It undergone through many evolutions, like first, second and third generations. But they all operate under centralized supporting structure, called ACCESS POINT. These are fixed points laid and connected by physical infrastructure. The mobile is free enough to roam until it is under the range of any one of the access point. The communication range through Bluetooth is around 10mts. MANET is scalable, number of nodes in the network can be increased dynamically. The network boundaries is not fixed. The range of network is increased as the nodes are added [1].

Life time of mobile ad-hoc networks is short but they are easy and quick to deploy. Ad-hoc is a Latin word describing ¨for this or for this only∵ MANET is autonomous system established by link of wireless connection.

Ad-hoc network simply is dynamically forming network of mobile nodes. The network is temporary to support information transfer on the fly. The mobile devices include cell phones, laptops, handheld digital devices, personal digital assistants, and wearable computers. The nodes are equipped with the capabilities of both receiving and transmission. The nodes act as router, communication between source and destination node is routed through the nodes which occur in the communication range between them. The MANET is not laid for an economic profit, but for supporting information exchange between the nodes. The intermediate nodes acting as routers do not impose any charge on source, destination for supporting the communication between them. MANET forms multi hop network.

1.1.1 Charecteristics of MANET

MANETs have following characteristics.

1. **Dynamic Topology:** Nodes move freely with various speeds in arbitrary

directions, so network topology is random and unpredictable.

2. **Limited energy source:** Source of energy at the nodes is battery. Batteries produce limited energy and are hard to recharge. The most important system design optimization criteria is energy conservation.

3. **Limited bandwidth:** Wireless links provide lower capacity compared to infrastructured networks. Interference, noise, multiple access conditions make it more worse.

4. **Security threats:** Network is more prone to physical security threats like eavesdropping, spoofing, and denial-of-service attack.

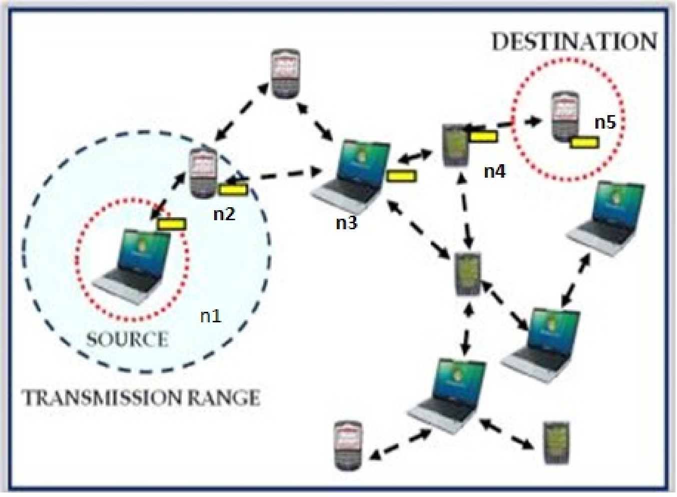


Figure 1.1: MANET

The figure 1.1 shows different kinds of mobile electronic communication gadgets are connected by wireless links to support communication between the nodes where communication between source node n1 and destination node n5 takes through other inter mediate nodes n2,n3,n4 acting as routers.

1.1.2 Applications of MANET

Daily applications of an organization like file transfer and electronic mail can be done. It also supports web services by making a node as gateway that connects to internet. This technology is initially developed to serve military applications, like establishing quick network for communication of soldiers in battlefield in unknown territories where infrastructured network is hard to deploy. Multimedia applications are also made compatible, global roaming capability, and in the case of requirement they can also be connected to the other networks. Some well-known ad-hoc networks are:

1. **Collaborative work**: Business environments need collaborative computing outside the organization like corporate meeting where people need to cooperate and exchange information on a given project.

2. **Crisis-management Applications**: These situations like natural disasters occur cause the damage to established infrastructure networks. Immediate rescue operations are required to save lifeś. Rescue operations need quick network establishment within hours.

3. **Personal Area Networking and Bluetooth**: A personal area network (PAN) is short range, localized network. Network of devices associated with given person like the devices could be connected to the persona pulse watch, belt etc. In these cases, mobility is the major thing to consider when several PANs interact. Considering a situation, people meet in real life. Bluetooth is aimed at supporting PANs by removing the requirement of wired cables between devices like printers, PDAs, digital cameras, notebook computers etc.

1.1.3 Types of MANET

Depending on node mobility, range of communication there are various kinds of MANETś like:

1. **Vehicular Ad hoc Networks (VANETs):** Where vehicles are equipped with wireless routers which can communicate in the range upto 100 to 300 meters, supporting the speed of the node upto 40 kmph. This kind of technology is used by police, fire vehicles. Odometers serve as speed source to estimate speed of vechile.

2. **Smart Phone Ad hoc Networks (SPANs):** Where smart phones create peer-to-peer network without depending on any traditional network infrastructure, wireless access points or cellular carrier networks. SPANś are different from Bluetooth, Wi-fi since there will not be any group leader and peers can connect and disconnect without disturbing the existing network.

3. **Internet based mobile ad hoc networks (iMANETs):** These are ad-hoc networks that connect mobile nodes to fixed internet-gateway. In this kind of networks the traditional ad-hoc routing algorithms will not work. Persistent System's CloudRelay is an implementation of this kind.

4. **Mitltary and Tactical MANETs:** where security is primary consideration Persistent Systems' Wave Relay is implementation of this kind. Waveforms like Harris's ANW2 and HNW are used. It is to be noted A mobile ad-hoc network (MANET) is an ad-hoc network but inverse is not true, i.e every ad-hoc network cannot be MANET.

1.2 MANET Routing Protocols

Many routing protocols have been designed for communication between the nodes in an ad hoc environment. In MANET, routing is a difficult task to achieve because of its high mobility. The main issues in MANET which requires routing are network management, traffic management, broadcasting, mobility, topological change, Quality of Service (QoS), fast data transfer, etc. These are the challenging elements which require efficient routing techniques. In this section, we survey briefly on different routing protocols used in MANET implementations.

1.2.1 Reactive Routing Protocols

Reactive protocol tries to find the route in an on-demand manner. Route discovery process is initiated on demand by route request (RREQ) packets flooding throughout the network. Route tables are also updated only when required. So these are also known as On Demand routing protocols. When routes are requested, nodes flood the request query into large part of network. And try to get the route to destination as reply. This process leads to delay in communication. Routing protocols like Ad hoc on-demand Distance Vector (AODV) are examples of reactive routing protocols.

Ad hoc on-demand Distance Vector(AODV) Protocol

AODV does not require any periodic global routing announcements. Even in the case of broken link it provide loop-free route while repairing. Itś a pure on-demand route acquisition system. A node does not discover and exchange the routing information to the other node until it is requested. Only the nodes that lie in the path between source and destination help to get rote reply and further transfer of packets. AODV does route discovery by broadcast mechanism, it follows source routing but also depends on intermediate nodes by creating dynamic entries in routing table. The nodes use destination sequence number, by maintaining the monotonically increasing sequence number counter to maintain the most recent updates only to ensure loop-free routing.

Path discovery is started when the source need to send data to some other node. Initially the node does not have any information about routes to the destination node. There are two counters node sequence number, broadcast_id at every node. The route request process starts by source sending route request packet (RREQ) to its neighbours. The RREQ contains source address, source sequence_number, broadcast_id, destination address, destination sequence_number, hop count. Source updates broadcast id number by 1 when it sends the next new RREQ. All the nodes which get RREQ packet send the route reply packet (RREP) back to the source if the nodes have path to the destination in their routing table. Else they forward RREQ by broadcasting, If a node receives a duplicate RREQ it simply drops it. When the RREQ reaches an intermediate node which has information about destination, it compares destinations sequence number in its route entry with that of RREQ packet to find if its current route. If sequence number in RREQ is greater the route is not used and RREQ is forwarded by broadcasting. Else RREP is sent back to source. RREP packet contains source address, destination address, destination sequence_number, hop count, lifetime. RREP is sent back to the source using the obtained by reversing path RREQ travelled. When RREP received by intermediate node it sets pointer to node from which it received, updates timeout information, records latest destination sequence_number. The source node starts the actual transmission whenever it receives the first RREP.

All the intermediate nodes store source, destinations sequence number in route table entry called soft-state associated with entry. Route request expiration timer is used to delete reverse path entries in all those nodes that are not in path between destination and source.

Simulation results [2] show the fraction of packets delivered is low in AODV compared to DSDV. And as the number of nodes, node mobility increases fraction of packets delivered will fall considerably low compared to that of other protocols like DSDV. It is also observed delay of the packets is high compared to DSDV and significantly increase as number of nodes increase, with little change occurring due to mobility.

1.2.2 Proactive Routing Protocols

In proactive routing protocol each node has information to reach every other node in the network. Routing information at the node is periodically exchanged with neighbours. They use periodic broadcast of information. So the routes are available without any delay, but causes substantial overhead, affecting bandwidth utilization and throughput. And more importantly it consumes significant amount energy greater than that is required for actual data transmission.

Destination-Sequenced Distance Vector(DSDV) Protocol:

It uses Bellam-Ford routing algorithm. In DSDV, every node has a routing table. Routing table contains information of all available nodes. The node entry contains next hop, sequence_number and metric associated with that node. In this protocol each node is assigned an attribute called sequence_number, which is used to find the updated information and avoid routing loops. Each node broadcasts or multicast its routing table as advertisements, periodically or immediately when the network topology changes. Initially routing table at all the nodes are empty. After the first advertisement period routing table at the node contains entries of neighbouring nodes with associated metric to the node. Generally metric to the nodes at 1-hop distance is considered as 1. In the next advertisement period when the nodes broadcast their neighbour table, all the node will have entries of neighbours of distance 2-hop. When a node(x) receives an advertisement from a node(y), the node(x) computes updated metric to each the nodes in the advertisement packet as summation of metric to the respective node mentioned in the advertisement packet and metric of sender to receiving node. If a node(x) receives information of same destination from different neighbouring nodes, it calculates the metric to the destination using the information received from different neighbour nodes. And creates an entry in the routing table for the destination node with next hop as the neighbouring node which gives least metric. If node(x) receives multiple update packets of same destination node, node(x) updates routing table entry with the information in the packet with greater sequence_number. If the update packets have the same sequence_number, the update packet with smallest metric will be used. Upon the updated routing information, each node has to relay data packet to other nodes upon request in the dynamically created ad hoc network.

Simulation results [2] show the normalized routing load initially in DSDV is low compared to AODV but as the number of nodes increases routing overhead in DSDV significantly increases compared to AODV.

1.2.3 Hybrid Routing Protocols

Hybrid Routing Protocols try to take the advantages from reactive and proactive routing protocols. More importantly they are scalable to any number of networks. Different routing approach is followed at different levels of hierarchy. Routing is initially established with proactively prospected routes and later on serves the further demands by additionally activated nodes through reactive flooding on the lower levels of hierarchy. It uses clusters to decrease routing control overhead and use proactive routing inside cluster to decrease packet delay.

Chapter 2

Cluster Based Routing Protocol

2.1 Introduction

Cluster Based Routing Protocol (CBRP) is route mapping protocol intended for Mobile Ad hoc Networks [2]. In CBRP the network can be partitioned into groups. A group is called cluster, there may be disjoint or overlapping clusters. Clusters are forms with the radius of k-hop distance from central node of the cluster called cluster head. There are different mechanisms to elect cluster head among the nodes. Each cluster head maintains information of the nodes in its cluster. Routes inside the are discovered dynamically with the help of the information about the nodes in the clusters present at the cluster heads, this increases the protocol efficiency since by dividing network into clusters, we are minimising the flooding of control packets required for route discovery and decreasing end-to-end delay of the packets.

CBRP also utilise the presence of unidirectional links and use this links for routing in intra cluster and inter cluster. The CBRP also has other features like route shortening and local repair. These two features utilise 2-hop-topolgy information present at each node. The path shortening feature dynamically chooses the shortest source route of the data packet and also sends information of best route back to the source.

2.1.1 Features of CBRP

1. *Fully distributed*
2. *Less flooding of control packets*
3. *Utilisation of unidirectional links*
4. *Local repair of the broken routes*
5. *Dynamic route shortening*

2.1.2 CBRP Terminology

1. **NodeID:** The address of the node that helps to uniquely identify the node. For this purpose we generally use the Internet Protocol address of 32 bit. The routing of the packets from one node to other is done by checking the node address.
2. **Cluster:** It consists of collection of node units, with one particular node selected as a cluster head.
3. **Cluster Head(CH):**The formation of cluster is done by cluster head. All the nodes which are in the transmission region of the cluster head forms a cluster.
4. **Host Cluster:** If the node has bidirectional link to the ClusterHead(x) then it is said that cluster(x) is host cluster of the node.
5. **Cluster Member(CM):** All other nodes inside a cluster other than Cluster Head. There is a bi-directional link between cluster head and each of its cluster members.
6. **Cluster Gateway(CG):** The nodes that are cluster members of more than one cluster are called gateway nodes.

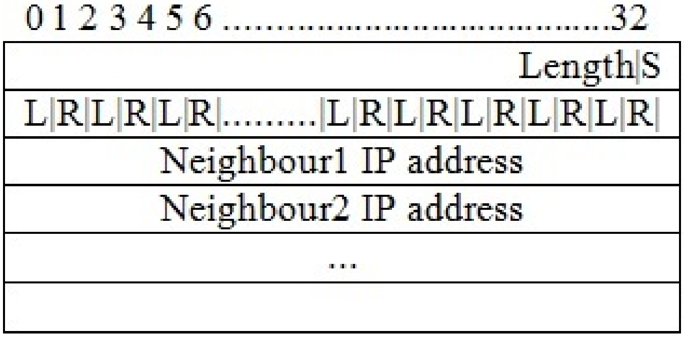
7. **HELLO packet:** These are the control packets that are exchanged periodically between the nodes. Each node broadcasts these packets after every frequent interval called *HelloInterval*. The HELLO packet sent by a node consists of its NodeID, STATE, and its NeighbourTable information.

8. **NeighbourTable(NT):** A data structure that is present at each node. It stores the details of all its 1-hop neighbour nodes. Constructed by extracting node idś from received HELLO packets.

9. **TwoHopNeighbourTable(TNT):** A data structure that is present at each node. It stores the details of all its 2-hop neighbour nodes. Constructed by extracting NeighbourTableś from received HELLO packets.

10. **CHNeighbourTable(CHNT):** A data structure that is present at Cluster Head/Cluster Gateway. It stores the details of all its neighbour cluster head nodes.

2.1.3 HELLO Packet



0 1 2 3 4 5 6 32

Length|S
L|R|L|R|L|R|.........|L|R|L|R|L|R|L|R|L|R|
Neighbour1 IP address
Neighbour2 IP address
...

Figure 2.1: NeighbourTable in HELLO packet

The node addresses and their corresponding L and R bits are taken from the neighbour table. The senders address is inscribed in the IP headerś source field. The four byte long L bit, R bit block gives the link status and role of 16 neighbours. If there are more than 16 neighbours, this block appears after every 16 neighbours.

Length specifies the number of neighbours listed

S the current status of the node

0 Undecided

1 Cluster Head

L link status of the corresponding neighbour

0 Link Bidirectional

1 Link From

R role of the corresponding neighbour of the sender

0 Non Cluster Head

1 Cluster Head

2.1.4 NeighbourTable Updation

When the HELLO packet sent by the node(B) is received by its neighbour nodeA. Then node(A) makes necessary changes in its NeighbourTable as follows.

1. It verifies if B is prior present in its NeighbourTable. If no entery is found and it had heard from node(B) previously within the *HelloInterval* before.
    - Then it checks if node(B)ś NeighbourTable contains entry for node(A), if present then A sets its NeighbourTable *LINK* field of node(B) entry as bi-directional.
    - Else if node(B)ś NeighbourTable does not contain entry for node(A) in its NeighbourTable. A sets its NeighbourTable *LINK* field of node(B)ś entry as uni-directional.
2. If node(B)ś entry already present in node (A)ś Neighbour table.
    - If the *LINK* field of Bś entry is bi-directional but A is not listed in Bś HELLO packet, then update it to uni-directional. .

- If it is unidirectional but node(A) is present in Bś HELLO packet, then update it to bi-directional.

3. Update the role of node B in its entryś role field.

Each entry in the NeighbourTable has a $EntryValidTime$ field. The timer gets initialised when the entry is created or any field of the entry is updated. The entry is discarded if the node doesnt́ listen hello message from the corresponding node for (HelloLoss+1)*HelloInterval.Generally HelloLoss =3*HelloInterval. So the entry is removed if the node does not here consecutively 3 HELLO packets from the corresponding node.

When the neighbours are unvarying, the neighbour table information becomes constant and has the whole information of all the connected nodes that either uni-directionally or bi-directionally connected. But the problem is nodes cannot know, which other nodes have unidirectional link towards them.

With constant HELLO packets broadcast, the nodes can get the awareness of all the node that are bi-directionally connected to it with radius 2-hop. Nodes maintain this information in a data structure called TwoHopNeighbourTable. So a TwoHopNeighbourTable can give the information of all the nodes that are bi-directionally connected it. But the problem is nodes cannot know, which other nodes have unidirectional link towards them.

2.2 Literature Review

In Linked Clustered Algorithm (LCA) [3],it is the first basic clustering algorithm of the nodes in network connected by links of HF band (2-30 MHz). HF band is divided into M sub bands, each runs the clustering algorithm consecutively during its epoch period. Once the M runs are done, we again cyclically run epochs which helps in updating the process .There are two stages in the epoch cluster formation, cluster linkage. Nodes are allowed to transmit the control messages in the time slot allotted to them. A connectivity matrix is maintained at each node. In Frame1: The node updates ith row in its assigned time slot i. It fills all the values[i,j] that satisfy j¿i. In Frame2: Each node broadcasts its full connectivity row in its assigned time slot. At the ith slot of second frame node i compare its cluster id with the cluster idś of nodes in its connectivity row. If the node has highest cluster id and none of the neighbour node is a cluster head then the node sends a cluster head claim message. Else node i also checks if it is higher than any of its neighbour j¡i, by checking the connectivity rows received by neighbours. If node i is highest in jth,, connectivity row it becomes cluster head of j. Then broadcast its node status. This information helps in cluster linkage. We select the highest node as the cluster id because a node cannot know its status before its frame 2 transmission, and we need to have any extra frame to exchange information of node status. By the end of second frame each node has its NeighbourTable and TwoHopNeighbourTable.

In Lowest-ID (LID) Algorithm [4].It is designed for High Frequency (HF) Intra Task Force (ITF) Network, to provide survivability to Linked Cluster Algorithm even in the case of connectivity changes like jamming. Frequency hopping is required to avoid jamming so code division multiple access (CDMA) techniques are used to allow multiple users communicate simultaneously. HF ITF networks range from 50 to 100km, with frequency band 3 to 30 MHz. Both voice and data communications are supported with point-to-point and broadcast transmissions. This algorithm tries to utilize the clusterhead as polling agent or busy-tone emitter. So two clusterheads cannot be connected directly to each other. Gateways handle the paths of communication that are required to connect the clusters. In Ephremides, Anthony, Jeffrey E. Wieselthier Lowest-ID (LID), chooses the one node having lowest ID from the remaining nodes that are not in any cluster. It repeats the task until all nodes are part of any cluster. Probe messages, acknowledgment messages are sent in two different TDMA frames. Each node has a different slot once in each frame. In its slot node broadcasts probe message and acknowledges for the previous probe message. Backbone is formed by only bidirectional links. The information is calculated before transmission of frame 2. If the node has decided to become cluster head, node announces it in the frame 2. Node transmits the ID of its cluster in frame 2. (Node chooses the neighbour with lowest ID which is bidirectional connected to it). A node can become clusterhead only if it is not bi directionally connected to any clusterhead. By the completion of second frame complete cluster are formed. Slot duration is taken much greater than expected uncertainties timing to maintain network-wide synchronization. So long duration is required to form a structure when there is large number of nodes. The set of clusters produced are not optimized in anyway. The HF band is divided into several sub bands. LCA runs on each band, thus create a connectivity map for simultaneous communications in network. Typically it creates large clusters in small number at low end of HF band, where communication is most, and smaller cluster in large number at upper end of HF band, where communication is smallest. More than one of these networks will not organise at same time, while one network is organising the other networks can maintain communication.

In the Highest-Degree algorithm [5], node with maximum number of neighbors (degree) is chosen as a CH; since the degree of a node changes very frequently, the CHs are not likely to play the CH role as CH for very long. In this algorithm when the number of nodes in a cluster increases, the throughput and performance is decreased.

2.3 Protocol operations

CBRP has fully distributed operations.

1. **Cluster Formation:** In this phase we apply Cluster Head Election to choose the cluster head among the nodes, depending on which we form the clusters.
2. **Cluster Maintanance:** In this phase we update the cluster structure according to the underlying network topology change during the operation.

2.3.1 Cluster Head Election

The primary goal is to form the some grouping or hierarchy of the disorganised ad hoc network. There various algorithms for grouping based on different considerations. How the groups are formed depends on how the cluster head is chosen. The following are different ways to elect a cluster head.

2.4 Proposed Cluster Head Election

Most of the previous clustering schemes used only a single parameter and consider node mobility. But MANET nodes need additional equipment to know their present location, which consumes additional resource.

In this protocol developed, we assign a weight to each node. The weight is taken as function on the parameters which try to avoid the frequent reclustering by making the clusters stable, and at the same time factors are considered as not to over burden the same node. Reclustering is try to be avoided because the formation of the clustering needs the exchange of control packets. The cluster goes down when the current cluster head node resigns it state. Before resigning it broadcasts CLUSTER RESIGN message, which is heard by all cluster members. This triggers the exchange of control information, and updating, processing of the newly received information by all the cluster members to form new cluster. Considerable amount of energy is consumed for exchanging and processing the information. Frequent changes of cluster can make major loss of energy at nodes. It is to be noted that resigning of single cluster head may affect the other neighbouring clusters, i.e change in cluster head of one cluster may change the entire network.

The other reason to avoid cluster changes is to avoid data loss. The data in ongoing transmission is lost if the host cluster of the destination is down, and this would require retransmission. Packet loss decreases the throughput, increase end to end delay as the intermediate nodes need to find the new path and retransmissions cost energy of nodes in the path.

We allocate the weights, which are made into three groups to each node. A group signifies the scope of node becoming a head. The priority of each group is mentioned in prior. A node that is capable of delivering the messages faster to neighbourhood and is in higher group has more chance to be chosen as CH. So the formation of initial cluster does not take longer time. The node selected as CH broadcasts its previous cluster head address in its LIVE message. So that if the members of that cluster become isolated from cluster head and in neighbourhood range of this node, then they would choose this node as CH. This causes stability of clusters.

At this stage we assume the nodes can be the following possible states ISOLATED, CLUSTERHEAD CLUSTER MEMBER and GATEWAY. Every node is initially at ISOLATED state, they create the NEIGHBOUR table which stores neighbouring nodes information.CH have an additional table called as CHNEIGHBOUR table which stores information of neighbouring cluster heads. Each node calculates the weight periodically, which is give by an equation:

$$Weight = aN + bR + cT + dP \tag{2.1}$$

N is number of neighbour nodes, a node is considered under the count only if the power level of currently received message is greater than power level of previously received message. This ensures that the node is moving closer towards it. R is remaining battery lifetime of the node, take into consideration which avoids bottle neck of particular node and consuming all its energy. So a node can relinquish from being cluster head when it has lower level of remaining battery power. T is cumulative time during which the node had been in the last cluster. The more amount time spent in the cluster implies more stable cluster. P is transmission power, the node with less transmission cannot cover more number of cluster members and is almost equivalent to non clustering protocols. So the nodes with higher transmission power are preferred to minimize number of clusters. The parameters a,b,c,d are weighting factors that are choosed depending on which parameter has to be given more priority for the specific MANET application.

2.5 Cluster Formation

All the nodes have initial state set to ISOLATED. The node in this state broadcasts HELLO messages periodically in the advent of knowing the information of its neighbour nodes. We also broadcast HelloRequest packets at this stage to receive triggered HelloReply messages. The HELLO message consists of the nodeś ID, nodeś cluster head ID IDch, nodeś Weight, nodeś STATE, and NeighbourTable. At initial state the NeighbourTable is empty and IDch is set to -1. Each node also receives HELLO packets from its neighbour nodes. Each node extracts ID from the received HELLO packets and forms NeighbourTable and recalculates its $Weight$.

Once the $Weight$ are calculated HELLO packets are sent with updated Weight.After the predetermined time(Te) set at each node, cluster head election algorithm runs at each node. If a node at ISOLATED state receives HELLO packet from come CH, before it runs its cluster head election algorithm. Then the node just avoids it and become the cluster member of that CH. If ISOLATED node does not receive HELLO message from any CH within its predetermined time, then it compares its $Weight$ with that of nodes in its NeighbourTable. If the node finds its $Weight$ is higher than its all neighbour nodes it becomes the cluster head, by changing its state to CLUSTERHEAD, IDch with its own ID and broadcasts cluster head claim message CHClaim. Else if the nodes $Weight$ is not greater than all of its neighbours it continues to broadcast HELLO packets for 2Te period expecting to receive a HELLO packet from any CH. This is done to avoid every isolated node trying to become cluster head, by giving it chance so that by this time it could come into range of any CH. So that to maintain smaller number clusters. If it did not receive any HELLO packet within this Te then it selects itself as a CH.

Cluster Member node does not try to become a CH as long as it has some Cluster Head. So as to avoid frequent cluster changes. In CBRP when the cluster member of some cluster head(x) receives a HELLO message from other cluster head(y) which is not in its neighbour table. Then the node changes its state to CLUSTER-GATEWAY and sends CTGateway message to its cluster head(x). The CTGateway message contains information of ch(y). On receiving CTGateway the CH(x) adds CH(y) information into its CHNeighbourTable if node not exists in its neighbour table. CH sets gateway field of this entry set to the nodeś ID. And CH replies to the normal node with ARGateway message. Else CH replies to normal node with NR-Gateway message. A normal node that receives ARGateway message will change its status to CLUSTERGATEWAY and sets its cluster id IDch to cluster with highest $Weight$. This is done because cluster has to minimize the number of gateways to a particular cluster neighbour. In this thesis We call this algorithm as stable clustering algoritm(SCA). The figure 2.2 shows the simlation of proposed stable weighted clustering algorothm(SCA) in NS2,with parameters a=0.1, b=0.4, c=0.4, d=0.1.

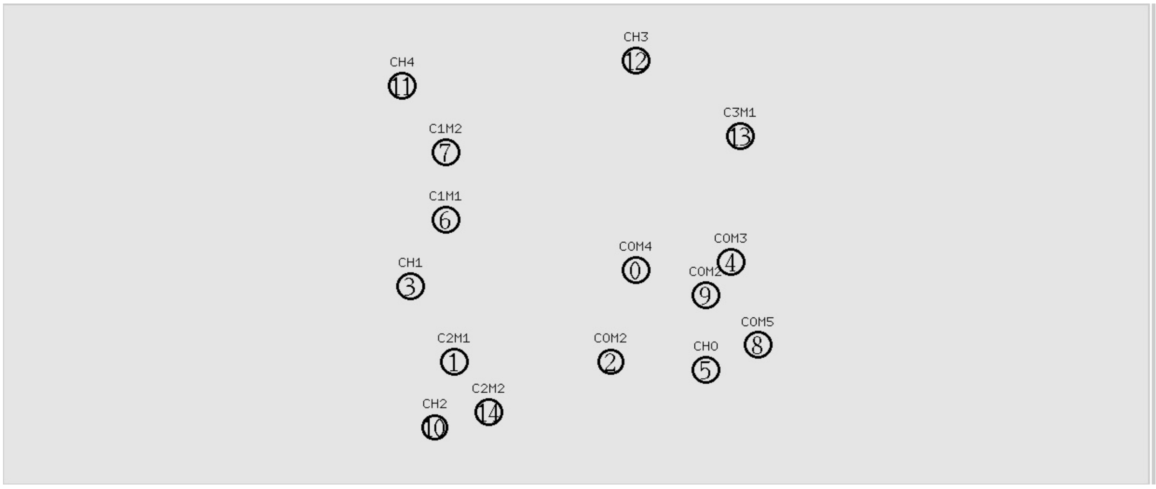


Figure 2.2: Simulation of SCA

2.6 Simulation and Results

Simulations are done in NS2, using CBR Traffic and Random Way Point movment, For every change in cluster state from ClusterHead to ClusterMember/ClusterGateway or viceversa is counted as *Recluster* is updated by 1. Simulation is done with a=0.1,b=0.4,c=0.4,d=0.1 and following network Parameters.

Table 4.2 SCA simulation parameters.

Table 2.1: SCA simulation parameters

No. of nodes	40
Size of network	250m*250m
Transmission range	30m
Pause time	30s
HelloInterval	5.0s
Simulation duration	100s

The figure2.3 shows the reclustering is very high in both HCCM and SCA increases with increase in speed of nodes. But compared to HCCM the proposed SCA algorithm has low reclustering as we considered parameters cumulative time of node in the cluster that avoids reclustering due to new node in the cluster. Where as in HCCM there is always a chance of reclustering with new node in cluster.

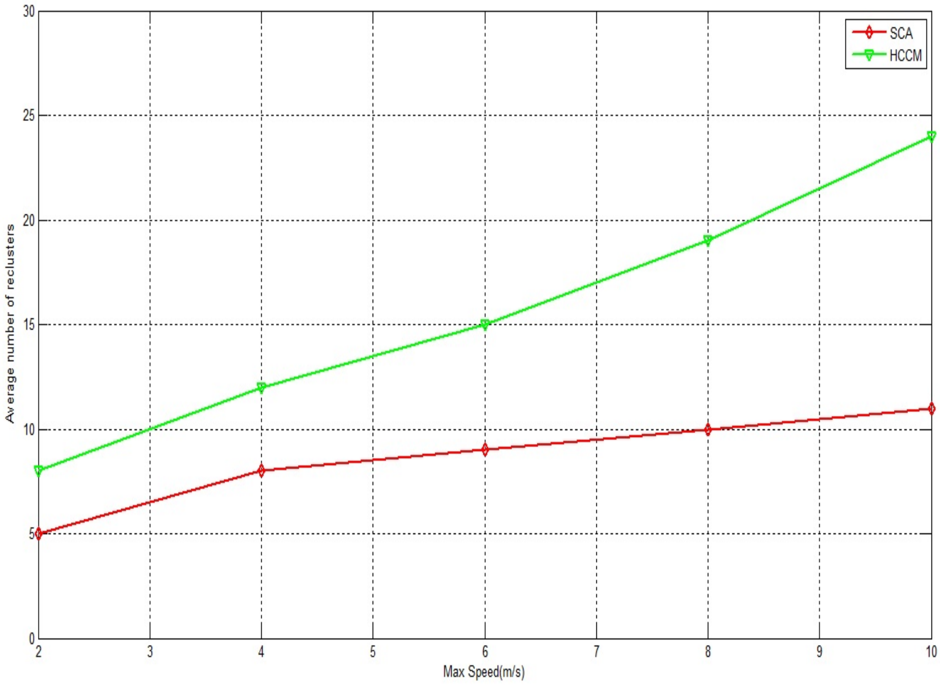


Figure 2.3: Avg No.of Reclusters vs Max nodes speed

Chapter 3

Efficient clustering scheme

Efficient Clustering Scheme is low susptible to node mobility and select the cluster heads that are only from dominant set of nodes. [6]

3.1 Cluster Guest formation

When a member node(n1) of some cluster(s) moves and finds it is disconnected with its all ClusterHead(s), then the node queries for HELLO packets from its neighbours. All the nodes which receive the HelloRequest send triggered HELLO packets. If the node(n1) receives any HELLO packet from the ClusterMember(x) of the nodes previous cluster then the node access that ClusterMember(x) as ACCESSPOINT. And from then on it access the cluster head through AP and still remains with the cluster. Or else if it receives HELLO packet from the ClusterMembers of some other cluster(s) then it access the cluster member which is nearer to it and having higher strength as its ACCESS POINT.

The node(n1) sends HELLO packet indicating its state as CLUSTERGUEST. The access point stores n1 in its NeighbourTable with state as ClusterGuest. HELLO packet from ACCESS POINT, containing cluster guest information is received by ClusterHead. The ClusterHead creates a row for n1 in the TwoHop-Neighbour table and specifies access point id in the NextHop field.

The figure 3.1 shows the node 12,21 are the members of cluster head node 5. As the

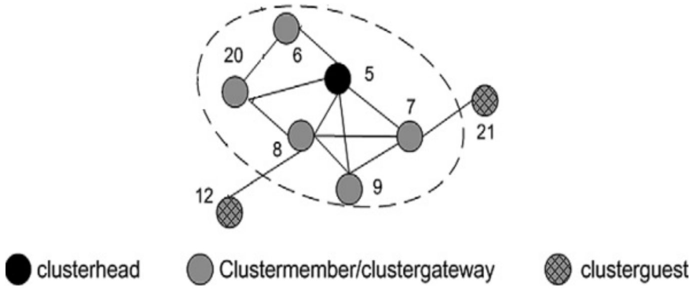


Figure 3.1: Cluster Guest Formation

time passes they move away from the cluster head, and they are now ClusterGuests of CH(5).Node 8 is AccessPoint of ClusterGuest node 12 and node 7 is AccessPoint of ClusterGuest node 21.

The TwoHopNeighbourTable of cluster head node 5 contains a row for node id 12,21 with the next hop id 8,7 respectively. The cluster head of node 12,21 will not change and they still contain status IDch=5. Cluster guest nodes 12,21 create a row for node id 5 with the next hop ids 8,7 respectively. If the node(n1) receive HELLO packet only from cluster members not from its previous cluster then the node is too far away from previous cluster to access its previous cluster head. The node becomes the cluster guest of the other cluster from whose cluster member it receives HELLO packet.

3.2 Avoiding overlapping clusters

We try to avoid over overlapping clusters by avoiding 1-hop neighbouring clusters. And allow the distance between neighbouring cluster heads to be exactly 3-hops. Avoiding the formation of 2-hop neighbour clusters is done by considering any ISOLATED node that receives HELLO packet from a ClusterMember or Cluster-Gateway cannot claim to become cluster head. Occurrence of 2-hop neighbour clusters due to mobility is prevented by cluster deletion. When a CLUSTERHEAD(x) receives HELLO packet from cluster member node with IDch (y), CH(x) resigns. The node that resigns its CLUSTERHEAD status sets its status as CLUSTERGUEST to CH(y).

If a ClusterMember of ClusterHead(x) receives HELLO packet from ClusterMember/ClusterGateway of ClusterHead(y), then it changes its state to CLUSTERGATEWAY. The node stores its neighbour cluster details in its CHNeighbourTable.

The ClusterHead depends on its ClusterGateway to know its 3-hop neighbour clusters.The ClusterGateway sends its CHNeighbourTable along with its HELLO packet.

This kind of cluster deletion with the help of cluster guest helps cover more area with less number of clusters. In this thesis we call this algorithm along with cluster formation discussed in *chapter*3 as efficient stable clustering algorithm(ECSA). The

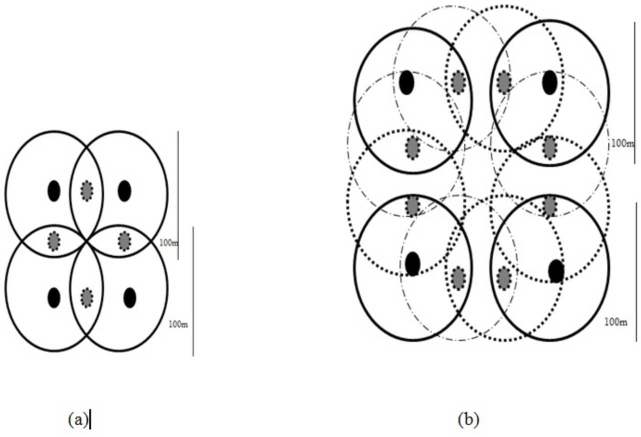


Figure 3.2: Area covered by 4 neighbour cluster

figure 4.1(a) show area covered by 4 cluster heads each of transmission range 50mts is less than $100mts^2$. The figure 4.1(b) using Efficient Clustering Scheme 4 cluster heads cover the area $125mts^2$. Which shows the coverage area with same number of cluster heads is increased by 25

3.3 Simulation and Results

Simulations are done in NS2, using CBR Traffic and Random Way Point movment, For every change in cluster state from ClusterHead to ClusterMember/ClusterGateway or viceversa is counted as *Recluster* is updated by 1. Simulation is done with a=0.1,b=0.4,c=0.4,d=0.1 and following network Parameters.

Table 4.2 ESCA simulation parameters.

Table 3.1: ESCA simulation parameters

Max Speed of node	5m/s
Size of network	500m*500m
Transmission range	30m
Pause time	30s
HelloInterval	5.0s
Simulation duration	100s

Thr figure3.3 shows the number of clusters formed using Efficient Clustering Scheme proposed in chapter 4 is about 40% less than that of SCA in the highly densed network. That avoids overhead due to node mobility.

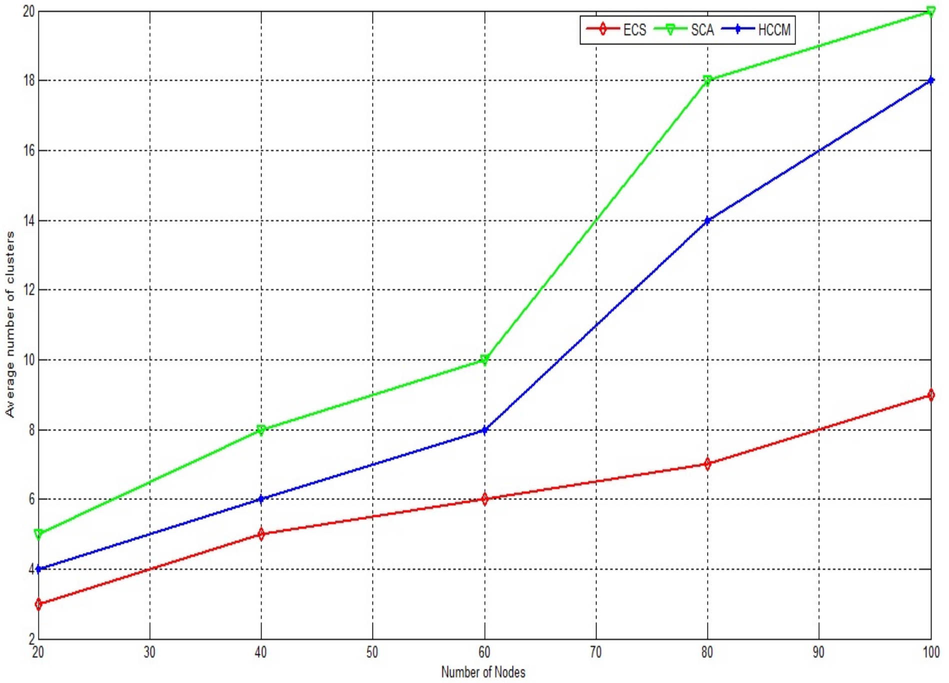


Figure 3.3: Avg No.of clusters vs No.of nodes

Chapter 4

Energy Conserving in MANET

4.1 Literaterue Review

The energy at source of the mobile nodes can be saved by various techniques. Some of the these are (i) Design hardware with minimum energy consumption; (ii) Reduce complexity of calculation for reducing of using CPU and RAM and (iii) Employ some communication techniques to reduce send and receive information.

In this research we look into the communication techniques for reducing energy consumption. And also there are various methods by which energy consumption is reduced through effective communication techniques. The simple and basic method is synchronized power save mechanism PSM [7]. Following are some research papers in the area (reducing energy consumption): Energy Efficient Cluster Based Routing in MANET proposed by Alak roy [8]. Energy Efficient Location Aided Routing Protocol for Wireless MANETs proposed by A.Mikki [9], in this paper the circular region under transmission range of base station is divided into six equal sub areas. New routes are discovered in the limited zone i.e for discovery of the new route instead of flooding the control packets to the whole network, they are flooded to only the sub-area of the destination mobile node thus having low control packet overhead. But the base station needs to store the location of mobile nodes in position table. An Advanced Save-Energy Mechanism of Ad hoc Networks proposed by Feng Zhenxin [10].In Energy Efficient Cluster Based Routing Protocol for MANETs by Tat-Chee Wan [11], the nodes are allowed to low power consuption sleep mode. In our research we allow the nodes in the proposed efficient stable clustering algorithm to go into SLEEP mode. In sleep mode the node cannot transmit or receive any data, since node does not listen to network, thus save the energy of the node.

Mobile nodes have the following modes.

Transmit mode, a mode in which it transmits the data to some other node. The energy consumed in transmission mode(ECT) is given by:

$$ECT = P\_tx * txtime \tag{4.1}$$

Receive mode a mode in which the node receives the data to some other node. The energy consumed in received(ECR) mode is given by:

$$ECR = P\_rcv * rcvtime \tag{4.2}$$

Idle mode is mode in which the node may receive or may transmit the data. A node can go into transmit mode or receive mode only if it is previously in idle mode. Node in Idle mode is not doing any receive or transmit of data but still consumes energy as the node needs to constantly keep listening to the network. The table show the energy consumed in idle(ECI) is almost equal to energy consumed in receive mode(ECR).

Sleep mode is a mode in which a node cannot transmit or receive any data, since node does not listen to network, thus save the energy of the node.

Where P_tx and P_rcv are the transmitting and receiving power (respectively) required by the node's interface

Table 4.1: Power consumption rates of 802.11 Wi-Fi cards

Activity	WaveLAN [[12]]	Atheros [[13]]
Transmission	1.65W	1.35W
Reception	1.4W	1.02W
Idle or Listen	1.15W	0.89W
Sleep or Doze	0.045 W	0.16W

But making a mobile to go into sleep mode is not feasible, as there may be packets designated to the node, and it need to receive .If the node is in sleep mode it cannot receive packets, and the packets are be dropped. There is a need for some central base station which buffers and store the packets designated to sleep node, and later sends the buffered packets to the node when it is in idle mode. In MANETs using CBRP, it is possible to assign sleep mode to a node for limited period of time, if the nodes are moving with the speed less than the predefined maximum speed. Only ClusterMember can go into sleep mode. Since the cluster members receive its designated data through its cluster head. When the ClusterMember goes into SLEEP mode, all the packets designated to that node are buffered and stores at cluster head. The cluster head sends these stored packets back to cluster member for which they are designated when its SleepTtime expires and node comes to IDLE mode. For a node to go into sleep mode it requires the acceptance of the cluster head. When the node its mode changes into idle mode it resets its IdleTimer, if the node is IDLE for t1 seconds then the node may go into sleep mode by requesting its cluster head SleepReq. The cluster head may acknowledge the request by sending SleepAck.

4.2 Sleep mode in CBRP

Each node also has SleepTimer, IdleTimer. Any node that comes into IDLE mode resets its IdleTimer increments as long as it is in IDLE mode. If the IdleTimer reaches predefined time (Ti), then the node sends SleepReq to its CH. The Cluster-Head checks if its SEnergy > ThresholdEnergy.If its greater then it sends SleepAck

$$SEnergy = R - RCE; \tag{4.3}$$

Where R is remaining battery capacity,RCE consumed energy in previous (Ts) seconds.

If the node receives the SleepAck it starts its SleepTimer.The optimal number of nodes in the that are allowed to go into SLEEP mode depends on the queue size of cluster head, number of cluster members, expected traffic in the network. The node automatically switches back into IDLE mode once the SleepTimer reached predifined time(Ts) seconds, and sets its state to ISOLATED and send HelloReq packet. If the node is still in the cluster it receives a HELLO packet from its ClusterHead and the cluster head forwards all the stored packets of that node. Else if the node does not receive any HELLO packet from its cluster head it means the node has moved away from the cluster. In CBRP if the node moves away from the cluster head the following cases 1)The node may form a new cluster head if the node moves into no cluster region or 2)The node may become member of the another cluster if the node moves into another cluster region with another cluster head. In this case the node cannot become the new cluster head since new nodes can never become cluster heads. Any of these two cases may result in the change of cluster head of the node and this results in the loss of packets as the node can no longer receive its packets stored by its cluster head when the node was in sleep mode or may increase the end to end delay of the packet as the local route repair takes time. These two cases need to be avoided. The case of forming a new cluster head can be avoided by introducing a new state called ClusterGuest. And the case of becoming cluster member of another cluster head can be avoided by preventing overlapping clusters. In this thesis cluster election algorithm in $Chapter3$ along with efficient clustering algorithm in $Chapter4$ and ennergy efficient technique is called energy efficient stable cluster algorithm(EESCA).

4.3 Simulation and Results

Simulations are done in NS2, using CBR Traffic and Random Way Point movment, For every change in cluster state from ClusterHead to ClusterMember/ClusterGateway or viceversa is counted as *Recluster* is updated by 1. Simulation is done with a=0.1,b=0.4,c=0.4,d=0.1,Ti=30,Ts=30sec and following network Parameters.

Table 4.2 EESCA simulation parameters.

Table 4.2: EESCA simulation parameters

Max Speed of node	5m/s
Size of network	500m*500m
Transmission range	30m
Pause time	30s
HelloInterval	5.0s
Simulation duration	100s
Transmission power	1.65w
Receiving power	1.4w
Intial energy	500j

Thr figure 4.1 shows More energy can is conserverd with the more number of clusters with less number of cluster members.

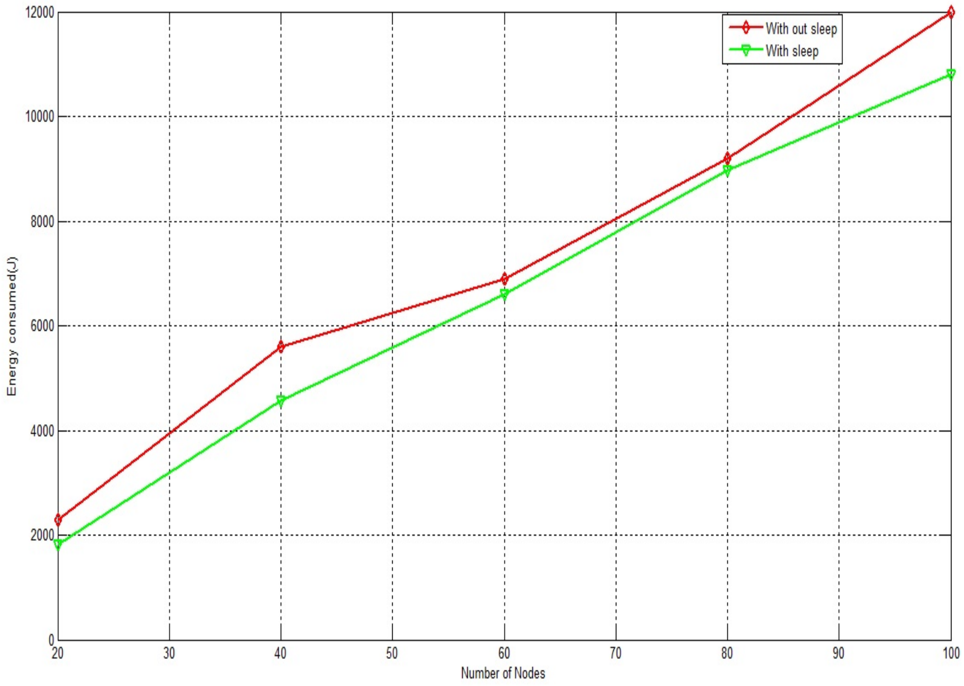


Figure 4.1: Avg Energy conumed vs No.of nodes

Chapter 5

Conclusion

The EESCBRP algorithm has used the approaches to minimize the overheads that occur due to reclustering. And to overcome the limitation of the number of orthogonal codes, we use only one code within each cluster. This approach best suites in highly densed MANET where energy conservation is the most important criteria. It is need to be noted key tradeoffs between transmission range and throughput performance, and shown the advantages of code separation,spatial reuse,power save mode. The approach allows more nodes in the network to be mobile and still give better performance.

Scope for Further Research

The Throughput of network can be increased by network coding. By using COPE protocol we combine packets at intermediate nodes to reduce number of transmissions.

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