CLUSTERING BASED POWER AWARE ROUTING FOR ADHOC NETWORKS

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

COMPUTER SCIENCE AND ENGINEERING

By

M. SARATH CHANDRA

DEPARTMENT OF ELECTRONICS AND COMPUTER ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

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CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in the dissertation entitled "*Clustering based Power aware Routing for Ad-hoc Networks*" towards the partial fulfillment of the requirement for the award of the degree of **Master of Technology** in **Computer Science Engineering** submitted in the Department of Electronics and Computer Engineering, Indian Institute of Technology Roorkee, Roorkee (India) is an authentic record of my own work carried out during the period from June 2007 to June 2008, under the guidance of **Dr. A. K. Sarje, Professor, Department of Electronics and Computer Engineering, IIT Roorkee.**

I have not submitted the matter embodied in this dissertation for the award of any other degree or diploma.

Date: 30 June 08

Place: Roorkee

(M.SARATH CHANDRA)

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

Date: 30 June 08

Place: Roorkee

30/6/08

(Dr. A. K. SARJE)

Professor

Department of Electronics and Computer Engineering

IIT Roorkee – 247 667

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M.SARATH CHANDRA

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Abstract

Among various types of network architectures, the *mobile ad hoc network (MANET)* and the *wireless sensor network (WSN)* are two of the most attractive wireless networks. One critical issue for almost all kinds of wireless devices supported by battery power is *power saving (PS)*. Without power, any wireless device will become useless. Battery power is a limited resource. Hence, how to lengthen the lifetime of batteries is an important issue, especially for MANETs and WSNs, which are supported by batteries only. The PS protocols design for MANETs can also be applied to irregular WSNs.

For irregular wireless networks, several novel power saving protocols for multi-hop MANETs are proposed. But they ignore the problems with current hardware. Such as per packet level power switching is not available and the available energy levels for transmission are discrete.

We have described the issues of conceptualizing the power control problem, and provided an architecturally simple solution. The solution simultaneously satisfies three objectives : maximizing the traffic carrying capacity of the entire network, extending battery life through providing low power routes, and reducing the contention at the MAC layer. In Current work makes partitions of network based on the network connectivity. These partitions run at common power which satisfies bidirectional links and reduces route power.

Chapter 1

Introduction

Ad-hoc networks have witnessed an explosion of interest in the last few years as they are expected to have a significant impact on the efficiency of many military and civilian applications, such as combat field surveillance, security and disaster management, data gathering, and conferences.

One of the constraints for building an efficient ad-hoc network is finite battery supplies. Since the network nodes are battery operated, and in many cases they are installed in an environment where it may be impossible to retrieve the nodes in order to recharge the batteries, the network nodes need to be energy conserving so that the battery life and hence the network lifetime (total time in which the network is connected and functioning) are maximized.

Previously many reactive, proactive and combination of reactive and proactive protocols are proposed for maintaining routes in ad-hoc networks [1]. These do not take transmission power as a parameter. Their objective is to maintain reliable network connections.

There have been extensive studies on routing in wireless networks in recent years. Among various metrics used for evaluating the routing quality, the most common one is the number of hops on the routing path. Many protocols are developed [1].The protocols that use shortest-path routing include Dynamic Source Routing (DSR)[2] , Ad Hoc On-Demand Distance Vector routing (AODV)[3] , and many others.

On the other hand, energy-aware routing algorithms, which try to maximize network survivability, have attracted considerable interest as day by day need for energy awareness is increasing[4][5]. For efficient routing algorithm to be developed, sources of power consumption must be understood initially [6] [7] [11].

Transmitted power decays nonlinearly according to the formula [6]:

$$S(r) = S\, r^{-\alpha}$$

Where S is the amplitude of the transmitted signal, r is the distance from the transmitter, S(r) is the amplitude of the received signal at distance r, and α is a parameter whose value ranges from 2 to 4.

With this knowledge distance between nodes is the major factor in the power consumption calculations. So, some research is being done in this area by controlling the transmitted power [8] [9].

With the rise of small power constrained devices like PDA, need for power awareness is also increased. Some research is going on this area like J Gomez [4] proposed a power aware routing protocol (PARO) which is a greedy route finding algorithm. Furthermore, S Narayanaswamy [8] proposed a COMPOW protocol that considers the maximum power between two nodes in the network and taking this power as the common power in the total network. This protocol minimizes the need of changing power at every node thus eliminates the need for including transmission power in routing information

1.2 Research gaps:

Common protocols like DSR, AODV, DSDV are developed with the main objective of discovery and maintenance of routes at maximum available power. But this model will not suitable for battery constrained devices. So, protocols with power optimization are to be considered.

In previous protocols like PARO power optimization is greatly dependent on the initial optimization. So, the final path may not be optimized in power in all cases and also routing delay increases.

COMPOW protocol also fails when network is divided into sub-networks by considerable distances and node density is high within the sub network. So, now protocol chooses inter-network power as the common network node power which considerably increases the total power consumption in the network. Formation of the subnet is common phenomenon in the physical networks because of common human tendency to come together.

All the above protocols ignore the fact of quality of individual hardware and initial power at a node which mainly determines the node survivability. For example a laptop with battery having higher duty cycle may be able to stand for more time than a PDA with low battery capacity. So we can safely use laptop as a intermediate node in many routes to increase the survivability of smaller devices. Sometimes there may be a node like desktop with constant power supply, hence this can be part of most routes. Again we need to consider the congestion at a node that will lead to loss of transmission packets.

1.3 Statement of the Problem

The battery dependent nature of MANETs results in frequent and unpredictable changes in the network topology, which add to the difficulty and complexity to routing among the nodes within the network. Thus, establishing communication among mobile nodes is a great challenge in itself. The applications associated with the field of MANETs, make them an important part of the next generation wireless networks.

In this dissertation work, focus has been put on the strategy to address the energy efficiency issue because MANETs are generally more vulnerable to node loss and energy consumption than fixed-wired networks. Further, a lot of emphasis has been given on the routing mechanism and the security area has not been addressed adequately in existing research. Thus, the issue to design and develop an energy efficient with common powered clusters is still wide open.

The main objective of the present work can be stated as – *"to design and develop a Energy efficient routing protocol for MANETs"*. In order to handle the above problem, the following outline is proposed:

1. Evaluation and Analysis of existing ad hoc routing protocols – The assessment and study of different types of routing protocols will help in better understanding of the basic characteristics and functioning of the protocols. Analysis of some of the routing protocols can be carried through simulation,
2. Design and development of the proposed routing protocol - Based upon the knowledge of previous protocols. The new protocol will be proposed after proper verification and validation through simulations. The proposed protocol makes advantage of human behaviour to group together to make partitions.

1.4 Organization of Report

Chapter 2 provides backgrounds knowledge on the mobile adhoc networks. Here review of networks is given. Then it provides primary knowledge of mobile adhoc networks and wireless sensor networks.

Chapter 3 provides an overview of related work. Here diffent protocols are given with their advantages and disadvantages.

Chapter 4 presents need for the current work. It also presents possible solutions for the power problem nad how power is consumed in adhoc networks with factors affecting power consumption.

Chapter 5 presents proposed algorithm in combination with previous algorithms. It also gives overview of how problems from previous protocols are solved.

Chapter 6 discusses proposed algorithm performance on random dataset and chosen data set.

Chapter 2

Back Ground on Ad-hoc networks

The types of mobile devices and their applications have grown exponentially over the last few years. They range from laptops, PDA's, notebooks to cell phones. Most of these devices can currently perform all the tasks of a traditional PC with the added advantage of portability. However, they are limited in the duration of activity that can be accomplished during the lifetime of their batteries. Lithium-ion rechargeable batteries are the most commonly used batteries. They have a typical lifetime of a few hours of active workload and a couple of days of idle time.

2.1 wireless networks

Wireless networks , in general, refer to the use of infrared or radio frequency signals to share information and resources between devices. Due to the basic difference in the physical layer, the wireless devices and networks show distinct characteristics from their wireline counterparts, such as:

1. Higher interference results in lower reliability.
2. Low bandwidth and much slower data transfer rate.
3. Highly variable network conditions.
4. Limited computing and energy resources.
5. Device size limitation, and
6. Weaker security.

Apart from these limitations the wireless networks are immensely popular because of the benefits of using wireless technologies,

- **Access to more than one technology** - Users can use more than one access technology to service various parts of their network and during the migration phase of their networks, when upgrading occurs on a scheduled basis. It enables a fully comprehensive access technology portfolio to work with existing technologies.
- **Minimal cost** - The inherent nature of wireless is that it doesn't require wires or lines to accommodate the data/voice/video pipeline. Although paying fees for access to elevated areas such as masts, towers, and building tops is not unusual but the associated logistics, and contractual agreements are often minimal as compared to the costs of trenching a cable.

- **Reduced time to revenue** - Companies can generate revenue in less time through the deployment of wireless solutions than with comparable access technologies because a wireless system can be assembled and brought online in a very short span of time.
- **Provides broadband access extension** - Wireless commonly competes and complements existing broadband access. Wireless technologies play a key role in extending the reach of cable, fibre, and Digital Subscriber Link (DSL) markets, and it does so quickly and reliably.

S.No	Criteria	Types
1.	Communication Coverage area	WAN WMAN WLAN WPAN BAN
2.	Access technology	GSM networks TDMA networks CDMA networks Satellite networks Wi-Fi(802.11) networks Hiperlan2 Networks Bluetooth networks Infrared networks
3.	Network Applications	Enterprise Networks Home Networks Tactical Networks Sensor Networks Pervasive Networks Wearable Computing Automated Vehicle Networks.
4.	Network Formation and Architecture	Infrastructure Based Networks Infrastructureless Networks

Table 1.1. Wireless Network Classification

Wireless networks can be broadly classified into 2 categories Infrastructured and infrastructureless networks . These are defined as follows:

a) **Infrastructured networks** have fixed and wired gateways. They have fixed base stations connected to other base stations through wires. The transmission range of a base constitutes a cell. A "hand-off" occurs as mobile host travels out of range of one station and into the range of another and thus, the mobile host is able to continue communication seamlessly throughout the network, represented in Figure1.1. The *Cellular networks* fall under this category.

b) **Infrastructureless networks** Do not have fixed routers and all nodes are capable of movement and can be connected dynamically in an arbitrary manner. The entire network is mobile, and the individual terminals are allowed to move at will relative to each other, represented in Figure1.2. Mobile Ad hoc Networks *(MANETs)* falls under this category.

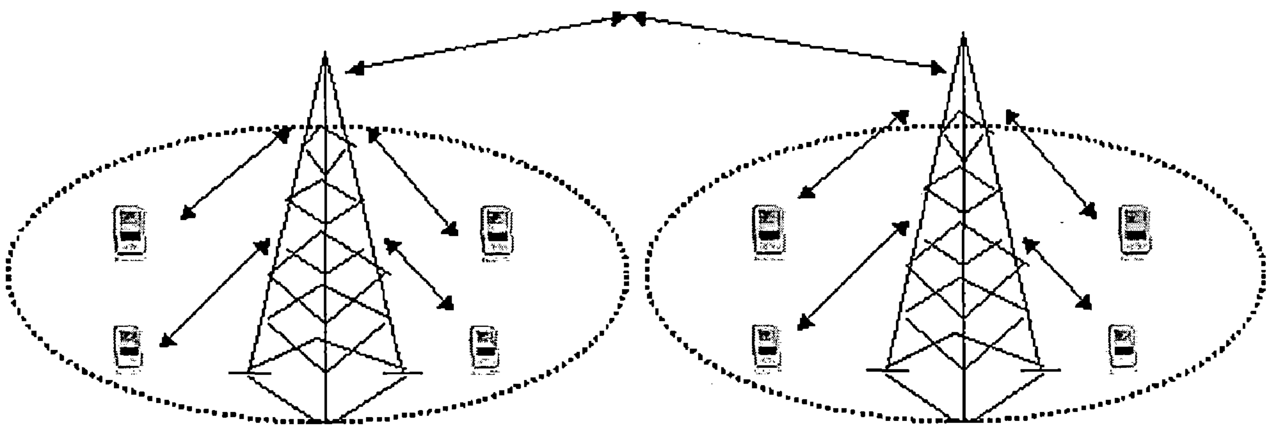

Figure 1.1. An infrastructured network

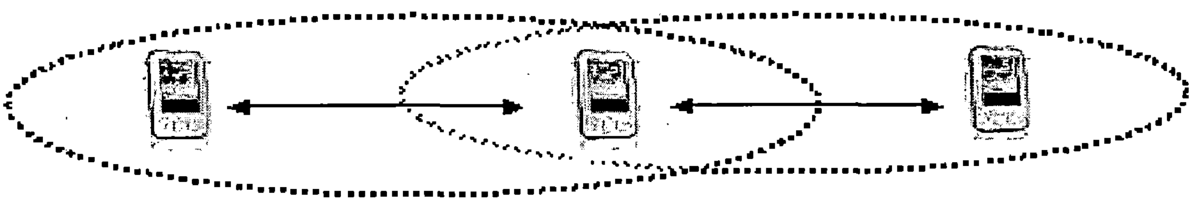

Figure 1.2. An infrastructurless network

Infrastructured networks are supported by well powered base stations and wire connected gateways. But as infrastructureless networks formed by independent nodes like cellular phones and laptop computers lack of these connectivity and power availability. So it is necessary to optimize network routes for

i. Max life time of the nodes,
ii. Min connection delay.
iii. Quick network discovery.

Among various types of network architectures, the *mobile ad hoc network (MANET)* and the *wireless sensor network (WSN)* are two of the most attractive wireless networks.

Applications	Descriptions/Services
Tactical networks	Military communication and operations, Automated Battlefields
Sensor networks	Collection of embedded sensor devices used to collect real-time data to automate everyday functions. Data highly correlated in time and space, e.g., remote sensors for weather, earth activities; sensors for manufacturing equipment. Can have between 1000–100,000 nodes, each node collecting sample data, then forwarding data to centralized host for processing using low homogeneous rates
Emergency services	Search-and-rescue operations as well as disaster recovery; e.g., early retrieval and transmission of patient data (record, status, diagnosis) from/to the hospital, replacement of a fixed infrastructure in case of earthquakes, hurricanes, fire, etc.
Commercial	E-Commerce, e.g., electronic payments from anywhere (i.e., in a taxi) Dynamic Business environment- access to customer files stored in a central location on the fly provide consistent databases for all agents mobile office, Transmission of news, road conditions, weather, music local ad hoc network with nearby vehicles for road/accident guidance.
Home and enterprise	Home/office wireless networking (WLAN), e.g., shared whiteboardnetworking application, use PDA to print anywhere, trade shows Personal Area Network (PAN), Body Area Network (BAN).
Educational	Set up virtual classrooms or conference rooms applications Set up

	ad-hoc communication during conferences, meetings, or lectures
Entertainment	Multiuse games, Robotic pets, Outdoor Internet access.
Location-awareservices.	Follow-on services, e.g., automatic call forwarding, transmission of the actual workspace to the current location Information services Push, e.g., advertise location-specific service, like- gas stations; Pull, e.g., location-dependent travel guide;Services (printer, fax, phone) availability information; etc

Table 1.3. Mobile Ad hoc Network Applications

2.2 MANET and WSN

A MANET is a network consisting of a set of mobile hosts which can communicate with one another and roam around at their will. No base stations are supported in such an environment, and mobile hosts may have to communicate with each other in a *multi-hop* fashion. Applications of MANETs occur in situations like battlefields, major disaster areas, and outdoor assemblies. A WSN consists of numerous sensor nodes. Each sensor node is equipped with a MEMS (micro-electro-mechanical systems) component, which includes sensor, radio circuit, data fusion circuitry and general purpose signal processing engines[12]. The wireless sensor node collects the information from the environment by its sensor, processes the information by its signal processing engine, and exchanges the information with other sensor nodes by its radio circuit. We can use the WSN to monitor the conditions of a place, where the traditional wired network is not available, such as battlefield, forest, outer space and human body.

One critical issue for almost all kinds of wireless devices supported by battery power is power saving *(PS)*. Without power, any wireless device will become useless. Battery power is a limited resource, and it is expected that battery technology is not likely to progress as fast as computing and communication technologies do. Hence, how to lengthen the lifetime of batteries is an important issue, especially for MANETs and WSNs, those are supported by batteries only. The PS protocols design for MANETs can also be applied to irregular WSNs. However, when applied to regular WSNs, these protocols are more complicated and less efficient than the protocols design for regular WSNs. Therefore, besides the PS protocols of MANETs, we also design PS protocols for regular WSNs.

Regular WSNs differ from MANETS in manner they dissipate power. In WSN mainly power is dissipated in sensor is less than the transmission power between the nodes so it is neglected in all proposed protocols and only transmission power is taken as parameter. But in MANETs communicating power is only a small percentage of power dissipation in nodes like laptops. In these nodes computation power and power taken by other parts of device is more than communication subsystem's power dissipation. So here network lifetime not only depends on the routing power but also on the lifetime of the node.

Chapter 3

Literature Review

3.1. Adhoc networks

As stated in [1] A mobile ad-hoc network (MANet) is a kind of wireless ad-hoc network, and is a self-configuring network of mobile routers (and associated hosts) connected by wireless links – the union of which form an arbitrary topology. The routers are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet.

In ad hoc networks, nodes do not have a priori knowledge of topology of network around them, they have to discover it. The basic idea is that a new node (optionally) announces its presence and listens to broadcast announcements from its neighbors.

An Ad hoc routing protocol is a convention or standard that controls how nodes come to agree which way to route packets between computing devices in a mobile ad-hoc network (MANET).

3.2 Classification of Ad hoc network protocols

There are mainly two categories of protocols.

i. Pro-active (Table-driven)

These algorithms maintain fresh lists of destinations and their routes by distributing routing tables in the network periodically[1]. Destination Sequence Distance Vector routing protocol (DSDV), Wireless Routing Protocol (WRP) and Cluster-head Gateway Switch Routing (CGSR). etc are some of the popular table-driven protocols for mobile ad-hoc networks.

ii. Reactive (On-demand)

The protocol finds the route on demand by flooding the network with Route Request packets[1]. Some of the known on-demand protocols are Ad-hoc On-demand Distance Vector routing (AODV), Dynamic Source Routing (DSR)[2] and Temporary Ordered Routing Algorithm (TORA).

Protocols falling into either category have their disadvantages, Table-driven protocols might not be considered an effective routing solution for mobile ad-hoc network.

i. Nodes in mobile ad-hoc networks operate with low battery power and with limited bandwidth.
ii. Presence of high mobility, large routing tables and low scalability result in consumption of bandwidth and battery life of the nodes.
iii. continuous updates could create unnecessary network overhead.
iv. high overhead in periodic/triggered routing table updates
v. low convergence rate
vi. waste in maintaining roots that are not going to be used

a) Dynamic State Routing (DSR)

The DSR protocol requires each packet to carry the full address (every hop in the route), from source to the destination. This means that the protocol will not be very effective in large networks, as the amount of overhead carried in the packet will continue to increase as the network diameter increases. Therefore, in highly dynamic and large networks the overhead may consume most of the bandwidth. However, this protocol has a number of advantages over other routing protocols, and in small to moderately size networks (perhaps up to a few hundred nodes), this protocol performs better. An advantage of DSR is that nodes can store multiple routes in their route cache, which means that the source node can check its route cache for a valid route before initiating route discovery, and if a valid route is found there is no need for route discovery. This is very beneficial in network with low mobility, because the routes stored in the route cache will be valid for a longer period of time. Another advantage of DSR is that it does not require any periodic beaconing (or hello message exchanges), therefore nodes can enter sleep node to conserve their power. This also saves a considerable amount of bandwidth in the network. A full description of this protocol appears in later text .

b) Ad hoc On-demand Distance Vector (AODV)

The AODV routing protocol is based on DSDV and DSR algorithm. It uses the periodic beaconing and sequence numbering procedure of DSDV and a similar route discovery procedure as in DSR. However, there are two major differences between DSR and AODV. The most distinguishing difference is that in DSR each packet carries full routing information, whereas in AODV the packets carry the destination address. This means that

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AODV has potentially less routing overheads than DSR. The other difference is that the route replies in DSR carry the address of every node along the route, whereas in AODV the route replies only carry the destination IP address and the sequence number. The advantage of AODV is that it is adaptable to highly dynamic networks. However, node may experience large delays during route construction, and link failure may initiate another route discovery, which introduces extra delays and consumes more bandwidth as the size of the network increases.

c) Temporally Ordered Routing Algorithm (TORA)

Temporally ordered routing algorithm (TORA) is a distributed routing algorithm. The basic underlying algorithm is the one in the family is referred to as link reversal algorithms. TORA is designed to minimize reaction to topological changes. The key concept is that control messages are typically localized to very small set of nodes. It guarantees that all routes are loop free and typically provides many routes to source/destination pair .It provides only the routing mechanism and depends upon Internet MANET Encapsulation Protocol (IMEP) for other underlying functions. Each node has a quintuple associated with it, as represented • Logical time of link failure, • The unique ID of the node that defined the new reference level, • A reflection indicator bit, • A propagation ordering parameter, and

• The unique ID of the node. The first three elements collectively represent the reference level. A new reference level is defined each time a node loses its last downstream link due to link failure.

Main disadvantages in reactive routing protocols are.

i. Delay in route finding
ii. Excessive flooding can lead to network clogging.

Hybrid protocols

So some hybrid protocols are designed which uses both proactive and reactive protocols good features and try to eliminate their disadvantages. These hybrid protocols include zone Routing Protocol(ZRP) and SHARP.

a) Zone Routing Protocol (ZRP)

In ZRP, the nodes have a routing zone, which defines a range (in hops) that each node is required to maintain network connectivity proactively. Therefore, for nodes within the routing zone, routes are immediately available. For nodes that lie outside the routing zone, routes are determined on-demand (i.e. reactively), and it can use any on-demand routing protocol to determine a route to the required destination. The advantage of this protocol is that it has significantly reduced the amount of communication overhead when compared to pure proactive protocols. It also has reduced the delays associated with pure reactive protocols such as DSR, by allowing routes to be discovered faster. This is because, to determine a route to a node outside the routing zone, the routing only has to travel to a node, which lies, on the boundaries (edge of the routing zone) of the required destination. Since the boundary node would proactively maintain routes to the destination (i.e. the boundary nodes can complete the route from the source to the destination by sending a reply back to the source with the required routing address). The disadvantage of ZRP is that for large values of routing zone the protocol can behave like a pure proactive protocol, while for small values it behaves like a reactive protocol.

Chapter 4

Power awareness

4.1 Need for power awareness

Building ad hoc networks poses a significant technical challenge because of the many constraints imposed by the environment. Normally nodes are to be light weighted and are powered by rechargeable Li-ion battery thus limiting the amount of up time. And sometimes power supply or node availability or both is scarce. In this kind of networks shutdown of one node may lead to some or total network break. So there is a unavoidable need for maintaining the maximum number up.

Many researchers tried to achieve these goals by targeting specific components of the computer and optimizing their energy consumption. Such as low-power displays, algorithms to reduce power consumption of disk drives, low-power I/0 devices such as cameras, etc. contribute to overall energy savings. Other related work includes the development of low-power CPUS (such as those used in laptops) and high-capacity batteries.

Nowadays cellular phones, cameras and other devices which have networking capabilities are developed for maximizing user experience which are more power conscious as batteries included must be small. For devices where the transmission power accounts only for a small percentage of the overall power consumed (e.g., a wireless LAN radio attached to a notebook computer) reducing the transmission power may not significantly impact the device's operational lifetime. For small computing/communication devices with built-in or attached radios (e.g., cellular phones, PDAs, sensors, etc.) reducing the transmission power may significantly extend the operational lifetime of a device, thus, enhancing the overall user experience.

Main focus, in the past year, has been on developing strategies for reducing the energy consumption of the communication subsystem and increasing the life of the nodes. Recent studies have stressed the need for designing protocols to ensure longer battery life. In Sleep mode the power consumption ranged is less and in idle state the power consumption is increased. In transmit mode the power consumption typically double to that of sleep mode [3]. And there is significant over head of signaling and maintenance of routing table in proactive protocols.

The problem of routing in mobile ad hoc networks is difficult because of node mobility. Thus, we encounter two conflicting goals on the one hand, in order to optimize routes; frequent topology updates are required, whereas on the other hand, frequent topology updates result in higher message overhead. Several authors have presented routing algorithms for these networks that attempt to optimize routes while attempting to keep massage overhead small (see [1]).

4.2 Scope to improve the power efficiency

First we shall see that how wireless network works. A wired network is having definite links between the nodes. Hence geometry and routing tables will not change. As shown in figure 4.1

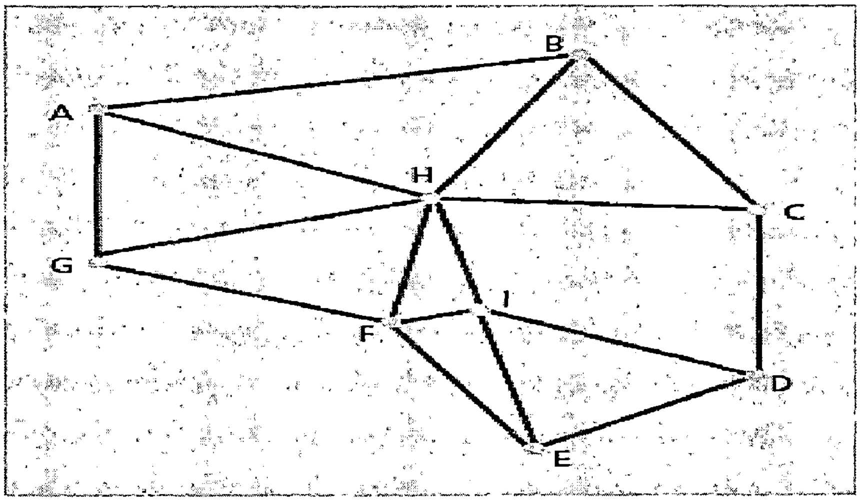

Figure 4.1 wired network

But wireless Adhoc networks don't have such hard links and may move around also thus changing both geometry and routing tables. The notion of a "link" between, say, nodes A and B is an entirely relative one.

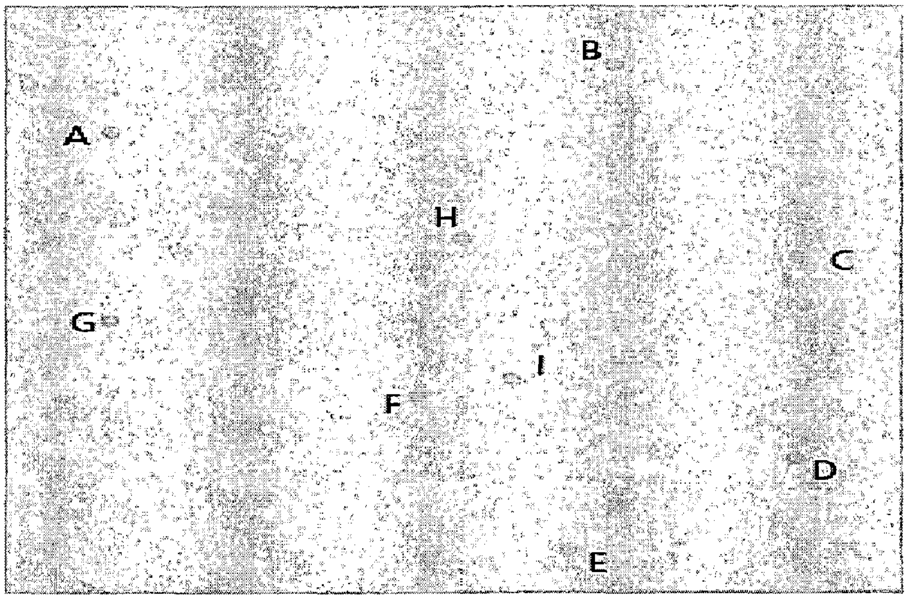

Figure 4.2 Wireless Network

It is known that energy emitted from a wireless antenna travels over unlimited distances. As it scatters in the surrounding space, smaller and smaller fractions of it are capable of reaching remotely located receiver antennas. Nonetheless, finite amounts of such energy do indeed reach a node receiver, no matter how far that node is. Thus, it would seem that any wireless network is in fact a fully connected or mesh network (just like a WLAN). Of course, this is not a useful model because the signal strength is severely attenuated as the signal travels away from the transmitter. In fact, it decays nonlinearly according to the formula

$$S(r)=S\,r^{-\alpha} \quad \text{------------------------------}>(1)$$

where S is the amplitude of the transmitted signal, r is the distance from the transmitter, S(r) is the amplitude of the received signal at distance r, and α is a parameter whose value ranges from 2 to 4.

So the transmitted data to be successfully received by a receiver depends on

1. Terms of the maximum acceptable value of the bit error rate (BER). Depending on the application and the desired fidelity of reception, this value can range from 10^{-2}-10^{-11}
2. Modulation/demodulation schemes, coding/decoding schemes, antenna profile, detection structure, and additional signal processing elements at the transmitter and receiver
3. Amount of noise or other impairments (interference, fades) the channel introduces.

So Putting this all together, the criterion for successful reception is summarized by the requirement that

$$\mathbf{SINR} > \theta \quad \text{-------------------->} \ (2)$$

Where SINR is the received signal-to-interference-plus-noise ratio at the receiver and θ is a threshold that depends on the detector structure, modulation/demodulation, and coding/decoding used.

So existence of the link in a network depends on the all above factors, and many of these factors are directly dependent on the power level chosen by the transmitter. Hence it determines which links are feasible and hence which paths can be used for routing to the final destination. Clearly, then, energy concerns lead to further coupling among the layers in the protocol stack.

4.3 Power consumption in ad hoc networks

To save energy we should know ways in which energy is consumed in a wireless network. Clearly there are three major modes of operation for any wireless node. It is either transmitting, receiving, or simply "on." In the last mode it typically "listens" but is not actively receiving. In the transmitting mode energy is spent in two major ways. The first is in the front-end amplifier that supplies the power for the actual RF transmission. This includes the radiated energy as well as the internal heat losses in the antenna and the amplifier itself. The second is in the node processor that implements all the signal generation, formatting, encoding, modulation, memory access, and other signal processing functions. We call the first transmission energy and the second processing energy

In the receiving mode, energy is consumed entirely by the processor, including the low noise amplifier that boosts the output of the receiving antenna to levels suitable for demodulation, decoding, buffering, and so on. That is, in this case the consumed energy is only of the processing type. Finally, in the "on" mode, the energy consumed is again of the processing type (since the voltage controlled oscillator, VCO, is operating to be ready to commence demodulation of an incoming signal, and all circuits remain properly initialized and charged) but also possibly of some transmission type, since a listening device may be required by network protocol to emit periodic beacon signals. The grand total amount of energy spent per unit time while in the "on" mode is quite small compared to the receiving and transmitting modes. As previously mentioned for small devices such as phones may have spent most of the time in on mode requires the optimization of the processing power.

it is necessary to examine the role of every one of these components and to also look at the way they interact.

4.4 Factors affecting network power consumption

i. Selection of batteries and pattern of draining energy(some draining patterns require less power than other[5])

ii. Selection of mac protocol for example time-division multiple access (TDMA) protocol might be more energy efficient than other MAC protocols (if everything else that affects consumption remains the same)

iii. Energy can be saved by proper selection of hardware.

    i. Power amplifiers are known to be nonlinear. Thus, when driven to saturation (which may be necessary if transmission at maximum power is desired) they are very inefficient and consume a much higher amount of joules per joule delivered to the antenna

    ii. the circuit layout of every chip has notorious energy consumption effects.

    iii. the choice of antenna has energy repercussions.

iv. Chosen combination of modulation/demodulation and coding/decoding determines the spectral efficiency of the system (i.e., the achievable number of bits per second per hertz).

v. the choice of signal processing algorithm implementations — including their software specifications as well as their very large scale integration (VLSI) incarnations — have significant effects on energy expenditure. For example, choosing how to compress a signal, or store and/or retrieve it from memory does have measurable effects on energy consumption

vi. choice of higher-level protocols (e.g., routing or multi casting) has equally significant effects on energy consumption.

Of all the above the performance improvement via routing protocols has gained a large interest [3] in this time.

4.5 redirectors is a possible solution

Equation 1 says that power transmitted decays exponentially. so the power required to transmit from A to B via C may not be equal to to direct transmission and in many cases It is less also.

$$P_{AB}=f(p,r1)$$

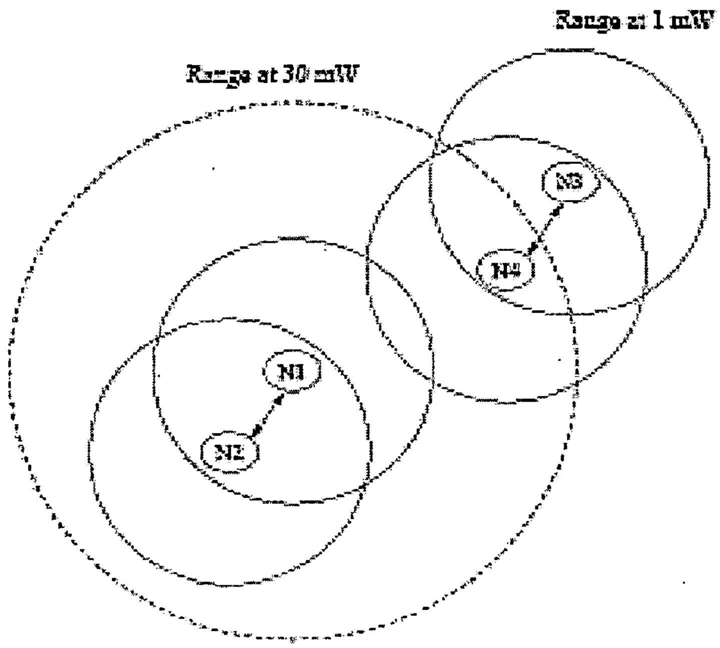

Figure 4.3 nodes reachable at different powers

$$P_{AB}>P_{AC}+P_{BC}$$

Assuming power transmission signal is symmetrically distributed(no noise and fading) so represented by circles in figure 4.3

.N1 can transmit to N3 at 1mW there is no need for N1 in Figure 1 to broadcast at 30mW to send a packet to the neighboring N2, since N2 is within range even at 1mW. Thus it can save on battery power. For the second point, suppose that in the same figure, N3 also wishes to broadcast a packet at the same time to N4 at 1mW. If N1 broadcasts at 1mW to N2, then both transmissions can be successfully received simultaneously, since neither is N2 in the range of its interferer N3 (for its reception from N1), nor is N4 in the range of its interferer N1. However, if N1 broadcasts at 30mW, then that interfere with N4's reception from N3, and so only one packet, from N1 to N2, is successfully transmitted. Thus, power control can enhance the traffic carrying capacity.

Clearly, power control impacts on the physical layer due to the need for maintaining link quality. However, power control also impacts on the network layer, as shown in Figure 4.4. If all nodes are transmitting at 1mW, then the route from node N1 to node N5 is

N1->N2->N3->N4->N5

However, if they all transmit at 30mW, then one can choose the route

N1->N3->N5

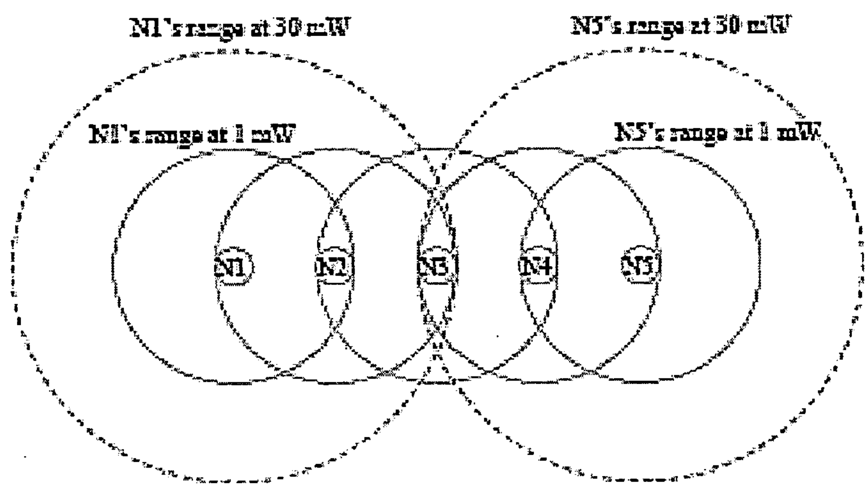

Figure 4.4 Power saving by multi hop

In addition, power control also impacts on the transport layer. In Figure 4.5, Every time node N1 transmits at high power to node N2, it causes interference at N3 to the packets from.N4 Thus there is a loss of several such packets on the link from N4 to N3. These impacts on the congestion control algorithm regulating the flow from source to destination via the intermediate relay node. The need for power control is thus obvious

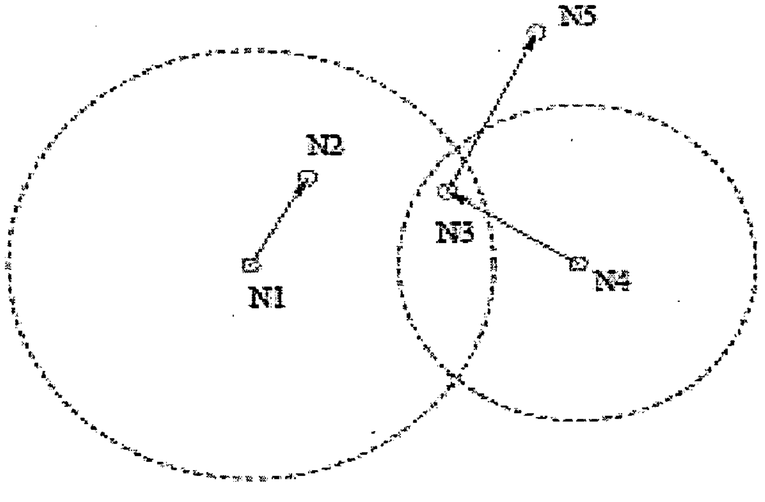

Figure 4.5 High power is cause of extra interference

So an effective protocol can be designed by using redirectors which over hears the transmitted messages and will transmit to them using less power. or by building a network route which minimizes the transmission power.

Several power-aware routing protocols based on various power cost functions have been proposed in [15], [16], [17], [18], [19]. In [15], when a mobile host's battery level is below a certain threshold, it will not forward packets for other hosts. In [18], five different metrics based on battery power consumption are proposed. Reference [19] considers both hosts' lifetime and a distance power metric. A hybrid environment consisting of battery-powered and outlet-plugged hosts is considered in [10]. Two distributed heuristic clustering approaches for multicasting are proposed in [17] to minimizing the transmission power.

Some of the power aware protocols are COMPOW which tries to optimize the routing by working at same power throughout the network this fails when network is not evenly distributed. And many GPS based methods like random progress method [8],NFP method[9] are proposed. PARO (Power Aware Routing Optimization) is selected because it can result in considerable power saving from the first iteration and it is suitable for any density of nodes in the network.

Chapter 5
Design of Partitioning Algorithm

Now we will analyze two power aware protocols *PARO (a power-aware routing optimization)* and COMPOW(common power routing algorithm) and their advantages and disadvantages compared to proposed protocol.

5.1 PARO (power-aware routing optimization)

PARO, one or more intermediate nodes called "redirectors" elects to forward packets on behalf of source-destination pairs thus reducing the aggregate transmission power consumed by wireless devices. PARO is applicable to a number of networking environments including sensor networks, home networks and mobile ad hoc networks. PARO is capable of outperforming traditional broadcast-based routing protocols (e.g., MANET routing protocols) due to its power conserving point-to-point on-demand design.

Overview

PARO uses a packet forwarding technique where immediate nodes can elect to be redirectors on behalf of source- destination pairs with the goal of reducing the overall transmission power needed to deliver packets in the network, thus, increasing the operational lifetime of networked devices.

As previously stated wireless spend more power in transmission than in over hearing so one way of minimizing the power consumption is to use redirection nodes. So Transmission to a distant device at higher power may consume a disproportionate amount of power in comparison to transmission to a node in closer proximity. PARO is based on the principle that adding additional forwarding (i.e., redirectors) nodes between source- destination pairs significantly reduces the transmission power necessary to deliver packets in wireless ad hoc networks.

PARO attempts to maximize the number of redirector nodes between source- destination pairs thereby minimizing the transmission power. This is in direct contrast to MANET routing protocols (e.g., AODV, DSR[2] and TORA)which attempt to minimize the number of hops between source-destination pairs. One common property of these routing protocols [4] is that they discover routes using a variety of broadcast flooding protocols by transmitting at maximum power in order to minimize the number of forwarding nodes between any source-destination pair. PARO provides wide-area routing protocols with local energy-conserving routes and wide-area routing is used to forward packets when the source and destination nodes are outside the maximum transmission range of each other.

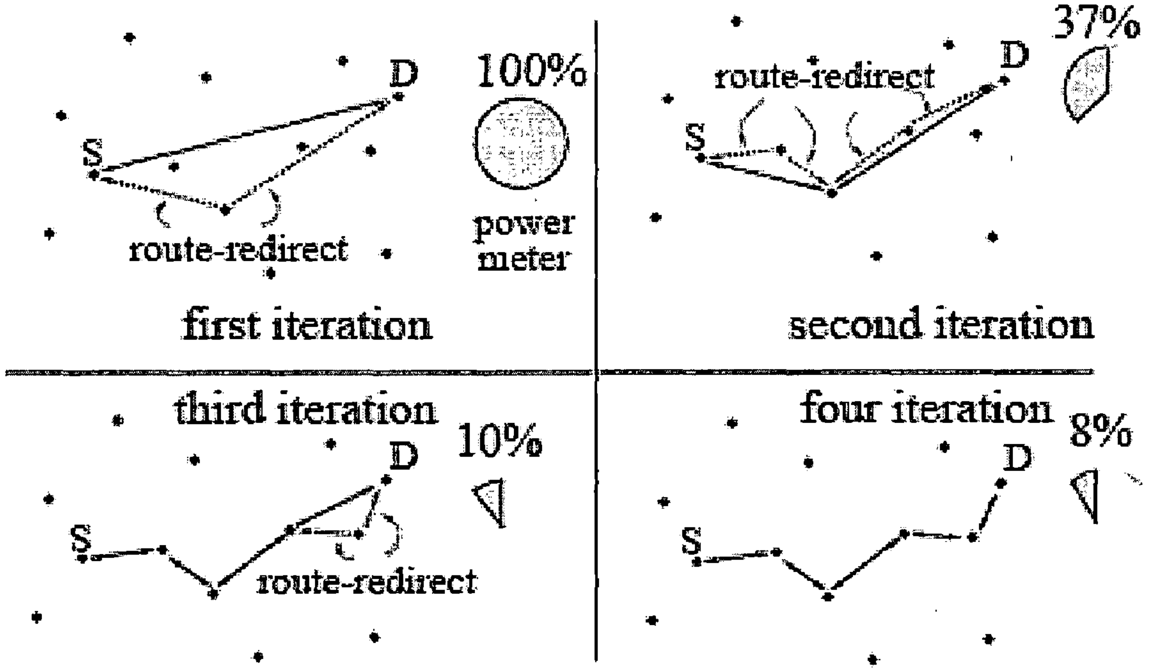

Figure 4.1 PARO Route Optimization with %power used for transmission

5.2 PARO Assumptions.

1. Radios are capable of dynamically adjusting the transmission power used to communicate with other nodes. Normally IEEE 802.11 and Bluetooth include a provision for power control
2. Symmetry in transmission power,i.e power required from B to A is similar to that of A to B.so assumption here is that interference/fading conditions in both directions are similar in space and time
3. Every data packet successfully received is acknowledged at the link layer and that nodes in the network are capable of overhearing any transmissions by other nodes as long as the received signal to noise ratio (SNR) is above a certain minimum value

5.3 Problems With PARO

i. As PARO adopts per packet level power control which is very difficult with available hardware [13].

ii. Available power levels with hardware are also limited which means finest control on the power levels is not available as desired by protocol.

iii. Protocol operation depends on dynamic readjustment of transmission power. but normally device drivers will soft restart the device which will disrupt the connection speed and typically these restart times range up to 2ms [13].

iv. Simulation results show that this algorithm finally relies on the paths which are having minimum energy cost.

v. In this algorithm hop distance is high which means delay is high. Routing through many nodes will make the channel congested which increases the packet loss. Retransmission of these packets will cost more power.

5.4 Motivation for using Common Power

The simplest approach, assuming nodes are homogeneous, is for nodes to transmit at the same power. Since all physical paths taken by radio waves from a node to a node can be reversed, be they multipath or reflection, and the attenuation is the same in either direction, it follows that if two nodes and transmit at the same power, then if M can hear N then N can also hear M. Note that this does not require a spherical region for the range, that is, equal range in all directions.So all links are Bidirectional in IEEE 802.11b protocol.

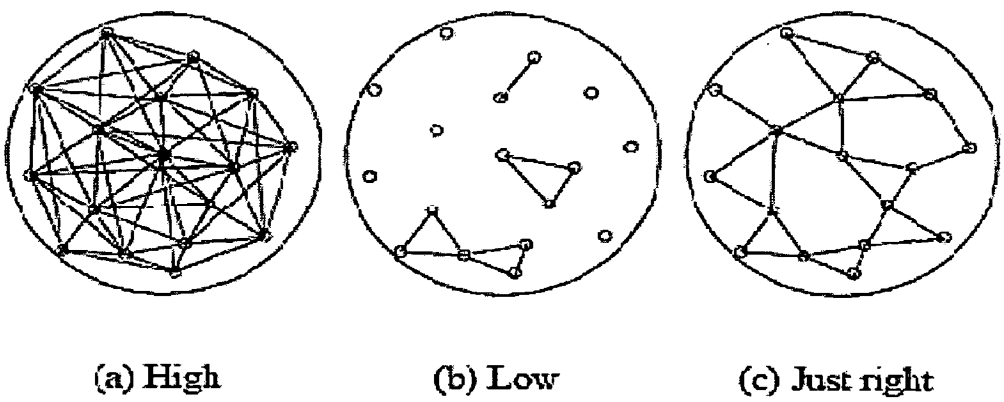

Figure 4.2: Choice of power level affects network connectivity and level of interference.

Figure 4.2 shows a mobile network and its connectivity at different power levels. At high power levels total network is overly connected. But at very lo power level network is partitioned. Last one shows network when the network is at power level where total network is connected but not having any extra links.

We can see from the above diagram that high power levels will

i. Increase network connectivity.
ii. Increases network SNR.
iii. Reduce network life time.

So Thus the approach in the thesis, as shown in the sequel, is to keep transmit powers small, hence transmit neighbourhood small too, and take advantage of the spatial dispersion of nodes to achieve more or less equal SINRs.

Piyush Gupta and P.R Kumar [14] shown that the per node throughput for a random destination can never be more than $\frac{c}{\sqrt{n}}$for every n, where n is the number of nodes in the network, even if all transmissions are allowed to be at different power levels. However, a per node throughput of $O(1/\sqrt{(n\, logn})$ can be guaranteed even in a network with randomly located nodes and even when all nodes broadcast at a common power level. The additional factor $1/\sqrt{logn}$ is negligible, thus showing that a common power is nearly optimal.

A key feature of the wireless channel is that it is a shared medium. Thus, choosing an excessively high power level causes excessive interference as seen in Figure 4.2(a). This reduces the traffic carrying capacity of the network in addition to reducing battery life. On the other hand, in Figure 4.2(b), having a very small power level results in fewer links and hence network partitioning. When the power level is just right, the network is still connected and there is no excessive interference as shown in Figure 4.2(c).

5.5 Operation of COMPOW protocol

In COMPOW protocol total network runs at common power. This common power is power where total network remains connected. The protocol operation achives this by running different routing daemons in parallel, one for each power level. The routing tables for each power level are maintained automatically through periodic control packets/ then protocol selects minimum power level where total network is connected.

5.6 Problems in COMPOW Protocol

COMPOW protocol fails when network is divided into sub-networks by considerable distances and they are dense within the sub network. So, now protocol chooses inter-network power as the common network node power which considerably increases the total power consumption in the network. Formation of the subnet is common phenomenon in the physical networks because of common human tendency to come together.

Based on 50 simulation results with random generated nodes in an area of 1000x1000m with 100 nodes with available distances as

D= [250 160 80 40 20 10]

Maximum number of times COMPOW settles down at power level corresponding to 160m i.e 50mw [13]. But min_cluster is connected in 20m whose corresponding power level is 5mw.

We have assumed a manageable number of discrete transmit power levels in our design. This is true of the only commercially available wireless cards (at the time of our design) which support transmit power control, namely the CISCO Aironet 340 and the 350 series. The 340 series has four power levels (1, 5, 10 and 30 mW) and 350 has six power levels (1, 5, 20, 30, 50 and 100 mW). If there are cards with many discrete power levels then we can optimize the algorithm by maintaining routing tables at power levels close to the current optimum rather than at all power levels.

5.7 Clustering Method:

It is common human tendency to group together. We can observe this in the large crowds of human population. This can be taken as a advantage in the present routing algorithm. It is not nessisary to use over power to communicate with in the group

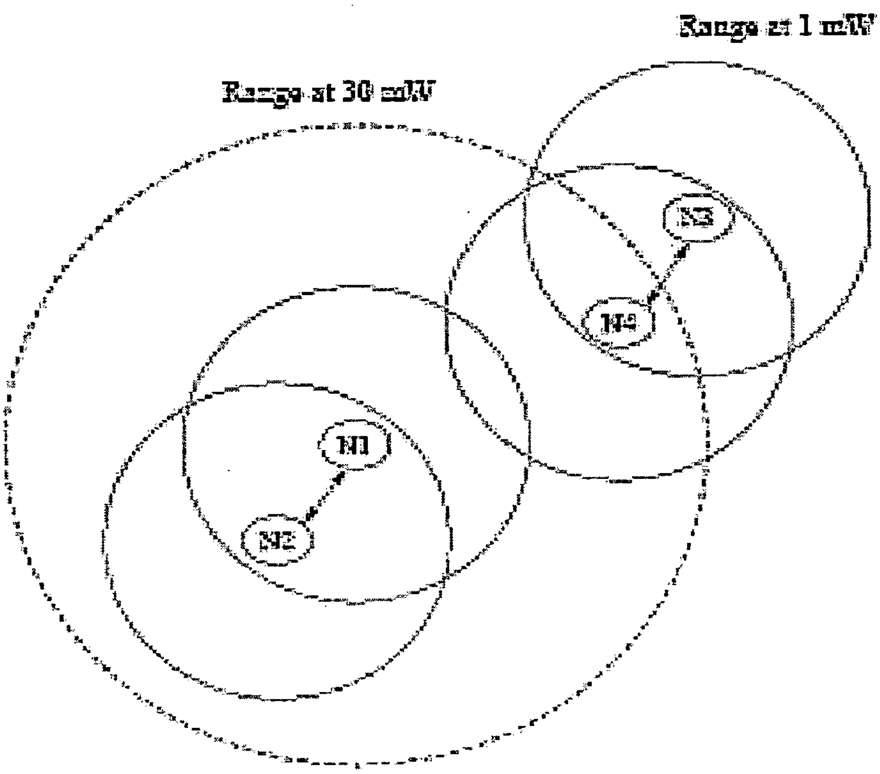

Figure 4.3 Range of nodes at different power levels

For example it is not nessisary waste 30mw for sending from node n1 to n2 as it can be reached at power level 1mw.

We can see this type of scenarios in the real world ex: collage clusters can be seen at classroom, labs, canteen etc. So if we use COMPOW protocol here then total network will operate at power level at which total network is connected. If these groups are far apart then total wastage of power will be more. So clustering algorithm is inherent solution here.

Our algorithm is based on GPS but can be easily extended to non GPS based nodes by periodic exchange of 'hello' packets. And distance between nodes can be calculated by entering into promiscuous mode to over hearing and observing power at receive end.

In our algorithm first we calculate distance between all node pairs then replace all non connected nodes with ∞ in the distance matrix. Then run Warshall algorithm for the distance matrix. Find minimum connection distance using procedure makeparti when network is partitioned find route at previous power level and use same route in current power level with inter partition communication node at misconnected power level.

This model works well even with mobility of nodes. As moving node will first become edge of the partition So will be change its power level to next power level and remain connected with network until next routing update period.

5.8 Operation of proposed method.

Our proposed algorithm will use available distance information from GPS. After getting distances we caliculate power using the formula.

$$P=C.r^{-\alpha}$$

Where α depends on the preoperational model and geometry of the surroundings and C depends on the antenna gains, cahnnel properties, wave frequency.

Then we mark all links whose link power is greater than maximum power level by setting their power level at infinity as these nodes are not reachable. Then we find which nodes are connected by running warshall algorithm, If any node pair is having infinity after running this algorithm then that node pair is disconnected. If we find atleast one disconnected pair then network is marked as partitioned and formed partitions are caliculated. Current power level is used as intra-cluster power level.edge nodes will operate at next power level.

For example if {100,75,50,20,10}mw are the power levels available with the card and networks is portioned at power level 20mw then 20mw will be intra-partition power level amd 50mw will be inter partition power level.

5.9 Algorithms

1. Formulate distance matrix D
2. P_lvl=available power levels
3. i=0;
4. Replace all links which are not reachable at power level i by infinity in Distance matrix D.
5. Run warshall algorithm for D.
6. If there are entries remaining in the matrix which are infinity then that two nodes are not connected.
7. If nodes are not connected Then

   mark previous p_lvl as min connected power level.

   Calculate partitions in current power level

   Else

   i=i+1

   repeat from step4

   End

8. Find minimum Hop routes in the min_connected power level.
9. Store a nodes paths to other in the corresponding node
10. If a node is in the boundary of the partition then

    Node power_lvl= min_connected power lvl

    Else

    Node power_lvl=p_lvl(i-1)

    End

11. If a node communicates inside its zone then
    i. Route=Route at min_power level with
       1. Total route power=$\sum_{i \in R} N_p$

5.9.2 Warshall Algorithm for connected graph detection:

Y is distance/power matrix passed

```
1. for k=1:l
2. for i=1:l
   i.  for j=1:l
              y(i,j)=min(y(i,j),y(i,k)+y(k,j));
   ii. end
3. end
4. end
```

This algorithm will give minimum distance/power for all node pairs. After running this algorithm if any node remains with d(I,j)=inf then that node is not connected.

5.9.3 Partition making algorithm:

```
1. Take input D as minDistance matrix
2. Assign list=1 to n
3. Assign i= 1(p is partition number)
4. Assign p(i).ele=p_ele=list(1)
5. Remove list(1) from list
6. For j=1 to n

      If D(p_ele,j)=inf then

           a. Add element j to partition i
           b. Remove element j from list

      end

7. end
```

5.9.4 Route finding Algorithm:

We used modified warshall algorithm for find routes between all pairs. This algorithm works as fallows

1. Take D as input Distance/power matrix
2. if D(i,j)=inf Make r(i,j).route=[] Else make r(i,j).route=[i j] for all $1<i,j<N$
3. replace route with better route if
4. (r(i,j).metric > (r(i,k).metric + r(k,j).metric
5. Else keep route

Chapter 6

Results and discussion:

Proposed algorithm is tested for various randomly generated node location on 100x100, 500x500, 1000x1000m areas with 25,50,100 nodes each.

Results were given on data set of randomly placed 50 nodes populated as in below figure on 100x100 area.

```
d_min     =  [250 160 80 40 20 10 5 1];
c         =  1*10^-6
alpha     =  2.5
```

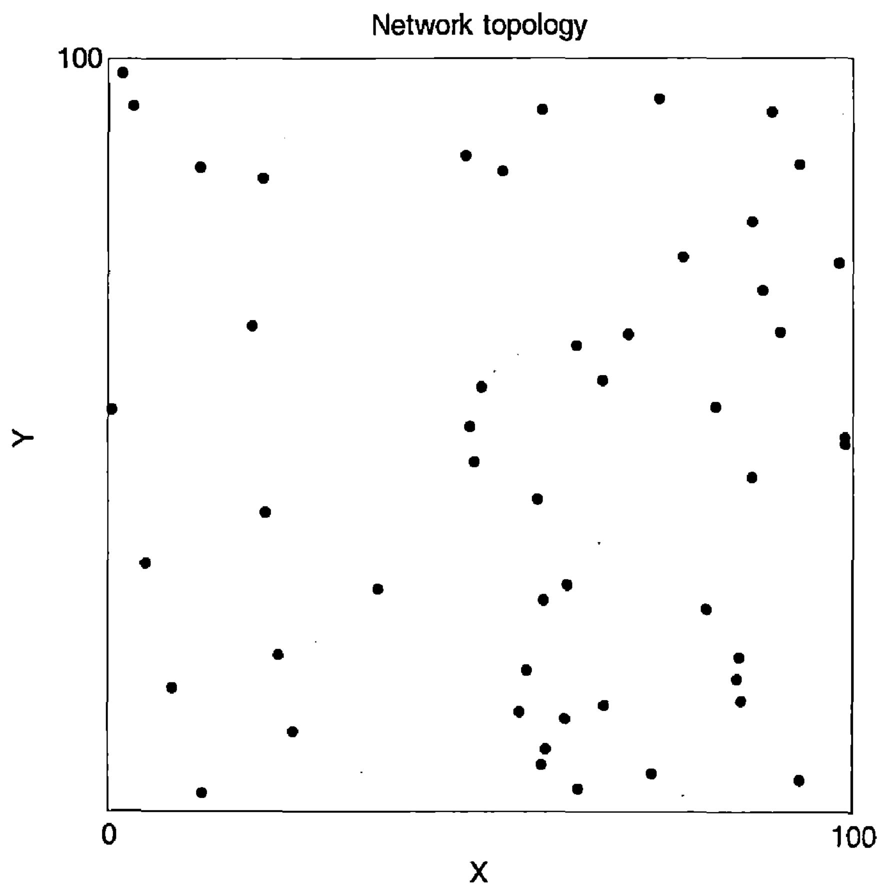

Figure6.1 network topology of randomly generated data set

Finding routes given by shortest path using route finding algorithm and plotting all routes found by this algorithm will result in fallowing graph

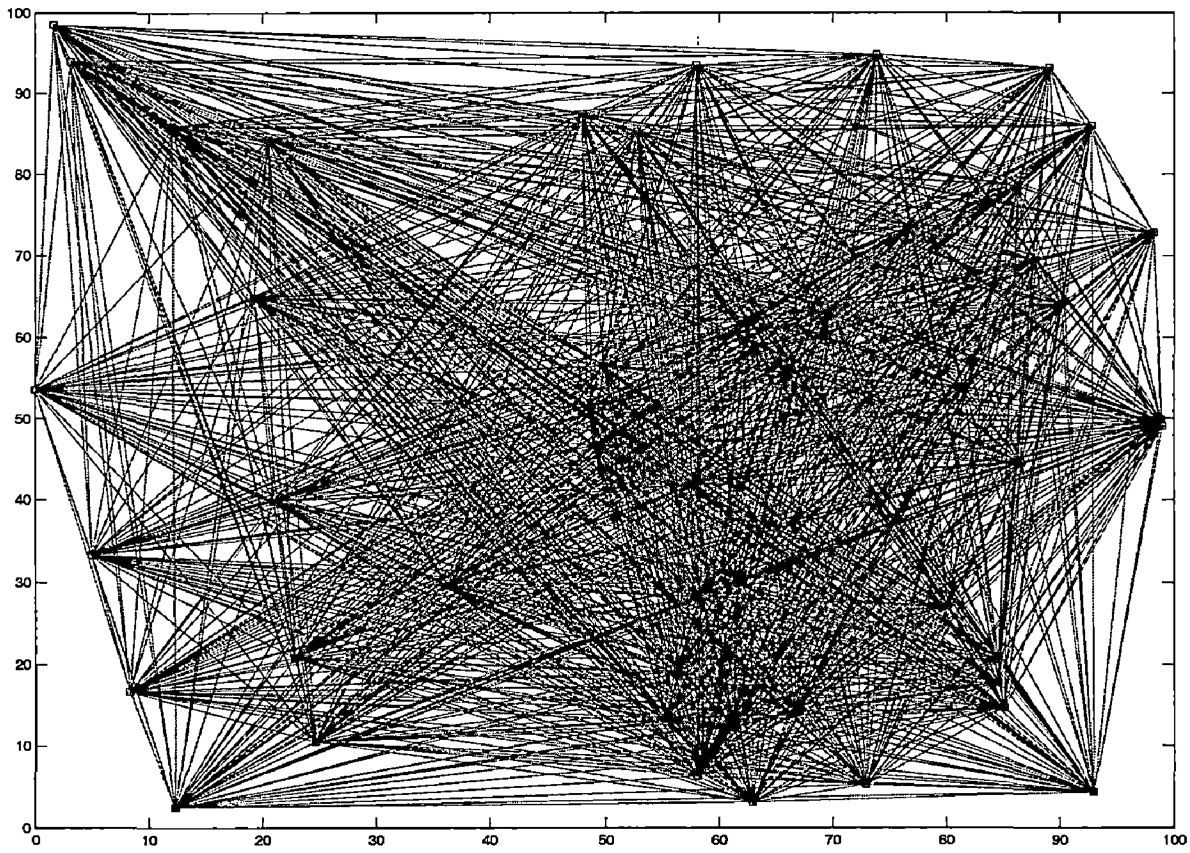

Figure6.2 Routes using shortest path algorithm

From the figure 6.2 we can see that almost all the available paths are used. Making load evenly distributed on nodes. This case is same as routes by DSR if connection speed for all nodes is same.

Finding routes given by minimum energy path using route finding algorithm and plotting all routes found by this algorithm will result in fallowing graph.

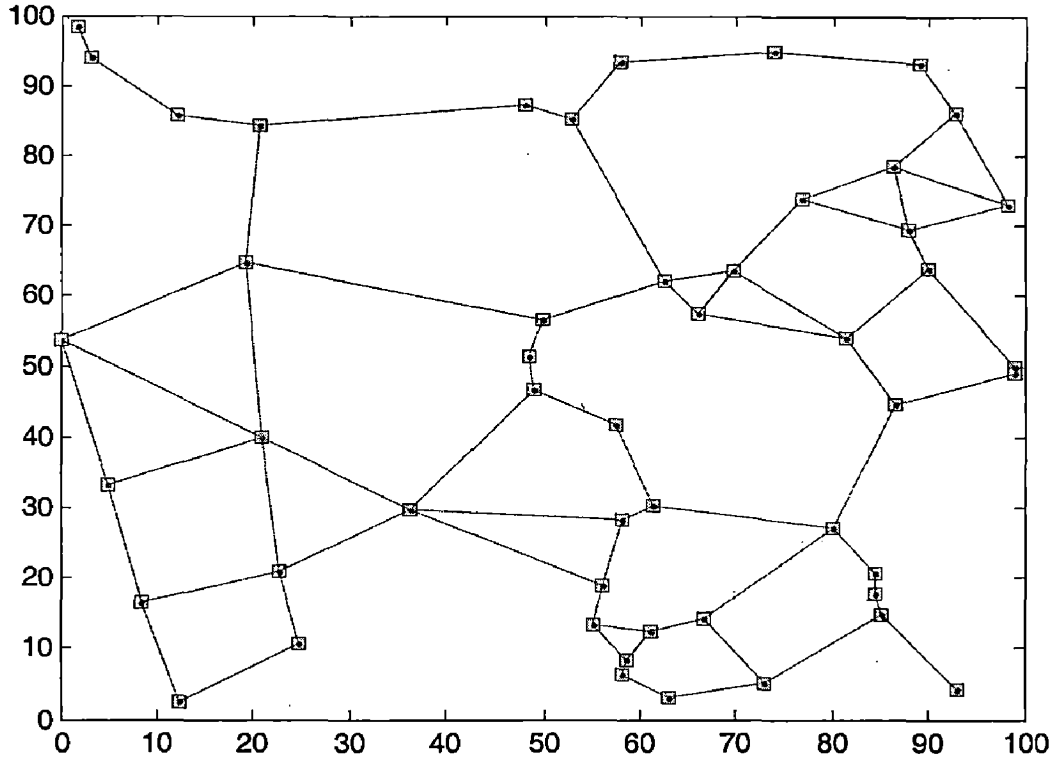

Figure6.3 routes using minimum energy algorithm

By observing figure 6.3 we can see that at minimum power level no two paths are crossing each other and network traffic is limited to few numbers of paths.. By the testing algorithm for minimum connection distance for given dataset

This partition making algorithm will make partitions for Given data set 4 partitions are made

Partition 1 = { 1 2 3 4 5 6 7 8 10 11 12 13 14 15 17 18 19 20 21 22 24 26 27 28 29 30 31 32 33 34 37 38 39 41 42 44 47}

Partition 2 = {9}

Partition3 = { 16 23 25 40 45 46 49 }

Partition 4 = { 35 36 43 48 50 }

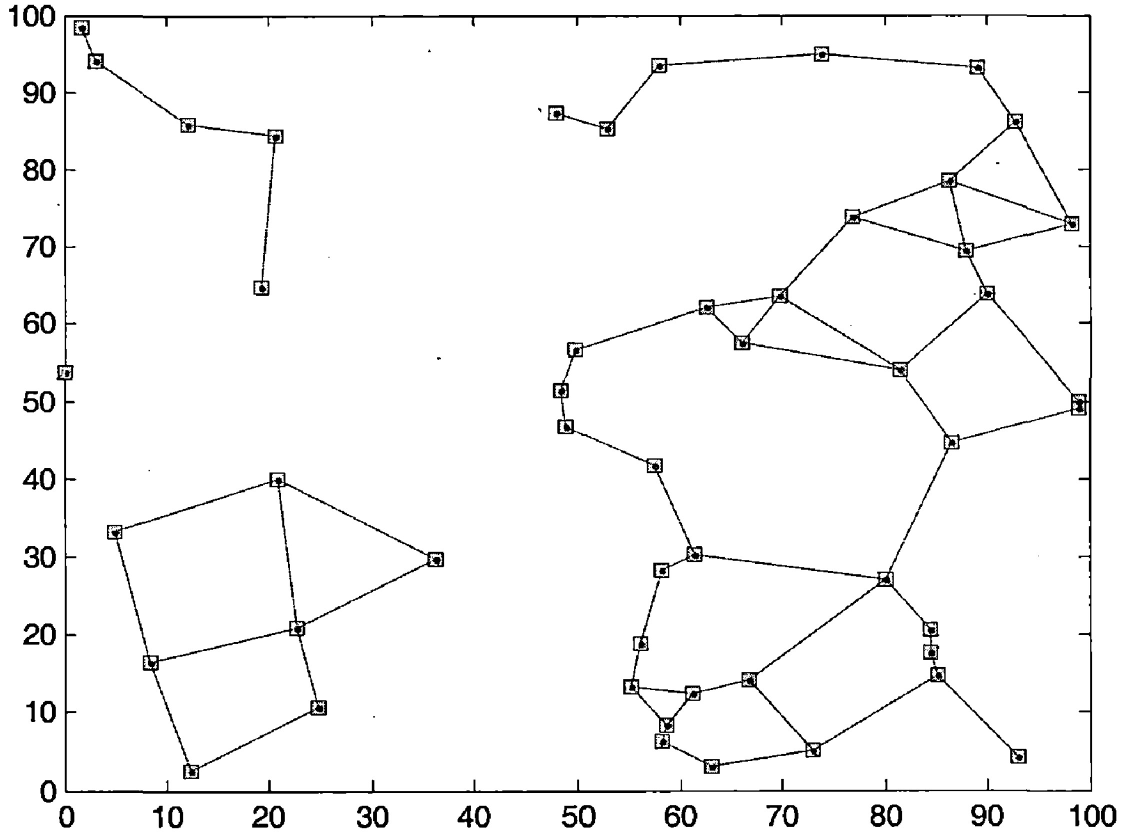

Figure 6.4 partitions made at power level corresponding to distance=20

r(4,16).route = 4 26 26 17 17 38 38 47 47 45 45 16

r1(4,16).route= 4 5 5 16

r(4,16).power = 4.1158e+003

r1(4,16).power = 1.6306e+004

Power improvement=75%

Data set for human grouping nature

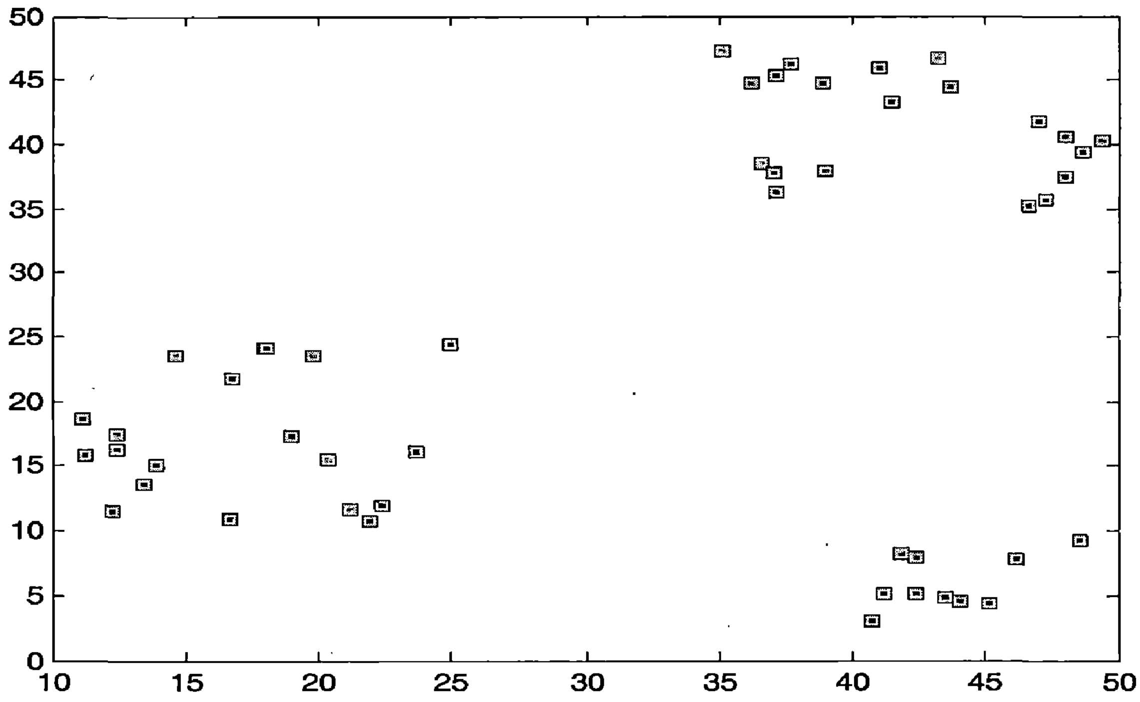

Figure6.5 Routes using shortest path algorithm

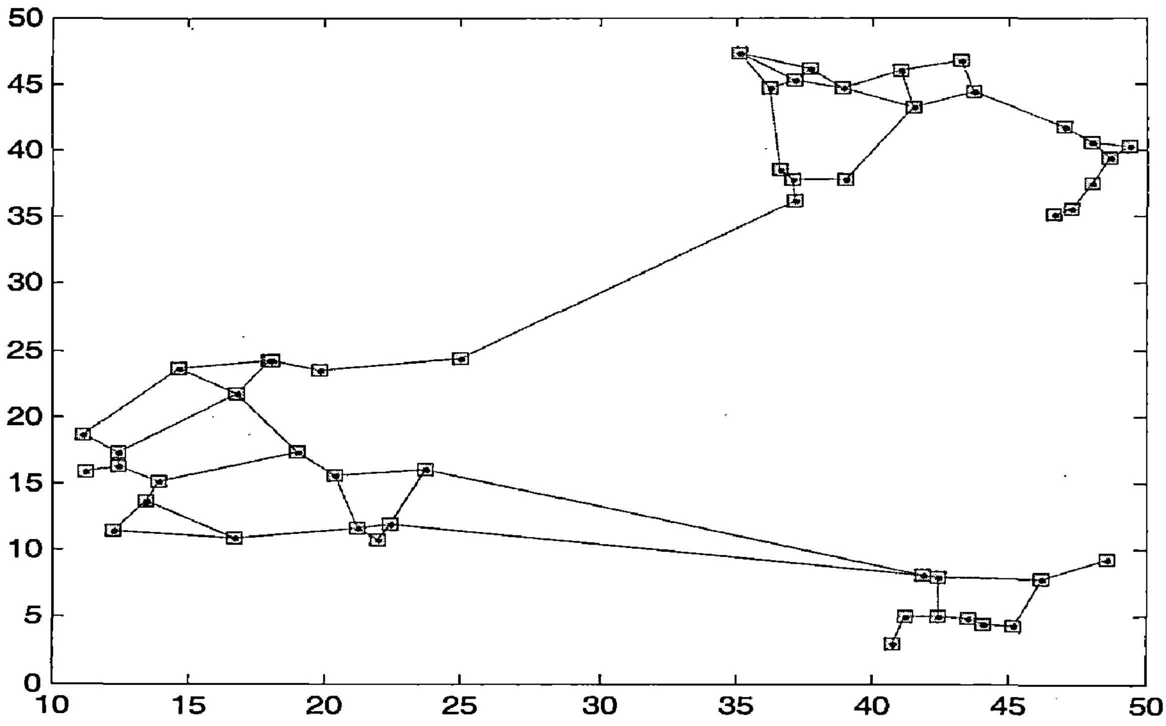

Figure 6.6 routes using minimum energy algorithm

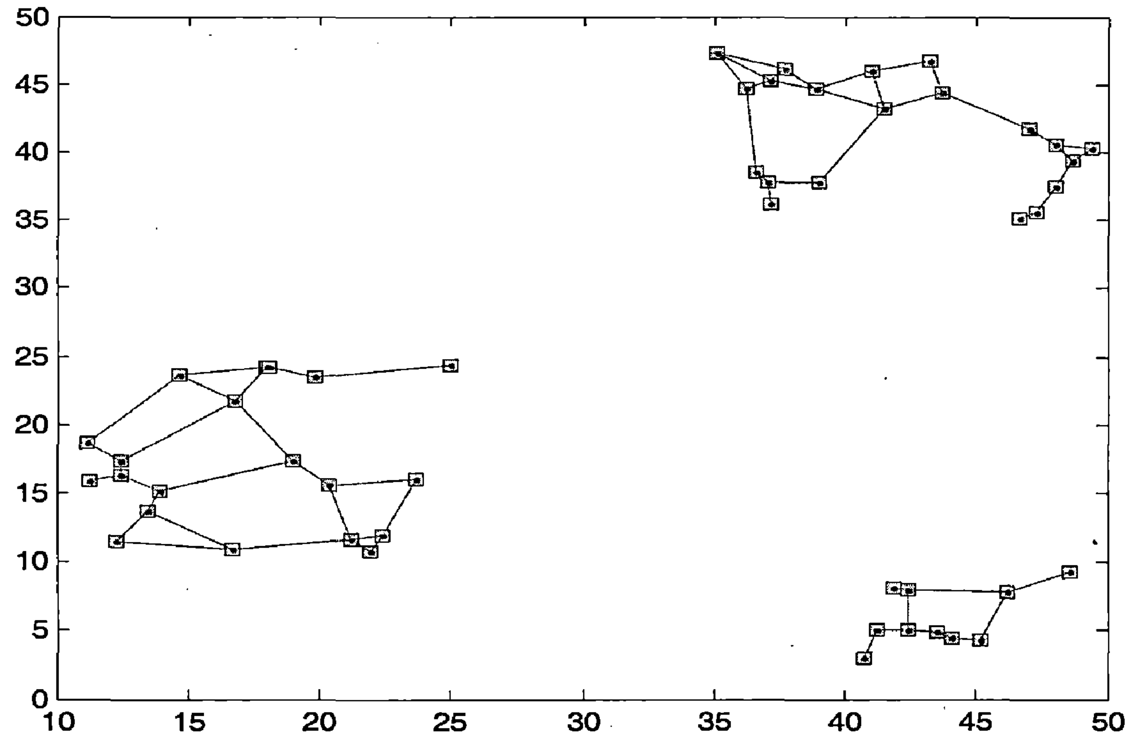

Figure 6.7 partitions made

Partition 1 = { 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20}

Partition 2 = { 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40}

Partition 3 = { 41 42 43 44 45 46 47 48 49 50}

Intra partition power = 0.3mw

Inter partition power = 1.8mw

Power saving in route

r(1,40).route = { 1 5 5 11 11 4 4 17 17 8 8 18 18 40}

Power by DSR = 120m

Power by COMPOW = 12.8mw

Power by Proposed protocol= 3.2mw

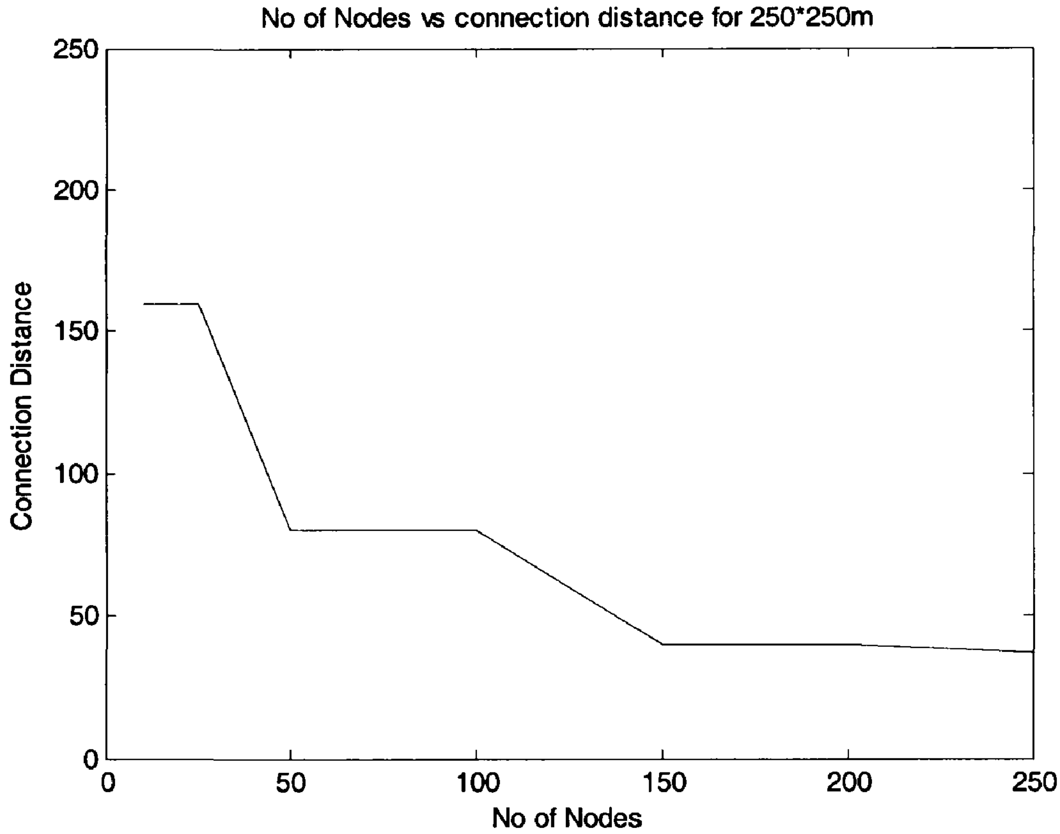

Figure 6.8 Number of nodes vs minimum Connection distance where network is connected

From figure 6.8 we can observe that if number of nodes increases then minimum connection distance where total network is connected reduces as nodes can find other nodes in neighbourhood with increase of network node density.

Chapter 7

Conclusions and Future Work

In this report the need for power awareness in ad hoc networks is focused. This is particularly needed if the network is formed by small devices where battery life is crucial. we have also seen two power aware routing algorithms PARO,COMPOW and their pros, cons.

We proposed a method for clustering total networks into groups of common power. And achieved 3X improvement over DSR and 50% of Improvement over COMPOW in random test data. By observing number of simulation we can justify that this protocol works best in common human nature scenarios ie when number of nodes are grouped together.

The proposed algorithm can be improved to semi-infrastructured like network with given power levels and power inputs of nodes. nodes which can reach other cluster and with average power loss as nearly zero can be made cluster head and all inter cluster communication can be done via cluster heads.

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