AN ENERGY EFFICIENT DYNAMIC SOURCE ROUTING FOR MANET

Thesis submitted in partial fulfillment of the requirements for the degree of

Master of Technology

in

Computer Science and Engineering

by

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Orissa-769008, India
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Under the Guidance of

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Dedicated to my parents

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Certificate

This is to certify that the work in the thesis entitled **"An Energy Efficient Dynamic Source Routing in MANET"** submitted by **Mr. Shine V J** 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 in the department of Computer Science and Engineering, National Institute of Technology Rourkela. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere

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ABSTRACT

Ad hoc networking allows portable mobile devices to establish communication path without having any central infrastructure. Since there is no central infrastructure and the mobile devices are moving randomly, gives rise to various kinds of problems, such as routing and security. In this thesis the problem of routing is considered.

Routing is one of the key issues in MANETs because of highly dynamic and distributed nature of nodes. Especially energy efficient routing is most important because all the nodes are battery powered. Failure of one node may affect the entire network. If a node runs out of energy the probability of network partitioning will be increased. Since every mobile node has limited power supply, energy depletion is become one of the main threats to the lifetime of the ad hoc network. So routing in MANET should be in such a way that it will use the remaining battery power in an efficient way to increase the life time of the network.

In this thesis, we have proposed an energy efficient dynamic source routing protocol (EEDSR) which will efficiently utilize the battery power of the mobile nodes in such a way that the network will get more lifetime. Transmission power control approach is used to adjust the node to node communication power and load balancing approach is used to avoid over utilized nodes. Transmission power control is done by calculating new transmission power between every pair of nodes on that route which will be the minimum power required for successful communication. Load balancing is done by selecting a route which contains energy rich nodes. Simulation studies revealed that the proposed scheme is more efficient than the existing one.

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INTRODUCTION

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INTRODUCTION

1.1 INTRODUCTION

Ad-hoc wireless networks are a comparatively new paradigm in multi-hop wireless networking that is increasingly becoming popular and will become an essential part of the computing environment, consisting of infra-structured and infrastructure-less mobile networks [1]. Mobile ad hoc network (MANET) is an infrastructure-less multi-hop network where each node communicates with other nodes directly or indirectly through intermediate nodes. The credit for growth of ad-hoc network goes to its self organizing and self configuring properties. All nodes in a MANET basically function as mobile routers participating in some routing protocol required for deciding and maintaining the routes. Since MANETs are infrastructure-less, self-organizing, rapidly deployable wireless networks, they are highly suitable for applications involving special outdoor events, communications in regions with no wireless infrastructure, emergencies and natural disasters, and military operations, mine site operations, urgent business meetings and robot data acquisition [2, 3]. In general, routes between nodes in an ad hoc network may include multiple hops and, hence, it is appropriate to call such networks “multi-hop wireless ad hoc networks. Figure 1.1 shows an example mobile ad hoc network and its communication topology.

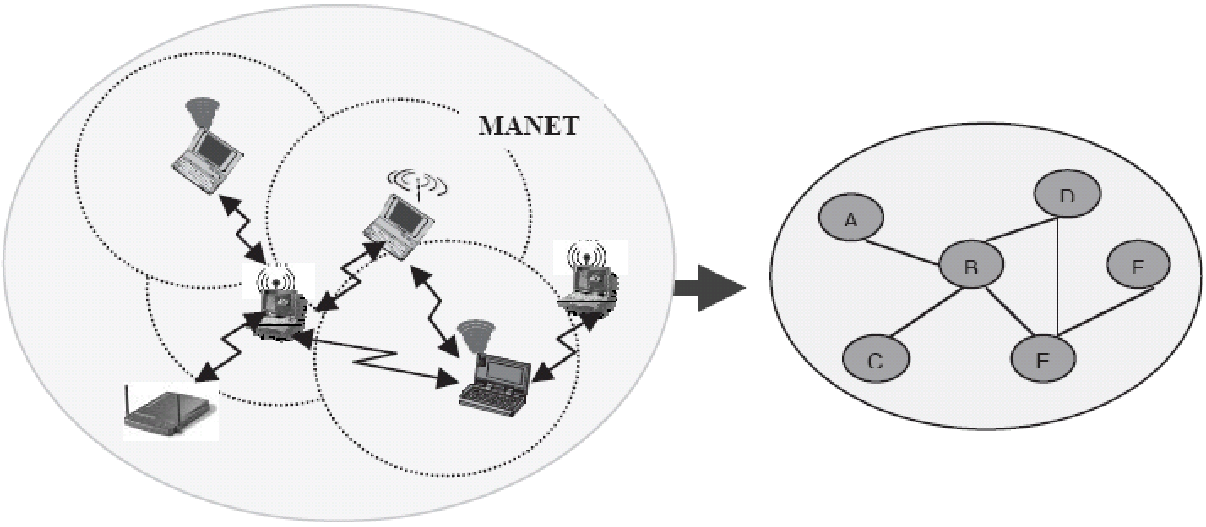


Figure 1.1 Mobile Ad Hoc Network

1.2 Characteristics & Advantages of MANET

MANET is having the characteristics of wireless network in general, and additional characteristics that are specific to the Ad Hoc Networking:

- ***Wireless.*** Nodes communicate wirelessly and share the same media (radio, infra-red, etc.).
- ***Ad-hoc-based***. A mobile ad hoc network is a temporary network formed dynamically in an arbitrary manner by a collection of nodes as need arises.
- ***Autonomous and infrastructure-less***. MANET does not depend on any established infrastructure or centralized administration. Each node operates in distributed peer-to-peer mode, acts as an independent router, and generates independent data.
- ***Multi-hop routing***. No dedicated routers are necessary; every node acts as a router and forwards each others' packets to enable information sharing between mobile hosts.
- ***Mobility.*** Each node is free to move about while communicating with other nodes. The topology of such an ad hoc network is dynamic in nature due to constant movement of the participating nodes, causing the intercommunication patterns among nodes to change continuously.

  Advantages are

- ***Accessibility:*** MANET provides access to information and services regardless of geographic position.
- ***Deployment:*** The networks can be set up at any place and time.
- ***Infrastructure-less:*** The networks work without any pre-existing infrastructure. This allows people and devices to interwork in areas with no supporting infrastructure.
- ***Dynamic***: Can freely and dynamically self-organize into arbitrary and temporary network topologies.

1.3 MANET Applications

Because ad hoc networks are flexible networks that can be set up anywhere at any time, without any infrastructure, including pre-configuration or administration, people have come to realize the commercial potential and advantages that mobile ad hoc networking can bring.

This section describes some of the most prevalent applications for ad hoc wireless networks. The self-configuring nature and lack of infrastructure inherent to these networks make them highly appealing for many applications, even if it results in a significant performance penalty. The lack of infrastructure is highly desirable for low-cost commercial systems, since it precludes a large investment to get the network up and running, and deployment costs may then scale with network success. Lack of infrastructure is also highly desirable for military systems, where communication networks must be configured quickly as the need arises, often in remote areas. Other advantages of ad hoc wireless networks include ease of network reconfiguration and reduced maintenance costs. However, these advantages must be balanced against any performance penalty resulting from the multi-hop routing and distributed control inherent to these networks.

1.3.1 Data Networks

Ad-hoc wireless data networks primarily support data exchange between laptops, palmtops, personal digital assistants (PDAs), and other information devices. These data networks generally fall into three categories based on their coverage area: LANs, MANs, and WANs. Infrastructure-based wireless LANs are already quite prevalent, and deliver good performance at low cost. However, ad hoc wireless data networks have some advantages over these infrastructure-based networks. First, only one access point is needed to connect to the backbone wired infrastructure: this reduces cost and installation requirements. In addition, it can be inefficient for nodes to go through an access point or base station. For example, PDAs that are next to each other can exchange information directly rather than routing through an intermediate node.

Wireless MANs typically require multi-hop routing since they cover a large area. The challenge in these networks is to support high data rates, in a cost-effective manner, over multiple hops, where the link quality of each hop is different and changes with time. The lack of centralized network control and potential for high-mobility users further complicates this objective. Military programs such as DARPA’s GLOMO (Global mobile information systems) have invested much time and money in building high-speed ad hoc wireless MANs that support multimedia, with limited success [4].

Wireless WANs are needed for applications where network infrastructure to cover a wide area is too costly or impractical to deploy. For example, sensor networks may be dropped into remote areas where network infrastructure cannot be developed. In addition, networks that must be built up and torn down quickly, e.g. for military applications or disaster relief, are infeasible without an ad hoc approach.

1.3.2 Home Networks

Home networks are envisioned to support communication between PCs, laptops, PDAs, cordless phones, smart appliances, security and monitoring systems, consumer electronics, and entertainment systems anywhere in and around the home. Such networks could enable smart rooms that sense people and movement and adjust light and heating accordingly, as well as “aware homes” that network sensors and computers for assisted living of seniors and those with disabilities. Home networks also encompass video or sensor monitoring systems with the intelligence to coordinate and interpret data and alert the home owner and the appropriate police or fire department of unusual patterns, intelligent appliances that coordinate with each other and with the Internet for remote control, software upgrades, and to schedule maintenance, and entertainment systems that allow access to a VCR, set-top box, or PC from any television or stereo system in the home [4].

1.3.3 Device Networks

Device networks support short-range wireless connections between devices. Such networks are primarily intended to replace inconvenient cabled connections with wireless connections. Thus, the need for cables and the corresponding connectors between cell phones, modems, headsets, PDAs, computers, printers, projectors, network access points, and other such devices is eliminated. The main technology drivers for such networks are low-cost low-power radios with networking capabilities such as Bluetooth. The radios are integrated into commercial electronic devices to provide networking capabilities between devices. Some common uses include a wireless headset for cell phones, a wireless USB or RS232 connector, wireless cards, and wireless set-top boxes.

1.3.4. Sensor Networks

Wireless sensor networks consist of small nodes with sensing, computation, and wireless networking capabilities, as such these networks represent the convergence of three important technologies. Sensor networks have enormous potential for both consumer and military applications. Military missions require sensors and other intelligence gathering mechanisms that can be placed close to their intended targets. The potential threat to these mechanisms is therefore quite high, so it follows that the technology used must be highly redundant and requires as little human intervention as possible. An apparent solution to these constraints lies in large arrays of passive electromagnetic, optical, chemical, and biological sensors. These can be used to identify and track targets, and can also serve as a first line of detection for various types of attacks. Such networks can also support the movement of unmanned, robotic vehicles. For example, optical sensor networks can provide networked navigation, routing vehicles around obstacles while guiding them into position for defense or attack. The design considerations for some industrial applications are quite similar to those for military applications. In particular, sensor arrays can be deployed and used for remote sensing in nuclear power plants, mines, and other industrial venues.

1.4 Design Issues and Challenges

Ad hoc wireless networks inherit the traditional problems of wireless communications, such as bandwidth optimization, power control, and transmission quality enhancement, while, in addition, their mobility, multi-hop nature, and the lack of fixed infrastructure create a number of complexities and design constraints that are new to mobile ad hoc networks.

- ***Infrastructure-less network:*** The most fundamental aspect of an ad hoc wireless network is its lack of infrastructure, and most design issues and challenges stem from this characteristic. Also, lack of centralized mechanism brings added difficulty in fault detection and correction.
- ***Dynamic Topology:*** The dynamically changing nature of mobile nodes causes to the formation of an unpredicted topology. This topology change causes frequent route change, network partitioning and packet dropping.
- ***Limited Link Bandwidth and Quality.*** Because mobile nodes communicate each other via bandwidth-constrained, variable capacity, error-prone, and insecure wireless channels, wireless links will continue to have significantly lower capacity than wired links and, hence, more problematic network congestion.
- ***Energy Constrained Operation.*** Energy constraints are another big challenge in ad hoc wireless network design [5]. These constraints in wireless network arise due to battery powered nodes which cannot be recharged. This becomes a bigger issue in mobile ad hoc networks because as each node is acting as both an end system and a router at the same time, additional energy is required to forward packets [6].
- ***Robustness and Reliability.*** In MANET, network connectivity is obtained by routing and forwarding among multiple nodes. Although this replaces the constraints of fixed infrastructure connectivity, it also brings design challenges. Due to various conditions like overload, acting selfishly, or failed links, a node

may fail to forward the packet. Misbehaving nodes and unreliable links can have a severe impact on overall network performance. Due to the lack of centralized monitoring and management mechanisms these types of misbehaviors cannot be detected and isolated quickly and easily. This increases the design complexity significantly.

- ***Network Security.*** Mobile wireless networks are more vulnerable to information and physical security threats than fixed-wired networks. The use of open and shared broadcast wireless channels means nodes with inadequate physical protection are prone to security threats. In addition, because a mobile ad hoc network is a distributed infrastructure-less network, it mainly relies on individual security solution from each mobile node, as centralized security control is hard to implement.
- ***Quality of Service:*** Quality of Service (QoS) guarantee is very much essential for the successful communication of nodes in the network. The different QoS metrics includes throughput, packet loss, delay, and jitter and error rate. The dynamically changing topology, limited bandwidth and quality makes difficulty in achieving the desired QoS guarantee for the network.

1.5 Thesis outline

Thesis is organized as follows. Chapter two gives a brief introduction to MANET routing protocols. Chapter three describes literature review. Chapter four describes the proposed method of energy efficiency. Chapter five includes simulation result and finally conclusion and future work.

CHAPTER 2

INTRODUCTION TO MANET ROUTING

Chapter
2

INTRODUCTION TO MANET ROUTING

2.1 INTRODUCTION

The highly dynamic natures of the mobile nodes create frequent and unpredictable network topology changes. This topology change increases the routing complexity among the mobile nodes within the network. There for traditional routing algorithms are not sufficient to the successful routing in MANET. Routing in a MANET depends on many other factors including topology, selection of routers, and location of request initiator and specific underlying characteristics that could serve as a heuristic in finding the path quickly and efficiently. This makes the routing area perhaps the most active research area within the MANET domain. Especially over the last few years, numerous routing protocols and algorithms have been proposed and their performance under various network environments and traffic conditions closely studied and compared.

MANET routing protocols are mainly categorized into three :

1. Topology based approach
2. Location based approach
3. Power/energy aware approach

2.1.1 Topology based approach

In topology based approach, it uses the knowledge of instantaneous connectivity of the network with emphasis on the state of the network links. In this approach the associated routing protocols are again classified into three categories, based on the time at which the routes are discovered and updated.

1. Proactive Routing Protocol (Table Driven)
2. Reactive Routing Protocol (On-Demand)
3. Hybrid Routing Protocol

2.1.1.1 Proactive Routing Protocols

Proactive routing protocols attempt to maintain consistent, up-to-date routing information between every pair of nodes in the network by propagating, proactively, route updates at fixed time intervals. These protocols are sometimes referred to as table-driven protocols since the routing information is maintained in tables. The proactive routing approaches designed for ad hoc networks are derived from the traditional routing protocols. The primary characteristic of proactive approaches is that each node in the network maintains a route to every other node in the network at all times. Route creation and maintenance is accomplished through some combination of periodic and event-triggered routing updates. Periodic updates consist of routing information exchanges between nodes at set time intervals. The updates occur at specific intervals, regardless of the mobility and traffic characteristics of the network. Event-triggered updates, on the other hand, are transmitted whenever some event, such as a link addition or removal, occurs. The mobility rate directly impacts the frequency of event-triggered updates because link changes are more likely to occur as mobility increases. Proactive approaches have the advantage that routes are available the moment they are needed. Because each node consistently maintains an up-to-date route to every other node in the network, a source can simply check its routing table when it has data packets to send to some destination and begin packet transmission. However, the primary disadvantage of these protocols is that the control overhead can be significant in large networks or in networks with rapidly moving nodes. Further, the amount of routing state maintained at each node scales as $O(n)$, where n is the number of nodes in the network. Proactive protocols tend to perform well in networks where there is a significant number of data sessions within the network. In these networks, the overhead of maintaining each of the paths is justified because many of these paths are utilized.

Proactive routing protocol includes Destination-Sequenced Distance-Vector (DSDV) protocol, Wireless Routing Protocol (WRP), Optimized Link State Routing Protocol (OLSR) and Fisheye State Routing (FSR).

In DSDV every node in the network maintains a routing table in which all the possible destinations within the network as well as the number of hops to reach each destination are recorded. Each route entry is marked with a sequence number. Nodes periodically transmit routing table updates throughout the network in order to maintain table consistency. Route updates contains the address of some node, the number of hops to reach the destination, the destination sequence number as well as a sequence number that uniquely identifies the update.

OLSR is an optimization over the classical link state protocol. The key idea is to reduce duplicate broadcast packets in the same region. This is achieved with the use of the so called multipoint relay nodes. Each node selects a minimal set of multipoint relay nodes from among its one-hop neighbors. The goal behind the MPR principle is to achieve efficient flooding. When a node want to flood a message it sends the message only to the nodes in MPR, which in turn send the message to their MRP nodes and so on.

A node retransmits a message if it has not received the message before, and the node is selected as multipoint relay by the node from which the message is received.

WRP is another loop-free proactive protocol whereby four tables are used to maintain distance, link cost, routes, and message retransmission information. General route updates are sent among neighboring nodes with distance and second-to-last hop information for each destination, resulting in faster convergence.

The FSR protocol is also an optimization over Link State algorithm using the fisheye technique. In essence, FSR will propagate link state information to other nodes in the network based on how far away the nodes are. The protocol will propagate link state information more frequently with nodes that are in a closer scope as opposed to ones that are further away. This means that a route will be less accurate the further away the node is, but once the message gets closer to the destination, the accuracy increases.

2.1.1.2 Reactive Routing Protocol

Reactive routing techniques, also called *on-demand* routing, take a very different approach to routing than proactive protocols. A large percentage of the overhead from proactive protocols stems from the need for every node to maintain a route to every other node at all times. In a wired network, where connectivity patterns change relatively infrequently and resources are abundant, maintaining full connectivity graphs is a worthwhile expense. The benefit is that when a route is needed, it is immediately available. In an ad hoc network, however, link connectivity can change frequently and control overhead is costly. Because of these reasons, reactive routing approaches take a departure from traditional Internet routing approaches by not continuously maintaining a route between all pairs of network nodes. Instead, routes are only discovered when they are actually needed. When a source node needs to send data packets to some destination, it checks its route table to determine whether it has a route. If no route exists, it performs a *route discovery* procedure to find a path to the destination. Hence, route discovery becomes on-demand. If two nodes never need to talk to each other, then they do not need to utilize their resources maintaining a path between each other. The route discovery typically consists of the network- wide flooding of a request message. To reduce overhead, the search area may be reduced by a number of optimizations.

The benefit of this approach is that signaling overhead is likely to be reduced compared to proactive approaches, particularly in networks with low to moderate traffic loads. When the number of data sessions in the network becomes high, then the overhead generated by the route discoveries approaches, and may even surpass, that of the proactive approaches. The drawback to reactive approaches is the introduction of route *acquisition latency*. That is, when a route is needed by a source node, there is some finite latency while the route is discovered. In contrast, with a proactive approach, routes are typically available the moment they are needed. Hence, there is no delay to begin the data session.

Reactive type routing creates routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery process within the network. This process is completed once a route is found or all possible route permutations have been examined. Once a route has been established, it is maintained by some form of route maintenance procedure until either the destination becomes inaccessible along every path or until the route is no longer desired [8]. Reactive routing protocol includes Dynamic Source Routing (DSR) protocol, Ad hoc On-demand Distance Vector (AODV) protocol, Temporally Ordered Routing Algorithm (TORA).

DSR is based on the concept of source routing. In source routing each packet carries the complete ordered list of nodes in which the packet should pass through the network. This is done by maintaining a cache with route from source to destination. It includes two phases: Route discovery and Route maintenance. Route discovery is based on flooding the network with a RREQ packet. A RREQ message includes the senders address, the target address, a unique number to identify the request and a route record listing the addresses of each intermediate node through which the RREQ is forwarded. On receiving RREQ packet, the destination replies to the originator with a RREP packet.

AODV is an improvement on the DSDV protocol. AODV minimizes the number of route broadcasts by creating routes on an on-demand basis, as opposed to maintaining a complete list of routes as in the DSDV algorithm. Like DSR, route discovery is initiated on an on-demand basis, the route request is then forward to the neighbors, and so on, until either the destination or an intermediate node with a fresh route to the destination are located.

TORA is another source-initiated on-demand routing protocol, built on the concept of link reversal of Directed Acyclic Graph (ACG). In addition to being loop-free and bandwidth-efficient, TORA has the property of being highly adaptive and quick in route repair during link failure, while providing multiple routes for any desired source/destination pair. These features make it especially suitable for large highly dynamic mobile ad hoc environments with dense populations of nodes. The limitation in TORA’s applicability comes from its reliance on synchronized clocks. If a node does not have a GPS positioning system or some other external time source, or if the time source fails, the algorithm cannot be used.

2.1.1.3 Hybrid Routing Protocols

Hybrid protocols seek to combine the proactive and reactive approaches. An example of such a protocol is the Zone Routing Protocol (ZRP). ZRP divides the topology into zones and seek to utilize different routing protocols within and between the zones based on the weaknesses and strengths of these protocols. ZRP is totally modular, meaning that any routing protocol can be used within and between zones. The size of the zones is defined by a parameter r describing the radius in hops. Intra-zone routing is done by a proactive protocol since these protocols keep an up to date view of the zone topology, which results in no initial delay when communicating with nodes within the zone. Inter-zone routing is done by a reactive protocol. This eliminates the need for nodes to keep a proactive fresh state of the entire network.

2.1.2 Location based approach

Location based routing uses the geographic position of nodes to make routing decision. Location information can be obtained through GPS or some other mechanism.

One of geographical-based routing protocols is location-aided routing (LAR) [8]. The central point of LAR is the limited flooding of routing request packets in a small group of nodes which belong to a so-called request zone. To construct the request zone, the expected zone of the destination needs to be obtained first. The procedure of route discovery in LAR is: The source puts the location information of itself and the destination in the routing request packet. Then routing request packet is broadcast within the request zone. In other words, the nodes within the request zone forward the message, others discard the message. On receipt of the route request packet, the destination sends back a route reply packet which contains its current location; If LAR fails to find the route to the destination due to estimation error or other reasons, the routing protocol resorts to flooding of routing message throughout the MANET.

2.1.3 Power/energy aware approach

COMPOW is based on a very simple idea. Each node proactively maintains multiple routing tables, one for each of the power levels available on the wireless card. Routing table RT_i, corresponding to the ith power level, is built and maintained by exchanging hello messages at power level P_i. Thus, the number of entries in RT_i of node u corresponds to the number of nodes reachable from u using power level P_i. Clearly, the number of entries in $RT_{\max}$ (the routing table that corresponds to the maximum power level) gives the total number of network nodes. The optimal power level is then defined as the minimum level *i* such that the number of entries in *RTi* equals the number of entries in *RT*max. Once the optimal power level *i* is chosen, table *RTi* is set as the master routing table, which is used to route packets between nodes.

The CLUSTERPOW protocol displays many similarities with the simpler COMPOW protocol. As in COMPOW, every node in the network maintains separate routing tables, one for each power level. Routing table *RTi* , referring to power level *Pi* , is maintained by exchanging *hello* messages at power level *Pi* . When node *u* has to send a message to node *v*, it calculates the minimum power level needed to reach node *v*: it is the minimum level *Pi* such that *RTi* contains an entry for node *v*. Then, the packet is sent using this minimum power level. This process of calculating the minimum power level needed to reach the destination is repeated at each intermediate node in the route from the source to the destination [9].

CHAPTER 3

LITERATURE REVIEW

Chapter 3 LITERATURE REVIEW

3.1 INTRODUCTION

In the previous chapters we discussed briefly about the basics and classification of MANET routing protocols. Among that we realized that power consumption of a mobile node is the most important factor to be noticed. So we have made a detailed literature review about the different energy efficient routing protocols that already exist.

3.2 Energy Efficient MANET routing protocol

We are using different routing protocol to establish a correct and efficient route between a pair of nodes. But because of the limited available power of each node, the selected route cannot remain for a long time so that the source-destination pair can use it for its successful communication. To achieve the goal of getting longer lifetime for a network, we should minimize nodes energy not only during active communication but also when they are in inactive state. Two approaches to minimize the active communication energy are:

1. Transmission power control approach and
2. Load distribution approach.

and to minimize energy during inactivity [10]the following approach is used

1. sleep/power-down mode

3.2.1 Transmission Power Control Approach

A routing algorithm essentially involves finding an optimal route on a given network graph where a vertex represents a mobile node and an edge represents a wireless link between two end nodes that are within each other’s radio transmission range. When a node’s radio transmission power is controllable, their direct communication ranges as well as the number of its immediate neighbors are also adjustable. While stronger transmission power increases the transmission range and reduces the hop count to the destination, weaker transmission power makes the topology sparse which may result in network partitioning and high end-to-end delay due to a larger hop count. Table 3.1 shows the classification of routing protocol according to the above protocol.

There has been active research on topology control of a MANET via transmission power adjustment [11-14], and the primary objective is to maintain a connected topology using the minimal power. Energy efficient routing protocols based on transmission power control find the best route that minimizes the total transmission power between a source-destination pair. It is equivalent to a graph optimization problem, where each link is weighted with the link cost corresponding to the required transmission power. Finding the most energy efficient (min-power) route from *S* to *D* is equivalent to finding the least cost path in the weighted graph.

Approach		**Protocol**	**Goal**
Minimize active communication energy	Transmission power control	• Flow Argumentation Routing (FAR) • Online Max-Min (OMM) • Power aware Localized Routing (PLR)	Minimize the total transmission energy but avoid low energy nodes.
		• Smallest Common Power (COMPOW)	Minimize the total transmission energy while considering retransmission overhead
	Load distribution	• Localized Energy Aware Routing (LEAR) • Conditional Max-Min Battery Capacity Routing (CMMBCR)	Distribute load to energy rich nodes.
Minimize inactive communication energy	Sleep/Power down mode	• SPAN Protocol • Geographic Adaptive Fidelity (GAF)	Minimize energy consumption during inactivity.

Table 3.1 Taxonomy of energy efficient routing protocol

Flow Augmentation Routing (FAR) [15], Online Max-Min Routing (OMM) [16], and Power aware Localized Routing (PLR) [17] protocols fall into this category. Since each node runs the routing algorithm, equivalently the graph optimization algorithm, in a distributed way, it must be supplied with information such as the transmission energy over the wireless link (link cost) and the residual battery energy of the node (reciprocal of node cost). The latter is used to balance the energy consumption by avoiding low energy nodes when selecting a route. The main goal of Minimum Energy Routing

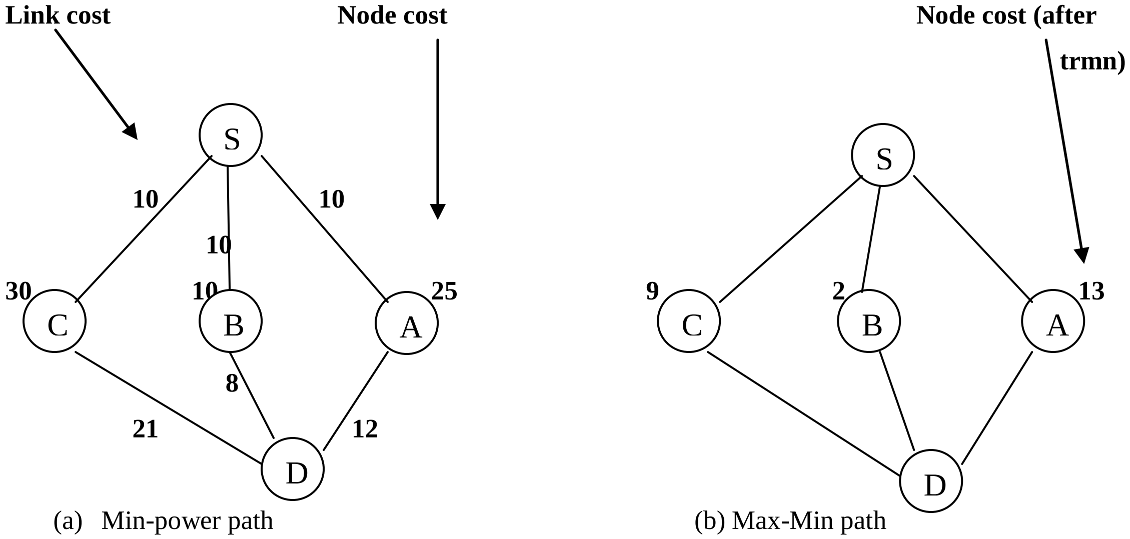
(MER) protocol [18, 19] is not to provide energy efficient paths but to make the given path energy efficient by adjusting the transmission power just enough to reach to the next hop node. Smallest Common Power (COMPOW) protocol [20] presents one simple solution to maintain bi-directionality between any pair of communicating nodes in a MANET.

3.2.1.1 Flow Augmentation Routing (FAR) Protocol

The FAR protocol assumes a static network and finds the optimal routing path for a given source-destination pair that minimizes the sum of link costs along the path. Here, the link cost for link (i,j) is expressed as eij^x1Ei^x2Ri^-x3. , where *eij* is the energy cost for a unit flow transmission over the link and *Ei* and *Ri* are the *initial* and *residual energy* at the transmitting node *i*, respectively, and *x*1, *x*2, and *x*3 are nonnegative weighting factors. A link requiring less transmission energy is preferred. At the same time, a transmitting node with high residual energy that leads to better energy balance is also preferred. Depending on the parameters *x*1, *x*2, and *x*3, the corresponding routing algorithm achieves a different goal. While *eij* and *Ei* are constant for a wireless link (*i, j*), *Ri* continues to drop as communication traffic moves on. An optimal solution at one moment may not be optimal at a later time because *Ri'*s and the corresponding links costs have changed. For this reason, FAR solves the overall optimal solution in an iterative fashion: Solve the optimal route for the first time step, update nodes' residual energy and link costs, and solve another for the next time step, etc. Data generation rate at all nodes during each time step is assumed to be available beforehand.

3.2.1.2 Online Max-Min Routing (OMM) Protocol

The OMM protocol achieves the same goal without knowing the data generation rate in advance. It optimizes two different metrics of the nodes in the network: *Minimizing power consumption (min-power)* and *maximizing the minimal residual power (max-min*). The second metric is helpful in preventing the occurrence of overloaded nodes. Given all link costs, the OMM protocol first finds the optimal path for a given source-destination pair by using the *Dijkstra's algorithm* (*single-source shortest-path algorithm*). This min-power path consumes the minimal power (*Pmin*) but it is not necessarily the max-min path. In order to optimize the second metric, the OMM protocol obtains multiple near-optimal min-power paths that do not deviate much from the optimal value (i.e., less than *zPmin*) and selects the best path that optimizes the max-min metric.



(a) Min-power path (b) Max-Min path

Figure 3.1 Min-power path and max-min path in the OMM protocol.

Figure 3.1 shows an example of the algorithm for a given source (*S*) and a destination (*D*) pair. In Figure 3.1(a), *S→B→D* is the min-power path as it consumes the minimal energy (*Pmin =18*). If *z=2*, alternative paths *S→A→*D (path cost=22) and *S→C→D* (path cost=31) can also be considered since their path costs are within the tolerance range (*zPmin =36*). In order to obtain the max-min path among those three path candidates, the node with the minimal residual power in each path must be compared. In this example, each path contains only one intermediate node and thus their residual energies (nodes *A*, *B*, and *C*) are compared. Node *C* has the residual energy of 30 but it will drop to 9 if that path is used to transfer the packets from *S* to *D*. Similarly, nodes *A* and *B* will have the residual energy of 13 and 2, respectively, a shown in Figure 3.1(b). Therefore, the max-min path among the three min-power paths is *S→A→D*. The parameter *z* measures the tradeoff between the max-min path and the min-power path. When *z*=1, there will not be any alternative path candidate other than the optimal min-power path.

3.2.1.3 Power aware Localized Routing (PLR) Protocol

Routing algorithms based on global information, such as data generation rate or power level information of all nodes (node costs), may not be practical because each node is provided with only the local information. The PLR protocol is an algorithm but it assumes that a source node has the location information of its neighbors and the destination. It is equivalent to knowing the link costs from itself to its neighbors and to the destination. Based on this information, the source cannot find the optimal path but selects the next hop through which the overall transmission power to the destination is minimized. As discussed previously, a direct communication may consume more energy than an indirect communication via intermediate nodes due to the super-linear relationship between transmission energy and distance. In Figure 3.2, when node A has data packets to send to node D, it can either send them directly to D or via one of its neighbors (1, 2, or 3). Note that A to i is a direct transmission while i to D is an indirect transmission with some number of intermediate nodes between i and D. In order to select the optimal route, node A evaluates and compares the power consumption of each distance is known, i.e., $p(d)=ad^\wedge a +c$, where a and c are constants, d is the distance between two nodes. It has been shown that power consumption of indirect transmission is minimized when (n-1) equally spaced intermediate nodes relay transmissions along the two end nodes, and the resultant minimum power consumption is $q(d)^\wedge 2$. Therefore, the node (A), whether it is a source or an intermediate node, selects one of its neighbors (1, 2, or 3) as the next hop node which minimizes $p(|Ai|) + q(|iD|)$.

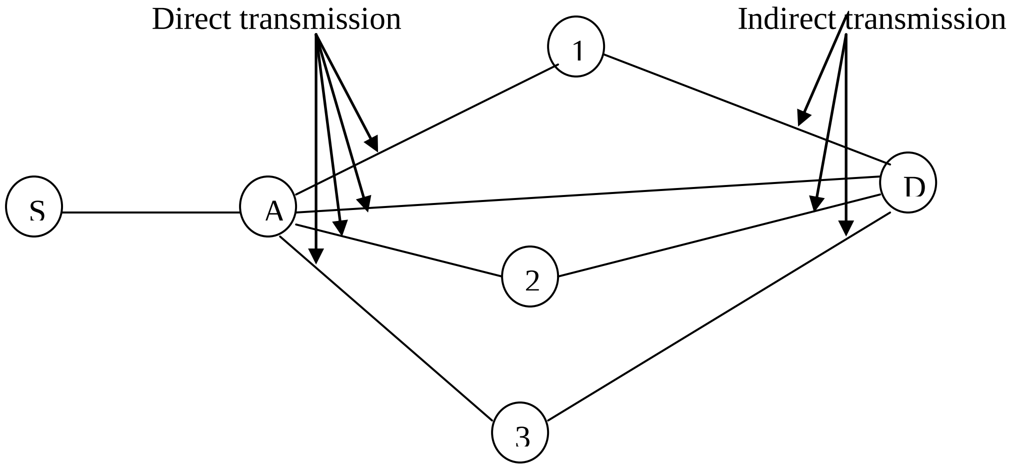
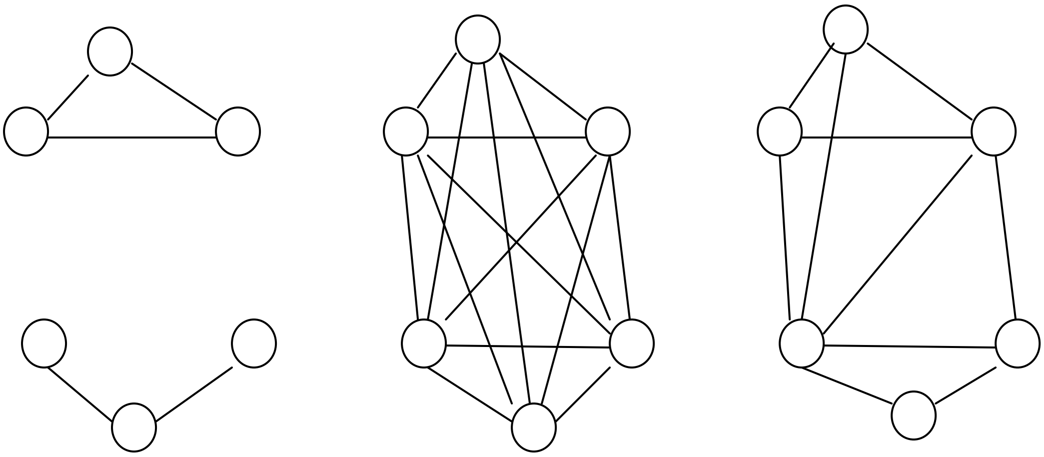


Figure 3.2: Selection of the next hop node in the PLR protocol.

3.2.1.4 *Common Power* (COMPOW) protocol

Smallest Common Power (COMPOW) protocol [20] presents one simple solution to maintain bi-directionality between any pair of communicating nodes in a MANET. This is achieved by having all the nodes in the MANET maintain a common transmission power level (Pi). If Pi is too low, a node can reach only a fraction of the nodes in the MANET as in Figure 3.3(a). If Pi is very high, a node can directly reach all other nodes as in Figure 3.3(b) but results in high energy consumption. In fact, a node can directly or indirectly reach the entire MANET with a smaller Pi as shown in Figure 3.3(c).

Therefore, the optimum power level (*Pi*) is the smallest power level at which the entire network is connected. In COMPOW, it is assumed that the transmission power levels cannot be arbitrarily adjusted but instead it must be selected among a small number of discrete power levels (*P*1, *P*2,. ...., *Pmax*). Different power levels result in different node connectivity since they cover different radio transmission ranges. Each node maintains a routing table as in table-driven routing mechanism, but one for each power level (*RTP*1, *RTP*2, …, *RTPmax*). The number of entries in *RTPi*, denoted as |*RTPi*|, means the number of reachable nodes at *Pi*. This includes directly connected nodes as well as indirectly connected nodes via intermediate nodes. By exchanging these routing tables, nodes find the minimal *Pi* that satisfies |*RTPi*|=*n* for all nodes, where *n* is the total number of nodes in the MANET.



(a) Pi is too low (b) Pi is too high (c) Pi is optimal

Figure 3.3 Proper selection of the common transmission power level in COMPOW.

3.2.2 Load Distribution Approach

The specific goal of the load distribution approach is to balance the energy usage of all mobile nodes by selecting a route with underutilized nodes rather than the shortest route. This may result in longer routes but packets are routed only through energy-rich intermediate nodes. Protocols based on this approach do not necessarily provide the lowest energy route, but prevent certain nodes from being overloaded, and thus, ensures longer network lifetime. This subsection discusses two such protocols: *Localized Energy-Aware Routing (LEAR)* and *Conditional Max-Min Battery Capacity Routing (CMMBCR)* protocols.

3.2.2.1 Localized Energy Aware Routing (LEAR) Protocol

The LEAR routing protocol is based on DSR but modifies the route discovery procedure for balanced energy consumption. In DSR, when a node receives a route-request message, it appends its identity in the message's header and forwards it toward the destination. Thus, an intermediate node always relay messages if the corresponding route is selected. However, in LEAR, a node determines whether to forward the route-request message or not depending on its *residual battery power* (*Er*). When *Er* is higher than a *threshold value (Thr)*, the node forwards the route-request message; otherwise, it drops the message and refuses to participate in relaying packets. Therefore, the destination node will receive a route-request message only when all intermediate nodes along a route have good battery levels, and nodes with low battery levels can conserve their battery power. **[**21**]**

3.2.2.2 Conditional Max-Min Battery Capacity Routing (CMMBCR) Protocol

As in LEAR, the CMMBCR protocol uses the concept of a threshold to maximize the lifetime of each node and to use the battery fairly. If all nodes in some possible routes between a source-destination pair have larger remaining battery energy than the threshold, the min-power route among those routes is selected. If all possible routes have nodes with lower battery capacity than the threshold, the max-min route is selected [22]. However, unlike LEAR, the threshold value is fixed leading to a simpler design.

3.2.3 Sleep/Power-Down Mode Approach

The sleep/power-down mode approach focuses on inactive time of communication. Since most radio hardware supports a number of low power states, it is desirable to put the radio subsystem into the sleep state or simply turn it off to save energy. However, when all the nodes in a MANET sleep and do not listen, packets cannot be delivered to a destination node. One possible solution is to elect a special node, called a *master*, and let it coordinate the communication on behalf of its neighboring slave nodes. Now, slave nodes can safely sleep most of time saving battery energy. Each slave node periodically wakes up and communicates with the master node to find out if it has data to receive or not but it sleeps again if it is not addressed. This subsection introduces three routing algorithms that exploit the radio hardware's low power states. The *SPAN* protocol [23] and the *Geographic Adaptive Fidelity* (GAF) protocol [24] employ the master-slave architecture and put slave nodes in low power states to save energy.

3.2.3.1 SPAN Protocol

To select master nodes in a dynamic configuration, the *SPAN* protocol employs a distributed *master eligibility rule* so that each node independently checks if it should become a master or not. The rule is that *if two of its neighbors cannot reach each other either directly or via one or two masters, it should become a master*. This rule does not yield the minimum number of master nodes but it provides robust connectivity with substantial energy savings. However, the master nodes are easily overloaded. To prevent this and to ensure fairness, each master periodically checks if it should withdraw as a master and gives other neighbor nodes a chance to become a master. Non-master nodes also periodically determine if they should become a master or not based on the master eligibility rule.

3.2.3.2 GAF (Geographic Adaptive Fidelity) Protocol

In GAF protocol, each node uses location information based on GPS to associate itself with a "*virtual grid*" so that the entire area is divided into several square grids, and the node with the highest residual energy within each grid becomes the master of the grid. Other nodes in the same grid can be regarded as redundant with respect to forwarding packets, and thus they can be safely put to sleep without sacrificing the "*routing fidelity*" (or routing efficiency). The slave nodes switch between off and listening with the guarantee that one master node in each grid will stay awake to route packets.

Master election rule in GAF is as follows. Initially, a node is in the discovery state and exchanges discovery messages including grid IDs to find other nodes within the same grid. A node becomes a master if it does not hear any other discovery message for a predefined duration *Td*. If more than one node is in the discovery state, one with the longest expected lifetime becomes a master. The master node remains active to handle routing for *Ta*. After *Ta*, the node changes its state to discovery to give an opportunity to other nodes within the same grid to become a master. In scenarios with high mobility, sleeping nodes should wake up earlier to take over the role of a master node, where the sleeping time *Ts* is calculated based on the estimated time the nodes stays within the grid.

3.3 Summary

In order to facilitate communication within a MANET, an efficient routing protocol is required to discover routes between mobile nodes. Energy efficiency is one of the main problems in a MANET, especially in designing a routing protocol. In this chapter, we surveyed and classified a number of energy aware routing schemes. In many cases, it is difficult to compare them directly since each method has a different goal with different assumptions and employs different means to achieve the goal. For example, when the transmission power is controllable, the optimal adjustment of the power level is essential not only for energy conservation but also for the interference control. When node density or traffic density is far from uniform, a load distribution approach must be employed to alleviate the energy imbalance problem. The sleep/power-down mode approach is essentially independent of the other two approaches because it focuses on inactivity energy. Therefore, more research is needed to combine and integrate some of the protocols presented, to keep MANETs functioning for a longer duration

CHAPTER 4

AN ENERGY EFFICIENT DYNAMIC SOURCE ROUTING

Chapter

4 AN ENERGY EFFICIENT DYNAMIC SOURCE ROUTING PROTOCOL

4.1 INTRODUCTION

Energy efficient routing is very essential in MANET. We have observed the different approaches used to bring energy efficiency in routing. These approaches make them efficient but then also it can’t go beyond a limit. This makes us for the search of new innovative approaches.

4.2 Motivation

Energy efficient routing techniques play a significant role in saving the energy consumption of the network. There are many existing MANET routing protocols as described above, each one is having its own advantages as well as disadvantages. After looking through this existing protocol, we decided to design an energy efficient routing protocol which reduces the total energy consumption in the network and thus maximize the life time of the network. We proposed a new energy efficient dynamic source routing protocol which is based on the minimum-hop fixed-transmit power version of DSR.

4.3 Dynamic Source Routing (DSR)

DSR [25] is a popular flat-on-demand-reactive ad-hoc routing protocol, which benefits from very quick adaptation to routing changes and frequent host movements. Sender of the packet knows the complete sequence of nodes through which packets must pass to the destination. DSR is optimally designed for wireless ad-hoc networks with no periodic router updates and advertisements.

One of the primary characteristics of DSR is that it is a source routing protocol; instead of being forwarded hop by hop, data packets contain strict source routes that specify each node along the path to the destination. Route request (RREQ) and route reply (RREP) packets accumulate source routes so that once a route is discovered, the source learns the entire source route and can place that route into subsequent data packets. The basic mechanism of DSR includes route discovery and route maintenance.

When a node with a route to the destination receives the RREQ, it responds by creating a RREP. If the node is the destination, it places the accumulated source route from the RREQ into the RREP. Otherwise, if the node is an intermediate node, it concatenates its source route to the destination to the accumulated route in the RREQ, and places this new route into the RREP. Hence, in either scenario the message contains the full route between the source and the destination. The source route in the RREP is reversed and the RREP is unicast to the source. Note that as intermediate nodes receive and process the RREP, they can create or update routing table entries to each of the nodes along the source route. When a link break in an established path occurs, the node upstream of the break creates a route error (RERR) message and sends it to the source node.

Route maintenance is the mechanism that enables a node to detect any changes in the network topology such that it cannot send a packet using a route because a link along the route is broken. In DSR, each node transmitting the packet is responsible for confirming that data can flow over the link from that node to the next hop. An acknowledgment provides confirmation that the link is capable of carrying data to the next hop. This type of acknowledgment is provided by the existing MAC layer protocol, (IEEE 802.11). After sending the packet to the next hop, the transmitting node waits for an acknowledgment. If it does not receive an acknowledgment, the transmitting node treats the link to the next hop is ’broken’. It marks all the routes in the route cache that uses that link as ’invalid’. It will return a route error to each node that has sent a packet over that broken link so that all those nodes can update their own route cache as well. After receiving the broken route information from the route error message, the source node tries to find another route from its route cache. If it cannot find any other alternative route available in the cache, it will start another route discovery to find another route for that destination.

Instead of maintaining a route table for tracking routing information, DSR utilizes a route cache. The cache allows multiple route entries to be maintained per destination, thereby enabling multipath routing. When one route to a destination breaks, the source can utilize alternate routes from the route cache, if they are available, to prevent another route discovery. Similarly, when a link break in a route occurs, the node upstream of the break can perform route salvaging, whereby it utilizes a different route from its route cache, if one is available, to repair the route. However, even when route salvaging is performed, a RERR message must still be sent to the source to inform it of the break. Other characteristics that distinguish DSR from other reactive routing protocols include the fact that DSR’s route cache entries need not have lifetimes. Once a route is placed in the route cache, it can remain there until it breaks. However, timeouts, capacity limits, and cache-replacement policies have been shown to improve DSR’s performance. Additionally, DSR nodes have the option of promiscuous listening, whereby nodes can receive and process data and control packets that are not addressed, at the MAC layer, to themselves. Through promiscuous listening, nodes can utilize the source routes carried in both DSR control messages and data packets to gratuitously learn routing information for other network destinations. Finally, to reduce the overhead of carrying source routes in data packets, DSR also allows flow state to be established in intermediate nodes. This flow state effectively allows hop-by-hop forwarding with the same source-based route control as provided by the source route.

4.4 Proposed method

We have proposed an Energy Efficient Dynamic Source Routing (EEDSR) which is based on Transmission power control approach and Load balancing approach. To reduce the transmission energy we are using a hop-by-hop power control mechanism [26] and for load balancing it will select the nodes which are underutilized by avoiding the node which is having the least remaining power. Here during the route discovery phase itself we are calculating the minimum energy required to communicate to the node which sends the request to it. At the same time we observe each nodes remaining power to avoid a route which is having a tendency to die out. The destination node will make a decision about the selection of best route among the multiple requests that reaches to it and sends reply packet to the destination through the selected route. We avoid the additional computations required to find out the route as well as the multiple replies to the source. The minimum energy routing protocol is designed and implemented by making changes in the minimum-hop fixed-transmit power version of DSR.

4.5 Energy Efficient Dynamic Source Routing (EEDSR) Protocol

To obtain an energy efficient routing protocol we uses power control approach and load balancing approach. In our proposed EEDSR, a hop-by-hop power control mechanism is used to adjust the total power consumption of the network. To improve the lifetime of the network we avoid over utilized nodes and instead we select energy rich nodes to take part in routing.

In EEDSR, the route which is having the tendency to break early is detected and avoided by adding a Min_Pow field in the RREQ packet. This Min_Pow field is used to hold the remaining battery power of a node. When a node accepts a RREQ packet from its neighbor it compares the Min_Pow value in the packet with its remaining energy. If the remaining power is less than Min_Pow , this power is assigned as the Min_Pow. This process will continue up to the destination. The destination which accepts more than one RREQ from different route, select the route which is having the highest value in the

Min_Pow field and send RREP to the source. That means we are selecting a route by avoiding the node which is having a tendency to die out. This way we are removing the route which may break early [27].

To save the remaining battery energy we uses a hop-by-hop control mechanism in which the nodes that receives a RREQ at power P_{recv} which transmitted it at P_{trmn} , calculates the new transmission power p_{new} for this receiving node such that this node can communicate with the sender by using this minimum required power P_{new} using:

$$P_{new}=P_{trmn}-P_{recv} + P_{threshold} + P_{margin} \qquad \textbf{(1)}$$

Where $P_{threshold}$ is the required threshold power of the receiving node for successful reception of the packet and P_{margin} is the power included to overcome the problem of unstable links due to channel fluctuations. While sending back the RREP it sends the same power to the sender node and it uses this power for data packet transmission.

The calculated power at each node is stored in a power table and this is the minimum required power for successful transmission and reception. The node rebroadcast the RREQ with maximum power, if it is not the destination. The next hope node also does the same procedure and it will continue up to the destination. The destination node may get more than one RREQ packet from different available route from the source. It will select a route which is having more energy in the RREQ packet so that it can communicate with the destination for a long time. It simply ignores the remaining request packet in the assumption that it cannot live for long time as compared to the selected one. So the selected route doesn’t have a node that may early die out and is an energy efficient one since the hop-by-hop power control. Each pair of nodes in the rout will use the required transmission power for its successful communication. So the destination node will send a RREP packet to the source through the selected route and it reduces the overhead of multiple RREP.

4.6 Analytical proof

Route Discovery process in EEDSR is illustrated in figure 4.1. Node 1 is taken as source and node 5 as the destination. Initially node 1 broadcast RREQ to its neighbor node 2 and node 3. The nodes which received the RREQ packet first time from the source, it adds its remaining power to the Min_Pow field in the RREQ packet. It then rebroadcast the RREQ to its neighbors, if it is not the destination. The next hope which receives the RREQ will check the Min_Pow field value with its remaining energy and if it is less than the Min_Pow field it simply replace the Min_Pow value. Here, node 2 rebroadcast RREQ destination node accept it and will wait for other RREQs. At the same time node 3

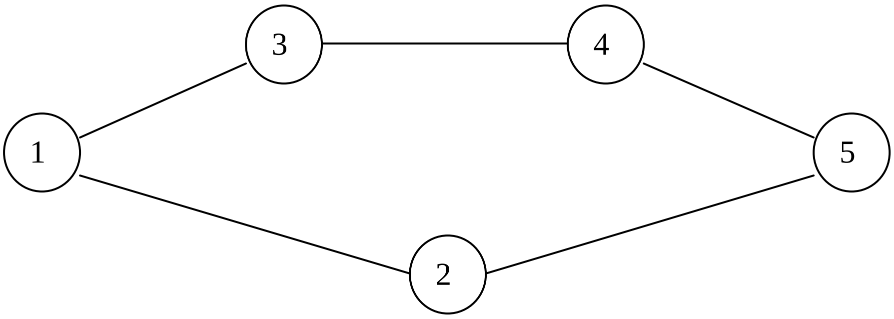


Figure 4.1 Route Discovery in EEDSR

broadcasts to node 4 and it compares the two values and will broadcast to node 5. The destination node now compare the Min_Pow field values of all the RREQs received and select the route which is having highest value in the Min_Pow field. Let us take the remaining power of the nodes 2, 3, 4 as 0.2, 0.3and 0.5 respectively. The destination node will select the route 1-3-4-5 since it is having highest value in Min_Pow field and so the better route among them as per EEDSR. At the same time each node calculates the new transmission power to its successor (from where it received the RREQ) and keeps it in a power table. The destination node 5 selects a route by comparing the Min_Pow values of RREQs accepted from different routes and send a RREP to the source only through the selected path. Source node 1 accepts the RREP from the destination and starts to send data packet to the destination.

CHAPTER 5

SIMULATION RESULT

Chapter

5

SIMULATION RESULTS

5.1 INTRODUCTION

We have done simulation work for our proposed EEDSR in Network Simulator (NS2). The simulation result shows that the proposed method is more efficient than the existing method.

5.2 Network Simulator 2

NS-2 or Network Simulator [28] is a discrete-event simulator whose implementation was started by 1989 with the development of the Real Network Simulator. Initially, NS-2 was focused on the simulation of wired technologies but the Monarch group from the Department of Computer Science at the University of Rice developed the necessary extensions in order to include the software for wireless and mobile hosts. This contribution is widely accepted and it is commonly included in the recent version of ns-2 that can be downloaded from the official site.

The ns-2 employs two languages. Firstly, the main characteristics of the scenario to simulate are described by OTcl. Secondly, the kernel of ns-2 is specified by C++. It is organized in different folders, each one corresponds to an specific protocol. For example, there is a folder called AODV where all the files that are necessary for the implementation of this protocol are stored. If a user wants to utilize the already developed software that is included in the ns-2 release, he will have to know how to specify the scenario by OTcl. However, if some new protocols want to be tested or studied, the inclusion requires the modification of C++ files.

5.3 Simulation Setup

We used DSR version with flow state disabled. We also disabled the tap function. Since the receiving power is constant and a fixed amount of energy is dissipated when a node receives the packet, we set receiving power to zero. The medium access control (MAC) protocol was based on IEEE 802.11 with 2 Megabits per second raw capacity. The 802.11 distributed coordination function used Request-To-Send (RTS) and Clear-To-Send (CTS) control packets for unicast data transmission, and implemented a form of virtual carrier sensing and channel reservation to reduce the impact of hidden terminal problem. Data transmission was followed by an ACK. For radio propagation model, a two-ray path loss model was used. The traffic sources were Constant Bit Rate (CBR) with 512 bytes per packet. A static scenario of 2 mobile nodes was randomly distributed initially in an area of 200m by 200m (a square area). The source and destination pairs were spread randomly over the network but the numbers of pairs were kept constant during each scenario. Each CBR source started randomly at the beginning 0 to 10 seconds of the simulation and each simulation was run for 250 seconds. The number of connections was 2 in our case. We measured total energy consumptions of the nodes at the end of simulation.

Parameter	Value
Transmission range	60-250 m
Simulation time	56
Topology size	200 x 200
Number of nodes	2
Traffic type	CBR
Packet size	512 bytes
Rate	1 Mb

Table 5.1 General parameters used in simulation

5.4 Simulation Result

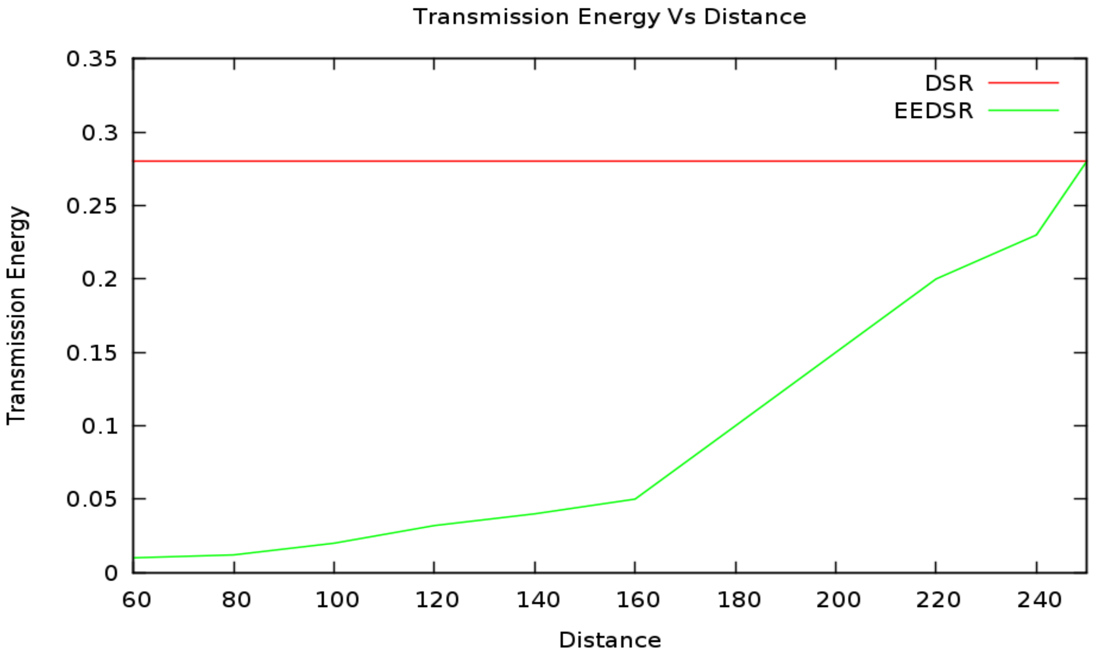


Figure 5.1 Transmit power variation Vs distance

Simulation result shows that the proposed scheme uses transmission power according to the distance. If the distance is less, transmission power used is also less.

CHAPTER 6

CONCLUSION AND FUTURE WORK

Chapter

6 CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

We have studied MANETs, its properties and challenges in the Routing. We also studied the different types of routing and its properties. We studied and analyzed DSR algorithm and proposed a method to make it energy efficient.

We analyzed our new proposed EEDSR and the simulation results shows that the performance is better than DSR. We concluded EEDSR works far better than DSR in giving more lifetimes to the network.

6.2 FUTURE WORK

We used hop-by-hop power control for making the EEDSR to be more efficient. Load balancing approach is also used to avoid over utilized nodes. We will use our proposed algorithm in other efficient protocols also

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