

ENERGY EFFICIENT ROUTING PROTOCOL FOR MANETS

By

SHIVAM KAPOOR *

RAJESH KUMAR **

* Research scholar, Thapar University, Patiala, Punjab, India.

** Head of Department, School of Mathematics and Computer Applications, Thapar University, Patiala, Punjab, India.

ABSTRACT

In 1990's, Mobile Adhoc networks have been widely researched for many years. Mobile Ad-hoc Networks are a collection of two or more devices equipped with wireless communications and networking capability. These devices can communicate with other nodes that are within their radio range or one that is outside their radio range. For the latter, the nodes should select an intermediate node to be the router to forward the packets from the source to the destination. In MANETs, every node can act as the gateway. In this dissertation, focus is laid on energy efficiency. There are many routing protocols in MANETs like DSDV, DSR and AODV etc. and each one has its own approach for dissemination of data packets in MANETs. But these routing protocols are less energy efficient. The aim of this dissertation is to design a routing protocol which would be better than the existing ones in terms of energy utilization and delivery ratio. In this dissertation, an energy efficient routing protocol has been proposed which uses Dijkstra's algorithm as a fundamental algorithm to route the nodes to their intended destination and a comparison is laid between the proposed protocol, AODV, DSDV and DSR, and the performance measures are evaluated.

Keywords: Energy, MANETs, Protocol, Efficiency, Routing, Packets, Delivery ratio.

INTRODUCTION

Deployed in 1990's, Mobile Adhoc networks have been widely researched for many years [3]. Among all the contemporary wireless networks, Mobile Ad hoc Networks (MANETs) is one of the most important and unique applications [5, 10]. Mobile Ad-hoc Networks is a collection of two or more devices equipped with wireless communications and networking capability. These devices can communicate with other nodes that are within their radio range or one that is outside their radio range. For the latter, the nodes should deploy an intermediate node to be the router to route the packet from the source toward the destination. The Wire-less Ad-hoc Networks do not have gateway, every node can act as the gateway. Although since 1990s' lots of research has been done on this particular field, it has been questioned as to whether the architecture of Mobile Adhoc Networks is fundamental flawed architecture. The main reason for the argument is that Cellular Networks are almost never used in practice, almost every wireless network nodes communicate to base station and access points instead

of co-operating to forward packets hop-by-hop.

Mobile Adhoc Network (MANET) is a collection of independent mobile nodes that can communicate with each other via radio waves. The mobile nodes that are in radio range of each other can directly communicate, whereas others need the aid of intermediate nodes to route their packets. These networks are fully distributed, and can work at any place without the help of any infrastructure. Figure 1 shows view of MANETs [1].

Following are the characteristics of MANETs [2]

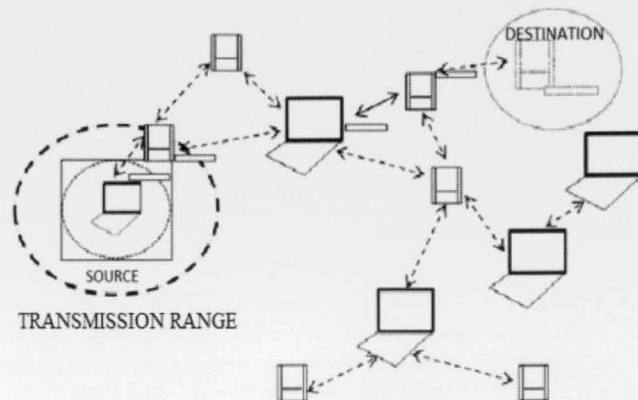


Figure 1. View of Mobile Adhoc Networks [1]

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- Communication via wireless means.
- Nodes can perform the roles of both hosts and routers.
- No centralized controller and infrastructure.
- Intrinsic mutual trust.
- Dynamic network topology.
- Exile
- Robust

1.1 Research Issues and Challenges in MANETs

The emergence of MANETs has made a tremendous impact on IT industry over the past few years. MANETs provide cheap, flexible and reliable ways of computing to IT industry. MANETs are in initial stage, with many issues still to be addressed [8, 17].

- *Routing*: Since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Most protocols should be based on reactive routing instead of proactive. Multi cast routing is another challenge because the multi cast tree is no longer static due to the random movement of nodes within the network. Routes between nodes may potentially contain multiple hops, which are more complex than the single hop communication.
- *Security and Reliability*: In addition to the common vulnerabilities of wireless connection, an ad hoc network has its particular security problems due to nasty neighbor relaying packets. The feature of distributed operation requires different schemes of authentication and key management. Further, wireless link characteristics also causes reliability problems, because of the limited wireless transmission range, the broadcast nature of the wireless medium (e.g. hidden terminal problem), mobility induced packet losses, and data transmission errors.
- *Quality of Service (QoS)*: Providing different quality of service levels in a constantly changing environment will be a challenge. The inherent stochastic feature of communications quality in a MANET makes it difficult to offer fixed guarantees on the services offered to a device. An adaptive QoS must be implemented over the

traditional resource reservation to support the multimedia services.

- *Inter-networking*: In addition to the communication within an ad hoc network, inter-networking between MANET and fixed networks (mainly IP based) is often expected in many cases. The coexistence of routing protocols in such a mobile device is a challenge for the harmonious mobility management.
- *Power Consumption*: For most of the light-weight mobile terminals, the communication-related functions should be optimized for lean power consumption. Conservation of power and power-aware routing must be taken into consideration.
- *Multicast*: Multicast is desirable to support multiparty wireless communications. Since the multicast tree is no longer static, the multicast routing protocol must be able to cope with mobility including multicast membership dynamics (leave and join).

1.2 Research Motivation

The nodes in the Mobile Adhoc Networks are normally power curb because of their dependency on power. In wireless communication, especially in MANETs, remarkable amount of energy is consumed not only in transmission among the nodes, but also in overhearing of the packets sent from other nodes [4]. As green computing is emerging, it is required to formulate a routing protocol which is energy-efficient. One of the most important objectives of MANETs routing protocols is to maximize energy efficiency, since nodes in MANETs depend on limited energy resources. The possible energy consumption states are: transmit, receive, idle and dead.

The main objectives of MANETs routing protocols are to maximize throughput (network), energy efficiency, network lifetime and to minimize the delay. The network throughput is usually measured by packet delivery ratio, while the most significant contribution to energy consumption is measured by routing overhead which is the number or size of routing control packets.

2. Related Work

"Routing is the process of information exchange from one host to the other host in a network." [3]. Routing is the

mechanism of forwarding packet towards its destination using most efficient path. The primary objectives of MANET routing the protocols are to maximize network throughput, to maximize energy efficiency, maximize network lifetime, and to minimize delay. The network throughput is usually measured by packet delivery ratio, while the most significant contribution to energy consumption is measured by routing overhead, which is the number or size of routing control packets. In order to achieve Quality of Service (QoS), several routing models have been proposed. Routing protocol for ad-hoc network can be categorized into two strategies.

- Pro- active routing protocol.
- Re- active routing protocol.

2.1 Proactive routing protocol

In proactive routing scheme, every node continuously maintains complete routing information of the network. This is achieved by flooding network periodically with network status information to find out any possible change in network topology. Current routing protocols like Link State Routing (LSR) protocol (open shortest path first) and the Distance Vector Routing Protocol (Bellman-Ford algorithm) are not suitable to be used in mobile environment.

Destination Sequenced Distance Vector (DSDV) routing protocol and Optimized Link State Routing (OLSR) protocol were proposed to eliminate counting to infinity and looping problems of the distributed Bellman-Ford algorithm and widely used in mobile environment [12].

2.1.1 Destination Sequenced Distance Vector Routing

This protocol is based on classical Bellman-Ford routing algorithm [7, 14] designed for MANETs. Each node maintains a list of all destinations and number of hops to each destination. Each entry is marked with a sequence number. It uses full dump or incremental update to reduce the network traffic generated by route updates. The broadcast of route updates is delayed by settling time. The only improvement made here is avoidance of routing loops in a mobile network of routers. With this improvement, routing information is always available, regardless of whether the source node requires the

information or not. With the addition of sequence numbers, routes for the same destination are selected on the basis of following rules [1]:

- A route with a newer sequence number is preferred.
- If the two routes have a same sequence number, the one with a better cost metric is preferred.

The routing table of DSDV maintains the following list of fields as shown in Table 1 :

The sequence number is used to distinguish stale routes from new ones and thus it avoids the formation of loops. The stations periodically transmit their routing tables to their immediate neighbours. A station also transmits its routing table, if a significant change has occurred in its table from the last update sent [16]. So, the update is both time-driven and event driven.

Each row of the sent update is of the following form:

<Dest. IP address, Dest. Sequence number, Hop count>

After receiving an update, neighbouring nodes utilize it to compute the routing table entries. This resolves the route failure of DSDV [9].

Destination	Next Hop	No.of Hops	Sequence No.	Install Time
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Table 1. Fields of DSDV routing protocol

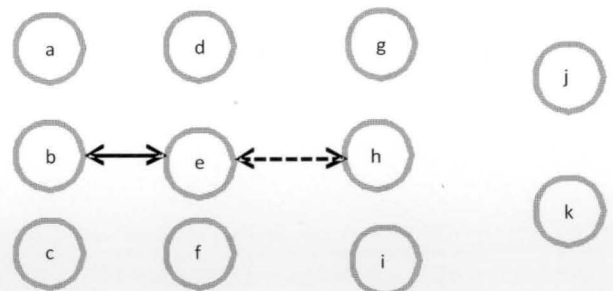


Figure 2. Link from e to h breaks [9]

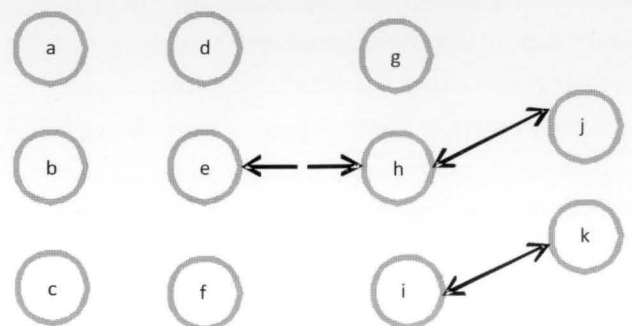


Figure 3. A broadcast request to the neighbours [9]

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Figure 2 shows that link between e and h has broken. Figure 3 shows that a broadcast request has been made to the neighbors to update the routing tables. Figure 4 shows that new links have been established.

2.2 Reactive routing protocol

Every node in this routing protocol maintains the information of only active paths to the destination nodes. A route search is needed for every new destination, therefore, the communication overhead is reduced at the expense of delay to search the route. Rapidly changing wireless network topology may break the active route and cause subsequent route search [6, 11]. Most effective routing protocols are AODV and DSR.

2.2.1 Adhoc On demand Distance Vector (AODV)

Ad hoc On-demand Distance Vector Routing (AODV) is an improvement of the DSDV algorithm discussed in section 2.1.1. AODV minimizes the number of broadcasts by creating routes on-demand as opposed to DSDV that maintains the list of all the routes [15, 16].

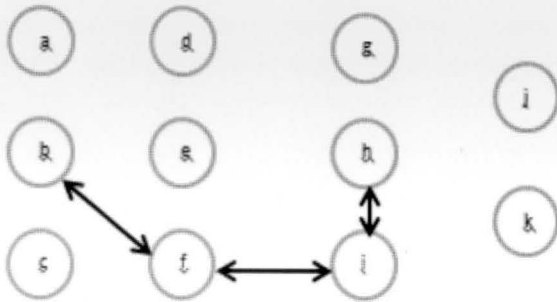


Figure 4. Link Established [9]

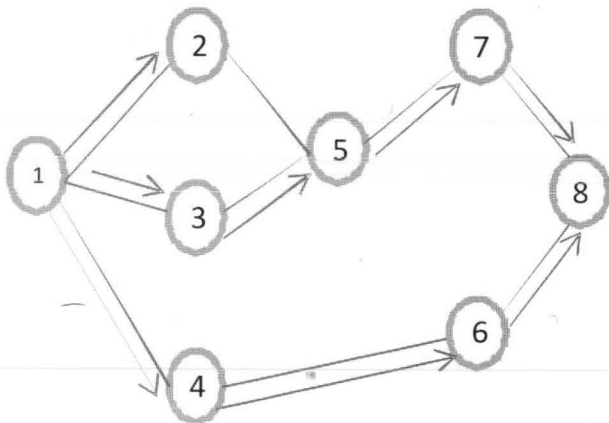


Figure 5. Propagation of route Requests (RREQ) Packets [18]

To find a path to the destination, the source broadcasts a route request packet [7, 13]. The neighbours in turn, broadcast the packet to their neighbours till it reaches an intermediate node that has recent route information about the destination or till it reaches the destination shown in Figure 5 [17]. A node discards a route request packet that has already been seen. The route request packet uses sequence numbers to ensure that the routes are loop free and to make sure that if the intermediate nodes reply to route requests, they reply with the latest information only [6, 14].

When a node forwards a route request packet to its neighbours, it also records in its tables, the node from which the first copy of the request came. This information is used to construct the reverse path for the route reply packet. AODV uses only symmetric links because the route reply packet follows the reverse path of route request packet. As shown in Figure 6, the route reply packet traverses back to the source [18], and the nodes along the path enter the forward route into their tables. If the source moves, then it can reinitiate route discovery to the destination. If one of the intermediate routing nodes move, then the moved nodes' neighbour realizes the link failure and sends a link failure notification to its upstream neighbours and so on, till it reaches the source upon which the source can reinitiate route discovery, if needed.

2.2.2 Dynamic Source Routing (DSR)

The Dynamic Source Routing Protocol is a source-routed on-demand routing protocol. A node maintains route caches containing the source routes that it is aware of. The

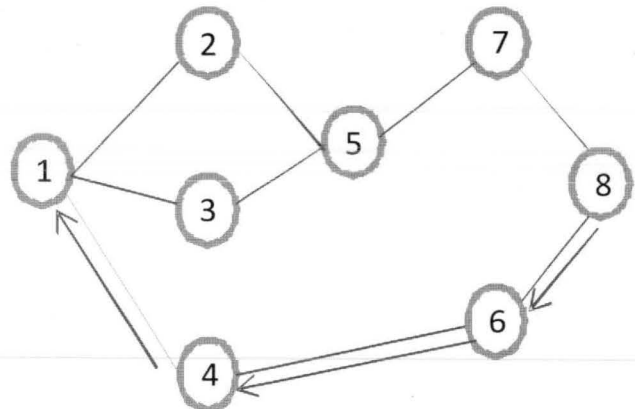


Figure 6. Path taken by the Route Reply (RREP) Packets [18]

node updates entries in the route cache as and when it learns about new routes.

The two major phases of the protocol are: route discovery and route maintenance [7, 14]. When the source node wants to send a packet to a destination, it looks up its route cache to determine if it already contains a route to the destination. If it finds that an unexpired route to the destination exists, then it uses this route to send the packet. But if the node does not have such a route, then it initiates the route discovery process by broadcasting a route request packet. The route request packet contains the address of the source and the destination, and a unique identification number [15, 16]. Each intermediate node checks whether it knows of a route to the destination. If it does, it appends its address to the route record of the packet and forwards the packet to its neighbors. To limit the number of route requests propagated, a node processes the route request packet only if it has not already seen the packet and its address is not present in the route record of the packet.

A route reply is generated when either the destination or an intermediate node with current information about the

destination receives the route request packet. A route request packet reaching such a node already contains in its route record, the sequence of hops taken from the source to this node. Figure 7 [18] shows the building of route during route discovery and Figure 8 [18] shows the propagation of route reply with the route record.

3. Proposed Work

As green computing is emerging, it is required to formulate a routing protocol which is energy efficient. Here, a new routing algorithm has been articulated which has been observed to be an energy efficient technique. The research work has been classified into three cases based on the number of nodes. First case when $n = 20$, second case when $n = 25$, third case when $n = 50$.

3.1 Assumptions and System Models

- *Transmission Energy*

Energy required for transmission of packets. It is denoted by E_t . Here, the value of transmission energy is assumed as $E_t = 0.32$.

- *Processing Energy*

Energy required for processing of packets. It is denoted by E_p . Here, the value of processing energy is assumed as $E_p = 0.25$.

During routing $E_t > E_p$

Also transmission energy and processing energy of each node would be same, as the network is homogenous.

- *Total Energy*

Total energy is denoted by T.E. Total energy for all the intermediate nodes is taken as T.E. = 10 Joules. For source node and destination node, it is taken to be T.E. = 50 Joules.

- *Energy Utilized*

While transmission of data packets, energy utilized at each node = number of data packets each node can handle * (Transmission energy + processing energy) i.e.

$$E.U = n * (E_t + E_p)$$

$$E.U. = n * (0.32 + 0.25)$$

- *Remaining Energy*

The remaining energy of each node would be E.R. = Total

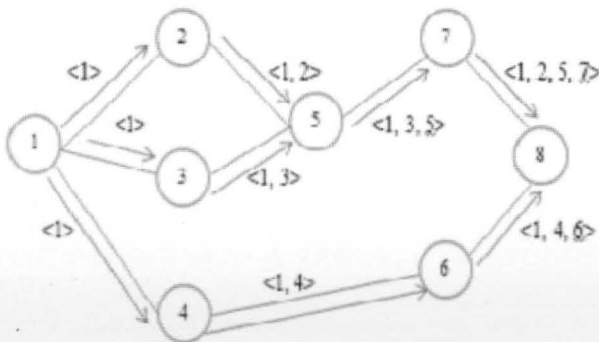


Figure 7. Building Record Route during Route Discovery [18]

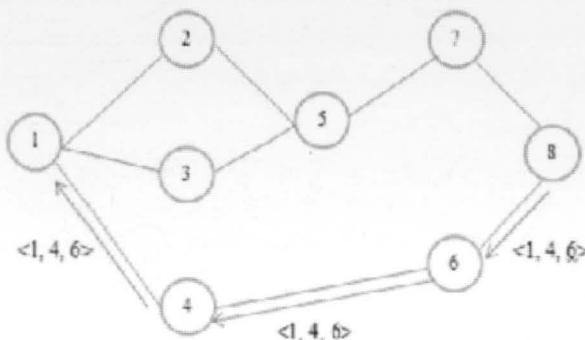


Figure 8. Propagation of Route Reply with the Route Record [18]

energy – Energy utilized i.e.

$$T.E. - E.U. = 10 - n * (0.57)$$

- *Maximum Packets*

Maximum number of packets which each node can handle without failure when number of nodes is 10 has been calculated as shown below:

$$10 - n * (0.32 + 0.25) = 0$$

comes out to be ≈ 17 . So if a node tries to handle equal to or greater than 17 packets, it would be considered as dead node in the network. Also, the total amount of data that can be simultaneously transmitted for one hop increases linearly with the total area of the ad hoc network.

- *System Model*

The routing algorithm proposed in this thesis has been designed using Dijkstra's Algorithm for graphs. First of all, energy utilization of each mobile node of the Mobile Adhoc Network has been calculated as described above. Also, an incidence matrix $edge[][]$ is created for the network connectivity. Now for two nodes i, j if an edge exist, then $edge[i][j] = 1$. The energy utilization for each nodes would become the weight of the edges, i.e. for two node i, j , $w[i][j] = E.U.$ Let $S1$ be our source node and let $S2$ be our destination node. Now, using the above parameters, path from $S1$ to $S2$ with minimum energy utilization has been calculated.

After calculating the path, we would number the packets routed from source to destination which actually reached destination (say P). Total number of packets in to the network from source was (say Q). So delivery ratio would be as follows:

Delivery ratio (D) = Packets actually reaching destination/total number of packets.

$$D = P/Q$$

Here, dynamic network topology for mobile nodes has been created. Connectivity of the network has been shown using the incidence matrix. After calculating the energy utilization (E.U.) for each node, the values are stored in array $E.U[][]$. Also, number of packets that each node can handle successfully was calculated and stored in an array $Packets []$. Now a text file "Data.txt" has been

created and the following data was written into it using the commands available for file handling. Data written in text file are number of nodes (n), the end points for all the edge connections between various nodes based on incidence matrix, the energy utilization array $E.U []$ and number of packets stored in array $Packets []$. Table 2 shows the Number of Nodes and Corresponding Pause Time for EEUR.

Now the entire data from the text file Data.txt was read and using it we have calculated the shortest path for the dynamic network. Actually, Dijkstra's technique is the basis to calculate the shortest path from source to destination using energy utilization (E.U.) as an optimization parameter for each node. Number of edges gets stored in a variable named e . End points for all edges goes into variables u, v and correspondingly, energy utilized gets stored in a static 2_D array say $energyutil [u][v]$, number of packets gets stored in $packets []$ array. User specifies the source (say S) which wants to send the data packets and would start the connection and destination (say D) which would receive the data packets. Now we pass source (S), destination (D) and $energyutil[][]$ array to our shortest energy path function named $shortest(int S, int D, float energyutil [][])$. Table 3. shows the Number of Nodes and Corresponding Pause.

Now here $energyutil [][]$ will act as the initial weights of the graph and S as the source. The final values of energies get stored in an array $energy []$.

3.2 Proposed Algorithm

Initially $energy [] = \infty$ and $energy[s] = 0$. Integers i, k , mini are variables whose value changes while program gets executed.

Visited $[]$ is an integer array. Its value is either 0 or 1

Number of nodes (n)	Pause time (Pt)
20	400 ms
25	625 ms
50	2500 ms

Table 2. Number of Nodes and corresponding Pause Time for EEUR

Number of nodes (n)	Pause time (Pt)
20	11.7639 ms
25	15.8002 ms
50	38.4052 ms

Table 3. Number of Nodes and corresponding Pause Time partition based Speed-Up of Dijkstra's scheme

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depending upon whether the element has been visited or not. For example: Visited [i] = 0, if i-th element has not been visited.

Pathindex [] array stores the indices of the mobile nodes in increasing order of their energy utilization value after shortest path algorithm is called.

Pathfinal [] stores the shortest path from source to destination.

Edge [][] carries either value 1 or 0, 1 where there is an edge between the two vertices and 0 if there is no edge between them.

Experimental results show that this approach gives better results in term of energy efficiency as compared to other approaches. Hence, this approach has been used in our algorithm for extracting energy efficient solution. For reliable and energy efficient execution of routing in MANETs the technique proposed by us in this thesis is very effective.

```

For each i ← 0 to n do
    energy[i] ← ∞.
    visited[i] ← 0
End loop.
energy[] = 0.
For each k ← 0 to n do
    mini ← -1
    For each l ← 0 to n
        If !(visited[l]) && ((mini == -1) || (d[l] < d[mini]))
do
            mini = l.
        End if
    visited[mini] = 1
    End for.
For each l ← 0 to n do
    if energyutil[mini][l]
    If energy[mini] + energyutil[mini][l] < energy[l]
        energy[l] ← energy[mini] + energyutil[mini][l].
    End if.
    End if.

```

End for

End for.

The running time complexity for the algorithm varies from $O(n \cdot \lg(n))$ in best case to $O(n^2)$ in average case. Here, the running time complexity is $O(n^2)$.

Pause Time:

Time taken for the system to compute the shortest path is called pause time. In our case, it is $O(n^2)$ where n is the number of nodes and the pause time is directly proportional to square of n i.e. Pause time (Pt) $\propto n$. Table 3 shown the pause time for n = 20, 25 and 50.

We can further optimize our code and reduce the pause time to $k \cdot n(\lg(n))$ by Partition-Based Speed-Up of Dijkstra's Algorithm where k is a small constant (say 0.4521).

Clearly, Partition Based Speed – Up of Dijkstra's Algorithm lead to a factor 34 improvement of time.

Now array energy carries the minimum energy values. Now based on the values energy[], the shortest path for transmitting data packets is calculated and stored in an array path[]. The array path [] will hold the shortest path. dest is an integer variable which carries the destination node value. In order to calculate the shortest path, first of all we sort array energy and store the result in a new array sortenergy. Next, we compare the value of energy with the values of sortenergy and check the index in the former array and store them in the array path []. Now we check elements of new path in consecution to check whether they are connected or not. If any of them is not connected, we will delete that element. This result will get stored in pathnew[] array and we will get our shortest path. Here, we have taken the node which is farthest from the root i.e. the node at position n as the destination node, dest = n. The pseudo code is as follows:

```

sortenergy[] ← insertion sort(energy[]).
k ← 0.
Temp ← sortenergy[0].
For each i ← 0 to n - 1 do
    If !(temp == sortenergy[i] && i > 0) do
        For each j ← 0 to n - 1 do
            If sortenergy[i] == energy[j] do

```

```

        pathindex[k]←j.
        k←k+1.
    End if.
End for
End if
End for
i←0 and k←1
pathindex[i1]←pathfinal[i]
a←pathindex[i]
i←i+1
b←pathindex[i]
while pathindex[i1]≠pathindex[n]
    if edge[a][b]=1 then
        pathindex[i1]←b
        i1←i1+1
        a←b
        i←i+1
        b←pathindex[i]
    else
        i←i+1
        b←pathindex[i]
    End if else
End while
if edge[pathfinal[i1-1]][pathindex[n-1]]=1 then
    pathindex[i1]=path[n-1]
else do
while(edge[pathfinal[i1-1]][pathindex[n-1]]≠1)
    i1=i1-1
End while.
End if else.
pathfinal[i1]=pathindex[n-1]
end.

```

Hence, we got the shortest path too. The process for routing the packets described above concerns majorly with energy utilization of nodes for transmitting and processing the packets and route them to a destination node. Hence it would be called Energy Utilization Unicast

routing protocol (E.E.U.R.).

4. Performance Analysis

4.1 Tools for Creating Simulated Network

We have used Network Simulator 2.35 (NS 2.35) for creating a network environment to analyse our proposed algorithm.

4.1.1 Network Simulator NS 2 [19]:

The Network Simulator 2.35 (NS 2.35) is a discrete event driven simulator developed at UC Berkeley. It is part of the VINT project. The goal of NS 2.35 is to support networking research and education. It is suitable for designing new protocols, comparing different protocols and traffic evaluations. NS 2.35 is developed as a collaborative environment. It is distributed freely and as open source [20]. A large amount of institutes and people in development and research use, maintain and develop NS 2.35. NS 2.35 can run under both UNIX and Windows operating systems. There are many components needed to be installed before running NS 2.35. The user can choose to install it partly or completely. For beginners, it is suggested to make a complete installation which automatically installs all necessary components at once and it requires 320 MB disk space. Installing it partly could save some disk space.

4.1.1.1 Scenario Generation

- This is done using the setdest command. There are two versions for setdest. Version 2 is most recently implemented and used.
- Version 2 signature of setdest command is setdest -v <2> -n <nodes> -s <speed type> -m <min speed> -M <max speed> -t <simulation time> -P <pause type> -p <pause time> -x <max X> -y <max Y>
- -v version number; Here 2
- -n number of nodes. Generated node number will be 0 to (n-1)
- -s speed type (uniform, normal); s=1 uniform speed from min to max; s=2 normal speed clipped from min to max
- -m minimum speed > 0

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- M maximum speed
- -P pause type (constant, uniform); P=1 constant pause; P=2 uniform pause [0, 2*p]
- -p pause time (a median if uniform is chosen)
- -x x dimension of space
- -y y dimension of space

After running the command a scenario will be generated.

Example: `setdest -v 2 -n 10 -m 10 -M 100 -t 20 -P 1 -p 10 -x 200 -y 400 > scen-exp1`

4.1.1.2 Cbr Traffic Generation

This is done with the help of `cbrgen.tcl` file executing with `ns` command

- Open terminal in `~ns-allinone-2.31/ns-2.31/indep-utils/cmu-scen-gen`
- `ns cbrgen.tcl [-type cbr|tcp] [-nn nodes] [-seed seed] [-mc connections] [-rate rate]`
- -type traffic type (tcp, udp/cbr)
- -nn the highest node number (node number will be 0 to nn)
- -seed seed for random variable generation which is used to create random number of source-destination pair
- -mc maximum number of connections; i.e.; source-destination pair
- -rate it is the inverse of the interval between packet transmission & should be < 0

After running the command, a cbr traffic will be generated.

Example: `ns cbrgen.tcl -type cbr -nn 9 -seed 1 -mc 10 -rate .25 > cbr-exp1`

4.1.1.3 Trace Generation

Paste the tcl file to the `~ns-allinone-2.31/ns-2.31/tcl/ex` directory

- Open terminal in `~ns-allinone-2.31/ns-2.31/tcl/ex`
- Execute command `ns <tclscript>`
- Example: `ns sample.tcl`

If the simulation is successful, the desired trace file will be generated.

4.1.1.4 Animation: NAM File Generation

Animation is generated using a nam trace file. The nam trace file should contain topology information like nodes, links, queues, node connectivity etc. as well as packet trace information.

5. Results

Graphs for DSR, DSDV, AODV and proposed algorithm (EEUR) have been plotted and compared on the basis of parameters such as:

Packets Sent for Route discovery during packets and Packets Received during Route Discovery

- Data Sent
- Data Received
- Delivery Ratio
- Energy consumed during Routing
- Energy Efficiency during Routing

5.1 Parameter: Packets Sent during Route Discovery and Packets Received during Route Discovery

Table 4 shows comparison between the protocols laid on the basis of packets sent during route.

Here, the proposed protocol is more of a proactive protocol which does not send packets for route discovery and hence the time is saved. So, EEUR is outperforming

PROTOCOL/NODE	20	25	50
S			
AODV	1224	1729	168
DSDV	0	0	0
DSR	27	13	15
EEUR	0	0	0

Table 4. Comparison on the basis of Packets Sent during Route Discovery

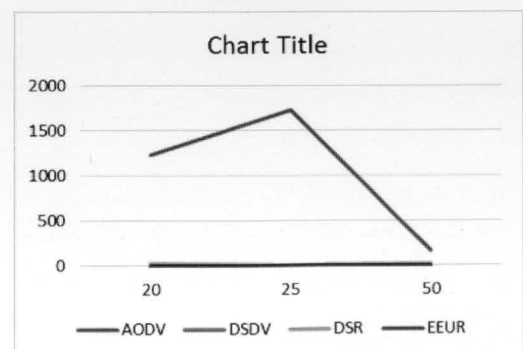


Figure 9. Packets Sent during Route discovery

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the other three routing protocols. Figure 9. shows the Packets Sent during Route discovery.

Following Table 4 shows comparison between the protocols laid on the basis of packets received during route discovery.

Here, the proposed protocol is more of a proactive protocol which does not receive packets for route

PROTOCOL/NODES	20	25	50
AODV	1873	3471	597
DSDV	0	0	0
DSR	84	47	319
EEUR	0	0	0

Table 5. Comparison on the basis of Packets Received during Route Discovery

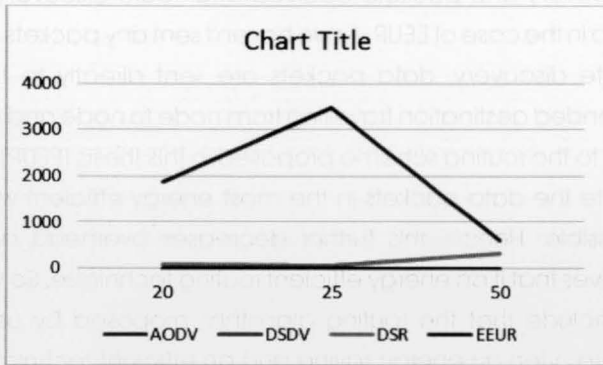


Figure 10. Packets Received during Route Discovery

PROTOCOL/NODES	20	25	50
AODV	1065	1070	25
DSDV	1076	219	449
DSR	84	47	21
EEUR	357	750	1490

Table 6. Comparison on the basis of Data Sent

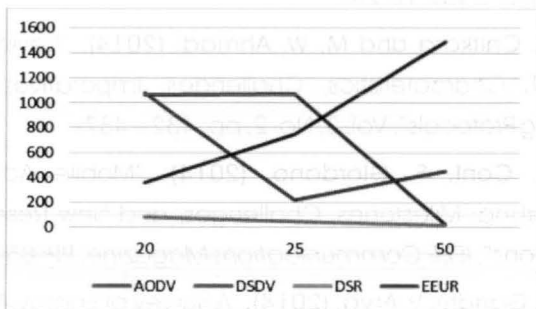


Figure 11. Data Sent

PROTOCOL/NODES	20	25	50
AODV	156	190	1
DSDV	48	16	23
DSR	16	20	1
EEUR	159	290	1000

Table 7. Comparison on the basis of Data Received

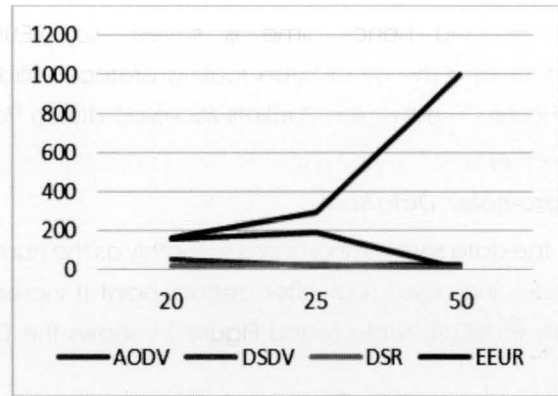


Figure 12. Data received

PROTOCOL/NODES	20	25	50
AODV	14.6	17.5	4
DSDV	4.46	7.3	5.12
DSR	44.4	83.3	4.76
EEUR	44.53	38.67	67.11

Table 8. Comparison on the basis of Delivery Ratio

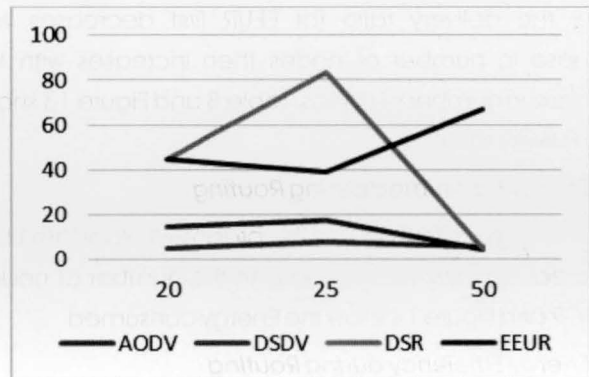


Figure 13. Delivery Ratio

PROTOCOL/NODES	20	25	50
AODV	535	320	110
DSDV	570	585	300
DSR	550	425	195
EEUR	67.26	169.14	303.24

Table 9. Comparison on the basis of Energy Consumed during Routing

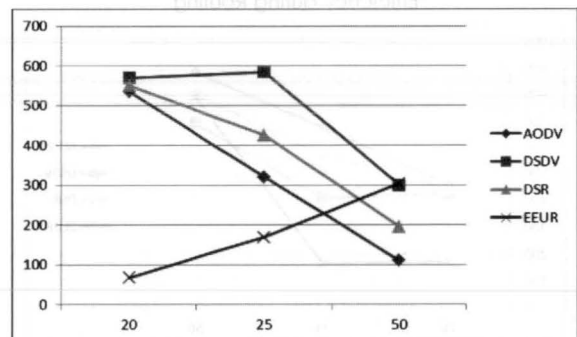


Figure 14. Energy Consumed

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discovery and hence time is saved. So, EEUR is outperforming the other three routing protocol. Table 5 and Figure 10 shows the Packets received during Route Discovery.

5.2 Parameter: Data Sent

Here, the data sent first increases smoothly as the number of nodes increases, but after certain point it increases sharply for EEUR. Table 6 and Figure 11 shows the Data sent.

5.3 Parameter: Data Received

Here, the data received first increases smoothly as the number of nodes increases, but after certain point, it increases sharply for EEUR. Table 7 and Figure 12 show the Data received.

5.4 Parameter: Delivery Ratio

Here, the delivery ratio for EEUR first decreases with increase in number of nodes then increases with the increase in number of nodes. Table 8 and Figure 13 shows the Delivery ratio.

5.5 Energy Consumed during Routing

Here, energy consumed for the proposed algorithm EEUR is increasing fairly with increase in the number of nodes. Table 9 and Figure 14 show the Energy consumed.

5.6 Energy Efficiency during Routing

In Figure 15, energy efficiency for the proposed routing

PROTOCOL/NODES	20	25	50
AODV	465	680	890
DSDV	430	415	700
DSR	450	575	805
EEUR	172.74	169.14	796.76

Table 10. Comparison on the basis of Energy Efficiency during Routing

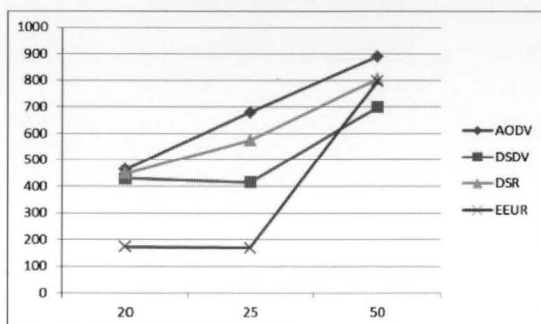


Figure 15. Energy Efficiency

algorithm remains constant till number of nodes =25, then energy efficiency increases with increase in the number of nodes. Table 10 shows the comparison based on energy efficiency during routing.

Conclusion

From the above results based on the analysis of the four routing protocols i.e. AODV, DSDV, DSR AND EEUR, it is clear that the value of delivery ratio which is data received/data sent is relatively better for the routing algorithm proposed by us (EEUR) in this thesis as compared to the other three. Since none of the routers failed, the value of router drop is zero for all cases. The value of packet sent for route discovery and packets received after route discovery is zero in the case of EEUR. As we haven't sent any packets for route discovery, data packets are sent directly to the intended destination travelling from node to node and it is left to the routing scheme proposed in this thesis (EEUR) to route the data packets in the most energy efficient way possible. Hence, this further decreases overhead and proves that it an energy efficient routing technique. So we conclude that the routing algorithm proposed by us is more often an energy saving and an efficient technique for routing the data packets in MANET.

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ABOUT THE AUTHORS

Shivam Kapoor is currently working as an Associate Consultant in Oracle Financial Services Software Pvt. Ltd. He has obtained his B.Tech (computer science and engineering) at Kurukshetra University, Haryana in 2012. M.Tech (computer science and application) at Thapar University in 2014. His research interests include Mobile Adhoc Networks, Energy Efficiency in MANETS, Data Base Management Systems, Software Engineering, and ASP.NET with C #and Java Core.



Dr. Rajesh Kumar is currently working as an Associate Professor in School of Mathematics and Computer Application. He has received his M.Sc. (Post-Graduation) University of Roorkee, Roorkee in 1988. Then he obtained his Master of Philosophy (Computer Applications) at University of Roorkee in 1990 and Ph. D in 1995. His research interests include Software Engineering, Pattern Recognition, and Fracture Mechanics.



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