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Energy Efficient Routing Protocol in MANET

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Abstract: ***Energy Efficient Routing Protocol (EERP), a power aware routing protocol increases the network lifetime of MANET. EERP is an on demand source routing protocol which is basically an improvement on DSR. In EERP path is chosen based on energy unlike DSR where path is chosen based on minimum number of hops. In EERP, Initially source node generates a Route Request packet (RREQ) with Minimum Energy field (E_{min}) in the packet set to 100 %. An intermediate node on receiving RREQ overwrites minimum energy field of the RREQ packet with the residual energy of the node at the particular time if the residual energy of the node is less than the minimum energy field in the RREQ packet. Otherwise, Minimum energy field remains unchanged. Now, intermediate node forwards route request to its neighbors only if its residual energy is more than a threshold value. This process goes on until RREQ reaches to the destination. Thus, lowest hop energy of each path from source to destination is calculated. Finally, the path is then selected by the destination node by choosing the path with the maximum lowest hop energy and sends the RREP to through that path. EERP is dynamic distributed load balancing approach that avoids power-congested nodes and chooses paths that are lightly loaded. EERP achieves minimum variance in energy levels of different nodes in the network and maximizes the network lifetime.***

Keywords: MANET, DSR, EERP, Energy Consumption, network lifetime

1. Introduction

Wireless ad hoc networks have gained importance and popularity in both research and industry. In many situations, the nodes in the network are designed to operate for long periods of time without human intervention. MANETs suffers from limitations like lower capacity, limited security, higher loss rates, more delays and jitter as compared to fixed networks. A critical issue for MANETs is that the activity of node is energy-constrained. In MANET[1], operations of nodes rely on batteries or other exhaustible power supplies for their energy. Hence depletion of batteries will have greater effect on overall network. As a consequence, energy saving is an important system design criterion. Mobile Ad hoc wireless networks are energy constrained since nodes operate with limited battery energy. If some nodes die early due to lack of energy, they cannot communicate with each other. Therefore, inordinate consumption of nodes energy should be prevented. Dynamic Source Routing protocol (DSR) for Mobile Ad Hoc Networks (MANETs). has been an outstanding routing protocol that outperforms consistently than any other routing protocols. But it could not pervade the same place when the performance was considered in term of energy consumption at each node, energy consumption of the networks, energy consumption per successful packet transmission[2], and energy consumption of node due to different overhead because, DSR protocol does not take energy as a parameter into account at all. And as MANET is highly sensible towards the power related issues and energy consumption as it is operated by the battery with the limited sources, there is a need of a routing protocol that takes energy parameter into consideration and aims at increasing the lifetime of the network.

2. Literature Survey

Routing protocols between any pair of nodes within an ad hoc network can be difficult because the nodes can move randomly and can also join or leave the network. This means that an optimal route at a certain time may not work seconds later. 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. Since last 10 years many energy efficient routing protocols have been proposed and wondering the best solution out of all. As it is very difficult to restrict technologies and research digging for optimal solution, many noticeable enhancement and modifications have been done to convert DSR as an energy efficient routing protocol and serve it as efficient routing protocols like other protocols. So in the next session here are few important routing protocols which are made after doing some modification in traditional DSR protocol.

2.1 Local Energy Aware Routing Protocol (LEAR)

Localized Power Aware Routing (LEAR) Protocol is based on DSR routing mechanism. The basic idea of LEAR is to consider only those nodes for the communication which are willing to participate in the routing path. This “Willingness” is the special type of parameter used in the modified DSR to find the route from source to destination. The new parameter can be determined by the Remaining Battery Power (Er). If it is higher than a “threshold Value (thr)”, then the node will be considered for the route path and ‘Route Request’ is forwarded, otherwise the packet is dropped. It means only when the intermediate nodes will have good battery levels then only the destination will receive route request message. So the first message that arrives at the destination will be considered to follow an energy efficient as well as reasonably shortest path. LEAR routing protocol not only achieves balanced energy consumption based only on local information. Other than that it has also an advantage of being its simplicity characteristic and being integrated easily into existing ad hoc routing algorithm without affecting the other layers of protocol stack. This was the first work to explore the balanced energy consumption in the realistic environment taking DSR as its base protocol where mobility, radio propagation, routing algorithm are concerned.

2.2 Energy Saving Dynamic Resource Routing Protocol (ESDSR)

Energy Saving Dynamic Source Routing (ESDSR) protocol is another modified DSR protocol which is aimed to prolong the network life time by using basic two approaches of power consumption, one is transmission power control approach and the second one is load balancing approach. In the first phase it decides the route based on the load balancing approach and in the second phase it dynamically adjusts the transmitting power at every node before it transmits packet. The idea came from the traditional routing mechanism which is basically based on minimum hop count. Instead o having minimum hop count approach while selecting the path and having fixed transmitting power, it introduces two new parameters. One is the current energy level and the other one is the current transmitting power level o individual node. Because it assumes that the ration of the current power level and the current transmitting power is nothing but the depletion rate o the battery. When the following cost is maximized, then only a source node finds the route R (t):

$$C(R, t) = \max (Rj (t))$$
$$Rj (t) = \min (Ei / Pti)$$

Where Rj (t) is called the minimum expected lift time at time “t” or the path j. So while selecting the path it selects the path which is having maximum of minimum expected life time among different possible path. Then each node calculates the minimum transmitting power in order to send the packet to its next neighbor node. This minimum transmitting power is calculated in the following way:

$$P_{min} = P_{tx} + P_{recv} + P_{threshold}$$

Where P_{tx} is the transmitting power to send the packet, P_{recv} is the receiving power of the node at which it receives the packet, required threshold power of the receiving node for successful reception of data. Each node maintains a power table where the required transmitting power of that node and it transmits the packet at that power.

ESDSR is implemented by considering various parameters like total numbers of data packets reached at the destination, energy consumption per packet, number of dead nodes and outperforms better than DSR routing protocol irrespective these different parameters.

2.3 Local Minimum Energy Dynamic Source Routing Protocol (MEDSR)

Energy Saving Dynamic Source Routing (ESDSR) protocol is another modified DSR protocol which is aimed to prolong the network life time by using basic two approaches of power consumption, one is transmission power control approach and the second one is load balancing approach. Minimum Energy Dynamic Source Routing Protocol (MEDSR) has done one of the finest attempts to make DSR more as an energy aware routing protocol. The whole MEDSR approach is based on two mechanisms:

- Route Discovery
- Link Power Adjustment

The route Discovery process itself is classified into two sub processes.

- Route Discovery mechanism using low power level
- Route discovery mechanism using high power level

Route Discovery mechanism using low power level:

In this process of route discovery when source node S has some packets to send, then it sets a minimum level transmitting power for all the nodes. So the route packet will be broadcasted to only nodes within the range of the minimum level of transmitting power. Once the route request arrives at the destination, the destination node copies the power level information from the route request packet into the route reply. The route reply is sent back to the nodes that are within the small range of transmitting power level from the destination node. The moment, the intermediate node will receive the route reply; it will calculate the minimum power for itself. The minimum transmitting power level for any node can be calculated as

$$\mathbf{P_{min} = P_{tx} - P_{rec} + P_{tz}.}$$

Where P_{tx}=Transmitting Power of Destination

P_{rec}=Receiving Power of the node that has received th route reply

P_{th}= Threshold receive power for successful reception of the packet. And it will keep continuing at each node until the route reply is received by the source. Once the route reply reaches at the source, the source sets the transmitting power. And start sending with that transmitting power on the route that is been selected for data transmission.

Route Discovery mechanism using High Power Level:

High power route discovery is just same as the low power route discovery. The only difference is that instead of setting up the low transmitting power, it sets high transmitting power while sending route request. This process is highly needed for route discovery, especially when no path is found due to unreachability by setting the transmitting power low. So to overcome this problem high power routing is also mandatory. MEDSR uses two levels of powers; the network connectivity is highly maintained and results less network partition.

3. Methodology

3.1 Route Discovery in EERP

In case of EERDSR, route discovery starts as follows:

- Source node creates a route request packet (RREQ).
- RREQ has a special field $E_{min;}$ here minimum energy level E_{min} is the energy level of the weakest node along the route.
- Initially source node generates a RREQ with E_{min} set to 100 %.
- All intermediate nodes sets minimum energy level field of RREQ to their energy level. An intermediate node on receiving RREQ, overwrites minimum energy level E_{min} of the RREQ packet if $E_{Res} < E_{min}$, where E_{Res} is the residual energy of the node and is calculated as given in equation (3.6).
- Otherwise, E_{min} remains unchanged.
- Next intermediate node checks if its residual energy is less than the threshold energy, E_{th} set at that node. If $E_{Res} < E_{th}$ then the RREQ is dropped else the RREQ is forwarded to its neighbours.
- This process goes on until RREQ reaches to the destination.
- Destination node may receive multiple copies of RREQ from different routes. Destination maintains a timer T and Counter, which is set to some value when first RREQ is received.
- The first RREQ and its E_{min} value are stored in the table.
- When the next RREQs are received, the destination checks if this new RREQ's E_{min} > First RREQ's E_{min}. If yes then the new RREQ is stored and old one is discarded.
- Destination continues this until either timer expires or Counter value equals four, which is means four RREQs are received.
- Finally a route with Max {E_{min}} is stored and is selected.
- A route reply packet RREP is generated sent to source along the selected route.

After RREP arrives at the source, the newly established route now can be used to send the data packets.

3.2 Energy Model in EERP

In case of EERP a simple energy consumption model has been used to calculate the energy values at different times. This model is discussed below.
Energy = Power * Time (1)

Energy consumed during transmission is given by:
Transmit Energy = Transmit Power * Transmit Time (2)

Energy consumed during reception is given by:
Receive Energy = Receive Power * Receive Time (3)

Energy consumed when node is idle is given by:
Idle Energy = Idle Power * Idle Time (4)

Total Energy consumption of a node after time t is calculated using equation (5)
E_c (t) = (Transmit Energy*N_t) + (Receive Energy*N_r) +Idle Energy (5)
Where
$E_c(t)$, energy consumed by a node after time t.
N_t , no. of packets transmitted by the node
N_r , no. of packets received by the node.

If E is the initial energy of a node, the residual energy E_{Res} of a node at time t, can be calculated as:
$E_{Res}=E-E_c(t)$ (6)

3.3 Energy Based Path Selection in EERP

EERP selects a path based on the residual energy of the nodes. The Fig. 1 shows a network with 8 nodes deployed randomly on a plane. Node S is chosen as the source and node D as the destination. Nodes have been assigned different energy levels randomly (for illustration purpose only).The route request packet is stamped by respective E_{min} through S and broadcasted to reach D from various paths. The first three RREQ packets to reach D are considered. The paths are:

Path 1: S-A-B-D, $E_{min\text{-}path1}$= 50%

Path 2: S-C-D, $E_{min\text{-}path2}$ = 70%

Path 3: S-E-F-G-D, $E_{min\text{-}path3}$ = 85%

Route discovery procedure of EERP selects the path with Max {$E_{min\text{-}path1}$, $E_{min\text{-}path2}$, $E_{min\text{-}path3}$}. Path 3 with maximum value of E_{min} is selected. Finally selected path 3 (S-E-F-G-D) is shown in the Fig.1 with dotted arrows.

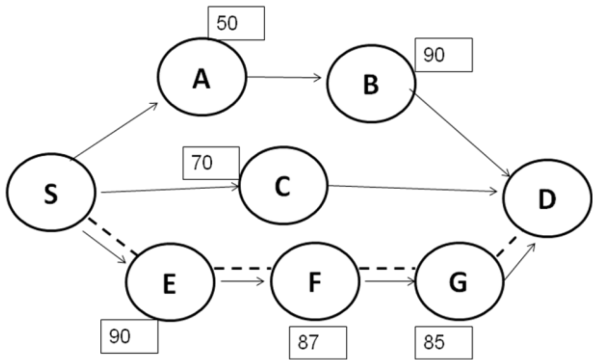

Figure 1: Route discovery for EERP

3.4 EERP Routing Packet Structure.

Table 1: EERP RREQ packet structure

SA	DA	Current Address	Request Valid	Request Number	TTL	Minimum Energy

Table 2: EERP RREQ packet structure

SA	DA	Reply Valid	Request Number	Pat h	Minimum Energy

3.5 Route Discovery Algorithm

At the source node
1. If(route to destination found in the cache)
Then
Forward the packet to the destination through that route
Else
Construct the Route Request (RREQ) packet with
Emin=Initial energy
Broadcast to the neighbours
End If

2. Wait for the Route Reply by starting a timer and Queue all the packets need to be sent
If (Timer not expired and Route Reply received)
Then
Make an entry in the cache for the new Route
Send the packets waiting to be sent through the newly acquired route
Else
Start Route Discovery Phase again.
End If

At the intermediate node
On receiving RREQ, Calculate the Residual energy (Eres) of the node
Begin
If($E_{Res} > E_{threshold}$) Then
If ($E_{Res} < E_{min}$) Then Set $E_{min} = E_{Res}$
Else
Emin not changed
End if
Forward the RREQ to all the neighbours
Else
Discard the RREQ
End if
End

At the destination node

On Receiving the RREQ Packet
Begin
If (Reply to First RouteRequestOnly is true)
If (RREQ is not first RREQ)
Then ignore the RREQ
Else
Save the RREQ Sequence number in the request table
Create a RREP
Set RREP Emin=RREQ Emin
Send RREP to source
End if
Else
Counter++ and Start timer
Put the RREQ packet in the queue
Save Emin in the request table.
Destination waits for other RREQ until counter>=N RREQ packets are received or timer expires
When Other RREQs are received check
If (Emin of New RREQ < Emin of Previous RREQ)
Then RREQ in Queue=New RREQ
Old Emin =New Emin
Else
discard New RREQ
End If
After receiving N values of RREQ
Send a RREP packet to the source with a route with Max {E_{min}}
End If
End

4. Network Metrics for Proposed Protocol Performance

4.1 Energy Consumption and Remaining Energy

Total remaining energy of the network is the sum of all the residual energies of the nodes in the network. Total energy consumption in the network is the Total energy exhausted by the nodes in the network during reception, transmission of packets.

Remaining Energy= $\sum^{N} E_{res}$ (7)

Where N=number of nodes, Eres =Residual Energy

Energy Consumption= N * (initial energy) – (remaining energy) (8)

4.2 Packet Delivery Fraction

Packet delivery fraction is the ratio of the data packets delivered to the destinations to those generated by the sources. The packet size and the intervals at which the packets are sent are user defined.

$$PDF = \frac{\text{No of packets delivered}}{\text{No of packets generated}} \quad (9)$$

5. Simulation Setup and Results Discussion

The implementation of this simulation is done by using the ns-2.34. When the tcl script is simulated in NS2 simulator, it generates trace file and nam file. Trace file is used for extraction of the required performance parameters. Nam file gives the animation of the simulation. By using the performance parameters we plot the graph using Ms-Excel. Based on the graphs we can compare and obtain the best protocol in the given scenario.

Table 3: General parameters used in simulation

Parameter	*Value*
Simulation Time	200
Topology size	1000*1000
Number of Nodes	6, 9, 15
Number of Mobile Nodes	2, 3
Number of sources	2
Number of Destinations	2
Traffic Type	Cbr
Packet Size	700
Max Packets in Queue	10
Queue Type	CMUPriqueue
Maximum Speed	5 m/s
Initial Energy	100 J
Transmit Power	5.0 W
Receive Power	1.0 W
Idle Power	0.0005 W

The below given figures 2 and 3 are the snapshots of 15 nodes static and mobility scenario for EERP implementations.

In the similar manner, 6 nodes and 9 nodes simulations are performed.

Figure 2: Static Scenario

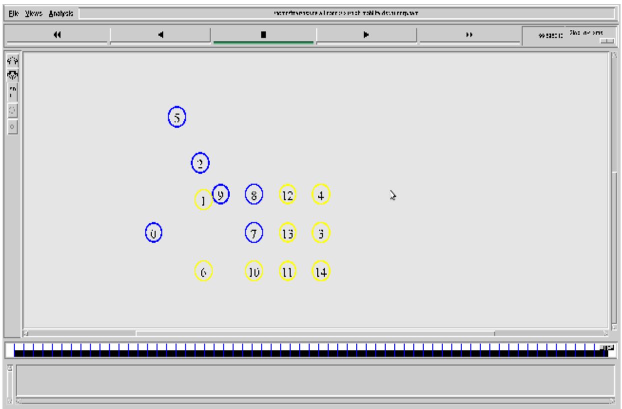

Figure 3: Mobility Scenario

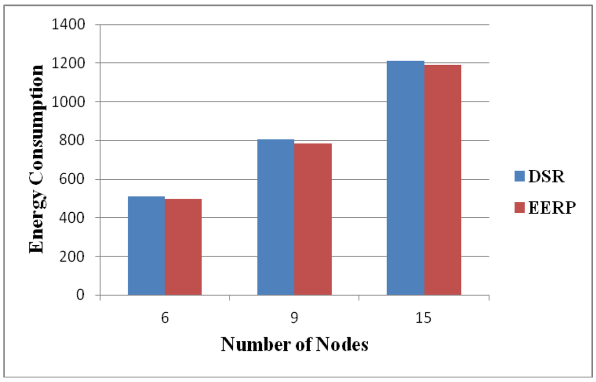

Figure 4: Energy Consumption in static scenario

The above graph shows that EERP has the less value for total Energy consumption. DSR has the slightly higher value. Hence EERP shows the best performance for total Energy consumption in static scenario.

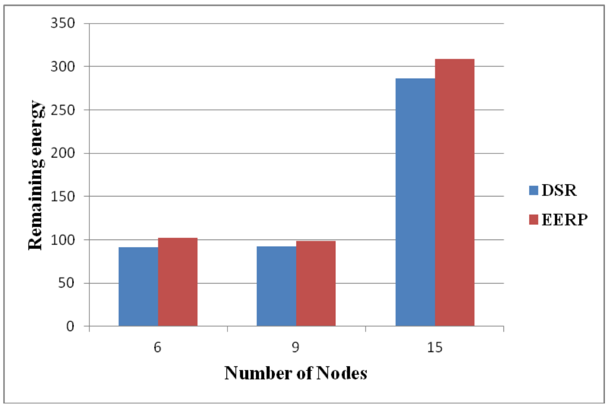

Figure 5: Remaining energy in Static Scenario

The above graph shows that EERP has the high value for total Energy remaining. DSR has the less value. Hence EERP shows the best performance for total Energy remaining in static scenario and also increases the network lifetime.

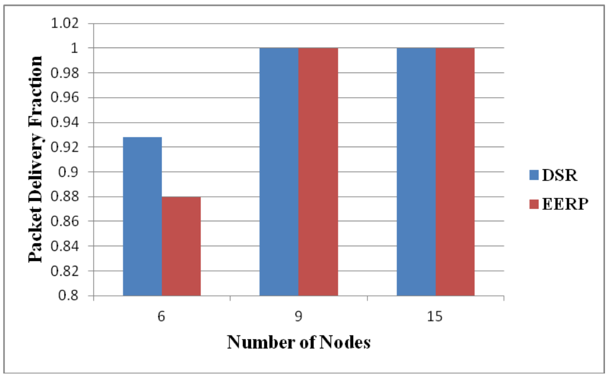

Figure 6: Packet Delivery Fraction in static scenario

The above graph shows that EERP has the low value for PDF for 6 nodes network while DSR has the high value. But for more number of nodes DSR and EERP have equal PDF value. Hence EERP performance in packet delivery is also good in static scenario.

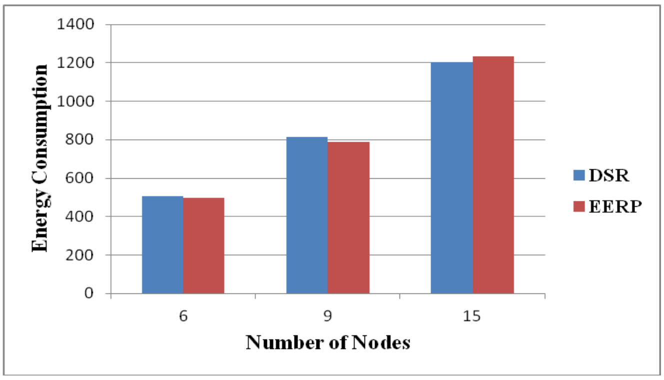

Figure 7: Energy Consumption in mobility Scenario

The above graph shows that EERP has slightly more value for total Energy consumption in terms of 15 nodes. DSR has the less value. But all other scenarios EERP performs better than DSR.

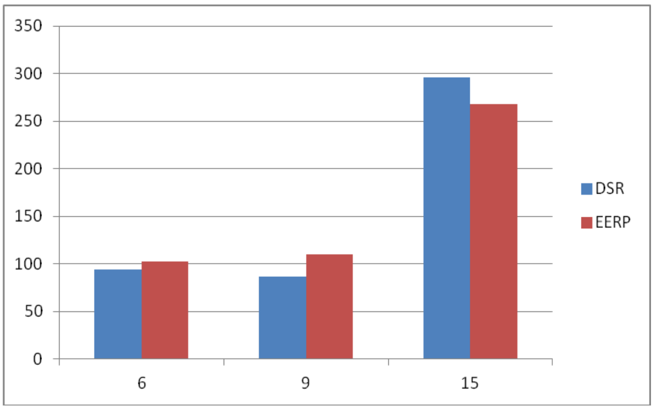

Figure 8: Remaining energy in mobility scenario

The above graph shows that EERP has the least value for remaining energy. DSR has the high value in terms of 15 nodes. But all other scenarios EERP performs better than DSR.

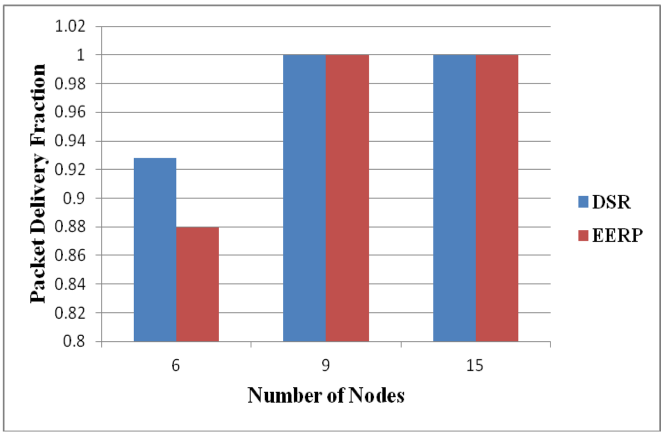

Figure 9: Packet Delivery fraction in mobility scenario

The above graph shows that EERP and DSR are both perform equally in the packet delivery fraction metric in mobility scenario.

6. Conclusion

This project is aimed at implementing an Energy Efficient Routing Protocol (EERP), a protocol increases the network lifetime of MANET. EERP is an on demand source routing protocol which is basically an improvement on existing DSR. In EERP path is chosen based on energy unlike DSR where path is chosen based on minimum number of hops. EERP chooses a routing path from source to destination based on the residual energy of the nodes in the path. Intermediate nodes are also given an opportunity to decide whether to take part in the routing process based on their energy level. In this way, EERP chooses a path which is less congested and which has higher residual energy. This also increases the network lifetime. This project has evaluated EERP and DSR adhoc routing protocols in different network environment taking into consideration network lifetime and packet delivery ratio. Overall, the findings show that the energy consumption is slightly more in DSR; hence total remaining energy is slightly less compared to the EERP. From the various graphs, we can successfully prove that our proposed algorithm performs slightly better than DSR in terms of network lifetime in most of the scenarios. EERP needs to be implemented for larger number of nodes and a larger network in terms of area. In the current implementation the Packet Delivery Ratio in EERP is below that of DSR. Hence the enhancements to the current implementation can be done to increase the packet delivery ratio of EERP. It also has to be tested for other performance metrics like Throughput and average end-to-end delay.

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