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SELA-DSR: STABILITY ENERGY AND LOAD AWARE DYNAMIC SOURCE ROUTING PROTOCOLS OF MOBILE AD HOC NETWORKS

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Abstract- Design an energy efficient routing protocol in mobile ad hoc networks is one of the major challenges, because of highly dynamic and distributed characteristics of the nodes and nodes are battery powered. Most of the research works in this field have done which is based on specific issues like energy consumption, stability, security and load balancing. In this paper, we present a model of stability, energy and traffic load aware dynamic source routing protocol in which we presents a modified the route discovery process and route maintenance which is based on energy, traffic load and stability of nodes in unified way. This work describes the models, mathematical description and flowcharts. Also, we described this modified routing protocol with help of suitable example. Finally we present simulation results which shows that our SELA-DSR perform better than existing DSR protocol.
Keywords- Ad Hoc Network Routing, Energy Aware Routing, Energy factor, Stability factor, Traffic load factor

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Introduction

In the recent years, major research efforts have been focusing such as unreliable wireless links, limited energy, security and dynamic network topology. Routing is one the important issues in MANETs because of highly dynamic and distributed nature of nodes. Particularly energy efficient routing [4] is most important because all the nodes are battery powered. Failure of one node may affect the entire network because nodes involved not only in data communication but also in forwarding data on behalf of other. If a node runs out of energy the probability of network partitioning will be increased. Since each mobile node has limited power supply, energy depletion is become one of the main threats to the lifetime of the ad hoc network and routing plays major roll in this regards. So routing in mobile ad hoc network should be in such a way that it consider to use the remaining battery power in an efficient way to increase the life time of the network. To accomplish the goal of getting longer lifetime for a network, we should minimizing nodes energy consumption not only during active communication but also when nodes are in inactive state. Two approaches to minimize the active communication energy [3,4] are as transmission power control and load balancing approaches and to minimize energy during inactive approach as sleep/power-down mode. Transmission power control scheme is used to adjust communication power hop to hop and load balancing scheme is used to avoid over utilized nodes. Transmission power control is done by calculating required transmission power between every pair of nodes on that route which will be the minimum power required for effective communication. Load balancing is done by selecting a route which contains better energy nodes. Finding the most energy efficient (min-power) route is equivalent to finding the least cost path in the weighted graph. The main protocols as Online Max-Min Routing (OMM) [11], Power aware Localized Routing (PLR) [8,15] protocols of this category based on the concept to balance the energy consumption by avoiding low energy nodes when selecting a route. The objective of Minimum Energy Routing (MER) protocol [13,14] is not only to provide energy efficient paths but also to make the given path energy efficient by adjusting the transmission power just sufficient to reach to the next hop node. The Smallest Common Power (COMPOW) protocol [2] presents one simple solution to maintain bi-directionality between any pair of communicating nodes in a MANET.

Energy efficient routing approaches [16,17] play a major role in saving the energy consumption of the network. There are several existing MANET routing protocols they have their own advantages and disadvantages. In this paper, first we have discussed energy models, stability model and traffic load model. We present modified DSR which used stability factor, energy factor, traffic load factor in unified way to select stable energy efficient route to the best of my knowledge there is no any work which used these three factors in DSR. This protocol can reduce the total energy expenditure due to balanced route maintenance and thus maximizes the life time of the network.

The rest of the paper is organized as in section 2 presents literature review we review the conventional DSR protocol and other latest works, section 3 presents different models used in our proposed routing approach. Section 4 presents discussion of our proposed protocols with help of suitable example; section 5 presents simulation results; finally we provide conclusion and future work in section 6.

Literature Review

The sources of power consumption, with consideration to network operations have to be classified in two ways as: computation-related and communication-related. Communication related power consumption involves usage of the transceiver at the source, intermediate nodes and destination nodes. The transmitter is used for sending control messages, route request messages and response messages, as well as data packets originating at or routed through the transmitting node. The receiver is used to receive data packets and control packets. Understanding of the power characteristics of the mobile radio used in wireless devices is important for the energy aware design of routing protocols. As a typical mobile radio may be present in three modes: transmit, receive and standby. Maximum power is consumed in the transmit mode and the least in the standby mode. Thus, the goal of routing protocol development for environments with limited power resources is to optimize the transceiver usage for a given communication task. Computation costs, involving packet processing and the CPU, not considering in our discussion.

The Dynamic Source Routing protocol (DSR)[1,6] is a simple and proficient reactive routing protocol designed particularly for use in multi-hop wireless mobile ad hoc networks. This protocol is truly based on source routing whereby all the routing information is maintained (frequently updated) at mobile nodes. The DSR protocol is designed primarily for mobile ad hoc networks of up to about two hundred nodes and is designed to work well even with very high rates of mobility. It has two main mechanisms, "Route Discovery" and "Route Maintenance", which work together to allow nodes to determine and maintain routes to random destinations in the ad hoc network. Route reply would only be generated if the message has reached the proposed destination node (route record which is initially contained in route request would be inserted into the route reply). To return the route reply, the destination node must have a route to the source node. If the route is in the destination node's route cache, the route would be used. Otherwise, the node will reverse the route based on the route record in the route reply message header (this requires that all links are symmetric). Route maintenance phase is initiated whereby the route error packets are generated at a node. The erroneous hop will be removed from the node's route cache; all routes containing the hop are truncated at that point. Again, the Route Discovery Phase is initiated to determine the most viable route. Dynamic Source Routing (DSR)[1] protocol is a milestone in this development of ad hoc network but it has various shortcomings like

- Even though the protocol performs well in static and low-mobility environments, the performance degrades quickly with increasing mobility.
- It does not used energy efficient routing, as mobile nodes have limited power supply and energy efficient protocols are required for routing in MANETs so modification of DSR is required.
- It does not consider the energy efficient path. In case of various routes, DSR selects the route on minimum hop count basis which could result poor route selection.
- The route maintenance mechanism does not locally repair a broken link.
- It does not consider about any security mechanism.

Minimum Battery Cost Routing (MBCR): This routing protocol was proposed in [14]. Authors try to use battery power consistently by using a cost function which is inversely proportional to residual battery power. One possible choice for the cost function of a node i is given as

$$f(bi)=1/bi$$

where, bi is the residual battery energy of node i,
the whole cost of the route is defined as the sum of costs of nodes that are the major components of the route and route selection is based on the minimum total cost. MCBR seems to expand the network lifetime due to selection of route whose nodes have high remaining battery power. The drawback of MCBR is that it may select a rather short path containing mostly nodes with high remaining battery capacity but also a few nodes with lower remaining battery capacity. The cost of such a routing solution may be lower than that of a path with a large number of nodes all having medium level of remaining battery capacity. However, the former routing solution is in general less desirable from the network prolonged existence point of view because such a path will become disconnected as soon as the very first node on that path dies.

Minimum Total Power Routing (MTPR): Many power aware routing proposals for MANETs are investigated in [14]. One of these routing proposals is MTPR scheme tries to minimize the total transmission power consumption of nodes participating in an acquired route. If the total transmission power for route R is P_R, then the route can be obtained from

$$P_{MTPR} = \min_{R \in S} P_R$$

Where, S is the set which containing all the possible routes.

This routing approach main goal is minimize the total transmission power for route R. But during energy efficient route computation it does not take consider the energy level of the mobile node battery source during energy efficient route computation. This approach may select the route that includes one or more mobile node with least energy level.

Online Max-Min Routing (OMMR): This routing protocol [11] finds the shortest (minimum energy Pmin) path by using Dijkstra's algorithm. After that, it defines a set of paths not deviating more than zPmin from the shortest path. Commencing, these, it chooses the one that maximizes minimum residual power. 'z' is the tradeoff between the max-min path and min-path.

Minimum Energy Routing (MER): This routing protocol includes the power levels that should be used by every intermediate node. The calculation of these levels done during initial phase when every receiving intermediate node calculates the required power from the knowledge of transmitted power and received power. MER has eight options, some in firmware and others implemented in software [13].

An Energy Dependent Dynamic Source Routing (EDDSR)[6,10] is energy dependent DSR algorithm which helps node from sharp and sudden drop of battery power. EDDSR provides better power utilization compare to LEAR (least energy aware routing) and MDR (minimum drain rate). EDDSR avoids use of node with less power supply and residual energy information of node is useful in discovery of route. Residual battery power of each node is computed by itself and if it is above the specific threshold value then node can participate in routing activities otherwise node delays the rebroadcasting of route request message by a time period which is inversely proportional to its predicted lifetime. With help of ns-2 simulator author performed simulation which shows MDR and EDDSR is better than DSR in terms of node lifetime. EDDSR has further advantage over MDR because it can use route cache used by DSR.

Cache Based Energy Efficient Strategies [7] is the alternative of existing DSR protocol which is based on energy efficient changes to this protocol. It works in two phases; first is route discovery and second is route maintenance. It is necessary to decrease the cost of route discovery therefore each node maintains cache of source routes it has obtained through route discovery.

Variable Range DSR [5,12] the use of variable range transmission improved the drawback of general range transmission in terms of energy use and also improves network lifetime. The improvement for node, speed and pause time variations for variable transmission range protocol show by the network parameters. This modified protocol show the improvement in number of active nodes, network lifetime is due to variable range transmitter power adjustment done at every node before transferring the data. This makes effective utilization of different nodes in the network possible. In this modification also not considers the path selection on the basis of the energy aware.

Weight Based DSR (WBDSR) [3,9] is an enhancement to the existing DSR protocol. In this protocol battery backup and stability of node is used to compute node weight. Also, this protocol is capable to solve the problem of energy efficiency in DSR. This protocol improves the stability of nodes. On receiving RREQ every node calculates its node weight by adding its battery life and stability and before further broadcasting, node weight is inserted in route request packet. Every intermediate node performs the same process, when destination node receives RREQ packet it waits for a short predefined time t for more route requests. Now, destination computes the weight of the route for each route as the minimum of node weight among all nodes in that route. After this, select the route with greatest route weight for transmission of data. Although, if two or more routes have equal or very close to route weight then the route selected with minimum hop count.

WBDSR has limitations as each node insert its node weight in RREQ packet therefore the packet size increases which causes overhead to each intermediate node and if the route has many intermediate nodes then overhead becomes severe.

Problem Identification

There are several existing MANET routing protocols as described above, everyone having its own advantages and disadvantages. As lot of research has been conducted in recent years to develop different approaches to bring energy efficient routing in MANETs. General, to all these routing protocols are assuming that all of the nodes in MANETs are battery powered. Energy efficient routing approaches play a major role in saving the energy consumption of the network. After looking through above discussed existing routing protocol, they motivated us to design an energy efficient routing protocol which reduces the total energy expenditure in the network and thus maximize the life time of the network. Many improvements to existing DSR have been discussed and observed that these approaches make them energy efficient but they have limitations also. Few limitations are as follows:

- Scalability, since source node needs to add IDs of all nodes along the path to the destination which increase the overhead.
- In DSR protocol, the route reply send through all the available route large number of unwanted route replies leading to waste of energy(battery power). Basic DSR protocols have not considered energy efficiency.
- When error due to link broken the route error packets need to go all the way to the source then source discovered new route discovery process or used route presents in their cache but this my not be valid, hence increase the packet delay time.
- WBDSR[3], this protocol used battery power and stability of node to calculate node weight each node insert its node weight in route request packet which causes packet size keeps increasing, if route have many intermediate nodes then overhead becomes severe.
- Few other energy based modifications of DSR routing protocols have considered energy based route request and/or reply or load balancing but to the best of my knowledge there is no any work which considered stability factor, energy factor and traffic load factor, all three in unified ways.

This makes us for the search of new innovative approaches. We proposed a new stability, energy and traffic aware dynamic source routing protocol which is based on DSR protocol. In this paper, we gives an algorithms of energy aware dynamic source routing protocol (SELA-DSR) protocol which used energy factor, stability factor and traffic load factor in unified ways.

Proposed Approach

As we discussed in related work, many improvements to existing DSR protocol have been showed and observed these approaches make them energy efficient but they have limitations also. This motivated us for the search of new innovative approaches. In this section we present a modified DSR routing protocol which is based on stability, energy and traffic load of nodes in a path. Our proposed protocol has modified route discovery and route maintenance strategies on the basis of stability factor, energy factor and traffic load factor. The modifications in the MAC layer are also done, as it is main part of controlling the various parameters of network activities.

Description of Proposed Protocol

In ad hoc network each node can work like host as well as router. Energy efficient routing is the prime concern in mobile ad hoc networks. Therefore energy factor play very important role in enhancement of the network life. The nodes in the high traffic load path will die off faster than nodes in paths of lower traffic load. Mobility causes ink break required route maintenance more link break more route maintenance it show stability of nodes also play major role. Hence stability, energy efficiency and traffic load awareness can improve the performance of the network.

To implement proposed protocol we consider the following models to compute stability factor, energy factor and load factor for route discovery process.

Stability Model

In mobile ad hoc network, the network topology frequently changes because of the dynamic characteristics of nodes. When the distance increases between two nodes then certain extent, the destination node is unable to receive the transmission signal properly. Therefore, it will result in link failure and rediscovery of route required, which will result in routing delay and packet loss. In order to minimize this problem, the link stability factor plays a major role.

The stability of a link is specified by its probability to persevere for a certain time span, which is not necessarily linked with its probability to reach a very high age. The stability of a path [10] powerfully depends on the stability of the constituting links, because the break of any link will lead to the break of the whole path. Thus, links stability factor is expected to be consider in path selection.

If relative position of node with its neighborhood doesn't changes frequently then this is said to be stable. Stability factor of node k is defined as follows.

$$Stability\ S_{fk} = \frac{((total\ number\ of\ neighbor's\ node)_{t-t1} - (number\ of\ absent\ nodes)_t)}{(total\ number\ of\ neighbor's\ node)_{t-t1}} \quad (1)$$

Where S_{fk} is the stability factor of node k, t is the current time and (t $-t_1$) is the time before t.

Energy Model

Let there be a node k, we can calculate the energy factor considering residual energy of the node at particular instance [18]. A node in packet transmission consumes energy in four steps. Those are as follows a) transmit, b) receive, c) idle and d) sleep.

The main sources of energy waste in MAC suppose collision, message overhearing and control packet operating cost and idle listening. The battery level of node affects the transmission range of the node therefore we have to consider nodes currently available energy to choose the optimal route. Energy factor with stability of the node k is calculated as follows:

$$E_{fk}= E_{rk}/E_{tk} \quad (2)$$

$$E_{rk}= E_{tk}-E_{ck} \quad (3)$$

$$E_{ck}= E_{idle} +E_{active}+E_{sleep}+E_{transient} \quad (4)$$

$$E_{active}= E_{recieved}+E_{transmit} \quad (5)$$

Where

E_{fk} : Energy factor of node k;

E_{tk} : Total initial energy of node k;

E_{rk} : Remaining energy of node k at instance

E_{ck}: Energy consumed by node k.

E_{idle}: Energy consumed when node k is in idle mode

E_{active} : Energy consumed when node k is in active mode

E_{sleep}: Energy consumed when node k is in sleep mode

$E_{transient}$: Energy consumed when node k is in transient mode

Every time a node sends or received data or control packet and how much time node in idle or sleep, the energy consumed is subtracted from the initial energy of the node.

$$ES_{fk}= E_{fk} + S_{fk} \quad (6)$$

$$ES_{fsdi}= Min\ \{ES_{f1}, ES_{f2}, ES_{f3}, ES_{f5}, \ldots, ES_{fNsdi}\} \quad (7)$$

Where

ES_{fsd} : Minimum value of the energy factor and stability factor of i[th] path

N_{sdi} :Set of node on i[th] path from source s to destination d

$ES_{f1}, ES_{f2}, ES_{f3}, ES_{f5}, \ldots, ES_{fNsdi}$: nodes of i[th] path

$$L_{fk}= Q_{pk}/Q_{tk} \quad (8)$$

$$Q_{pk}= Q_{tk}-Q_{rk} \quad (9)$$

Where

Q_{rk}: Remaining network interface queue size of node k at instance

Q_{tk}: Initially full interface queue size of node k

Q_{pk}: At instance number of data packets in interface queue of node k

L_{fk} : Traffic load factor of node k

Now, traffic load factor of the i[th] route is calculated as follows:

$$L_{fsdi} = \frac{\sum_{k \in N_{sdi}} L_{fk}}{N_{sdi}+1} \quad (10)$$

Where

$N_{sdi}+1$: Set of links on i[th] path from source s to destination d

Percentage of network interface queue that is occupied capacity of the node at the instance as shown in [Eq-8]. The default maximum size of network interface queue is 25. L_{fsdi} indicated the traffic load of i^{th} path from source *s* to destination *d* that is occupied capacity of network interface queue. The higher value of the L_{fsdi} indicates that route has maximum traffic means congested route, such paths should avoided to choose because it leads to higher packet loss and longer delay. We will choose the path which has lower L_{fsdi} value. The integrated model is the combination of all three the energy factor, traffic load factor and Stability factor. So, these factors use to calculate path selection factor is as follows:

$$P_{fsdi} = \frac{ES_{fsdi}}{L_{fsdi}} \quad (11)$$

The route will be selected with highest P_{fsdi} value for the data transmission.

Energy Aware Route Discovery Process

Route Discovery is the mechanism by which a source node S wishing to send a packet to a destination node D. SELA-DSR obtains an energy, load and stability aware source route with a list of minimum transmit powers to D. Energy Efficient Route Discovery is initiated just when the source node S attempts to send a packet to destination node D and does not already know a route to D. The process of Energy Efficient Route Discovery is entirely on demand.

The Energy Efficient Route Discovery procedure used a Route Request (RREQ) and Route Reply (RREP) messages, to find a route from source to destination in Ad Hoc network. When several source nodes originates a new packet addressed to some destination node, the source node places in the header of the packet a source route giving the sequence of hops along with the stable, energy efficient and load balanced route at which the packet is transmitted for each hop. The node will look up in its cache to select the Energy Efficient route to the destination. If no route is found in the cache, it will initiate route discovery process similar to initial route request process carried out in the DSR protocol. This route discovery process is illustrated by [Fig-1].

At the Source Node

When a source node wants to communicate with destination node then source check route cache

if (route source to destination found)

{

then prepare route validation message and send to destination and start the timer

if (ACK arrives before timer expire)

then send packets with existing route

else

(No any update)

}

else

it has no route in its cache then it initiates route discovery process and broadcast RREQ packet to its neighbors. The RREQ packet will carry two additional information, node's energy factor with stability factor and traffic load factor.

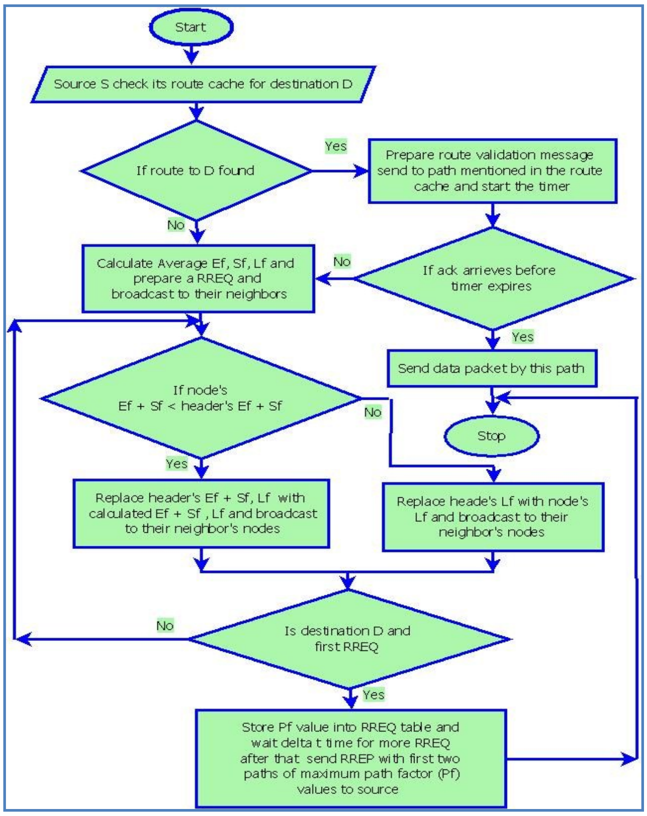

Fig. 1- Flow chart for route discovery process in SELA-DSR protocol

At Each Intermediate Node

When node receives the RREQ message from neighbor it will calculate the traffic load factor i.e. the number of packets currently stored in the queue and divide it with the size of queue and add it to the reserved field in RREQ message. Also, calculate the value of energy factor, stability factor and sum of stability and energy factor will compare it with the stability energy (SE_f) field in the header of RREQ packet.

if

(RREQ field's $SE_f > SE_f$ of current node k && SE_f of current node ≥ 25%)

then (Replace the value of RREQ SE_f field of header with current node's SE_f value and add node's average traffic load factor then broad cost to their neighbor)

else

(No update required in RREQ SE_f field only add node's average traffic load factor and broad cost to their neighbor)

At Destination Node

When a destination receives route request it will strip the information in the L_f and SE_{fk} field of the RREQ and update its route cache and wait δ time for more route requests. Destination will calculate path selection factor for each path as shown in [Eq-11] and now destination will finally select maximum value $P_{sf,}$ the most energy efficient and less congestion, the efficient route is replied by the destination node by RREP to the originator of the RREQ. We present discussion and analysis in next section.

Energy Aware Route Maintenance

Route maintenance is a procedure of monitoring the proper operation of route in use in DSR protocol. Any node, if it detects that its neighboring node, which is the next hop for a route, is not working then the node sends an error packet to the source containing its address and the address of the hop not working. On receiving the route error packet by the node removes the hop in error from its routing cache. On each forwarding link, the transmitting node expects a link-layer acknowledgement in return. In case the ACK is not received within a specified certain time interval, the node removes that link from their cache. As in DSR, if it is not the source of the packet, it generates a route error message specifying the link that is broken and sends the route error packet to the source node. Energy Aware Route maintenance involves tracking the maximum energy of the links on the route.

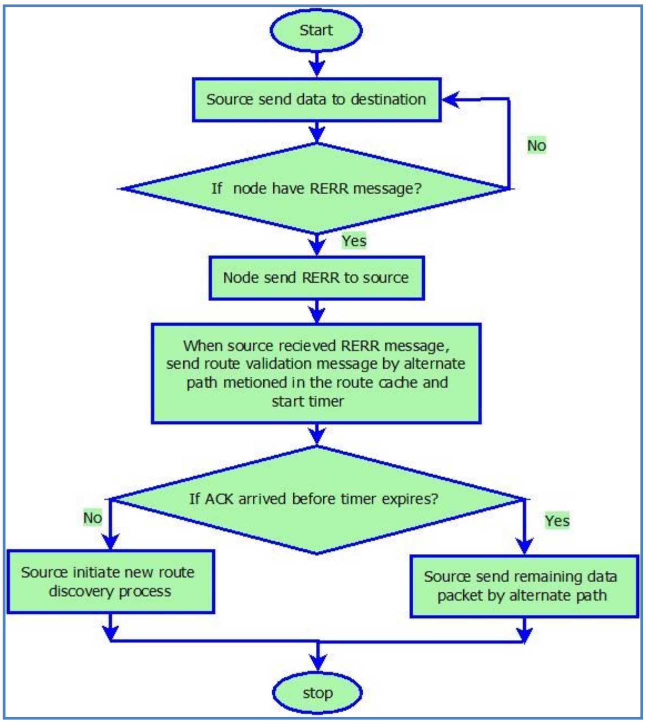

Fig. 2- Flow chart for route maintenance process in SELA-DSR protocol

Discussion and Analysis

In this section, we discussed and analyze our proposed protocol with suitable example of topology as shown in [Fig-2], in this topology we considered 9 ah hoc node designated with number shown on it. S indicate source node which want to communicate to target node, designated by D and all intermediate nodes are represented by integer value given on node itself. The values given in rectangular block are represented to particular instant as stability in first part, energy of the node in joules by second part and third part show the traffic load by queue length, i.e. (Stability, Energy and Traffic Load) of the node.

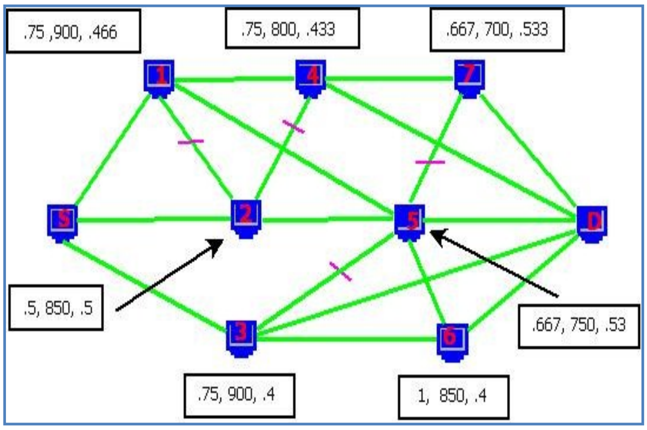

Fig. 3- Initial values of the nodes in form of (stability, energy, traffic load) at the instance

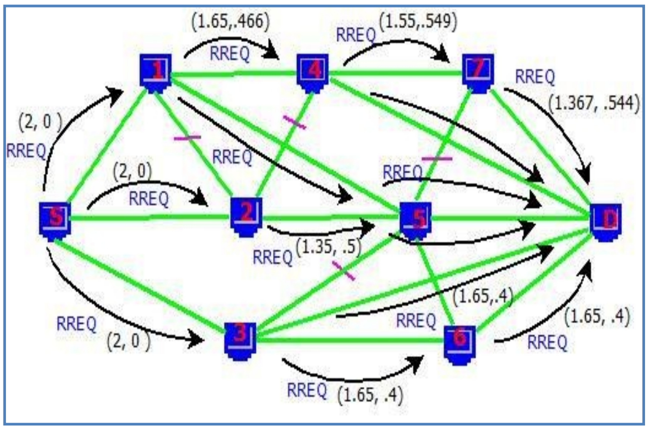

Fig. 4- Route Request Process

In [Fig-3] we show that how route request is forwarded from source to destination, in the route request (RREQ) we added two more fields' first one for stability and energy and second one for traffic load which is monitored by queue size of outgoing link of the node. We have considered queue size of 30 packets and calculate traffic load of the node as per traffic load model given in section 3.1.3, [Eq-8], [Eq-9] and [Eq-10] represents traffic factor of the particular node. Stability factor of the node is calculated as per stability model given in section 3.1.1 by [Eq-1]. Energy factor of the node is calculated as per energy model given in section 3.1.2 by [Eq-2] and [Eq-3]. After that we calculated stability and energy in unified way as (*SE*) because both are directly proportional to each other. When any node has data to communicate but they have no route then route discovery process required to discover the route as follow: assumptions source node send RREQ with maximum stability and energy factor *(SE)* that is 2 and traffic load is zero and also considered that every interface queue has same traffic load for simplicity in calculation. When RREQ goes to node 1 compare own value of *SE* with headers value of *SE* is header value min. carry with route and second field traffic load calculated average with neglecting source node and send to their neighbor same process is considered at every intermediate node. When RREQ reached to source node calculate its path factor and stored in path table. Repeat this process for every path. As most of the values shown in the [Fig-3] and [Fig-4] itself but actual process as follows:

RREQ by path S-1-4-7-D:

At node 1: *Stability factors* (S_f)= 3/4= .75, *Energy factor*(E_f)= 900/1000= .9, SE_f=1.65, *Traffic load*(L_f)= 14/30= .467.

At node 4: S_f= 3/4= .75, E_f= 800/1000= .8, SE_f=1.55, L_f= 13/30= .433

At node 7: S_f= 2/3= .667, E_f= 700/1000= .7, SE_f=1.367, L_f= 13/30= .433

At node D: path factor as per question (11), P_f= 1.367/.477= 2.86

RREQ by path S-1-4-D:

At node 1: S_f= 3/4= .75, E_f= 900/1000= .9, SE_f=1.65, L_f= 14/30= .467

At node 4: S_f= 3/4= .75, E_f= 800/1000= .8, SE_f=1.55, L_f= 13/30= .433

At node D: path factor as per question (11), P_f= 1.55/.449= 3.45.

RREQ by path S-1-5-D:

At node 1: S_f= 3/4= .75, E_f= 900/1000= .9, SE_f=1.65, L_f= 14/30= .466

At node 5: S_f= 4/6= .667, E_f= 750/1000= .75, SE_f=1.417, L_f= 16/30= .53

At node D: path factor as per question (11), P_f= 1.417/.549= 2.58.

RREQ by path S-2-5-D:

At node 2: S_f= 2/4= .5, E_f= 850/1000= .85, SE_f=1.35, L_f= 15/30= .5

At node 5: S_f= 4/6= .667, E_f= 750/1000= .75, SE_f=1.417, L_f= 16/30= .53

At node D: path factor as per question (11), P_f= 1.35/.515= 2.62.

RREQ by path S-2-5-6-D:

At node 2: S_f= 2/4= .5, E_f= 850/1000= .85, SE_f=1.35, L_f= 15/30= .5

At node 5: S_o= 4/6= .667, E_{ve}= 750/1000= .75, SE_f=1.417, L_f= 16/30= .53

At node 6: S_f= 3/3=1, E_f= 850/1000= .85, SE_f=1.85, L_f= 12/30= .4

At node D: path factor as per question (11), P_f= 1.35/.476= 2.836.

RREQ by path S-3-D:

At node 3: S_f= 3/4= .75, E_f= 900/1000= .9, SE_f=1.65, L_f= 12/30= .4

At node D: path factor as per question (11), P_f= 1.65/.4= 4.125.

RREQ by path S-3-6-D:

At node 3: S_f= 3/4= .75, E_f= 900/1000= .9, SE_f=1.65, L_f= 12/30= .4

At node 6: S_f= 3/3=1, E_f= 850/1000= .85, SE_f=1.85, L_f= 12/30= .4

At node D: path factor as per question (11), P_f= 1.65/.4= 4.125.

RREQ by path S-3-6-5-D:

At node 3: S_f= 3/4= .75, E_f= 900/1000= .9, SE_f=1.65, L_f= 12/30= .4

At node 6: S_f= 3/3=1, E_f= 850/1000= .85, SE_f=1.85, L_f= 12/30= .4

At node 5: S_f= 4/6= .667, E_f= 750/1000= .75, SE_f=1.417, L_f= 16/30= .53

At node D: path factor as per question (11), P_f= 1.417/.443= 3.3.

RREQ by path S-1-5-6-D:

At node 1: S_f= 3/4= .75, E_f= 900/1000= .9, SE_f=1.65, L_f=

14/30= .467
At node 5: S_f= *4/6= .667,* E_f *= 750/1000= .75,* SE_f*=1.417,* L_f*= 16/30= .53*
At node 6: S_f*= 3/3=1,* E_f*= 850/1000= .85,* SE_f*=1.85,* L_f*= 12/30= .4*
At node D: path factor as per question (11), P_f*= 1.417/.465= 3.05.*

[Fig-5] showing the route reply process our proposed RREP process, destination node must wait delta t time for more RREQ after that destination node send RREP to source node by two RREP first which have maximum value of path selection factor (P_f) as shown [Fig-5] by blue arrows *(S-3-D)* and second RREP by RREQ which have next maximum value of path selection factor (P_f) as shown in [Fig-5] RREP by black arrows(S-3-6-D).
[Fig-6] shows that the process of route maintenance process. Our proposed SELA-DSR protocol is considered the process of route selection based on stability, energy and traffic load in unified way by which we are able to select the paths which have maximum stability, energy and minimum traffic load as shown in [Fig-2].

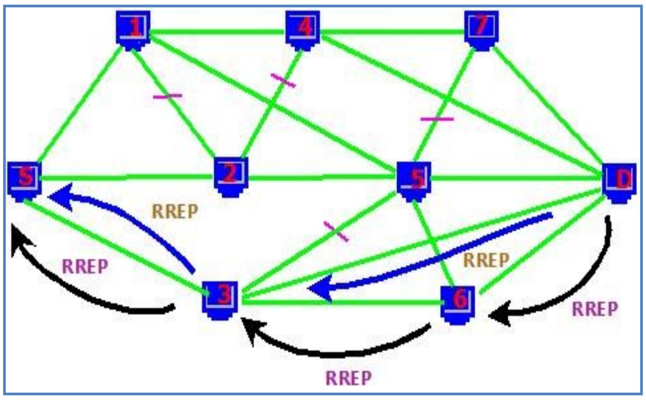

Fig. 5- Route Reply Process

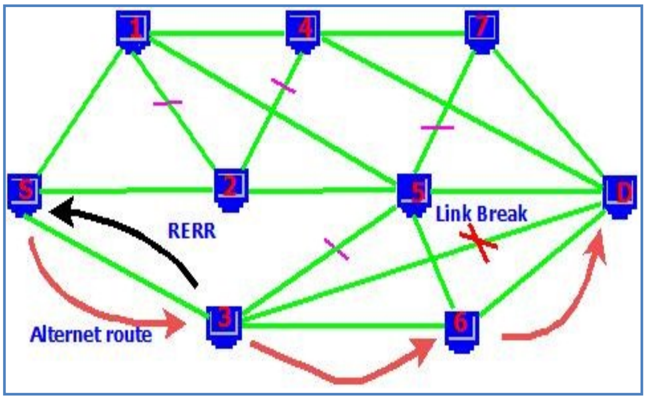

Fig. 6- Route Maintenance Process

Route reply process is considered to send two route reply, source sends data packet by first path and if there is any fault occurs in the existing path as shown in [Fig-6] link node from 3 to D is broken and node 3 sends RERR to source after that source can send route validation method by the alternate path and stat timer if ACK received before the timer expired, source can send data packet by this alternate path otherwise stat the route discovery process. Due to this we are able to minimize the RREQ process to save the node energy to enhance the network's life.

As per above calculated values of our proposed ESLA-DSR protocol shows that if we consider energy factor with stability and traffic load in unified way then we can select energy efficient and stable path with possibly minimum load. Route maintenance is also effective because our route reply sends two paths main and alternate path, communication started with main path, if there is any problem in this path then we can use the alternate path with simply testing its validity. Due to this we balanced route reply process to save energy of the nodes as being not route reply all RREQ only reply once to carry both paths.

Simulation Results

NS-2 simulator version 3.34 has been used for simulating energy consumption and other of ESLA and DSR protocols [19][20]. The underlying MAC layer protocol is defined by IEEE 802.11; Distributed Coordination Function (DCF) is used. The interface queue is a 50-packet drop-tail priority queue. Every simulation is performed with 60 mobile nodes in a rectangular area of 800m x 800m. The length of each simulation is 600 seconds. Every MAC layer operations of the wireless ad hoc network interfaces are logged in .tr trace files. The simulation parameters for analyzing the performance of SELA-DSR and DSR for various metrics are as given in [Table-1].

Table 1- Simulation Parameters

No. of nodes	10-100
Radio propagation model	TwoRayGround
Transmission range	250 mtr.
Transmission power (txPower)	1.4W
Reception power (rxPower)	1.0W
Idle power	0.53W
Sleep power	0.13W
Initial energy	1000Jules
Packet size	512 bytes
Channel Capacity	2Mbps
Frequency	2.4 Ghz
Packet generation rate	2 packets/second
Transmitted signal power	0.2818 W

The following are performance metrics used:

1. Energy consumption per packet is defined by the total energy consumption divided by the total number of packets received. This metric reflects the energy consumption for each protocol when average speed of nodes varies;
2. Energy consumption per packet - when number of nodes varies;
3. Packet delivery ratio - the total number of packets received are divided by the total number of data packets transmitted; and
4. Energy consumption per packet when size of packet varies.

[Fig-7] presents the comparison of SELA-DSR with existing DSR protocol, the performance over five average speeds of the nodes as 2mtr./sec., 4mtr./sec., 6mtr./sec. 8mtr./sec. and 10mtr./sec. corresponding average energy consumption per packet is defined the total energy consumption divided by the total number of packets received. Stability energy and traffic load aware dynamic source routing (SELA-DSR) protocol perform better than existing DSR protocol at every speed level.
[Fig-8] shows that energy consumption per packet corresponding to number of nodes participating in communication. As number of

nodes increasing in participation of communication from 10 to 100 their per packet energy consumption is also increases in SELA-DSR as well as DSR, but energy consumption in SELA-DSR is less than existing DSR at every level.

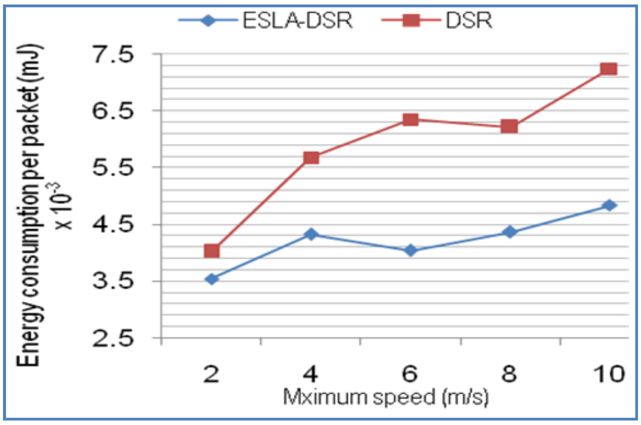

Fig. 7- Energy consumption per packet versus node's speed

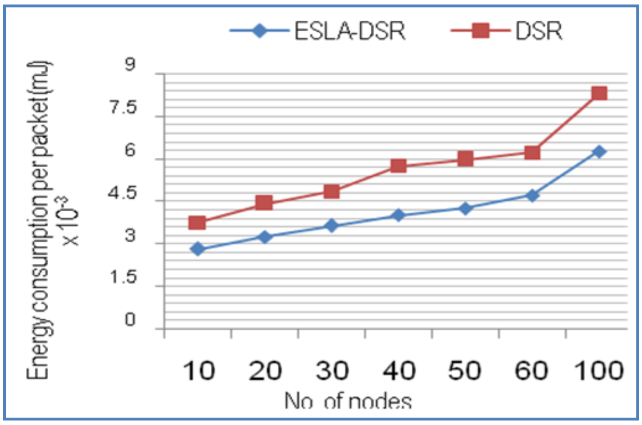

Fig. 8- Energy consumption per packet versus no. of nodes

[Fig-9] show the packet delivery ratio of SELA-DSR and DSR protocols over different mobility speed. The packet delivery ratio is more in SELA-DSR than DSR at different mobility speeds and it increases in SELA-DSR as well as DSR protocols when mobility speed is deceases.

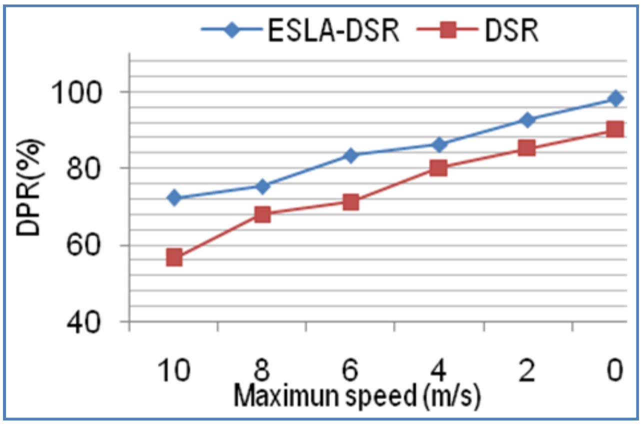

Fig. 9- Packet Delivery Ratio (PDR) versus nodes mobility

The next performance metric number of node alive for different simulation time as node die of when its energy zero (battery fully exhausted) results minimize number of alive nodes in the network; analysis of number of alive node versus simulation time is illustrated in [Fig-10]. It is clear that SELA-DSR is energy efficient than DSR due to number of live nodes in the network. It can also noted that SELA-DSR outperform than DSR at every instance when simulation time increases.

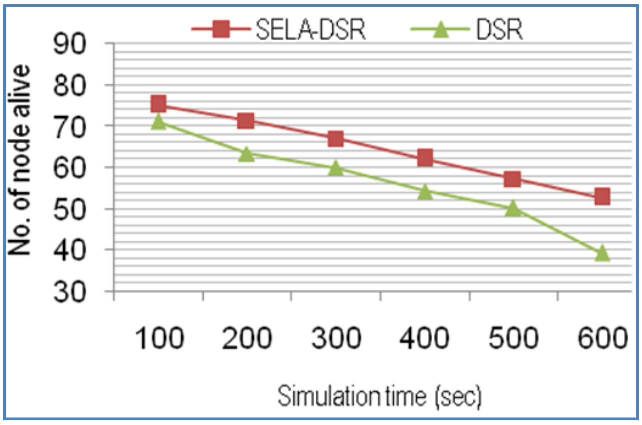

Fig. 10- Number of node alive versus simulation time

Conclusion and Future Work

In this paper we discussed our proposed routing protocol named as SELA-DSR in which we presented stability model, energy model and traffic load models. Using these models we have given modified route request, route reply and route maintenance approaches. We explained these approaches with help of flow chat and steps of algorithm. After that we discussed and analyzed our proposed approach with help of suitable example which shows if we consider energy factor with stability and traffic load in unified way then we can select better. Route maintenance is also effective because our route reply sends two paths at single RREP so not increases number of root reply which great helps in route maintenance. As communication started with main path, if this path failed then we can use the alternate path with simply testing its validity. Due to this we balanced route reply process to save energy of the nodes as being not route reply to all RREQ, only single RREP to carry both paths. Our simulation results showed that proposed SELA-DSR is energy efficient than DSR; it enhanced nodes life by avoiding selection of min energy node in a path which possibly increases the life of the network as well as overall performance. In simulation we consider various metrics for verification of our protocols by all these metric it showed that our protocol performed better than existing routing protocol.

We can also improve this routing protocol with considering variable range power model. By this power model we can send data packet with suitable required energy from node to node not with the full energy. Which possibly saved energy and minimize the interference?

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