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ENERGY AND LOAD AWARE STABILITY ROUTING FOR MOBILE AD HOC NETWORK

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ABSTRACT

Due to mobility, the topology of a mobile ad hoc network (MANET) changes frequently, making it more difficult to find routes that last for the entire duration of data transfer. Energy awareness and congestion control is becoming a crucial factor in the design of routing protocols. Satisfying both stability and energy constraints is a complex task. In this paper, we propose a novel, Energy and Load Aware Stability based Routing (ELSR-AODV) protocol that integrates energy and load metrics into stability routing to alleviate congestion and improve the performance of the network through cross layer approach. This model computes the reliability factor based on the link stability and the residual energy of the intermediate nodes, where load balancing mechanisms is incorporated to sustain the network functionality. It is simulated using ns2, under different mobility conditions. This protocol is compared with other similar routing protocols: LAER, PERRA. Our experimental results show better performance in terms of Packet Delivery Ratio, Control Overhead and Network Lifetime.

Keywords: *MAN ET, Reliable Routing, Route Stability, Energy-aware routing, Congestion Control.*

1. INTRODUCTION

One of the fast developing areas of wireless networks is mobile ad hoc networks. The Mobile Ad hoc Networks (MANETs) are collections of wireless mobile devices, which can communicate with each other without any infrastructure support. It is a self-configured and self-maintained network with no central authority. It allows people to exchange information in the field, in the class room by simply turning on the computers, laptops or PDAs. New applications for MANET will continue to emerge and become an important part of the communication. Dynamic topology, limited bandwidth, battery, CPU resources and multi-hop communication are the characteristics that put special challenges in routing protocol design [1].

Several routing protocols have been proposed for MANETs. Based on the route discovery principle, we can classify them into either proactive or reactive. Proactive routing protocols update routes for every pair of nodes at regular intervals irrespective of their requirement. The reactive or on-demand routing protocols, determine route only when there is a need to transmit a data packet, using a broadcasting query-reply (RREQ-RREP) procedure. Most of these protocols use min-hop as the route selection metric. It is found that shortest path route has short lifetime, especially in highly dense ad hoc networks even with low mobility, due to edge effect [2].

They do not address the issue of reducing the path breakage during data transmission. In most of the on-demand routing algorithms it will take some time to detect the link failure after which, route recovery procedures are initiated. These procedures consumes substantial amount of resources like bandwidth, power, processing capacity at nodes and also introduce extra delay. Selecting routes that endure long time reduce the possibility of route failure and route re-discovery process, which considerably improve the network performance of ad-hoc networks.

Link stability is a measure of how stable the link is. Stability based routing protocols tends to select paths that will last longer [3]. Signal strength, pilot signals, relative speed between nodes are the parameters used for the computation of link stability. Lifetime of network is considerably reduced by inefficient consumption of battery.

IEEE standard 802.11 wireless networks react to degraded link performance in infrastructure mode when they no longer hear beacons. Power-Aware routing protocols are developed with the aim of maximizing the network lifetime by minimizing the power consumption during the data transfer, at the time of route establishment [4]. Routing with load balancing mechanism computes energy efficient path with lesser traffic, resulting in the improved network performance and extended network lifetime [5].

In this work, we propose a novel routing scheme, namely, ELSR-AODV that integrates energy and load metric into stability routing through cross-layer design of MANET architecture. Performance results show that ELSR outperforms LEAR and PERRA in high load and highly dynamic environment.

2. RELATED WORK

We first expose relevant research work related to stability and energy based routing. Then, we will explicit how our approach combines both energy and load metrics in it, to find reliable path for communication and extend the network lifetime.

In [6], Link stability is defined as a measure of how stable the link is and how long the communication will endure. Signal Strength is one of the parameter used to estimate the stability of links. The link quality for each of the links to the neighboring nodes may be compared with a threshold, and new discovery may be done based upon the determined quality of the link. In SSA [7], the route discovery is based on the average signal strength and location stability of nodes. Sulabh Agarwal and Pal Singh propose RABR [8], in which the route selection is done based on the intelligent residual lifetime assessment of the candidate routes. The major challenge with this protocol is, to choose the optimal threshold values. Both SSA and RABR depend strongly on the propagation characteristics of the radio channels, as fading can also produce fluctuations. They also adapt the transmit power depending on the distance between the nodes and not adapting the constant transmit power constantly. In [9], the authors estimated the link stability based on the signal strength.

In [10], N.Sharma and S.Nandi propose RSQR, in which the link stability and route stability are computed using received signal strength. Based on the threshold values the links are classified as stable or unstable link.

Gun Woo and Lee propose EBL [11], in which the authors give importance to both link stability and the residual Battery capacity. The EBL not only improve the energy efficiency but also reduce network partition. Floriano and Guerriero propose LAER [12], in which they consider joint metric of link stability and energy drain rate into route discovery, which results in reduced control overhead and balanced traffic load.

The expected route lifetime is mainly predicted with the parameters node battery energy and link stability. It is preferable to select stable links [13]. In [15], Guerriero propose PERRA, an reactive routing protocol, which accounts both link stability and power efficiency. Control overhead is greatly reduced due to constrained flooding and maintenance of alternate path.

Load based MANET routing protocol are based on load metrics such as Active path, traffic size, packets in interface queue, channel access probability, node delay. It is generally categorized into delay-based and traffic based. Hassanein proposes LBAR, an on-demand routing protocol for delay-sensitive applications. It prefer route with least traffic and load such that the delay will be low. To identify the minimum traffic path it calculates and update the number of active paths and traffic interference on that path.

In [16], saigal et al propose LARA, an on-demand routing protocol for efficient data transmission. It uses a new metric called traffic density to represent the degree of contention at the MAC layer. This is used to select the route with least traffic load during the route setup. Neighborhood table stores the queue estimation at each of its neighbor periodically and it used during the route setup phase and it is updated using the hello packet periodically.

In CSLAR, load balancing is achieved by combining both traffic and delay based techniques. Channel contention information, interface queue length and number of hops are used as routing metrics in it. Interface queue length alone is not the good indicator of traffic of a node. Fengu and Zhang propose LBPSR, which makes route selection based on the packet success rate derived from the MAC layer.

In WLAR [17], metric traffic load is used as the routing metric. It is defined as the product of average queue size of the interface at the node and the number of sharing nodes. If the average queue size is greater than the threshold value, then it is not preferred. This greatly reduces the transient congestion at the intermediate nodes.

3 PROBLEM FORMULATION

The problem can be stated as – "To find the most reliable path for data communication incorporating energy and load awareness into stability routing"

The topology of a MANET is modeled as an undirected graph G= (V, E), where V is the set of nodes and E is the set of edges connecting the nodes. A link e = (u, v) ∊ E has a link stability LS (e).

Let, P (u, v) = {P_0, P_1, P_2…, P_n} where each P_i is a feasible path between u and v. The problem of selecting the optimal path from source to destination, by accounting the route stability, residual energy and load can be mathematically stated as

$$f1 = \prod_{e \in P_i} LS(e) \qquad (1)$$

$$f2 = \prod_{e \in P_i} C_e(t) \qquad (2)$$

where

$$C_e(t) = \rho_i . \left(\frac{R_i}{F_i(t)} \right) \qquad (3)$$

where R_i and Q_i are the residual energy and interface queue length of the intermediate node i.

The above optimization problems can be transformed into a single objective problem, by providing importance factor (i.e. p1 and p2) for each criterion of the objective and represented as shown below.

$$RFACT(P_i) = p1.\ f1 + p2.f2$$

$$= p1. \prod_{e \in P_i} LS(e) + p2.(\prod_{e \in P_i} C_e(t)) \qquad (4)$$

where p1 + p2 = 1.

The sum of the objectives has to be maximized and can be represented as

$$RFACT(P_i) = \max\{RFACT(P_1), RFACT\ (P_2) \ldots RFACT\ (P_n)\} \qquad (5)$$

$$\forall i \quad R_i > EThr$$

$$\forall i \quad QLen_i < QThr$$

4 ENERGY AND LOAD AWARE STABILITY ROUTING

In this section, we discuss the working procedure of ELSR routing model.

4.1 Route Discovery

When a node needs to send packets to some destination, it searches for route in its route cache. If route to the destination is not available, it starts broadcasting route request packet to its entire neighbor. If an intermediate node receives a RREQ packet from its neighbor, it measures the strength at which it received the packet and energy level of the receiving node. If the signal strength and energy metrics are above the threshold value, node process through the load metrics otherwise it drops the route request.

If the queue length is above the QThresh value, then the route request packet is dropped, to avoid future congestion during data transmission. If the signal strength is above SThr1 then LS is set to 1. If the signal strength is in between SThr1and SThr2, then LS is calculated based on the differentiated signal strength (DSS). Then, Energy cost for the link is calculated using the Cost function (cf. equation 3).

The accumulated path stability (APST) and accumulated Energy cost (AEC) is calculated with the help of the respective functions and updated in the header of the RREQ packet, before forwarding to its neighbor.

The calculated stability value is also updated in the Neighbor Information Table. Then the route request is forwarded to its neighbor with the updated values of APST and AEC.

Algorithm 1: Implemented in the Intermediate nodes.

Input: A RREQ packet P from neighbor node.
Input: Threshold values SThr1, SThr2, EThr, QThr, u1, u2

```
if ( P is a RREQ packet)
if (NodeBattery < EThr)  or (SS1 <  SThr2)
      then
          Drop Packet P
           return
       endif
if    (Qlength >= QThresh)
       then
          Drop Packet P
          return
       endif
 if ( (RREQ not already forwarded) or
      (RREQ has better RelFact value))
        then
         if  (SS1 >  SThr1 ) then LS = 1
             DSS = SS2 –SS1
         if  (SS1 <  SThr1 ) and (SS1 >  SThr2 )
              then
                 If (DSS < u1)
                    then
                      LS=1
                    else
                      LS = (u2 – DSS)/ (u2 – u1)
                    endif
          endif
      APST = APST * LS
      $AEC = AEC*(TP_i * (RBC_i / FBC_i))$
      Update RREQ with APST, AEC
      Broadcast the RREQ packet to next hop
 else
      Drop Packet P
       Return
 endif
 endif
```

4.2 Route Selection at Destination Node

When the destination node receives the first RREQ, it starts the timer Δt for t sec. It calculates the reliability of the path using the objective function (equation 6), using the APST and AEC values received in the route request. It stores all the RREQ that arrives, with its reliability value in its route cache. After the timer expires, it finds the path with minimum objective value and sends the RREP to it. The entire route requests that arrive after the expiry of timer Δt will be dropped.

Algorithm 2 : Implemented in the Destination
Input : A packet P from neighbor node.

```
if ( P is a RREQ packet) then
    if (SS1 <  SThr2)     then
           Drop Packet P
           return
    endif
    if  (SS1 >  SThr1 ) then LS = 1
          DSS = SS2 –SS1
          if  (SS1 <  SThr1 ) and (SS1 >  SThr2 )
           then
              if (DSS < u1)   then
                  LS=1
           else
                  LS = (u2 – DSS)/ (u2 – u1)
           endif
     endif
     APST = APST * LS
     RFACT := P1*APST + P2 *AEC
     Make Entry in Route Cache
   if (N=1) then
     Send a RREP Packet to the source
  else
     Select a route with maximum RFACT value
     Send a RREP Packet to the source
     endif
  endif
```

4.3 An Example

Referring to Figure 1, Node A wants to communicate with Node F, it does not have route to the destination. Node A broadcast RREQ packet to look for the destination. The intermediate nodes “B”, “C”, “D” and “E” on receiving the RREQ packet undergo the admission process. In the admission process, it checks for the queue status. If the queue length of the receiving node is greater than the threshold value, then it checks for the energy and stability status. If the queue length is greater than the QThresh value, then the intermediate nodes will simply drop the RREQ packet it received.

After passing the admission process it updates the APST and AEC field in it based on the strength of the packet it received and the remaining energy of the node.

Then it broadcast the RREQ packet to the neighbor nodes. The destination node “F” on receiving its first RREQ starts the timer for 1micro sec. Before the timer expires, it received RREQ through the following path.

Path I : A – B – F
Path II : A – E – F
Path III: A – C – D – F

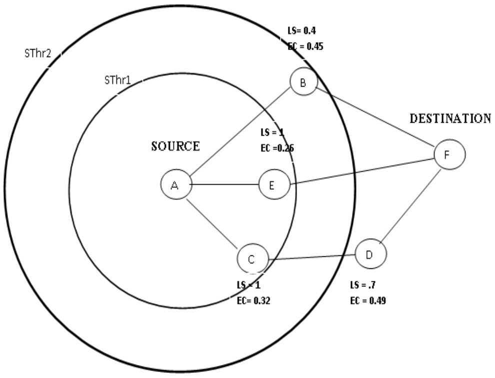

Figure.1: Route Establishment in ELSR

The path A – E – F has the highest RFACT compared with other two paths. Hence the RREP is send to E. Source node A on receiving the RREP packet starts data transmission on that path.

5 SIMULATION AND PERFORMANCE EVALUATION

In this section, we analyses the performance of our proposed protocol and it is compared with the similar protocols LEAR and AODV.

5.1 Performance Metrics

Packet Delivery Ratio: It is the ratio of number of packets received at the destinations and the number of data packets sent by the sources.
Normalized Control Overhead: It is the ratio of control packets sent and the number of packets delivered at the destinations.
End-End Delay : It is a measure of the average time a data packet has taken to reach its destination.
Variance of node residual energy: This metric is to calculate the distribution of energy usage among the nodes.

5.2 Simulation Parameters

We have simulated it in NS2 2.31. The simulation parameters are listed in the table 1.

Table 1: Simulation Parameters

Parameter Name	Values
Topology	1000m ×500m
Number of nodes	50
Mobility model	Random Way point
Channel Capacity	2
Transmission Range (m)	250
Pause time (s)	0
Simulation time (s)	600
Number of flows	10
Traffic type	CBR
Traffic Rate (packets/sec)	10
Packet size (B)	512
Node Speed	0, 5,10,15,20
P1,P2	0.1,0.3,0.5,.7, 0.9
Hello interval	2s
Traffic rate (packets/s)	10
SThr1	1.5 × RxThr,
SThr2	1.2 × RxThr
Ethr	10% of Battery
Transmission Power	1.4 W
Receiving Power	1 W
Minimum Bandwidth	50 kbps
Maximum Delay	0.1 s

5.3 Result Analysis

An extensive set of simulations is carried out with different mobility speed of 0, 5, 10, 15 and 20. We run the simulation for 10 times and the average of the results obtained is given as the values of the performance metrics.

A set of simulation are performed for the selection of the parameters of the ELSR model. We used the fixed transmission power per hop and linear modeling for energy consumption.

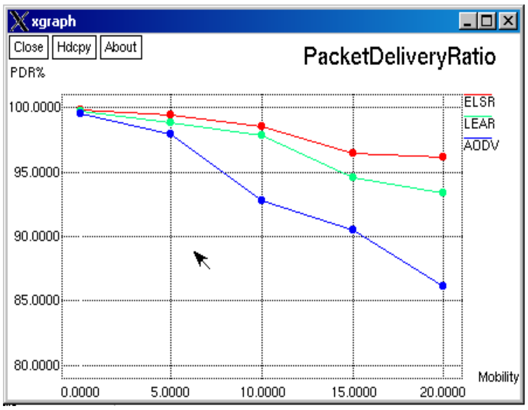

Figure 2: PDR versus Node Mobility (m/s)

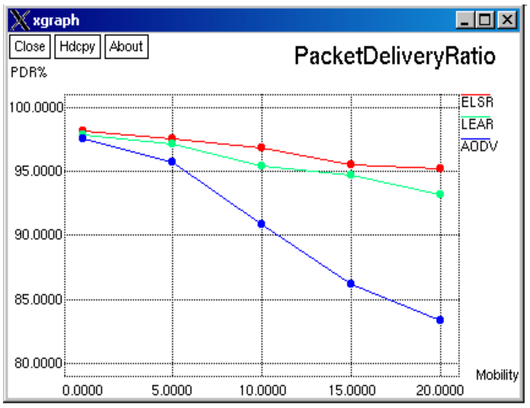

Figure 3: PDR versus Node Mobility (m/s)

From figures 2 and 3, we can observe that the PDR decreases as the velocity increases in all the three protocols. The reason for the decrease is unsuccessful local route repairs as the velocity increases and initiation of global route recovery. In high load, the PDR of ELSR, LAER and AODV are 95.5%, 93.1% and 82.33% respectively, in case of high velocity. The stability and load aware route chosen by ELSR helps in reducing the number of path breakages and packet losses, resulting in the higher PDR compared to LAER and AODV.

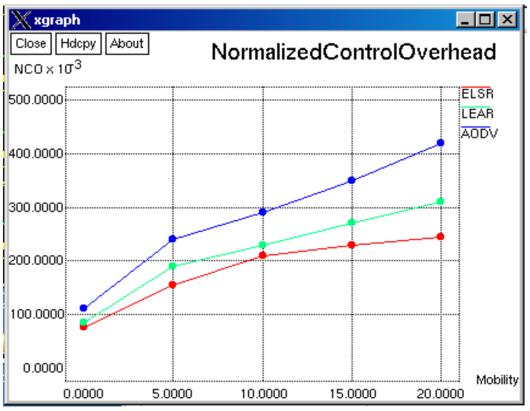

Figure 4: Control Overhead versus Node Mobility

From figures. 4 and 5, it is observed that NCO increases with the increase in mobility, due to frequent route failures and local route repairs. In moderate load at low mobility, the NCO of ELSR, LEAR and AODV are 8.2%, 8.8% and 10.4% respectively. At high mobility, the NCO of ELSR, LEAR and AODV are 24.4%, 31.2%, and 42.3% respectively. ELSR results in the lower NCO, due to stable and energy aware route selection that reduce route recoveries considerably. In high load at high mobility, ELSR shows about 10% and 34% less NCO compared to LEAR and AODV respectively. ELSR shows considerably better performance at high mobility.

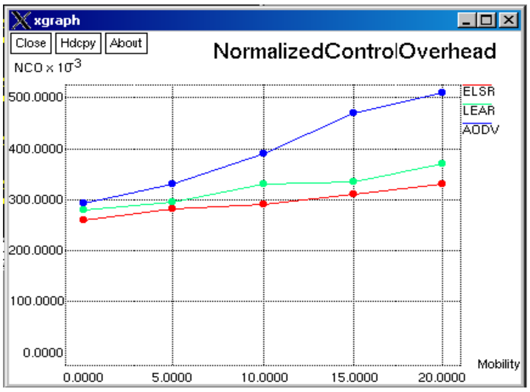

Figure 5: Control Overhead versus Node Mobility

Figures 6 and 7, depict the end-to-end delay of the three protocols, which increases with the increase in mobility. It is due to frequent path breakage. It is noted that the average delay of ELSR is below .35s in both moderate and high load, due to the reduction in waiting time in the interface queue. It is achieved by the load awareness of ELSR.

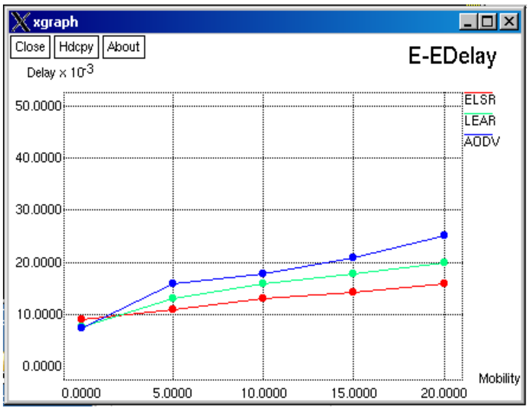

Figure 6: End-to-End Delay versus Node Mobility

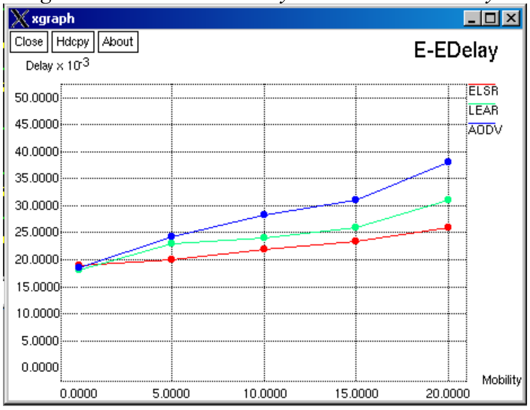

Figure7: End-to-End Delay versus node mobility

The variance of residual node energy is depicted in figures 8 and 9. This parameter shows the load balancing capability of the protocols. It is observed that as mobility increases, there is a decrease in variance of nodes residual energy. It is due to frequent route transitions. In low load at high mobility, the energy variance of ELSR, LEAR and AODV are 8.3%, 9% and 11.12% respectively. In high load at high mobility, the energy variance of ELSR, LEAR and AODV are 7.13%, 9.4% and 13.12% respectively.

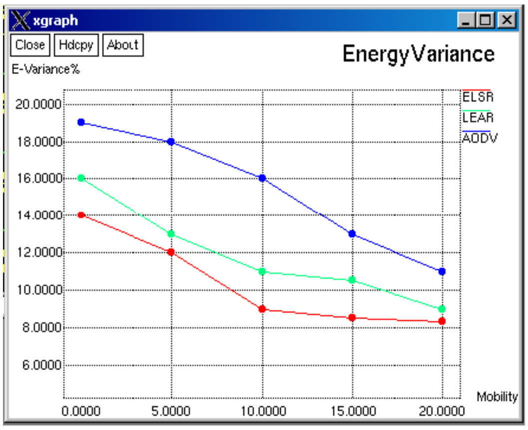

Figure 8: *Energy Variance versus Node Mobility*

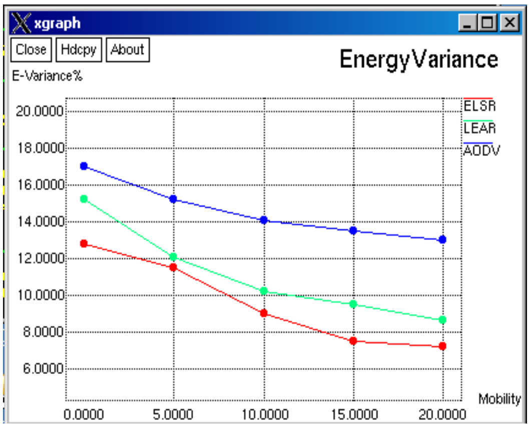

Figure 9: *Energy Variance versus Node Mobility*

From Figure 10, it is observed that there is a gradual increase in the hop count as the mobility increases. The increase in hop count is due to the selection of short and stable link. The average physical length of the hops chosen by ELSR is 45-55% of the transmission range . It is 50-60% in case of LAER and 55-65% in case of AODV. Higher the average length of hops, higher the probability of link breakage and route transitions in near future.

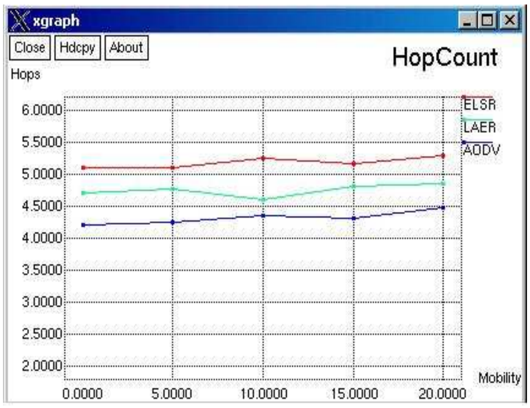

Figure 10: *Hop Count versus Node Mobility*

6. CONCLUSIONS AND FUTURE WORK

This paper presented ELSR model, proposed for reliable route discovery accounting both energy and load metric in stability routing. The proposed routing strategy significantly reduces the number of route recoveries and considerably increase the network lifetime. Simulation results show that ELSR outperforms LEAR and AODV in terms of Packet Delivery Ratio, Control Overhead and delay in highly dynamic environment. In case of low or nil mobility, the proposed model has slightly high delay compared with LEAR and AODV. It is also observed that the variance in residual battery of the nodes is reduced significantly in the proposed scheme compared with the other two.

Performance of the protocol under different node densities, traffic loads and mobility models are left as part of our future work.

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