Energyaware and Link-Stable Routing in MANET

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Abstract

Energy awareness for computation and protocol management is becoming a crucial factor in the design of protocols and algorithms in Distributed Wireless Networks. In order to support node mobility, scalable routing strategies have been designed and these protocols try to consider the path duration in order to respect some QoS constraints and to reduce the route discovery procedures. Often energy saving and path duration and stability can be two contrasting efforts and trying to satisfy both of them is very difficult. Here a Novel routing strategy is introduced which tries to account for link stability and for minimum drain rate energy consumption. In order to verify the correctness of the proposed solution a biobjective optimization formulation has been designed and a novel routing protocol called Link-stAbility and Energy aware Routing protocols (LAER) is proposed. The novel routing scheme has been compared with other existing protocols namely PERRA, GPSR AND E-GPSR in terms of Data Packet Delivery Ratio, Normalized, Control Overhead, Link duration, Node lifetime and Average energy consumption.

Keywords: MANET, link stability, LAER, energy consumption, scalable routing

1. Introduction

The aim of this contribution is the proposal of a novel routing protocol able to account for a joint metric of link stability and minimum energy drain rate in mobile ad hoc network (MANET). This protocol was enhanced by the integration of a multiobjective integer linear programming optimization model, whose solution was calculated through the LINGO tool [1]. Energy is an important resource that needs to be preserved in order to extend the lifetime of the network [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]; on theother hand, the link and path stability among nodes allows the reduction of control overhead and can offer some benefits also in terms of energy

saving over ad hoc networks. However, as will be shown in this contribution, the selection of more stable routes under nodes mobility can lead to the selection of shorter routes. This is not always suitable in terms of energy consumption. On the other hand, sometimes, trying to optimize the energy can lead to the selection of more fragile routes. Thus, it is evident that both the aforementioned parameters (i.e., link stability associated with the nodes mobility and energy consumption) should be considered in designing routing protocols, which allow right trade-off between route stability and minimum energy consumption to be achieved. The main aim of this work is to propose an optimization routing model within a MANET. The model attempts to minimize simultaneously the energy consumption of themobile nodes and maximize the link stability of the transmissions, when choosing paths for individual transmissions. The idea of considering, at the same time, energy consumption and link stability is motivated by the observation that most routing protocols tend to select shorter routes, in this way high efficiency in using wireless bandwidth and increase path stability are ensured. However, such routes may suffer from a higher energy consumption, since higher transmission ranges are needed. Consequently, in order to take into account the energy consumption and link stability of mobile nodes, a biobjective integer programming (BIP) model was formulated. Moreover, a greedy approach to find the solution to the BIP model was adopted and the found suboptimal solution was previously verified in by using the software package LINGO [1]. In this manuscript, on the basis of the biobjective optimization model presented in, a routing protocol is proposed and its validity is experimentally investigated through simulations. A comparison with otherknown approaches, such as Power Efficient Reliable Routing Protocol for Mobile Ad Hoc Networks (PERRA) [12] and geographic routing [2] (in particular GPSR), is also carried out.The main aim of this work is to propose an optimization routing model within a MANET.

2. Related works

The aim of stability based routing algorithms is to choose the routes which are more stable at time. Some of the previous works established that by choosing routes based on the parameters like position of the nodes, their remaining battery level and mobility patterns will give way for new routing strategies that promising a better and error resilient paths. Such stability oriented routing works consider the link stability as the fundamental criteria. There are many protocols that concentrate on metrics like link and path stability. Some of them are based on route breakage probability and some others on link duration distribution. But, most of these protocols are by considering some of the parameters connected with mobility models for calculating the stability metric.

By using a random mobility model, link stability probability has been defined for finding out a stable route. In a model which predict the lifetime of routes based on a prediction technique and concept of random walk mobility. In this approach, the probability is defined through dividing the area of node movement into different sub cells of and the movement of nodes is observed on that cells. A state based movement of nodes in the cells is considered and transition probabilities are estimated. Here, the wireless link is considered as a connection between each node in a cell with its neighbour nodes in other cells. The wireless link dynamic between a node and its neighbour nodes is used to calculate the link lifetime. Also, the breakage probability is estimated with the assumption of independent route breakage. There are many papers which uses the concept of signal stability to estimate the link stability probability. The drawback of this technique is that in most cases it is not suitable since signal stability can be affected by some of the environmental conditions. Another reason is that the value of signal strength changes frequently for same set of nodes. Thus there is the chance of variations in radio signal measurements and which in turn affects the link stability.

In [14],[15] the authors proposed a novel approach to determine the residual link lifetime based upon the link age and the previous link measurements. Different metrics were proposed in which one is by selecting youngest link as more stable link since they are more breakage resilient. Another one technique selects the oldest link as stable one. One approach shown is that electing links with highest residual lifetime yields a stable path. Another metric taken into consideration was the persistence probability. The last one is the connection failure probability which is the robust one. Another approach is to rely on some devices like Global Positioning System (GPS) to for calculating the correct location of mobile nodes. According to this technique, each node calculates its position and it requests for others position information using some protocols. The main problem of this approach was its difficulty in indoor applications or it is not that much functional when the mobile nodes have limited energy.

In a prediction location based routing approach is introduced to increase the packet delivery ratio of GPSR by selecting more stable path. In the number of route transition a routing protocol incurs in sending data is taken into account to find the path stability. In this work, the concept called Stability delay tradeoff was introduced as a measure of route stability. A protocol called Power Efficient Reliable Routing protocol for Mobile Ad-hoc networks determines a stable path by considering the path stability along with energy metrics calculation.

3. Problem statement

In MANET, the nodes are connected by means of wireless links that varies in the network due to the changes in node's position, mobility and congestion. This variation results in the data packet rate variations and affects the link quality. If the variability is very high, it may result in higher jitter that violates the QoS requirements.

It is evident that, the variations in link quality in turn affect the route quality. So, a route consisting of too many variable links does not result in effective data transfer. Thus, finding out a path which accounts for better link stability and path stability also that requires less control overhead and minimum energy is an important challenge of routing in mobile networks. In order to overcome such a problem, we propose a link stability based routing protocol called LSAR for MANET. The system calculates the link period and the Remaining Link Life time. These stability metrics are used to determine more stable links. Finally, a stable route is selected for the routing purpose.

4. Link stability aware routing protocol

In this paper, link stability taken into consideration rather than considering path stability. For that purpose we introduce a concept of link period which

is the time duration between the initialization and breakage of that link and which is represented by *p*. For any link from node *i* to node *j*, its link period is given by,

P(i,j)= t final -t initial …………………(1)

Different from other existing techniques a statistical based approach is used to differentiate the stable links from others. A link is said to be stable if it can withstand some amount of time. Based on the observed values of each links in the previous instants, the remaining link lifetime is estimated which is the remaining time that the link can exist without breaking. Here, the remaining link lifetime is essential since stabile links are determined in terms of the probability of that links to stick with the network. The remaining lifetime *RLTi,,j (p i,,j)* for any link from node *i* to node *j* with link period p *i,,j* is determined as,

$$RLT_{i,j}(p_{i,j}) = \frac{\sum_{p=pij}^{Pmax} p \cdot a[p]}{\sum_{p=pij}^{Pmax} a[p]} - p_{i,j} \; \forall (i,j) \in P \; \text{..........} (2)$$

where, *Pmax* is the maximum observed period of links, *P* is the set of links in the network and *a[]* represents an array used to store all the link period values. The term *a[p]* represents the count of all the links having link period as *p*. Here comes a problem that a stable link cannot be resolved when there are more links with same link period. In order to avoid this drawback, the average of distances *Davg* travelled by a node is calculated. This is how, the total distance crossed by the node is stored and its average is estimated. Thus even if there are more than one links with same remaining link lifetime, a path with shorter average distance is taken for transmission.

Using the average distance *Davg*, a coefficient for stability *Si,j(t)* if calculated using equation,

$$S_{ij}(t) = (D_{avg} / RLT_{i,j}(P_{i,j})) \times V(I,j) \in P$$

This stability coefficient can be considered as the reciprocal of stability. This is how as the Remaining link lifetime increases, the link will be more stable. Also, for higher the average traveled distance, the chance for link breakage also is higher.

5. Protocol of the proposed work

The main contributions of the proposed system are the following:

- A multi-objective mathematical formulation for the joint stability and energy problem is presented.
- The proposed protocol is based on a geographic paradigm different by other routing protocols accounting for joint metrics, such as PERRA and GPSR. PERRA [16] is an on-demand routing protocol that provides new features achieving power efficiency and reliable data transmission. Greedy Perimeter Stateless Routing (GPSR) [17] is routing protocol for wireless datagram networks that uses the positions of routers and a packet's destination to make packet forwarding decisions.
- Adoption of a novel stability metric based on the residual link lifetime concept. This metric is considered because it is independent on the transmission radius and node speed parameters that can be affected by measurement errors.
- A novel energy aware-metric, adopted in our previous contributions, has been introduced in the proposed optimization model in order to consider not only the residual energy but also its time variation associated with the traffic load.
- The multi-objective routing algorithm is integrated in the scalable routing protocol and its performance is tested through simulations and comparison with PERRA [6], GPSR [12].

In this study, it is assumed that each wireless node has the capability of forwarding an incoming packet to one of its neighboring nodes and to receive information from a transmitting node. In addition, each node is able to identify all its neighbors through protocol messages. It is assumed that each node does not enter in standby mode and each node can overhear the packet inside its transmission range and it is not addressed to itself.
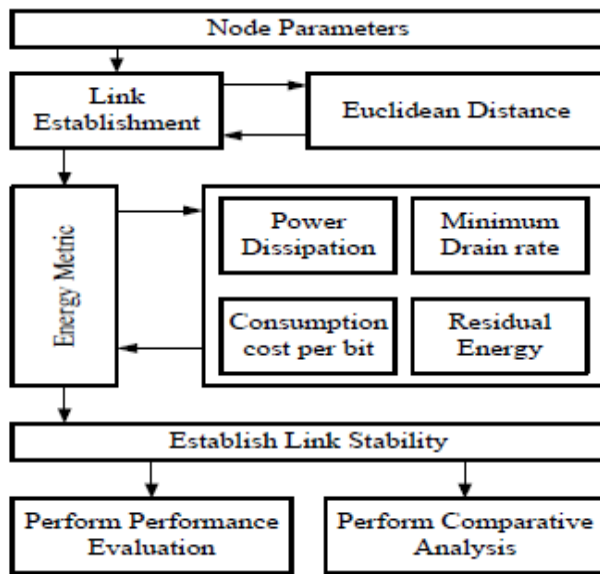
Fig. 1 Overall Schema of Proposed System

6. Performance Evaluation

It is assumed that all mobile nodes are equipped with IEEE 802.11a network interface card, with data rates of 11 Mbps. In our simulations, the voltage V is chosen as 5 V and it is assumed that the packet transmission time tp
is calculated by

$$\frac{Ph}{(6.10)^\wedge 6} + \frac{Pd}{(54.10)^\wedge 6}\left(\frac{Ph}{6.10} + Pd/54.10\right)$$

seconds, where ph is the packet header size in bits and Pd the payload size. In order to validate the effectiveness of the LAER protocol, some simulations and comparisons with other energy aware protocols have been assessed. In the following, it will be shown how LAER represents a good trade off in terms of protocol overhead, data packet delivery ratio (DPDR), and average energy consumption in comparison with the other protocols.

6.1 Protocols Considered for Comparison

Protocols adopted for comparison purpose are, respectively,PERRA as representative of on-demand routing protocolsaccounting multiple metrics and E-GPSR and GPSR asrepresentative of scalable- and location-based routing.

6.1.1 PERRA

PERRA is an on-demand routing protocol that provides new features achieving power efficiency

and reliable datatransmission. Some basic functions are listed below:

- PERRA uses a route discovery procedure throughthe RREQs propagation that involves just nodes thatmeet the source's energy requirements beforetransmitting data packets.
- Data packets are transmitted through the optimum path on the basis of the minimum residual energy,path stability, and total estimated energy to transmitand process a data packet.
- Alternative routes are prepared in case of link breakand used before an actual break occurs. The objective function in PERRA is the following:

$$F_{tot} = W_1 + E_t - W_2 X\ min[E_{res}] - W_3\ min[LL]$$

where, Et is the energy spent in the transmission and in theprocessing of a packet, Eres is the residual energy, and LLis the link lifetime. This approach selects the minimumEres and LL among nodes belonging to the path from source to destination. The main differences with our proposal are the application of an on-demand strategy, the flooding of the routerequest for the path discovery, and the different definition of the metric. However, because this protocol is an exampleof a routing protocol using multiple metrics in the path establishment, it has been considered a good candidate for comparison with LAER.

6.1.2 Ellipsoid Algorithm-Based GPSR

In order to compare LAER protocol with a novel GPSR version, we considered an enhanced GPSR called E-GPSR. The main features of E-GPSR are brieflylisted below:

- Calculation of future position of neighbour nodes onthe basis of a prediction technique based on theLeast Squares Lattice filter and time series.
- Selection of the next node to reach the destinationbased on the ellipsoid algorithm. Through thisapproach is selected the neighbour node that minimizesthe difference distance between current totaldistance d and the future total distance d' fromcurrent node to destination node. In particularconsidering a source node S, an intermediate nodeR, and a destination node D the ellipsoid algorithmselects the node that minimizes Δ

$= d + d0$, where $d= dSR + dRD$ and $d0= d0$ $SR + d0RD$.

7. Simulation Parameters

To evaluate the LAER protocol, the ns-2 network simulator was used. A wireless network is simulated, with50 nodes moving in a 870 _ 870 m2 area. Each node moves randomly in this area, with a speed selected in a range [0, Vmax] with no pause time. Between mobile hosts there are 8 and 16 CBR/UDP sources generating 8 packets/s (with apacket size of 512 bytes). The duration of each simulation is 700 seconds. To extract average values, we simulated eachscenario five times. Simulation output variables that have been considered in our simulator are:

- Data packet delivery ratio: it is the number of packets received at destination on data packets sent by source.
- Protocol overhead: it is calculated as the number of HELLO packets sent in the LAER and GPSR protocols and the number of RREQ, RREP, and RERR in the PERRA protocol.

To have detailed energy-related information over a simulation, the ns-2 code was modified to obtain the amount of energy consumed (energy spent in transmitting, receiving) over time. In this way, accurate information was obtained about energy at every simulation time.
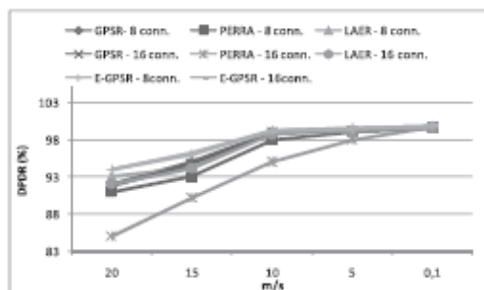

Fig. 2. Data packet delivery ratio for different maximum node speed and number of connections

8. Simulation Results

Two simulation campaigns are shown in the following sections. The first one exploits the performance of the proposed protocol against PERRA, GPSR, and E-GPSR considering the standard statistics such as DPDR and control overhead. The second campaign focuses on the link stability and energy consumption.

8.1 Data Packet Delivery Ratio and Control OverheadEvaluation

The DPDR for different number of connections is shown in Fig. 2. GPSR, E-GPSR, PERRA, and LAER present similar performance when the traffic load is not heavy with percentage value about 99 percent for very low mobility. However, for higher traffic load and high mobility (10-20 m/s) the low scalability of PERRA is visible and LAER, GPSR, and E-GPSR perform better. PERRA wastes bandwidth for control overhead and the reactive management of the protocol leads to a degradation of performance reducing the DPDR to 85-90 percent. The curve depicted in Fig. 3 testifies the increase in the normalized control overhead for higher speed. It is possible to observe the good scalability of protocol based on the local topology knowledge such as LAER, GPSR, and E-GPSR. The greedy technique applied to both protocols and the only local control packets exchange (HELLO pkts) determines a similar performance of LAER, GPSR, and E-GPSR, differently by PERRA that is forced to start new route discovery procedure that increases the control overhead.
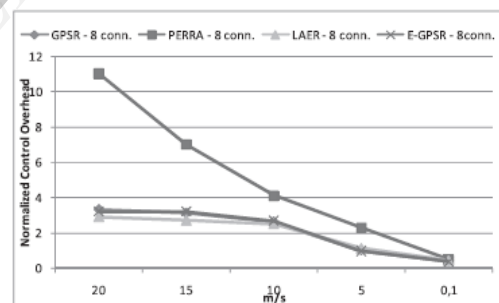

Fig.3 Normalized control overhead versus maximum node speed.

8.2 Link Stability and Energy Evaluation

Both PERRA, E-GPSR and LAER increase the link duration because specific link aware metrics permit to select the most appropriate nodes. However, it is possible to see that LAER can increase the average link duration for fixed p1 and p2 values (they are fixed both to 0.5 in the graphics where the nodes speed changes). This means that the link stability aware metric can better discriminate the neighbour nodes through the adoption of the history of the link lifetime and the statistical behaviour to infer consideration on the residual link duration, whereas PERRA through consideration of only node speed is not always able to discriminate the longer link from a

lifetime point of view. The imprecision in the link stability metric of PERRA is accentuated when more independent movements are made by a mobile node and the RREP message of PERRA is not able to predict these fast variations. On the other hand, a statistical characterization of the link duration can avoid tosend often control packets on the built path in order to refresh the previously discovered info. It is interesting to observe as the advantage of link stability metric of LAER is more evident for lower speed. This is due to the fact that when the most stable node is selected and discriminated among other neighbour nodes its link lasts more times due to the lower node mobility and this increases a lot the average link duration.

The average energy consumption for decreasing nodes speed and different stability weight values are shown, respectively, in Figs. 5. It is interesting to observe how both GPSR, E-GPSR and LAER consume lower energy: this is due to the simplest topology management and to the absence of route discovery procedures that are energy consuming. Moreover, LAER improves further the performance reducing the energy consumption about 15-20 percent in comparison with GPSR for 0.1-10 m/s and about 30 percent in comparison with PERRA.
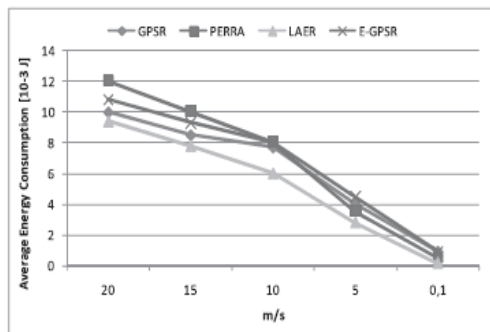

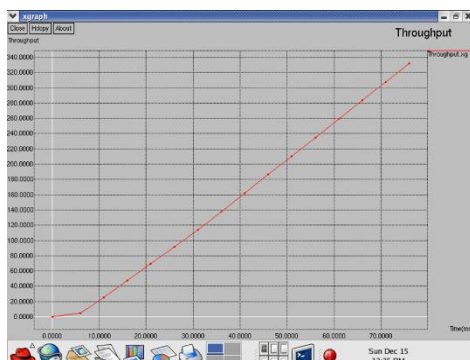**Fig. 4Average energy consumption versus maximum node speeds**

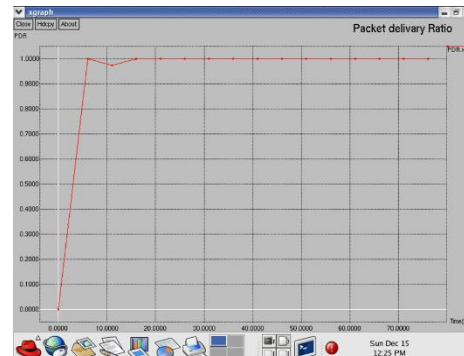## Fig.5 Throughput of the proposed system

Fig.6 Packet Delivery Ratio

Throughput and Packet delivery ratio of the LAER protocol is shown is the fig. 6 and fig.7 respectively. These graphs are obtained with a red-hat Linux operating system with Network Simulator software installed in it. As the inference from the figure shows that both the parameters satisfy the condition of a good routing protocol.

9. Conclusion

The proposed system discusses about a scalable routing protocol based on the joint metric of link stability and energy drain rate, has been proposed. It is based on the local topology knowledge and it makes use of a greedy technique based on a joint metric and a modified perimeter forwarding strategy for the recovery from local maximum. Its performances have been compared with other three protocols proposed in literature such as GPSR and PERRA. The proposed protocol inherits the scalability of GPSR improving the performance in terms of node selection with higher link duration when a higher weight is given to the stability index and a higher residual energy is given to energy aware index. Proposed framework reduces the variance permitting a lower dispersion of node energy around the average, because the use of an energy aware metric is able to consider not only the residual energy but also the drain rate trend and the traffic load on each single node. A higher traffic load on a specific node implies a higher drain rate and faster energy consumption. This means that also the energy metric of PROPOSED FRAMEWORK is better than PERRA permitting to discriminate between nodes with the same residual energy but with different traffic load. The proposed protocol outperforms PERRA in terms of control overhead and in terms of

a higher capability to balance traffic load due to the minimum drain rate metric included in the joint metric. Moreover, also the average link duration can be longer in comparison with PERRA and GPSR, due to the capability to better discriminate the node behavior associated not only with the current node condition but also with the history of link lifetime.

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