Load Balanced DSR Protocol for Wireless Ad Hoc Networks

Vahid Nazari Talooki†, Jonathan Rodriguez¥
† Instituto de Telecomunicações, Aveiro, Portugal
Phone +351-915581141, e-mail: vahid@av.it.pt
¥ Instituto de Telecomunicações, Aveiro, Portugal
Phone +351-234377900, fax +351-234377901, email: jonathan@av.it.pt

Abstract — In this paper we improved the Dynamic Source Routing (DSR) protocol to Load Balanced DSR (LBDSR) protocol. We modified control messages in DSR in order to maintain remained energy of intermediate nodes. Routes discovered by these modified control messages, have a remained energy array field which shows total of remained battery power of all nodes in a route. Selecting a route is depending on length, freshness, traffic and energy level of routes. LBDSR shows better traffic balancing, energy consumptions balancing, and end-to-end delay metrics than DSR and can be customized to achieve even better performance related to a specific metric.

I. Introduction

However ad hoc networks can be independent from a central point[1], but some particular mobile nodes can being unfairly burdened to support many packet-relaying functions and consequently, more loads on these hot spots. This load on nodes appears in two major aspects: traffic and power consumption. Load Balanced DSR (LBDSR) protocol tries to balance this load.

II. Description of Protocols

A. Dynamic Source Routing (DSR)

DSR is a source routing protocol, and requires the sender to know the complete route to destination. It is based on route discovery and route maintenance process. Discovered routes will be cached in the relative nodes [1]. After first version, some improvement applied to this basic version [2, 3]. We use latest version of DSR for our study.

B. Ad Hoc On-demand Distance Vector (AODV)

AODV uses the on-demand mechanism of route discovery and route maintenance from DSR and also a mechanism for the hop-by-hop routing and sequence number. Per each destination, AODV creates a routing table, while DSR uses node cache to maintain routing information [1].

III. Load Balanced Dynamic Source Routing

A. Modifying Control Messages

An energy field in the form of an array like the address array field to RREQ and RREP which contains the remaining power (battery energy) of each node that RREQ or RREP is forwarded by is added. Hence when a node forwards a RREQ or RREP, it will append its remaining power to the end of the energy array field.

This work was carried out in the scope of the PEACE project that is supported by the European Commission in the framework of FP7 ICT-SEC-2007 with contract number 225654.

B. Modifying Route´s Table in Nodes Caches

A new field which maintains remaining energy of all intermediate nodes is added. The amount of this array field can be extracted from modified RREQ and RREP messages.

C. Modifying the Route Selection Process

We defined a *Route Priority Function* which determines the priority of each route. For a specific source and destination pair, the route which has the maximum priority will be selected as the candidate route. Assume that for a specific (source, destination) pair of nodes in a network we have N routes like route i ordered by time which are available in the source node's cache. All input parameters are normalized in range [0…1] to make them comparable. Route Priority Function has four parameters with respect to each route. They are:

1) Length, which indicates the priority of route i with respect to the length of the route, is defined below:

$$L(i) = \frac{Actual\_Length\_Route(i)}{Max\_Length} \quad (1)$$

Actual_Length_Route(i) is the actual length of route i (i.e number of hops in route i) and *Max_Length* is the maximum length that a route can take in DSR routing protocols.

2) Measure of freshness, which indicates the priority of route i with respect to the measure of freshness, is:

$$F(i) = \frac{N - i + 1}{N} \quad (2)$$

3) Traffic, A route with a lower traffic cost has a higher priority in the routing process. The total traffic which can affect a route can be caused by traffic of the route's nodes. Traffic of each node is related to the number of routes through it. *TT(i)* which indicates total traffic of route i is:

$$TT(i) = \sum_{j=1}^{M_i} N_j \quad (3)$$

Where Nj is the number of routes through node j and Mi is the number of nodes in route i. Packet delay is not caused only from traffic load at the current node, but can also be caused by traffic load at neighboring nodes [4]. Therefore:

$$TT(i) = \sum_{j=1}^{M_i} N_j + \sum_{k=1}^{G_j} R_j^k \quad (4)$$

G_j is the number of neighbors for node j, R^k_j is the number of routes through kth neighbor of node j. Since the maximum connection that a node can establish is limited, a node with a high traffic load can turn into a bottleneck for the route. So:

$$T(i)=\frac{TT(i)}{NE_i \times Max.Con}\times\frac{MT(i)}{Max.Con} = \frac{TT(i)\times MT(i)}{NE_i \times Max.Con^2} \quad (5)$$

Where NE_i is the number of neighbors of nodes in route i which has M_i nodes (repetitive neighbor is taken into account once), *Max.Con* is the maximum connection which a node can establish in a network (which is set to the same value for all nodes), and *MT(i)* is the maximum traffic load on a node between nodes of the route i (i.e maximum N_j in equation 5).

In the above equation, *MT*(i) is an agent for drawback of the node which is turned to a bottleneck for the route because of its high traffic load. But *MT(i)* is a part of *TT(i)* and, consequently is taken into account twice. Hence equation 5 can be modified like below:

$$T(i)=\frac{(TT(i)-MT(i))\times MT(i)}{NE_i \times Max.Con^2} \quad (6)$$

4)Remaining Energy Level, A route with a maximum remaining battery power in its nodes can be an ideal route with respect to energy level. Sometimes a route may have a high remaining energy level but it may have some nodes with very low energy levels too and so there is a high probability of failure in these hot spots which makes these nodes and the routes which pass through them undesirable.

The *E(i)*, which indicates the priority of route i with respect to the remaining energy level, is defined below:

$$E(i)=\frac{RE(i)}{M_i \times InitialEnergy}\times\frac{MRE(i)}{InitialEnergy}$$

$$=\frac{RE(i)\times MRE(i)}{M_i \times InitialEnergy^2} \quad (7)$$

Where M_i is the number of nodes in the route, *InitialEnergy* is the node's energy in the beginning of simulation (which is set to the same value for all nodes), *RE(i)* is the total of the remaining energy in the nodes of route i, and *MRE(i)* is the minimum of the remaining energy between all nodes of route i. In the above equation, *MRE* is an agent for the drawback of the node which is turned into a bottleneck for the route because of its low energy level. But *MRE(i)* is a part of *RE*(i) and is taken into account twice. Hence equation 7 can be modified as shown below:

$$E(i)=\frac{(RE(i)-MRE(i))\times MRE(i)}{M_i \times InitialEnergy^2} \quad (8)$$

When a routing path is searched for, "Route Priority Function" will be computed for all available routes to the destination which are present in the source node's cache and the route with maximum *RoutePriority* will be selected for transferring. Hence with respect to equations 1, 2, 6, 8:

$$RoutePriority(i)=\frac{K_F \times F(i)+K_E \times E(i)}{K_T \times T(i)+K_L \times L(i)} \quad (9)$$

Where KF, KE, KT, and KL are coefficients of freshness, energy, traffic, and length of route respectively. Desirable values of these coefficients obtained by simulation make a quadruple for length, freshness, traffic, and energy parameter. Other alternative functions can be also used without impacting the generality of the proposed approach. Based on a variety of workloads and scenarios for simulation, the coefficient of parameters can be determined to be a trade-off for improving end-to-end delay, traffic balancing, and power consumption balancing all together. Note that we can achieve higher LBDSR performance with regard to end-to-end delay ($LBDSR_d$), Traffic ($LBDSR_t$), or Energy consumption ($LBDSR_e$) by adjusting the weighting coefficient KF, KE, KT, and KL respectively in (9) .

Table 1.
Parameters of movement models and communication model

Parameters of movement model I, characterized by paused time	
Topology area	1500m x 300m
Maximum mobility of nodes	10 m/s
Paused time	0..200
Number of nodes	50
Simulation time	200s
Parameters of movement model II, characterized by maximum node mobility	
Topology area	1500m x 300m
Maximum mobility of nodes	0m/s…40m/s
Paused time	50s
Number of nodes	50
Simulation time	200s
Parameters of communication model	
Traffic sources	CBR
Data packets size	512 bytes
Sending rate	8 packets/second
Maximum connection	10

IV. METRICS

Comparisons will be perform based on four metrics: I) Average end to end delay[1], II) Normalized Routing Load[1] (NRL) which is the number of routing packets transmitted per data packet delivered successfully at the destination[1], III) Traffic balancing IV) Energy consumption balancing. For Traffic balancing metric, first of all we compute Traffic Load, TL(i) for each node i in the network. Where $Packet\_size_{ij}$ is the size of packet j forwarded by node i, M_i is the number of packets that node i have forwarded, and N is the number of the network's nodes. Then we can compute deviation of these load values. This deviation will be our metric for traffic load balancing of protocol. The smaller the deviation means better traffic load balancing.

$$TL(i)=\frac{\sum_{j=1}^{M_i} packet\_size_{ij}}{\sum_{i=1}^{N}\sum_{j=1}^{M_i} packet\_size_{ij}} \quad (10)$$

For energy consumption balancing, first we compute Energy Load, EL(i) for each node i in the network. Deviation of these loads will be our metric for energy consumption balancing of protocol. The smaller the deviation, the better the energy consumption balancing.

$$EL(i) = \frac{ConsumedEn\ ergy(i)}{TotalConsu\ medEnergy} \quad (11)$$

V. METHODOLOGY

Nodes in the simulation move according to "random waypoint" model and all settings are similar to references works like [5]. The movement scenario files are categorized into two different groups based on paused time and maximum node mobility. We used GloMoSim simulator[6].

VI. SIMULATION RESULTS

A. Average end_to_end delay

In LBDSR all routes to a destination which are available in the source node's cache must be evaluated by running the *RoutePriority* function on all of them, which leads to an increase in route discovery process time (although this process happens once only in the beginning of a continuous transition). Despite the fact that route discovery latency is higher in LBDSR compared to DSR, LBDSR considers the traffic of routes and has superiority to DSR. When LBDSR is customized to $LBDSR_d$ by giving a higher coefficient to traffic and the length of the route (which can decrease transfer time), it shows a better performance with respect to end-to-end delay, obviously up to near 20% fewer deviation than DSR by varying pause time or mobility(Fig. 1,2).

B. Normalized Routing Load

In LBDSR, RREQ and RREP control messages have an extra field which is an array of the remaining energy of nodes in the current path. Hence routing in LBDSR causes more traffic loads compared to DSR. Although this extra load is small it can lead to greater NRL.In another hand, nodes with a high traffic load drop RREQ due to their full queue buffer, which result in more RREQ being produced. In the network, LBDSR can better handle this event by greater balancing in traffic loads. Considering the aspects in some special scenarios (based on the movement and communication model of the nodes within the network), LBDSR can decrease NRL, while at other times it shows more NRL. This situation leads to fluctuation in the LBDSR curve with respect to NRL (Fig. 3, 4).

C. Traffic Balancing

Increasing pause time leads to fewer network topology changes and so the selected paths by the protocols will be more stable. Therefore, protocols have a greater tendency to use particular nodes (through these paths). This, in turn, leads to more loads on these nodes and consequently, more deviation of the network's load (Figure 5).

With a higher mobility ratio, more links will be disconnected and the stability of the paths will decrease. This pattern results in decreasing the delivery ratio and as a result, fewer sample points. This in turn, leads to a decrease in the deviation of the network's load (Figure 6).

As shown in figures 5 and 6, LBDSR has a higher performance than DSR with regard to traffic balancing (in other words LBDSR has a lower deviation in traffic load), and deviation of traffic load is 15% and 10% lower than DSR by varying pause time and mobility, respectively .When we customize LBDSR by giving a higher weight to the traffic of routes and obtain $LBDSR_t$, a higher performance can be achieved and $LBDSR_t$ shows a nearly 25% lower deviation than DSR by varying pause time or mobility.

D. Energy Consumption Balancing

A scenario similar to the previous one happens with respect to energy consumption balancing, which leads to more deviation with a higher pause time and a decreased deviation by more mobility. Figure 7 and 8 show the performance of protocols with regard to average energy consumption balancing by varying pause time and mobility respectively.

As shown in figures 7 and 8, LBDSR has a higher performance than DSR regarding energy consumption balancing and shows lower deviation in energy consumption. Deviation of energy consumption is 15% and 10% lower than DSR by varying pause time and mobility respectively. By customizing LBDSR into $LBDSR_e$ by giving a higher weight to the remaining energy of routes, a higher performance can be achieved. Figure 7 and 8 shows $LBDSR_e$ has 25% less deviation than DSR by varying pause time or mobility.

VII. CONCLUSION AND FUTURE WORKS

LBDSR modified control packets, route tables, and route selection method in DSR protocol to achieves a higher performance in load balancing. The proposed approach can apply to many of the current routing protocols especially, on the other important reactive protocol namely, AODV.

REFERENCES

[1] Nazari,V. and Ziarati, K., "Performance Comparison of Routing Protocols for Mobile Ad Hoc Networks," IEEE Conf., Asia-Pacific Conference on Communications, Busan, Korea, 2006 pp. 1-5.

[2] D.B. Johnson, D.A. Maltz, Y.-C. Hu, Dynamic source routing protocol for mobile ad hoc networks (DSR).

[3] G. Chakrabarti, S.Kulkarni, Load Balancing and resource reservation in mobile ad hoc networks, Ad Hoc Networks, Volume 4, Issue 2, 1 March 2006.

[4] K. Woo and B. Lee, Non blocking localized routing algorithm for balanced energy consumption in mobile ad hoc networks, Proc. IEEE MASCOTS'01, 2001.

[5] C.E. Perkins, E.M. Belding-Royer, S.R. Das, "Ad hoc on demand distance vector (AODV) routing.

[6] Available from: http://pcl.cs.ucla.edu/projects/glomosim/

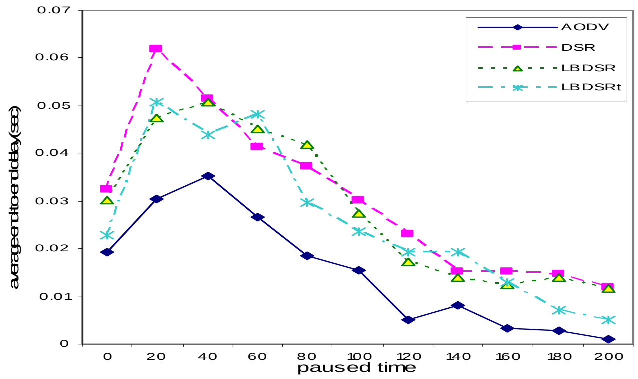

Fig. 1. Delay vs. paused time

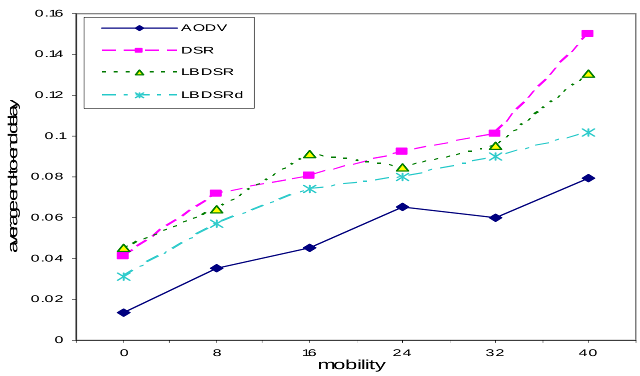

Fig. 2. Delay vs. mobility

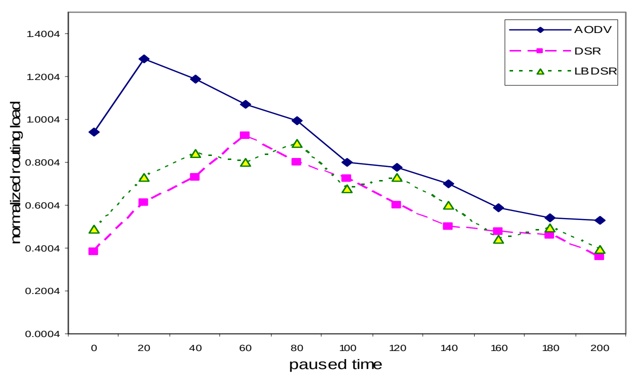

Fig. 3. NRL vs. pause time

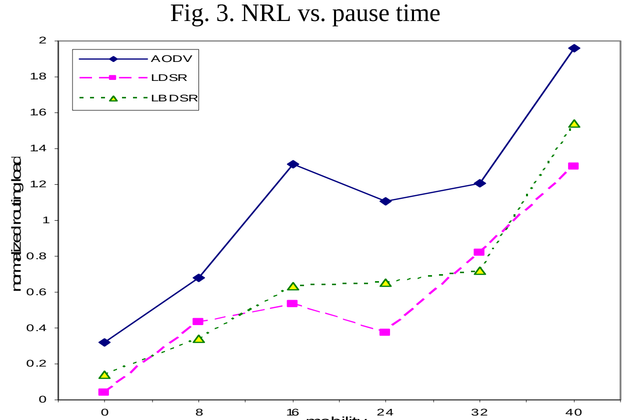

Fig. 4. NRL vs. mobility

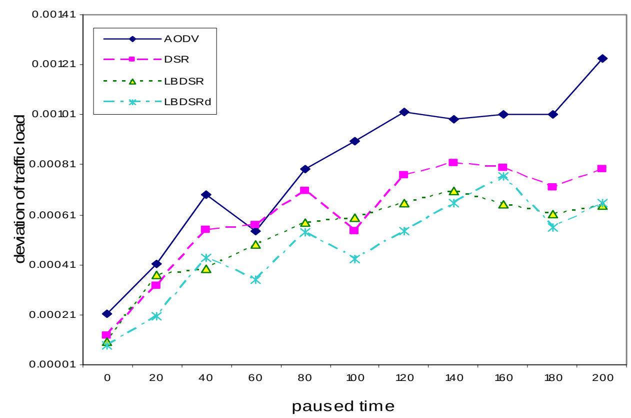

Fig. 5. Traffic balancing vs. paused time

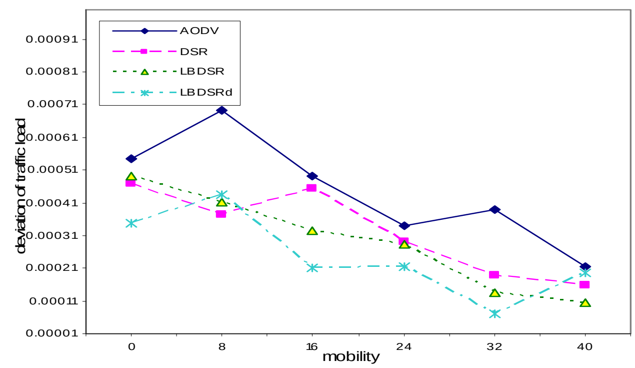

Fig. 6. Traffic balancing vs. mobility

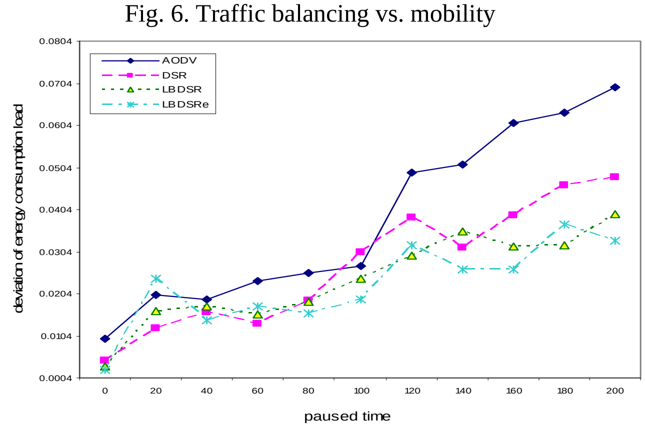

Fig. 7. Energy consumption balancing vs. paused time

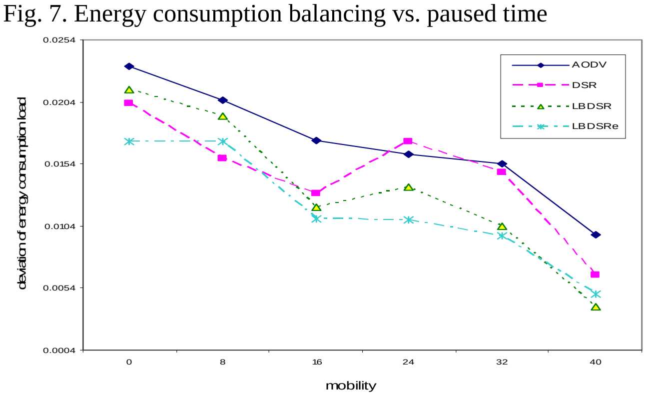

Fig. 8. Energy consumption balancing vs. mobility