Node Centric Load Balancing Routing Protocol for Mobile Ad Hoc Networks

Amjad Ali, Wang Huiqiang

Abstract— **Load balancing is a crucial part of MANET routing protocols. Most of the currently implemented routing protocols do not account for load balancing. A number of new mechanisms and routing protocols have been proposed recently to deal with load balancing in MANET routing. A majority of the schemes proposed already add to the routing overhead which is an area of great concern since MANETS are resource constrained networks and efforts must be made to somehow achieve both load balancing and avoid adding any extra routing overhead. In this paper we propose a new load balancing routing protocol with the emphasis on adding as little routing overhead as possible to the operation of this protocol. Simulation results show that our proposed scheme can improve the overall network performance.**

Index Terms—**Congestion, load balancing, routing protocols, MANETS**

I. INTRODUCTION

MOBILE ad hoc networks (MANETS) [1] are characterized by low processing power, bandwidth and limited communication range as compared to other wireless access networks. The reason for this constrained environment exists in the nature of MANETS as MANETS operate in environments where providing infrastructure support is not possible such as natural disasters or combat operations. Routing is one of the most challenging aspects of MANETS and all these constraints along with a highly dynamic network topology add to the complexity of routing in MANETS. Low bandwidth of devices in MANETS means that there is a high likelihood of congestion in the network and effective measures need to be taken to curb congestion if and when it occurs. Over the years a number of new routing protocols have been proposed and developed for MANETS with little or no emphasis on load balancing. The primary objective of load balanced routing protocols is to divert data traffic from routes and nodes that are currently congested or larger amounts of data are passing through them compared to other nodes or routes. If there is no load balancing mechanism in place then data packets will take routes that could introduce more delay hence increasing latency. With proper ways to transferring traffic load onto routes that are relatively less congested can result in overall better throughput and reduced latency. Load balancing can greatly affect the performance of MANET routing protocols. The protocol we propose in this paper uses AODV [2] as its basic structure. We summarize below some of the techniques and protocols proposed in the past to deal with load balancing.

The Load Balanced Ad hoc Routing protocol (LBAR) [3] uses setup messages to get information on all possible paths and defines a new metric known as the degree of nodal activity to distribute traffic on different routes. Weighted Load Aware Routing (WLAR) [4] uses a somewhat similar approach to the one we are proposing here in this paper but in this approach RREQ packets are only delayed for a period of time and then broadcasted. Apart from that, it uses periodic hello messages which further add to the routing overhead generated throughout the network. DLAR [5] uses three different schemes for route selection. The first two schemes uses the sum of all routing packets and the average number of routing packets in queue respectively to determine the least congested route while the third scheme uses the route with the least number of congested intermediate nodes. The scheme proposed in CLAR [6] considers traffic load at a node and its neighboring nodes before selecting a suitable route. Traffic load is shared among neighboring nodes by either exchanging periodic hello messages or it is incorporated into RREQ packets, both of which add to the routing overhead. The approach used in LSR [7] also requires nodes to share path and route load promiscuously. Delay-based Load-Aware On demand Routing protocol (D-LAOR) [8] obtains least congested routes based on total path delay and hop count. It significantly decreases the end-to-end delay and a better packet deliver fraction but the routing overhead is comparatively high. The SLA [9] again uses an approach somewhat similar to what we are proposing in this paper, the difference is in how it treats certain scenarios that could possibly arise in a MANET environment as we have discussed in the next section. A similar approach is used in SLAR [10] to prevent nodes that have just passed a traffic load threshold value. A state called the GIVE_UP is initiated by such nodes indicating to the source node that they should find alternate routes to the destination. Load Balancing and Resource Reservation in Mobile Ad Hoc Networks [11] achieves load balancing based on bandwidth

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usage. The potential bottleneck with this approach is that the bandwidth reserved for alternate routes is predetermined and not dynamic. The study in [12] puts the primary responsibility of load balancing on individual nodes themselves but fails to guard against the terminal node (terminal node is explained later) problem that could arise in MANET environments. Multipath Routing Protocol with Load Balancing (MRP-LB) [13], uniformly distributes traffic over N disjoint routes. The disadvantage of this scheme is that it introduces additional fields that lead to a higher overhead. In Busy Node Avoidance Routing (BNAR) [14] route selection is based on the sum of busy rates of nodes in the route. Busy rate is the ratio of time during which a node receiving or sending packets to the observation time. It performs better than the hop based shortest path routing protocols but it needs to be further scrutinized in heavy traffic environments. BNAR with Network Allocation Vector (BNAR_with_NAV) [15] further disperses traffic compared to BNAR and other hop based shortest path routing protocols but needs to be studied under heavy traffic environments. The study carried out in [16] focuses on energy consumption rate of nodes for selecting load balanced routes. Energy consumption rate of every node is computed after a time interval which exerts extra computing burden on nodes. The Weighted Load Balanced Routing Protocol for MANET (WLBR) [17] determines a route based on three factors, the aggregate interface queue length, the route energy and hop count. It gives least congested routes but adds to routing overhead since each node adds its route energy and current interface queue length to RREQ packets and then broadcasts RREQ packets. A source node receiving a RREP message aggregates the interface queue and node energy of all nodes and checks the number of hops in those routes to decide the best route possible to the destination.

Most of the protocols suggested and implemented so far deal with load balancing by either sending probing packets through the network to detect delay or congestion on the desired route or by adding extra routing overhead to RREQ packets which generates further congestion in the network. Our focus in this paper is to achieve load balancing without contributing to the routing overhead. The rest of the paper is organized as follows. In section II we describe our proposed protocol; section III explains the methodology to evaluate our proposed idea; section IV is simulation results and section V concludes this paper.

II. NODE CENTRIC LOAD BALANCING ROUTING PROTOCOL (NCLBR)

This protocol is similar to how AODV operates. Most of the operations are similar to AODV apart from minor changes to the format of RREQ packets and its subsequent dissemination through the network. There are three distinct roles for nodes in NCLBR protocol, namely, terminal, trunk and normal nodes. Terminal nodes are those nodes that are connected to the rest of the network through only a single link, in other words, they have only one neighboring node. Trunk nodes are the ones that connect two distinct network segments. This distinction is purely based on their geographical location as is described in the section III b. Normal nodes are the ones that are neither trunk nor terminal nodes.

A. Basic Operation of NCLBR

In NCLBR each node takes it upon themselves the task of avoiding congestion in a greedy fashion. Since in a MANET environment, it is always likely that there will be alternative routes to a particular destination. Each node is responsible for diverting congestion away from itself onto other alternative routes that may exist in the network. The primary objective of NCLBR is to avoid new routes forming through a congested node. Each node obtains its current congestion status from the interface queue size. Each node uses an interface queue size of 60. During operation a queue size of 50 is considered the congestion threshold. When a node notices that the congestion threshold has been reached, it automatically starts ignoring new RREQ packets so as to not allow any new routes passing through it and adding to the current congestion level of the node in question. The extra 10 packets in the interface queue are used for special scenarios discussed in the next subsection.

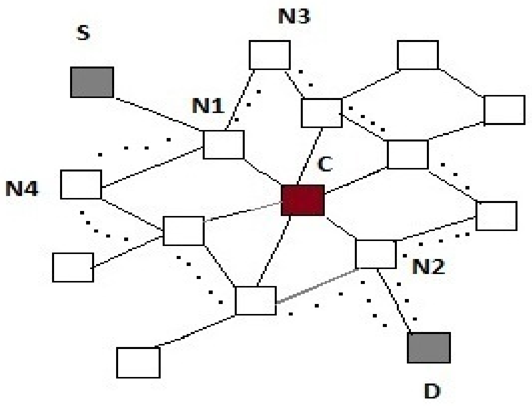

Fig.1. A MANET scenario of congested node C between source node S and destination node D

This can be best illustrated by looking at an example scenario in Figure 1. Source node S wants to communicate with destination D. The conventional shortest path would be through nodes N1, C and N2. But if node C is currently congested then the shortest path is not necessarily the best route from S to D. In the case of node C suffering from congestion, alternative routes through node N3 and N4, represented by dotted lines would be best routes to node D. If node S wants to communicate with destination node D, Node S initiates route discovery procedure by Broadcasting a RREQ packet. The algorithm is defined as follow:

```
If { Node S is a terminal node}
 Use a modified RREQ indicating S is a terminal node
Else
    Use a normal RREQ packet
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If an intermediate node receives a RREQ and is also experiencing congestion at that time, the following algorithm is followed.

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If {RREQ originated from a terminal node & the node
has a fresh route to the destination}
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- send a RREP back to the source

Else if { (RREQ originated from a terminal node OR is a retransmitted RREQ from a normal node) AND the node has no fresh route to the destination}

- Treat the RREQ as normal RREQ packet
- Put RREQ in priority queue for broadcast

Else

- 1 Do not broadcast the RREQ
- 2 Temporarily buffer RREQ
- 3 Wait a certain amount of time for a retransmission for the same RREQ packet

Node can easily find out if they are terminal nodes by passively listening to their surrounding. Before transmitting a RREQ packet a node checks wheather it is a terminal node or not.

B. *Special Scenarios*

Certain special scenarios may occur with regard to using this scheme which we will discuss below.

Scenario 1

If a source is a terminal node and its neighboring node is currently congested. In this case the source node broadcasts a modified RREQ message to indicate that the source has no other neighbors to forward this broadcast through. Hence exempting terminal node's RREQ from being suppressed by congested nodes.

Scenario 2

Another possible scenario is when a node that has two or more immediate neighbors but both or all of them are congested and not allowing RREQ messages from non terminal that is, the normal nodes to pass through it in order for a new paths to be formed through the congested nodes that they are neighbors of. The probability of having such a scenario is extremely low but it can happen so there has to be ways to deal with it. In this case, the source node broadcasts RREQ message to all its immediate neighbors. The congested nodes temporarily buffer the RREQ packets and waits for a retransmission. If a retransmission for the same RREQ message is received the node assumes that there are no alternative routes to the destination and hence the RREQ packet is put in priority queue and subsequently broadcasted.

Scenario 3

The third possible scenario could be when two congested nodes act as a trunk for two network segments. Figure 2 illustrate this situation. The link between N1 and N2 act as a trunk between two geographically distinct located network segments. This is again one highly unlikely scenario in a MANET environment but one that theoretically can happen so the same scheme as is used in scenario 2 to allow network access to such nodes.

Scenario 4

If a terminal node's only neighboring node is suffering from congestion and another node wants to access that terminal node, again the same procedure of buffering the initial RREQ packet until a retransmission arrives for the same destination node is adopted.

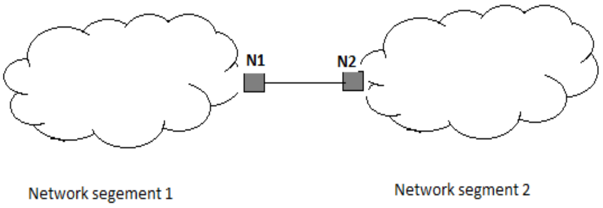

Fig. 2. Nodes N1 and N2 acting as trunk between two network segments

The above four scenarios are the ones that could possibly degrade the performance of the NCLBR protocol but the probability of them occurring is far too low but as in computing if something can happen then we should prepare as if they will happen for sure and hence measures should be put forth to deal with such cases in order to maintain a network wide connectivity and avoid service disruption.

III. METHODOLOGY

A. *Simulation Environment*

We have used ns-2 [18] for our experiment. ns-2 is a discrete event simulator. The performance of NCLBR is compared against AODV. The simulation area is 1000 x 600 square meters and the number of nodes vary from 50 to 100 nodes. The nodes follow the random way point mobility model with speed ranging from 4 to 18 meters per second. Nodes are configured to have an interface queue size of 60 packets for every experiment. Each experiment is run for 100 seconds of simulation time. Nodes are configured with a single transceiver with bandwidth of 2Mbps. Maximum communication range of nodes is 250 meters. Twenty sources have been identified for data transmission which uses constant bit rate (CBR) with a packet size of 512 bytes.

B. *Performance Metrics*

Two performance metrics have been considered in our experiments. Average End-to-end delay and normalized routing load. Average End-to-End delay is the overall average delay for a packet to reach from source to destination. Normalized routing load is the average number of routing control packets needed per data packet delivered.

IV. SIMULATION RESULTS AND DISCUSSION

The simulations were run with 4 and 6 packets per second. Figures 3-6 show the comparative results of AODV and NCLBR. NCLBR outperforms AODV more so when data rates are higher. This is because NCLBR transfers traffic through routes that that are less congested. In Fig. 3, the average end-to-end delay of NCLBR and AODV converges because at low traffic loads NCLBR behaves

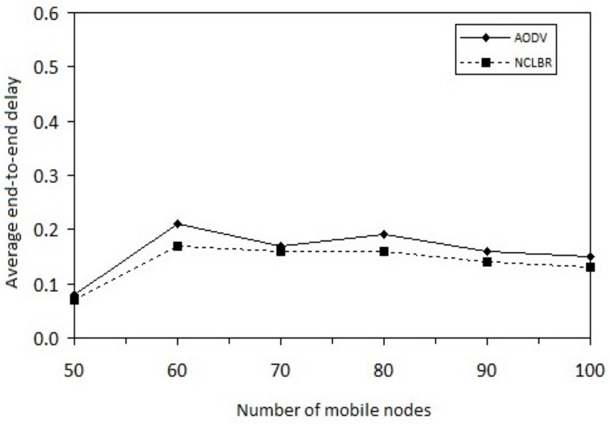

Fig.3. Average end-to-end delay with 4 packets per second

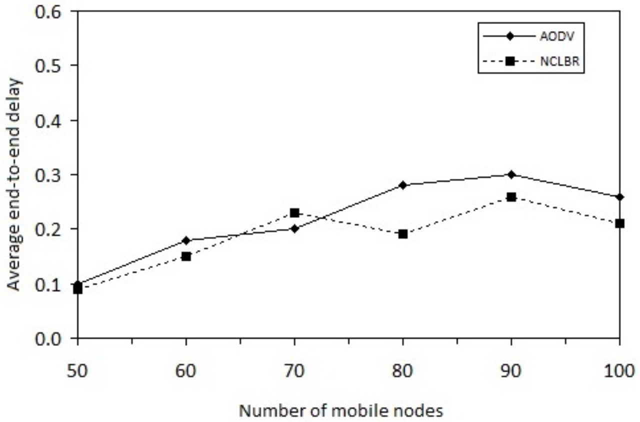

Fig. 4. Average end-to-end delay with 6 packets per second

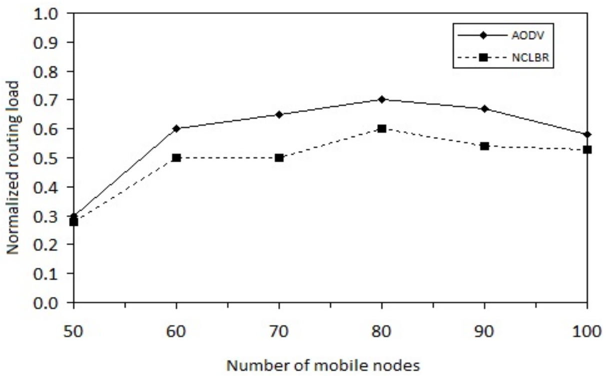

Fig. 5. Normalized routing load with 4 packets per second

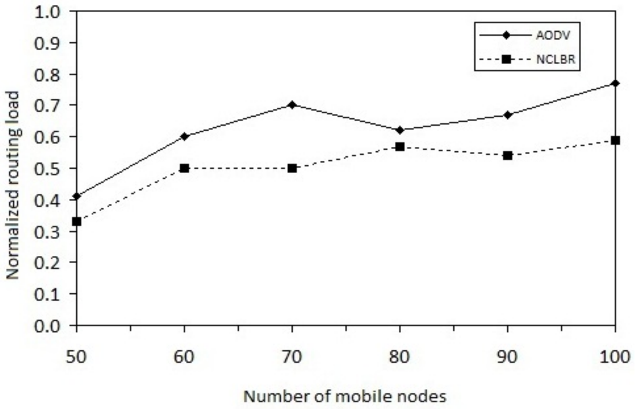

Fig. 6 Normalized routing load with 6 packets per second

similar to AODV. Similarly in Fig. 5 the average end to end delay of NCLBR for low data traffics converges to that of AODV but for high rate scenarios, NCLBR gives a low end to end delay compared to AODV as is clear from Fig. 6. The average end-to-end delay and normalized routing load is also affected by the number of nodes in the network.

V. CONCLUSION

In this paper we proposed NCLBR, a protocol to deal with load balancing in MANETS. As long as the interface queue length of nodes remain under 50 packets, NCLBR behaves almost similar to AODV, but once that threshold is breached the load balancing mechanisms starts affecting RREQ and its dissemination. Our proposed protocol is designed with the main focus on reducing the overall routing overhead while achieving load balancing. In case of congestion, our proposed protocol stops the broadcasting of RREQ packets which is another advantage since in a dense and congested environment it is highly desirable to reduce routing overhead. Hence load balancing with minimum routing overhead is achieved.

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