

Study of Load Balanced Routing Protocols in Mobile Ad hoc Networks

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Abstract

Mobile ad hoc network is a collection of wireless mobile nodes, such devices as PDAs, mobile phones, laptops etc. that are connected over a wireless medium. There is no pre-existing communication infrastructure (no access points, no base stations) and the nodes can freely move and self-organize into a network topology. Such a network can contain two or more nodes. Hence, balancing the load in a MANET is important because The nodes in MANET have limited communication resources such as bandwidth, buffer space, battery power. This paper discusses various load metric and various load balancing routing protocols for efficient data transmission in MANETs.

Keywords: Load Balancing, Mobile Ad hoc Networks, Routing.

1. Introduction

Manet is a temporary wireless network formed by a group of mobile nodes which may not be within the transmission range of each other. The nodes in MANET are self organizing, Self-configuring, Self-maintaining and characterized by multi-hop wireless connectivity and frequently changing topology. Mobile nodes in MANET are connected by wireless links and each node act as host end router in the network. It is a collection of mobile nodes, such devices as PDAs, mobile phones, laptops etc. that are connected over a wireless medium The routing protocols in MANET can be categorized in to three different groups: Table Driven/Proactive, On-demand/Reactive and Hybrid routing protocols. In Table Driven routing protocols, each node stores and maintains routing information to every other node in the network. These done by periodically exchanging routing table throughout the networks. These Protocol maintain tables at each node which store updated routing information for every node to every another node within the network. In on-demand routing protocols, routes are created when required by the source node, rather than storing up-to-date routing tables. Hybrid routing protocols combine the basic properties of the two classes of protocols.

2. Ad-hoc Networks

These networks have no fixed routers, every node could be router. All nodes are capable of movement and can be connected dynamically in arbitrary manner. The responsibilities for organizing and controlling the network are distributed among the terminals themselves. The entire network is mobile, and the individual terminals are allowed to move freely. In this type of networks, some pairs of terminals may not be able to communicate directly with each other and have to relay on some terminals so that the messages are delivered to their destinations. Such networks are often referred to as *multi-hop* or *store-and forward* networks. The nodes of these networks function as routers, which discover and maintain routes to other nodes in the networks. The nodes may be located in or on airplanes, ships, trucks, cars, perhaps even on people or very small devices.

3. Load Balanced Routing Protocols

Load balancing deals with improving the performance of the system by transferring the jobs from over headed nodes to under loaded or idle nodes. In ad hoc networks, only Associatively-Based Routing (ABR) [1] considers the loads the metric. ABR, however, uses the routing load as the secondary metric. Furthermore, the load is measured in the number of routes a node is a part of, and hence the protocol does not account for various traffic loads of each date session.

3.1 Dynamic Load Aware Routing (DLAR)

DLAR [2] considers the load of intermediate nodes as the main route selection metric and monitors the congestion status of active routes to reconstruct the path when nodes of the route have their interface queue overloaded.

DLAR builds routes on-demand. When a route is required but no information to the destination is known, the source floods the ROUTE REQUEST packet to discover a route. When nodes other than the destination receive a no duplicate ROUTE REQUEST, they build a route entry for the <source, destination> pair and record the previous hop to that entry (thus, backward learning).

Nodes then attach their load information (the number of packets buffered in their interface) and broadcast the ROUTE REQUEST packet. After receiving the first ROUTE REQUEST packet, the destination waits for an appropriate amount of time to learn all possible routes. In order to learn all the routes and their quality, the destination node accepts duplicate ROUTE REQUESTS received from different previous nodes. The destination then chooses the least loaded route and sends a ROUTE REPLY packet back to the source via the selected route. A node can detect a link break by receiving a link layer feedback signal from the MAC protocol, not receiving passive acknowledgment, or not receiving hello packets for a certain period of time. When a route is disconnected, the immediate upstream node of the broken link sends a ROUTE ERROR message to the source of the route to notify the route invalidation. Nodes along the path to the source remove the route entry upon receiving this message and relay it to the source. The source reconstructs a route by flooding a ROUTE REQUEST when informed of a route disconnection.

DLAR introduce three algorithms in selecting the least loaded route. DLAR scheme 1 simply adds the routing load of each intermediate node and selects the route with the least sum. If there is a tie, the destination selects the route with the shortest hop distance. When there are still multiple routes that have the least load and hop distance, the path that is taken by the packet which arrived at the destination the earliest between them is chosen. DLAR scheme 2 is similar to scheme 1. However, instead of using the sum of number of packets queued at each intermediate node's interface as in scheme 1, scheme 2 uses the average number of packets buffered at each intermediate node along the path. DLAR scheme 3 considers the number of congested intermediate nodes as the route selection metric. Basically, it chooses the route with the least number of intermediate nodes that have their load exceeding the threshold value T.

DLAR does not allow intermediate nodes to reply from cache. DLAR periodically monitors the congestion status of active data sessions and dynamically reconfigures the routes that are being congested. Using the least-loaded routes helps balance the load of the network nodes and utilize the network resources efficiently.

3.2 Load-Aware Destination-Controlled routing for MANET (LBAR)

LBAR [3] defines a new metric for routing known as the degree of nodal activity to represent the load on a mobile node. In LBAR routing information on all paths from source to destination are forwarded through setup messages to the destination. Setup messages include nodal activity information of all nodes on the traversed path.

After collecting information on all possible paths, the destination then makes a selection of the path with the best-cost value and sends an acknowledgement to the source node. LBAR also provides an alternate path maintenance technique to patch up broken links by detouring traffic to the destination.

Load-Balanced Ad hoc Routing (LBAR) is an on-demand routing protocol intended for delay-sensitive applications where users are most concerned with packet transmission delay. Hence, LBAR focuses on how to find a path, which would reflect least traffic, load so that data packets can be routed with least delay. The algorithm has four components: Route Discovery , Path Maintenance ,Local Connectivity Management, Cost Function Computation. First Route recovery, The route discovery process is initiated whenever a

source node needs to communicate with another node for which it does not have a known route. The process is divided into two stages: forward and backward. The forward stage starts at the source node by broadcasting setup messages to its neighbors. A setup message carries the cost seen from the source to the current node. A node that receives a setup message will forward it, in the same manner, to its neighbors after updating the cost based on its nodal activity value. The backward stage begins with an ACK message forwarded backward towards the source node along the selected path, which we call the active path. If a link on the selected path breaks, the ACK message is discarded and an error message is sent backward along the path fragment to the destination. The destination node will then choose another path.

Second Path maintenance, If the source node, an intermediate node on the active path or the destination node moves out of the communication range, an alternate path must be found. If the source node moves away from the active path, In that case, the source has to reinitiate the route discovery procedure to establish a new route to the destination. When either the destination node or some intermediate node moves outside the active path, path maintenance will be initiated to correct the broken path. Once the next hop becomes unreachable, the node upstream of the broken hop propagates an error message to the destination node. Upon receiving notification of a broken link, the destination node picks up an alternative best-cost partial route passing through the node propagating the error message and then sends an ACK message to the initiator of the error message. If the destination has no alternative path passing through the node sending the error message, the destination picks up another route and sends an ACK message to the source. The source will use this new route to send data packets if it still has data to send. By then, a new active path is defined. In the worst case, where the destination has no alternate paths, it propagates an error message to the source and lets it restart route discovery.

Third Local connectivity management, Whenever a node receives a broadcast from a neighbor, it updates its local connectivity information in its Neighborhood table to ensure that it includes this neighbor. Source broadcasts a hello message to its neighbors, containing its identity and activity. Neighbors that receive this packet update their local connectivity information in their Neighborhood tables. Receiving a broadcast or a hello from a new neighbor, or failing to receive consecutive hello messages from a node previously in the neighborhood, is an indication that the local connectivity has changed. If hello messages are not received from the next hop along an active path, the upstream active neighbors using that next hop send notification of link failure and the path maintenance protocol is invoked. The cost function is used to find a path with the least traffic so that data packets can be transmitted to the destination as fast as possible which achieves the goal of balancing loads over the network. In this protocol, Active path is a path from a source to a destination, which is followed by packets along this selected route. Active node is considered active if it originates or relays data packets or is a destination. Inactive node is considered inactive if it is not along an active path. Activity is the number of active paths through a node is defined as a metric measuring the activity of the node. Cost is the minimum traffic load plus interference is proposed as the metric for best cost. Unlike wired networks, packet delay is not caused only from traffic load at the current node, but also by traffic load at neighboring nodes. We call this traffic interference. In the context of traffic interference, the best cost route is regarded as a path, which encounters the minimum traffic load in transmission and minimum interference by neighboring nodes. To assess best cost, the term node activity is used as an indirect means to reflect traffic load at the node. Such activity information can be gained at the network layer, independent of the MAC layer. Traffic interference is defined as the sum of neighboring activity of the current node. During the routing stage, nodal activity and traffic interference are calculated at every intermediate node along path from source to destination. When the destination received routing information, it chooses a path, which has minimum cost.

2.3 Load Aware Routing in Ad hoc networks (LARA)

Load Aware Routing in Ad hoc (LARA) [4] networks protocol for efficient data transmission in mobile ad hoc networks. We also define a new metric for routing called traffic density to represent the degree of contention at the medium access control layer. During the route setup, this metric is used to select the route with the minimum traffic load. LARA protocol requires that each node maintain a record of the latest traffic queue estimations at each of its neighbors in a table called the neighborhood table. This table is used to keep the load information of local neighbors at each node. This information is collected through two types

of broadcasts. The first type of broadcast occurs when a node attempts to discover route to a destination node. This type of broadcast is called route request. The second type of broadcasting is the hello packet broadcasting. In the event that a node has not sent any messages to any of its neighbors within a predefined timeout period, called the hello interval, it broadcasts a hello message to its neighbors. A hello packet contains the sender node's identity and its traffic queue status. Neighbors that receive this packet update the corresponding neighbor's load information in their neighborhood tables. If a node does not receive a data or a hello message from some of its neighbors for a predefined time, it assumes that these nodes have moved out of the radio range of this node and it changes its neighborhood table accordingly. Receiving a message from a new node is also an indication of the change of neighbor information and is handled appropriately. Traffic queue. The traffic queue of a node is defined as the average value of the interface queue length measured over a period of time. For the node i ; it is defined as the average of N samples over a given sample interval.

where $q_i(k)$ is the k th sample of the queue length. q_i is the average of these N samples.

$$q_i = \frac{\sum_{k=1}^N q_i(k)}{N}$$

Traffic density. The traffic density of a node i is the sum of traffic queue q_i of node i plus the traffic queues of all its neighbors,

$$Q(i) = \sum_{\forall j \in N(i)} q_j$$

where $N(i)$ is the neighborhood of node i and q_j is the size of the traffic queue at node j ; $Q(i)$ is the sum of traffic queues of all the neighbors of node i plus that of node i itself. Hop cost. This factor captures the transmission and propagation delay along a hop. Traffic cost. The traffic cost of a route is defined as the sum of the traffic densities at each of the nodes and the hop costs on that particular route. During the route discovery procedure, the destination node selects the route with the minimum traffic cost, which basically reflects the contention at the MAC level, for the non-TCP source. For TCP sources, it takes into account both the number of hops and the traffic cost of the route. This methodology of route selection helps the routing protocol to avoid congested routes. This helps to uniformly distribute the load among all the nodes in the network, leading to better overall performance.

2.4 Delay-based Load-Aware On-demand Routing (D-LOAR)

Delay-based Load-Aware On-demand Routing (D-LAOR) [5] protocol, which determines the optimal path based on the estimated total path delay and the hop count. D-LAOR scheme that utilizes both the estimated total path delay and the hop count as the route selection criterion. D-LAOR also has a mechanism in new route selection to avoid a congested node by selectively dropping the Route Request (RREQ) packets. Simulation results show that our proposed D-LAOR scheme increases packet delivery fraction and decreases end-to-end delay by more than 10 % in a moderate network scenario when compared with the original AODV and other LAOR protocols. Delay based Load Aware On-demand Routing (D-LAOR) protocol is an extension of the AODV.

1) D-LAOR allows the intermediate nodes to relay duplicate RREQ packets if the new path (P') to the source of RREQ is shorter than the previous path (P) in hop count, and DP' is smaller than DP (i.e., $DP' < DP$).

2) Each node updates the route entry only when the newly acquired path (P') is shorter than the previous path (P) in hop count, and DP' is smaller than DP (i.e., $DP' < DP$).

DLAOR does not allow the intermediate nodes to generate a RREP packet to the source node to avoid the problem with stale path delay information. The source node broadcasts a RREQ packet to its neighbors, which then update the total path delay and forward this RREQ packet to their neighbors, and so on, until the

destination is reached. The RREQ packet carries the source and destination addresses, the sequence number, hop-count, and the total path delay DP of a path P , which the RREQ packet has traversed.

D-LAOR can route around a congested node and thus can reduce the control overhead. This is achieved by dropping the RREQ packets at congested nodes, which prevents the congested node from becoming an intermediate node of a path. D-LAOR determines the congested node by comparing the estimated total node delay and the number of packets being queued in the interface queue of two serial nodes in a RREQ packet-forwarding path. DLAOR drops a RREQ packet only when the following two conditions are satisfied simultaneously,

- 1) The estimated total node delay of a node A is greater than that of previous node B .
- 2) The number of packets being queued at the interface queue of a node A is more than 80% of its buffer size.

2.5 Weighted Load Aware Routing (WLAR)

However, these routing protocols reflect neither burst traffic nor transient congestion. To work out this problem, Weighted Load Aware Routing (WLAR) [6] protocol is proposed. This protocol selects the route based on the information from the neighbor nodes which are on the route to the destination. In WLAR, a new term traffic load is defined as the product of average queue size of the interface at the node and the number of sharing nodes which are declared to influence the transmission of their neighbors. (WLAR) protocol adopts basic AODV procedure and packet format. In WLAR, each node has to measure its average number of packets queued in its interface, and then check whether it is a sharing node to its neighbor or not. If it is a sharing node itself, it has to let its neighbors know it. After each node gets its own average packet queue size and the number of its sharing nodes, it has to calculate its own total traffic load. Now when a source node initiates a route discovery procedure by flooding RREQ messages, each node receiving an RREQ will rebroadcast it based on its own total traffic load so that the flooded RREQ's which traverse the heavily loaded routes are dropped on the way or at the destination node. Destination node will select the best route and replies RREP. Average number of packets queued in interface is calculated by Exponentially Weighted Moving Average (EWMA). The reason to use average number of packets queued in interface is to avoid the influence of transient congestion of router. Sharing node is defined as nodes whose average queue size is greater than or equal to some predetermined threshold value. Sharing node is expected to give some transmission influence to its neighbors. If its average queue size is not greater than a threshold value, it is assumed that its effect is negligible. Total traffic load in node is defined as its own traffic load plus the product of its own traffic load and the number of sharing nodes. Path load is defined as sum of total traffic loads of the nodes which include source node and all intermediate nodes on the route, except the destination node.

2.6 Simple Load-Balancing Ad hoc Routing (SLAR)

Simple Load-Balancing Ad hoc Routing (SLAR) [7] protocol is based on the autonomy of each node. Although it may not provide the network-wide optimized solution but it may reduce the overhead incurred by load balancing and prevent from severe battery power consumption caused by forwarding packets. In SLAR, each node determines whether it is under heavy forwarding load condition, and in that case it gives up forwarding packets and lets some other nodes take over the role. In MANETs, since nodes have limited resources, the message overhead for load balancing is more critical than that of the wired network, i.e., in the ad hoc network, the network-wide optimized load balancing approach of the wired network may be inappropriate. SLAR is designed not as an entirely new routing protocol but as an enhancement of any existing ad hoc routing protocols like AODV, DSR etc.

CONCLUSION

In this paper we have discussed some important issues related to the load-balanced routing protocols for mobile ad hoc networks. Load balanced routing protocols have different load metric as route selection criteria to better use MANET resources and improve MANET performance. The heavily loaded nodes are

also likely to incur high power consumption. MANET can maximize mobile nodes packet delivery ratio, throughput lifetime and load unbalanced as a result end-to-end delay can be minimized.

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Parameters	DLAR	LARA	D-LOAR	LBAR	WLAR	SLAR
Route Selection Criteria	No. of Packets in interface	Traffic Density	Cost of path delay and hop count	Degree of nodal activity	Total traffic load	Forwarding load
Routing Path	Single Path	Single Path	Multi Path	Single Path	Multi Path	Single Path
Category	Traffic Size	Traffic Size	Delay based	Traffic Size	Delay based	Traffic Size
Traditional Protocol Used	DSR	DSR	AODV	DSR	AODV	AODV + DSR
Neighboring Load Consideration	NO	YES	NO	YES	NO	NO
Load Balancing Decision	Destination Based	Destination Based	Intermediate-node-based	Destination Based	Destination Based	Destination Based
Interface Queue	NO	YES	YES	NO	YES	NO
Advantages	Routes are reconstructed dynamically in advance of congestion	Uniformly distributes the load among all the nodes in the network, leading to better overall performance	Increases packet delivery fraction and decreases end-to-end delay in a moderate network scenario in comparison to AODV and other LAOR protocols.	Mainly intended for connectionless applications	Avoids the influence of burst traffic	Reduces message overhead

Table 1 :CHARACTERISTIC COMPARISONS OF LOAD BALANCED AD HOC ROUTING PROTOCOLS

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