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Review on Load Balancing in Mobile Ad-hoc Networks

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Abstract: The dynamic nature of network topology, high mobility, limited bandwidth, limited battery power makes routing a challenging task. Routing protocols play a vital role in the functioning of adhoc networks. An ideal routing protocol should fairly distribute the routing tasks among mobile nodes. Most current routing protocols consider only the shortest path with minimum hop count as optimal route neglecting node's traffic. This can have an adverse effect on network performance causing issues like congestion, power depletion and queuing delay. Therefore, it is important to investigate the load balancing in routing protocols for efficient data transmission in MANETs.

Keywords: MANET, Load Balancing, Congestion

I. INTRODUCTION

Mobile ad hoc network (MANET) consists of wireless mobile nodes which can move randomly within a network premises. An infrastructure-less or ad hoc network is built without any fixed base stations and does not require centralized management. Each node can switch from a host to a router as and when required and communicates via multiple wireless links [1]. The wireless networks have limited bandwidth and nodes require multiple hops to send information to other nodes in the network.

Due to unorganized connectivity, absence of centralized authority, dynamic changing topology, routing in MANET has become a challenging task and there is a need to manage whole network without causing long link breaks [1]. Further, low capacity and error prone wireless links, limited battery power of mobile nodes degrade the performance of MANET routing protocols. A number of routing protocols have been proposed in recent past that cope up with ad hoc networks characteristics. A critical challenge in an adhoc routing is the design and development of efficient routing protocols that provide minimum disconnections and high quality communication with minimum delay. An ideal routing protocol should distribute routing tasks and traffic fairly among the nodes in MANET in account of resource constraints like bandwidth, buffer queue length and battery power.

An unbalanced distribution of traffic often leads to power depletion of heavily loaded nodes. The network connectivity suffers leading to frequent disconnections due to network partitioning as more number of nodes is powered down. In addition, end to end delay and packet loss increases for the connections using these heavily loaded nodes. Load balancing can maximize lifetime of mobile nodes, minimize traffic congestions, energy consumption of mobile nodes and end to end packet delays [2].

This paper is organized as follows. In section 2, we presented the classification of adhoc routing protocols. Section 3 provides considerable insight into various proposed Load Balanced routing protocols in the literature and Section 4 concludes the paper.

II. LOAD BALANCING IN MANET

Based on the routing path used, load balanced adhoc routing protocols can be broadly classified into single path and multiple path routing [11] as shown in Figure 2.

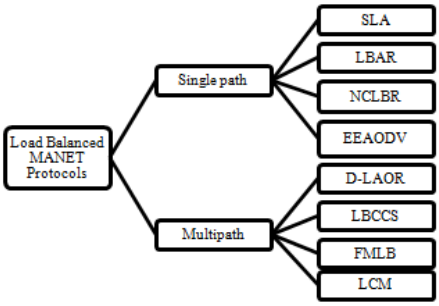

Fig.. 1 Classification of Load Balanced MANET Routing Protocols

A. Single Path Routing

In single path routing, only a single route is used between a source and destination node and if a link fails, then alternative route is searched.

1) *Simple Load-Balancing Approach (SLA):* Yoo and Ahn [12] proposed SLA which resolves the congestion problem by allowing each node to drop RREQ implicitly or to give up packet forwarding explicitly depending upon its own traffic load. SLA tries to extend the expiration of mobile node power by preventing the traffic congestion on a few nodes, which generally occurs during low mobility. Normal routing protocols like AODV, DSR searches for othe route only when primary route fails that leads to node congestion but SLA allows each node to determine if it is heavily loaded or not and distributes the traffic uniformly over the entire network thereby increasing lifetime of a node and making all nodes to fairly consume the energy. There may be some selfish nodes in the network that do not participate in pack forwarding intentionally to save their own energy. In SLA, a credit-based scheme called Protocol-Independent Fairness Algorithm (PIFA) is employed to give due credit to nodes for voluntarily participating in forwarding packets. The nodes can earn the credits by forwarding other's packets and when they have enough credits with them, they are allowed to send their own packets.
2) *Load Balanced Ad Hoc Routing(LBAR):* H. Hassanein et al. [13] proposed load-aware destination controlled on-demand routing protocols designed for transmission delay sensitive neighbouring applications. LBAR focuses on finding path with least traffic load to transmit packets with minimum delay. LBAR utilizes a new metric for routing known as degree of nodal activity to represent load on a node. It proposed four stages: Route Discovery subdivided into forward and backward stages, Path Maintenance, Local Connectivity Management and Cost Function Computation. 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 forward stage of route discovery phase starts at the source node by broadcasting setup messages carrying cost information as seen from the source to the current node to its neighbors. A node receiving a setup message updates the cost based on its nodal activity and forwards it to its neighbors. The backward stage starts with an ACK message sent backward towards the source node along the selected or an active path. Due to mobility if the link failure occurs, destination node finds an alternative best-cost route and sends the ACK message in Path Maintenance phase. In local connectivity management phase, each node sends Hello message to its neighborhood to check for path breakage. The cost function is used to find the best path with the minimum traffic load and interference by neighboring nodes to achieve the goal of load balancing loads over the network.
3) *Energy Efficient Ad-Hoc On Demand Vector (E^2AODV):* Kumar et al. [14] proposed E^2AODV protocol which balances the load with energy efficiency considering both congestion and the nodes energy usage. RREQs packets are broadcasted by source node like in normal AODV. An intermediate node receiving the RREQ will compare its current queue length with its threshold before rebroadcasting it further in the network. If the queue length at node is greater than the threshold, the RREQ packets will be dropped thus bypassing the node from path establishment. Otherwise, the node will deal with RREQ normally and further the node's energy is compared with threshold energy. If the node's energy is less than the threshold energy than the packets are transmitted or less the packets are dropped. In above scheme, the threshold value plays an important role in selecting nodes whether or not to forward RREQ and the threshold value changes dynamically with the current load status of network. Every time an intermediate node receives a RREQ packet threshold value is re-calculated according to the nodes' queue length around the backward path.
4) *Node Centric Load Balancing Routing Protocol (NCLBR):* Ali et al. proposed NCLBR [15] for MANET in which each node avoids the congestion in greedy fashion. This algorithm uses the alternative route towards the destination to divert traffic away from itself onto other routes existing in the network and to avoid establishment of new routes through congested nodes. Each node monitors the current status of its interface queue size. When a node notices that the congestion threshold (say 50) has been reached, it automatically starts ignoring new RREQ packets so as to not allow any new routes passing through it. There are three different categories of nodes in NCLBR protocol, namely, terminal, trunk and normal nodes. Terminal nodes are connected to the rest of the network through only a single link, i.e. they have only one neighboring node. Trunk nodes are the ones that are connected to two distinct network segments and rest of all the nodes are normal. Simulation results revealed that NCLBR outperforms AODV more at higher data rates because NCLBR transfers traffic through less congested routes.

B. Multiple Path Routing

In multipath routing, multiple alternative paths through a network are stored that can provide fault tolerance, enhanced bandwidth and security.

1) *Delay-Based Load Aware On-Demand Routing (D-LAOR) Protocol:* J-H. Song et al. proposed D-LAOR protocol as an extension of normal AODV for mobile ad hoc networks [16], which utilizes the optimal path based on the estimated total path delay and the hop count as the basic route selection criterion. The delay corresponding to each node is calculated on the basis of packet arrival time and packet transmission time. The average delay at node includes the queuing contention and transmission delays. Then total path delay is calculated by sum of node delay from source to destination.

$Delay_p = \sum Q_k$ where k =1, 2… n

Where Q_k is the queuing delay at each node.

During route discovery process, each RREQ packet carries hopcount and the total path delay $Delay_p$ of a path P. On receiving the RREQ packet, only the destination node can send RREP packet back to source node and not any intermediate node. If the duplicate RREQ packet is received by a destination node then RREP is sent back immediately to source node if it has smaller total path delay and hop count than the previous one. Each intermediate node updates the route immediately if newly acquired path is better than previous entry in terms of hop count and path delay.

2) *Load Balancing Congestion Control Scheme (LBCCS):* Maheshwari et al. [17] proposed Load Balancing Congestion Control Scheme which improves the routing process in AOMDV protocol. In this scheme, the rate of sender is controlled through Acknowledgement (ACK) of intermediate nodes that are unable to handle the extra load in network. The sender takes some time to control it so the packets are stored in the memory (queue) of nodes for that duration and memory management scheme is assigned. This scheme can handle the packets beyond the capacity, thus minimizing packet dropping.
3) *Fibonacci Multipath Load Balancing Protocol. (FMLB):* Tashtoush et al. [18] proposed FMLB which distributes data packets over multiple paths through the mobile nodes using Fibonacci sequence. Fibonacci distribution increases the packet delivery ratio by reducing the network congestion. The FMLB protocol's responsibility is balancing the packets transmission over the selected paths and ordering them according to hops count. The shortest path is used more frequently than the other ones. Mathematically, Fibonacci sequence is the sequence of numbers that starts with 0, and 1, and each number is the sum of the previous two numbers. Fibonacci series is: 0, 1, 1, 2, 3, 5, 8…….so on. Consider there are 7 routes between source and destination node and these routes are arranged in descending order according to the length of each path. The first path will be the longest path and the seventh path will be the shortest path. For each of these seven paths the corresponding Fibonacci value is assigned and the distributed packet ratio is calculated. Distributed packets ratio is the corresponding Fibonacci value divided by the summation of the corresponding Fibonacci values. The source node starts the distributing of the data packets through the paths according to their weights. The simulation results illustrated that FMLB protocol has achieved an enhancement on packet delivery ratio as compared to other well known protocols. Though FMLB protocol has a higher E2E delay than AODV protocol but lower than other linear multiple path routing protocols.
4) *Load-Balancing And Coding-Aware Multicast (LCM) Protocol:* Geng et al. [19] proposed a LCM protocol which used a new route metric called Expected Transmission Time with Coding and Load Balancing (ETTCL). This protocol selects the path that has possible coding opportunity and where overflow due to network overload can be prevented effectively. ETTCL-based protocol includes multiple node-disjoint paths, multicast routing discovery by constructing the node-disjoint multicast tree on the basis of ETTCL and route maintenance through network coding to encode the data flows that reduces routing overhead of LCM protocol. When a source node has new data to transmit, it will initiate route discovery to select the best possible path according to the network coding-aware ECTTL routing metric with load balancing and then select the node-disjoint paths. Node disjoint paths are established as in MAODV protocol. An alternate routing table is used to store the information of multiple paths. After the establishment of a path, the packets to be transmitted on this active path are encoded for transmission. Route maintenance is initiated when one of the following conditions exist that is if the transmission of present data flow has completed and the data flow has been encoded with other data flows, this data flow has to be rerouted or if the number of the failure links has exceeded a certain range and the destination node cannot decode the original data. Simulation results shows that LCM multicast routing protocol improve network performance in terms of packet delivery ratio, average end-to-end delay and routing control overhead compared to other existing protocols by varying network load capacity, the dynamical adaptability and the network scalability.

Table I Comparison of load balanced adhoc routing protocols

Scheme	Route Selection	Technique used	Routing protocol	Routing Path used	Merits	Demerits
SLA	Node's self traffic load	Traffic based	AODV, DSR	Single path	It resolves the traffic concentration problem and extends expiration of power of a mobile node. It can also detect and isolate a single malicious node.	A reliable server node called Credit Manager (CM) is required which manages nodes.

LBAR	Degree of nodal activity	Traffic based	DSR	Single path	Intended for delay-sensitive applications. In addition, in order to keep up with frequent topology change, LBAR provides quick response to link failure by patching up the broken routes in use, thus guaranteeing reliability of data transmission.	Mainly used for connectionless application.
E^2AODV	Interface queue length and energy	Traffic based	AODV	Single path	It shows good packet delivery ratio and throughput and consumes less energy as compared to AODV protocol.	Average end to end delay is high as compared to AODV.
NCLBR	Interface queue size	Traffic based	AODV	Single path	NCLBR outperforms AODV more at higher data rates	It is not mentioned how the optimum threshold value is chosen. Interface queue length doesn't give a true picture of actual load
D-LAOR	Total path delay and hop count	Delay Based	AODV	Multi Path	Increases packet delivery fraction and Decreases end-to-end delay in a moderate Network scenario in comparison to AODV and other LAOR protocols.	Routing overhead is comparatively high
LBCCS	Rate control and memory management module	Traffic based	AOMDV	Multi Path	It improves the reliability of data delivery by minimizing packet drops due to rate control module that handles congestion and memory management module that handles the load until the rate is not controlled.	More suitable for networks with high mobility.

FMLB	Routes are sorted in an increasing order of hop count and each route will be assigned a Fibonacci weight.	Traffic based	AODV	Multi Path	FMLB protocol has achieved an enhancement on packet delivery ratio, up to 21%, as compared to AODV protocol, and up to 11% over the linear Multiple-path routing protocol.	FMLB protocol has scored a higher E2E delay than AODV protocol
LCM	ETTCL including coding possibility, bandwidth, link delivery ratio and data packet size and load balanced factor includes queue length, retransmission number and channel busy time.	Traffic based	MAODV	Multi Path	It achieves better network performance in terms of packet delivery and delay as the network load capacity, the dynamical adaptability and the network scalability vary. There is no need to reroute when the number of link failure is limited by utilizing network-code for multicast transmission.	Routing overhead is comparatively high

III. CONCLUSION

In this paper, we have discussed several load-balanced routing protocols for mobile adhoc networks for improving MANET performance by maximizing mobile nodes lifetime, packet delivery ratio, throughput and minimizing traffic congestion and load unbalance. Nodes in MANET have limited bandwidth, buffer space, battery power etc so it becomes vital to distribute evenly the traffic among the mobile modes. Load balanced routing protocols utilizes different load metrics as route selection criteria to make efficient use of MANET resources.

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