A Survey on Load Balancing Techniques in Wireless Networks

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Abstract: **Mobile Ad hoc Network (MANET) consists of mobile nodes which are a part of self-organizing and self-autonomous network. Since there is no centralized infrastructure in such a network, a highly adaptive routing scheme to deal with the frequent topology changes and congestion is required. Load balancing turns out to be an emerging tool to use MANET resources in an efficient manner in order to improve network performance. The load must be uniformly transferred to different alternative routes to provide effective utilization of the network, increase packet delivery ratio and reduce packet delay.**

Keywords—Manat ,load balancing , protocols

I. INTRODUCTION

MANET (mobile ad hoc network) is defined by its own characteristics such as self-organizing nature, self-autonomous, dynamic changing topology and high mobility [1]. Due to lack of centralized infrastructure, various issues arise in the adhoc networks i.e. security, load balancing, routing etc [2]. The network relies on multi-hop radio relaying in case destination lies outside the radio range of source node. Each node act as router or host interchangeably. The typical applications of mobile ad hoc network are battlefields, emergency rescue operations and data acquisition in remote areas.

Ad hoc routing protocols lack load balancing capabilities when they were developed initially and consider the route with minimum hop count as optimal path. This makes some of the innermost nodes acting as backbone in the network as highly congested and loaded which in turn leads to higher packet drops and packet delays. The congestion problem is further aggravated by the use of route cache in some of the routing protocols. The heavily loaded nodes are also likely to incur high power consumption. This is an undesirable situation, as it reduces battery power. Hence they cannot balance the load on the different routes thus degrading the performance by causing serious problems in mobile node like congestion, power depletion and queuing delay.

Congestion is still the major reason for frequent link breaks in a network. The excessive load on the nodes can cause the queue buffer overflow that further lead to the more packets being dropped. This leads to packet delay and affects the packet delivery ratio of MANET. While some nodes may be involved in routing, others are heavily congested and most of the routing network traffic flows through them. Because of this heterogeneous load distribution, the nodes loaded quickly consume their limited energy resources and show a high congestion. These effects can significantly degrade the performance of ad hoc network.

Load balancing is an effective solution to avoid congestion problem in the network. The principal metric, load balancing is to simultaneously use all available resources. Indeed, if two or more disjoint paths between a source and destination, we can theoretically achieve throughput equal to the cumulative sum of the rates possible on the routes separately [3]. The use of this visibility may influence the choice of intermediate nodes to route traffic to the correct destination. This technique improves network performance. The capacity is thus uniformly spread across the ad hoc network. If the load is balanced then it will provide effective use of the network and reduce packet delay and improve packet delivery ratio.

II. CLASSIFICATION OF MANET ROUTING PROTOCOLS

Routing protocols for ad hoc wireless networks can be classified in several ways: based on the routing information update mechanism or routing topology etc [3].

2.1 Based on Routing Information Update Mechanism

Ad hoc wireless network routing protocols can be classified into 3 categories based on routing information update mechanism [3].

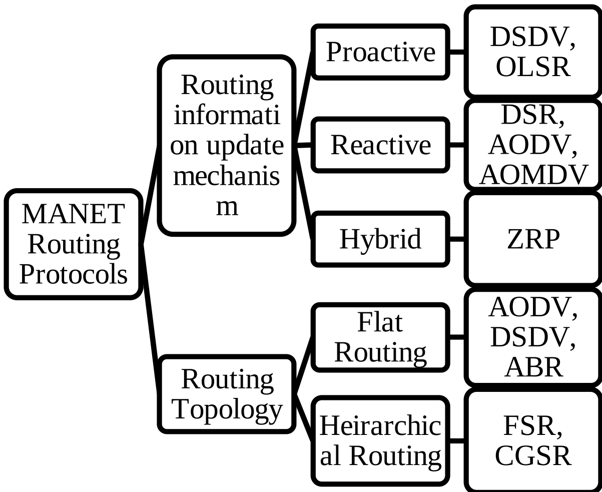

Figure 1. Classification of MANET Routing Protocols

These are as follows:

- **Proactive or table-driven routing protocols:** In proactive protocols, routes are always available in routing tables and every node maintains route to other nodes in the network by periodically exchanging routing information. Routing information is updated periodically or whenever there is a change in topology. Whenever a node wants to send some information to other node, it runs a suitable path finding algorithm on the topology information stored in its routing tables. Though latency for finding route is less but a large overhead is associated in maintaining huge amount of data. Eg. DSDV, OLSR.
- **Reactive or on-demand routing protocols:** These protocols do not maintain the network topology information. They obtain the necessary route when required, by flooding the network with route request packets in route establishment phase. These protocols do not exchange route information periodically so overhead is less. But, latency in finding route is high. Eg, AODV, DSR, AOMDV etc.
- **Hybrid routing protocols:** These protocols combine the best characteristics of the above two categories. Nodes within a certain distance from other nodes or within a geographical region often referred as zone of a given node follow a table-driven approach and for nodes located outside this zone use on-demand approach for routing. Eg. ZRP (Zone Routing Protocol).

2.2 Based on Routing Topology

Ad hoc wireless networks based on the number of nodes can make use of either a flat topology or hierarchical topology for routing.

- **Flat topology routing protocols:** Protocols under this category uses flat addressing scheme similar to the one used in IEEE 802.3 LANs. It assumes the presence of a core routers and globally unique addressing mechanism for nodes in an ad hoc wireless network [4]. This scheme is suitable for smaller number of nodes in a network. Routing topology being used in the Internet is hierarchical in order to reduce the state information maintained at the core routers.
- **Hierarchical topology routing protocols:** Protocols belonging to this category make use of a logical hierarchy in the network and an associated addressing scheme to reduce the state information maintained at central routers. The hierarchy could be based on geographical information or it could be based on hop distance.

III. Classification of Load Balancing Algorithms

Based on the load balancing technique used, adhoc routing protocols can be broadly classified into following three categories as shown in Figure 2:

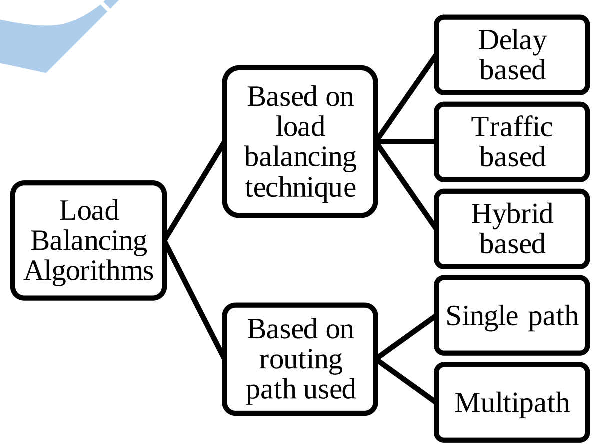

Figure 2. Classification of Load Balanced Algorithms

- **Delay-based scheme:** In this approach, load balancing is achieved by avoiding nodes with high link delay in further route establishment or path selection phases. Eg. LAOR.

- **Traffic-based scheme:** In this approach, load balancing is achieved by evenly distributing traffic load among mobile nodes. Eg, ALBR-G, CCMQVR.
- **Hybrid scheme:** In this approach, load balancing is achieved by combining the features of traffic-based and delay-based techniques. Eg. FMLB, EALBM.

Based on the routing path, they are classified as single path or multiple paths as follows [5]:

- **Single path:** A single path is maintained between a source and destination node and if a link fails, then alternative route is searched. Eg. ALBR-G, RTLB-DSR.
- **Multiple paths:** Multiple paths between a source and destination node are kept such that if link fails, alternative route is already available. Eg. FMLB, CCMQVR

IV. LOAD BALANCED MANET PROTOCOLS

4.1 LAOR: J-H. Song et al. proposed LAOR protocol [6] as an extension of normal AODV for mobile ad hoc networks, which uses the optimal route on the basis of the estimated total path delay and the hop count. The delay for each corresponding node is calculated based on the packet arrival time and packet transmission time. The average delay at each node includes the queuing contention and transmission delays both. Then total path delay is calculated by sum of node delay from source node to destination node.

$Delay_p = \sum Q_k$ where k =1, 2… n

Where Q_k is the queuing delay at each node.

During route discovery process, each route request packet carries hop count and the total path delay $Delay_p$ of a path P. On receiving the request packet, only the destination node can send route reply packet back to source node and not any intermediate node is allowed to send the reply packet. If the duplicate request packet is received by a destination node then reply 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.

4.2 ALBR-G: Bin et al. [7] have proposed a novel adaptive load balancing routing approach which is based on a gossiping mechanism. This algorithm merges gossip based routing and load balancing scheme efficiently. It adjusts the forwarding probability of the route request messages adaptively as per the load status and distribution of the nodes in the phase of route discovery.

The load L(i) of node n_i is calculated as:

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

Where node n_i samples the interface queue length in MAC layer periodically, $q_i(k)$ is k^{th} sample value, and N is the sampling period.

The load intensity function LI (i) of node ni is defined as:

$$LI(i) = \frac{L(i)}{q_{max}(i)}$$

Where $q_{max}(i)$ is total interface queue length of node in the MAC layer.

The forwarding probability of RREQ for node $n_i$is given by:

P_i = 1 if ((R(i) <=4) or (n<=4)

$1 - \frac{R(i)}{n+1}$otherwise

Where n is number of neighboring nodes and R (i) is the sorted list of sequence number according to LI(i) values.

ALBR-G extends the HELLO packet in AODV, and adds the load intensity function to HELLO packet to calculate forwarding probability. Every node samples the interface queue length periodically, and calculates LI using above formulas. ALBR-G demonstrates up to 45% less routing overhead than DLAR and AODV. This performance gain is obtained mainly from the suppression of RREQ packets. The total load is more evenly distributed among the network nodes than DLAR and AODV.

4.3 QMRB-AODV: Ivascu et al. [8] have presented a quality of service mobile routing backbone over AODV for supporting QoS in mobile ad hoc networks. It utilizes mobile routing backbone to dynamically distribute traffic within the network and to select the route that can support best a QoS connection between a source and its destination. A MRB is created based on the characteristics of mobile nodes in the network. Paths connecting source and destination nodes are found on this MRB. Four QoS support metrics (QSMs) are used to differentiate nodes in the network and identify the nodes that can take part in the MRB and the route discovery process. Their approach improves network throughput and packet delivery ratio by directing traffic through less congested and resource-rich links of the network. However since only a single MRB is identified between a source and destination, frequent route breaks may happen in highly dynamics networks leading to more frequent route re-discovery processes and hence increased overheads.

4.4 Fibonacci Multipath Load Balancing protocol (FMLB): Tashtoush et al. [9] proposed FMLB which balances the data transmission by distributing data packets over multiple alternate paths using Fibonacci sequence and ordering them according to hops count. There are more chances that shortest path is selected more often than the other paths. Fibonacci distribution increases the packet delivery ratio by reducing the network congestion. Let us consider 5 alternate routes between source and destination node and these routes are arranged in descending order according to the hop count. For each of these paths, the corresponding Fibonacci value is assigned (0, 1, 1, 2, 3) and the distributed packet ratio is then calculated. Distributed packets ratio is the corresponding Fibonacci value divided by the summation of the corresponding Fibonacci values. The source node starts distributing the data packets through the paths according to their Fibonacci weights. The simulation results show that the 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. Also the results show the effect of nodes pause time and speed on each of the data delivery ratio and End-to-End (E2E) delay transmission time.

4.5 LUNAR: Load eqUilibrium Neighbor Aware Routing (LUNAR) [10] which combines the advantages of neighbor coverage knowledge and load balancing techniques to implement decision making system at every intermediate node. It significantly decreases the retransmission of route request packets and thus reduces the routing overhead within the network. The scenarios have varying node density, node mobility, number of source-destination connections and queue length. LUNAR dynamically calculates the Cumulative Active Path Count (CPAC) at every intermediate node to decide whether to rebroadcast the route request packet in the network or not. Uncovered neighbor set (UCN) calculations utilize the neighbor coverage information which further reduces the redundant broadcasts. Each intermediate node (n_i) calculates its Uncovered Neighbor (UCN) set (UCN(n_i)) from the neighbor set (NS) information received from the source ({s}) or its previous node (NS(p)) and its own neighbor set (NS(n_i)). UCN is computed as:

$$UCN(n_i) = NS(n_i) - [NS(n_i) \cap NS(p)] - \{s\}.$$

If the UCN set is empty then it simply drops the RREQ packet as every neighboring node has already received the same RREQ packet from the source node or the previous node. If UCN set is not empty then it calculates Cumulative ActivePath Count (CAPC(n_i)) as average of CAPC (CAPC(p)) received with RREQ packet and its own APC (APC(n_i)). CAPC is computed as:

$$CAPC\ (n_i) = [APC(n_i) + CAPC(p)]/2.$$

Each intermediate node waits for duplicate RREQ packet arrival from other neighbourhood until *hello timer* expires. After receiving the duplicate RREQ packets from other neighbors, for every RREQ packet the node recomputes its UCN set. CAPC is calculated separately for every RREQ packet, for every possible path, if the UCN is not empty. The node rebroadcasts the RREQ which has the lowest CAPC. In this way, destination node receiving multiple RREQ packets from different routes first compares the CAPC values. It selects the reverse path based on lowest value of CAPC from these multiple RREQ packets.

The simulation results revealed that LUNAR generated lesser rebroadcast traffic as compared to AODV, LBR [11] and NCPR.[12]. The normalized routing overhead for LUNAR is reduced by 25 to 30 % as compared to above stated protocols. Further, the PDR is increased by up to 3% and the end to end is decreased by 5% approximately.

4.6 EALBM: AnEnergy efficient and Load Balancing Multi-path [13] and on-demand routing protocol which uses multiple paths at the same time. It consists of three phases: neighbor discovery, multipath discovery and data transmission. The source initiates multipath discovery process to determine all existing disjoint multipath from source to destination. Each disjoint path is assigned a weight based on the energy level of nodes along that path. The path with maximum energy has least weight i.e. most preferred. The algorithm is validated using four different scenarios, static nodes with same or different energy level of nodes, and dynamic node mobility with same or different energy of nodes. Simulation results show that EALBM performs better as compared AOMDV. The throughput of EALBM is higher by 6% (static nodes) upto 16% (dynamic topology) as compared to AOMDV. The packet delivery ratio of EALBM is higher by 7% (static) upto 52% (dynamic) as compared to AOMDV. The packet loss, latency and normalized load in case of EALBM are also substantially lower than AOMDV. The latency in EALBM is lower than AOMDV by 34% (static) to 50% (dynamic), and the normalized load is lesser by 18% (static) and 39% (dynamic topology). The average residual energy of the nodes is increased by 0.31% as compared to AOMDV.

4.7 RTLB-DSR: Maleki et al. [14] presented Real-Time Load Balancing Dynamic Source Routing protocol that provides load balancing in DSR routing. It ensures Quality of Service in the network through a differentiating service method among best effort and real-time flows. It is based on an effective graph-based method that applies varied routing policies to DSR. Then the entire network flow is divided into two components: best-effort and real-time flows using a classifier. The best effort flows do not demand any specific requirements; while real-time packets need to reach their destination within a specific deadline. This protocol addresses best-effort flows through the network edge using a node centrality defined as the number of its neighbors in the network. The load-balancing routing criterion becomes:

$$Minimize\ \frac{1}{n}\sum_{k=1}^{n} size(neighbors\_count(k))$$

where n represents number of nodes.

On the other hand, real-time flows are routed through a network center, which contained a smaller load as a result of load-balancing policy. The simulation results showed that RTLB-DSR produced a significant improvement in latency, packet delivery ratio and jitter. The results also demonstrated that this method can address both real-time and best effort traffic.

4.8 CCVQMR (Congestion Control using Varying Queue base approach as well as Multipath Routing): Gupta et al. [15]proposed an approach which consists of three sub processes: multipath routing using AOMDV, varying queue technique and analysis of packet drop using static and varying queue to minimize the congestion. It analyzes the packet drop at each node present in the network and chooses those nodes where maximum congestion occurs and then applying varying and dynamic queue on those nodes to stop packet drops and improve the network performance. After applying varying queue, multipath routing technique using AOMDV protocol is applied to minimum routing overhead and maximum congestion control. In varying queue technique, queue length is not fixed and can vary depending on the number of incoming data packets. So, two queues are used i.e. drop tail queue and priority queue. Drop tail queue is based on FIFO mechanism to manage data packets in the node, but the problem in drop tail queue is static queue size. If static queue size is large and number of data packets are very less than queue length, it will lead to wastage of memory, and if static queue size is small than data may be dropped due to overflow of queue. In order to remove this problem, varying queue technique is being used. Varying queue does not drop any data packet whether queue size is full, because it increases queue length by one if any data packet comes in the queue

Table 1. Comparison of load balanced routing protocols in MANET

Protocol	Load balancing technique	Rout-ing path	Routing Protocol compare d with	Simula-tor	Perform-ance Metrics	Simulation Results	Future prospect
LAOR	Total path delay and hop count	Multi path	AODV	NS2	Packet delivery ratio and end to end delay	Increases packet delivery fraction and decreases end-to-end delay in a moderatenetwork scenario.	To find link cost value assignments which change the hopcount role in routing.
ALBR-G	Merges gossip based routing and load balancing	Single path	AODV, DLAR	NS2	Routing Overhead, Total load distribution of nodes	It can significantly reduce the routing overhead, and balance the load in the network than AODV and DLAR.	To modify it for heterogeneous networks also.
QMRB	Mobile routing backbone to dynamicall y distribute traffic	Single Path	AODV, DSR	Qualnet	Network throughput, packet delivery ratio, messages overhead and end-to-end delay.	It outperforms both protocols in terms of packet delivery ratio. It makes better use of available bandwidth.	To reduce routing overhead
FMLB	Routes are sorted in an increasing order of hop count	Multi path	AODV and AOMDV	Glomos im	Packet delivery ratio and E2E delay	Achieved an enhancement on packet delivery ratio, scored a higher E2E delay	Another numbering sequence to find the best route that reduces

	and each route will be assigned a Fibonacci weight.					than AODV and a lower than linear multiple path routing protocol	congestion. Fuzzy logic techniques can be used to dynamically distribute the load over multiple paths.
LUNAR	Cumulative Active Path Count (CPAC) and Uncovered neighbor set (UCN)	Single path	AODV, LBR, NCPR	NS2	Packet delivery ratio, norm-lized routing overhead and end-to-end delay	Improves overall performance of the network by around 7-8%, as compared to other routing protocols	Further investigations are needed to determine the cause of minor improvements in PDR and EED and to determine the performance of LUNAR as the number of active connections increase.
EALBM	Path energy i.e. average of energy of nodes along the path.	Multi path	AOMDV	NS2	Throughput , delay, packet delivery ratio, packet loss, residual energy, and load.	The throughput increases by 6% to 16% and packet delivery ratio rises by 7%-52%.	To design an algorithm which can permit partially overlapping paths and to set an energy threshold value of node for notifying nodes to recharge or replace battery.
CCVQMR	Packet drop using static and varying queue	Multi path	AOMDV	NS2	Throughput , Queue base Dropped Packets, Routing Load	Data drop is very lower as compared to static queue model.	Further investigation is needed to determine its performance additional path parameters like node queue status, current delays, residual energy etc.
RTLB-DSR	Node centrality as metric and graph-based approach that applies	Single path	DSR	NS2	End to end delay, packet delivery ratio and average per-hop	It provides a significant improvement in latency, packet delivery ratio and jitter for both real-time	To assign link costs dynamically based on the network status. It can be extended

	varied routing policies.				delay variance	and best effort traffic.	to estimate the distance between the intermediate nodes and destination so that real-time packet with a farther destination would be forwarded quickly based on remaining deadline.

V. CONCLUSION AND FUTURE SCOPE

There is no pre-existing communication infrastructure such as access points or base stations and the nodes are free to move and self-organize. The nodes in MANET have limited resources such as bandwidth, buffer space and battery power so load balancing becomes one of the most important research areas in the field of MANETs. In this paper, we have discussed some important issues and approaches related to the load-balancing for MANET routing protocols. Different load balanced routing protocols chooses different load metric as route selection criteria for efficient usage of network recourses. Many areas of research in this field which deserve further attention include robustness, security, energy efficiency, reliability and scalability. Effective and efficient solutions to these issues require the design and development of new routing protocols in MANETs.

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