A Review of Load Balanced Routing Protocols in Mobile Adhoc Networks

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Abstract-- **A wireless Mobile Adhoc NETwork (MANET) is an infrastructure-less mobile network which is based on radio to radio multi-hoping and has no centralized controller or a fixed router. All nodes are capable of movement and can be connected dynamically in an arbitrary manner. Due to the dynamic nature of network topology, frequent mobility, bandwidth limitation, limited battery power, routing in MANETs is a challenging task. Routing protocols are vital for the proper functioning of Adhoc networks. A routing protocol in MANET should fairly distribute the routing tasks among mobile hosts. Most current routing protocols for mobile Adhoc networks consider the shortest path with minimum hop count as optimal route without any consideration of any particular node's traffic and thus degrading the performance by causing serious problems in mobile node like congestion, power depletion and queuing delay. Therefore it is very attractive to investigate Routing protocols which use a Routing Metric to Balance Load in Adhoc networks. In this paper we present various load Balanced Routing protocols for efficient data transmission in MANETs.**

Keyword-- **Index Terms: LoadBalancing, MobileAdhoc Networks (MANETs), Routing.**

1 INTRODUCTION

A critical challenge in the design of Ad hoc networks is the development of efficient routing protocols that provide high quality communication. The nodes in MANET have limited communication resources such as bandwidth, buffer space, battery power etc. Resource constraints in MANET require the traffic to be properly distributed among the mobile host. A routing protocol in MANET should fairly distribute the routing tasks among the mobile host. An unbalanced assignment of data traffic will lead to power depletion on heavily loaded hosts. With more hosts powered down, the connectivity of the network will be reduced which will lead to call failures due to network partitions. In addition, the nodes with heavy routing duties likely have large queuing delay and high packet loss ratio. Therefore, the end-to-end delay and packet loss ratio are large for the connections using those nodes. Thus load balancing is emerging as a key tool to better use MANET resources and improves MANET performance. With Load Balancing, MANET can minimize traffic congestion and load unbalance, as a result, end-to-end packet delay can be minimized, mobile nodes lifetime can be maximized and network energy consumption can be balanced. Currently, Ad hoc routing protocols lack load-balancing capabilities. In fact, a major drawback of all existing ad hoc routing protocols is that they consider the path with minimum number of hops as optimal path to any given destination. However, this strategy does not have provision for conveying the load and quality of path during route setup.Since, the fewer innermost nodes become the backbone for most for the traffic, leading to congestion at medium access control layer (MAC) in these nodes. This may in turn lead to high packet delays, since some nodes may carry excessive loads. This problem is further aggravated by the use of route cache in some of the protocols. This may result in a high probability of packet drops due to congestion severely affecting the TCP performance. The heavily loaded nodes are also likely to incur high power consumption. This is clearly 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.
Thus in this paper we present various novel Load Balancing Protocols.

This paper is organized as follows. In section 2, we described the characteristics of Adhoc networks and existing routing protocols. Section 3 provides considerable insight into various Load Balanced routing protocols, finally we include the comparison of the protocols and conclude the paper.

2 PREVIOUS WORK

2.1 Ad-Hoc Network

In recent, the proliferation of portable devices like PDAs and Laptop computers with diverse wireless communication capabilities has made a mobility support on the Internet an important issue. A mobile computing Environment includes both Infrastructured wireless network and novel infrastructure-less mobile adhoc networks. A MANET [1] is a self organizing system of mobile nodes connected by multihop wireless links forming a temporary network which is based on Radio to Radio multihoping and has neither fixed base station nor a wired backbone infrastructure. Since this network can communicate without a base station and a fixed cable network, the network can be configured dynamically and are deployed in applications such as search and rescue, automated battle fields, disaster recovery, crowd control, sensor networks, military settings,minesite operations and wireless classrooms or meeting rooms in which participants wish to share information or to acquire data. Major challenge in such a network is that nodes can freely move, hence the network topology continuously change. In addition, the characteristics of wireless channel such as limited data transmission range, low bandwidth ,high error rate, limited battery power, frequent mobility, high interference, link failure due to mobility[2] make routing on adhoc network a difficult problem to deal with. The routing issues in infrastructure-based networks are very different from routing in infrastructure-less netwoks.Each intermediate host between source and target node acts as router in an adhoc network and the topology of the network changes frequently. Therefore distribution of up-to-date information about the nodes can saturate the network. Also, late arrival of the information can drive the network into instability. Besides this, another problem is that link failure due to mobility is usually very high. Thus for efficient data transmission in MANETs a lot of research effort has been dedicated to the development of efficient routing protocols.

2.2 Routing Protocols for MANETs

Routing protocols for ad hoc wireless networks can be classified into several types based on different criteria [3]. These protocols can be broadly classified into four categories based on:

1. Routing information update mechanism
2. Use of temporal information for routing
3. Routing topology
4. Utilization of specific resources.

A classification tree is shown in the figure below.

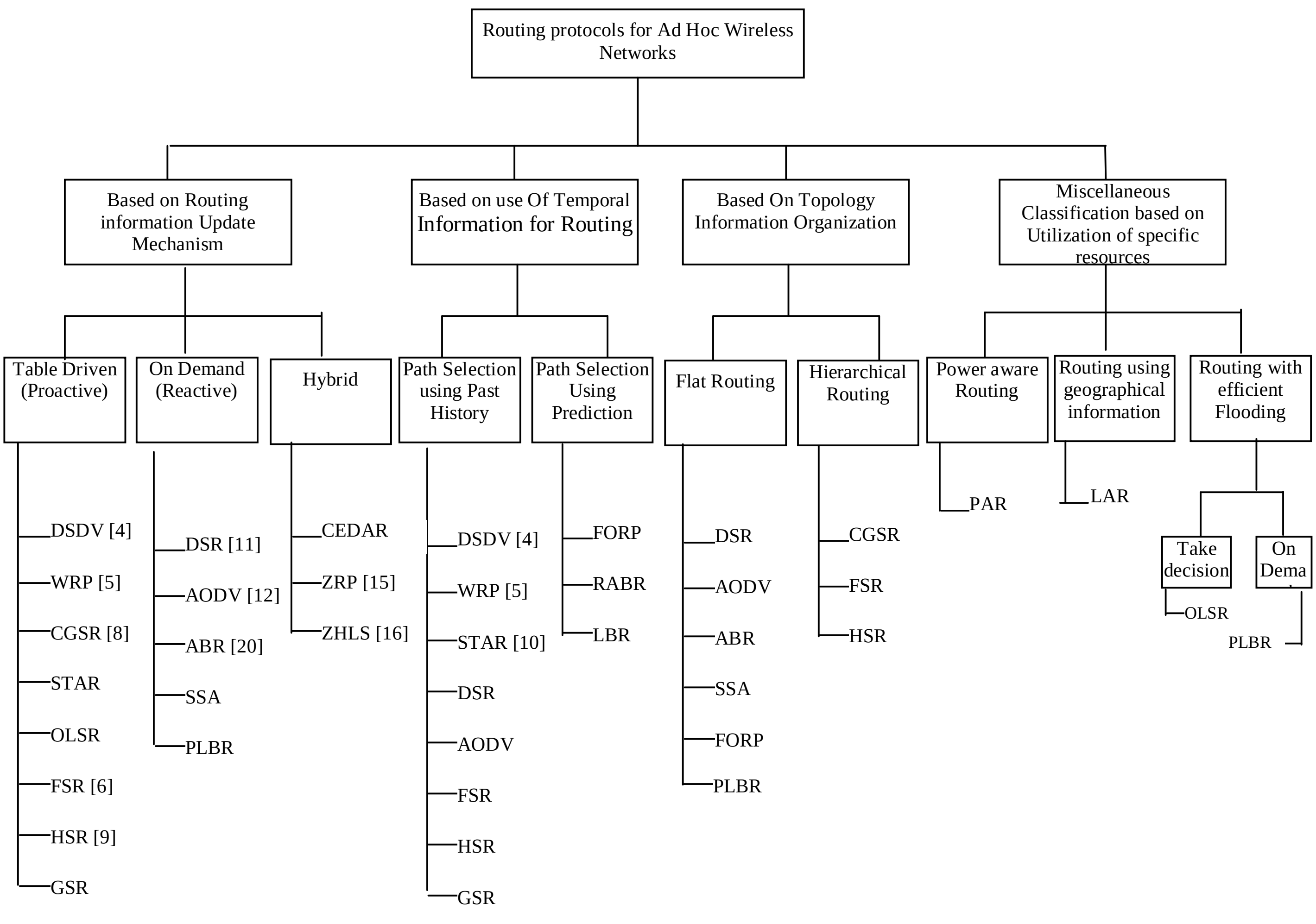

Fig 1: Classifications of Ad hoc Routing protocols [3]

2.2.1 Based on Routing Information Update Mechanism

Ad hoc wireless network routing protocols can be classified into three major categories based on routing information update mechanism. They are:

1. *Proactive or table-driven routing protocols*: In table driver routing protocols, every node maintains the network topology information, in the form of routing tables by periodically exchanging routing information. Routing information is generally flooded in the whole network. Whenever a node requires a path to a destination, it runs an appropriate path finding algorithm on the topology information it maintains.
2. *Reactive or on-demand routing protocols:* Protocols that fall under this category do not maintain the network topology information. They obtain the necessary path when it is required, by using a connection establishment process. Hence these protocols do not exchange routine information periodically. [13], [14].
3. *Hybrid routing protocols*: Protocols belonging to this category combine the best features of the above two categories. Nodes within a certain distance from the node concerned or within a particular geographical region are said to be within the routing zone of the given node. For routing within this zone, a table-driven approach is used. For nodes that are located in this zone, are on-demand approach is used.

2.2.2 Based on Use of Temporal Information for Routing

Since ad hoc wireless networks are highly dynamic and path breaks are much more frequent than in wired networks, the use of temporal information regarding the lifetime of the wireless links and the lifetime of the path selected assumes significance. The protocols that fall under this category can be further classified into two types:

1. *Routing Protocols using past temporal information*: These routing protocols use information about the past status of the links or the status of links at the time of routing to make routing decisions. For example, the routing metric based on the availability of wireless links (which is the current/present information here) along with the shortest path finding algorithm, provides a path that may be efficient and stable at the time of path finding. The topological changes may immediately break the path, making the path undergo a resource-wise expensive path reconfiguration process.
2. *Routing protocols that use future temporal information*: Protocols belonging to this category use information about the expected future status of the wireless links to make approximate routing decisions. Apart from the lifetime of wireless links, the future status information also includes information regarding the lifetime of the node (which is based on the remaining battery charge and discharge rate of non-replenishable resources, prediction of location and prediction of link availability.

2.2.3 Based on Routing Topology

Routing topology being used in the Internet is hierarchical in order to reduce the state information maintained at the core routers. Ad hoc wireless networks, due to their relatively smaller no. of nodes, can make use of either a flat topology or hierarchical topology for routing.

1. *Flat topology routing protocols*: Protocols that fall under this category make use of a flat addressing scheme similar to the one used in IEEE 802.3 LANs. It assumes the presence of a globally unique (or at least unique to the connected part of the network) addressing mechanism for nodes in an ad hoc wireless network [7].
2. *Hierarchical topology routing protocols*: Protocols belonging to this category make use of a logical hierarchy in the network and an associated addressing scheme. The hierarchy could be based on geographical information or it could be based on hop distance.

2.2.4 Based on Utilization of Specific Resources

1. *Power-aware routing:* This category of routing protocols aims at minimizing the consumption of a very important resource in the ad hoc wireless networks – the battery power. The routing decisions are based on minimizing the power consumption either locally or globally in the network.
2. *Geographical information assisted routing*: Protocols belonging to this category improve the performance of routing and reduce the control overhead by effectively utilizing the geographical information available.

3 Load balanced Routing Protocols

Routing with load balancing in wired networks has been exploited in various approaches [17], [18], [19]. In ad hoc networks, only Associativity-Based Routing (ABR) [20] 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.

Alternate Path Rourting Protocol

Alternate Path Routing (APR) protocol [21] provides load balancing by distributing traffic among a set of diverse paths. By using the set of diverse paths, it also provides route failure protection. However, Alternate path Routing protocols potential is not fully realized in ad-hoc networks because of route coupling resulting from the geographic proximity of candidate paths between common endpoints. In multiple channel networks, coupling occurs when paths share common intermediate nodes. The coupling problem is much more serious in single channel networks, where coupling also occurs where one path crosses the radio coverage area of another path.

DLAR, Dynamic Load Aware Routing

DLAR, Dynamic Load Aware Routing [22] uses the number of packets buffered in the interface as the primary route selection criteria. The source floods the ROUTE REQUEST packet to discover a route. When nodes other than the destination receive a non-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 this protocol, intermediate nodes cannot send a ROUTE REPLY back to the source. To utilize the most up-to-date load information when selecting routes and to minimize the overlapped routes, which cause congested bottlenecks, DLAR prohibits intermediate nodes from replying to ROUTE REQUESTS. During the active date session, intermediate nodes periodically piggyback their load information on data packets. Destination node can thus monitor the load status of the route. If the route is congested, a new and lightly loaded route is selected to replace the overloaded path. Routes are hence reconstructed dynamically in advance of congestion.

Load Aware Routing (LARA)

Another network protocol for efficient data transmission in mobile ad hoc networks is Load Aware Routing in Ad hoc (LARA) [23] networks protocol. LARA networks define a new metric called traffic density, to represent the degree of contention at the MAC level. The traffic density of a node is the sum of traffic queue qi of node i plus the traffic queues of all its neighbors, formally

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

Where N (i) is the neighborhood of node i and qj 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. 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. 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:

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

Where qi (k) is the kth sample of the queue length. qi is the average of these N samples. During the route discover 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. Hop cost factor captures the transmission and propagation delay along a hop. Traffic Cost is the traffic cost of a route is defines as the sum of the traffic densities at each of the nodes and the hop costs on that particular route.

Load-Balanced Ad hoc Routing (LBAR)

The Load-Balanced Ad hoc Routing (LBAR) [24] 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.LBAR, defines a new metric for routing known as Degree of Nodal activity to represent load on a metric node. 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. In order to prevent looping when setup messages are routed, all setup messages are assumed to contain a route record, including a list of all node Ids used in establishing the path fragment from the source node to the current intermediate node. The destination node collects arriving setup messages within a route-select waiting period, which is a predefined timer for selecting the best-cost path. The backward stage begins with an ACK message forwarded backward towards the source node along the selected path, which we call the active path. 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 note 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 contest 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.

Load Sensitive Routing (LSR) protocol

Load Sensitive Routing (LSR) protocol [25] is based on the DSR. This protocol utilizes network load information as the main path selection criterion. The way to obtain network load information in LSR does not require periodic exchange of load information among neighboring nodes and is suitable for any existing routing protocol. Unlike LBAR and DLAR, LSR does not require the destination nodes to wait for all possible routes. Instead, it uses a re-direction method to find better paths effectively. The source node can quickly respond to a call for connection without losing the chance to obtain the best path. Based on the initial status of an active part, LSR can search dynamically for better parts if the active path becomes congested during data transmission. In route discovery we use a redirection method similar to we developed in Multi path routing to forward Route Reply (RREP) messages. This method can let the source node obtain better path without an increase of flooding cost and waiting delay in the destination nodes. In LSR, we adapt the active routes in a route in a different context, by using network load information. When a used path becomes congested, LSR tries to search for a lightweight path. The source node continues to send data traffic along the congested paths until a better path is found. Route adaptation strategy is based on the initial status and current status of an active path.

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) [26] 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 defied 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.

Simple Load-Balancing Ad hoc Routing (SLAR)

Simple Load-Balancing Ad hoc Routing (SLAR) [27] 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.

Simple Load-balancing Approach (SLA)

Yoo and Ahn [28] proposed Simple Load-balancing Approach (SLA) on similar concepts. SLA resolves the traffic concentration problem by allowing each node to drop RREQ or to give up packet forwarding depending upon its own traffic load. SLA tries to extend the expiration of mobile node power by preventing the traffic concentration on a few nodes, which may frequently occur under low mobility situations. AODV and DSR do not search for new routes as long as current routes are available. In the case with low mobility, this feature may cause the nodes on the current routes to be congested. Hence, SLA allows each node to determine whether it is under heavy load conditions or not and to take some other nodes to take its place by explicitly giving up packet forwarding or implicitly dropping RREQ from other nodes. Consequently it spreads the traffic uniformly over the complete network and extends the lifetime of an entire ad hoc network by making all MANET nodes to fairly consume their energy. However, there may be some selfish nodes that may deliberately give up packet forwarding to save their own energy, if an appropriate compensation is not given to them. Therefore, in SLA a credit-based scheme called Protocol-Independent Fairness Algorithm (PIFA) for urging nodes to voluntarily participate in forwarding packets is proposed. In MANETs using PIFA, nodes earn the credits by forwarding other's packets and only when they have enough of the credits with them, they are allowed to originate packets. PIFA can detect and isolate a single malicious node, which tries to cheat others on the number of forwarding packets to acquire more credits than it should actually receive. Similar to SLAR, SLA is not an independent protocol but a supplementary part to any existing ad hoc routing protocol like AODV and DSR.

Delay-based Load-Aware On-demand Routing (D-LAOR) [29]

J. H. Song et.al. Proposed a Delay-based Load-Aware On-demand Routing (D-LAOR) [29] protocol that utilizes both the estimated total path delay and the hop count as the route selection criterion. 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). 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).D-LAOR does not allow the intermediate nodes to generate a RREP packet to the source node to avoid the problem with stale path delay information. We define DP as the total path delay of a path P from node 1 to n. When a source node does not have a valid route to a destination, it initiates a route discovery process. 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. Once the first RREQ packet has arrived at the destination, the destination node responds by unicasting a RREP packet back to the neighbor from which it received the corresponding RREQ packet. If the duplicate RREQ packet has a smaller total path delay and hop count than the previous one, the destination sends a RREP packet again to the source node to change the route immediately. D-LAOR does not allow any intermediate node to generate a RREP packet instead of the destination node because the intermediate node's record of the path delay to the destination may not be accurate. When an established path is broken due to node mobility, a RERR packet is sent to the source node. The source node reinitiates the route discovery process as described above. Moreover, our proposed 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.

Correlated Load-Aware Routing (CLAR)

Correlated Load-Aware Routing (CLAR) [30] protocol is an on-demand routing protocol. In a CLAR, traffic load at a node is considered as the primary route selection metric. The traffic load of a node depends on the traffic passing through this node as well as the traffic in the neighboring nodes [6]. The traffic load in a node is thus defined as the product of the average queue size at the node and the number of sharing nodes, which is that its average queue size is over one packet. The average queue size is calculated with an exponentially weighted moving average (EWMA) of the previous queue lengths. Traffic load of surrounding nodes is defined as number of sharing nodes. When a source node desires to send packets to some destination node and does not have a valid route to that destination, it broadcasts a RREQ packet to its neighbors. Once the destination node receives the RREQ, it first searches its forwarding route table for the originator. If the matching route is not found, it inserts the forwarding route entry to its routing table. Otherwise, it compares the path load in new RREQ with that in its route cache. If the path load in the RREQ is less than that in route cache, it updates routing table and responds by unicasting a RREP packet back to the neighbors from which it received the RREQ. As the RREP is routed back along the reverse path, intermediate nodes along this path set up forwarding route entries in their route tables. When an originator receives the RREP, it can begin to transmit data packets to the destination through the received route. If a source node moves, it is able to re-initiate the route discovery protocol to find a new route to the destination. If a node along the route moves, its upstream neighbor notices the movement and propagates a link failure notification message to each of its active upstream neighbors to inform them of the failure of that part of the route. The destination node must select the best route among multi-paths since CLAR supports multi-paths between the source and the destination. When the RREQ reaches the destination node, it selects the path with the least sum among multi-paths as its best route. If there are one more routes, which have same traffic load, the destination selects the route with the shortest hop distance. When there are still multiple paths that have the least load and hop distance, the earliest path arrived at the destination is chosen.

Energy Consumption Load Balancing (ECLB) [31]

In existing On-Demand routing method, message transmission occurs after forming the optimal route, however successive message transmission occur with particular nodes acting as routes when the network topology alteration is small. As a result, excessive traffic makes transmission delay and excels the energy consumption in the node used as a router, which means that most of energy is spent in the routing function. As it were, traffics are concentrated into a particular node when the mobility of node is low. When network topology is relatively stable, the energy deficient nodes are included in the routing path, which could shorten the lifespan of the whole network. To solve this problem, a routing method which concerns power consumption rate is proposed. ECLB makes balanced energy consumption available by calculating energy consumption rate of each node and choosing alternative route using the result to exclude the overburden-traffic-conditioned node in route directory. The point is that not only main path but also alternative path can be formed on the basis of the measure energy consumption rate using present packet amount per unit and mean packet throughput of the past. By forming route in advance and conversing into performed alternative path when route impediment occurs, transmission for route rediscovery and control traffic overhead can be decreased.

Prediction based Adaptive Load Balancing (PALB)

This mechanism is based on multipath routing protocol and traffic prediction [32]. It is assumed that several disjoint paths between source and destination node have been established by a multiple path routing protocol such as [33] [34] [35]. PALB locates at source node and its objective is to minimize traffic congestion and load imbalance by adaptively distributing the traffic among multiple disjoint paths based on traffic prediction. Source node periodically predicts the cross-traffic of each node in the multiple disjoint paths and adjusts traffic distribution across multiple disjoint paths. Data packets first enter into packet filtering model whose objective is facilitate traffic shifting among multiple paths in a way that reduces the possibility that packets arrive at the destination out of order. In PALB, a per-flow filtering method is used. The packet distribution model then distributes the traffic out from packet filtering model across the multiple paths. The distribution of traffic is based on load balancing model which decides when and how to shift traffic among the multiple paths. The load balancing model operates based on evaluation of paths stability and measurement of paths statistics. The load balancing model consists of three phases: balancing-off (when paths are unstable), balancing-on (when paths are stable) and imbalance detecting. In balancing-off phase, if the paths turn to be stable, it transits to balancing-on phase. In the balancing-on phase, the load balancing algorithm tries to equalize the congestion measures among multiple paths. The congestion measure of path is a function of path traffic load. Once the measures are equalized, the phase moves to imbalance detecting phase. In imbalance detecting phase, if it is detected that congestion measures are unequal, the phase returns balancing-on phase. In both balancing-on phase and imbalance detecting phase, if the paths turn to be unstable, it transits to the balancing-off phase.

Workload-Based Adaptive Load Balancing (WBALB)

Another protocol given by Y. J. Lee and George F. Riley is Workload-Based Adaptive Load Balancing (WBALB) [36] makes each node react to RREQs according to a simple rule based on the local information of the node and it runs on top of existing routing protocols. This protocol is motivated by the observation that ad hoc on-demand routing protocols flood route request (RREQ) messages to acquire routes, and only nodes that respond to those messages have a potential to serve as intermediate forwarding nodes. In other words, a node can completely be excluded from a path if the node drops the RREQ in a route discovery phase for the path. This protocol enables a node to join the RREQ forwarding action selectively. It utilizes interface queue occupancy and workload to control RREQ messages adaptively. Each node maintains a threshold value which is a criterion for each node's decision of how to react to a RREQ message. If the interface queue length of a node is greater than the threshold value, the node simply drops the RREQ. Otherwise, the node forwards the RREQ by re-broadcasting it. By doing so, additional traffic flows are not allowed to set up through overloaded nodes, and therefore, the overloaded nodes are naturally excluded from the newly requested paths. The threshold value is initially set to a pre-determined value. The threshold value keeps changing according to the load status of a node. If a node experiences overload to an extent, its threshold value decreases. When the node senses that its load has been low for a long enough period, it is considered as an indication that the node's overloaded status is dissolved, and its threshold value returns to the initial value. From that time on, the node allows additional communications to set up through it as long as not overloaded.

Traffic Size Aware Routing (TSAR)

The "Traffic-Size" based load balancing routing Protocols like DLAR, LARA, LBAR, LSR etc measure the traffic size in number of packets. Measuring the load by the number of packets is inaccurate since the size of the packets may differ. A more accurate method is to measure the traffic size in bytes. This protocol [37] is an extension to the Virtual Path Routing Protocol (VPR) [38]. Every node maintains an entry for every active virtual path it services. The creation time of any entry (i.e., the creation time of a virtual path) is recorded in the entry itself by the node. The node also accumulates the number of packets and the size (in bytes) of every packet that it routes using a particular entry. The accumulated traffic size and number of packets are also recorded in the entry. Thus, any given entry contains the time at which the entry was created, the number of packets, and the size of the traffic that was routed using that entry. Traffic-Size Aware routing scheme that uses the size of the traffic, through and around the network nodes, as the main route selection criterion. In this scheme, the network nodes keep track of the size of traffic (in bytes) being routed. The nodes are also aware of the size of the traffic that is routed through their neighbors. For any path that consists of multiple hops, the load metric of the path is the sum of all the traffic that is routed through all the hops that make up that path.

TABLE 1:

CHARACTERISTICS OF LOAD BALANCED AD HOC ROUTING PROTOCOLS

S.No	LBR Protocol	RSC	Category	TPU/ Extension of	RPU	LBE	R S	BR	Limitation
	DLAR [22]	No. of packets buffered in interface	Traffic Size	DSR	Single path	Network	F	Y	Interface queue length doesn't give a true picture of actual load
	LARA [23]	Traffic Density	Traffic Size	DSR	Single path	Network	F	Y	Condition of the route is not considered, once it has been selected for data transmission
	LBAR [24]	Degree of nodal activity	Traffic Size	DSR	Single path	Network	F	Y	Mainly intended for connectionless applications
	LSR [25]	Network load information	Traffic Size	DSR	Single path	Network	F	N	No consideration for burst traffic or transient traffic
	WLAR [26]	Total traffic load	Delay based	AODV	Multi path	Network	F	Y	Overhead of route request packets
	SLAR [27]	Forwarding Load	Traffic Size	AODV+ DSR	Single path	Node	F	F	Mobile nodes may deliberately give up forwarding packets to save their own energy
	SLA [28]	Own Traffic Load	Traffic Size	AODV+ DSR	Single path	Node	F	F	A reliable server node called Credit Manager (CM) is required which manages nodes
	D-LAOR [29]	Estimated total path delay and hop count	Delay Based	AODV	Multi path	Network	F	F	Routing overhead is comparatively high
	CLAR [30]	Traffic load through and around neighboring nodes	Traffic Size	AODV	Multi path	Network	F	Y	More useful for high load network with low mobility
	ECLB [31]	Energy consumption rate of each node		DSR	Multi path	Network	F	N	Outperforms only in the environment of lower power level

	PALB[33]	Prediction of network traffic	Traffic Based	AODV	Multi path	Network	F	Y	In order to predict traffic correctly, a special traffic pattern is required.
	WBALB [37]	Interface queue occupancy and workload	Traffic based	AODV	Multi path	Node	F	Y	Determining the appropriate threshold value
TS	TSAR[38]	Size of traffic, through and around the network nodes	Traffic Based	VPR	Multi path	Node	F	Y	Do not guarantee the utilization of nearly current load information.

LBR Protocol- Load Balanced Routing Protocol
RSC-Route Selection criteria
TPU- Traditional Protocol Used
RPU-Routing Path Used, LBE-Load Balancing Effect
RS- Routing Structure
BR-Beaconing Required, F-Flat, H-Hierarchica

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 metrics as route selection criteria to better use MANET resources and improves MANET performance. With Load Balancing, MANET can maximize mobile nodes lifetime, packet delivery ratio, throughput, and minimize traffic congestion and load unbalance, as a result, end-to-end packet delay can be minimized, and network energy consumption can be balanced.

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