# Manet Load Balancing Parallel Routing Protocol

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**Abstract**
In recent years, multi-path routing protocols have attained more attention in mobile ad hoc networks as compared to other routing schemes due to their abilities and efficiency in improving bandwidth of communication, increasing delivery reliability, responding to congestion and heavy traffic.
Several protocols have been developed to address multi path routing, but it always has a problem that the discovered paths may be not 100% disjoint and sending data is done in only one path until it's broken; the discovery of multiple paths also generates more overhead on the network.
Load Balancing Parallel Routing Protocol [LBPRP] tried to solve previous multi path problems, distributing traffic among multiple paths) sending data in parallel form as it uses all paths in the same time.
We employed a simple test scenario to be sure of proposed model efficiency and to validate the proposed Load Balancing Parallel Routing Protocol. [LBPRP] will achieve load balancing in sending data**,** decreasing the end-to-end delay and increasing the packet delivery ratio and throughput, thus the performance of multi-path routing protocols can be improved consequently.

***Keywords:*** Wireless Networking, MANET, Multi Path, Dynamic source Routing, Load Balancing.

## Introduction

Wireless networks have become increasingly popular in the computing industry. This is particularly true within the past decade, which has seen wireless networks being adapted to enable mobility. There are currently two variations of mobile wireless networks. The first is known as the infrastructure network (i.e., a network with fixed and wired gateways).The second type of mobile wireless network is the Infrastructureless mobile network, commonly known as an *ad hoc network*.

Mobile Ad hoc Network (MANET) [1] is a group of mobile wireless nodes that form a network independently of any centralized administration, while forwarding packets to each other in a multi-hop fashion. In Mobile Ad Hoc Networking, the communication does not rely on any existing infrastructure such as dedicated routers, transceiver base stations or even cables. Mobile devices with wireless radio equipment are supposed to communicate with each other, without the help of any other (fixed) devices.

In order to make that work, each node needs to act as a router to relay packets to nodes out of direct [2] communication range. Under these circumstances, routing is much more complex than in conventional (static) networks.

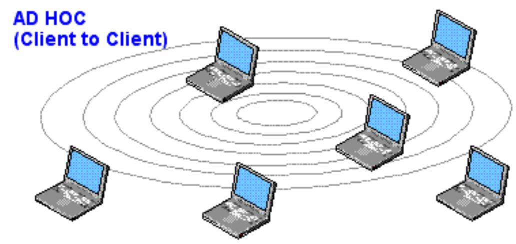


Fig. 1: Mobile Ad Hoc Network

Routing is the most active research field in MANETs. The routing protocols designed for wired networks are not suitable for wireless networks due to the node mobility issues in wireless networks [1][2]. Numerous protocols have been developed for ad hoc mobile networks. Such protocols must deal with the typical limitations of these networks, which include high power consumption, low bandwidth, and high error rates.

Routing protocols for MANETs can be classified in several ways one of the classifications is according to the number of paths, uni-path routing protocols and multipath routing protocols. In uni-path routing protocols: one route is used to deliver data from source node to destination node while in multipath routing protocols more than one route is used to deliver the data [3].

Because of the dynamic nature of the network, ad hoc routing faces many unique problems not present in wired networks. Due to node mobility, node failures, and the dynamic characteristics of the radio channel, links in a route may become temporarily unavailable and making the route invalid. The overhead of finding alternative routes may be high and extra delay in packet delivery may be introduced. The multipath routing addresses this problem by providing more than one route to a destination node. Multipath routing appears to be a promising technique for ad hoc routing protocols.

Providing multiple paths [3][4] specifically disjoint paths is beneficial in network communications, where routes are broken and the session is still active. Also because of mobility and poor wireless link quality, the source and intermediate nodes can use these routes as primary and backup routes. Alternatively, traffics can be distributed among multiple paths for maximizing network lifetime and enhancing load balancing.

Recent researches have shown that the data flow between the source and destination MANET nodes could be speeded up if it is efficiently split on multiple paths between them. The source node will estimate how busy these paths are and send packets to these paths according to its estimation (load balancing).

Load balancing [5] is a methodology to distribute workload across multiple paths, to achieve optimal resource utilization, maximize throughput, minimize response time, increase network life time, and avoid overload. Using multiple paths with load balancing, instead of a single [5] path, may increase reliability through redundancy. The load balancing service is usually provided by dedicated software or hardware, such as a multilayer switch or a Domain Name System server.

Load balancing techniques may have a variety of special features as:

- Asymmetric Load: A ratio can be manually assigned to cause some paths to get a greater share of the workload than others.
- Priority Activation: the workload is distributed according to paths priority as the size of free bandwidth and number of hops.

We will introduce a load balancing parallel routing protocol (LBPRP) that make benefits of load balancing and parallsim in multipath routing. Proposed LBPRP protocol tries to increase node and network life time which is considered one of the difficult dilemmas that face MANET.

This paper is organized as follows: a background review in multipath routing and load balancing is presented in Section 2. Section 3 introduces a description of our proposed model the LBRPR, while Section 4 represents an example on testing LBRPR model. Finally, Section 5 outlines our conclusions and suggested future work.

## 1. Background

Developing routing protocols for MANETs has been an extensive research area during the past few years. In particular, energy efficient routing is the most important design criteria for [1][3][6] MANETs since mobile nodes will be powered by batteries with limited capacity. The power failure of a mobile node not only affects the node itself but also its ability to forward packets on behalf of others and thus the overall network lifetime which is our most interest.

The on-demand routing [4][6] is the most popular approach in the MANET. Instead of periodically exchanging route messages to maintain a permanent route table of the full topology, the on-demand routing protocols build routes only when a node needs to send the data packets to a destination. The standard protocols of this type are the Dynamic Source Routing (DSR) [7] and the Ad hoc On-demand Distance Vector (AODV) [6] routing.

However, these protocols do not support multipath. Multiple paths can be useful in improving the effective bandwidth of communication pairs, responding to congestion and bursty traffic, and increasing delivery reliability.

The multipath on-demand routing protocols as the Ad hoc On-demand Multipath Distance Vector (AOMDV)[8], the Split Multipath Routing (SMR) [9], the Multipath Source Routing (MSR) [5], the Ad hoc On-demand Distance Vector Multipath Routing (AODVM) [10] and the Node-Disjoint Multipath Routing (NDMR). These protocols build multiple routes based on demand.

Also Routing On-demand Acyclic Multipath (ROAM) [11] presents an on-demand distance-vector which is basically a multipath version of DUAL [12], which uses a concept called feasible distance to maintain routes and loop freedom.

Finally Energy Aware On-demand Multipath Routing protocols as the Grid-Based Energy Aware Node-D Disjoint Multipath Routing Algorithm (GEANDMRA) [13] considers energy aware and node-disjoint multipath, it uses grid-head election algorithm to select the grid-head which is responsible for forwarding routing information and transmitting data packets. The Ant-based Energy Aware Disjoint Multipath Routing Algorithm (AEADMRA) [14] is based on swarm intelligence and especially on the ant colony based meta heuristic.

All the previous multi-path routing protocols achieved great results in multi-path routing but they are still suffering from balancing data through sending in parallel routes. A multi-path routing protocol with load balancing policy (MRP-LB) was proposed in [15]. The objective here is to spread the traffic equally into multiple paths which are available for each source-destination pair. The algorithm distributes the load into multiple paths evenly, i.e. the total number of congested packets on each route is equal.

In [16], a heuristic equation was proposed to balance the traffic load based on an intuitive assumption. The work of [17] analyzed theoretically the characterization of optimal routing, and gave an example of a network with two paths. But their analysis did not consider cross-traffic when solving the load-balancing problem.

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While [18] analyzes the effect on the distribution of input traffic among multiple paths in AODV-MP (Ad Hoc On-Demand Distance Vector Routing with Multi-Path), first of all, by giving the essence of the AODVMP, and then designing and realizing a load-balancing algorithm based on AODV-MP made up of independent nodes, which source node distributes packets reasonably in the several paths according to the load state of the network.

From the previous we can see that the former load balancing multi-path algorithms suffers from many dilemmas as the Limited number of generated paths and the non efficient load balancing technique. In AODV-MP load balancing the maximum number of generated paths is three paths. While in MRP-LP balancing the data load is distributed into multiple paths evenly non concerning the each path state and load.

In next section we will present our proposed load balancing parallel routing protocol representing how it avoids and maintains other load balancing multi-path dilemmas as we mentioned in previous sections.

## 2. Load Balancing Parallel Routing Protocol [LBPRP]

Multipath routing allows building and use of multiple paths for routing between a source-destination pair. It exploits the resource redundancy and diversity in the underlying network to provide benefits such as fault tolerance, load balancing, bandwidth aggregation, and improvement in Quality of Service [QoS] metrics such as delay.

Our main concern in this paper is to introduce a model that increases the MANET life time through load balancing multipath new technique representing parallism in sending data using 100% disjoint multiple paths (all selected paths sending data at the same time). We applied the load balancing concept to distribute data packets on the generated disjoint paths to solve the overloading problem and to prevent node starvation in next few sections.

We will divide LBPRP proposed protocol into three parts, first part describe how can we select 100% disjoint paths (section 3.1), second part distributing traffic among paths to achieve load balancing in sending data (section 3.2) and if one of paths is broken we will use path maintenance in third step (section 3.3).

### 3.1 Disjoint Paths Finding

In this section we will see how can our proposed LBPRP model find multipath (100% disjoint paths): We have G (V, E) is the graph representing the predicted global topology. Note that *V* is the set of vertices and *E* is the set of edges in the predicted network graph. While the source is identified by *s*, destination by *d* and $P_N$ denote the set of node-disjoint *s*-*d* paths. As explained in fig 2.

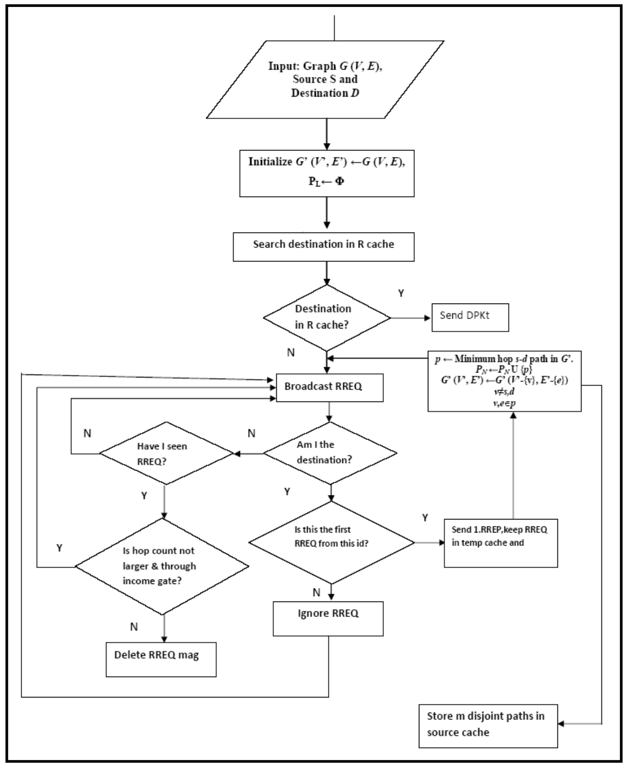


Fig. 2: LBPRP Disjoint Paths Finding

When the source needs a path, it floods the Route Request (RREQ). Only the destination is allowed to send back the Route Reply (RREP). The destination will receive several RREQ from different paths. Instead of dropping every duplicate RREQ, intermediate nodes forward the duplicate packet if it is from a different incoming link and the hop count is not larger than the first received RREQ.

If there is at least one *s*-*d* path in *G*, LBPRP includes the minimum hop *s*-*d* path *p* in the set *PN*. Our protocol then removes all the intermediate nodes (nodes other than source *s* and destination *d*) and edges that were part of the minimum-hop *s*-*d* path *p* in the original graph *G* to obtain the modified graph *G*' (*V*', *E*'). LBPRP repeats this procedure until there exists no more *s*-*d* paths in the network. The set PN contains the node-disjoint *s*-*d* paths in the original network graph *G*. Store the $P_N$ disjoint paths in source cache. In previous section we explain how to get all parallel paths .In next section we will explain second part of our work how we can send data achieving load balancing depending on path speed.

### 3.2 Data Sending

In first sending LBPRP will start with sending data packets on the shortest path with the minimum hop count then in remaining paths depending on hop count in an ascending order fig (3).

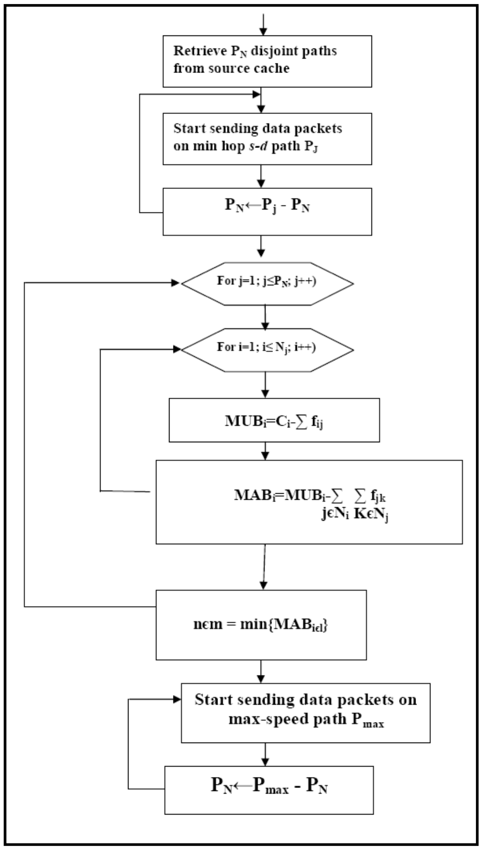


Fig. 3: LBPRP Data Sending

Then the protocol starts balancing the load of the remaining data through calculating the maximum available bandwidth MAB from which we can calculate each path speed. We first need to calculate the Maximum Unused Bandwidth (MUB)[4] as in equation (1)

$$MUB_i = C_i - \sum f_{ij} \quad (1)$$

With $\forall$j neighborhood of *i*. *Ci* is the maximum bandwidth, or the capacity of the Node *i*, and $f_{ij}$ denotes the traffic flow from Node *j* to neighbor Node *j* in bits/second. $f_{ij}$ contains traffic generated at the Node *i* and transit traffic through that node. From Eq. (2), the Maximum Available Bandwidth (MAB)[4], the remaining useable bandwidth, of Node *i* is defined as:

$$MAB_i = MUB_i - \sum_{j \epsilon N_i} \sum_{k \epsilon N_j} f_{jk} \quad (2)$$

Finally from equation (3) the path speed [4] is assigned equal to the node speed which has lowest bandwidth among all nodes in this path.

$$n\epsilon m = \min\{MAB_{i\epsilon l}\} \quad (3)$$

LBPRP arrange the paths in a descending order according to the path speed. The path with the highest speed starts sending first then the next one till the last one. The protocol repeats this process till all the data is sent.

### 3.3 Path Maintenance

The last stage of our protocol involves the path maintenance process fig. (4). It starts if one of the nodes over one of the discovered paths has moved out of the transmitting range of its previous node, during an active session

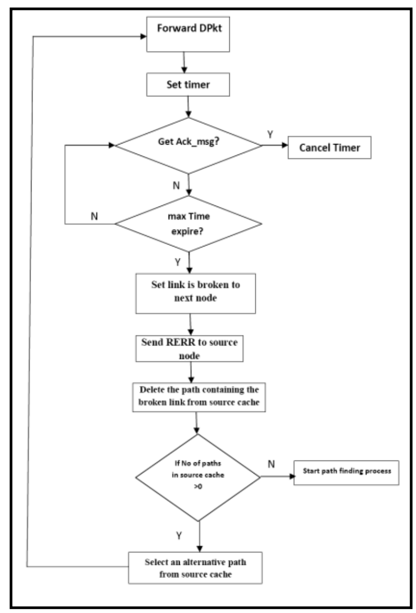


Fig. 4: LBPRP Path Maintenance

Now, we have a broken link between these two nodes. In such case, the previous node will send back a RERR packet to the source node to delete the path containing the broken link from its cache. Then the protocol will choose another path to resend through. If all the paths are broken at the same time, the LBPRP will start over again from stage one.

## 4. LBPRP Test Scenarios

For more explanations and to be sure of our proposed model efficiency we performed some tests on it using a real example as following:

a) RREQ: Node [A] propagates a route request to Node [G]

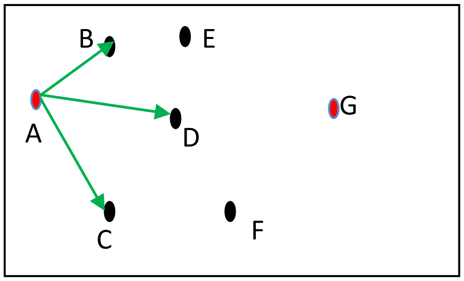


Fig. 5: LBPRP RREQ propagation

In figure (5), node [A] broadcasts a RREQ packet to destination node [G] and appends its own address in the route record field on the packet header. The RREQ packet is received by all nodes within the transmission range of the initiator node (node [A]). The RREQ packets arrive at node [B], node [C] and [D].

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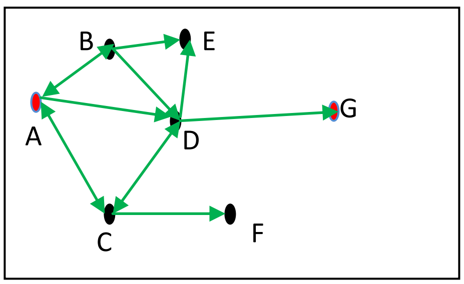


Fig. 6: LBPRP RREQ propagation

In figure (6) node [B], node [C] and node [D] rebroadcast the RREQ packet and appends their own addresses in the route record field. RREQ packet is received by all nodes within the transmission range of node [B], node [C] and [D]. The RREQ packets from node [B] arrive at nodes [A, D and E], from node [C] is received by nodes [A, D and F] and from node [D] is received by nodes [A, B, C, E &G].

Now, the RREQ packet arrives at the destination node [G]. Then node [G] replies with a RREP packet to the initiator node [A]. The RREQ packet arrives at its destination via node [D]

b) RREP: Node [G] sends a route reply to Node [A] while nodes [E] and [F] send RREQ.

The node [G] sends the RREP packet to the node [F]. RREP packet includes the traversed path by RREQ packets.

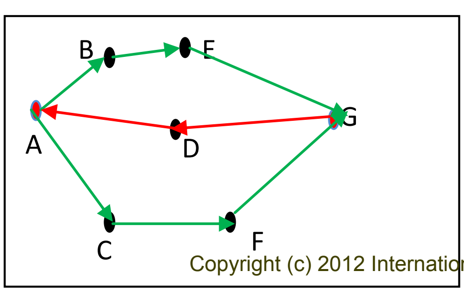


Fig. 7: LBPRP RREQ & RREP

All intermediate nodes and edges that were a part of the *s-d* path will be removed. Here node [D], [G]↔[D] and [D]↔[A] is deleted from the graph.

Node [E] and [F] rebroadcast the RREQ packets and appends their own addresses in the route record field. RREQ packet is received by all nodes within the transmission range.

The RREQ packets from nodes [E] and [F] arrive at node [G], and then node [G] replies with a RREP packet to the initiator node [A], through two paths [G→F→C→A] and [G→E→B→A]

c) LBPRP arranges the paths in an ascending order depending on the hop count, and start sending data on the shortest one with least hop counts. Then the next shortest path till it sends on all paths. Here in our example the protocol will start sending on [A-D-G] path first.

In next round of sending LBPRP balances data load through arranging paths in a descending order depending on path speed calculated using equations (1), (2) and (3). Then it starts sending data on arranged paths starting with the highest speed path then the next till it uses all paths. In each sending LBPRP repeat this step.

d) finally if any link is broken during sending for example if [D-G] link is broken, node[D] sends RREP packet to source [A] to delete [A-D-G] path from source cache. Then LBPRP selects another path for resending corrupted data.

In the end we can finally say that our LBPRP multipath protocol steps forward other load balancing multipath algorithms as it has no limitation to the number of generated paths and introduces a reliable and efficient load balancing techniques. Theoretical analysis shows that LBPRP provides a high packet delivery ratio, a good effect on increasing network life time, a high level of reliability and low routing overhead. In the future we will pursue a simulation of the LBPRP to perform more tests on it.

## 5. Conclusion

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This paper has proposed a load balancing parallel routing protocol (LBPRP) for mobile ad-hoc networks. LBPRP allows routing multiple packets in parallel from a source node to a destination node over disjoint paths. The LBPRP balances the data load through calculating each path speed and selecting the path with the high speed for sending first.

LBPRP is a load balancing parallel routing protocol achieving low communication delays, high packet delivery ratios, high routing path stability, and low routing overheads.

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