A Novel Multipath Load Balancing Approach Using Fibonacci Series for Mobile Ad Hoc Networks

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Abstract—**This paper explores Fibonacci Multipath Load Balancing protocol (FMLB) for Mobile Ad Hoc Networks (MANETs). MANET is a temporary network with a group of wireless infrastructureless mobile nodes that communicate with each other within a rapidly dynamic topology. The FMLB protocol distributes transmitted packets over multiple paths through the mobile nodes using Fibonacci sequence. Such distribution can increase the delivery ratio since it reduces the congestion. The FMLB protocol's responsibility is balancing the packet transmission over the selected paths and ordering them according to hops count. The shortest path is used frequently more than other ones. The simulation results show that the proposed protocol has achieved an enhancement on packet delivery ratio, up to 21%, as compared to the Ad Hoc On-demand Distance Vector routing protocol (AODV) protocol. Also the results show the effect of nodes pause time on the data delivery. Finally, the simulation results are obtained by the well-known Glomosim Simulator, version 2.03, without any distance or location measurements devices.**

Index Terms—**MANETs, congestion, load balancing, multipath.**

I. Introduction

A Mobile Ad Hoc Network (MANET) is described as a volatile temporary network contains a group of wireless infrastructureless nodes that communicate with each other within a rapidly dynamic topology. In fact, there are many restrictions that make MANET a network with complicated topology, especially the bandwidth, memory, and energy constrained. One of the most essential characteristics in MANETs is that each node in the network will have two rules at the same time; host role and router role. Ad hoc networks are widely used in the automated battlefields, search and rescue, crowd control, and disaster management [1].

MANET routing is considered as one of the most essential issues that need a scalable mechanism because the network topology and transmitted data may become larger over time [2]. Routing is classified into two main categories: proactive routing and on-demand or single-path routing and multi-path routing [2]. Many of routing protocols were designed for MANETs such as Ad Hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Temporally Ordered Routing Algorithm (TORA), these three protocols are considered as on demand routing protocols since the routes are formed and fixed upon request [1]. Our study is built upon the Ad-hoc on demand distance victor (AODV) routing protocol which chooses a single shortest path in order to transmit data packets. The main disadvantage of using such route is the congestion problem. The congestion problem normally occurs when the network is stressed by a large number of transmitted data packets. Congestion is one of the most popular factors of packet loss in MANETs [3]. So, the load balancing Fibonacci algorithm appears in order to keeps a way the network bandwidth and the nodes buffers from congestion by distributing the data packets over multiple paths using the Fibonacci sequence.

Manuscript received February 15, 2012; revised March 26, 2012.

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Our research intent is to build an efficient routing algorithm that decreases congestion by detecting multiple paths and distributes transmitted packets over these paths using the idea of Fibonacci sequence concept. Such distribution decreases the number of dropped packets and increases the delivery ratio because it can use the shortest paths more efficiently and achieve better load balancing as we illustrate in section five. 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, as shown by the following equation:

$$\begin{aligned} &f_0 = 0 \\ &f_1 = 1 \\ &f_n = f_n + f_n; n \geq 2. \end{aligned} \tag{1}$$

To illustrate our proposed protocol, suppose that we have seven routes between source and destination node, where 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 packets 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.

This paper divided into six sections: In section two, the MANET network is introduced. Section three discusses the related work. The Fibonacci algorithm and its implementation are explained in section four. Section five presents the simulation results. Section six concludes this work and provides suggestions for future work.

II. Mobile Ad Hoc Networks (MANETs)

Mobile ad hoc network (MANET) is an unstructured decentralized wireless network which depends on the routing mechanism in its communication. The main components of MANET are mobile nodes, and wireless communication devices such as the transmitters, receivers and smart antennas [4]. Nodes in MANET can be static or mobile. These nodes have the capability to perform several tasks such as transmitting and retransmitting data packets from a source to destination nodes. Such networks have proposed for many applications that are useful for humanity. The subsequent sections introduce the MANET network, its applications, challenges, and routing protocols.

A. Applications of Ad Hoc Networks

MANETs are often used in cases where fixed networks are so expensive, they are also used in the situations where fixed networks are impractical because of some challenges [8].MANETs are frequently used in various applications due to their flexibility [9] such as :

1) MANET in office: Files and emails are synchronized between the personal digital assistant (PDA) and the office desktop which allow transferring data in flexible way [9]
2) Personal Area Networks: The personal area networks (PANs) are computer networks that are mainly focused for individual uses. PANS are shaped between different types of mobile devices [10]. The key rule of personal area networks (PANs) is to set up an embedded network using some nodes that are inside or near the human body; these nodes can easily exchange digital information [8]. Node communications in different PANS can utilize facilities of ad hoc network. As an example of PANs; a doctor can distribute a set of devices (sensors) on the patient's body in order to get medical information.
3) MANET at home: Two ad hoc devices one with the user and the other in the home can communicate with each other in order to accomplish particular task such as activate lights on getting home [9].
4) Military Applications: Military communication in battle fields can be considered as one of the most popular application of ad hoc networks in battle fields. This is because we extremely need an infrastructureless network that offers a reliable communication and fast failure recovery in such environments. In fact, it is not efficient and very complicated to build a fixed network for military communication in battle fields. Ad hoc networks can present a very robust solution to the required communication under these conditions [5, 8].
5) Other Civil and Commercial Applications: such as car tracking, monitors its mechanical components, and keep in touch with other vehicles in the area. We can also mention the application that detects for road safety messages, navigation purposes, and other peer to peer applications [10].

B. Limitations of Ad Hoc Networks

There are many restrictions that make routing techniques for MANETs rather complicated:

1) Limited CPU capacity [5, 6]: Nodes have limited processing operations.
2) Limited storage capacity [5, 6]: Memory resources are normally restricted in the mobile nodes.
3) Limited battery power [6, 7, 8]: where each node has a limited life time battery.
4) Limited bandwidth [5, 7]: Bandwidth is shared by a number of mobile nodes.
5) Nodes have limited transmission range since they depend on the radio waves [8].
6) Rapidly changing topology, where the nodes are continuously moving and changing their places.

C. Routing for Ad Hoc Networks

Routing is a principle component of any ad hoc network as it is responsible for load balancing between the source and destination. Routing is the mechanism of finding an optimum route in order to transfer messages (or packets). Routing protocols are divided into two basic types by [4], which are:

Static routing: In this type of routing the administrator manually assigns the routes in order to forward the data packets in the network, which means there are fixed routes between sources and destinations, these routes are changed by the administrator on demand, since that the router is not responsible for building the routing table.

Dynamic Routing: The router is responsible for building and exchanging the routing table information according to the changes that occur in the network topology, since that the router should be aware of the network status in order to take its decision. There is no doubt that dynamic routing is more flexible than static routing since it can detect the congestion paths [4]. Dynamic routing protocols are categorized by [4, 11] into three different types:

D. Reactive Protocols

Reactive protocols are on demand routing protocols where the network does not aware by the routes between its nodes until a source node request a route to transmit data for a destination node, at that time just the source node initiates a route request. The high latency is the main disadvantage of the reactive algorithm. The following four characteristics describe the reactive protocols [11]:

1) The route should be found just on demanded
2) Flooding technique is used in order to broadcast the route request.
3) Saving bandwidth by decreasing the number of control packets.
4) Bandwidth is used when a source node decides to transmit data for destination node. Ad Hoc On-demand Distance Vector Routing Protocol (AODV) is an example of on-demand routing protocol which we improve in this paper.

E. Proactive Protocols

Networks designed by proactive routing protocols should have full information about the routes between each pair of nodes regardless of whether or not the nodes need to transmit data between each other or not. The networks also should be aware of each change that occurs in the network topology in order to update all of the nodes route tables. The full information about the routes in the network is obtained by sending control messages within periodically intervals.

F. Hybrid Protocols

Hybrid protocols are described as a mixed between the reactive and proactive protocols where they can combine the advantage of each one [4, 11, 12].

Fig. 1 shows the hierarchy of each reactive, proactive, and hybrid protocols and examples on each type:

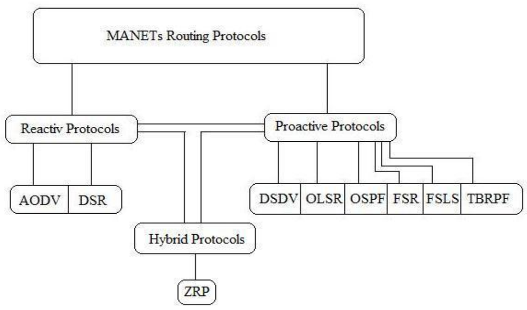

Fig. 1. MANETs routing protocols [11]

Single and Multi-Path routing algorithms is another classified for routing algorithms where the algorithms detect multi paths between each pair of source and destination instead of a single path . The main purposes of using Multipath algorithms are allowing load balancing, fault-tolerance [8] and gives high quality services [13].

G. Ad Hoc on-Demand Distance Vector Routing Protocol

Ad Hoc On-demand Distance Vector Routing Protocol (AODV) is the protocol where the host mobile node works as a router and the networks routes are build upon request using periodic advertisements control packets[14] .

The AODV routing protocol is designed for MANETs, because of its quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network [15]. Since the AODV is a routing protocol, it is necessary to deal with the concept of routing table [15]. Routing table information must be saved for a period of time in order to build paths [15]. The AODV table contains each of the following main fields [15]

1) Destination IP Address: The IP address of the destination node.
2) Destination Sequence Number: A sequence numbers that increment for each new route to the destination.
3) Hop Count: The number of hops needed to reach a specific destination
4) Next Hop: The next node in the route.
5) The states routing flags (e.g., valid, invalid, repairable, being repaired): Each of this flags indicate the states of the route in the table route.
6) Lifetime: The expired time or when to remove route from the table routes.

The main three types of messages in AODV are:

1) The route request message RREQ: The RREQ message is initiated by the source node broadcasted to the intermediates in order to acquire a route to the destination node.
2) The route reply message RREP: The RREP message is initiated either by the destination node or by an intermediate node that has a route to the acquired destination.
3) The route error message RERR: The RERR message is initiated by any intermediate node that detects a broken route between the source and destination.

III. Related work

In this section, we briefly review many of the protocols proposed for solving the congestion problem.

Sambasivam, Murthy and M. Belding-Royer [7] in their paper obtain multiple paths during the route discovery process. Each path maintained using the unicast periodic update packets. The unicast periodic update packets goal is to compute the signal strength for each hop that composes the alternatives paths. At any point of time, their algorithm selects the path that has the highest signal strength in order to transmit data packets. The main advantage in their approach that they can keep track of the quality of all the paths exist in the network topology to particular destination and using the best paths, since that they can discard the weakness paths which lead to increase the data delivery ratio due to avoid such paths [7].

Ahn, Chung, etal. [6] depends on find the main route using the AODV mechanism, when the primary route is detected, the source node starts sending the data packets over this paths while another process are initiated in order to find the backup paths. This backup path process excludes the nodes available on the main route which we called the node-disjoint paths. As soon as the main route is broken, the source node starts to send the data packets through the back up route [6].

Karthikeyan etal. [16], they presents an overview of the broadcasting techniques in mobile ad hoc networks, and they makes their experiments on each the simple Flooding algorithm and Probability based flooding algorithm using the NS2 simulator ,in the simple flooding mechanism each node involves in the network should rebroadcast all packets. The Probability based mechanisms use apart of the network topology in order to send the data packets depend on some basic ideas such as the node density in order to assign the probability of the rebroadcast node [16]

The Load Balancing Using Multiple Paths was proposed by Al-Tarazi [8], if we have n routes sorted in the non-decreasing order of their hop counts, they will be respectively assigned the priority values: n…, 2, 1. The transmitted packets should be distributed depending on these priorities.

Sridhar and Chan propose the Channel-aware Packet Scheduling for MANETs (CaSMA), they depend on two major criteria in their work which are the congestion state and the end-to-end path duration, congestion area should be avoided and packets flow during short-lived paths should be given high priority [17].

Finally, Fibonacci sequence was proposed to choose the proper back of time to access the medium channel. The standard MAC protocol IEEE 802.11 uses the binary equation.

IV. The Fibonacci Multipath Load Balancing Protocol (FMLB)

In this section, we introduce the Fibonacci Multipath Load Balancing Protocol (FMLB).To illustrate our idea, consider the network on Fig. 2, where node S wants to communicate with node D. Fig. 2 shows that there are four possible routes between S and D which are {S,E,F,D},{S,G,H,D},{S,A,B,C,D}, and {S,I,J,K,L,D}. If we choose threshold routes to be three ,then the routes {S,E,F,D}with three hops ,{S,G,H,D}with also three hops and route{S,A,B,C,D}with four hops could be chosen, while the route {S,I,J,K,L,D} with five hops should be ignored. These three routes will be sorted in an increasing order according to the number of hops. Then each route will be assigned aweigh. Thus, route {S,E,F,D} will have a weight of Fibonacci (3) ,route {S,G,H,D}will have a weight of Fibonacci (2) and route {S,A,B,C,D} will have a weight of Fibonacci (1).

Suppose that the source node has 5 packets to send:

- 2 packets are sent through the {S, E, F, D} route since Fibonacci (3) = 2.
- 1 packet is sent through the {S, G, H, D} route since Fibonacci (2) = 1.
- 1 packet is sent through the {S, A, B, C, D} route since Fibonacci (1) = 1.
- The last 1 packet of the 5 packets is sent through the {S, E, F, D} route again.

In our work, we have used threshold of 7 routs, since the 7 routes achieve the desired load balancing. If we apply one of the traditional a algorithm that follow the single shortest path such as AODV on the same network example we use just the single path {S,E,F,D} and ignore the other paths ,this approach leads to more stress and congestion to the {S,E,F,D} path and more of dropped packets. The general rule fore the FMLB algorithm is that if there are K paths arranged in increasing order regarding their number of hops, they will be respectively weighted by values: Fibonacci (k), Fibonacci (k-1), Fibonacci (k-2)… Fibonacci (2), Fibonacci (1). In the case of existing two routes with the same length, we will put the more recent route after the older one in the sorted list of routes; this will distribute data packets over multiple routes, balance the load, and avoid congestion.

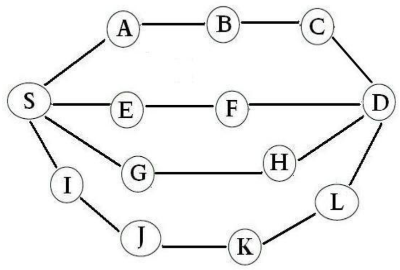

Fig. 2. Multiple paths between source and destination

V. Simulation Results

The simulations, we have changed each of the packet transmission rate and nodes pause time. The pause times are varied by 0, 50, 100,150, 200, 250 and 300 seconds. In order to assess the performance of the FMLB protocol, we compare the results of the FMLB protocol with the standard AODV protocol .All of the results are obtained by the Glomosim simulator version 2.03 without any distance or location measurements devices. The following table has the parameters which used for these scenarios.

TABLE I: Environment Parameters

Parameter	Value
Number of Nodes	30
Medium Bandwidth	2 Mb/s
Simulation Time	300 second
Application Model	(CBR)
Network Dimensions	1000 X 1000

There are many performance metrics that can be used in order to assess the routing protocols. In this paper, we concentrate on the Data delivery ratio which defined as the ratio of the total number of successfully delivered data packets to the total number of data packets sent by source. These metric are used in order to evaluate the enhancement of FMLB protocol as compared to the AODV.

Fig. 3 shows the packet delivery ratio of FMLB and AODV protocols when the number of sources are 15, the transmission rate is 1, 5, 10, 15, and 20 packets per second respectively, and 0 second pause time. FMLB outperforms AODV protocol based upon the simulation results. When the transmission rate is the highest (transmission rate = 20 packets/s), FMLB outperforms AODV by 26 %. At low transmission rate (transmission rate = 1 packet/s), FMLB outperforms AODV protocol by 13 %.

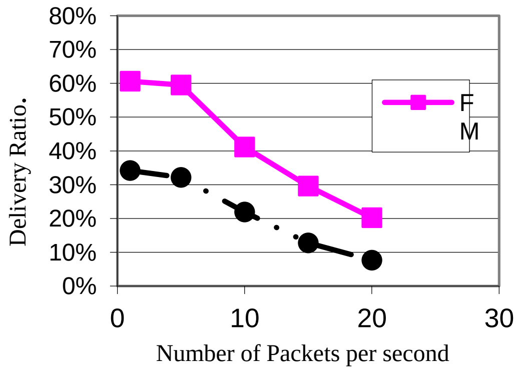

Fig. 3. Delivery ratio of FMLB and AODV with 0 second pause time

Fig. 4 shows the packet delivery ratio of the FMLB and AODV protocols when the source nodes are 15, the transmission rate is 1, 5, 10, 15, and 20 packets per second respectively, and 100 second pause time. FMLB outperforms AODV protocol based upon the simulation results. When the transmission rate is the highest (transmission rate = 20 packets/s), FMLB outperforms AODV by 14 %. At low transmission rate (transmission rate = 1 packet/s), FMLB outperforms AODV by 28 %.

Fig. 5 shows the packet delivery ratio of the FMLB and AODV protocols, when the source nodes are 15, the transmission rates are 1, 5, 10, 15, and 20 packets per second respectively with 200 second pause time. FMLB outperforms AODV protocol based upon the simulation results. When the transmission rate is the highest (transmission rate = 20 packets/s), FMLB outperforms AODV by 16 %. At low transmission rate (transmission rate = 1 packet/s), FMLB outperforms AODV by 29 %.

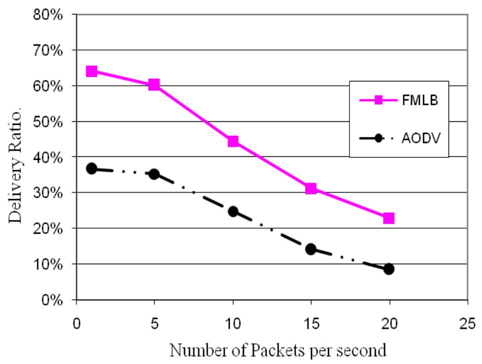

Fig. 4. Delivery ratio of FMLB and AODV with 100 second pause time

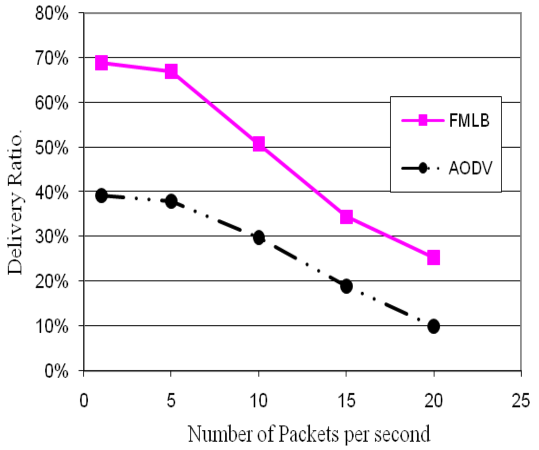

Fig. 5. Delivery ratio of FMLB and AODV with 200 second pause time

Fig. 6 shows the packet delivery ratio of the FMLB and AODV protocols, when the source nodes are 15, the transmission rate is 1, 5, 10, 15, and 20 packets per second respectively, and 300 second pause time. FMLB outperforms AODV protocol based upon the simulation results. When the transmission rate is the highest (transmission rate = 20 packets/s), FMLB outperforms AODV by 18 % respectively. At low transmission rate (transmission rate = 1 packet/s), FMLB outperforms AODV 30 %.

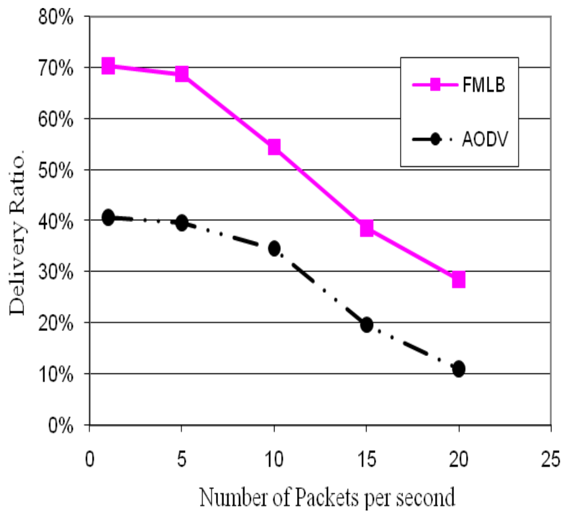

Fig. 6. Delivery ratio of FMLB and AODV with 300 second pause time

VI. Conclusions and Future Work

We have introduced a new approach for load balancing in ad hoc networks. The proposed approach finds multiple routes between the source and destination. These routes are selected according to their paths length. Paths with small number of hops will be strongly nominated to be among the selected routes. A Fibonacci weight is given for each of these paths. The source node transmits its packets over these selected routes according to their Fibonacci weights. The transmitted packets were distributed to utilize shortest paths and alleviate the effect of congestion on the network. The packet delivery ratio is the major metric to judge our approach as compared to the AODV protocol.

An extensive number of simulations were conducted to compare the FMLB, AODV protocols. The simulation results show that FMLB protocol has achieved an enhancement on packet delivery as compared with the well known protocol AODV. Future work includes involving another numbering sequence in order to find the best one that reduces the congestion problem. Furthermore, Fuzzy logic techniques can be one of the best choices to dynamically calibrate the load over multiple paths.

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