ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 5, May 2013

Performance Maximization for Wireless Mesh Networks by incorporating Non Linear Cost Functions

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Abstract: WMNs are multi-hop systems in which devices sustain each other in transmitting packets from beginning to end in the network. A mesh system offers multiple redundant interactions paths throughout the network. If one link fails for any reason, the network automatically routes messages through alternate paths. One of the principal issues in routing is to providing acceptable performance while scaling the wireless mesh network. It is appealing, however to look at what happens when routing nodes are extended in propagation environment and how that affects routing metric. In this paper, we examine the usage of different proactive, reactive and hybrid protocols in such a way so that we may be able to built a cost function which helps in selecting the optimum grouping of routing protocols for a particular urban wireless mesh network. The key metric is network throughput. A non linear cost function equation has been proposed analogous to routing metric taken. Bit rate is in use as constant (CBR).

Keywords: Bellman Ford, DYMO, STAR, Throughput, WMN, ZRP.

I. INTRODUCTION

(WMNs) are multi-hop systems in which devices assist each other in transmitting packets through the network. We can push these ad-hoc networks into place with minimal preparation. They provide a reliable, flexible system that can be extensive to thousands of devices. The wireless mesh network topology developed is a point-to-point-to-point system called an ad-hoc, multi-hop network [1] [2]. A node can send and receive messages and also functions as a router and can relay messages for its neighbors. If one link fails for any reason, the network automatically routes messages through alternate paths. A mesh network is self-organizing and doesn't require manual configuration. The network discovers the new node and automatically incorporates it into the existing system. A mesh network is also highly

adaptable. If a device or its link in a mesh network fails, messages are sent around it via other devices. Loss of one or more nodes doesn't necessarily affect the network's operation. A mesh network is self-healing because human involvement is not necessary for re-routing of messages. A mesh network is also scalable and can handle hundreds or thousands of nodes. Reliability, adaptability, and scalability are the most important attributes of a wireless network for different applications.

II. ROUTING PROTOCOLS

A routing protocol is a principle or standard that controls how nodes decide which way to route packets between computing devices in a mobile ad-hoc network [3]. The basic idea is that a new node may announce its presence and should listen for announcements broadcast by its neighbors. Routing protocols designed for Mobile Ad hoc Networks (MANETs) can be considered as platform for Wireless Mesh Networks, due to the common similarities between the two types of wireless networks [4].

A. Pro-active routing

These types of protocols maintain fresh lists of destinations and their routes by periodically distributing routing tables throughout the network [5]. Bellman ford and STAR protocols are the example of this type of routing. Bellman-Ford Routing Algorithm is also known as Ford-Fulkerson Algorithm. Routers that use this algorithm will maintain the distance tables, which tell the distances and shortest path to sending packets to each node in the network. The information in the distance table is always updated by exchanging information with the neighboring nodes. The columns of table represent the directly attached neighbors whereas the rows represent all destinations in the network.
STAR is a table-driven routing protocol. Each node discovers and maintains topology information of the network, and builds a shortest path tree (source tree) to store favored paths to destinations. The basic mechanisms in STAR include the detection of neighbors and exchange of topology information (update message) among nodes [6]. For STAR, there are importantly two alternative mechanisms to discover neighbors.

B. Reactive routing

These types of protocols find a route on demand by flooding the network with Route Request packets [7]. DYMO

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protocol is the example of this type of routing. The Dynamic MANET On-demand (DYMO) protocol is a reactive routing protocol being developed within IETF's MANET working group [7]. Typically, all reactive routing protocols rely on the quick propagation of route request packets throughout the MANET to find routes between source and destination.

C. *Hybrid routing*

These kinds of protocols combine the advantages of proactive and reactive routing [8]. The routing is initially established with some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding. ZRP protocol is the example of this type of routing. The Zone Routing Protocol (ZRP) was introduced in 1997 by Haas and Pearlman [9]. It is either a proactive or reactive protocol. It is a hybrid routing protocol. It combines the advantages from proactive and reactive routing. It takes the advantage of pro-active discovery within a node's local neighborhood and using a reactive protocol for communication between these neighborhoods. Each node may be within multiple overlapping zones, and each zone may be of a different size. Before constructing a zone and determine border nodes, a node needs to know about its local neighbors. ZRP is in fact a flat protocol [10].

III. RADIO PROPAGATION AND SIMULATION

A. *Okumara hata model*

There are a number of pragmatic or statistical models suitable for the outdoor environment. We present Okumara hata propagation model in our simulations. This is one of the most widely used models for propagation in urban areas. This model is an empirical formulation of the graphical path-loss data provided by Okumura's model [11]. Path loss can be expressed as the ratio of the power of the transmitted signal to the power of the same signal received by the receiver, on a given path. It is a function of the propagation distance. Estimation of path loss is very important for designing and deploying wireless communication networks [12]. The formula for the median path loss in urban areas is given by

Lso (urban) (dB) = 69.55+26.16logfC-13.82logthe-a (h,e)+(44.96.5510ghle)logd...(1)

Where *f* is the frequency (in MHz), which varies from 150 MHz to 1500MHz. he and h, e are the effective heights of the base station and the mobile antennas (in meters), respectively. d is the distance from the base station to the mobile antenna. This model is quite suitable for large-cell mobile systems, but not for personal communications systems that cover a circular area of approximately 1 km in radius [13].

B. *Simulation Model*

We use a simulation model based on QualNet 5.0 in our evaluation [14]. Our performance evaluations are based on the simulations of 25 wireless mobile nodes that form a wireless ad hoc network over a rectangular (1500 X 1500 m) flat space. The main goal of the mesh network simulation in Qualnet is to investigate the influence of node mobility on the routing protocol performance. Data traffic between pairs is generated using Qualnet's constant bit-rate (CBR) traffic generator. Qualnet is a commercial network simulator developed by Scalable Network Technologies [15].

C. *Routing metric for Performance Evaluation*

In these simulations, we collect results corresponding to the parameter namely network throughput. The throughput of a connection between two nodes is measured as the number of bytes delivered per time unit [16]. Formally, Throughput is equal to the total bytes received.

Nodes in the simulation set up move according to a model that is well known as the "random waypoint" model [17]. Each simulation ran for 100 seconds of simulated time. We ran our simulations with movement patterns generated for a fixed pause time of 30 Seconds.

D. *Application Traffic*

As the goal of our simulation is to compare the performance of each routing protocol, we decide our application traffic sources to be constant bit rate (CBR) sources. Constant Bit Rate is an encoding method that keeps the bit rate the same as opposed to VBR which varies the bit rate [18]. CBR processes audio faster than VBR due to its fixed bit rate value. When defining the parameters of the communication model, we experiment with sending rates of 1.2 packets per second and packet sizes of 512 bytes to observe the consistency.

The following section categorizes and presents the simulation parameters used in our experiments:

TABLE 3.1
NETWORK AND COMMUNICATION PARAMETERS

Nodes	Mobile
Number of nodes	5, 10, 15, 20, 25
area	1500m x 1500m
Simulation time	60 minutes
Nodes type	Mesh mobile node
Physical medium	802.11 DSSS
Data rate	11Mbps
Transmission power	0.005w
Packet reception	Power threshold 7.33E-14
RTS threshold	none
MAC protocol	802.11 MAC layer
PCF parameters	disabled
Mobility model	Random waypoint model

ISSN (Print) : 2319-5940
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International Journal of Advanced Research in Computer and Communication Engineering
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IV. RESULT AND ANALYSIS

A. *Simulation Results for Throughput*

The following figures in this section show the network Throughput results obtained from the simulation scenarios. The obtained results are according to the mobility considerations.

TABLE 4.1
THROUGHPUT OBTAINED FROM OKUMARA HATA MODEL (BITS/SECOND)

No. of nodes	BF	DYMO	STAR	ZRP
5	3465	5586	4337	4323
10	5460	8434	4411	4410
15	2494	5477	4914	4778
20	5461	5477	5461	5460
25	3644	4457	4253	4926

TABLE 4.2
DELAY OBTAINED FROM OKUMARA HATA MODEL (BITS/SECOND)

No. of nodes	BF	DYMO	STAR	ZRP
5	0.00813	0.73161	0.00329	0.00332
10	0.00330	2.93588	0.00332	0.00334
15	0.01204	0.00556	0.00333	0.00336
20	0.00331	0.00560	0.00351	0.00335
25	0.02172	3.29205	0.00310	0.01569

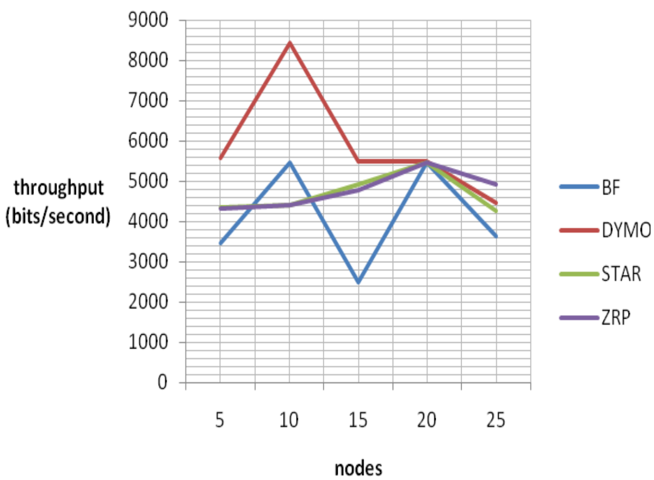

Figure 4.1 Throughput details for Okumara Hata Model

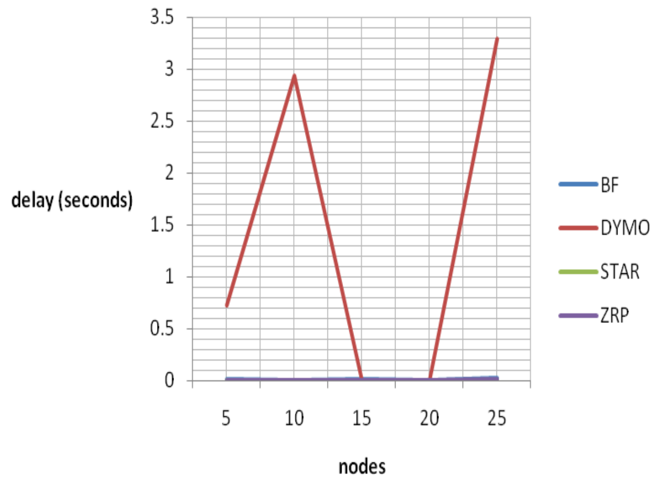

Figure 4.2 Delay details for Okumara Hata Model

V. PROPOSED COST FUNCTION EQUATION

The goals of wireless mesh networks are to provide satisfactory quality of service (QOS). However, it is difficult to determine how the appropriate mesh parameters should be selected to support QOS requirements. To address and resolve the problem, we propose a novel cost function named as mesh cost function (MCF) that is based on mesh routing metrics like average throughput and average end to end delay as to meet maximum quality of service [19]. This cost function MCF helps in choosing the best pairs of proactive, reactive and hybrid routing protocols in such a way so that maximum performance of mesh network can be achieved by considering different routing priority index constants.

A. *Throughput Priority based Cost Function*

Proposed cost function equation based on throughput is

$$MCF_{(throughput)} = a * T^{(1/8)} + b * D^{(1/2)} + EAF \quad \text{…. (2)}$$

Where a, b are priority index constants for throughput (T) and delay (D) respectively. The value of throughput priority index constant a is 0.3. The value of delay priority index constant b is 0.02. EAF is effective cost adjustment factor. The value of EAF is 0.1. The cost function algorithm is designed to find out the value of cost function for a wireless mesh network. T is in bits/second and D is in seconds.

ALGO (T, D, MCF (throughput))

Step1:
(T and D are the experimental values obtained by simulating the network with mentioned parameters. In this experiment, Value of throughput priority constant a= 0.3, Value of delay priority constant b = 0.02, Value of effective adjustment factor EAF = 0.1)

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Initialize
a = 0.3,
b = 0.02,
EAF = 0.1;
Step 2: input (T, D);
Step3:
Mesh cost function equation is
MCF (throughput) = $a * T^{1/8} + b * D^{1/2} + EAF * (0 < MCF < 1)$
Step 4: print MCF (throughput)
Step5: EXIT
}

B. Study of Throughput prior Cost Function values

By applying the experimental values for different node densities, we can wind up that higher the MCF throughput and lower the MCF delay for a particular wireless mesh network selection will be an optimal solution to choose a particular set of routing protocol combination.

TABLE 4.3
COST FUNCTION VALUES FOR THROUGHPUT IN OKUMARA HATA MODEL

No. of nodes	Bellman ford	DYMO	STAR	ZRP
5	0.93	0.98	0.96	0.95
10	0.98	1.03	0.96	0.96
15	0.90	0.98	0.97	0.97
20	0.98	0.98	0.98	0.98
25	0.94	0.96	0.95	0.97
Average value	0.95	0.99	0.96	0.97

It means that when the value of throughput constant is prior, cost function increases. So for maximum throughput, the cost function should be maximized and hence we can opt higher cost function values (nearer to 1) of protocols for optimization of performance of WMNs. So on the basis of cost function values obtained from the experiments, we can categorize different routing protocols.

TABLE 4.4
COST FUNCTION RATING FOR OKUMARA HATA MODEL

No. of nodes	Bellman ford	DYMO	STAR	ZRP
5	Average	Good	Good	Good
10	Good	Good	Good	Good
15	Average	Good	Good	Good
20	Good	Good	Good	Good
25	Average	Good	Good	Good

VI. CONCLUSION

After studying the throughput and delay behavior of these proactive, reactive and hybrid protocols, we see that DYMO proactive protocol helps in obtaining high throughputs but much delay in the transmission of data packets does not make this proactive protocol reliable for wireless mesh networking for long distances. The bellman ford protocol is best suited for lower node densities and STAR/ZRP protocols are appreciable more on intermediate node densities. As for the propagation model is concerned, we can bring to a close that reactive and/or hybrid routing can be best suited for Okumara hata model.

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