Improving Routing by finding Optimal Path for Wireless Mesh Network

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Improving Routing by finding Optimal Path for Wireless Mesh Network

Iftikhar Muhammad

359-FBAS/MSCS/F07

A dissertation submitted in partial fulfillment of the requirements

For the degree of MS in Computer Science

at the faculty of basic and applied sciences

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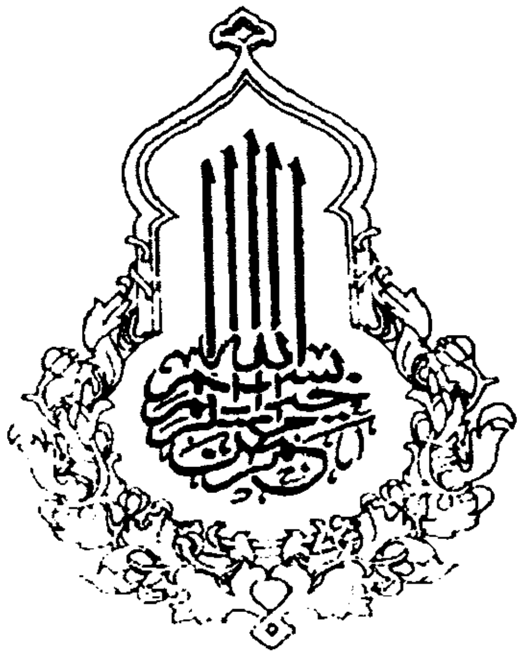

In the Name of

ALLAH,

The most merciful and compassionate, the most gracious and beneficent Whose help and guidance we always solicit at every step and every moment.

Dedication

I dedicate this research project to

My Parents, Teachers

and

My brother

Department of Computer Science

International Islamic University Islamabad, Pakistan

Date: 05/07/2012

Final Approval

This is to certify that we have read and evaluated the thesis entitled **Improving Routing by finding Optimal Path for Wireless Mesh Network** submitted by **Iftikhar Muhammad** under **Reg.No. 359/FBAS/MSCS/F07**. In our views it is completed in scope and quality for the degree of Master of Science in Computer Science.

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ABSTRACT

Wireless communication is widely used to provide multimedia and Internet services everywhere. As opposed to the wired networks it allows people to access these services anytime and anyplace. In the WMN when mesh nodes join the network, they create and maintain mesh connectivity without human intervention so WMN is called self-configured, self management and self organized.

WMN is a wireless multi-hop networks consisting of two types of nodes, mesh router and mesh client. Mesh Routers are more inert and less resource constrained than Mesh Clients. The Hybrid Wireless Mesh protocol (HWMP) is the default routing protocol for WMN. HWMP suggests two methods for routing, on-demand and proactive for wireless mesh networks. It is true that the on-demand routing method creates the optimum routing paths for transmission of data but the initial delay is very high while communicating with another station in a mesh. As compared to the on demand mode the proactive routing mode creates low initial latency while communicating with another node but the throughput decreases, when communicating with a destination because it gives the non optimal path. This also creates end- to- end delay and routing overhead. The performance of the HWMP protocol degrades rapidly and the reason is that the routing path through the root unnecessarily overloads the root. Furthermore, HWMP performance becomes more severe when the network size of WMN is large, which could lead to the huge amount of intra-mesh traffic towards the root. To overcome these problems, we propose a new routing mechanism, IMRWMN to quickly determine the optimal route for any source-destination pair inside the WMN. The experimental results showed that the proposed (IMRWMN) scheme overcomes the faults of HWMP protocol and searches for the optimum routing paths quickly and efficiently, it always has the lower initial latency and higher data transmission throughput compared with HWMP. Our simulation results also reveal that the proposed scheme (IMRWMN) outperforms the HWMP protocol with much lower average end-to-end delay and much higher packet delivery ratio. We will evaluate the performance of the proposed scheme through NS-2 simulation.

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With the name of Allah, Most Gracious, Most Merciful

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List of Abbreviation Used

HWMP	Hybrid Wireless Mesh Protocol
WMN	Wireless Mesh Network
MANET	Mobile Ad Hoc Networks
WLAN	Wireless LANs
AP	Access Point
NIC	Network Interface Card
HWMN	Hybrid Wireless Mesh Networks
RDR	Root Driven Routing
TBR	Tree Base Routing
IEEE	Institute of Electrical and Electronics Engineers
MP	Mesh Point
MPP	Mesh Point Portal
MR	Mesh Root
STA	Station
Wi-Fi	Wireless Fidelity
RANN	Root Announcement
PREQ	Route Request
PREP	Route Reply
PERR	Route Error
DF	Data Frame

RSET	Route Set
RNTF	Route Notification
RF	Route Flag
IMRWMN	Improving routing by finding Optimal Path for Wireless Mesh Network
NS2	Network Simulator 2

Introduction 1

1.1 Introduction

Wireless communication is widely used to provide multimedia and Internet services everywhere. As opposed to the wired networks it allows people to access these services anytime and anywhere. Most widely used access networks that facilitate such services are WLANs, MANETs and WMNs. WLANs are centralized networks but its coverage is limited. One access point (AP) can only cover a few hundred meters. Due to this limitation WLAN is not suitable for lager area. On the other hand MANET consists of multi hop self-organized router nodes that support its application to cover a larger area. MANETs are distributed networks that do not provide a centralized control. Wireless Mesh Network (WMN) is a communication network which provides multi-hop communication over wireless links, thus increasing the effective coverage area. A WMN is dynamically self organized and self configured with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves. WMN has some features of WLAN and also some features of MANET. Thus it takes advantages from both networks which make it more suitable technology to provide real-time multimedia and broadband services to cover larger areas with centralized control.

1.2 Overview of Wireless Mesh Networks

In the WMN when the mesh nodes join the network then they create and maintain the mesh connectivity without human intervention so the WMN is called self-configured, self management and self organized.

When a node in the network is down then the other mesh node delete the route from the routing table to that node and set up a new route automatically to handle the network.

These features bring many advantages to WMN such as cost, easy maintenance of network, robustness and reliable service coverage. In wireless mesh network conventional nodes (for example laptops, PDAs, mobile phones, etc.) are set with wireless network interface cards that can connected directly to wireless mesh routers. Clients that have no wireless Network interface card can connect to the WMN using Ethernet [1].

The main applications of the WMNs are military, residential, community, public safety, offices, small to medium businesses, emergency and rural networks. The above mentioned networks require an infrastructure network to connect to them. For example if there is an emergency the ambulance connects the hospital infrastructure network to communicate with the doctors [4].

There are two types of wireless nodes in WMN, one is mesh router and the second is mesh client. The mesh routers have better computational, communication and power resources as compared to mesh clients. Mesh routers are commonly static and form the multi-hop backhaul network. Mesh routers also provide multiple wireless network interfaces. Mesh clients may be mobile or stationary devices which are connected to the infrastructure provided by the Mesh router. Both mesh and conventional clients can connect to the mesh router. Mesh routers have the gateway and bridging functions but mesh clients doesn't have these functions. Due to the gateway or bridge functionalities in mesh routers facilitates WMNs to integrate various existing wireless networks such as WiMAX, Ethernet, wireless sensor, Wi-Fi and cellular etc. Mesh clients can also works as a router. But gateway or bridge functions do not exist in Mesh client. Mesh clients typically have only one wireless interface.

The WMNs has three types of groups based on the function of the nodes.

a. **Infrastructure wireless mesh Network**
b. **Client wireless mesh Network**
c. **Hybrid. Wireless mesh Network**

In an Infrastructure WMN, mesh clients obtain access to each other or to the backhaul network through mesh routers and not involved in routing and forwarding of packets. The WMN infrastructure/ backbone can be developed with different types of radio technologies. For conventional clients with the same radio technologies as mesh routers, they can directly communicate with mesh routers. If different radio technologies are used, clients must communicate with the base stations that have Ethernet connections to mesh routers. For example

The community and neighborhood networks can be built through infrastructure WMN. The mesh routers are located on the top of houses in the coverage area, which serves as access points for users inside that specific area.

Typically, two types of radios are used in the routers, for backbone communication and for user communication respectively.

In Client WMN, Mesh Clients are connected with each other without any Mesh Routers. A Client WMN is basically a pure multi-hop mobile ad-hoc wireless network. A Hybrid WMN is combination of both the Infrastructure and Client WMN. In such type of networks, both Mesh Clients and Mesh Routers are involved in routing and forwarding of packets and Mesh Clients can access the wireless backhaul network via multiple client hops [6].

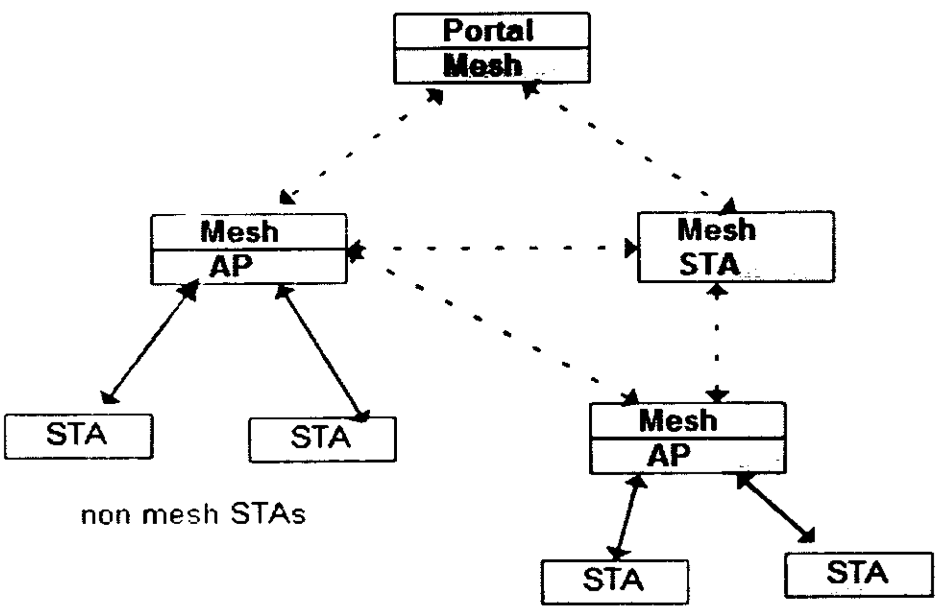

Figure 1.1 802.11s WLAN Mesh

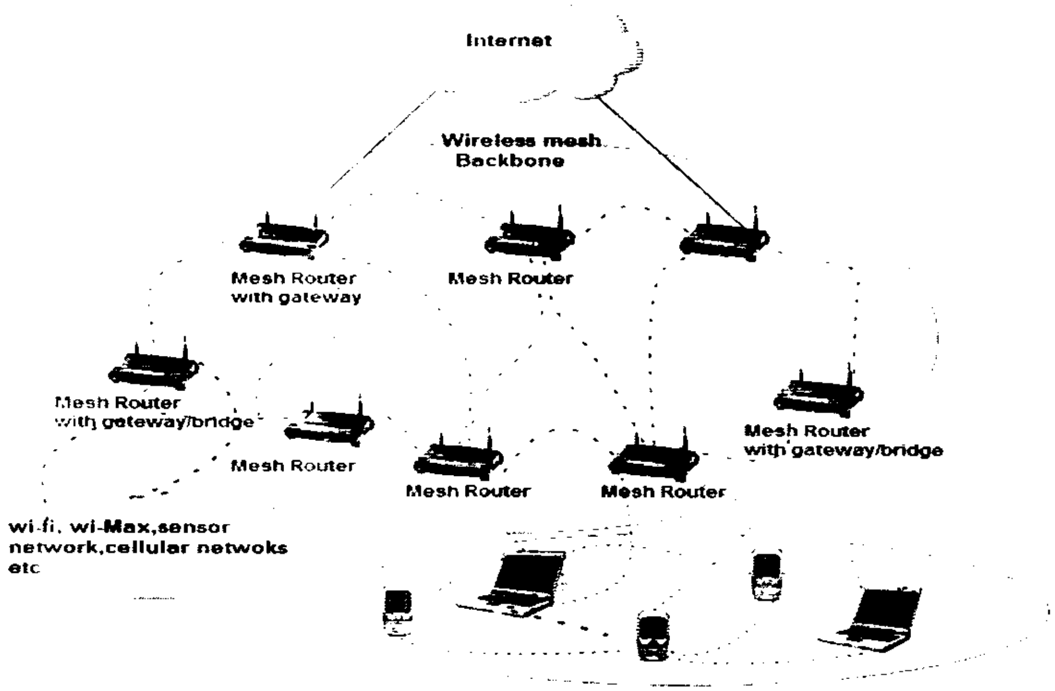

Figure 1.2: Hybrid WMN

MANETs or Mobile Ad Hoc Networks are infrastructure less networks in which mobile nodes are free to move randomly and organize themselves arbitrarily. Thus, the network's wireless topology may change rapidly and unpredictably. MANETs do not require any fixed infrastructure like a base station for their operation. The routes between nodes in an MANET may include multiple hops, and hence are called multihop networks. Each node can communicate with the node in its range, and those which are beyond its range; the node needs other intermediate nodes to relay its messages. In other words each node can act as a router to forward messages of its peers but In a WMN, each node not only operates as a host but also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. There are some similarities between WMN and MANET with respect to features but there are some differences between them [1], [7].

In the Ad Hoc network a client using a particular radio technology cannot access a client in a different network technology. For example a client in WiFi cannot access a client in WiMax or other networks. While in WMNs these two networks can be connected with the help of mesh routers employ a number of standard radios. Another difference in ad hoc and WMNs is effect of mobility on network architecture. In ad hoc networks, nodes mobility completely change the network shape which affects the routing decisions and network performance. In case of WMNs the clients mobility has limited effect on the overall routing decisions as the mesh routers are fixed and responsible for routing and network configuration. In WMN the mesh routers perform all the network routing and use multiple radio technologies. By using multiple radios and multiple channels per radio. the effective network capacity and throughput can be increased. MANET has usual power constraints but in the case in WMN where the mesh routers which are mostly fixed with no power constraints [7].

1.3 HWMP (Hybrid Wireless Mesh protocol)

The Hybrid Wireless Mesh Protocol (HWMP) is a default mesh routing protocol that provides the feature of both, on-demand routing and proactive routing. HWMP control messages are the Route Request (RREQ). Route Reply (RREP), and Route Error (RERR) and Root Announcement (RANN). The metric cost of the links determines which routes HWMP builds. For transmission of metric information between MPs, a metric field is used in the RREQ, RREP and RANN. To avoid loop-free connectivity the HWMP uses a sequence number.

HWMP is operated on data link layer (layer 2) that use MAC addresses unlike other routing protocols that operated on network layer (layer 3) with IP addresses. Routing on the layer 3 involved overhead because the data traffic is first forwarded to the network layer (IP layer) for routing then the IP addresses and the MAC addresses exchanged so this process involves overhead. However. HWMP uses the layer 2 for routing so the overhead of ARP is not come that results high network throughput [3].

Each MP has its own sequence number which is propagated to other MPs in the HWMP control messages.

Based on configuration. HWMP has two modes for operation. These modes are:

1.3.1 On-demand mode

The functionality of this mode is always provided. It enables the mesh station to communicate through peer to peer paths. The mode is used in situations where there is no configured root station (STA).

1.3.1.1 On demand path selection mode

When a source mesh STA wants to communicate to another mesh STA inside the mesh network using on demand mode, the source STA Broadcast PREQ with the destination STA specified in the list of targets and metric field is initialized to the initial value.

When a new PREQ is received by a mesh STA it exchanges its routing information to the sender mesh STA to create or update the path. The PREQ then sends to its neighbor peer mesh STAs, if the PREQ contains a greater HWMP sequence number or the HWMP sequence number matches the current path and the PREQ provides a better metric than the current path. Inside the mesh every mesh node received multiple PREQ and each PREQ has unique path. When the target STA receives the PREQ then the target mesh STA send PREP back to the originator mesh STA.

Target Only" (TO) and "Reply and Forward" (RF) flags are used to take advantages of already created previous paths to the destination node. These flags are used to allow the intermediate STA to send PREP to the source Mesh STA. If the TO flag is set to 1 the destination STA only send REPLY back to the source STA. if the TO flag is set to 0 used for quickly established path between source destination by sending reply back to the source mesh STA and then the data is sent with minimum path discovery delay.

If the RF flag is equal to 1 (and the TO flag to 0), then the first intermediate mesh STA that has a path to the target sends a PREP and propagates the PREQ with the TO flag set to 1 to prevent all intermediate mesh STAs sending a PREP. If the RF flag is set to 0 (and the TO flag to 0), then the mesh do not forward PREQ.

When the source STA receives the reply then the path is created toward destination STA. After this if the destination STA receives more PREQ message with best metric from the others intermediate node then the destination STA updates its routing path to the source and sends PREP to the source with new update path. So bidirectional, best metric end-to-end path is established between the source and destination mesh STA.

1.3.2 Proactive tree building mode

There are two mechanisms to share information for selection of path in order to reach the root mesh STA. The first method proposes a proactive Path Request (PREQ) message and it develops paths between the root mesh STA and all mesh STAs in the network in a proactive manner. The second method uses Root Announcement (RANN) message and issue path information for reaching the root mesh STA

1.3.2.1 Proactive PREQ mechanism

The root mesh STA sends PREQ to all the nodes in mesh to start the tree building process. The TO and RF flag is set to 1 and the PREQ message consists of metric and HWMP sequence number. The root node sends the PREQ periodically to all nodes in the mesh and with increase HWMP sequence number. When the mesh STA other than root STA receives the PREQ then it creates or updates the routing information to the root node, recorded the metric and hope count of the PREQ.

Each mesh station can receive several copies of a proactive PREQ and each consists of a unique path from the root mesh STA to the mesh STA. A mesh STA updates its current path to the root mesh STA if and only if the PREQ contains a better HWMP sequence number or the HWMP sequence number is same as current path and the PREQ offers a better metric than the current path to the root ode.

If the proactive PREQ is sent with the "Proactive PREP" bit set to 0, the recipient mesh STA may send a proactive PREP. If the PREQ is sent with a "Proactive PREP" bit set to 1, the recipient mesh STA shall send a proactive PREP. The proactive PREP establishes the path from the root mesh STA to the mesh STA.

1.3.2.2 Proactive RANN mechanism

The root mesh STA periodically sends a RANN message in the network. The information contained in the RANN is used to distribute path metrics to the root Mesh STA. When the STA received the RANN message, each mesh STA that has to create or refresh a path to the root mesh

STA sends an individually addressed PREQ to the root mesh STA via the mesh STA from which it receives the RANN.

The root node sends PREP in reply to each PREQ. The PREQ creates the reverse path from the root mesh STA to the source mesh STA and while the PREP creates the forward path from the mesh STA to the root mesh STA.

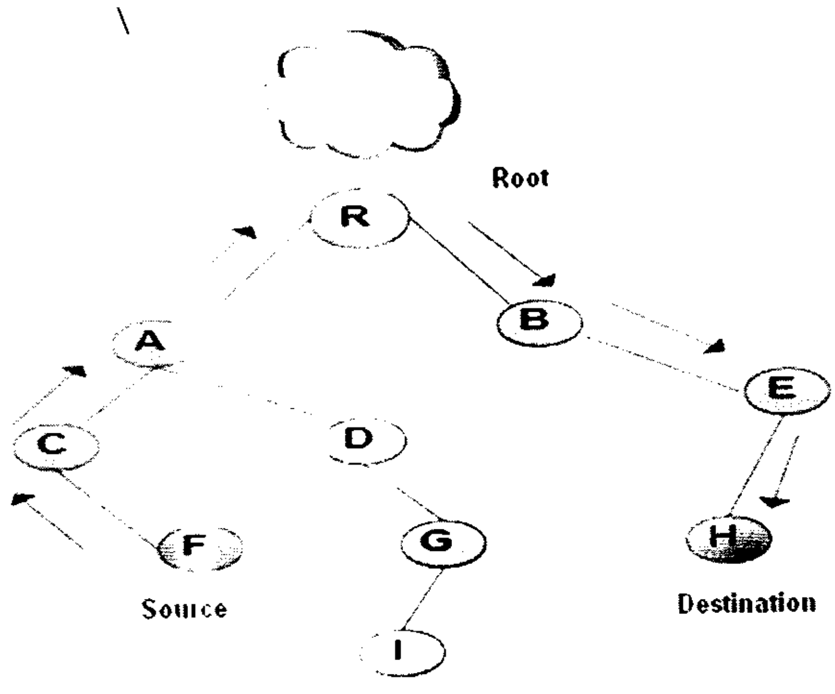

Figure 1.3 Proactive Tree modes

1.4 Summary

This chapter discussed about Wireless mesh network and its applications where it is used. A detailed description of Hybrid Wireless mesh Protocol (HWMP) and its two routing mode (On demand Mode and Proactive Routing Mode) is discussed and also explained faults of both routing modes.

Related Work 2

2.1 Introduction

In this chapter we perform a deep study of the literature to get information about the WMN. We study existing and main problems of the WMNs environment. This chapter analyzes all the approaches that are carried out for improving routing path for the wireless mesh network

2.2 Literature Survey

From many years researchers are vigorously working to improve routing of wireless mesh network. This section includes some protocols and mechanisms that are proposed for improving routing in wireless mesh network.

2.3. A Hybrid Centralized Routing Protocol for 802.11s WMN

In the intra mesh network for any source and destination to find the optimal and best path the root driven Routing protocol was proposed. For inter mesh traffic when the traffic is destined for outside the original TBR protocol is used. The TBR protocol builds the whole network topology when the root node is configured. So the hybrid centralized routing protocol used for all traffic scenarios because it combines both TBR and RDR [4].

2.3.1 RDR protocol

The RDR protocol that combines the TBR protocol so it forms a hybrid centralized routing protocol that is used for inside mesh traffic of WMN regardless of outside of the mesh network traffic. The RDR protocol has the whole network topology information at the root node and also has the tree topology information.

2.3.2 Protocol description and procedure

First the root node that compute the best optimal and efficient path for any source and destination node, the root node has to builds the whole network topology information (node position and their neighborhood position) in addition to tree topology.

To create whole network topology each node inside the mesh network piggybacks after receiving RANN message and piggybacks contains the addresses and the related metric of the neighbor nodes in the RREP message.

Secondly, RDR uses two extra messages route that is Route set (RSET) and route notification (RNTF).

So it is clear that the protocol is very simple and competent to give the routes for any source and destination on demand based in the mesh network.

Clearly to state that whenever a source mesh wish to forward its data traffic inside the mesh network for any destination then the root MPP suggest the optimal best path on demand base and then notify the destination node about the routing information by sending RSET message unicastly to the destination or source node. After receiving the RSET message the source or destination node then informs the midway nodes about the best metric path between source and destination through RNTF message (unicasting). For the regard of reliability in the RDR protocol the RSET message is sent to only destination node that is send by the root node.

The following Figure 2.1 and Figure 2.2 illustrate an example of RDR protocol used by the root node for intra mesh traffic through source to destination.

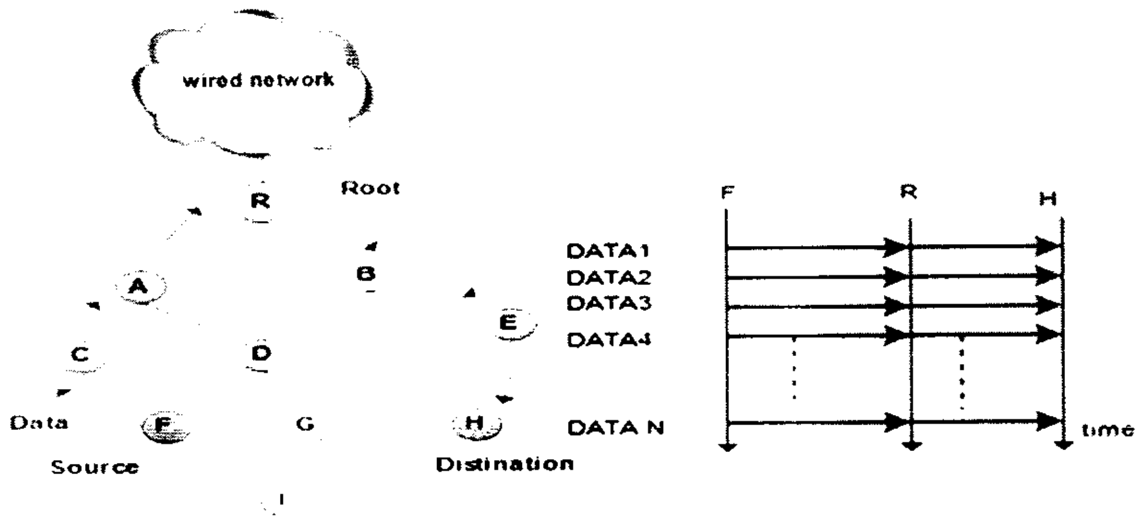

Figure 2.1: The TBR protocol working

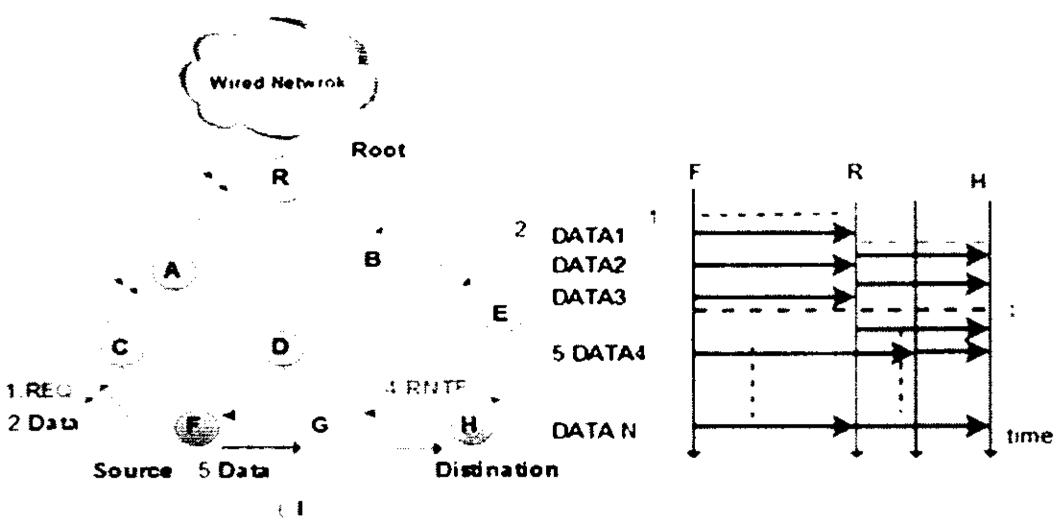

Figure 2.2: The RDR protocol working

When the source node i.e. F wants to communicate with destination node i.e. H but the source has no routing information about the destination node H that where is it located then the source node send the PREQ message to the root MP and also forward its data traffic to the root node. The root node chooses the optimal path for that source to destination (F to H) nodes looking to the whole network topology information after receiving the PREQ messages. The root node then forwards the RSET message to the destination node (H) to inform them about the optimal path. The root node also forwards the data traffic to the destination (H). After receiving the REST message by the H node from the root node which consists of the optimal path from source node (F) to the destination node (H) then the H node generates the RNTF message and delivers it to the F through G node. After receiving the RNTF message the source node (F) then forward it's all data traffic through the G node that is optimal path recommended by the root node.

2.3.3 Computation of optimal path

In the RDR protocol when the root node receives the RREP message, the neighbor nodes information is added to the PREP message builds a whole network topology. The root finds the optimal path for all source-destination based on the topology information of the entire network using the Dijkstra's algorithm. When the root received the PREQ message from the source node the root node initially selects the entire possible suitable paths for any source and target node then the root node select the best optimal paths form all possible valid paths. After this, root node matches the computation results with the presented TBR route information in its routing table to ensure. that the route suggested by the root node is optimal or not.

Figure 2.3 shows the procedure of the RDR protocol, algorithm of selecting the optimal path for source and target node and their computation.

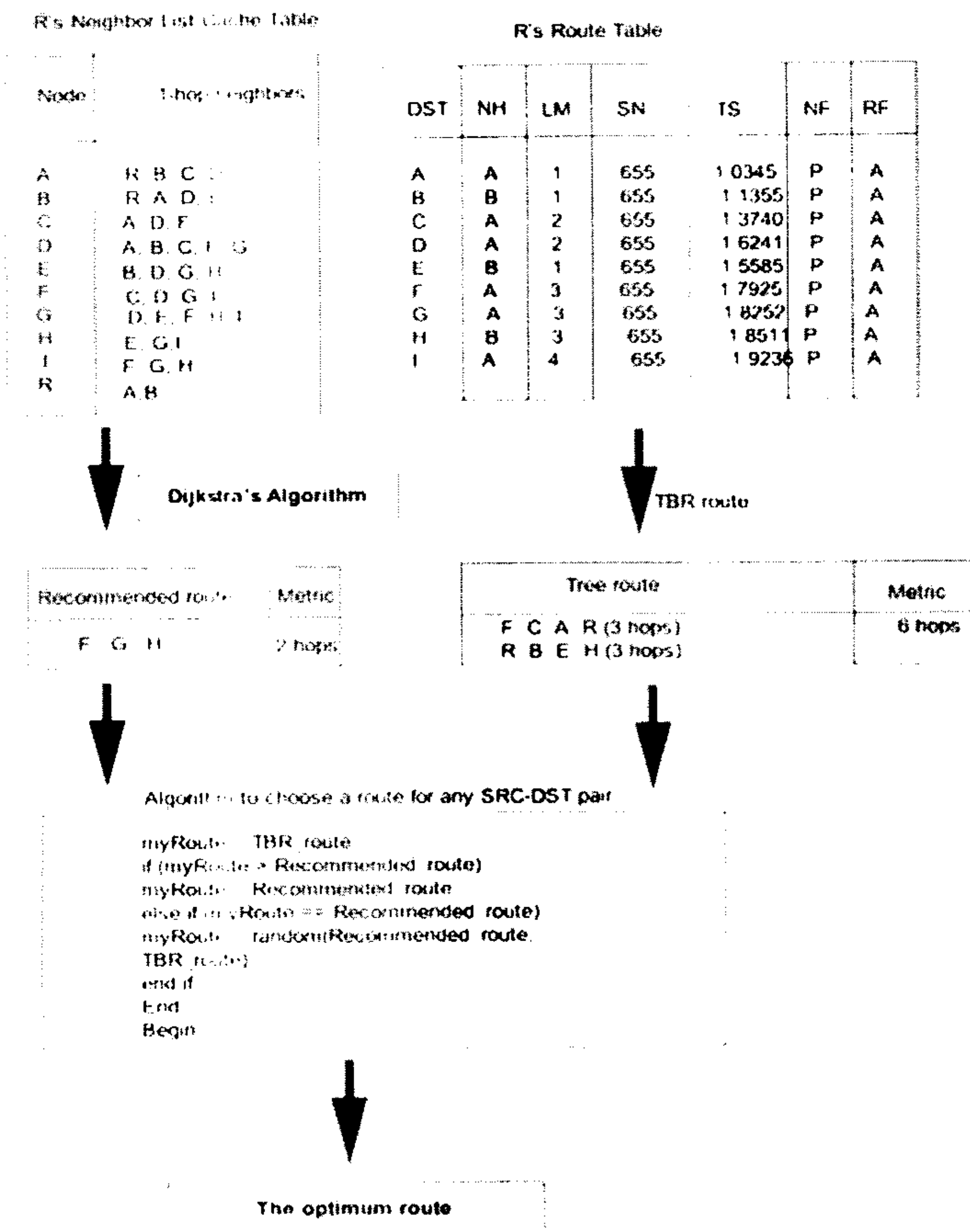

Figure 2.3: Algorithm of selecting optimal path

If TBR and RDR both has same result of best-optimal metic path then the algorithm selects an optimum route randomly.

2.3.4 On-demand active route

In this part we clarify how to employ and keep the on-demand active route for any source-destination pair when the RDR protocol is used. When the target node received the RSET message the target node itself make a RNTF message that consists of information of on demand which is optimal path that is suggested by root node. When the intermediate node received the RNTF message its update his routing table with an on demand entries after processing the RNTF messages and forward it to source node. In RDR protocol only one routing table is shared by the two modes (proactive and on demand) . In the shared table the route flag (RF) field is extra added. The purpose of the RF flag is that it is used to tell whether the destination entry is handling by on demand mode or proactive mode.

Figure 2.4 Shows the the routing table that how the both modes on deman and proactive is employed when the RDR protocol is used. When the source node recieved RNTF message then the originated node(F) forward its data traffic to the related target node(H) through the suggested optimal path by the root node. In the RDR protocol , the route between each originated and target pair is likely to be symmetric. The forward path and reverse path to the source and target are created when the RNTF message is received.

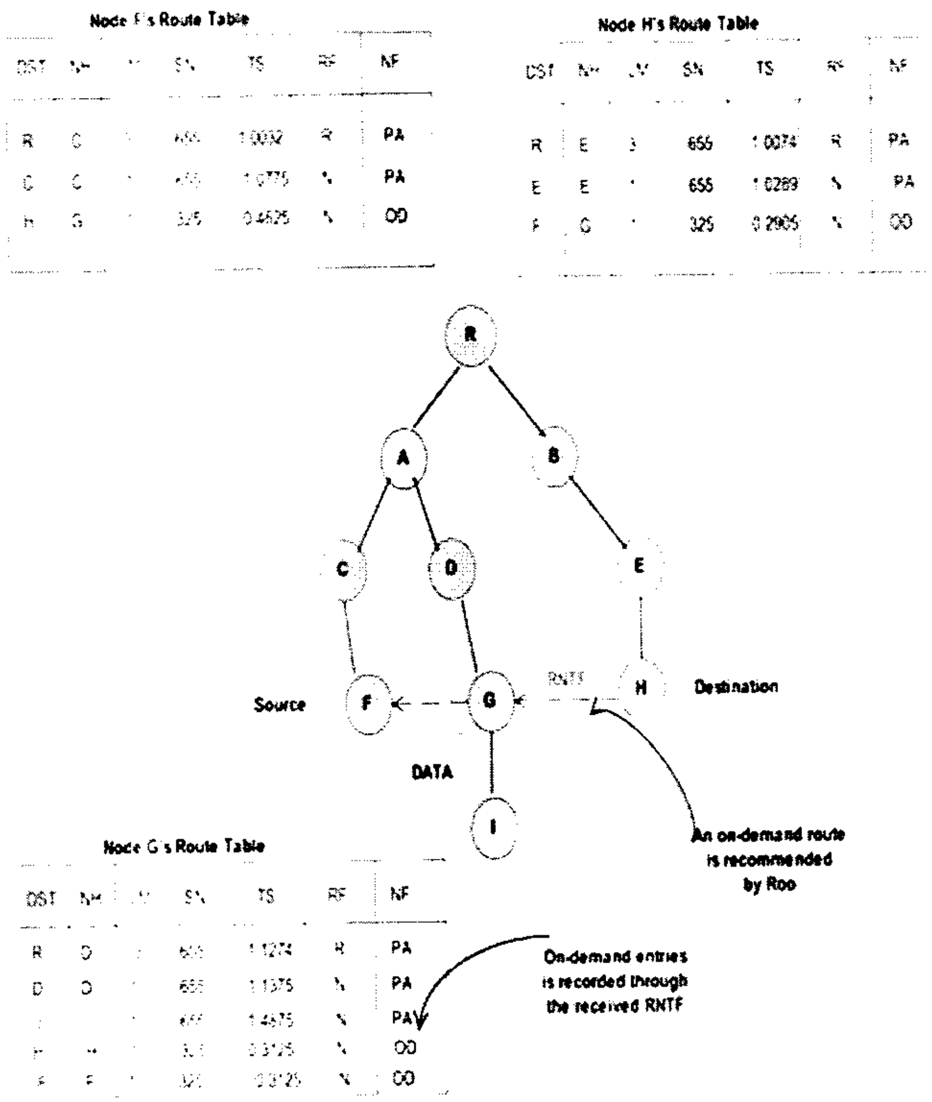

Figure 2.4: Construction of on demand route

This scheme gives the optimal path but the root will be overloaded due to high computation because the root node from time to time required to keep the neighbor information through piggybacked which was send by the nodes in RREP message to build whole network toplogy.

The life time for on demand optimal path is three second if this route is not used for three seconds then this route is marked as invalid. The source, destination and intermediate nodes delete their entry for the on demand route from the routing table. So after three seconds if the route is again required then the whole process will be done again from the start that leads to packet loss, end to end delay and routing overhead.

This scheme gives the optimal path but this scheme not provides the recovery mechanism to restore the optimal path for source and destination that is in during communication the routing path (optimal path) is broken. In mobility scenario the packet delivery reliability is less than 55 % because of link broken and delay is 400ms. The routing overhead is larger than (twice) from the static network when the nodes are moving.

2.4 The Proposed Efficient Cooperation Method

Every routing mode has its own advantages and disadvantages based on whether a target node is located inside the WMN with the originated node or in the outside mesh network linked through gateway nodes.

The authors propose the method called an efficient cooperation method of two routing modes and the taking benefits from both routing modes to beat their faults. The wireless mesh network is mostly used as infrastructure network (backbone network) that covers large area and the communication is mostly between mesh and gateway nodes. For such situation proactive routing mode is very useful when all the data traffic goes through gateway nodes. Hence the planned cooperation method is referred as the hybrid routing mode is considered in such method that the proactive routing mode of proposed protocol is default and the on- demand routing mode is used when the communication is made inside the mesh network.

2.4.1 Algorithm of hybrid routing mode

Step 1: Input: received data frame DF

Step 2: if (my MAC addr = destination MAC addr of DF)

Step 3: if (routing path to destination ∈ Routing Table) Then

intra-node flag in DF ← 1

Forward DF to child node

Step 4: Else if (root node) Then

Forward DF to external network

else

Forward DF to parent node

end if

else

Step 5: If (intra-node flag in DF =1) Then

Send PREQ message for on-demand routing

end if

end if

The author introduce the intra node in the data frame header in this paper and through this flag the destination node is informed whether the originated node is inside the mesh or outside. The mesh node checks the mac address of the destination node after receiving the data frame to decided whether the target node of data frame is itself or not. If the destination is not itself then the node search routing information for destination in its child nodes, in case the destination is one of its child nodes then the nodes set value of intra node flag DF set to 1 and the data frame is send to child node. If the information still now exists then it forwards data frame to root node.

The root node sends the data frame to destination because the root node know the whole network topology so when the destination node receive the data frame it checks the intra node flag that is set by the root node, so if the DF is set to 1 then it means that the source node is in inside the mesh network and destination node start on demand discovery for optimal path with PREQ message to all network nodes then the source node send reply with PREP message to destination on optimal path.

Suppose that source node 4 wants to communicate with destination node 6 inside mesh network.

i. The source node 4 forward data frame to the node 2 then the node 2 forward the data to the root node because the destination node 6 is not the node 2 itself and not one of its child nodes. The root then search for routing path for node 6.

ii. If the target is node X and the root node has no routing path for the destination node so then the root node send the data frame to the external network.

iii. If the destination node is inside the mesh network then the root node finding the routing path for node 6 and set the intra node flag DF to 1 and also sends data to node 6.

iv. The destination node 6 then checks the intra node flag value if the value is set to 1 then it means that the source node inside the mesh network so it start on demand discovery for optimal path.

v. So in finally after this process all data traffic goes through optimal path.

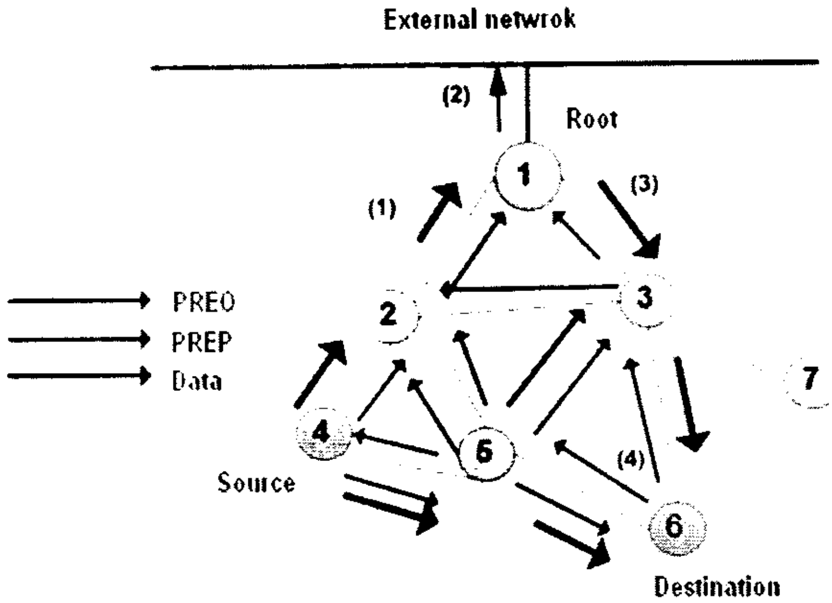

Figure 2.5: Operation of hybrid routing mode

But in this scheme the initial latency comes, because when a source wants to communicate with destination inside the mesh. first DF checks in parent's node if it is not in his child then it will forward to root node then the root node will find destination node. Again destination starts REQ on demand for optimal path for source. Require initial delay of 1532 as if the communications with the target node is done inside the WMN. The Initial latency's is still exists and not improved.

2.5 Summary

In this chapter we discussed in details some protocol and approach for improving routing in WMNs. We analyzed the mechanism with respect to remove the non optimal path between source and destination. Finally we presented the limitation and features of these mechanisms.

Problem Statement 3

3.1 Introduction

In this chapter we doing analysis the HWMP. The faults of two routing modes will discussed. The non optimal path through root node is pointed out and how the routing tree created is explained.

3.2 Problem Statement

In the tree-based proactive routing mode of HWMP, one mesh node is selected as tree root node and tree is created proactively to establish routing paths between the root node and all other nodes in the mesh network. The root node broadcasts either PREQ or RANN messages periodically to create and maintain the tree. During this tree creation, only the root node can know the routing information to all nodes in the mesh network and other nodes maintain only routing paths to root node and their child nodes.

There are three types of traffic in the WMN that passes through root node or gateway node, either traffic comes from the outside to the mesh network or traffic goes outside from the mesh network or traffic inside mesh network.

For traffic inside the mesh network, when an originated node wants to communicate to the target node then the source node sends its data to the root node, if there is no active path exist then the root node forward to the destination node through non optimal path without using the best metric path as shown in the figure 3.1 below.

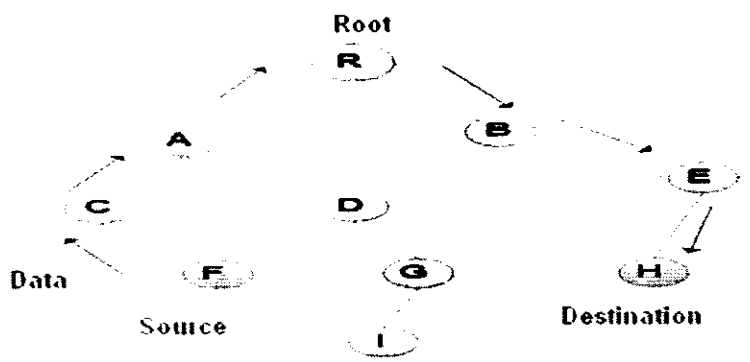

Figure 3.1 Problem of non optimal routing path

3.2.1 Faults of Proactive mode

One serious drawback of the proactive mode is that when a numbers of nodes(other than the root node) wants to communicate to the others nodes inside the mesh network and sends its traffic through root node without the best optimal path so root will be heavily overloaded as shown in the figure 3.1 below.

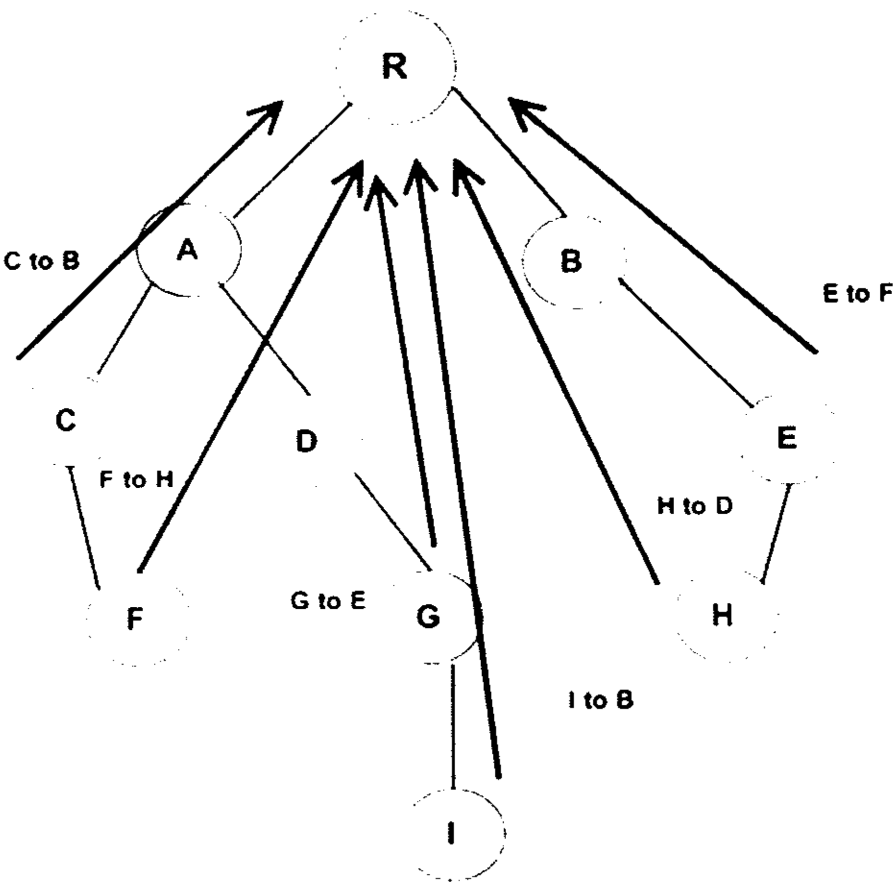

Figure 3.2: The inefficiency of HWMP protocol

Furthermore when the network size grows, the traffic inside mesh network through root node becomes significantly overloaded. So entire mesh network performance will slow down or even stop.

As result proactive mode of HWMP faces many problems like the bigger end-to-end packet loss, end- to- end delay routing overhead, failure of the root node and poor load balancing of the node near to the root node that carry traffic as result traffic congestion around the root node. The operating method and characteristics of on-demand routing mode of HWMP are very similar to existing AODV, except that HWMP uses layer 2 routing. In the on-demand routing mode, if a source node has no routing path to the destination node, it broadcasts a PREQ message inside mesh network. The destination node that receives the PREQ message sends a unicast PREP message back to source node and then a bidirectional routing path between the source node and destination nodes is established. During this procedure, the PREQ ID, destination sequence number is used to prevent sending duplicated messages and to establish loop-free routing paths.

The on-demand routing mode always provides optimum routing paths by establishing its path when data transmission is required. However, such a method results in high initial latency. In addition. the initial latency problem can be more significant due to characteristics of data traffic in wireless mesh network.

In on-demand mode the routing paths are searched only when needed. In on-demand mode, route searching before they can forward data packets. The source node starts route discovery procedure to reach to destination node and send PREQ request in the mesh network to all other mesh node. But the on-demand mode suffers from the long initial delays.

Second. in proactive routing mechanism the mesh node sends its traffic toward the root node without searching routing path to destination node. When destination node is present inside the intra mesh network, then overall transmission throughput can decreases because all data traffic is sent through non optimal path.

The Figure 3.3 below shows the non optimal problem when the two mesh node communicates inside mesh network.

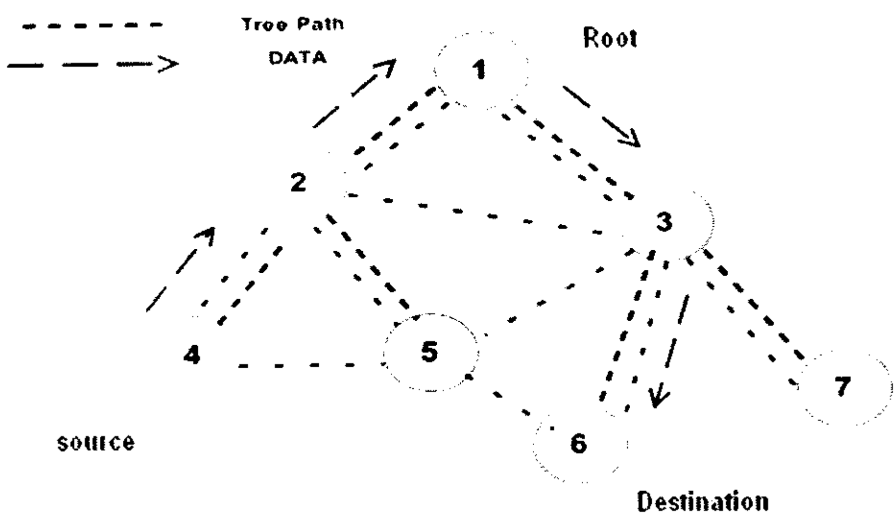

Figure 3.3: The non optimum routing paths in the proactive routing mode

The mesh node 1 is the root node as shown in Figure 3.3. The Mesh node 4 is source node and the mesh node 6 is the destination node. The routing path is shown above in the figure 3.3, while the best optimal path for source node 4 and destination node 6 should be 4 ,5 and 6 but the routing path from (4,2,1,3,6) is selected that is the non optimal path long path. Hence if better path exists between source and destination, all the data traffic is send to that of non optimal path.

First the source node 4 send its traffic to its parent node 2 then the node deliver to root node 1, if the target is not one of its child node and last the root node 1 sends the traffic to the target by using the routing information already in its table. The optimal path between source node 4 and destination node 6 is $4 \rightarrow 5 \rightarrow 6$ but the non optimal path $4 \rightarrow 2 \rightarrow 1 \rightarrow 3 \rightarrow 6$ is used because of the proactive mode of the HWMP, so all the data traffic will be forwards this non optimal path. Its means that the data transmission throughput decreases, end to end delay is large and the efficiency of data transmission drops so enhancement is needed.

3.3 Summary

In this chapter we studied the HWMP protocol, how tree topology is created and faults of the HWMP modes are discussed. The on-demand mode provides all time the best path for data traffic, but this mode suffer from long initial delay. The proactive tree mode has low initial delay but it offers the non optimum path for any source and destination, all data traffic pass through root node which results throughput decrease, packet loss and end to end delay.

Proposed Solution 4

4.1 Introduction

In this chapter we proposed a new routing method, IMRWMN to quickly decide optimal route for any source and destination in WMN..

4.2 IIMRWMN

IMRWMN is based on the same RDR Protocol. The responsibility of root node in the HWMP is to provide a path between source and destination, also all data is passing through root node (non optimal path).

IMRWMN is the extension of the HWMP and based on the same idea that proactive tree is made and tree node has whole network topology about the mesh. In IMRWMN root node acts like a central node. In IMRWMN root node send PREQ message to build the network topology when a mesh node receives the PREQ message then each mesh node send a PREP message back to the root node. The PREP message contains the neighbor information as well as their metric value. When root node receives these messages from the all nodes inside the mesh network then the root node creates a routing table that contains the whole network topology. Then this routing information is shared to all the nodes inside the mesh topology.

When a source wants to communicate to the destination inside the mesh network then it just performs computation to find the best optimal path for the source and destination. For route updating the PERR message is broadcast to the network to update its routing table.

Following are the steps of our proposed solution.

i. The root node broadcast the PREQ message in the network to build the network topology, then mesh nodes sends the PREP messages in response to the PREQ messages. The PREP message consists of neighbor addresses and corresponding metrics value in RREP message.

ii. When root node receives PREP messages from the all the mesh nodes then root node creates the whole network topology that consists of nodes, their neighbors nodes and metrics value.

iii. This routing information is broadcasted to all mesh nodes.

iv. All mesh nodes performs computation locally to find the optimal path for any source destination.

v. A change in the topology is broadcast to all the mesh nodes in the network.

vi. Sequence number are used for avoid Looping.

RREP message format with neighbor information

	Element ID	Length	Flags	Hopcount	Time to Live	Target Mesh STA Address	Target HWMP Sequence Number	Lifetime	Metric	Originator Mesh STA Address	Originator HWMP Sequence Number	Neighbor Node Address #1
Octets	1	1	1	1	1	6	4	4	4	6	4	4

Neighbor Node Link Metric #1	....	Neighbor Node Address #m	Neighbor Node Link Metric #m
4		4	4

m denotes number of neighbor nodes

Figure 4.1: PREP Message Format

4.3 Optimization & Maintenance

Our proposed solution is centralized because it has global view of topology. Our proposed solution does not depend only on root node as in proactive HWMP where traffic to all destinations go through root node and neither it use RREQ messages which may cause congestion in network. Every source node can calculate shortest path to destination node without flooding the network. In the propose solution there is small overhead initially when the network topology is shared but after that all the computation is done locally.

The mesh node will not send its neighbor information to root node until there is change in the network topology, for example new neighbor comes or the existing neighbor is quits. So this will reduce control overhead.

4.4 Algorithm of proposed solution

The detail algorithm of proposed solution is given below.

Procedure: root node builds the whole network topology and shared the topology with all nodes in the mesh network.

Output: The optimal path between source and destination

Begin

Step 1: The root Mesh Point (MP) broadcast PREQ

Destination address is set to all 1s.

Step 2: The Target Flag and Reply and Forward Flag is set to 1

Step 3: upon reception of a PREQ each Mesh Point (MP) has to create or refresh a path to the root MP

If "Proactive PREP"=1 Then

Each Mesh client (MC) shall send PREP

Else if ("Proactive PREP"=0) Then

MC may send a Proactive PREP if required.

Step 4: Mesh client looks routing table

If (sequence number is greater AND offers a better metric) Then

Update the path to the Root MP.

Step 5: MR collect the information about all links and store in its routing table.

If (Mesh client within the Root MP Radio range) then

Put in routing table.

Else every node use Hello message and update neighbors lists, path information and it's metric value.

Step 6: if MC sets its routing table then

Send information to Root MP.

Step 7: MR propagates Routing table detail up to k-hope nodes.

If (any changes in its one hope neighbor) then

Root MP updates routing table and share with all MC nodes.

4.5 Proposed Model

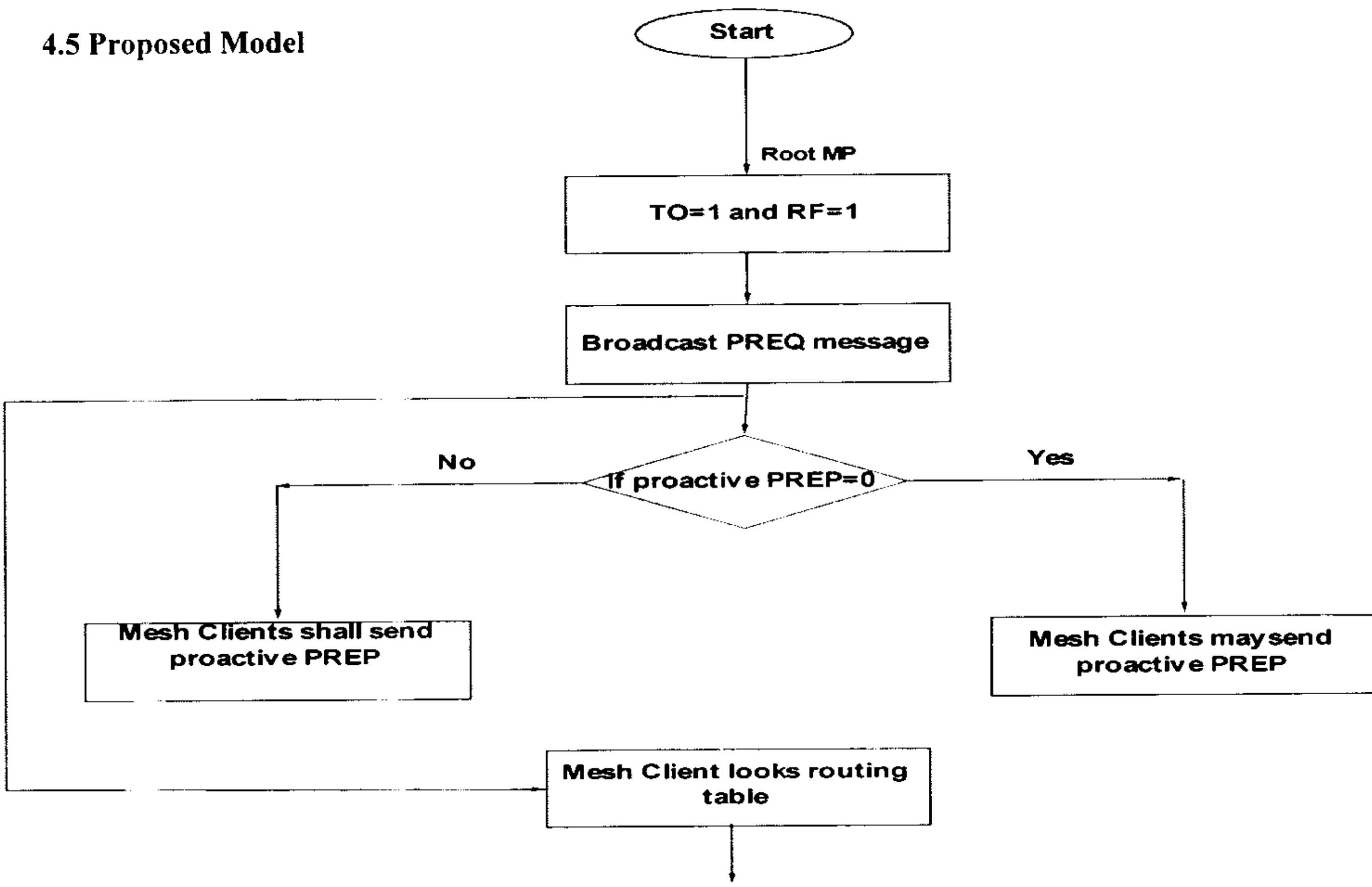

Figure 4.2 a: proposed Model

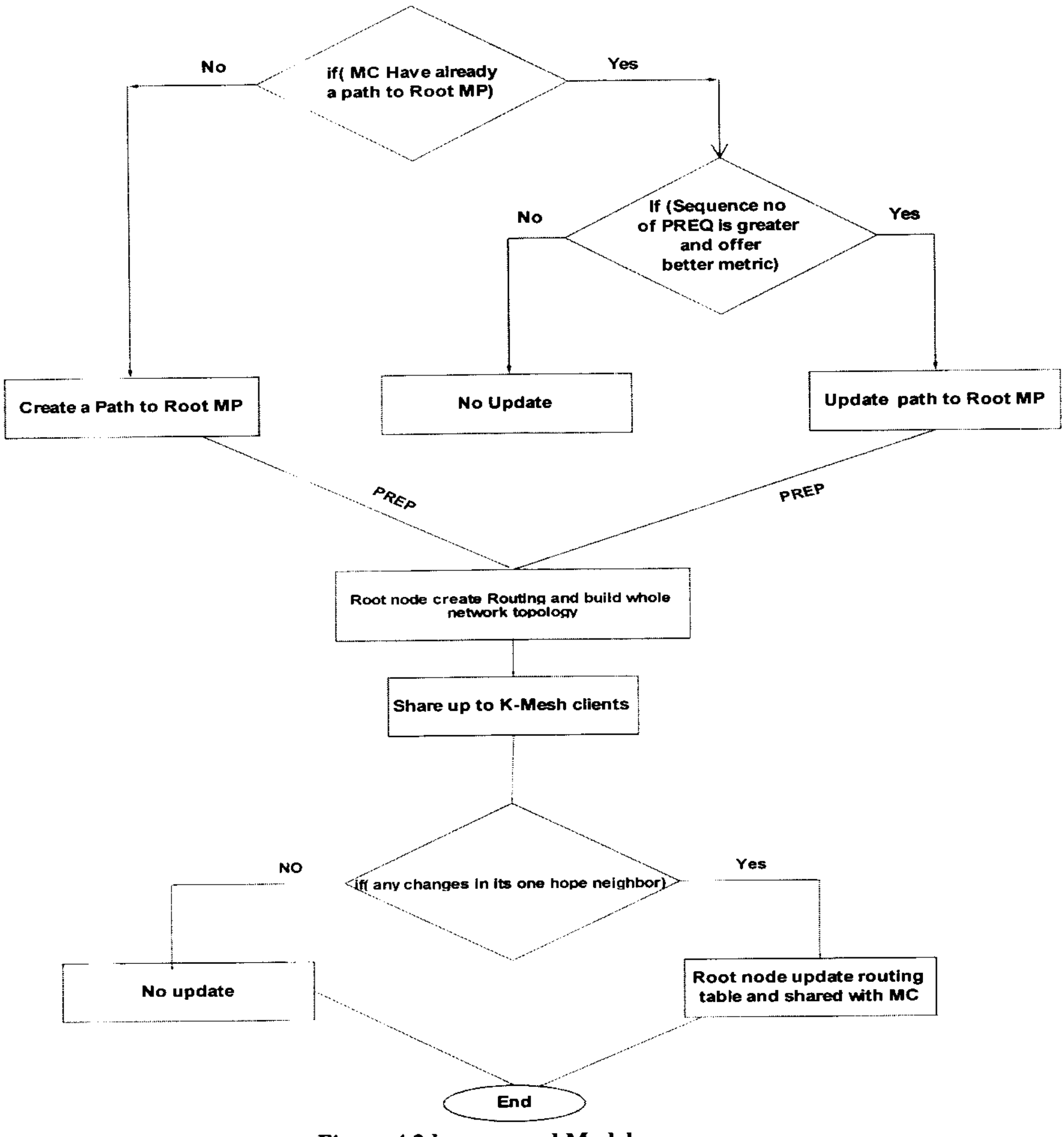

Figure 4.2 b: proposed Model

The proposed scheme provides the optimal path for the source and destination simply and efficiently in the mesh network. In brief the source node could compute the optimal path by itself to any destination node when the proposed scheme is used.

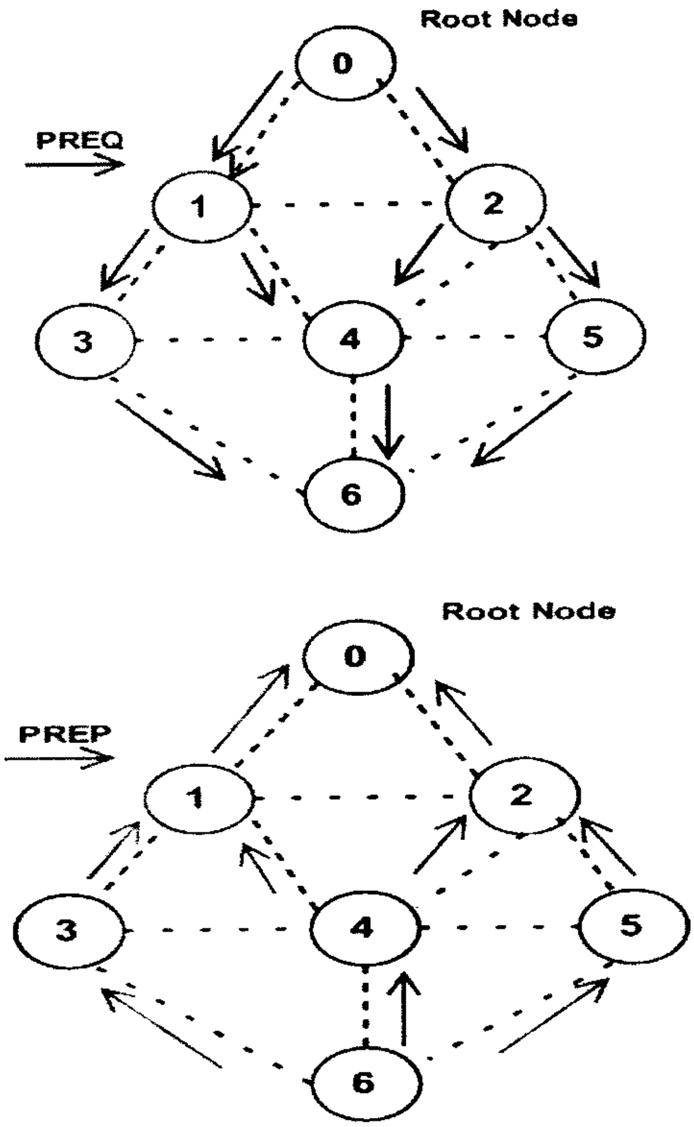

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Figure 4.3 a: IMRWMN tree creation process

The above figure show example of the operation of proposed scheme (IMRWMN). Assume that the source node 3 wants to send data to the destination node 5. So first the root node 0 needs to build a tree topology and a neighbor topology at the root node. The root node (0) broadcast the PREQ message in the network. When the child node received the PREQ messages, the child node choose the corresponding parent node. The child node then updates its routing table, and then broadcast the PREQ message. In this way the child node has known the path to root node and then sends Route Reply (PREP) message piggyback neighbor addresses and corresponding metric of their own to the root node to register.

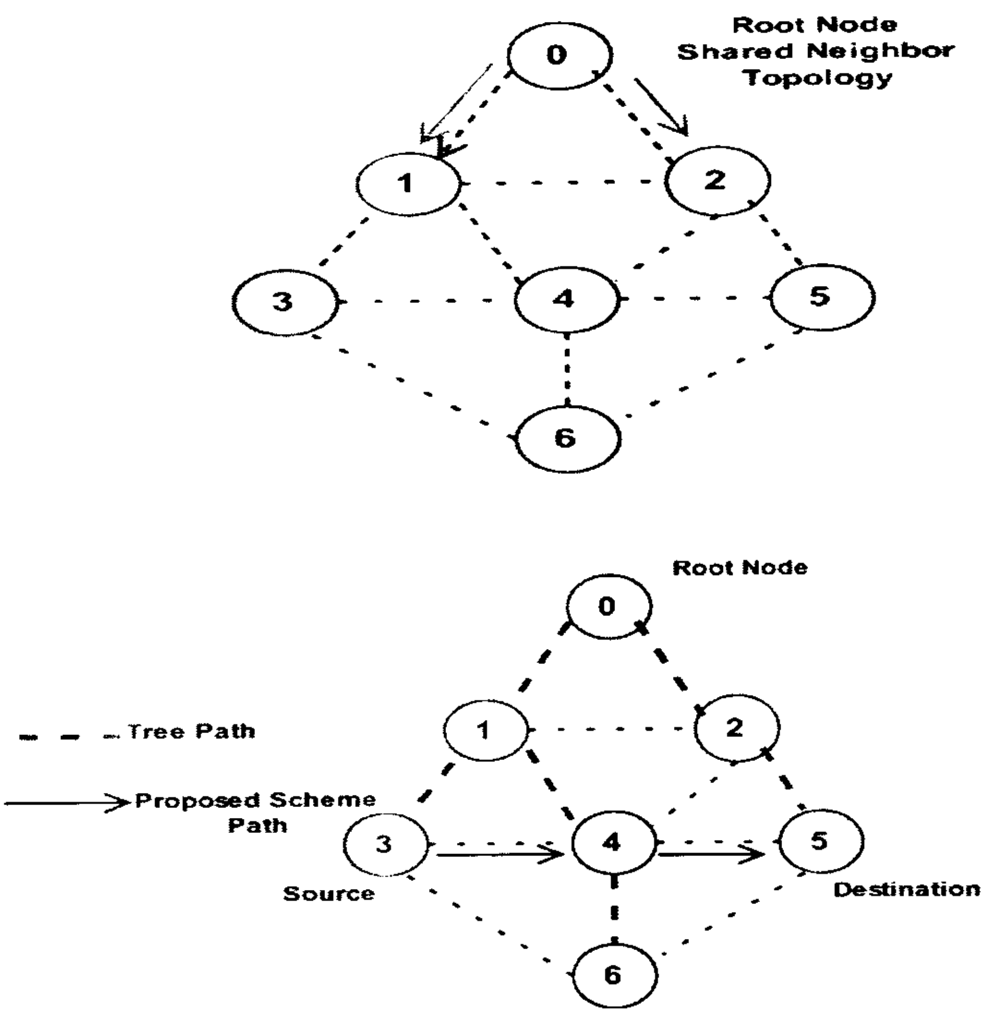

Figure 4.3 b: IMRWMN tree creation process

Upon receiving the RREP message, each intermediate node forwards it to its selected parent node and updates the node it was received from as the next hop child to reach the source node in its routing table. By this way, the root node can be aware of all the participating nodes and builds a tree topology and a neighbor topology of the whole network respectively. The root node then shared the whole network topology table information with all nodes in the mesh network. In this way each node maintains routing table of their own and neighbor topology of the whole network. Now the node 3 just performs computation to find the optimal path with the destination node 5 and send the data through the node 4.

Table 4.1 Neighbor Table

Node	One Hop Neighbor
0	1,2
1	0,2,3,4
2	0,1,4,5
3	1,4,6
4	1,2,3,5,6
5	2,4,6
6	3,4,5

Routing table

Destination	Next Hop	Hope count
1	1	1
2	2	1
3	1	2
4	1	2
5	2	2
6	1	3

Tree Route
3->1->0 0->2->5

Hop count=4

Figure 4.4: Routing table and Neighbor table

Neighbor table of source and destination

Node	One Hope Neighbor
3	1,4,6
5	2,4,6

Computed Route

computed	Hop count
3->4->5	2

Figure 4.5: Neighbor table of source and destination

4.6 Summary

In this chapter we presented our proposed scheme to find the optimal path between source and destination inside the mesh network. The IMRWMN provides the optimal path for any source and destination. Our proposed solution increases the network performance because all traffic not going through one root node.

Simulation 5

5.1 Introduction

Simulation is the process of designing an abstract model of a real system and doing experiments with this abstract model. Simulation is used to understand the behavior of the system and predict future behavior of the system. Simulation most widely used method for research operation. Simulation is performed when the testing of the real world is difficult, costly, dangerous, time consuming and impossible due to some reasons. We design the wireless mesh network using the network simulator (NS2).

This chapter provides information about our proposed simulation tool, model of simulation, simulation scenario, goals of simulation and finally simulation setup for different tests.

5.2 Simulation Tool

Network Simulator V2.33 (NS 2.33) is used for our simulation. Both wireless and wired the NS was most widely used simulation tool. Network Simulator (NS 2) is a discrete event object-oriented simulator. In 1989 the development of NS2 is started. Many version of NS 2 are available i.e. NS 2.27, NS 2.28, NS 2.29 and NS 2.33 etc.

Object oriented language C++ as back hand and OTCL (Object Tool Command Language*) as a* front end used in NS 2. The OTCL scripts are used for creating the Network topology then the NS 2 with different parameters performs simulation on that topology.

NS 2 can be run on the different operation system such as Linux Red Hat, Fedora, Sun Solaris and Microsoft operation system with the help of Cygwin Software.

C++ in NS 2 provides the facility of packet processing, algorithm implementation, effective use of packet headers, bytes and OTCL enables the developers to use different simulation configurations and parameters or exploring configuration setups for various scenarios.

5.3 Wireless mesh support in NS2

The HWMP is not fully support by the NS 2.33 all features of the HWMP is not provided by the NS 2. All other extensions to HWMP are mostly external contributions by different researches or communities. All these extensions those are available in open licenses only for research purpose. Most of the open source code or patches designed for specific NS 2 version then later updates due research for the current NS 2 versions. NS 2 provides two modes of the HWMP protocol ,first is On demand mode in which root node is not configure and second is proactive tree mode in which one node is configure as root node and all data pass through that node.

5.4 The AWK language

AWK means Aho, Kernighan and Weinberger, the authors of the AWK. AWK is programming language used access information from the Text and data files. In order to analyze the results AWK scripting language is used to extract and summarize the data from output trace file of NS-2. Complex text processing can be performed by the AWK in very limited time that is the main features of the AWK language. Through pattern matching the AWK scripts search the document and find the pattern match and perform action after find the pattern.

5.5 Simulation Goal

Our propose scheme Improving Routing by finding Optimal Path for Wireless Mesh Network(IMRWMN) used to find the optimal path between source and destination inside the mesh network.

One node 0 is selected as root node. The Node 0 has whole network topology information and this information among the others meshes nodes. When a node wants to communicates to another node then the source node apply a shortest algorithm and find an optimal path for the destination. Therefore this scheme gives the best optimal path for any source destination.

In the existing scheme no attention is given to the packet loss, packet delivery ration and end to end delay because all the data pass through the root node 0(non optimal path).

The scheme significantly reduces the packet loss at all time in the proactive mode of the HWMP domain: this increases the throughput and hence improves the performance.

In the existing schemes all the computation is perform at root node and the root node flooding to the all nodes in the mesh after some times which results overhead in the network, in our propose scheme all computation is done locally and not flooding the network.

We have evaluate the performance of our propose scheme by comparing the results of our scheme against the HWMP schemes, through NS-2.33 simulation using the following WMN scenario. We will analyze our proposed scheme under different simulation setup.

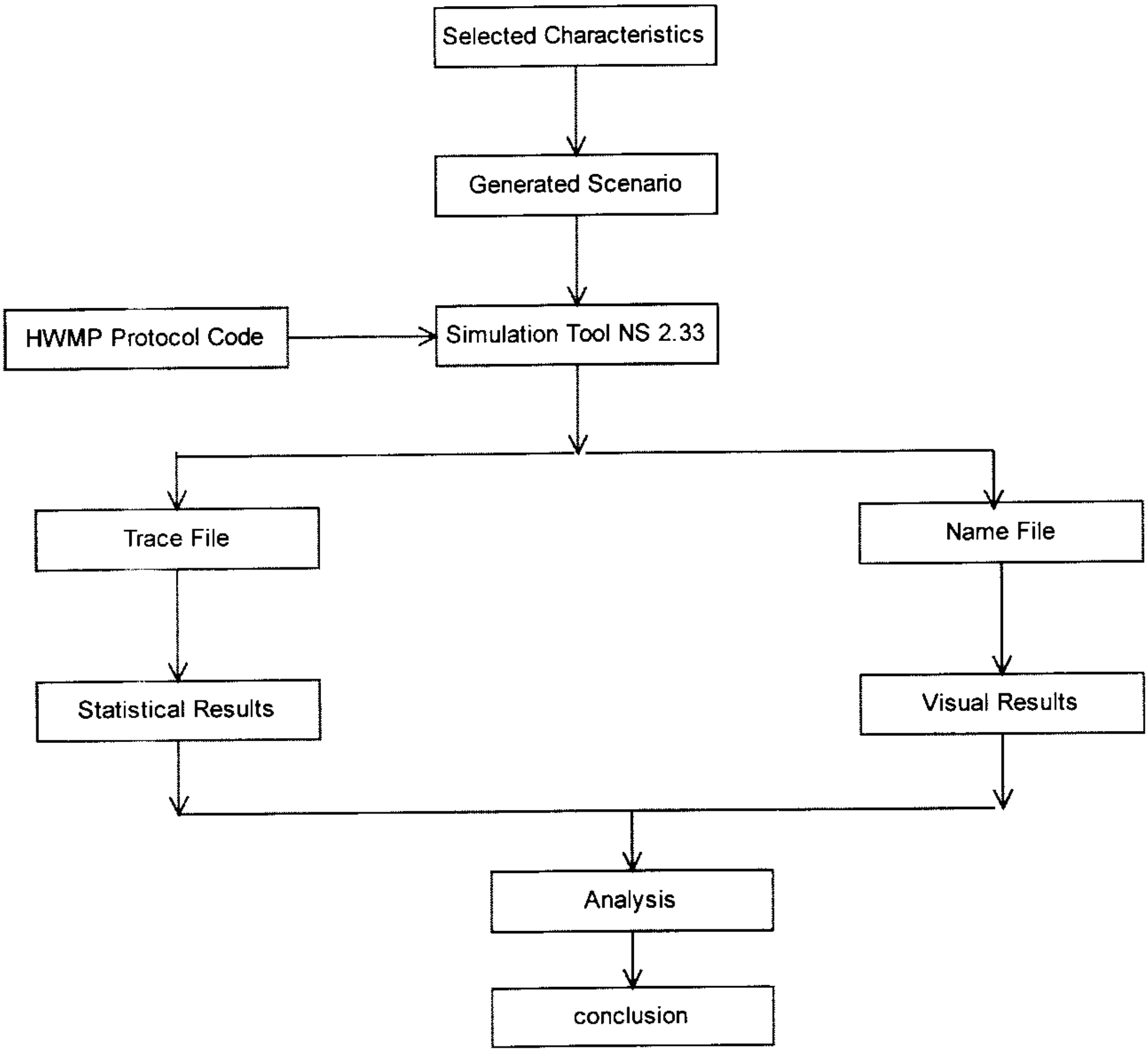

Figure 5.1: implementation of simulation

5.6 Model of Simulation

The HWMP software is used to study the simulation. This software patch is available for NS 2.33. This software was design for NS 2.29 then it is updated to NS 2.33 and this software provides the wireless mesh network framework.

In the HWMP the MMP and MP is the main components of WMN. The MMP is the central point of the mesh network and also acts a root MP that has complete routing information about the network and it is also called gateway node in which all data pass to the external network through root MP. MPs support mesh services, allowing them to forward packets on behalf of other nodes to extend the wireless transmission range.

Following are the major components of **HWMP** simulation model.

Mesh Point Portal (MPP)

The MPP in the WMN used the HWMP protocol for path selection where the node configure as MPP is configure as root to send proactive PREQ or RANN message.

Mesh Point

The MP supports the mesh services and forward data traffic of the other nodes that are in its transmission range. The MP received the PREQ message from the MPP and sends PREP message to the MPP to builds the Tree.

Mesh: A network consisting of two or more mesh stations (STAs) communicating via mesh services.

Mesh link: A link from one mesh station (STA) to a neighbor mesh STA that has been established with the peering management protocol.

Mesh neighborhood: The set of all neighbor mesh STAs relative to a particular mesh STA

Mesh path: A concatenated set of mesh links from a source mesh STA to a destination mesh STA.

Source mesh STA: A mesh STA where a frame enters the MBSS. A source mesh STA may be a mesh STA that is the original source of a frame or a proxy mesh STA that receives a frame from an entity outside of the MBSS and translates and forwards the frame on a mesh path.

Path originator: A node that want to start communication and start the path discovery process.

Path originator address: The address of the source node that path discovery process.

Path target: The destination node to whom the Path originator wants to establish the path.

Path target address: The MAC address of the path target.

Intermediate mesh STA: The intermediate mesh STA is not the source neither the destination STA it is only take part in the selection of path between source and destination.

Intermediate mesh STA address: The MAC address of the intermediate mesh STA.

Forward path: The path that is established by the source and intermediate node to the target node.

Reverse Path: The path that is established by the target and intermediate node towards path originator.

Next hop mesh STA: The next hop mesh STA is a neighbor peer mesh STA on the path to the destination mesh STA.

Next hop mesh STA address: The MAC address of the next hop mesh STA.

Precursor mesh STA: A precursor mesh STA is a mesh STA that identifies a given mesh

STA as the next hop mesh STA to the target mesh STA.

Precursors mesh STA address: The MAC address of the precursor mesh STA.

Unreachable destination: A destination mesh STA is considered unreachable if the mesh STA does not have valid forwarding information for that mesh STA.

HWMP Sequence Number (SN): Each mesh HWMP path selection message contains an HWMP sequence number that allows recipients to differentiate newer from old information. **Target sequence number:** This sequence number used for Target STA.

5.7 Simulation Scenario

The following figure given below shows our simulation scenario. It shows a real world picture of the HWMP network. There may be different scenario of this network, but all will work in the same behavior as the following topology shows.

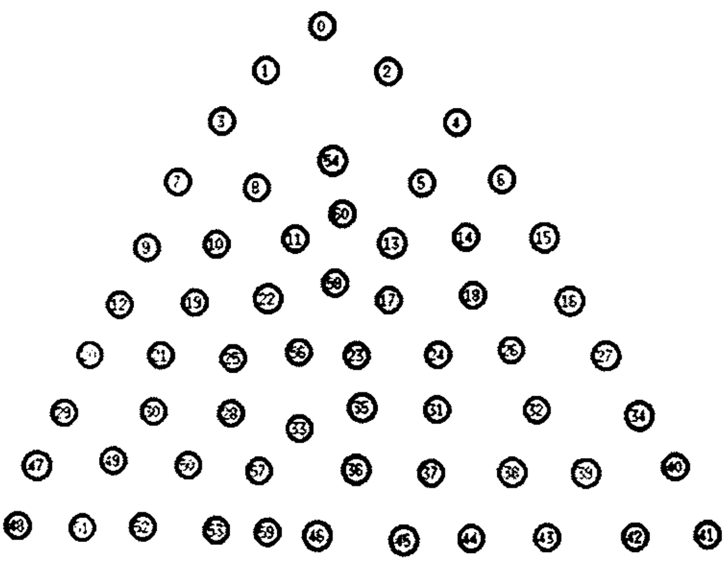

Figure 5.2 WMN Scenario

In the above scenario the node 0 is the root node (MPP) and the remaining nodes are mesh points (MP). The root node (MMP) first sends PREQ message to the entire network for the presence of the MPP then the MP send PREP message with the neighbor information to the MPP to build the whole network topology. The MPP then shared this information among the MP.

5.8 Research Methodology

This section describes the detailed setup of our simulation. The simulation time is 100 seconds for comparison purpose. We divide the simulation into three simulations. In the first experiment the number of nodes are fixed that is 60 nodes but the number of flows are different from 6 flows to 24 flows in steps of 6 flows. In the second experiment the numbers of flows are 15 the packet size is varied from 64, 128.256 and 512 bytes. In the third experiment we performed analysis when there is mobility in the network.

In each of this experiment we measured average end- to- end delay, packet loss, packet delivery ratio and throughput. The main tools used for simulation are the network simulator 2(NS-2), AWK scripts. Fedora 10, Intel processor 2 GHz and 1000Mb of RAM.

The following table shows the parameters used in this simulation.

Table 5.1 Parameters of simulation

Variables	Values
Simulation Tool	NS 2.33
Propagation Model	Two Ray Ground
Antenna Type	Omni Directional
MAC Type	802.11 MAC
Interface Queue	Wireless Phy
Interface queue Length	50
Topology Size	500 * 500
Transport Protocol	UDP
Packet Size	64,128,256,512
Traffic Type	CBR
Queue Type	Drop Tail
Routing Protocol	HWMP
Number of MPP	1
Number of MP	60
Simulation Time	100 sec
Packet Interval	0.02 sec

5.8.1 Experiment for increasing number of traffic flows

In this experiment we study the effect of increasing number of traffic flows on, packet loss, packet delivery ratio, average end to end delay and throughput ratio. Table shows the detail where we shall keep the other entire parameters constant and increasing only the number of traffic flows.

Table 5.2 Parameters for increasing number of traffic flows

Variable	Values
Experiment	Increasing number of traffic flows
Number of traffic flows	6,12,18,24
Number of nodes	60
Number of root	1
Number of tests	4

5.8.2 Experiment for increasing packet size

In this experiment we study the effect of increasing packet size on, packet loss, packet delivery ratio, average end to end delay and throughput ratio. Table shows the detail where we shall keep the other entire parameters constant and increasing only the packet size.

Table 5.3 Parameters for increasing packet size

Variable	Values
Experiment	Increasing packet size
Number of Mesh Nodes	60
Packet size	64,128,256,512
Number of root	1
Number of tests	4

5.8.3 Experiment for the Mobility

This experiment was performed analysis when there is mobility in the network for our proposed scheme. When mobility is taken then the root node is static, the entire nodes is moving and the moving speed is equal to human walking speed(1 m/s).

Table 5.4 Parameters for Mobility

Variable	Values
Experiment	Mobility in the network
Number of Mesh Nodes	60
No of traffic flows	6,12,18,24
Number of root	1
Number of tests	4

5.9 Summary

We have discussed detail of our simulation, goals, scenario, experimentation and model of the simulation. The necessary elements and their properties are discussed. Furthermore, we have given a detail study about the test bed for the evaluation of performance optimization of our proposed scheme.

Experimental Results and Discussions 6

6.1 Introduction

The outputs that are obtain form our simulation is analysis in this section. The performance of the existing HWMP and proposed IMRWMN scheme is compared. The results are in graphical form with proper explanation. We have performed three experiments and in each experiment the results for average end to end delay, packet loss, packet delivery ratio and throughput have been calculated. The next section describes the details of all experiments.

6.2 Elements of performance

Four major elements are selected for analysis in the simulation. These elements are average end to end delay, packet loss ratio, throughput, packet delivery ratio. The results are calculated using the following equations.

Packet Loss Ratio

The packet loss ratio is the average number of packets lost divided by the number of sent packets. It is calculated as

Packet loss Ratio $=\sum Tpl/\sum Tpt*100$ (6.1)

Where

Tpl = is the total number of lost packets

Tpt = is the total number of transmitted packets

Average end-to-end delay

It is the average time to send a packet form source to destination and includes all possible delays before data is received by the destination.

It is calculated as

Average end-to-end delay $= \sum Trv\text{-}Tsd/Tp$ (6.2)

Where

Trv= is the time stamp of receiver node

Tsd = is the time stamp of sender node

And Top is total number of received packets

Packet Delivery Ratio

It is the percentage ratio of received bytes to the sent bytes. It can be calculated as

Packet Delivery Ratio = Btr/Bts *100 (6.3)

Where

Btr = total received bytes

Bts = total sent bytes

Throughput

Throughput is defined as the average total number of bytes received by the destination during the total simulation time. It is calculated as

Throughput (Kb) = (Btr/Spt-Srt) *(8/1000) (6.4)

Where

Btr= received Size

Spt= stopTime

Srt= startTime

6.3 Results

The simulation results obtained for the HWMP and proposed scheme (IMRWMN) are given below.

6.3.1 Calculating results for testing increasing packet size, for increasing number of traffic flows and for Mobility.

6.3.2 Comparison of packet delivery ratio

Figure 6.1, Figure 6.2 and Figure 6.3 shows comparison of packet delivery ratio in HWMP and in proposed scheme. The packet delivery ratio is change when number of flows and packet size are increasing that as shown in the figures.

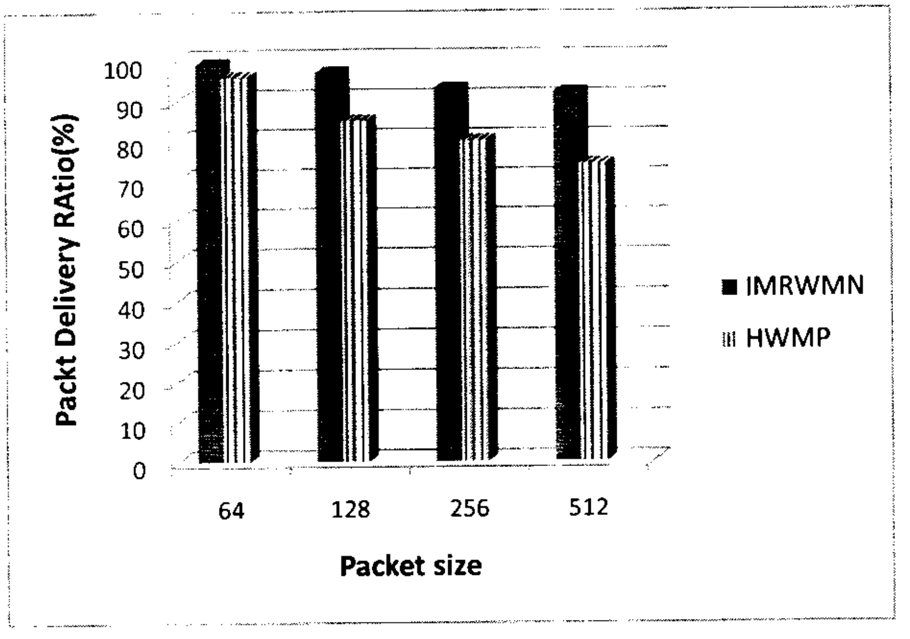

Figure 6.1 Packet delivery ratio

The figure shows that the packet delivery ratio is improved by the Improving Routing by finding Optimal Path for Wireless Mesh Network (IMRWMN). To analyze the packet delivery ratio with increase in size of packets, scenario with 60 nodes firstly runs with 64 byte packet size and finally runs with 512 bytes of packet size. The packet delivery ratio is about 90 % in the propose scheme (IMRWMN) when the packet size is 512 bytes but in the existing scheme (HWMP) the packet delivery ratio is about 70 % because all computation is performed by the root node.

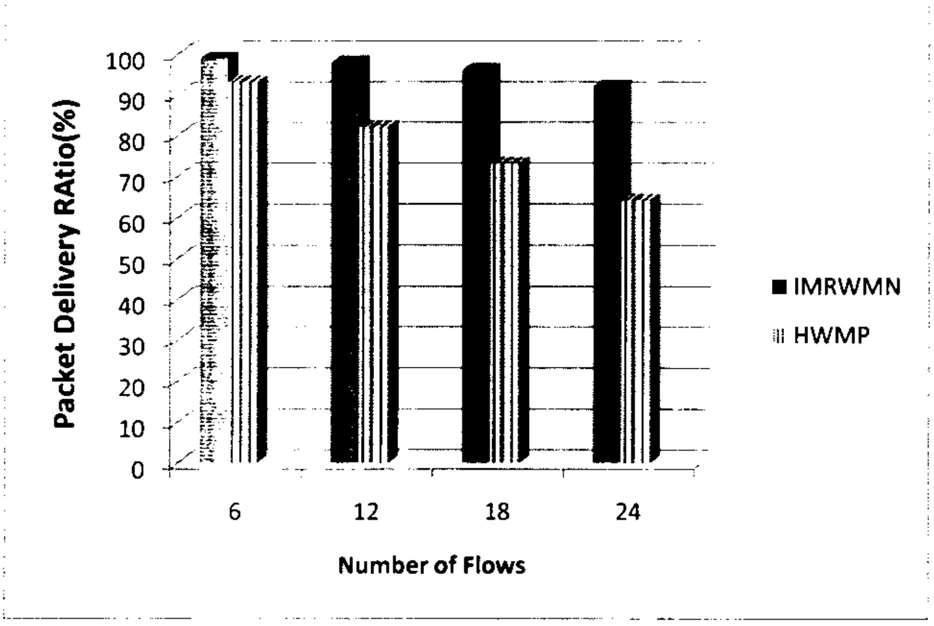

Figure 6.2 Packet delivery ratio

The figure shows that the packet delivery ratio is improved by proposed scheme. This because that all the traffic is not going through the root node in the proposed scheme. In the HWMP a lot of packet drops due to the collision in the root node also buffer overflow occurred. As the number of flows increases Packet delivery ratio decrease and finally for 24 flows HWMP path have low packet delivery ratio. The packet delivery ratio is greater than 90 % when the number of flows is 24 in the proposed scheme but in the HWMP Packet delivery ratio about 62 % because all the traffic goes through non optimal path (root node) and lot of packets dropped due to collision at root node.

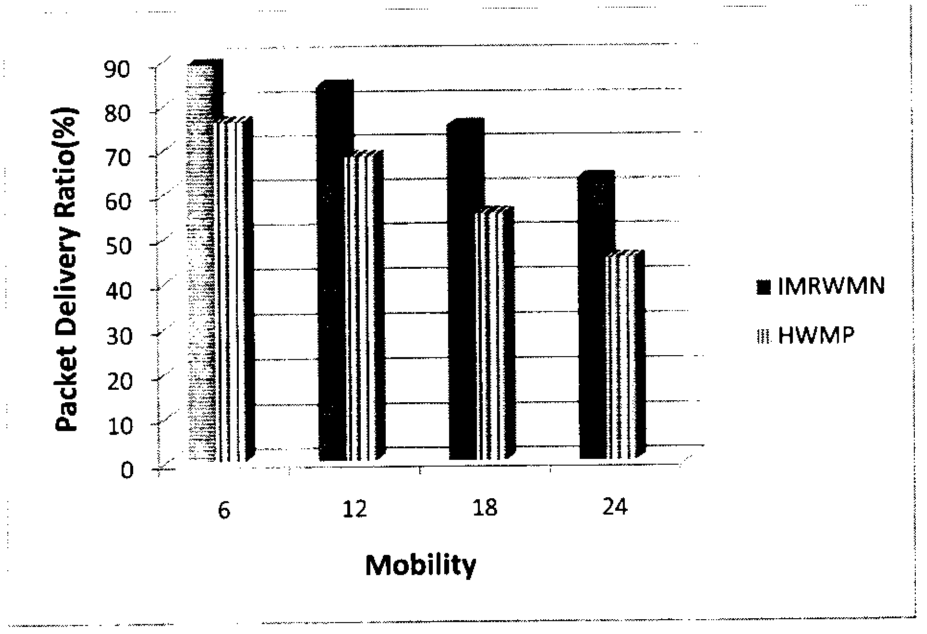

Figure 6.3 Packet delivery ratio

In the mobility network the packet delivery ratio of propose scheme is above 60 % when the number of flows is 24 due to the broken links occurs in the network. In the mobility environment the packet delivery ratio of the HWMP is lesser than the propose scheme because the HWMP maintains the proactive path and for maintain the proactive path the HWMP root node sends PREQ messages to all nodes.

6.3.3 Comparison of average end-to-end delay

Figure 6.4, Figure 6.5 and Figure 6.6 shows the comparison of the average end-to-end delay in the HWMP and IMRWMN scheme. In static network the average end to end delay of the propose scheme is smaller than HWMP average end to end delay in both cases means when the number of flows and packet size increase. This is due to routing traffic to destination with best optimal path, there is no contention of root node and not requires the number of transmission (which leads to low end to end delay).

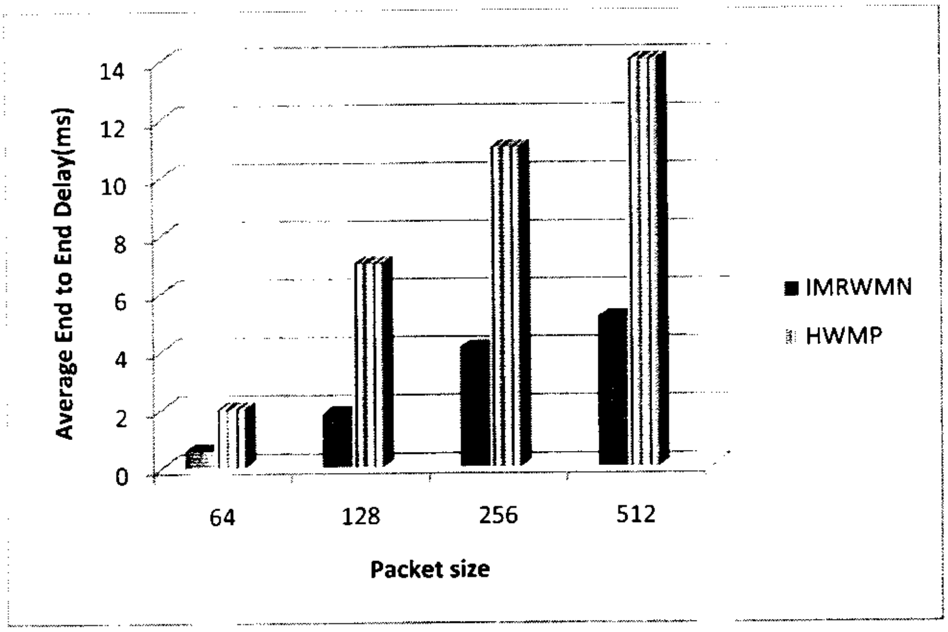

Figure 6.4 Average end to end delay

As the packet size increases delay increases and finally for 512 bytes packet size HWMP path has greater delay. The reason is that the root node has completed path information to all nodes in the network so if number of request is made to increases at root node, the delay is also increases. The end to end delay is about 6ms when the packet size is 512 bytes in the proposed scheme but in the HWMP the delay is about 14ms because all the traffic goes through non optimal path (long path) that results longer delay to reach the destination.

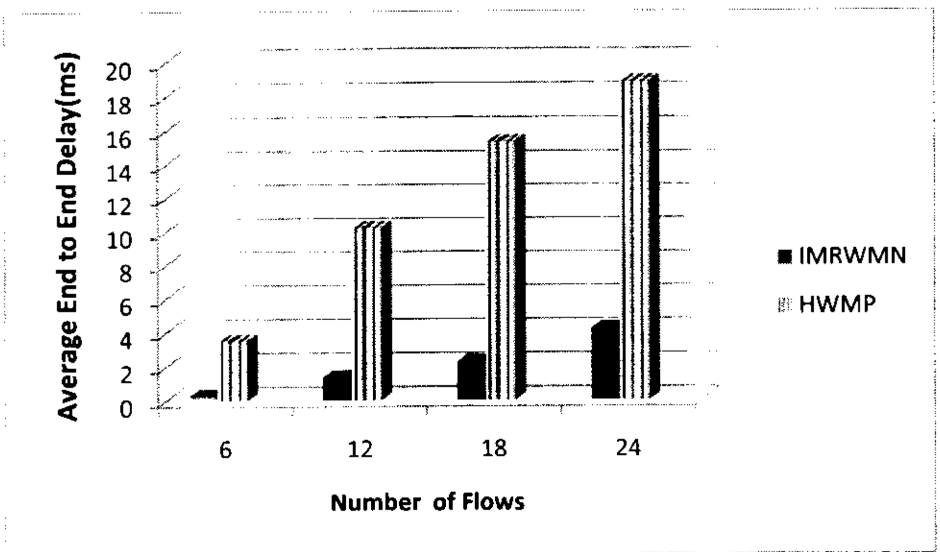

Figure 6.5 Average end to end delay

The figure shows that the delay of proposed scheme is smaller than the HWMP because our proposed scheme is not depended on the root node and all the traffic flow is not going through the root node that overload the root node. As the number of flows increases, delay increases and finally for 24 flows HWMP path has greater delay. The end to end delay is about 4ms when the numbers of flows are 24 in the proposed scheme but in the HWMP the delay is about 18ms because all the data flow traffic goes through non optimal path (long path) that results longer delay to reach the destination.

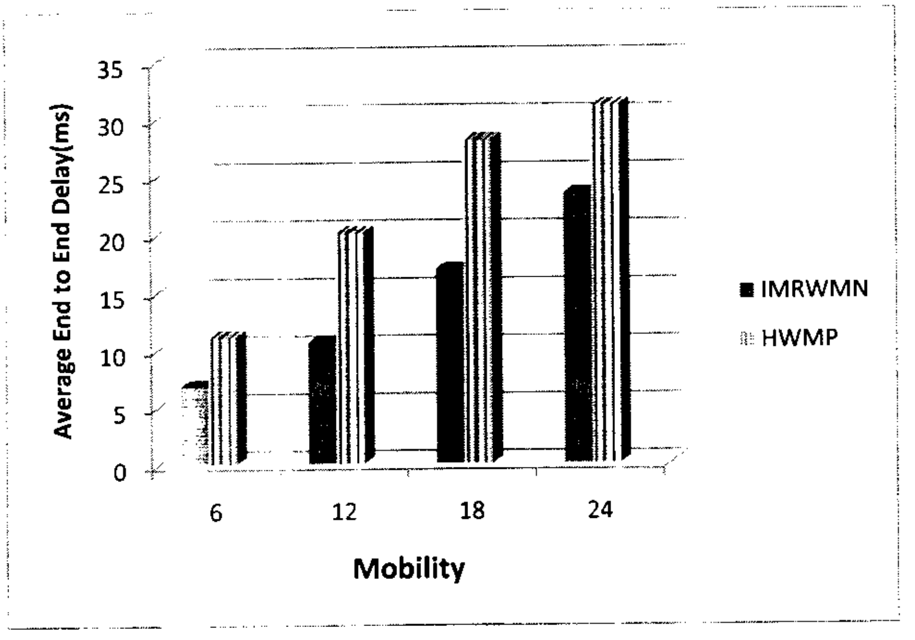

Figure 6.6 Average end to end delay

The delay of HWMP in mobility is greater than the proposed scheme because the HWMP maintains the proactive path and for maintain the proactive path the HWMP root node sends route request messages to all nodes.

When there is mobility in the network the delay is 23ms of the proposed scheme and HWMP has 31 delays due to the broken links occurs in the network.

6.3.4 Comparison of Packet loss Ratio

Figure 6.7, Figure 6.8 and Figure 6.9 show the comparison of the Packet loss ratio for increasing packet size, number of flows in the HWMP and IMRWMN proposed scheme. It is obvious that the packet loss in the existing HWMP scheme is higher and IMRWMN has reduced this loss to greater extent.

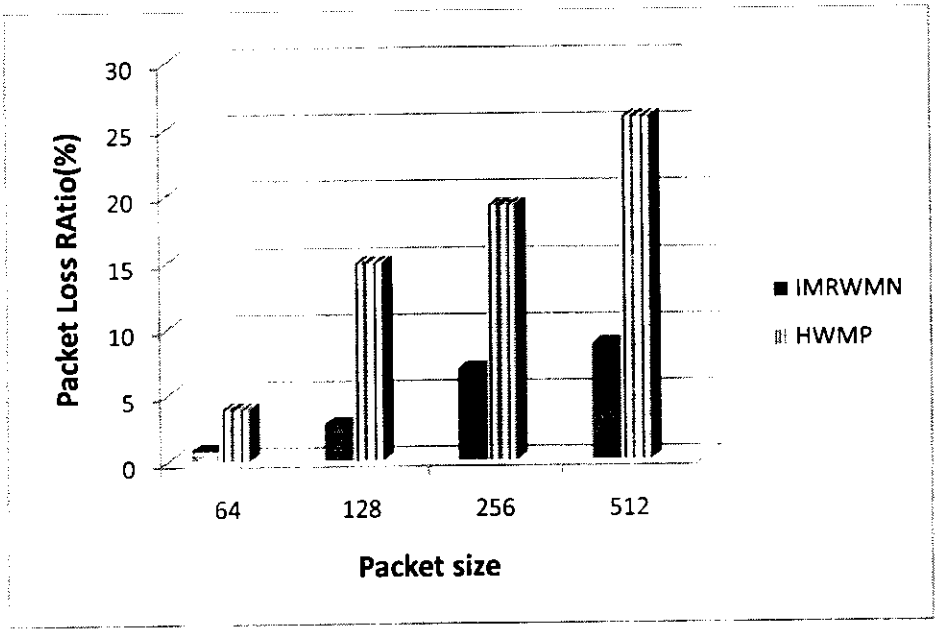

Figure 6.7 Packet loss ratio

Packet loss is certainly greater in proactive routing because all the requests are generated for root node. The root node is get more congested. But in the proposed scheme the all request is not made to the root node so the packet loss ratio is improved. As the packet size increases packet loss increases and finally for packet size (512 bytes) HWMP path has greater packet loss. The HWMP packet loss ratio for packet size (512 bytes) is 25 % and the proposed scheme packet loss ratio for packet size (512 Bytes) is 8 %.

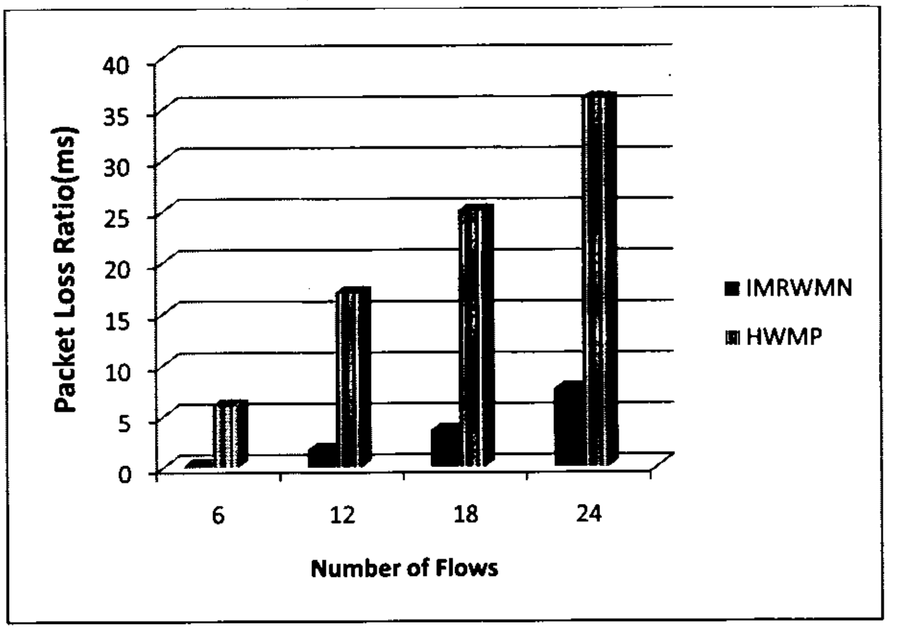

Figure 6.8 Packet loss ratio

As the number of flows increases packet loss increases and finally for 24 flows HWMP path has greater packet loss, because in the proposed scheme all the data traffic flows uses different paths to reached the destination but in the HWMP only one root node is responsible for the delivery of all data traffic. The HWMP packet loss ratio for 24 flows is 34 % and the proposed scheme packet loss ratio for 24 flows is 8 %.

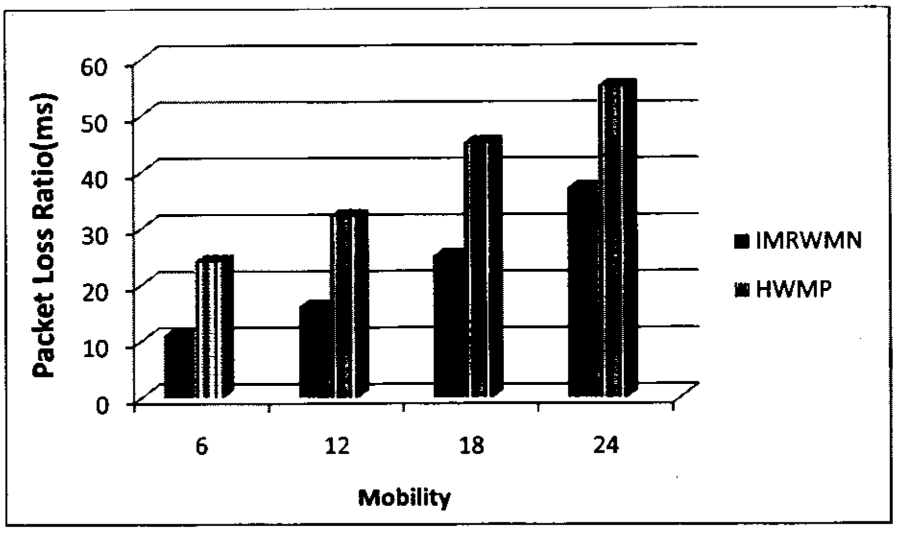

Figure 6.9 Packet loss ratio

When the nodes are moving the packet loss ratio of proposed scheme and HWMP protocol is increase due to link breakage. HWMP maintains the proactive path and for maintain the proactive path the HWMP root node sends PREQ messages to all nodes. Due to link breakage the root node also send PERR messages to all nodes in the network so the root node is highly overloaded. The packet loss ratio 55 % for HWMP and the packet loss ratio is 37 % for proposed scheme.

6.3.5 Comparison of Throughput

Figure 6.10, Figure 6.11 and Figure 6.12 shows the data throughput for HWMP and Propose scheme. HWMP shows lower data throughput as compared to proposed scheme. Root node is suffered from large number of route request so the HWMP has lower throughput. It is due to fact that fewer packets are lost in the proposed scheme as compared to the HWMP scheme therefore the performance of IMRWMN is better as compared to the HWMP schemes.

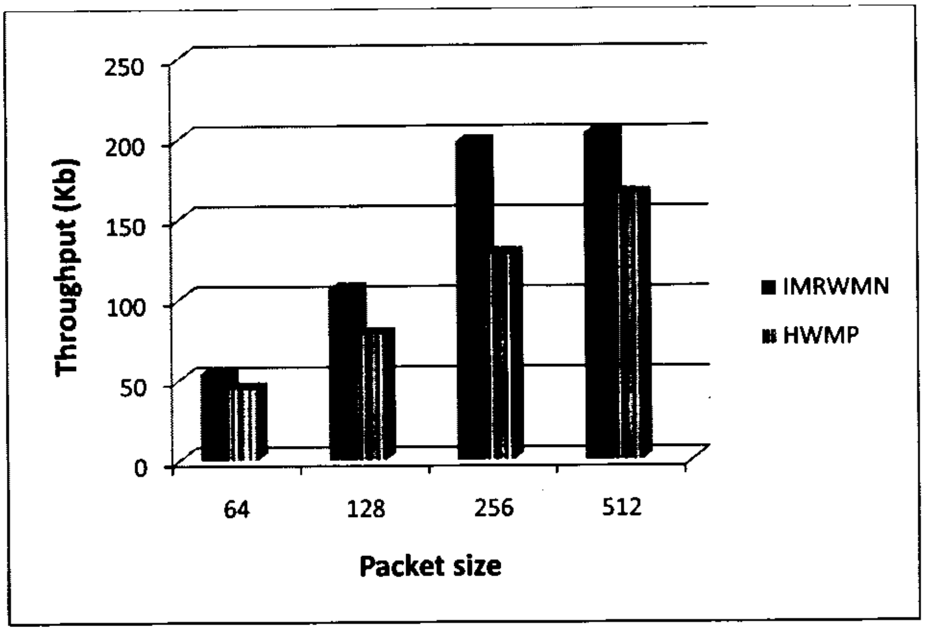

Figure 6.10 Throughput

Throughput of Proposed scheme for packet size (512) = 203(Kb)

Throughput of HWMP scheme for packet size (512) = 165(Kb)

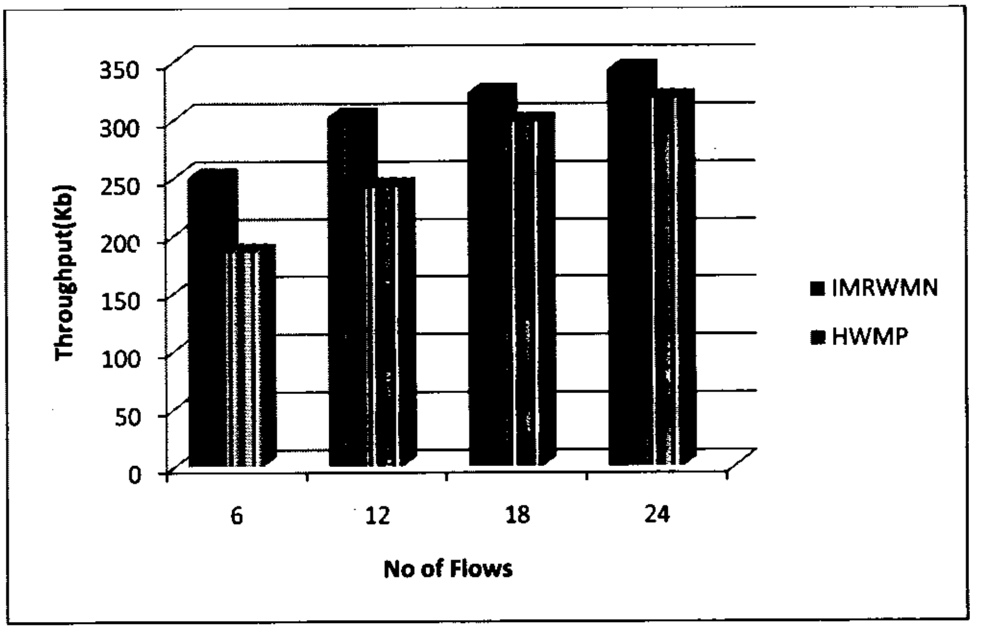

Figure 6.11 Throughput

Throughput of Proposed scheme for 24 flows = 344(Kb)

Throughput of HWMP scheme for 24 flows = 318(Kb)

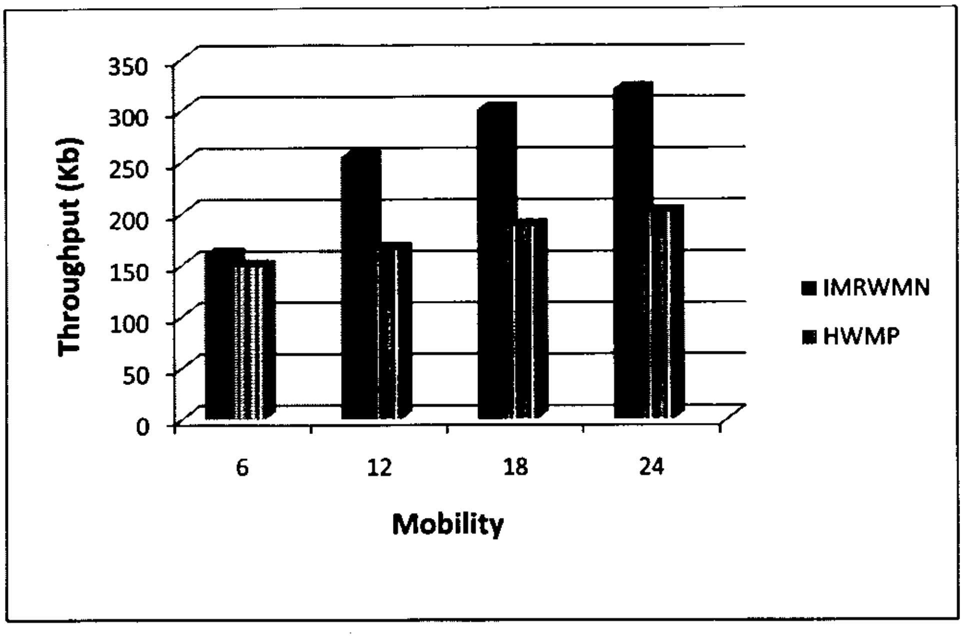

Figure 6.12 Throughput

Throughput of Proposed scheme for 24 flows(Mobility) = 320(Kb)

Throughput of HWMP scheme for 24 flows (Mobility) = 200(Kb)

6.4 summary

The results of our simulation are shown in detail in this chapter. The packet delivery ratio, average end to end delay, packet loss ratio and throughput are the parameters for testing the performance of both schemes. We have compared both schemes on the basis of these parameters.

Conclusion and Future work 7

7.1 Conclusion

We have proposed improved routing in wireless mesh network (IMRWMN) to solve the problem of the non optimal path through the root node when the traffic inside the mesh network is large such as high end to end delay occurs; routing overhead is large and so on. Every source node itself can calculate the optimal path to any target node without depend on the root node. The target node does not need transmit RREQ messages and the source does not reply RREP to construct bi-directional path. Our proposed solution does not depend only on root node as in proactive HWMP where traffic to all destinations goes through root node and neither it use RREQ messages which may cause congestion in network. Every source node can calculate a shortest path to destination without flooding the network. In the propose solution there is small overhead initial when the network topology is shared but after that all the computation is done locally. The IMRWMN provide the optimal path between any source and destination inside the mesh network. The HWMP has two routing modes. The on demand mode provide the optimal path but there is initial delay occurs. The proactive mode shows the less initial delay but the path is non optimal so the data throughput is decreases, packet loss and end to end delay is come. To evaluate the performance of the IMRWMN we use the NS2 and analyze the results. The simulation results show that our results are so encouraging. The simulation results shows that the our proposed protocol (IMRWMN) is higher to HWMP protocol and have low end to end delay ,high packet delivery ratio and high throughput ratio in wireless mesh network.

7.2 Future work

In the future will we wish to focus on the multiple gateways/ root nodes for wireless mesh network and we wish to remove the remaining end to end delay and packet loss in the scheme. We want to work for inter mesh network. Furthermore how many root nodes are needed and to where these nodes are place should be examined in future work. There still remain many research problems. Among them, the most important and urgent ones are the scalability and the security. Furthermore, current WMNs still have very limited capabilities of integrating heterogeneous wireless networks, due to the difficulty in building multiple wireless interfaces and the corresponding gateway/bridge functions in the same mesh router.

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