A FRAMEWORK FOR EFFICIENT ROUTING PROTOCOL METRICS FOR WIRELESS MESH NETWORK

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ABSTRACT

In this paper, our focus is on the study of appropriate routing metrics for routing in wireless mesh networks which provides global network access at low cost to the mobile users. We have defined a model for wireless mesh network to access global network and suggested some of the routing metrics for the best routing. Generally, we use global network to access information which are dispersed around the world. One way to reduce the global network access cost to mobile users is by implementing Wireless Mesh Network (WMN).

Key Words: Unicast, Multicast, WMN, Routing Protocol, Routing Metrics

I. INTRODUCTION

WMN is nothing but wireless network which has implemented the partial or fully connected mesh topology. In fully connected topology, each node is connected to rest of all nodes in a network while in partial connection, each node is connected to only few nodes. In WMN, most of the nodes are static and are connected by shared wireless medium. The main features of WMN are auto configurable and self healing network. To establish communication from one node to another node, it uses routing protocol. Routing protocol is designed based on the characteristics of the networks on which it will be used. Routing protocol assists the node in network to route or send data packets from source node to its destination. The characteristics of network are described by metrics; such metrics are used to improve the performance of the routing protocol. So the efficiency of the routing protocol is based on the routing metrics which are designed for that network. So far, very few works has been done to design routing metrics and also, they had consider only static nodes which form the WMN [6, 7].

In this paper, we have considered the WMN that contains both mobile and static nodes which describes exactly the actual environment. First, we have defined the network model for the WMN. Then, we have carefully studied the routing metrics that was already available and we have
suggested some of the routing metrics that is suitable to design protocol which will be used in the WMN. The rest of this paper is organized as Section-2 that deals with WMN network model which is connected to global network. Section-3 describes various routing metrics for WMN. Section-4 suggests some of the routing metrics for our WMN connected to global network. Section-5 contains conclusions and further extension of our work.

II. MODEL FOR WMN CONNECTED TO GLOBAL NETWORK

![Fig 1: WMN Connected to Global Network](image)

Wireless Mesh Network consists of static mesh routers and mobile mesh clients, where routers are stationary i.e. they do not have mobility. These static routers form the wireless backbone for our mesh network. It provides the global network access to mobile client. Though mobile client’s move around any mesh routers; they can connect to the network. Static mesh routers have been provided with single radio interface for wireless communication. These routers simply forward or relay the data which they have received. The integration of wireless mesh clients with global network can be accomplished via gateway router. The gateway router has some additional features such as hardware and software to access global network. But other mesh router and mesh clients don’t have such facilities. They can access global network through the gateway router only. Mesh clients can either be stationary or mobile and they form client mesh among themselves and also with mesh routers [5, 6].

We have fixed our WMN network topology that fig-1, has shown the network model and the related notations are described as follows: The WMN consists of static wireless router $R_m$, where $m=1,2,3,\ldots,n$, gateway router $G_n$, where $n=1,2,3,\ldots,n$, and mobile clients $K_s$, $s=1,2,3,\ldots,n$. The medium $M$ is a shared wireless for communication which is provided by radio interface $RI_i$ at the routed site and $MRI_i$ at the client site, where $i=1,2,3,\ldots,n$. The mobile node which is specified as $S_i$ generates message and $D_i$ acts as destination for that message respectively, where $i=1,2,\ldots,n$. At any instance of time the total number of $S_i$ should be less than $n$. The number of channels available are $l_i$, where $i=1,2,3,\ldots,n$. Assume the fraction of channel occupancy time allocated to $S_i$ as $t_i$, where $0 \leq t_i \leq n$. In time base fairness scheduling each station is assigned the same fraction of channel time. Thus,

$$T_i = \Delta t = 1 / n (1 \leq i \leq n)$$
Let $MCP_t$ be the power consumption (energy per second) of a mobile client in the transmission mode while $MCP_r$ is the power consumption of a mobile client in the listening or data receiving mode. Assume that,

$$MCP_t = \alpha MCP_r \ (\alpha > 1)$$

And also, we have taken an assumption that:

$$RP_t > MCP_t$$
$$RP_r > MCP_r$$

### III. STUDY OF ROUTING METRICS

Routing metrics [6, 7, 8] is a measure to select best route among more than one possible route from source to destination.

![Fig 2: Routing](image)

The possible routes from source S1 to destination D2 are
- Route 1: S1- R1- R2- D1
- Route 2: S1- R1- R3- D1

The selection of route is based on routing metrics like link capacity, security, delay, energy consumed etc. Routing metrics are classified as unicast and multicast based on the nature of routing intended for forwarding data packets to destination.

#### 3.1 Characteristics of Routing Metrics

Routing metrics selection and design is based on the network in which it is to be used with routing protocol. So, the characteristics of the network are considered at the time of designing the metrics. This characteristic is specified as the requirement for the routing metrics [6]. Here; we have given some characteristics of routing metrics.
1. Routing metrics must cope with the characteristic of WMN.
2. Routing metrics must select minimum weight path for best performance.
3. Routing metrics must ensure the stability of the network.
4. Routing metrics must ensure the minimum energy consumption.
5. Routing metrics must ensure security of routing data.

3.2 Unicast Routing Metrics

Unicast is the process of forwarding data packet from a source to a destination on a network. Unicast data is destined for a unique address; in this case there is just one sender, and one receiver [5].

Fig 3: Unicast Routing

In the above Fig-3, S1 is the sender and D1 act as receiver, there is only one sender and one receiver participating in this communication. So, this kind of data forwarding is called as unicast [11, 12]. There are so many routing metrics for unicast communication in WMN [3] [5] [6]. We have given those metrics in detail that are relevant to routing in WMN.

1) Hop Count (H)

The hop count metrics is denoted as a H. It measures the number of hops required to send data from source to destination. In this Fig-4, it can be seen that the data packet has to travel via the link \( l_1 \) and \( l_2 \) to reach the destination from the source.

Fig 4: Multi-hop Communication

The data packet has done two hops to reach its destination D1. It is very easy to implement in routing protocol. Each hop is specified as \( H_i \), where \( i=1, 2, 3...n \), preferable path is one which has \( \min \sum_{i=1}^{n} H_i \) value.

2) Expected Number of Transmission (ENT)

Due to wireless nature of medium it is possible for data packet loss during transmission. To provide reliability the data packet has to be sent once again when it is detected as lost. Here we can not say how many times the data might get lost. This ENT metrics measures the expected number of link layer transmission needed for transmitting a packet via wireless link successfully. Each link will be assigned by the value of \( \text{ENT}_j \), where \( j=1,2,3,...n \). The weight of a path is calculated as \( \sum_{j=0}^{n} \text{ENT}_j \) from source to destination. The best path is one should have \( \min \sum_{j=0}^{n} \text{ENT}_j \) value.
3) Expected Transmission Duration (ETD)

The ETD of a link x is defined as the expected MAC layer duration for successful transmission of a data packet at a link x, where x can take one of the value from the set 1, 2, 3, ..., n. The weight of a link is calculated as 

\[ \text{Weight}(x) = \frac{1}{n} \sum_{x \in S} ETD_x. \]

The good path must have the minimum ETD value.

4) Per-Hop Round Trip Time (PRTT)

PRTT is based on measuring the round trip delay caught by unicast probes signal between neighbor nodes.

\[ \text{PRTT} = n_{i_{\text{RT}}} - n_{i_{\text{ts}}}, \]

Where \( n_i \) is a neighboring node, \( i = 1, 2, 3, ..., n \). The best path which should have minimum PRTT values i.e. the route from A to B in Fig-5.

5) Per-Hop Packet Pair Delay (PPPD)

This metrics is based on measuring the delay between a pair of back to back probe signal to neighboring nodes. To calculate this metrics, a node sends two probe packet PPPDs, PPPDI, that is small and large probe, back to back each neighbor for every 2 secs (constant interval of time).

\[ \Delta_{N_i} = N_i RT_{PPPDDS} - N_i RT_{PPPDI} \]

Where \( \Delta_{N_i} \) is the delay, and \( N_i RT_{PPPDDS} \) is the receiving time of small probe by neighbor node \( N_i \), where \( i = 1, 2, ..., n \), and \( N_i RT_{PPPDI} \) is the receiving time of large probe by neighbor node \( N_i \), where \( i = 1, 2, ..., n \). Then, this \( \Delta_{N_i} \) will be returned back to the sender by its neighbor. Then, the sender calculate sdelay for the probe returned back from neighbor.

\[ \Delta_{S_i} = N_i RT_{PPPDDS} - N_i RT_{PPPDI} \]

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Finally, sender calculates average as

\[ \Delta_{avg} = \frac{\Delta_{S} + \Delta_{N}}{2} \]

The best path should have least \( \Delta_{avg} \) value.

3.3 Multicast Routing Metrics

The authors have suggested metrics for multicast routing \([13, 14, \text{and} 15]\) in WMN. Multicast is the process of forwarding data packet from a one source to many destinations on a network. Multicast data is destined for more than one address; in this case there is just one sender, and many receivers.

![Fig 7: Multicast Routing](image)

In the above Fig-7, S1 is the sender and D1,D2 act as receivers, there is only one sender and two receivers participating in this communication. So, this kind of data forwarding is called as multicast \([2]\).

1) Expected Number of Transmission (ENT)

The predicted number of data transmissions needed to send a packet including retransmission, in the case of unicast is \( ENT = 1/(d_f \times d_r) \), where \( d_f \) is forward delivery ratio and \( d_r \) is reverse delivery ratio (acknowledgement from receiver).

Modification: Here, reverse path link quality was not considered, so \( ENT = 1/d_f \)

2) Expected Transmission Duration (ETD)

The ETD can be calculated by

\[ ETD = ETX \times \frac{S}{B} \]

Where, \( S \): size of the packet
\( B \): bandwidth of the link

Modification: To calculate ETD, the small packet is used.

3.4 Routing Metrics Based on Security

In case of secure data transfer, we have to encrypt data before sending it over the communication link. The next node on the route decrypts the data in order to access the header and decide which route to follow, and then encrypts it again before sending it out and so on. At each stage the node uses its own key for encryption and decryption. We assume that node uses MD5 algorithm for security purpose. When MD5 is used to exchange keys by that link between those nodes, it is considered to be secure \([7]\).
This metric will follow a binary composite rule i.e. metric value is true (or 1), if the route is using MD5 and false (or 0) otherwise. Then the path value is equal to

\[ SP = sw_1 \cup sw_2 \cup sw_3 \cup .......... \cup sw_n \]

\( sw_i = 1 \) if MD5 authentication is used, otherwise 0. Where, \( SP \) refers to the absolute path between source and destination.

### 3.5 Routing Metrics Based on Energy

In [1], the author has proposed routing metrics to measure energy for hop by hop retransmission as

\[ HHR = \sum_{i=1}^{n} \frac{E_i}{(1 - p_{err})} \]

Where \( i \) denote the \( i^{th} \) link, \( E_i \) is the energy required to transmit over that link and \( p_{err} \) is the error rate of that link. The best path is one which has minimum HHR value from source to destination.

### IV. METRICS FOR OUR NETWORK MODEL

In wireless network, we have to give importance to the link quality. So, we have selected the link based metrics such as ETD, ENT to assist the routing protocol to route data from source to destination. Energy is also the next important factor, so we have selected the metrics based on energy and further the security is most vital factor that should be considered in the wireless environment. Finally, we have selected metrics based on security in addition to that above said metrics.

### V. CONCLUSION AND FUTURE WORK

In this paper, we have studied various routing metrics which are suggested by various authors for wireless mesh network. We have defined the network model for wireless mesh network which is connected to global network. So it can provide the global network access to mobile users at low cost. To establish communication in this network, routing protocols are needed. The efficiency of the routing protocol is based on the routing metrics which is used to select the best path. Thus, we have suggested some routing metrics which will be used along with routing protocol in the network model. In future, we will study the various routing protocols for wireless mesh network, based on the metrics and will evaluate the performance of these selected metrics with routing protocol in WMN using ns2 simulator.

### REFERENCES


