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Fault Tolerant Multi Path Routing in 802.16 Wireless Mesh Networks

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Abstract . The main goal of multipath routing is to construct multiple paths for improving fault tolerance and reduction in routing overheads. But in 802.16 wireless mesh networks (WMN), there is little work done on multipath routing and traditional multipath routing protocols cause the flooding of routing control messages and congestion in gateways. In this paper, we propose a fault tolerant multipath routing for 802.16 wireless mesh networks. A combined routing metric is computed based on interference and load on the links. Multiple shortest paths are discovered based on the combined routing metric and the source node chooses the path with the minimum weight value as the primary path. The paths with next minimum weight values are selected as backup paths. Initially the data transmission takes place using the primary path and during any fault, it can be switched over the backup paths. By simulation results, we show that the proposed approach is the efficient multipath routing protocol in 802.16 wireless mesh networks**.**

Keywords: wireless mesh networks (WMN), IEEE 802.16, multipath routing protocol, quality of service (qos), backup paths.

1. Introduction

Since Wireless Mesh Networks (WMN) posse's easy installation facility and faster expendability with inclusion of new mesh nodes, they can be utilized to widen the cell ranges, cover shadowed areas, and to improve the system throughput. The Quality of Service (QoS) needs for multimedia applications can be accomplished by means of mesh mode in IEEE 802.16 which defines both physical and MAC layer similar to other IEEE standards [1]. IEEE 802.16 is economic and gives high data rates and high quality radio coverage and also it maintains improved QoS for high data rate applications [2]. In *Mesh mode* mode, SS can interact with each other directly. This is employed as a technology for wireless mesh networks and can put up longer distance coverage with the help of cooperative packet relaying and this is superior to PMP mode [3]. The effective method to avoid congestion and losses in the networks is by multipath routing which is otherwise termed as alternate path routing (APR) and this technique provide improved capacity [4]. The main goal of multipath routing is to construct multiple paths to enhance fault tolerance and decrease routing overheads. The drawback is that multipath routing protocol cannot accomplish throughput due to the inter-intra flow channel competition and interference [5]. The traditional multipath routing protocols causes flooding of routing control messages and congestion in gateways [6]. If multiple non-disjoint paths are chosen for transmitting the packet, deterioration occurs and the intersection node turns out to be the bottleneck [7]. In our first work, a distributed multi-channel assignment with congestion control (DMAC) routing protocol is proposed. In this protocol, a traffic aware metric provides solution for multi channel assignment and congestion control. In the next work, a priority based bandwidth reservation protocol (PBRP) for wireless mesh network is proposed. The protocol describes the bandwidth request and reply phase and destination node precedes the reply according to the priority of traffic classes and reserves the bandwidth on the reply path. In both works, the routing algorithm is not reliable. During the time of faults, the routing algorithm can't deal with the faults immediately which may result in the packet loss and poor network quality of service (QoS) since it is single path. Hence in this paper, we propose a fault tolerant multipath routing in 802.16 wireless mesh networks.

2. Fault Tolerant Multipath Routing Technique

2.1 Overview

In this paper, we propose a fault tolerant multipath routing in 802.16 mesh networks. The combined metric for interference avoidance (IAP) is designed with exclusive expected transmission time (EETT), interference load aware (ILA) and interference aware metrics (iAWARE). The source node chooses the path with the minimum weight as the primary path to the next hop. If there is failure notification in primary path, the alternate path is chosen that has the second minimum value of W.

2.2 Interference avoidance protocol (IAPij)

We propose an interference avoidance protocol IAP_{ij} for a wireless mesh networks. It is designed with the help of following metrics.

2. Exclusive Expected Transmission Time ($EETT_{ij}$)
3. Interference Load Aware (ILA_{ij})
4. Interference Aware ($iAWARE_{ij}$)

2.2.1 Exclusive expected transmission time (EETTij)

EETT of a link i characterizes the busyness of the channel with the link i. The presence of several neighboring links on the same channel with link i causes the link i to remain for longer duration for the transmission to be executed over the channel. If the path has larger $EETT_{ij}$ value, rigorous interference is caused and it requires additional time to complete the transmission over all links within the path. [9]

EETT is computed as follows

$$EETT_{ij} = \sum_{i \in s} ETT_i \quad (1)$$

where ETT_i represents expected transmission time to successfully transmit a packet at the MAC layer and it is defined as follows

$$ETT_{ij} = ETX_{ij} \times \frac{AvS}{Bw_c} \quad (2)$$

Where

AvS = average size of a packet

Bw_c = current bandwidth of the link.

ETX_{ij} = expected transmission count

Overall, ETT_i improves the throughput of the path via the measurements of link capacities and hence increases the overall performance of the network.

The expected transmission count metric (ETX) involves the process of conversion of the links success probabilities. Computation of ETX

$$New\,ETX_{ij} \leftarrow \frac{1}{(NewP_{ij} \times NewP_{ji})} \quad (3)$$

This value of the ETX is utilized in the computation of ETT_i

where P_{ij}, and P_{ji} be the probabilities,

2.2.2 Interference load aware (ILA))

The Interference-Load Aware metric (ILA) metric is utilized to discover paths between the mesh routers and two components included in them are as follows

1) Metric of Traffic Interference (MTI_i) and
2) Channel Switching Cost (CSC_i).

Both intra-flow and inter-flow interferences are present in mesh networks. The MTI metric captures the inter-flow interference and this metric is considered in our approach. [10]

Metric of Traffic Interference MTI

In metric of traffic interference, the traffic load of the interfering neighbors is taken into account. The degree of interference is based on load generated by the interfering node. Thus MTI metric is defined as follows:

$$MTI_i(d) = \begin{cases} ETT_{ij}(d) \times AvL_{ij}(d), IN(d) \neq 0 \\ ETT_{ij}(d), IN(d) = 0 \end{cases} \tag{4}$$

where $AvL_{ij}(d)$ = Average load of the neighbors which interferes during the transmission between nodes i and j over channel d.

$IN(d)$ = set of interfering neighbors of nodes i and node j.

$AvL_{ij}(d)$ is given by the following equation

$$AvL_{ij}(d) = \frac{\sum_{IN} L_{ij}(d)}{IN(d)} \tag{5}$$

$$IN(d) = IN_i(d) \cup IN_j(d) \tag{6}$$

where $L_{ij}(d)$ = load of the interfering neighbor.

The optimum path selection is selected by MTI based on the following condition

2.2.3 Interference aware $(iAWARE)$

The interference aware $(iAware)$ metric takes into account the amount of traffic generated by interfering nodes [11]. It is expressed using the following equation

$$iAWARE_p = (1-\delta) \times \sum_{i=1}^{n} iAWARE_i + \delta \times \max_{1 \le i \le d} H_j \tag{7}$$

H_i = sum of the ETT values of links that are on channel j in a system that has d orthogonal channels and

δ = tunable parameter within the bounds $0 \le \delta \le 1$ that allows controlling the preference over path length versus channel diversity. The $(iAware)$ value of a link j is explained using the following equation

$$iAWARE_j = \frac{ETT_J}{I_j} \tag{8}$$

where I_j represents interference ratio and its value for a link j between nodes s and t is given by the following equation

$$I_j = \min(I_j(s), I_j(t)) \tag{9}$$

Thus the interference ratio (I) at a single node u for a link i is defined as follows.

$$I_i(s) = \frac{SINR_i(s)}{SNR_i(s)} \tag{10}$$

where

$SINR_i(s)$ = signal to interference noise ratio

$SNR_i(s)$ = signal to noise ration at node s for link i.

2.2.4 Interference avoidance protocol

Based on the computation made in the section 3.2.1-3.2.4, we formulate a combined metric for avoiding interference which is given by the following equation

$$IAP_{ij} = \frac{EETT_{ij}(d) * AvL_{ij}(d)}{I_k} + IAR \quad (11)$$

where AvL_{ij} = Average load of neighbors. This hinders the transmission among nodes i and j over channel C and it is derived from equation (5).

I_k = Interference ratio for a link k and it based on the equation (10)

IAR = Total time period between the generation of a packet up to its successful transmission.

$EETT_{ij}$ = exclusive expected time which is derived based on the equation (1).

2.3 Multipath routing

2.3.1 Multipath discovery

Let N_j be the next hop node of the node N_i

The WMN topology is abstracted into n-node undirected graph $G = (N, E)$. The n-order square matrix and element in the matrix describes the adjacency matrix.

D = distance among neighbor nodes

$$C[i][j] = \begin{cases} D, if (N_i, N_j) \in E \\ 0, if (N_i, N_j) \notin E \end{cases} \quad (12)$$

The matrix $C[i][j]$ has the distance values in the ascending order stored in them.

The condition to choose next hop (N_j) is based on the following condition

For each Ni

Let Path$[i] = \{N_i\}$

For each N_j of N_i

Find $W_j = C[i][j] \times IAP$

Sort W_j in ascending order

Select N_j such that $W_j = \min(W_k)$

Path $[i] = Ni \cup Nj$

End for

End For

The source node chooses the minimum value of W for the purpose of transmission to the next hop as per the above condition which is the primary path P_1. Then the source node chooses the paths that have the next minimum values of W as backup paths P_2 and P_3. Initially the transmission takes place using primary path P1 and during any fault, it can be switched over the backup paths P2 or P3 (will be explained in the next section)

2.3.2 Fault tolerant routing

Let P_1 = Primary path

$$P_2, P_3 \cdots P_n = alternate\ path\ 2, 3 \cdots n$$

The primary and alternate paths are set up from source to destination with the help of both distance among nodes and the metrics in the interference avoidance protocol. The process by which the source node transmits the data packet to the destination through the available paths is as follows.

3.3.1 Source node forwards the data packet through P1

3.3.2 If there is any fault detection in P1, then

Fault notification message is feedback to the source node in advance by the intermediate nodes available in the paths.

End if

3.3.3 After reception of fault notification, source node triggers P2 to transmit network traffic.

3.3.4 If fault condition disappears, then

P2 is disabled and primary path is only used for transmission of data.

Else

if source receives fault notification from P2, then

Source activates P3 to transmit traffic.

End if

End if

3. Simulation Results

3.1 Simulation model and parameters

We use NS2 [12] to simulate our proposed protocol. We use the IEEE802.16e simulator [13] patch for NS2 version 2.33 to simulate a WiMAX Mesh Network. It has the facility to include multiple channels and radios. It supports different types of topologies such as chain, ring, multi ring, grid, binary tree, star, hexagon and triangular. The supported traffic types are CBR, VoIP, Video-on-Demand (VoD) and FTP. In our simulation, mobile nodes are arranged in a ring topology of size 500 meter x 500 meter region. We vary the number of nodes from 5 to 25. All nodes have the same transmission range of 250 meters. A total of 4 traffic flows (two VoIP and one VoD) are used. The simulation time is 100 sec.

3.2 Performance metrics

We compare our Fault Tolerant Multipath Routing (FTMR) protocol with the MPRP [8] protocol**.** We evaluate mainly the performance according to the following metrics, by varying the simulation time and the number of channels. Average end-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations. Average Packet Delivery Ratio: It is the ratio of the number of packets received successfully and the total number of packets sent. Overhead: It is the control overhead measured in packets

Based on Nodes

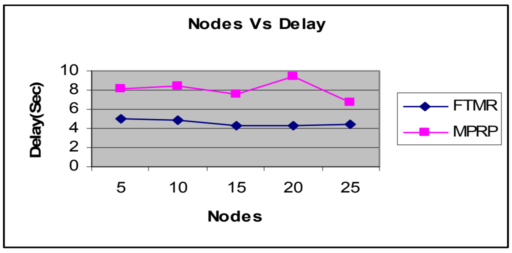

Fig. 1: Nodes Vs Delay

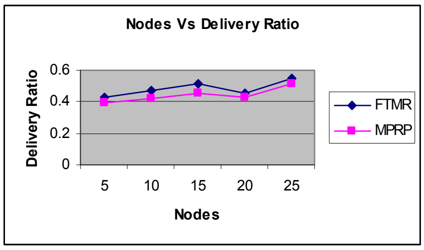

Fig. 2: Nodes Vs Delivery Ratio

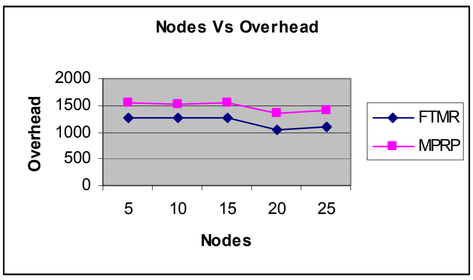

Fig .3: Nodes Vs Overhead

We vary the number of nodes as 5,10,15,20 and 25. From Fig. 1, when the number of nodes increases, the average end-to-end delay also increases. We can see that the average end-to-end delay of the proposed FTMR protocol is less when compared to the MPRP protocol. Fig. 2 presents the packet delivery ratio of both the protocols. When the number of nodes increases the packet delivery ratio decreases. We can observe that FTMR achieves good delivery ratio, when compared to MPRP. Fig. 3 gives the overhead of both the protocols when the number of nodes is increased. When the number of nodes increases the overhead decreases. As we can see from the figure, the overhead is more in the case of MPRP than FTMR.

4. Conclusion

In this paper, we have proposed a fault tolerant multipath routing in 802.16 wireless mesh networks. The combined metric for interference avoidance (IAP) is computed based on exclusive expected transmission time (EETT), interference load aware (ILA) and interference aware metrics (iAWARE). The source node chooses the path with the minimum value of IAP and distance as the primary path to the next hop. If there is failure notification in primary path, the alternate path is chosen that has the second minimum value. If fault condition disappears in alternate path, source node shifts to primary path. In case there is fault in alternate path also, source node chooses second alternate path that has next minimum value of W and this process continues and thus optimal path is selected for transmission. By simulation results, we have shown that the proposed approach is the efficient multipath routing protocol in 802.16 wireless mesh networks.

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