Multipath Routing for Load Balancing in Wireless Mesh Network

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1. Introduction

Wireless Mesh Networks (WMNs) have been attracting much attention due to its desirable characteristics such as auto configuration, bandwidth fairness, low cost, easy deployment, self-healing and self-organization.

However, routing protocols for WMNs are different from those in wired networks and cellular networks. An optimal routing protocol for WMNs is required to capture the following features, performance metrics, fault tolerance with link failures, load balancing scalability and so on [1].

Routing protocols for WMNs are classified and discussed from the viewpoint of the performance metrics in [2]. Emphasis is on multipath routing for load balancing in WMN in this paper.

2. Multi-path routing for load balancing in WMN

Multi-path routing is proposed to perform better load balancing and to provide high fault tolerance. When link is broken on a path due to a bad channel quality or mobility, another path in the set of existing backup paths can be chosen. Thus, without waiting for setting up a new routing path, the end-to-end delay, throughput, and fault tolerance can be improved.

A drawback of multi-path routing is its complexity. Whether or not the multi-path routing can be used for WMNs needs to be investigated depending on applications. Another problem is that multi-path routing is infeasible if the shortest path is taken as the routing performance metric.

Thus, how to design an effective multi-path routing protocol with appropriate performance metrics is an interesting research topic.

The related research on multi-path routing protocol is described in Section 3. Section 4 deals with cross-layer multi-channel multipath approaches with novel performance metrics. And Section 5 gives the conclusions.

3. Multi-path routing protocols

In WMNs, traffic flow is mainly routed either towards the Internet Gateways (IGWs) or from the IGWs to the Access Points (APs). Thus, if multiple APs choose the best throughput path (hot path) towards a gateway, the traffic loads on certain paths and mesh routers increases tremendously thereby deteriorating the overall performance of the network.

N. S. Nandiraju [3] proposed a multipath hybrid routing protocol, Multipath Mesh (MMESH) to discovers multiple paths effectively. The idea of restricting the set of routes for delivering traffic flow from a particular source is derived from the traditional source
routing technique. With source routing, they can incorporate the decision of choosing the route with good channel diversity which is otherwise not possible in distance vector routing.

Marc Mosko [4] reviewed the premise that a routing protocol should prefer disjoint path construction and argued that using disjoint paths limits route reliability in WMNs compared to using multiple well-connected loop-free paths that need not be disjoint. In WMNs, link lifetimes may be relatively short compared to traffic flows. It is argued that a routing protocol should exploit the mesh connectivity over non-disjoint loop-free paths to improve source-destination connectedness lifetime in a mobile network. Exploiting mesh connectivity amortizes expensive path discovery operations and may lead to better performance than using disjoint or maximally disjoint paths. They used a Boltzmann distribution to distribute load over next hops

\[ b_{i,j} = \frac{\exp(x_{i,j}/T_j)}{\sum_i \exp(x_{i,j}/T_j)} \]  

where \( b_{i,j} \) is the probability to select link \( i \) for metric \( j \) and a normalized exponential function where the value of metric \( j \) for choice \( i \) has the value \( x_{i,j} \).

4. Joint multi-channel and multipath routing

Under the combinations of the channel diversity and the path, there are 4 scenarios (a) single-channel single-path (SCSP), (b) multi-channel single-path (MCSP), (c) single-channel multipath (SCMP), and (d) multi-channel multi-path (MCPM) shown in figure 1 [5].

1) Joint Multi-channel and Multi-path control (JMM)

Wai-Hong Tam et al. introduce a protocol named Joint Multi-channel and Multi-path control (JMM) which combines multichannel link layer with multi-path routing. This protocol is able to overcome the bottleneck at intermediate nodes and increase end-to-end throughput by decomposing the traffic over different channels, time and space [5]. In the route discovery phase, the goal is to find two paths from each node to its gateway that are as disjoint as possible. A Gateway REQUEST (GREQ) forwarding strategy is proposed to reduce the number of broadcast messages. A weighted routing metric which explicitly accounts for the disjointness between paths and interference among links is proposed as the following.

\[ \text{Metric} = w_{node} V_{node} + w_{ch} V_{ch} + w_{qty} V_{qty} \]  

where the metrix is affected by 3 factors \( V_{node}, V_{ch} \) and \( V_{qty} \). The evaluation results showed significant throughput improvement.

2) Channel Aware Multipath metric (CAM)

Irfan Sheriff et al. [6] propose a Channel Aware Multipath metric (CAM). They focuses on exploiting channel diversity through multipath and studying selection of multiple concurrent paths between 2 nodes to increase effective throughput. Multipath here means concurrent multiple paths combination or a set of 2 or more paths instead of backup paths used only when the primary path fails. Additional capacity is gained in multi-radio networks through simultaneous data transmission on multiple orthogonal frequency channels. CAM is defined as

\[ \text{CAM} = \beta \times \lambda + (1 - \beta) \times \gamma \]  

where inter-path interference index \( \Box \) accounts for the interference among the common channel links on the two paths and independent path quality index \( \Box \) accounts for end-to-end characteristics of the two paths.

The main idea of CAM is weighted average evaluation of intra-path and inter-path factors. The simulation results show the effectiveness of CAM metric for selection of multipath combination which improves throughput of the networks.
CAM improves channel utilization and increase effective throughput by using multiple concurrent paths. CAM attempts to quantify the channel diversity by means of weighted average of intra-path and inter-path issues using a weighted factor $\beta$.

5. Conclusion
Multipath routing approaches for load balancing in WMN are studies in this paper. Multipath routing is proposed to perform better load balancing and to provide high fault tolerance. Common factors on multi-path routing are discussed and the key issues on how to design an effective multi-path routing protocol with appropriate performance metrics are also mentioned through the case studies.

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