International Journal of Scientific Research in Science and Technology
Available online at : www.ijsrst.com
OPEN ACCESS
Print ISSN: 2395-6011 | Online ISSN: 2395-602X
doi : https://doi.org/10.32628/IJSRST

Study of Routing in Wireless Mesh Network

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ARTICLEINFO

Article History:

Accepted: 10 Nov 2023
Published: 24 Nov 2023

Publication Issue
Volume 10, Issue 6
November-December-2023

Page Number
535-541

ABSTRACT

Routing protocol design is also highly jointed with the underlying link and physical layers. For example, designing a routing protocol for a network using a multi-channel MAC protocol will tend to favor channel diversity and load balancing among channels. Routing in networks with directional antennas will try to benefit from the uni-casting capability of the directional antennas and alleviate problems that arise for such types of networks. In the present paper, we discuss routing protocols developed for best-effort traffic.
Keywords: Wireless, Antenna, Mesh Network, WLAN.

I. INTRODUCTION

Routing and link scheduling are important components in satisfying the QoS requirements and utilizing the network bandwidth efficiently. Routing protocols developed for the WMNs according to the QoS level that they provide have been classified as: Best Effort Routing Protocols or QoS-aware Routing Protocols. Under this classification, we further divide routing protocols of channels used in data transmission and their combination with the type of antenna, mainly the directional antenna.

II. BEST-EFFORT ROUTING

Best-effort services are those that do not request any QoS guarantees. An example of a best-effort application is web browsing in which an internet user requests a web page through a web browser and then waits without any guarantee that the page will not be delayed for a long time, or even though it may not open at all due to network congestion or server overloading. For such type of traffic, the network tries to accommodate as many flows as it can. Therefore, increasing network capacity becomes the main concern. In the wireless environment, the main cause of capacity degradation is interference between neighboring links. To increase capacity, we should try to alleviate or decrease interference. Several approaches have been adopted to increase capacity including a better selection of routes, the use of multi-channels, and the use of directional antennas[1].

Since routing depends on metrics that are mainly measured in the underlying link and physical layers, cross-layer routing has gained much research effort. Routing can be done based on metrics like throughput, delay, packet loss rate, power control, load distribution, and many others that are measured at the link or physical layers. In that case, routing protocols are dependent on the underlying structure [2]. So, routing protocols can be developed to work on top of a multi-channel architecture while others developed to benefit from using a directional antenna. Routing protocol design is also highly jointed with the underlying link and physical layers. For example, designing a routing protocol for a network using a multi-channel MAC protocol will tend to favor channel diversity and load balancing among channels. Routing in networks with directional antennas will try to benefit from the uni-casting capability of the directional antennas and alleviate problems that arise for such types of networks. In the next sections, we present and discuss routing protocols developed for best-effort traffic. The protocols are classified based on the number of channels used throughout the network [3].

2.1 Routing Protocols for Single-Channel Networks

In [4], discusses the theory that selecting the minimum hop count as a metric for routing protocols in multi-hop wireless networks tends to achieve poor performance. The reason is declared in the tendency protocol to include longer links which means distant nodes. The longer the link between two nodes, the more it becomes exposed to fading, noise, and other interference. This leads to an increase in packet loss rate and therefore to poor throughput. *De Couto* introduces a new routing metric, called ETX, which accounts for the link loss rate. A route that has the minimum ETX is selected to be the recommended one [5].

This metric is based on measuring the loss rate of broadcast packets between pairs of neighboring nodes. Several small-sized packets are sent to measure the link loss rate followed by the reception of replies for these packets. The percentage of successfully received packets out of the transmitted packets indicates the successful transmission rate. The reciprocal of its complementary indicates the estimated number of transmissions required to send a packet on that link.

This metric was adopted by other routing protocols. It is implemented in two of the well-known routing protocols for wireless networks, namely the DSDV and DSR routing protocols. The protocols are implemented in mobile nodes that form an ad-hoc network. A single channel is used and thus if a link is active, all neighboring links should not be active or there will be interference [6].

An extension for this work is done in [7]. Five routing metrics are compared including the traditional hop count, the proposed link transmission rate in [8], ETX, and another two metrics the per-hop round trip time (RTT) and the per-hop packet-pair metrics. The per-hop RTT is based on measuring the round-trip delay seen by unicast probes between neighboring nodes. The per-hop packet pair is based on measuring the delay between a pair of back-to-back probe signals to the neighboring node. According to their results, ETX outperforms the other two metrics when all the nodes are stationary while the 12 traditional minimum hop had the best performance when the sender is mobile. The ETX metric is included in a modified version of DSR which is called Link Quality Source Routing (LQSR).

A simple extension to this work is made in [9]. They modify the previous ETX to suit the multi-rate case. Instead of measuring the number of transmissions using a single rate, they use multiple rates from the set of rates supported by the underlying wireless technology to estimate the transmission time.

2.2 Routing for Multi-Channel Wireless Networks

To increase capacity, we should try to alleviate or decrease the effect of interference. Several approaches have been adopted to increase capacity. One active approach is the deployment of multiple channels. Two neighboring links interfere if they use the same channel. By proper assignment of multiple channels to neighboring links, we can activate more than one link simultaneously on condition that they use different channels. The term "channel" refers to a frequency band, like in FDMA, or an orthogonal code, like in CDMA. Routing protocols developed are often joined with a channel assignment scheme that enables many neighboring links to be active simultaneously to increase capacity. Some works are concerned only with channel assignment [10] leaving the routing problem as a standalone problem to be solved on top of the channel assignment.

The work in [11] presents an integer linear programming formulation for the fixed channel assignment problem in multi-radio. The goal is to maximize simultaneous transmissions in the network. Supposed to be centralized which puts a restriction on the network topology and limits the scalability of the network. In addition, all nodes have to access the channel assignment server, leading to high congestion in the paths to that server. Wu et al. propose a protocol, namely *Dynamic Channel Assignment* (DCA), which utilizes the multi-channel capability of the 802.11 physical layer. In this protocol, one channel is dedicated as a control channel for exchanging control messages among all hosts while the other data packets. Data channels are assigned dynamically on an on-demand basis. The control channel is one transceiver while data channels to the other transceiver(s). In this way, a host can listen to the control channel and the data channel simultaneously. The sender uses the control channel to set up the connection with the receiver. The request-to-send packet (RTS) includes a list of preferred channels. The receiver decides on channels and sends them to the sender in the clear-to-send packet (CTS). The sender announces the channel used to neighboring nodes through a reservation packet (RSV). This protocol does not have the multi-channel hidden terminal problem since there will be always one of the transceivers listening to the channel. In addition, there is no need for synchronization between the sender and receiver. The disadvantage is the cost of reserving a channel for the small control messages, thus wasting bandwidth.

A similar protocol is proposed in that uses one control channel and *N* data channels. The difference is that the decision on the channel to use is based on the channel condition at the receiver side. The best channel condition is selected. Although it has a throughput improvement over, it still has the same disadvantages.

The protocol in operates with a single radio (transceiver) per host. It does not separate the control channel from the data channel. The main disadvantage requires clock synchronization among all hosts. Another disadvantage incurs a bandwidth overhead to exchange traffic indication messages. At that time there will be no exchange of data packets. In, Gupta and Kumar show that using one radio per node extensively degrades. Moreover, the prices of adapters are decreasing in a way that makes employing more than one network adapter a more cost-effective solution. Most of the recent research effort has been directed towards the employment of more than one interface in a mesh router, and the network capacity increases.

In, *Draves* suggests implementing the link loss rate to be used in a multiple radio environment. The proposed metric favours the selection of different channels for neighboring links which will lead to minimizing the interference and thus increasing the capacity. The new protocol was named MR-LQSR (Multi-Radio Link- Quality Source Routing). The new metric WCETT (Weighted Cumulative Expected Transmission Time) allows to trade of channel diversity and path length by adjusting a control parameter. The WCETT combines the link quality in terms of the expected transmission time and the channel diversity by favoring paths that are more channel-diverse.

MR-LQSR uses several channels which is equal to several radio interfaces. Thus, in the case of two radios, as in their experiment, only two channels are used. Each radio has a fixed channel which has an advantage in that it does not incur a switching delay. On the other side, it is a restriction that if relaxed can yield better performance in terms of throughput and which incurs some tolerable delays.

In, so et al. propose an on-demand routing protocol for networks with single transceiver nodes benefiting from the multiple channels offered by 802.11. The protocol, named MCRP, assigns different channels to neighboring nodes to avoid interference. Each node can switch between channels under the constraint that no two neighboring nodes are switching to avoid the deafness problem. The protocol works on a synchronous TDMA access technique which is complex to implement.

In [12] proposes an architecture for multi-channel wireless networks. Although the architecture is developed for a network with single radio nodes, it can be extended to a multi-radio nodes network. The main restriction in this architecture is the tight coordination it requires among nodes which cannot be easily guaranteed.

An attempt to assign channels to interfaces and schedule flows is made by Bahl in. Bahl proposes a link layer solution named Slotted-Seeded Channel Hopping (SSCH). This work is implemented in networks with single interface nodes but can be extended to multiple interface nodes. In SSCH, nodes hop between channels after fixed intervals based on a schedule. This schedule is published to neighboring nodes so that two nodes can communicate by adjusting their schedule to have a common channel at some time. The paper includes also a flow scheduling algorithm per node. Bahl did not discuss a routing protocol to be implemented on top of his work.

A joint channel assignment and routing protocol is proposed in [13]. This work by Raniwala et al. focuses on improving the capacity of wireless mesh networks that are used as an intermediary between the wired backbone and the mobile mesh clients. Thus, all the traffic is directed towards specific gateway nodes. They assume each node to have more than one radio and each radio can switch among the available channels. Two-channel assignment and bandwidth allocation techniques are proposed. The first is based on network topology and the other is based on traffic load. They claim that any routing algorithm can work efficiently on their channel assignment techniques. However, they implement a routing protocol that has its routing metric as the shortest path and another one with randomized multi-path routing. In [14], Pradeep proposes a joint channel assignment and routing protocol. This work allows for a free traffic load from any point in the network to the other. He considers switching latency in the work and tries to minimize it by decreasing the channel switching rate for one interface. He also proposes a new routing metric incorporated into an on-demand routing protocol. The proposed Multi-Channel Routing (MCR) metric combines the measured link expected transmission time (ETT) and switching costs into a single path cost.

2.3 Routing for nodes with Directional Antenna

Another approach for improving wireless network capacity is the use of directional antennas [11]. By beam-forming at the transmitter we can restrict the transmission area, reducing interference and alleviating the exposed terminal problem. Therefore, capacity can be greatly improved and we can achieve higher throughputs. Placing the directional antenna at the receiver side can reduce the hidden terminal problem by only listening to the expected area of transmission.

Directional antennas have also an impact on the network layer. They help in finding routes with less hop count due to the longer transmission range of the directional antenna. They can also help in finding energy-efficient routes [13] and interference-aware[12] routes. On the other side, using directional antennas has found new problems including new kinds of hidden terminal problems and deafness and capture. Another problem that arises is the discovery of the neighbors. This new category of problems imposes a tradeoff between gaining benefits of using directional antennas and solving or adapting to the problems.

III. QoS-AWARE ROUTING

With the recent advances in communication technology and the flooding of multimedia services through the internet, QoS consideration in networking is becoming imperative. Providing QoS is a challenge to networking services providers especially in the wireless environment. Different layers can share in fulfilling QoS requirements individually or integrated with others.

3.1 Routing in Differentiated Service Networks

In this, an architecture for Differentiated services provision in the wireless mesh backbone is discussed. Hai et al. propose a scheme for WMN backbone routers. They recommend being class-based. For each traffic class, the routing protocol should select routes that satisfy the QoS requirements of that class. They suggest using an on-demand routing protocol similar to AODV to reduce signaling overhead and they assume the network to work with a single channel. This work is preliminary and is an open issue for further research.

Another approach to provide QoS routing is addressed in. The authors divide the network into clusters and suggested the routing to be done on two levels: inter-cluster routing and intra-cluster routing. Inter-cluster routing aims to route data cluster by cluster. While intra-cluster routing aims to route data inside the cluster. This coarse granularity routing can prove to be efficient scalability but is worse interference and thus throughput and delay.

3.2 Multiple-Constraints Routing

Traffic flows vary in their requirements. Flows can be bandwidth-sensitive requesting a minimum bandwidth or delay-sensitive requesting a maximum delay bound. Others can request for maximum packet loss rate (PLR) bound. Flows requesting multiple QoS metrics guarantees impose more difficulty. Solving a multi-constrained path problem is a NP-complete in many cases such as when the metrics are additive. Even satisfying one constraint may become NP-complete when link interference is taken into consideration [14]. Solving the multi-constrained routing problem in WMNs is addressed in. The authors propose a routing scheme based on Mean Field Network (MFN_RS). The goal is to find a solution for the routing optimization problem using a computational method that is faster than the Simulated Annealing (SA) approach.

The protocol uses heuristic algorithm problems. Researchers divide the two-constraint problem into two one-constraint problems. The first is the route that satisfies the PLR- packet loss rate requirement. The second step is to check if the discovered route satisfies the other requirement which is either bandwidth or delay.

3.3 Multi-Path Routing

Multipath routing is used to maximize utilization of network resources. The path reliability is calculated based on the link availabilities of all links along a path. Link availability is defined as the probability that a link is available for a defined. The calculation of the link availability node's movement; is a constraint that is not found in WMNs.

The same approach of path limiting is addressed in. Chen et al. propose a *ticket-based multipath routing.* The source node issues probes to discover routes. Each probe is assigned several tickets that are equal to the number of required multiple paths. The number of tickets is related to the stringency of the constraint requirements.

IV. CONCLUSIONS

Services guarantees are a typical requirement for applications involving audio and video transmission such as Voice over IP (VOIP), distant learning using online multimedia transmission and video conferencing. This type of traffic is characterized by having a variable bit rate (VBR). Allocating bandwidth is a challenge in that case since if it is allocated according to the maximum rate then resources are wasted and other applications will be blocked while there is unused capacity.

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Cite this Article

Surabhi, Dr. K. B. Singh, Dr. Pankaj Kumar, "Study of Routing in Wireless Mesh Network", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 10 Issue 6, pp. 535-541, November-December 2023.

Journal URL : https://ijsrst.com/IJSRSET2411128