ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 8, August 2015

Scheduling Approaches and Routing Protocols in Wireless Mesh Networks-A Survey

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Abstract: Wireless Mesh Networks (WMN) is an emerging distributed broadband network which has the potential to provide internet to stationary and mobile mesh clients. The mesh clients are interconnected by wireless backbone managed by Mesh routers. Routing protocol and Scheduling are the main challenges faced by Wireless Mesh Networks. This paper provides a review of routing protocol for WMN to efficiently utilize the resources available in the network. It also provides a review on various mechanisms of scheduling in WMNs.

Keywords: WMN, BS, MR.

I. INTRODUCTION

Wireless mesh networking is an auspicious design paradigm for next generation wireless networks. Wireless mesh networks (WMNs) consist of mesh clients and mesh routers, where the mesh routers form a wireless infrastructure backbone, which are interconnected with the wired networks to provide multihop wireless Internet connectivity to the mesh clients. Wireless mesh networking is self-organizing, self healing and auto-configurable wireless networking to provide adaptive and flexible wireless Internet connectivity to mobile users.

This concept is used for different wireless access technologies such as IEEE 802.11, 802.15, 802.16-based wireless local area network (WLAN), wireless personal area network (WPAN), and wireless metropolitan area network (WMAN) technologies respectively. To achieve the optimal throughput, the routing and scheduling parameters should be configured optimally in scheduling based wireless mesh networks [1].Network routing is determining the performance of a wireless mesh network. Most of the routing protocols focus on shortest path routing. One of the advantages of using shortest path routing is that it is good for overall energy efficiency because energy needed to transmit a packet is directly proportional to path length or number of hops. The key concept for designing such efficient routing protocol is to build up a channel assignment with proper routing metric [2].But the shortest path routing is limited to use the same set of hops to route the data packets, which results in heavily loaded mesh clients and thus causing some of the mesh clients to die earlier resulting into holes in the network or even worst into partitioning of the network.

In 802.16 mesh there are two different scheduling schemes, centralized and distributed. In the centralized scheme the base station (BS) is liable for defining the scheme of transmissions in the entire network. A network is partitioned into tree-based clusters. Each cluster has a BS node that is responsible for allocating network resources to the client nodes that it services. Although the centralized scheduling mode provides collision-free transmissions for control and data packets, it has several disadvantages. The distributed scheduling scheme is further divided into two sub schemes, the coordinated scheme and the uncoordinated scheme. In the distributed coordinated scheduling scheme the control messages required to establish data schedules are transmitted over transmission opportunities without collisions. In contrast, in the distributed uncoordinated scheduling scheme, such control messages can only be transmitted on the transmission opportunities left from the distributed coordinated scheduling scheme or on unallocated minislots. Because of this design, the distributed coordinated scheduling scheme provides better quality-of-service (QoS) supports than the distributed uncoordinated scheduling scheme.

II. SCHEDULING APPROACHES

Scheduling is the main issue in wireless Mesh Networks to maintain the network performance. A scheduling algorithm can also be classified based on whether or not they are centralized, the type of fairness and the metric or mechanisms they use in scheduling. High throughput is necessary in order to meet the increasing demand of network applications [14]. Centralized and decentralized are the two approaches for Scheduling. For situations where the Mesh Router (MR) are anticipated to be static, or the network size is small, it may be easier and more beneficial to use centralized scheduling. In contrast, when the MRs are mobile, it may be better to make use of a distributed approach in case the network becomes partitioned due to mobility. If reliability is a concern or the network size is large, distributed scheduling may also be preferred due to increased reliability and lower overhead.
There is a comparison between the key features of centralized and distributed approaches for scheduling. There are some observations which explain why distributed scheduling is beneficial. Nodes which cannot communicate with the coordinator cannot communicate at all in centralized schemes. Throughput and fairness are the most critical issues in WMN. Overhead from nodes

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

IJARCCE

International Journal of Advanced Research in Computer and Communication Engineering
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communicating with the coordinator is reduced or eliminated in distributed approach. The single point of failure problem is eliminated.

A. Centralized Scheduling

In centralized scheduling the scheduled transmissions for the Subscriber Station (SS) is defined by the Base Station (BS). The BS determines the flow assignments from the resource requests from the SSs. Then, the SS determine the actual schedule from these flow assignments by using a common algorithm that divides the frame proportionally to the assignments. Thus, the BS acts just like the BS in a PMP network except that not all of the SSs have to be directly connected to the BS, and the assignments determined by the BS extends to those SSs not directly connected to the BS. The SS resource requests and the BS assignments are both transmitted during the control portion of the frame. A simple example of the use of the centralized scheduling flow-mechanism in MSH-CSCH is as shown in Figure 2.4. The number of frames during which the CSCH schedule is valid is limited by the number of frames it takes to aggregate and distribute the next schedule. Each node uses the newly received schedule to compute the following points. The time the node shall transmit this schedule (if eligible) for nodes further down the transmission tree. The frame where the last node in the transmission tree will be receiving this schedule .The original transmission time by the Mesh BS of this schedule.

To compute this, the node uses the routing tree from the last Mesh Network Configuration messages as modified by the link updates of the last Mesh centralized scheduling message and the following steps. The Mesh BS transmits first in a new frame. Then, the eligible children of the Mesh BS (i.e., nodes with a hop count equals 1), ordered by their appearance in the routing tree, transmit. Then, the eligible children of the nodes from previous step are also ordered by their appearance in the routing tree, transmit. The process continues until all eligible nodes in the routing tree have transmitted.

B. Distributed Scheduling

Distributed scheduling would be more suitable for certain specific situations due to its flexibility, robust and Efficiency [15]. The stations that have direct links are called neighbors and shall form a neighborhood. A node's neighbors are considered to be "one hop" away from the node. A two-hop extended neighborhood contains all the neighbors of the neighborhood. In the coordinated distributed scheduling mode, all the stations shall coordinate their transmissions in their extended two-hop neighborhood. The coordinated distributed scheduling mode uses control portion of each frame to regularly transmit its own schedule All the stations in a network shall use this same channel to transmit schedule information in a format of specific resource requests and grants. Coordinated distributed scheduling ensures that transmissions are scheduled in a manner that does not rely on the operation of a BS, and that are not necessarily directed to or from the BS. Uncoordinated distributed scheduling can be used for fast, ad-hoc setup of schedules on a link-by-link basis. Uncoordinated distributed schedules are established by directed requests and grants between two nodes, and shall be scheduled to ensure that the resulting data transmissions (and the request and grant packets themselves) do not cause collisions with the data and control traffic scheduled by the coordinated distributed nor the centralized scheduling methods.

The differences between coordinated and uncoordinated distributed scheduling is that in the coordinated case, the Mesh Distributed Scheduling messages are scheduled in the control subframe in a collision free manner; whereas, in the uncoordinated case, Mesh Distributed Scheduling messages may collide.

III.ROUTING PROTOCOL

Since channel bandwidth is limited in wireless communication, it is important to consider the design of routing metrics . The different types of Routing metrics are distance, latency, traffic load, error rate, multiple channel, channel usage and compositive metric. A brief note on the following routing metrics.

- **Distance :** Most of the existing protocols use Hop-count for considering the distance, naming few AODV [3], DSR [4], and DSDV [5]. A routing protocol in this case considers the number of hops between source and destination. Hence, it finds the path with the minimum distance. However, it does not consider other issues such as link quality, transmission rates.
- **Latency:*Per-hop Round Trip Time (RTT)*** [6] is designed for Multi-Radio Unification protocol. It measures the round trip delay of unicast probes between neighbors. In this metric, each node sends out a probe packet with timestamp to all neighbors. When receiving the probe packet, each neighbor may give a response in the form of an acknowledgement. As sender receives the acknowledgement, it calculates the round trip time between sending probe and receiving acknowledgement. It avoids busy channel and link loss.
- **Traffic load *: Load-count*** [7] [8] is a load balancing metric for wireless network***s Neighborhood Load Balancing (NLR***) is the average load of each neighborhood, it is measured with aim to bypass the busy neighborhood instead of only bypassing the busy node with Load-count. In congestion-aware routing protocols, nodes make forwarding decisions by exchanging a time-varying metric, referred to as the congestion measure[9].
- **Error rate :** ***Expected Transmission Count*** (***ETX***) is a metric to estimate the expected number of MAC layer transmissions for the wireless links and measure the packet loss rate which is proposed by De Couto et al. [10] [11].
- **Multi-channel** : ***Weighted Cumulative ETT*** (***WCETT***) is also proposed by Draves et al [15] and it considers the multi-radio nature of the WMNs in two components: the total transmission time along all hops in the WMN and the channel diversity in the path.

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
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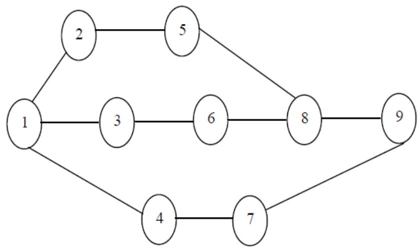
- **Channel usage : *Interference-Aware Routing Metric*** (***IAR***) [12] detects the channel busy level by capturing the MAC layer information.

A. Proactive Routing Protocols

a. *Destination Sequenced Distance Vector*
Destination Sequence Distance Vector (DSDV) protocol uses the concept of Bellman – Ford routing algorithm where each node maintains a routing table that contains the shortest path to all the possible destinations in the network and number of hops to the destination as shown in Fig.1.The sequence numbers allows the node to distinguish stale routes from new ones and avoid routing loops. A new broadcast route contains Destination Address, Number of hops to reach the destination, Sequence number of the information about the destination and a new sequence number unique to broadcast. Routing tables are updated periodically to maintain table consistency.

Fig. 1



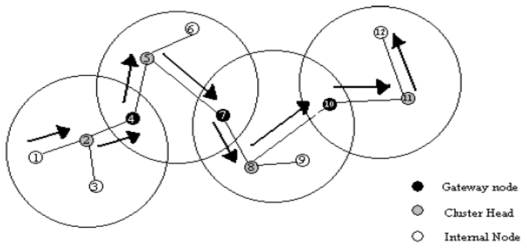


Fig. 2.

b. Clusterhead Gateway Switched Routing
Clusterhead Gateway Switched Routing protocol uses DSDV as an underlying protocol. It is a hierarchical routing algorithm, where number of nodes are formed into clusters and each cluster uses a cluster head (CH) which control a group of wireless nodes and hence achieve a hierarchical framework for code separation among clusters, channel access, routing and bandwidth allocation. Once cluster is formed then distributed algorithm is invoked to elect a cluster head in every cluster as shown in Fig. 2. Cluster head can be replaced frequently which affect the performance as nodes spend more time selecting a CH rather than relaying packets. To overcome this shortcoming, the Least Cluster Change (LCC) cluster algorithm is used. In LCC, CHs only change when two CHs come into contact or one of the node moves out of range with all other CHs. In CGSR, each node maintains Cluster Member Table (CMT) and Routing Table to determine the nearest CH along the route to the destination and the next node required to reach destination CH.

c. Optimized Link State Routing (OLSR)
Optimized Link State Protocol (OLSR) is a proactive routing protocol, so the routes are always immediately available when needed [13]. It is a proactive routing protocol where each node broadcasts its link state information to all other nodes in the network. OLSR mainly consists of updating and maintaining information in 1- hop, 2 – hop neighbor table and routing table. OLSR uses hello messages for link state information. Multi Point Relays (MPR) is important aspect of the OLSR protocol. An MPR for a node N is a subset of neighbors of N which broadcast packets during the flooding process, instead of every neighbor of N flooding the network. When a node propagates a message, all of its neighbors are receive message. Only MPR which have not seen the message before again propagates the message. Therefore flooding overhead can be reduced OLSR uses three kinds of Control messages: Hello Messages, Topology control (TC) messages and Multiple Interface Declaration messages. HELLO messages are transmitted to all neighbors. These messages are used for neighbor sensing and MPR calculation.

d. Scalable Routing using HEAT Protocol
The HEAT algorithm is a fully distributed, proactive any cast routing algorithm. It is inspired by the properties of temperature fields .HEAT has two unique features. First, the routing is decided based on length and robustness of the available path. Second, the field construction and maintenance mechanism of HEAT scales to the number of nodes and the number of gateways, as it only requires communication among neighboring nodes. HEAT protocol assigns a temperature value to every node in the mesh network. New nodes are assigned a value of zero and gateway nodes are assigned a well-defined maximum value.

This protocol determines the temperature of node based on Distances to the available gateways and Robustness of the paths towards these gateways. Here a path providing multiple alternative delivery opportunities along its way is preferred to a path over which packets cannot naturally be re-routed to an alternative path to one of the gateways. The Performance of the HEAT protocol is better in wireless mesh networks in terms of packet delivery ratio than the OLSR and AODV.

B. Reactive Routing Protocols

a. Dynamic Source Routing
The Dynamic Source Routing protocol (DSR) is reactive routing protocol which is based on source routing. The DSR Protocol works in two phases: route discovery and route maintenance. When a node wants to send a data then DSR initiates route discovery. In route discovery, the source node looks at the route cache for destination route. If the route exists then send the data. Otherwise it broadcast the Route Request Packet (RREQ) to its neighbors until it reaches the destination. The RREQ

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 8, August 2015

Packet contains the source address, destination address, route id and a route record . When the request reaches destination, a route reply (RREP) is sent back to the source node via the recorded route which has the minimum number of hops . In route maintenance, the route error packets are generated at a node during fatal transmission problem.

b. Ad hoc On Demand Distance Vector Routing

Ad hoc On Demand distance Vector Routing (AODV) protocol is reactive protocol which is built over the DSDV. AODV is pure on demand route acquisition algorithm. When a node wants to send a data then that node looks at the route cache for destination route. If the route exists then send the data, otherwise it broadcasts the Route Request Packet to its neighbors until it reaches the destination.

The Route Request Packet contains the source address, destination address, source sequence number, broadcast id and the most recent sequence number of source and destination node. When the request reaches destination, a route reply (RREP) is sent back to the source node via the route from which the destination receive first copy of the RREQ . Hence the AODV finds route which is fastest and shortest.

c. Link Quality Source Routing

Link Quality Source Routing (LQSR) is a reactive protocol for wireless mesh networks developed by Microsoft Research Group . LQSR is derived from DSR for improving link quality metrics and other related metrics. The metrics are hop count, round trip latency (RTT),packet pair latency and Expected Transmission Count (ETX). For improving the link quality, LQSR uses link cache instead of route cache. When a node wants to send a data then that node looks at the link cache for destination route.

If the route exists then send the data. Otherwise it broadcast the Route Request Packet to its neighbors until it reaches the destination. When a node receives a route request (RREQ) packet , it will add link quality metric for the link over which packet had arrived. When a Source node receives route reply (RREP) packet, it includes link quality information and node information. LQSR sends Hello message to its neighbors for link state information which is used to measure the link quality at each node for the link on which this message was received. All these messages are based on piggybacked approach.

d. Temporally Ordered Routing Algorithm

The Temporally Ordered Routing Algorithm (TORA) is a loop free, highly adaptive, efficient and scalable distributed routing algorithm for wireless networks. TORA uses destination oriented routing information that is already available at each node. Nodes only need to know their one-hop neighborhood. By the information of the neighbor TORA builds independently local routing information for each destination node. TORA also exhibits multipath routing capability. Directed Acyclic Graph (DAG) is maintained by each node to every destination. When source node wants to send data to destination node then it broadcasts a Query packet which containing the destination address.

IV. CONCLUSION AND FUTURE WORKS

In Wireless Mesh Networks a lot of fact finding has been made to resolve the issues of QOS, efficient routing and distributed scheduling. These issues are in the view of the use of multi hop, multi channel and other wireless communication techniques. Efficient communication can be attained by using well organized way of routing. In this paper a review of routing metrics and routing protocol techniques is mentioned. It also reviews the different scheduling strategies in Wireless Mesh Networks. Future works can focus on distributed, coordinated scheduling and efficient routing protocol for Wireless Mesh Networks.

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