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PROVIDING CENTRALIZED AND RTS/CTS-BASED CHANNEL ACCESS AND RESERVATION

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ABSTRACT

In a mesh topology, the traffic between access points (APs) is very closely related. Under the Institute of Electrical and Electronics Engineers (IEEE) standard 802.11, the carrier-sense multiple access with collision avoidance (CSMA/CA) and Request To Send (RTS)/Clear To Send (CTS) procedures only take into account station (STA)-to-STA transmissions, leading to inefficiencies and overhead for the mesh case. To address this type of challenge, techniques are presented herein that enable, within a wireless mesh network (WMN), collision-free RTS/CTS procedures supporting uplink channel access for the forwarding of backhaul traffic. Aspects of the presented techniques include a mechanism trough which every AP may be made aware of a WMN's coverage knowledge (e.g., the topology of the mesh network), provide a fine-grained wireless channel asymmetry identification between every mesh node, leverage the WMN coverage knowledge to perform augmented RTS and CTS heuristics, and implement a multi-hop network allocation vector (NAV) channel reservation and distribution facility.

DETAILED DESCRIPTION

In a mesh topology, the traffic between access points (APs) is very closely related. For instance, on certain network equipment vendor deployments a mesh may be hierarchical and the radio traffic either flows upwards or downwards.

Under the Institute of Electrical and Electronics Engineers (IEEE) standard 802.11, the carrier-sense multiple access with collision avoidance (CSMA/CA) and Request To Send (RTS)/Clear To Send (CTS) procedures only take into account station (STA)-to-STA transmissions, leading to inefficiencies and overhead for the mesh case.

It would be desirable to improve the channel access procedure to leverage the knowledge that in a wireless mesh network (WMN) a STA that is receiving traffic is very likely to shortly emit traffic towards another STA.

Presented herein are techniques that enable collision-free RTS/CTS procedures within a WMN in order to support uplink channel access for the forwarding of backhaul traffic. Under aspects of the presented techniques, all of the APs in a WMN maintain a view of the mesh topology, in a fashion that is similar to link-state routing protocols, using the method that is described below.

For example, in accordance with techniques herein, all of the nodes periodically share their `radio_mac -> parent_mac` mapping to the root or exit point. This may be accomplished using the mesh network (through, for example, a wireless local area network (LAN) context control protocol (WLCCP)) wherein the messages are forwarded by the mesh APs on a hop-by-hop basis. The root AP or exit point aggregates and maintains the above-described data. Accordingly, the root AP has a full view of the mesh topology. Leveraging that perspective, the root AP periodically sends an aggregated view of the topology to the other mesh APs.

Figure 1, below, depicts elements of an exemplary WMN environment according to aspects of the techniques presented herein and reflective of the above discussion.

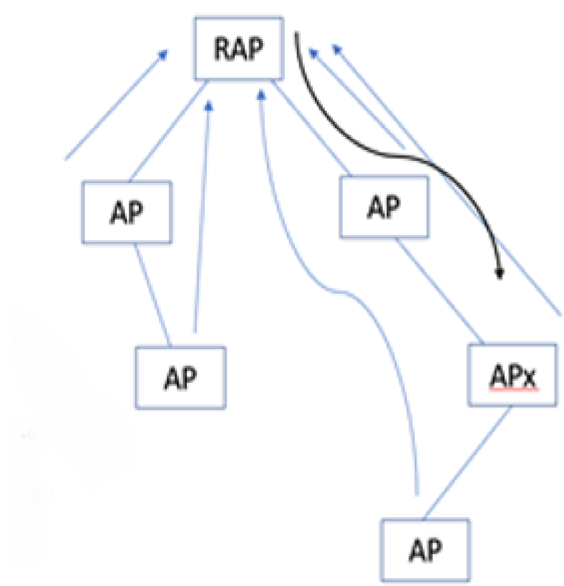

Figure 1: Exemplary WMN Environment

As illustrated in Figure 1, above, every AP informs the root AP (which is designated RAP in the figure) of the AP's neighbors and the various signal-to-noise ratio (SNR) values between its neighbors. Additionally, the RAP sends to every AP (with the specific AP APx indicated in the figure) the aggregated topology information.

The procedure that was described and illustrated above may be performed periodically so that all of the non-root APs of a tree are kept aware of the other APs.

Aspects of the techniques presented herein provide a fine-grained wireless channel asymmetry identification between every mesh node. In support of same, every AP periodically performs the procedure that is described below.

First, for each known mesh media access control (MAC) address in a tree, periodically a small number of Radio Resource Management (RRM) Neighbor Discovery Packets (NDPs) may be sent at various power levels.

Second, a mesh AP that receives such probing (according to Step 1, above) associates the sending MAC with the sent and received power levels through the mapping `src MAC -> {sent_power, recv_power}`. That data may be periodically sent to the root AP using, for example, a WLCCP.

Third, for each mesh AP the root AP may periodically send the list of all of the mesh APs that received all of the NDPs and the various power levels that were associated.

Fourth, as a consequence of the above steps every AP is aware of all of the unidirectional AP pairs that can transmit a signal along with the associated power. That information may be processed and plumbed in a driver.

While the theoretical complexity of the above is n^2 for an environment comprising n nodes, in practice it is linear as only a fixed number of nodes will hear each other (e.g., 4*n) in a proper deployment.

Aspects of the techniques presented herein leverage the WMN coverage knowledge that was described above to perform augmented RTS and CTS heuristics according to the procedures that are described below.

In connection with implementing a multi-hop network allocation vector (NAV) channel reservation and distribution facility, aspects of the techniques presented herein define a 'reservation' as the duration that is advertised in a packet and a 'distribution' as the destination MAC that is used.

An AP that has previously completed the above-described procedures will, among other things, be aware of the number of mesh nodes that it can reach towards the root AP.

Thus, when a mesh STA has a MAC Protocol Data Unit (MPDU) that it wishes to transmit towards the root AP or exit node it may send an RTS with:

- A NAV that is equal to the frame duration that is needed multiplied by the number of hops. Such an approach yields a multi-hop channel reservation that can, innovatively, span an arbitrary number of hops, and
- A destination MAC that is equal to, at most, the last mesh node MAC that is reachable by the transmitting AP. Under such an approach any intermediate node (i.e., any node that lies in between) shares the same topology knowledge and the NAV may be divided and understood within the number of hops by the intermediate APs.

APs may implicitly deduce which part or chunk of the duration time that they will be using or owning since they know that they are on the path of the RTS Receiver Address (RA) and Transmitter Address (TA). Each intermediate AP may anticipate channel usage. For instance, a top AP could still transmit on a first part if there is known channel asymmetry. To avoid long latencies that may be induced in the case of many hops, the APs are allowed to use that reservation to transmit other data to their neighbor on their allocated slot.

It is important to note that any intermediate APs may send a CTS on behalf of the last AP since they are aware of any potential asymmetry as a result of the previous procedures. Figure 2, below, depicts elements of an exemplary approach according to aspects of the techniques presented herein and reflective of the above discussion.

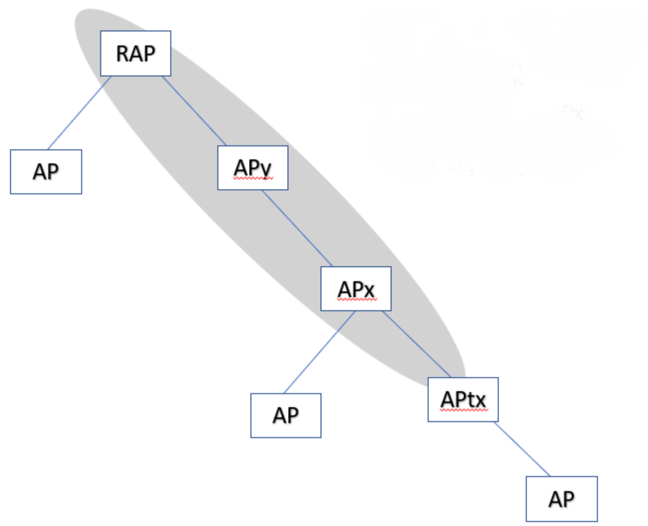

Figure 2: Exemplary Multi-Hop Arrangement

As indicated in Figure 2, above, the AP APtx may ‘reach up’ to the root AP (which is designated RAP in the figure) and may send a RTS with a NAV that includes (as described above) the combination of the duration of APtx → APx, the duration of APx → APy, and the duration of APy → RAP.

Figure 3, below, depicts elements of an exemplary RTS (that is sent by the AP APtx from Figure 2, above) according to aspects of the techniques presented herein and reflective of the preceding discussion.

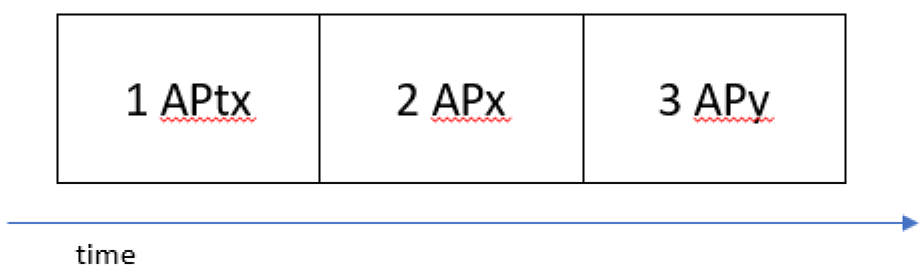

Figure 3: Exemplary RTS

As depicted in Figure 3, above, the NAV duration field in the RTS reflects three values – a first value that the AP APtx may use to transmit, a second value that the AP APx knows that it may use after the first node is passed, and a third value from which the AP APy knows that it will own the last part to transmit.

The recursive procedure that was described above may be applied either for uplink or downlink transmissions. Further, the procedure may be performed in parallel at any point in a mesh network. Additionally, the procedure provides a safeguard since mesh nodes ignore the RTS of wireless clients, and known non-clients, that have a destination MAC of one mesh AP.

Among other things, aspects of the techniques presented herein support a finer-grained RTS/CTS interpretation. With a full knowledge of channel symmetry and asymmetry, there is no need to wait for the absence of a CTS response to declare being an exposed node. Accordingly, it is possible to transmit immediately and the applicable list of possible APs is known. When receiving a CTS/CTS-self, from a knowledge of the peers that are transmitting it is possible to assert, given the unidirectional profile, to which AP the mesh AP may transmit.

It is important to note that the techniques presented herein differ from the mesh coordination function (MCF) controlled channel access (MCCA) facility, as defined in the IEEE specification 802.11S, in significant ways.

First, MCCA is a coordinated mechanism that employs coordination messages to indicate a reservation. A node must have MCCA enabled or supported in order for it to participate. Any non-enabled mesh node or neighbor will become a bottleneck.

Second, MCCA may suffer from an external interference impact since the non-MCCA mesh STAs are not aware of any MCCA reservations (i.e., acknowledgement (ACK) frames by hidden stations). In other words, since MCCA messages themselves must follow the established CSMA/CA approach they may be disrupted by a standard 802.11 reservation.

Third, aspects of the presented techniques employ knowledge of the specific mesh topology (e.g., a unique uplink to a gateway, unlike an 802.11s WMN) at each mesh node to reserve a path using standard RTS (where the mesh nodes that reside along the path understand that specific RTS message) and perform the necessary calculations, using metrics that have been collected from ongoing communications across the nodes, to reserve the channel to forward a frame that is arriving from a neighbor or other frames.

Fourth, aspects of the presented techniques handle the hidden station problem (which impacts MCCA as described in the second point, above) by allowing the intermediate mesh nodes to send a CTS on behalf of the last AP (initiating the reservation).

In summary, techniques have been presented herein that enable, within a WMN, collision-free RTS/CTS procedures supporting uplink channel access for the forwarding of backhaul traffic. Aspects of the presented techniques include a mechanism trough which every AP may be made aware of a WMN's coverage knowledge (e.g., the topology of the mesh network), provide a fine-grained wireless channel asymmetry identification between every mesh node, leverage the WMN coverage knowledge to perform augmented RTS and CTS heuristics, and implement a multi-hop NAV channel reservation and distribution facility.