

[0001] METHOD AND APPARATUS FOR SHARING SLOT
 ALLOCATION SCHEDULE INFORMATION AMONGST
 NODES OF A WIRELESS MESH NETWORK

[0002] FIELD OF INVENTION

[0003] The present invention is related to a wireless mesh network, (e.g., a wireless local area network (WLAN) mesh), including a plurality of nodes. More particularly, the present invention is related to the sharing of slot allocation schedule information amongst the nodes of a mesh network.

[0004] BACKGROUND

[0005] In an IEEE 802.11 mesh network, (e.g., a WLAN mesh), two or more nodes exchange data during periods called slots. The term "slot" implies multi-dimensional information, which may include, but is not limited to, timing information, (e.g., starting time and duration), radio frequency (RF) information, (e.g., the radio and the number of channels used by the node to exchange data), quality of service (QoS) information, (e.g., the QoS required by the data to be exchanged during the slot), peer node information, (e.g., the node identifiers for each node involved in the transmission of data during a particular slot), direction of data exchange, (e.g., unidirectional, bidirectional), or the like.

[0006] In conventional non-mesh WLANs, optional "scheduling" based on 802.11e HCCA is a one-sided procedure controlled by an AP in a basic service set (BSS). In a WLAN mesh, scheduling should be coordinated among the multiplicity of Mesh Points (MPs) that are providing WLAN mesh services.

[0007] It would be desirable to incorporate a mechanism in the nodes of a mesh network which allows the nodes to report information regarding their internal slot allocation schedule and to request such schedule information from other nodes. In order to accomplish this new level of coordination, a method and apparatus for exchanging schedule-related information among mesh points in a WLAN mesh is needed.

[0008] SUMMARY

[0009] In an IEEE 802.11 mesh network where traffic between nodes is scheduled into allocated slots, an efficient slot allocation across multiple nodes is achieved by allowing the nodes to share their own slot allocation schedule information amongst each other. This provides each node with advance knowledge of the slot availability of other nodes and thereby enables nodes to allocate slot resources in an efficient and non-conflicting manner.

[0010] The present invention provides a mechanism which allows nodes in a mesh network to report their internal slot allocation schedule to other nodes in the network, and provides a mechanism which allows nodes in the mesh network to request the internal slot allocation schedule the other nodes.

[0011] BRIEF DESCRIPTION OF THE DRAWINGS

[0012] A more detailed understanding of the invention may be had from the following description, given by way of example and to be understood in conjunction with the accompanying drawings wherein:

[0013] Figure 1 shows an information element format for slot allocation;

[0014] Figure 2 shows an enhanced information element format according to the present invention; and

[0015] Figure 3 shows an exemplary mesh network including two nodes which are configured in accordance with the present invention.

[0016] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] When referred to hereafter, a node includes but is not limited to a wireless transmit/receive unit (WTRU), a user equipment (UE), a mobile station, a fixed or mobile base station, a fixed or mobile access point (AP), a fixed or mobile subscriber unit, a pager, or any other type of device capable of operating in a wireless environment.

[0018] Within a mesh network, each node internally keeps track of the slots it has allocated after previous and mutual agreement with one or more peer nodes. During a particular slot, the node sends and receives data to/from these

peer nodes. The internal tracking record is referred hereafter as a "list of allocated slots" and comprises a list of slots. Each node includes an internal memory which stores a list of its allocated slots.

[0019] A new information element (IE) 100 is required to represent the list of allocated slots. Figure 1 shows the preferred format for an IE 100 in accordance with the present invention. The IE 100 includes a one octet element ID field 105, a one octet length field 110, and a variable-length element-specific information field 115. In accordance with the present invention, the ID field 105 indicates that the IE 100 represents a "list of allocated slots" IE. The length field 110 specifies the number of octets in the information field 115.

[0020] Figure 2 shows the new IE 100 in greater detail with respect to the information field 115. The information field 115 of the list of allocated slots IE 100 comprises a list size subfield 205, a plurality of information subfields for each slot $210_1, 210_2, \dots, 210_N$, and a slot number list size subfield 215. Each slot information subfield 210 comprises a timing information field 220, a radio frequency (RF) information field 225, a quality of service (QoS) information field 230, a peer nodes information field 235, and a direction field 240. As shown in Figure 2, the subfields shown in greater detail are with respect to slot #1. As such, the slot 1 timing information field 220 indicates a starting time and duration of the data exchange for slot #1. The RF information field 225 indicates the radio channel and the number of channels used by the node to exchange data. The QoS information field 230 indicates the QoS required by the data to be exchanged during Slot #1. The peer nodes information field 235 indicates the node identifiers for each node involved in the data transmission during Slot #1. The direction field 240 indicates whether the data exchange is uni-directional, (i.e., from one transmitter to one receiver), or bidirectional, (i.e., to/from all nodes involved), during Slot #1.

[0021] Each node is enabled to request and report its list of allocated slots. This is performed preferably by adding two additional management message types: 1) a "list of allocated slots request message" and 2) a "list of allocated slots response message". The list of allocated slots response message preferably

includes the list of allocated slots IE within its body.

[0022] The present invention introduces a modification to the existing management “action” frame. A category value “Slot Report” is added to the action frame definition in a medium access control (MAC) entity residing in each mesh node. Slot Report action frames are transmitted by a node to convey its slot allocation information to the other nodes. The Slot Report “category” is used in the management action frame to identify this new category of messages. Within this category, two aforementioned messages, “list request” and “list response”, are defined. Within the “list response” message, a new “list of allocated slots” IE is defined.

[0023] Figure 3 shows an exemplary mesh network 300 including two mesh nodes 305 and 310 which are configured in accordance with the present invention. The node 305 includes a transmitter 315, a receiver 320, a processor 325, a memory 330 and an antenna 332. The node 310 includes a transmitter 335, a receiver 340, a processor 345, a memory 350 and an antenna 352. The processor 325 in the node 305 is configured to generate a list of allocated slots request message 360, which is transmitted by the transmitter 315 via the antenna 332 of the node 305. When node 305 wants to transmit data to node 310, it has to know when node 310 is free to receive data. Thus, the node 305 requests node 310 to provide its “allocated slots,” (e.g., slots when node 310 is busy). Thus, the node 305 can request the “list of allocated slots” from node 310 to be able to allocate some free slot to exchange data with node 310.

[0024] Each memory 330 and 350 keeps track of slot allocation schedule information associated with its respective node 305, 310.

[0025] The memories 330 and 350 also keep track of the slot allocation information of other nodes besides the node that the respective memory resides in. Thus, each node can keep track of the slot allocation of another node after sending a “list of allocated slots request” and receiving a “list of allocated slots response”.

[0026] When the receiver 340 in the node 310 receives the list of allocated slots request message 360, the processor 325 retrieves the IE 100 from the

memory 350 and generates a list of allocated slots response message 365 which includes the IE 100, which is transmitted by the transmitter 335 via the antenna 352 of the node 310. Each of the processors 325 and 345 include a MAC entity (not shown) which facilitates the generation of the list of allocated slots request message 360 and the list of allocated slots response message 365.

[0027] The present invention may be implemented in a data link layer, network layer, as software, hardware, middleware, a future system architecture, radio resource management, or radio resource controller (RRC). The present invention is applicable to, but not limited to, IEEE 802.11, IEEE 802.11s, IEEE 802.15, IEEE 802.15.5, IEEE 802.16 and other relevant mesh technologies.

[0028] Embodiments

1. In a wireless mesh network including a plurality of nodes which transfer data during slots, a method of reporting slot allocation information, comprising:

each of the nodes storing slot allocation information associated with the node;

a first one of the nodes generating and transmitting a list of allocated slots request message; and

a second one of the nodes generating and transmitting a list of allocated slots response message in response to receiving the request message, the list of allocated slots response message including an information element (IE) that represents the slot allocations of the first node.

2. The method of embodiment 1 wherein the IE comprises:

an element identification (ID) field;

an element-specific information field of variable length containing the list of slot allocations; and

a length field which specifies a number of octets in the information field.

3. The method of embodiment 2 wherein the element ID field and the length field are each one octet in length.

4. The method as in any one of embodiments 2 and 3 wherein the information field comprises:

- a list size field; and
- a plurality of slot information fields.

5. The method of embodiment 4 wherein each slot information field comprises:

- a timing information field that indicates a starting time and duration of a data exchanged during a respective slot.

6. The method as in any one of embodiments 4 and 5 wherein each slot information field comprises:

- a radio frequency (RF) information field that indicates the radio channel and the number of channels used by the second node to exchange data during a respective slot.

7. The method as in any one of embodiments 4-6 wherein each slot information field comprises:

- a quality of service (QoS) information field that indicates the QoS required by the data to be exchanged during a respective slot.

8. The method as in any one of embodiments 4-7 wherein each slot information field comprises:

- a peer nodes information field that indicates node identifiers for each node involved in data transmission during a respective slot.

9. The method as in any one of embodiments 4-8 wherein each slot information field comprises:

- a direction field that indicates whether data exchanges by the second node is uni-directional from one transmitter to one receiver, or bidirectional to and from all nodes involved during a respective slot.

10. The method as in any one of embodiments 1-9 further comprising:

- including a slot report in an action frame used by a medium access control (MAC) entity located in the first node, the slot report conveying slot allocation schedule information associated with the first node to at least the second node of the wireless mesh network.

11. The method as in any one of embodiments 1-9 wherein the wireless mesh network is a wireless local area network (WLAN).

12. A wireless mesh network comprising:

a first node; and

a plurality of other nodes, wherein the first node and the other nodes transfer data during slots and store slot allocation information, the first node generates and transmits a list of allocated slots request message, and at least one of the other nodes generates and transmits a list of allocated slots response message in response to receiving the request message, the list of allocated slots response message including an information element (IE) that represents the slot allocations of the first node.

13. The wireless mesh network of embodiment 12 wherein the IE comprises:

an element identification (ID) field;

an element-specific information field of variable length containing the list of slot allocations; and

a length field which specifies a number of octets in the information field.

14. The wireless mesh network of embodiment 13 wherein the element ID field and the length field are each one octet in length.

15. The wireless mesh network as in any one of embodiments 13 and 14 wherein the information field comprises:

a list size field; and

a plurality of slot information fields.

16. The wireless mesh network as in any one of embodiments 13-15 wherein each slot information field comprises:

a timing information field that indicates a starting time and duration of a data exchanged during a respective slot.

17. The wireless mesh network as in any one of embodiments 13-16 wherein each slot information field comprises:

a radio frequency (RF) information field that indicates the radio channel and the number of channels used by the second node to exchange data during a

respective slot.

18. The wireless mesh network as in any one of embodiments 13-17 wherein each slot information field comprises:

a quality of service (QoS) information field that indicates the QoS required by the data to be exchanged during a respective slot.

19. The wireless mesh network as in any one of embodiments 13-18 wherein each slot information field comprises:

a peer nodes information field that indicates node identifiers for each node involved in data transmission during a respective slot.

20. The wireless mesh network as in any one of embodiments 13-19 wherein each slot information field comprises:

a direction field that indicates whether data exchanges by the second node is uni-directional from one transmitter to one receiver, or bidirectional to and from all nodes involved during a respective slot.

21. The wireless mesh network as in any one of embodiments 13-20 wherein a slot report is included in an action frame used by a medium access control (MAC) entity located in the first node, the slot report conveying slot allocation schedule information associated with the first node to at least the second node of the wireless mesh network.

22. The wireless mesh network as in any one of embodiments 13-22 wherein the wireless mesh network is a wireless local area network (WLAN).

23. In a wireless mesh network including a plurality of nodes which transfer data during slots, a mesh node comprising:

a memory configured to store slot allocation information associated with the mesh node;

a processor electrically coupled to the memory, the processor being configured to generate a list of allocated slots request message based on the stored slot allocation information; and

a transmitter electrically coupled to the processor, the transmitter being configured to transmit the list of allocated slots request message to another mesh node in the wireless mesh network.

24. In a wireless mesh network including a plurality of nodes which transfer data during slots, a first mesh node comprising:

a receiver configured to receive a list of allocated slots request message from a second mesh node in the wireless mesh network;

a memory configured to store an information element (IE);

a processor electrically coupled to the receiver and the memory, the processor being configured to retrieve the IE from the memory and generate a list of allocated slots response message which includes the IE in response to the receiver receiving the list of allocated slots request message; and

a transmitter electrically coupled to the processor, the transmitter being configured to transmit the list of allocated slots response message to the second mesh node.

25. The first mesh node of embodiment 24 wherein the IE comprises:
an element identification (ID) field;

an element-specific information field of variable length containing the list of slot allocations; and

a length field which specifies a number of octets in the information field.

26. The first mesh node of embodiment 25 wherein the element ID field and the length field are each one octet in length.

27. The first mesh node of embodiment 25 wherein the information field comprises:

a list size field; and

a plurality of slot information fields.

28. The first mesh node of embodiment 27 wherein each slot information field comprises:

a timing information field that indicates a starting time and duration of a data exchanged during a respective slot.

29. The first mesh node of as in any one of embodiments 27 and 28 wherein each slot information field comprises:

a radio frequency (RF) information field that indicates the radio channel and the number of channels used by the second mesh node to exchange data

during a respective slot.

30. The first mesh node as in any one of embodiments 27-29 wherein each slot information field comprises:

a quality of service (QoS) information field that indicates the QoS required by the data to be exchanged during a respective slot.

31. The first mesh node as in any one of embodiments 27-30 wherein each slot information field comprises:

a peer nodes information field that indicates node identifiers for each node involved in data transmission during a respective slot.

32. The first mesh node as in any one of embodiments 27-31 wherein each slot information field comprises:

a direction field that indicates whether data exchanges by the second mesh node is uni-directional from one transmitter to one receiver, or bidirectional to and from all nodes involved during a respective slot.

33. The first mesh node as in any one of embodiments 24-32 wherein the wireless mesh network is a wireless local area network (WLAN).

[0029] Although the features and elements of the present invention are described in the preferred embodiments in particular combinations, each feature or element can be used alone (without the other features and elements of the preferred embodiments) or in various combinations with or without other features and elements of the present invention.

* * *

CLAIMS

What is claimed is:

1. In a wireless mesh network including a plurality of nodes which transfer data during slots, a method of reporting slot allocation information, comprising:

each of the nodes storing slot allocation information associated with the node;

a first one of the nodes generating and transmitting a list of allocated slots request message; and

a second one of the nodes generating and transmitting a list of allocated slots response message in response to receiving the request message, the list of allocated slots response message including an information element (IE) that represents the slot allocations of the first node.

2. The method of claim 1 wherein the IE comprises:

an element identification (ID) field;

an element-specific information field of variable length containing the list of slot allocations; and

a length field which specifies a number of octets in the information field.

3. The method of claim 2 wherein the element ID field and the length field are each one octet in length.

4. The method of claim 2 wherein the information field comprises:

a list size field; and

a plurality of slot information fields.

5. The method of claim 4 wherein each slot information field comprises:

a timing information field that indicates a starting time and duration of a data exchanged during a respective slot.

6. The method of claim 4 wherein each slot information field comprises:

a radio frequency (RF) information field that indicates the radio channel and the number of channels used by the second node to exchange data during a respective slot.

7. The method of claim 4 wherein each slot information field comprises:

a quality of service (QoS) information field that indicates the QoS required by the data to be exchanged during a respective slot.

8. The method of claim 4 wherein each slot information field comprises:

a peer nodes information field that indicates node identifiers for each node involved in data transmission during a respective slot.

9. The method of claim 4 wherein each slot information field comprises:

a direction field that indicates whether data exchanges by the second node is uni-directional from one transmitter to one receiver, or bidirectional to and from all nodes involved during a respective slot.

10. The method of claim 1 further comprising:

including a slot report in an action frame used by a medium access control (MAC) entity located in the first node, the slot report conveying slot allocation schedule information associated with the first node to at least the second node of the wireless mesh network.

11. The method of claim 1 wherein the wireless mesh network is a wireless local area network (WLAN).

12. A wireless mesh network comprising:

a first node; and

a plurality of other nodes, wherein the first node and the other nodes transfer data during slots and store slot allocation information, the first node generates and transmits a list of allocated slots request message, and at least one of the other nodes generates and transmits a list of allocated slots response message in response to receiving the request message, the list of allocated slots response message including an information element (IE) that represents the slot allocations of the first node.

13. The wireless mesh network of claim 12 wherein the IE comprises:

an element identification (ID) field;

an element-specific information field of variable length containing the list of slot allocations; and

a length field which specifies a number of octets in the information field.

14. The wireless mesh network of claim 13 wherein the element ID field

and the length field are each one octet in length.

15. The wireless mesh network of claim 13 wherein the information

field comprises:

a list size field; and

a plurality of slot information fields.

16. The wireless mesh network of claim 15 wherein each slot

information field comprises:

a timing information field that indicates a starting time and duration of a data exchanged during a respective slot.

17. The wireless mesh network of claim 15 wherein each slot

information field comprises:

a radio frequency (RF) information field that indicates the radio channel and the number of channels used by the second node to exchange data during a respective slot.

18. The wireless mesh network of claim 15 wherein each slot information field comprises:

a quality of service (QoS) information field that indicates the QoS required by the data to be exchanged during a respective slot.

19. The wireless mesh network of claim 15 wherein each slot information field comprises:

a peer nodes information field that indicates node identifiers for each node involved in data transmission during a respective slot.

20. The wireless mesh network of claim 15 wherein each slot information field comprises:

a direction field that indicates whether data exchanges by the second node is uni-directional from one transmitter to one receiver, or bidirectional to and from all nodes involved during a respective slot.

21. The wireless mesh network of claim 12 wherein a slot report is included in an action frame used by a medium access control (MAC) entity located in the first node, the slot report conveying slot allocation schedule information associated with the first node to at least the second node of the wireless mesh network.

22. The wireless mesh network of claim 12 wherein the wireless mesh network is a wireless local area network (WLAN).

23. In a wireless mesh network including a plurality of nodes which transfer data during slots, a mesh node comprising:

a memory configured to store slot allocation information associated with the mesh node;

a processor electrically coupled to the memory, the processor being configured to generate a list of allocated slots request message based on the stored slot allocation information; and

a transmitter electrically coupled to the processor, the transmitter being configured to transmit the list of allocated slots request message to another mesh node in the wireless mesh network.

24. In a wireless mesh network including a plurality of nodes which transfer data during slots, a first mesh node comprising:

a receiver configured to receive a list of allocated slots request message from a second mesh node in the wireless mesh network;

a memory configured to store an information element (IE);

a processor electrically coupled to the receiver and the memory, the processor being configured to retrieve the IE from the memory and generate a list of allocated slots response message which includes the IE in response to the receiver receiving the list of allocated slots request message; and

a transmitter electrically coupled to the processor, the transmitter being configured to transmit the list of allocated slots response message to the second mesh node.

25. The first mesh node of claim 24 wherein the IE comprises:

an element identification (ID) field;

an element-specific information field of variable length containing the list of slot allocations; and

a length field which specifies a number of octets in the information field.

26. The first mesh node of claim 25 wherein the element ID field and the length field are each one octet in length.

27. The first mesh node of claim 24 wherein the information field comprises:

- a list size field; and
- a plurality of slot information fields.

28. The first mesh node of claim 27 wherein each slot information field comprises:

- a timing information field that indicates a starting time and duration of a data exchanged during a respective slot.

29. The first mesh node of claim 27 wherein each slot information field comprises:

- a radio frequency (RF) information field that indicates the radio channel and the number of channels used by the second mesh node to exchange data during a respective slot.

30. The first mesh node of claim 27 wherein each slot information field comprises:

- a quality of service (QoS) information field that indicates the QoS required by the data to be exchanged during a respective slot.

31. The first mesh node of claim 27 wherein each slot information field comprises:

- a peer nodes information field that indicates node identifiers for each node involved in data transmission during a respective slot.

32. The first mesh node of claim 27 wherein each slot information field comprises:

a direction field that indicates whether data exchanges by the second mesh node is uni-directional from one transmitter to one receiver, or bidirectional to and from all nodes involved during a respective slot.

33. The first mesh node of claim 24 wherein the wireless mesh network is a wireless local area network (WLAN).