

[0001] METHOD FOR SENDING AN ACKNOWLEDGEMENT TO
AN INGRESS MESH POINT IN A MESH NETWORK
AND A MEDIUM ACCESS CONTROL FRAME FORMAT

[0002] FIELD OF INVENTION

[0003] The present invention relates to wireless communication systems. More particularly, the present invention relates to a method for sending an acknowledgement (ACK) to an ingress mesh point (IMP) in a mesh network and a medium access control (MAC) frame format.

[0004] BACKGROUND

[0005] A mesh wireless local area network (WLAN) is a wireless network comprising two or more mesh points interconnected via wireless links. The mesh network typically serves one or more wireless stations (STAs) within the operating range of the mesh network. A mesh point is any entity within the mesh network which contains a MAC and physical layer (PHY) interface to a wireless medium and supports WLAN mesh services. An IMP is a mesh point through which data enters the mesh WLAN and an egress mesh point (EMP) is a mesh point through which data exits the mesh WLAN. Data sent by a STA is routed from the IMP to the EMP through the mesh WLAN.

[0006] IEEE 802.11 standards are one of the standards defining the wireless protocol for a mesh WLAN. Current IEEE 802.11 standards define an acknowledged mode that allows for more reliable data delivery at the lower layers. However, the current acknowledgement mechanism does not work in a mesh network since multiple hops are required over the mesh network before the data is delivered to the destination.

[0007] In a mesh WLAN, a communication between an IMP and an EMP can be required. As shown in Figure 2, a prior art MAC frame does not contain IMP MAC address during the multi-hop transmissions. Therefore, the EMP is unable to identify and communicate with the IMP. There is no mechanism or frame format for sending an acknowledgement between the IMP and the EMP in the mesh WLAN. This seriously limits the reliability of the data delivery. Since

there is no ACK mechanism between the IMP and the EMP, the IMP cannot know if the data through the mesh network has been correctly received by the EMP.

[0008] SUMMARY

[0009] In accordance with a first aspect of the present invention, there is provided a medium access control (MAC) frame in mesh wireless communication system, the system comprising a plurality of mesh points that are wirelessly linked together such that a data packet sent by a station (STA) is received by an ingress mesh point (IMP) in order to provide a service by the mesh wireless communication system, the MAC frame being used for transmission of the data packet, and the MAC frame comprising: a field comprising an IMP address and an egress mesh point (EMP) address, whereby an acknowledgement (ACK) for successful reception of the data packet is sent to the IMP.

[0009a] In accordance with a second aspect of the present invention, there is provided a method in a mesh wireless communication system comprising a plurality of mesh points that are wirelessly linked together such that a data packet sent by a station (STA) is received by an ingress mesh point (IMP) and forwarded to an egress mesh point (EMP) in order to provide a service by the mesh wireless communication system, the method being used for sending an acknowledgement (ACK) for the data packet to the IMP, and the method comprising: generating a medium access control (MAC) frame for transmission of a data packet, the MAC frame including a field comprising an IMP address and an EMP address; forwarding the MAC frame to the EMP via zero or more intermediate mesh point; and receiving an ACK at the IMP on condition that the data packet was successfully received by the EMP.

[0009b] Embodiments of the present invention relate to a method for confirming the delivery of a data packet in a mesh network by sending an ACK to an IMP. The mesh network may comprise a plurality of mesh points that are wirelessly linked together. A data packet may be sent by a STA is received by an IMP. A MAC frame may be generated for transmission of the data packet and the frame is forwarded to an EMP in order to provide a service by the mesh network. The MAC frame may include a field comprising an IMP address and an EMP address. When the EMP, (or optionally an intermediate mesh point), receives a

data packet successfully, the EMP or the intermediate mesh point may send an ACK to the IMP or preceding mesh point.

[0010] BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A more detailed understanding of the invention may be had from the following description of a preferred embodiment, given by way of example and to be understood in conjunction with the accompanying drawing wherein:

[0012] Figure 1 is a diagram of a mesh WLAN in which the present invention is implemented;

[0013] Figure 2 is a diagram of a prior art MAC frame;

[0014] Figure 3 is a signaling diagram for transmission of data and acknowledgement between an IMP, an EMP and intervening mesh points in accordance with the present invention;

[0015] Figure 4 is a diagram of a mesh MAC frame in accordance with the present invention; and

[0016] Figure 5 is a flow diagram of a process for sending an ACK to the IMP in accordance with the present invention.

[0017] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Hereafter, the terminology "station" (STA) includes but is not limited to a user equipment, a wireless transmit/receive unit (WTRU), a fixed or mobile subscriber unit, a pager, or any other type of device capable of operating in a wireless environment. When referred to hereafter, the terminology "mesh point" includes but is not limited to a Node-B, a base station, a site controller, an access point or any other type of interfacing device in a wireless environment.

[0019] The present invention is applicable to any wireless mesh networks including, but not limited to, IEEE 802.11, IEEE 802.11s, IEEE 802.15, IEEE 802.15.5.

[0020] Figure 1 is a diagram of an exemplary mesh WLAN 100 comprising eight (8) mesh points 104₁-104₈. In this example, mesh point 104₄ is an IMP for the STA 102 and mesh point 104₂ is an EMP for the data sent by the STA 102.

[0021] Data sent by the STA 102 is routed from one mesh point 104₄ to another mesh point 104₂ through the intermediate mesh points in the mesh WLAN 100 for the Internet access. Multiple data paths can be established within the mesh WLAN 100. As an example, two different data paths from the IMP mesh point 104₄ to the EMP mesh point 104₂ are illustrated by the solid lines designated "A" and "B" in Figure 1.

[0022] As aforementioned with reference to Figure 2, a drawback with the prior art 802.11 MAC frame format is that the IMP address is not included in the MAC frame in a multi-hop transmission. The present invention solves this problem by including the IMP address in the MAC frame 400. Referring to Figure 4, a diagram of a mesh MAC frame 200 in accordance with the present invention is shown. The MAC frame 200 includes a MAC header 204, a frame body 212 and a frame check sequence (FCS) field 214. This aspect of the MAC frame format is same to the one in prior art, which guarantees backward compatibility. The MAC header 204 includes a frame control, a duration/ID, address 1, address 2, address 3, a sequence control and address 4. These elements are well known to those of skill in the art.

[0023] In accordance with the present invention, however, the MAC header 204 further includes a mesh control field 202. The mesh control field 202 comprises an IMP address field 206 and an EMP address field 208. The receiving mesh point recognizes the IMP 104₄ and the EMP 104₂ with the mesh control field 202 and may send an ACK to the IMP 104₄ or other intermediate mesh point in accordance with the IMP address field 206. It should be noted that the MAC frame format in Figure 4 is provided as an example and the mesh control field 202 may be included in any location in the MAC frame 200 and the length of the IMP and EMP address fields may vary.

[0024] A routing function is available in each mesh point, which allows the mesh point, based on the EMP address included in the mesh control field 202, to know which path used to route the data. When the IMP 104₄ receives an ACK, the IMP 104₄ can discard the related data in its queue. If the IMP 104₄ receives a non-acknowledgement (NACK), the IMP 104₄ re-transmits the data. To avoid any buffer overflow, the IMP 104₄ should discard the data from its queue after a certain amount of time (time-out) if the IMP 104₄ does not receive ACK nor NACK from the EMP 104₂.

[0025] Figure 3 is a signaling diagram for transmission along data path "B" of a data packet and an ACK between an IMP (in this example mesh point 104₄), an EMP (in this example mesh point 104₂) and intermediate mesh points 104₇, 104₈, 104₆, 104₃, (not all of which are shown in Figure 3 for convenience), in accordance with the present invention. The data packet is forwarded from the IMP 104₄ to the EMP 104₂ through the intermediate mesh points 104₇, 104₈, 104₆, 104₃. As will be explained in detail hereinafter, the MAC frame 200 contains both IMP 104₄ and EMP 104₂ addresses in the IMP address field 206 and the EMP address field 208. When the intermediate mesh points 104₇, 104₈, 104₆, 104₃ and the EMP 104₂ receive a data packet successfully, the intermediate mesh points 104₇, 104₈, 104₆, 104₃ and the EMP 104₂ send an ACK to either the preceding intermediate mesh point or the IMP 104₄. It should be noted that Figure 3 is an example and zero or any number of intermediate mesh points may exist between the IMP 104₄ and the EMP 104₂. Additionally, the intermediate

mesh points used to send the ACK may be same mesh points via which the data packet is forwarded or may be different mesh points.

[0026] The acknowledgement mechanism of the present invention supports both single and multiple-hop data delivery over a mesh WLAN. The acknowledgement mechanism operates in four modes: 1) EMP-to-IMP data acknowledgement for more reliable data transfer, (e.g., FTP, HTTP); 2) single-hop data acknowledgement for reliable data transfer; 3) combined EMP-to-IMP and single-hop data acknowledgement for very-reliable data transfer, (e.g., signaling); and 4) no acknowledgement for high-throughput, packet-loss resilient, delay sensitive data transfer, (e.g., video/audio streaming).

[0027] In the first mode, (EMP-to-IMP acknowledgement), the acknowledgement is done through all the paths. Whenever the EMP receives a packet sent by the IMP, the EMP sends back an ACK to the originator using the IMP address included in the received packet.

[0028] In the second mode, (single hop acknowledgement), the acknowledgement is done at every hop between the transmitting mesh point and the next immediate receiving mesh point.

[0029] The third mode, (combined EMP-to-IMP acknowledgement and single hop acknowledgement), combines the first mode and the second mode.

[0030] In the fourth mode, no acknowledgement is required between the IMP and the EMP. Although this impacts the reliability of the data delivery, it reduces the delay in transmission.

[0031] A new frame subtype for the frame subtype information element in the frame control field 210 (shown in Figure 4) is also defined for indicating that the MAC frame 200 includes the IMP address field 206 and the EMP address field 208. The frame control field 210 may also inform which acknowledgement mode among the four modes stated above is to be used for this data packet.

[0032] For the first and third mode among the four modes stated above, the MAC frame format allows for an EMP-to-IMP ACK to be transmitted through another path different from the one used for transmission of the data packet. To reduce the delay of transmission, the sender does not need to wait for the ACK to

be received before sending the next frame, (i.e., sending and acknowledging can be asynchronous). In this case the bulk ACK can be used to reduce traffic on the network. An ACK can also be sent purposely via different paths depending on the traffic level in order to reduce contention of ACKs with data. This mechanism could be used for delay sensitive and error tolerant applications such as voice application.

[0033] Figure 5 is a flow diagram of a process 300 for sending an ACK to the IMP in accordance with the present invention. A MAC frame is generated by attaching a MAC header to a data packet (step 302). The MAC header includes fields for an IMP address and an EMP address. The MAC frame is forwarded to the EMP either directly or via one or more intermediate mesh points (step 304). The intermediate mesh point, if there is any, and the EMP sends an ACK for successful reception of the data packet to the IMP (step 306).

[0034] 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.

* * *

EMBODIMENTS

1. A wireless station (STA) comprising:
means for processing a medium access control (MAC) frame.
2. The STA of embodiment 1 for use in a mesh network.
3. The STA of any preceding embodiment using IEEE 802.11 wireless protocols.
4. The STA of any preceding embodiment using IEEE 802.11s wireless protocols.
5. The STA of any preceding embodiment using 802.15 wireless protocols.
6. The STA of any preceding embodiment using 802.15.5 wireless protocols.
7. The STA of any preceding embodiment using 802.16 wireless protocols.
8. The STA of any preceding embodiment wherein the MAC frame includes an IMP address.
9. The STA of embodiment 8 wherein the IMP address indicates an address of an ingress point to a MESH network.
10. The STA of any preceding embodiment wherein the MAC frame includes a MAC header.

11. The STA of any preceding embodiment wherein the MAC frame includes a frame body.

12. The STA of any preceding embodiment wherein the MAC frame includes a frame check sequence field.

13. The STA of any preceding embodiment wherein the MAC frame includes a MAC header and the MAC header includes a frame control.

14. The STA of any preceding embodiment wherein the MAC frame includes a MAC header and the MAC header includes a duration/ID.

15. The STA of any preceding embodiment wherein the MAC frame includes a MAC header and the MAC header includes an address field.

16. The STA of any preceding embodiment wherein the MAC frame includes a MAC header and the MAC header includes a plurality of address fields.

17. The STA of any preceding embodiment wherein the MAC frame includes a MAC header and the MAC header includes a sequence control.

18. The STA of any preceding embodiment wherein the MAC frame includes a MAC header and the MAC header includes a mesh control field.

19. The STA of any preceding embodiment wherein the MAC frame includes a mesh control field and the mesh control field includes an IMP address field.

20. The STA of any preceding embodiment wherein the MAC frame includes a mesh control field and the mesh control field includes an EMP address field.

21. The STA of embodiment 20 wherein the EMP address field indicates an egress point from a wireless mesh network.

22. The STA of any preceding embodiment comprising means for sending an acknowledgement to an IMP address.

23. The STA of any preceding embodiment wherein if the STA is an ingress point to a mesh network, the STA upon receipt of an acknowledgement discards associated data in its queue.

23. The STA of any preceding embodiment wherein if the STA is an ingress point to a mesh network, the STA upon receipt of a negative acknowledgement retransmits associated data in its queue.

24. The STA of any preceding embodiment wherein if the STA is an ingress point to a mesh network, the STA when not receiving an acknowledgement or a negative acknowledgement after a certain time period, discards associated data in its queue.

25. The STA of any preceding embodiment wherein upon successful receipt of the MAC frame sending an acknowledgment.

26. The STA of embodiment 25 wherein the acknowledgment follow a different path in the mesh network than the MAC frame.

27. The STA of embodiment 25 wherein the acknowledgement is sent using a single hop delivery over a mesh network.

28. The STA of embodiment 25 wherein the acknowledgement is sent using a multiple-hop delivery over a mesh network.

29. The STA of embodiment 25 wherein the acknowledgment is sent to an ingress address.

30. The STA of embodiment 25 wherein the acknowledgement is sent to an ingress address using a single-hop data acknowledgement.

31. The STA of any one of embodiments 1-21 wherein no acknowledgement is sent.

32. The STA of embodiment 25 wherein the acknowledgment is sent from an egress address to an ingress address.

33. The STA of embodiment 25 wherein the acknowledgement is sent from an egress address to an ingress address using a single-hop data acknowledgement.

34. The STA of any preceding claim wherein the STA transmits a next frame prior to receiving an acknowledgement from a prior frame.

35. A mesh system comprising at least one STA of any preceding claim.

36. The mesh system comprising a STA of any one of claim 1-34 and at least one other STA.

37. A method employing a STA of any one of claim 1-34.

38. A method employing a mesh system of any one of claims 35-36.

39. A method comprising:
providing a medium access control (MAC) frame.
40. The method of embodiment 39 for use with a wireless station (STA).
41. The method of embodiment 39 for use in a mesh network.
42. The method of any one of embodiments 39-41 using IEEE 802.11 wireless protocols.
43. The method of any one of embodiments 39-42 using IEEE 802.11s wireless protocols.
44. The method of any one of embodiments 39-43 using 802.15 wireless protocols.
45. The method of any one of embodiments 39-44 using 802.15.5 wireless protocols.
46. The method of any one of embodiments 39-45 using 802.16 wireless protocols.
47. The method of any one of embodiments 39-46 wherein the MAC frame includes an IMP address.
48. The method of embodiment 47 wherein the IMP address indicates an address of an ingress point to a MESH network.
49. The method of any one of embodiments 39-48 wherein the MAC frame includes a MAC header.

50. The method of any one of embodiments 39-49 wherein the MAC frame includes a frame body.

51. The method of any one of embodiments 39-50 wherein the MAC frame includes a frame check sequence field.

52. The method of any one of embodiments 39-51 wherein the MAC frame includes a MAC header and the MAC header includes a frame control.

53. The method of any one of embodiments 39-52 wherein the MAC frame includes a MAC header and the MAC header includes a duration/ID.

54. The method of any one of embodiments 39-53 wherein the MAC frame includes a MAC header and the MAC header includes an address field.

55. The method of any one of embodiments 39-54 wherein the MAC frame includes a MAC header and the MAC header includes a plurality of address fields.

56. The method of any one of embodiments 39-55 wherein the MAC frame includes a MAC header and the MAC header includes a sequence control.

57. The method of any one of embodiments 39-56 wherein the MAC frame includes a MAC header and the MAC header includes a mesh control field.

58. The method of any one of embodiments 39-57 wherein the MAC frame includes a mesh control field and the mesh control field includes an IMP address field.

59. The method of any one of embodiments 39-58 wherein the MAC frame includes a mesh control field and the mesh control field includes an EMP address field.

60. The method of any one of embodiments 39-59 wherein the EMP address field indicates an egress point from a wireless mesh network.

61. The method of any one of embodiments 39-60 comprising sending an acknowledgement to an IMP address.

62. The method of any one of embodiments 39-61 wherein if the STA is an ingress point to a mesh network, the STA upon receipt of an acknowledgement discards associated data in its queue.

63. The method of any one of embodiments 39-62 wherein if the STA is an ingress point to a mesh network, the STA upon receipt of a negative acknowledgement retransmits associated data in its queue.

64. The method of any one of embodiments 39-63 wherein if the STA is an ingress point to a mesh network, the STA when not receiving an acknowledgement or a negative acknowledgement after a certain time period, discards associated data in its queue.

65. The method of any one of embodiments 39-64 wherein upon successful receipt of the MAC frame sending an acknowledgment.

66. The method of embodiment 65 wherein the acknowledgment follow a different path in the mesh network than the MAC frame.

67. The method of embodiment 65 wherein the acknowledgement is sent using a single hop delivery over a mesh network.

68. The method of embodiment 65 wherein the acknowledgement is sent using a multiple-hop delivery over a mesh network.

69. The method of embodiment 65 wherein the acknowledgment is sent to an ingress address.

70. The method of embodiment 65 wherein the acknowledgement is sent to an ingress address using a single-hop data acknowledgement.

71. The method of any one of embodiments 39-64 wherein no acknowledgement is sent.

72. The method of embodiment 65 wherein the acknowledgment is sent from an egress address to an ingress address.

73. The method of embodiment 65 wherein the acknowledgement is sent from an egress address to an ingress address using a single-hop data acknowledgement.

74. The method of any one of embodiments 39-73 wherein the STA transmits a next frame prior to receiving an acknowledgement from a prior frame.

CLAIMS

What is claimed is:

1. A medium access control (MAC) frame in mesh wireless communication system, the system comprising a plurality of mesh points that are wirelessly linked together such that a data packet sent by a station (STA) is received by an ingress mesh point (IMP) in order to provide a service by the mesh wireless communication system, the MAC frame being used for transmission of the data packet, and the MAC frame comprising:
 - a field comprising an IMP address and an egress mesh point (EMP) address,
 - whereby an acknowledgement (ACK) for successful reception of the data packet is sent to the IMP.
2. The MAC frame of claim 1 wherein a frame control field of the MAC frame indicates that the MAC frame contains the IMP address and the EMP address.
3. The MAC frame of claim 1 wherein a frame control field of the MAC frame indicates an acknowledgement mode to be used for the data packet.
4. The MAC frame of claim 1 wherein the ACK is sent in an EMP-to-IMP data acknowledgement mode.
5. The MAC frame of claim 1 wherein the ACK is sent in a single-hop data acknowledgement mode.
6. The MAC frame of claim 1 wherein the ACK is sent in a combined EMP-to-IMP and single-hop data acknowledgement mode.
7. The MAC frame of claim 3 wherein the frame control field indicates that no acknowledgement should be sent for the data packet.

8. The MAC frame of claim 1 wherein the ACK is transmitted through a path different from a path used for transmission of the data packet.

9. The MAC frame of claim 8 wherein a bulk ACK is used for acknowledging multiple data packets.

10. The MAC frame of claim 8 wherein the ACK is sent via a different path in purpose depending on traffic level.

11. A method in a mesh wireless communication system comprising a plurality of mesh points that are wirelessly linked together such that a data packet sent by a station (STA) is received by an ingress mesh point (IMP) and forwarded to an egress mesh point (EMP) in order to provide a service by the mesh wireless communication system, the method being used for sending an acknowledgement (ACK) for the data packet to the IMP, and the method comprising:

generating a medium access control (MAC) frame for transmission of a data packet, the MAC frame including a field comprising an IMP address and an EMP address;

forwarding the MAC frame to the EMP via zero or more intermediate mesh point; and

receiving an ACK at the IMP on condition that the data packet was successfully received by the EMP.

12. The method of claim 11 wherein a frame control field of the MAC frame indicates that the MAC frame contains the IMP address and the EMP address.

13. The method of claim 11 wherein a frame control field of the MAC frame indicates an acknowledgement mode to be used for the data packet.

14. The method of claim 11 wherein the ACK is sent in an EMP-to-IMP data acknowledgement mode.

15. The method of claim 11 wherein the ACK is sent in a single-hop data acknowledgement mode.

16. The method of claim 11 wherein the ACK is sent in a combined EMP-to-IMP and single-hop data acknowledgement mode.

17. The method of claim 16 wherein the frame control field indicates that no acknowledgement should be sent for the data packet.

18. The method of claim 11 wherein the ACK is transmitted through a path different from a path used for transmission of the data packet.

19. The method of claim 18 wherein a bulk ACK is used for acknowledging multiple data packets.

20. The method of claim 18 wherein the ACK is sent via a different path in purpose depending on traffic level.