

MANAGING ASSOCIATIONS IN AD HOC NETWORKS

Technical Field

This invention relates to wireless networks and, more particularly, to ad hoc
5 networks of wireless devices that are in proximity to each other.

Background

In a typical wireless network, one or more wireless devices are associated with
a common wireless access point, which may be connected to a wired network.
Communication between wireless devices is through the access point. Such operation
10 is known as the infrastructure operating mode.

The IEEE 802.11 standard for wireless local area networks (LANs) provides
for an ad hoc operating mode in which wireless devices communicate directly with
each other without the use of a wireless access point or a wired network. However, in
order to operate an ad hoc network of wireless devices, the wireless devices require a
15 mechanism to associate with, or connect to, other wireless network devices in
proximity. Such a mechanism should have low power consumption, should create
limited radio interference and should have high throughput.

Summary

The present invention provides methods and apparatus to establish an
20 association between wireless devices in an ad hoc network. A first wireless device
establishes an association with a second wireless device by sending a connection
request packet to a previously-discovered second wireless device. The second
wireless device identifies the received packet as a connection request and responds
with a connection response packet, thereby establishing an association between the
25 first and second wireless devices. The wireless devices can then, for example, send
and receive data.

The invention also provides methods to terminate an association between
wireless devices and methods to disconnect from an ad hoc network. The invention
further provides methods to handle a case where two wireless devices send connection
30 requests to each other concurrently. In this case, the connection request of the
wireless device having a larger network address is processed, and the connection

request of the wireless device having a smaller network address is canceled. It will be understood that the criteria can be reversed so that the connection request of the wireless device with the smaller network address is processed and the connection request of the wireless device with the larger network address is canceled.

5 According to a first aspect of the invention, a method is provided to operate a wireless device in an ad hoc network. The method comprises: turning on a radio of a first wireless device in response to a connect call; sending a connection request packet from the first wireless device to a second wireless device; if a connection response packet is received by the first wireless device from the second wireless device within
10 a timeout period, establishing a connection to the second wireless device; and if a connection response packet is not received by the first wireless device from the second wireless device within the timeout period, indicating a connection failure.

 According to a second aspect of the invention, a method is provided to operate a wireless device in an ad hoc network. The method comprises: a first wireless device
15 receiving a connection request packet from a second wireless device; if the connection request packet is identified by the first wireless device as a valid connection request, sending a connection response packet to the second wireless device and recording an established connection; and if the connection request packet is not identified by the first wireless device as a valid connection request, remaining in an existing state.

20 According to a third aspect of the invention, a wireless device comprises: a computing device; a radio; and a wireless module logically connected to the computing device and to the radio, the wireless module comprising a processor programmed with instructions for: turning on the radio in response to a connect call; sending a connection request packet to a second wireless device; if a connection
25 response packet is received from the second wireless device within a timeout period, establishing a connection to the second wireless device; and if a connection response packet is not received from the second wireless device within the timeout period, indicating a connection failure.

Brief Description of the Drawings

In the drawings:

FIG. 1 is a simplified block diagram of an ad hoc wireless network;

FIG. 2 is a simplified block diagram of a wireless device suitable for forming
5 an ad hoc wireless network;

FIG. 3 is a flow chart of operations performed by a first wireless device to establish a connection to a second wireless device;

FIG. 4 is a flow chart of operations performed by the second wireless device to establish a connection to the first wireless device;

10 FIG. 5 is a flow chart of operations performed by a wireless device when concurrent connection requests are sent by two wireless devices;

FIG. 6 is a flow chart of operations performed by a first wireless device to terminate a connection to a second wireless device; and

15 FIG. 7 is a flow chart of operations performed by the second wireless device to terminate the connection to the first wireless device.

Detailed Description

Embodiments of the invention provide mechanisms for a wireless device to establish an association, or connection, with another wireless device in an ad hoc network. Further embodiments of the invention provide mechanisms to terminate an
20 association between wireless devices and methods for a wireless device to disconnect from an ad hoc network.

These mechanisms involve software in the wireless devices. The mechanisms can also be implemented in hardware and/or firmware of a wireless device. This allows wireless devices having these mechanisms to communicate and to form ad hoc
25 wireless networks. The communication between wireless devices in the ad hoc network has no effect on other wireless devices that do not support these mechanisms.

An example of a wireless ad hoc network 10 is shown in Fig. 1. Wireless devices 12, 14 and 16 communicate with each other by a wireless links. The wireless devices communicate using the mechanisms described below. It is assumed that each wireless device is within radio range of at least one other wireless device in the ad hoc network. It will be understood that all wireless devices in the ad hoc network do not need to be within radio range. For example, wireless devices 14 and 16 may be able to communicate directly with wireless device 12 but may not be able to communicate directly with each other. By way of example only, wireless devices 12, 14 and 16 may be laptop computers, mobile phones, mobile data devices, portable media player devices, home stereos, wireless speakers, or combinations of such devices which utilize a compatible protocol as described below.

A simplified block diagram of a wireless device 200 including components involved in communication in an ad hoc network is shown in Fig. 2. Wireless device 200 may correspond to wireless devices 12, 14 and 16 shown in Fig. 1. An upper layer device CPU 210 interfaces with peripheral components present in the wireless device, such as a display, a keypad or a keyboard, a pointing device, a storage unit such as a disk unit or a flash memory and any other peripheral components of the device. Device CPU 210 includes a device operating system 212 and a wireless driver 214. The wireless driver 214 communicates with a second layer wireless module CPU 220 containing wireless module software 222. The wireless module software 222 interfaces with a lower layer wireless RF interface 230 which communicates with a radio that transmits and receives RF signals via an antenna.

The wireless device 200 may represent a variety of different devices that may be hand-held and mobile or stationary. Examples of wireless devices include, but are not limited to, laptop computers, desktop computers, mobile data devices, mobile phones, stereo systems, and wireless speakers.

The operations of each wireless device in establishing associations with other wireless devices are described below. Operation is described in connection with the IEEE 802.11 standard. However, the present invention is not limited to the 802.11 standard and can be utilized in connection with other wireless protocols, such as Ultra

Wide Band and WiNet. It will be understood that the operations described below are embodiments only and are not limiting as to the scope of the invention.

Prior to establishing associations as described below, each wireless device discovers other wireless devices in the ad hoc network. Preferred techniques for
5 discovering wireless devices are described in the related applications referenced above. However, other discovery techniques may be utilized. After an association is established, data can be sent and received by the associated wireless devices.

Establish an Association with a Wireless Device in Ad Hoc Networks

A flow chart of operations performed by a first wireless device to establish an
10 association with a second wireless device in an ad hoc network is shown in FIG. 3.

If a wireless device decides to establish an association with another device in an ad hoc network, it becomes an association requestor and does the following:

- 1) Set the following settings:

Channel number or frequency (of the ad hoc network),

15 Desired SSID (of the target ad hoc network to associate with),

Desired BSSID (of the target ad hoc network to associate with), and

Mac address (of the target device to associate with).

- 2) The wireless service issues a connection call to the wireless module, step 300.

20 Connect (to associate with a device in an ad hoc network with Mac address
and the BSSID/SSID as configured above)

- 3) Upon receiving a connect call from the upper layer, the wireless module does the following:

Switch the channel or frequency to the one the ad hoc network is operating on if the channel/frequency is different, step 302.

Send out a connection request packet, step 304, which may contain the following information:

Receiver address: target device's MAC address

BSSID: BSSID of the ad hoc network

5 BSS type: ad hoc

SSID: (optional)

Special IE: (optional)

Operation type – virtual association request

10 Other optional configuration and capability information, such as supported data rates

The wireless device can use, but is not limited to, a unicast probe request packet or an authentication packet to convey connection request information, provided that the packet format and content are agreed and understood by the wireless devices.

15 4) After sending a connection request packet, the wireless module waits for a connection response packet, step 306.

20 The wireless device needs to identify that a connection response packet is used to establish an association in the ad hoc network. It can do so in different ways, provided the way is mutually agreed by the devices involved in the association process. Here are some examples:

a. Match a direct probe response packet with a special IE (information element) that specifies the intention of the connection response. The packet can have the following information:

Packet type: direct (unicast) probe response packet

25 Receiver address: matches association request's MAC address

BSSID: matches BSSID of the ad hoc network

BSS type: ad hoc

Special IE:

Operation type – virtual association request

5 Virtual association status – IEEE 802.11 status code

Other optional configuration and capability information,
such as supported data rates

10 b. Match a connection response packet with a packet pattern that is
agreed and understood by the wireless devices. Receiving this packet
means an acceptance of the association request from the association
responder. For example, a matched packet pattern may be:

Packet type: direct (unicast) authentication packet

Receiver address: matches association request's MAC address

BSSID: matches BSSID of the ad hoc network

15 BSS type: ad hoc

SSID: matches SSID of the ad hoc network

Special IE: (optional)

Configuration and capability information, such as
supported data rates

20 5) The wireless module waits for such connection response packet, step 308,
until a timeout value expires, step 312. This timeout value can have a default
value and is configurable. If the connection response packet is received and
the connection is successful, step 310, then the wireless module updates its
internal state to be associated to the target wireless device.

If this is the first device that it associates with, then the wireless module indicates a media connected event to the network stack.

The wireless module can optionally indicate that a new association has been established with the peer device by sending a notification such as a port up event to the network stack.

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- 6) If a connection response packet is not received, step 308, and the timeout expires, step 312, the connection is not successful, step 314, and the wireless module remains in its original state.

A flow chart of operations performed by the second wireless device in responding to the connection request by the first wireless device is shown in FIG. 4.

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If a wireless device in an ad hoc network receives a unicast connection request packet from another wireless device (the association requestor), step 400, it becomes an association responder and does the following:

- 1) Identify that a connection request packet is received to establish an association in the ad hoc network. The wireless device can do so in various ways, provided the way is mutually agreed by the devices involved in the association process. Here are two examples:

15

- a. Match a direct probe request packet with a special IE that specifies the intention of the connection request. The format of the special IE is understood by the wireless devices and can have the following information:

20

Packet type: direct (unicast) probe request packet

Receiver address: matches association request's MAC address

BSSID: matches BSSID of the ad hoc network

25

BSS type: ad hoc

Special IE:

Operation type – virtual association request

Other optional configuration and capability information,
such as supported data rates

- 5 b. Match a connection request packet with a packet pattern that is agreed
and understood by the wireless devices. Receiving this packet means
an association request from association requestor. For example, a
matched packet pattern could be:

Packet type: direct (unicast) authentication request

10 Receiver address: matches association responder's MAC
address

BSSID: matches BSSID of the ad hoc network

BSS type: ad hoc

SSID: matches SSID of the ad hoc network

Special IE: (optional)

15 Configuration and capability information, such as
supported data rates

- 2) The wireless module decides whether to accept the association, step 402, and
sends out a connection response packet, step 406, which may contain the
following information:

20 Receiver address: association initiator's MAC address

BSSID: BSSID of the ad hoc network

BSS type: ad hoc

SSID: (optional)

Special IE: (optional)

Operation type – virtual association response

Virtual association status – IEEE 802.11 status code

Other optional configuration and capability information, such as supported data rates

5 The wireless device can use, but is not limited to, a unicast probe response packet or an authentication packet to convey connection response information, provided that the packet format and content are agreed and understood by the wireless devices.

3) If the association is accepted, the association responder does the following:

10 If the association requestor is the first one associated with the wireless device, then the wireless module indicates a media connected event to the network stack, step 408.

15 The wireless module can optionally indicate that a new joiner has established an association by sending a notification such as a port up event to the network stack.

4) Otherwise, the association is not accepted, step 402, and the association responder stays in its original state, step 404.

When both wireless device are in the same ad hoc network and indicate media connected and/or port up to the network stack, a wireless connection is established.

20 The wireless devices can transmit and receive data packets to and from the peer devices.

Handle Simultaneous Association Requests between Two Wireless Devices in Ad Hoc Networks

25 A flow chart of operations performed by a first wireless device when two wireless devices send connection requests to each other concurrently is shown in FIG. 5.

It is possible that two wireless devices A and B send out connection requests to each other concurrently, and wait for a connection response from the other. In this case, the two wireless devices may avoid establishing two associations with each other. After a device (A) sends out a connection request to another device (B), step 500, and device
5 A receives a connection request from device B before it receives a connection response from the same device B within the timeout, step 502, device A does the following:

- 1) If the value of device B's MAC address is less than device A's MAC address, step 504, then device A ignores B's connection request, step 506.
- 10 2) If the value of device B's MAC address is larger than device A's MAC address, step 504, then device A replies to device B's connection request by sending a connection response, step 508. Meanwhile, device A also cancels its own state and operation for the connection request that device A sent to device B.
- 15 It will be understood that the criteria can be reversed so that the connection request of the wireless device with the smaller network address is processed and the connection request of the wireless device with the larger network address is canceled.

Monitor Associations

The wireless device may maintain a list of associated wireless devices internally and may monitor packets from the associated peer devices. If the wireless device does not receive any in-IBSS packets from an associated wireless device in the ad hoc network
5 for certain amount of time, it may disassociate from this device.

A packet is deemed as in-IBSS if and only if it has a BSSID that matches the one used by the ad hoc network.

Terminate an Association with a wireless device in Ad Hoc Networks

A flow chart of operations performed by a wireless device to terminate an
10 association with another wireless device is shown in FIG. 6.

If a wireless device decides to terminate an association with another device in an ad hoc network, it does the following:

- 1) Set the following settings:

Desired SSID (of the target ad hoc network to disassociate with),

15 Desired BSSID (of the target ad hoc network to disassociate with), and

Mac address (of the target device to disassociate with).

- 2) Issues a disconnection call to wireless module, step 600.

Disconnect (to disassociate with a device in an ad hoc network with Mac address and the BSSID/SSID as configured above)

20 3) Upon receiving a disconnect call, or the wireless module decides to disassociate from another wireless device due to its aging function as described above, the wireless module does the following:

Search the internal associated wireless device list for the device.

If such an associated device cannot be found, then return an appropriate error.

Otherwise, send out a disconnection request packet, step 602, which may contain the following information:

Receiver address: target device's MAC address

BSSID: BSSID of the ad hoc network

5 BSS type: ad hoc

SSID: (optional)

Special IE: (optional)

Operation type – virtual association request

10 Other optional configuration and capability information, such as supported data rates

The wireless device can use, but is not limited to, a unicast probe request packet or a de-authentication packet to convey the disconnection request information, provided that the packet format and content are agreed and understood by the wireless devices.

15 4) After sending a disconnection request packet, the wireless module can immediately remove the device from its associated device list, step 604. The wireless device stops sending any data packets to the disassociated wireless device and drops received data packets from that device.

20 If the disassociated device is the last one in the associated device list, then the wireless device indicates a media disconnected event to the network stack and deems itself leaving the ad hoc network.

The wireless device can optionally indicate that an association with the peer device has been removed by sending a notification such as a port down event to the network stack.

25 A flow chart of operations performed by a wireless device in response to receiving a disconnection request is shown in FIG. 7.

If a wireless device in an ad hoc network receives a unicast disconnection request packet from another wireless device, step 700, it does the following:

- 1) The wireless device needs to identify a disconnection request packet that is used for terminating an association in ad hoc network, step 702. It can do so in various ways, provided the way is mutually agreed and understood by the devices involved in the association process. Here are two examples:

- a. Match a special IE in a direct probe request packet to specify the intention of the disconnection request. The format of the special IE is understood by the wireless devices and can have the following information:

Packet type: direct (unicast) probe request packet

Receiver address: matches association request's MAC address

BSSID: matches BSSID of the ad hoc network

BSS type: ad hoc

- Special IE:

Operation type – virtual disassociation request

- b. Match a connection request packet with a packet pattern that is agreed and understood by the wireless devices. Receiving this packet means a disassociation request. For example, a matched packet pattern may be:

- Packet type: direct (unicast) de-authentication request

Receiver address: matches association responder's MAC address

BSSID: matches BSSID of the ad hoc network

BSS type: ad hoc

- SSID: matches SSID of the ad hoc network

- 2) After receiving a disconnection request packet, the wireless device does the following:

Search the internal associated wireless device list for the device.

- 5 If such an associated device cannot be found, then ignore the disconnect request packet, step 704.

Otherwise, the wireless device can immediately remove the device from its associated device list, step 706. The wireless device stops sending any data packets to the disassociated wireless device and drops received data packets from that device.

- 10 If the disassociated device is the last one in the associated device list, then the wireless device indicates a media disconnected event to the network stack and deems itself leaving the ad hoc network.

- 15 The wireless device can optionally indicate that an association has been removed with the peer device by sending a notification such as a port down event to the network stack.

Disconnect From an Ad Hoc Network

If a wireless device decides to leave an ad hoc network, it does the following:

- 1) Issue a disconnect call to wireless module
- 2) After receiving a disconnect call from upper layer, the wireless module does the following to leave the ad hoc network:
- 20

Indicate a media disconnect event to the network stack.

Stop sending any data packets to devices in the ad hoc network and drop received data packets from devices in the ad hoc network.

Clean up the internal list of associated wireless devices.

- 25 Clean up other internal states.

Special Information Element

The information element (IE) is a type-length-value object that used to carry variable length information.) The wireless device can optionally rely on the special information element to carry information for managing associations.

- 5 The special IE can either use a unique IE ID, or a customer IE ID (e.g., value 221 defined by IEEE 802.11 standard) with a unique OUI and OUI type combination to identify itself.

IE ID (1 byte)	Length (1 byte)	OUI (3 byte)	OUI Type (1 byte)	Other information (0-249 bytes)
221	8..253	(e.g. 00-50-F2 for Microsoft)	(unique value with the same OUI)	Other information for association

The special information element can contain the following information for managing the association:

- 10 Operation type
- Virtual association request
 - Virtual association response
 - Virtual disassociation request

Other information (optional)

- 15 - Data rates
- Capability information

The above description provides examples of values for various parameters, such as packet parameters. It will be understood that such values are given by way of example only and are not in any way limiting as to the scope of the invention.

Having thus described several aspects of at least one embodiment of this invention, it is to be appreciated various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within
5 the spirit and scope of the invention. Accordingly, the foregoing description and drawings are by way of example only.

What is claimed is:

Claims

1. A method to operate a first wireless device in an ad hoc network, comprising:

turning on a radio of the first wireless device in response to a connect call;

sending a connection request packet from the first wireless device to a second
5 wireless device;

if a connection response packet is received by the first wireless device from
the second wireless device within a timeout period, establishing a connection to the
second wireless device; and

if a connection response packet is not received by the first wireless device
10 from the second wireless device within the timeout period, indicating a connection
failure.
2. A method as defined in claim 1, further comprising:

the first wireless device receiving a connection request packet from the second
15 wireless device;

if the connection request packet is identified by the first wireless device as a
valid connection request, sending a connection response packet to the second wireless
device and recording an established connection; and

if the connection request packet is not identified by the first wireless device as
20 a valid connection request, remaining in an existing state.
3. A method as defined in claim 1, further comprising:

the first wireless device receiving a connection request packet from the second
wireless device before receiving a connection response packet from the second
wireless device;

if the network address of the second wireless device meets a criteria with respect to the network address of the first wireless device, the first wireless device sending a connection response packet to the second wireless device and canceling its own connection request; and

5 if the network address of the second wireless device does not meet the criteria with respect to the network address of the first wireless device, the first wireless device ignoring the received connection request from the second wireless device.

4. A method as defined in claim 1, further comprising switching the radio to an
10 ad hoc network channel in response to the connect call.

5. A method as defined in claim 1, further comprising monitoring packets from an associated wireless device, dissociating from the associated wireless device if a packet is not received from the associated wireless device for a predetermined time,
15 and otherwise continuing the association with the associated wireless device.

6. A method as defined in claim 1, further comprising:

sending a disconnection request packet from the first wireless device to the second wireless device in response to a disconnection call; and

20 removing the second wireless device from a connected device list.

7. A method as defined in claim 1, further comprising:

the first wireless device receiving a disconnection request packet from the second wireless device;

25 if the disconnection request packet is identified by the first wireless device, removing the second wireless device from a connected device list; and

if the disconnection request packet is not identified by the first wireless device, ignoring the disconnection request packet.

8. A method to operate a first wireless device in an ad hoc network, comprising:

5 the first wireless device receiving a connection request packet from a second wireless device;

if the connection request packet is identified by the first wireless device as a valid connection request, sending a connection response packet to the second wireless device and recording an established connection; and

10 if the connection request packet is not identified by the first wireless device as a valid connection request, remaining in an existing state.

9. A method as defined in claim 8, further comprising identifying the connection request packet by matching a direct probe request packet with a special information
15 element that describes the connection request.

10. A method as defined in claim 8, further comprising identifying the connection request packet by matching the connection request packet with a predetermined packet pattern.
20

11. A method as defined in claim 8, further comprising:

the first wireless device sending a connection request packet to the second wireless device;

25 the first wireless device receiving the connection request packet from the second wireless device before receiving a connection response packet from the second wireless device;

if the network address of the second wireless device meets a criteria with respect to the network address of the first wireless device, the first wireless device sending a connection response packet to the second wireless device and canceling its own connection request; and

- 5 if the network address of the second wireless device does not meet the criteria with respect to the network address of the first wireless device, the first wireless device ignoring the received connection request from the second wireless device.

12. A method as defined in claim 8, further comprising monitoring packets from
10 an associated wireless device, dissociating from the associated wireless device if a packet is not received from the associated wireless device for a predetermined time, and otherwise continuing the association with the associated wireless device.

13. A method as defined in claim 8, further comprising:
15 sending a disconnection request packet from the first wireless device to the second wireless device in response to a disconnection call; and
 removing the second wireless device from a connected device list.

14. A method as defined in claim 8, further comprising:
20 the first wireless device receiving a disconnection request packet from the second wireless device;
 if the disconnection request packet is identified by the first wireless device, removing the second wireless device from a connected device list; and
 if the disconnection request packet is not identified by the first wireless
25 device, ignoring the disconnection request packet.

15. A wireless device comprising:
- a computing device;
 - a radio; and
 - a wireless module logically connected to the computing device and to the radio, the wireless module comprising a processor programmed with instructions for:
 - turning on the radio in response to a connect call;
 - sending a connection request packet to a second wireless device;
 - if a connection response packet is received from the second wireless device within a timeout period, establishing a connection to the second wireless device; and
 - if a connection response packet is not received from the second wireless device within the timeout period, indicating a connection failure.
16. A wireless device as defined in claim 15, wherein the instructions further comprise instructions for:
- the wireless device receiving a connection request packet from a second wireless device;
 - if the connection request packet is identified by the wireless device as a valid connection request, sending a connection response packet to the second wireless device and recording an established connection; and
 - if the connection request packet is not identified by the wireless device as a valid connection request, remaining in an existing state.
17. A wireless device as defined in claim 15, wherein the instructions further comprise instructions for:

the wireless device receiving a connection request packet from the second wireless device before receiving a connection response packet from the second wireless device;

5 if the network address of the second wireless device meets a criteria with respect to the network address of the wireless device, the wireless device sending a connection response packet to the second wireless device and canceling its own connection request; and

10 if the network address of the second wireless device does not meet the criteria with respect to the network address of the wireless device, the wireless device ignoring the received connection request from the second wireless device.

18. A wireless device as defined in claim 15, wherein the instructions further comprise instructions for identifying the connection request packet by matching a direct probe request packet with a special information element that describes the connection request.

15 19. A wireless device as defined in claim 15, wherein the instructions further comprise instructions for identifying the connection request packet by matching the connection request packet with a predetermined packet pattern.

20 20. A wireless device as defined in claim 15, wherein the instructions further comprise instructions for monitoring packets from an associated wireless device, dissociating from the associated wireless device if a packet is not received from the associated wireless device for a predetermined time, and otherwise continuing the association with the associated wireless device.