

System and Method for Downlink Transmission in a Wireless Network

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TECHNICAL FIELD

[0002] The present invention relates to a system and method for wireless communications, and, in particular, to a system and method for downlink transmission in a wireless network.

10 BACKGROUND

[0003] Currently, IEEE 802.11ah defines a local area network protocol especially for sub 1 GHz carrier frequencies. The main requirements of IEEE 802.11ah include a large coverage area (e.g., up to 1km), a physical (PHY) layer data rate of at least 100 kbps, a maximum aggregate multi-station data rate of 20 Mbps, the use of orthogonal frequency division multiplexing (OFDM) PHY
15 modulation, and support of a number of associations beyond 2007 for outdoor applications.

[0004] Overhead is an issue under the 802.11ah protocol. The physical layer of 802.11ah uses a slower clock than that used in the normal 802.11 protocol. Therefore, each symbol length under 802.11ah is ten times as long as under the normal 802.11 protocol.

[0005] For a downlink traffic transmission scheme in the 802.11 protocol, at every beacon
20 frame, an access point (AP) broadcasts a traffic indication map (TIM) that has information on whether the downlink packet is buffered to each of the stations. If the downlink packet is buffered, a station, after reading the TIM, transmits a power save (PS)-Poll message indicating that the station

is awakened and ready to receive downlink data packet. If the access point is ready to transmit buffered data, the access point immediately transmits downlink data packets. If the access point is not ready to transmit buffered data, the access point transmits an acknowledgment packet, and the access point will transmit the buffered data shortly.

SUMMARY

[0006] An embodiment method of communicating in a wireless network includes transmitting, by a station, a null data packet (NDP) power save (PS)-Poll frame including a short training field and a long training field. Also, the NDP PS-Poll frame includes a signaling field including a message type indicator, a transmitter address (TA), a receiver address (RA), and a cyclic redundancy check (CRC). Additionally, the method includes receiving, by the station, buffered data in accordance with the NDP PS-Poll frame.

[0007] An embodiment method of communicating in a wireless network includes receiving, by an access point, a null data packet (NDP) PS-Poll frame including a short training field and a long training field. Also, the NDP PS-Poll frame includes a signaling field including a message type indicator, a receiver address (RA), a transmitter address (TA), and a cyclic redundancy check (CRC). Additionally, the method includes decoding, by the access point, the NDP PS-Poll frame and transmitting, by the access point, buffered data in accordance with the NDP PS-Poll frame.

[0008] An embodiment station includes a processor and a computer readable storage medium storing programming for execution by the processor. The programming includes instructions to transmit a null data packet (NDP) PS-Poll frame including a short training field and a long training field. Also, the NDP PS-Poll frame includes a signaling field including a message type indicator, a receiver address (RA), a transmitter address (TA), and a cyclic redundancy check (CRC). Additionally, the programming includes instructions to receive buffered data in accordance with the NDP PS-Poll frame.

[0009] An embodiment access point includes a processor and a computer readable storage medium storing programming for execution by the processor. The programming includes instructions to receive a null data packet (NDP) PS-Poll frame including a short training field and a

long training field. Also, the NDP PS-Poll frame includes a signaling field including a message type indicator, a receiver address (RA), a transmitter address (TA), and a cyclic redundancy check (CRC). Additionally, the programming includes instructions to decode the null data packet and transmit buffered data in accordance with the NDP PS-Poll frame.

[0010] The foregoing has outlined rather broadly the features of an embodiment of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of embodiments of the invention will be described hereinafter, which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures or processes for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawing, in which:

[0012] Figure 1 illustrates a power save (PS)-Poll message format;

[0013] Figure 2 illustrates an embodiment system for downlink transmission in a wireless network;

[0014] Figure 3 illustrates an embodiment physical layer header;

[0015] Figure 4 illustrates an embodiment signaling field allocation for a short PS-Poll packet;

[0016] Figure 5 illustrates a flowchart of an embodiment method for downlink transmission in a wireless network;

[0017] Figure 6 illustrates an embodiment traffic indication map;

[0018] Figure 7 illustrates a flowchart of an embodiment method of determining a receiver address;

[0019] Figure 8 illustrates an embodiment receiver address;

[0020] Figure 9 illustrates a flowchart of an embodiment method of determining a modulation and coding scheme; and

[0021] Figure 10 illustrates a block diagram illustrating computing platform that may be used for implementing, for example, the devices and methods described herein, in accordance with an embodiment.

[0022] Corresponding numerals and symbols in the different figures generally refer to corresponding parts unless otherwise indicated. The figures are drawn to clearly illustrate the relevant aspects of the embodiments and are not necessarily drawn to scale.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0023] It should be understood at the outset that although an illustrative implementation of one or more embodiments are provided below, the disclosed systems and/or methods may be implemented using any number of techniques, whether currently known or in existence. The disclosure should in no way be limited to the illustrative implementations, drawings, and techniques illustrated below, including the exemplary designs and implementations illustrated and described herein, but may be modified within the scope of the appended claims along with their full scope of equivalents.

[0024] For a downlink traffic transmission scheme in the 802.11 protocol, at every beacon frame, an access point (AP) broadcasts a traffic indication map (TIM) that has information on whether the access point has buffered downlink packets for each station that is associated with the access point. If the access point has buffered downlink packets for the station, after receiving the TIM information, the station transmits a power save (PS)-Poll frame indicating that the station is in an active state and ready to receive buffered downlink data packets. If the access point is ready to transmit buffered data, it directly transmits downlink data packets. However, if the access point is not ready to transmit buffered data, the access point transmits an acknowledgment packet to the station, and the access point transmits the buffered data packets to the station shortly thereafter.

[0025] Figure 1 illustrates a PS-Poll frame 100 that is configured to indicate that a station is in an active state and is ready to receive buffered data. The PS-Poll frame 100 includes two octets for frame control, two octets for an association identification number (AID), six octets for a basic service set identification number (BSSID), six octets for a transmitter address (TA), and four octets for a frame check sequence (FCS). Hence the PS-Poll frame 100 contains 20 octets. The BSSID may be the receiver address (RA). The media access control (MAC) header of the PS-Poll frame

100 includes the frame control, the AID, the BSSID, and the TA. Additionally, the PS-poll frame 100 contains a short training field, a long training field, and a signaling field. (not pictured)

[0026] Figure 2 illustrates system 110 for downlink data transmission in a wireless network. System 110 includes access point 112 and station 114. Access point 112 initially broadcasts a TIM. Then, station 114 responds by transmitting a null data packet (NDP) PS-Poll frame to the access point. An NDP is a physical layer convergence procedure (PLCP) protocol data unit (PPDU) that carries no data field. Thus, an NDP packet may be a physical layer header only packet that carries no data field. The NDP may have a fixed packet length and modulation and coding scheme (MCS) level, and may be encoded in the lowest available MCS level. Next, access point 112 decodes the NDP PS-Poll frame. If access point 112 is ready to transmit buffered data to station 114, access point 112 immediately begins transmitting buffered data to station 114. However, if access point 112 is not immediately ready to transmit data, access point 112 transmits an acknowledgment frame to station 114, and access point 112 transmits the buffered data to station 114 when access point 112 is ready.

[0027] An example of packet 120 that may be used as an NDP PS-Poll frame is illustrated in Figure 3. In an example, the packet 120 may consist of only a physical (PHY) layer preamble. The packet 120 may include a short training field (STF), a long training field (LTF), and a signaling field (SIG). The short training field is used for initial frame synchronization, for coarse frequency offset compensation, and for automatic gain control (AGC) settings. Additionally, the long training field is used for fine frequency offset compensation and channel estimation. In an example, the lowest modulation and coding scheme (MCS) level is used to transmit the NDP PS-Poll frame. The NDP PS-Poll frame may be delivered using the physical layer header field of an IEEE 802.11 packet format.

[0028] Figure 4 illustrates an embodiment signaling field of an NDP PS-Poll frame 125. The signaling field may include four bits for a message type indicator, nine bits for a transmitter address (TA) or the address of the station, nine bits for a receiver address (RA) or the address of the access point, four bits for a preferred modulation and coding scheme (MCS) subfield, six bits for tail bits for Viterbi decoding, and four bits for a cyclic redundancy check (CRC). In one example, the signaling field also includes one bit for a message type indicator and one reserved bit, for a total of 36 bits. In another example, the signaling field also includes nine bits for a message type indicator and three reserved bits for a total of 48 bits. The preferred modulation and coding scheme (MCS) subfield for downlink data packets indicates the preferred MCS level. Also, a preferred number of concurrent streams for downlink data packet transmission may be included in the signaling field of an NDP PS-Poll frame 125.

[0029] In an example, the signaling field has 48 bits or fewer bits. In another example, the signaling field has 36 bits or fewer. In one embodiment, the signaling field contains an uplink data indicator, a transmitter address, a receiver address, and a cyclic redundancy check (CRC). In another embodiment, the signaling field additionally contains a preferred MCS subfield indicating the preferred MCS for downlink data packets. In one example, the preferred MCS subfield is based on the quality of previous packets broadcast by the access point. Also, the signaling field may include decoder tail bits for Viterbi-decoding. In an example, the lowest MCS level is used to transmit the NDP PS-Poll frame. In another example, field indicating a preferred number of concurrent streams for downlink data packet transmission is included in an NDP PS-Poll frame. The NDP PS-Poll frame may be delivered using the physical layer header field of an IEEE 802.11 packet format. In one example, the transmitter address is generated by a function including at least a portion of the AID. Both the station and the access point know how the transmitter address is generated from the original AID. In another example, the receiver address is generated by a

function including at least portion of the BSSID of the access point. The station and the access point may know how the receiver address is generated from the original BSSID.

[0030] A method of downlink transmission from an access point to a station is illustrated in Figure 5. Initially, in step 130, the access point broadcasts a TIM. After receiving the TIM, if the station is in an active state and ready to receive buffered data, in step 132, the station transmits an NDP PS-Poll frame to the access point. Upon receiving the NDP PS-Poll frame, the access point decodes the NDP PS-Poll frame, and, in step 136, the access point determines if the access point is ready to transmit buffered data to the station. If the access point is ready to transmit buffered data, the access point, in step 140, immediately transmits buffered data to the station. If the access point is not ready to transmit buffered data, the access point, in step 138, transmits an acknowledgment frame to the station. Then, in step 140, the access point transmits buffered data to the station when the access point is ready. In an example, the partial virtual bitmap information in the IEEE 802.11 standard is used as the information of downlink traffic buffered at the access point.

[0031] An access point broadcasts a TIM indicating stations to which the access point is prepared to deliver buffered data. For example, out of 1024 stations that are associated with the access points, the access point may be prepared to send buffered data to only 16 stations. When an NDP PS-Poll frame is used only in response to a TIM, an identifier needs to distinguish the 16 stations that the access point is prepared to send buffered data. For example, when the access point is prepared to send buffered data to 16 out of 1024 stations, the identifier may consist of only four bits to identify the 16 stations, not the 10 bits required to identify the 1024 stations, which is used to identify the station in an NDP PS-Poll frame. Figure 6 illustrates TIM 150 having 100 stations, where the access point is prepared to send buffered data to five stations. In TIM 150, the stations have AIDs ranging from 0 to 99. A “1” for traffic indication means that data in the access point is buffered for this station, while a “0” for traffic indication means that there is no data in the access

point buffered for this station. In TIM 150, there are five stations that the access point has buffered data to deliver. The transmitter address used in an NDP PS-Poll frame sent by station 1 may be N ($0 \leq N \leq 4$), the transmitter address used in an NDP PS-Poll frame sent by station 3 may be $\text{mod}(N+1, 5)$, the transmitter address used in an NDP PS-Poll frame sent by station 24 may be $\text{mod}(N+2, 5)$, the transmitter address used in an NDP PS-Poll frame sent by station 58 may be $\text{mod}(N+3, 5)$, and the transmitter address used in an NDP PS-Poll frame sent by station 98 may be $\text{mod}(N+4, 5)$, where N is an offset value and mod is the modulo operation. In one example, N is equal to zero. Alternatively, N may be a random offset used so every station has an equal opportunity to get the first address.

[0032] When only a portion of BSSID is used as the receiver address in an NDP PS-Poll frame, it is possible that multiple access points use the same partial BSSID. Figure 7 illustrates a method of determining a partial BSSID by an access point to avoid using the same partial BSSID as another access point. Initially, in step 160, the access point continuously monitors management packets from other access points to determine the partial BSSIDs used by other access points. For example, the management packets may be a beacon frame, a probe response frame, or an association response frame in the IEEE 802.11 protocol. Also, stations may report the partial BSSIDs used by nearby access points to the access point. In step 159, the access point determines whether another access point uses the same partial BSSID as it. If the access point's partial BSSID is not the same as the BSSID of another access point, the system returns to step 160 for further monitoring. However, if the access point's partial BSSID is the same as the partial BSSID of another access point, the system proceeds to step 161, where it determines if there is a partial BSSID that does not conflict with the partial BSSID of another access point. If there is a partial BSSID that does not conflict with the partial BSSIDs used by other access points, the access point, in step 162, sets its partial BSSID to that partial BSSID. Then, in step 164, the access point broadcasts management packets, such as

beacon frames, probe response frames, or association response frames. The management packet indicates that, if the access point uses another partial BSSID, the access point does not follow the general rule for extracting partial BSSID. The management packet also may include the partial BSSID used by the access point. However, if there is not another partial BSSID that does not conflict with the partial BSSIDs used by other access points, the access point, in step 163, determines that the access point will not use an NDP PS-Poll frame. Then, in step 165, the access point broadcasts a management packet that indicates that the use of NDP PS-Poll frames is disabled by this access point.

[0033] A partial BSSID information element 170 that may be broadcast on a beacon frame by an access point is illustrated in Figure 8. In one example, the partial BSSID information element 170 includes one octet for an element ID, one octet for a length field, and N octets for a partial BSSID. The partial BSSID may include 1 bit to indicate whether or not a partial BSSID is used, where a “1” indicates the uses of a partial BSSID in the following field, and a “0” indicates that the access point does not use a partial BSSID, or vice versa. In an example, the inclusion of the partial BSSID in the beacon frame indicates that the access point does not use the standard method of extracting partial BSSIDs. The partial BSSID is N1 bits, while there are $N*8-(N1+1)$ reserved bits. In one example, N1 is equal to nine, N is equal to 2, and there are six reserved bits.

[0034] Figure 9 illustrates a flowchart of a method where a station determines a preferred MCS level for the buffered data. Initially, in step 180, an access point transmits a packet, such as a beacon frame, a probe response frame, or an association response frame. Then, in step 182, the station determines the preferred MCS level of the access point, for example based on the signal quality of the received packet from the access point. The preferred MCS level may be indicated in a preferred modulation and coding field of an NDP PS-poll frame. In one example, the absolute preferred MCS level is indicated. In another example, a portion of the bits for the preferred MCS

level is included in the NDP PS-Poll frame. Alternatively, a differential MCS level might be included in the NDP PS-Poll frame, where the differential MCS level indicates the level difference between the preferred MCS level and the MCS level of the previous successfully received downlink transmission.

[0035] Figure 10 illustrates a block diagram of processing system 270 that may be used for implementing the devices and methods disclosed herein. Specific devices may utilize all of the components shown, or only a subset of the components, and levels of integration may vary from device to device. Furthermore, a device may contain multiple instances of a component, such as multiple processing units, processors, memories, transmitters, receivers, etc. The processing system may comprise a processing unit equipped with one or more input devices, such as a microphone, mouse, touchscreen, keypad, keyboard, and the like. Also, processing system 270 may be equipped with one or more output devices, such as a speaker, a printer, a display, and the like. The processing unit may include central processing unit (CPU) 274, memory 276, mass storage device 278, video adapter 280, and I/O interface 288 connected to a bus.

[0036] The bus may be one or more of any type of several bus architectures including a memory bus or memory controller, a peripheral bus, video bus, or the like. CPU 274 may comprise any type of electronic data processor. Memory 276 may comprise any type of system memory such as static random access memory (SRAM), dynamic random access memory (DRAM), synchronous DRAM (SDRAM), read-only memory (ROM), a combination thereof, or the like. In an embodiment, the memory may include ROM for use at boot-up, and DRAM for program and data storage for use while executing programs.

[0037] Mass storage device 278 may comprise any type of storage device configured to store data, programs, and other information and to make the data, programs, and other information

accessible via the bus. Mass storage device 278 may comprise, for example, one or more of a solid state drive, hard disk drive, a magnetic disk drive, an optical disk drive, or the like.

[0038] Video adaptor 280 and I/O interface 288 provide interfaces to couple external input and output devices to the processing unit. As illustrated, examples of input and output devices include the display coupled to the video adapter and the mouse/keyboard/printer coupled to the I/O interface. Other devices may be coupled to the processing unit, and additional or fewer interface cards may be utilized. For example, a serial interface card (not pictured) may be used to provide a serial interface for a printer.

[0039] The processing unit also includes one or more network interface 284, which may comprise wired links, such as an Ethernet cable or the like, and/or wireless links to access nodes or different networks. Network interface 284 allows the processing unit to communicate with remote units via the networks. For example, the network interface may provide wireless communication via one or more transmitters/transmit antennas and one or more receivers/receive antennas. In an embodiment, the processing unit is coupled to a local-area network or a wide-area network for data processing and communications with remote devices, such as other processing units, the Internet, remote storage facilities, or the like.

[0040] Advantages of an embodiment include using fewer bits for NDP PS-poll frames.

[0041] While several embodiments have been provided in the present disclosure, it should be understood that the disclosed systems and methods might be embodied in many other specific forms without departing from the spirit or scope of the present disclosure. The present examples are to be considered as illustrative and not restrictive, and the intention is not to be limited to the details given herein. For example, the various elements or components may be combined or integrated in another system or certain features may be omitted, or not implemented.

[0042] In addition, techniques, systems, subsystems, and methods described and illustrated in the various embodiments as discrete or separate may be combined or integrated with other systems, modules, techniques, or methods without departing from the scope of the present disclosure. Other items shown or discussed as coupled or directly coupled or communicating with each other may be indirectly coupled or communicating through some interface, device, or intermediate component whether electrically, mechanically, or otherwise. Other examples of changes, substitutions, and alterations are ascertainable by one skilled in the art and could be made without departing from the spirit and scope disclosed herein.

CLAIMS

1. A method of communicating in a wireless network, the method comprising:
transmitting (132), by a station, a null data packet (NDP) power save (PS)-Poll
frame comprising
 - 5 a short training field,
 - a long training field, and
 - a signaling field comprising
 - a message type indicator,
 - a transmitter address (TA),
 - 10 a receiver address (RA), and
 - a cyclic redundancy check (CRC);

wherein the signaling field further comprises a preferred modulation
and coding scheme (MCS) subfield; and

receiving (140), by the station, buffered data in accordance with the NDP

 - 15 PS-Poll frame.
2. The method of claim 1, wherein the method further comprises decoding the
received buffered data using the preferred MCS subfield.
 3. The method of claim 1, wherein the preferred MCS subfield comprises a direct
indicator of a modulation and coding scheme level; or

a difference between a preferred MCS level and an MCS level of a packet previously received by the station from an access point.

4. The method of claim 1, wherein the signaling field has fewer than 37 bits.

5. The method of claim 1, wherein the TA is generated in accordance with a portion
5 of an association ID (AID).

6. The method of claim 1, wherein the RA is generated in accordance with a portion
of a basic service set ID (BSSID).

7. A method of communicating in a wireless network, the method comprising:
receiving (132), by an access point, a null data packet (NDP) PS-Poll frame
10 comprising

a short training field,

a long training field, and

a signaling field comprising

a message type indicator,

15 a receiver address (RA),

a transmitter address (TA), and

a cyclic redundancy check (CRC);

wherein the signaling field further comprises a preferred modulation and
coding scheme (MCS) subfield;

decoding, by the access point, the NDP PS-Poll frame; and

transmitting (140), by the access point, buffered data in accordance with the
NDP PS-Poll frame.

8. The method of claim 7, wherein the preferred MCS subfield comprises a direct
5 indicator of a modulation and coding scheme level; or

a difference in level between a preferred MCS level and an MCS level of a packet
previously transmitted by the access point to a station.

9. The method of claim 7, wherein the method further comprises encoding the
buffered data using the preferred MCS subfield.

- 10 10. The method of claim 7, wherein the signaling field has fewer than 37 bits.

11. The method of claim 7, wherein the TA is generated in accordance with a portion
of an association ID (AID).

12. The method of claim 7, wherein the RA is generated in accordance with a portion
of a basic service set ID (BSSID).

- 15 13. A station comprising:

a processor; and

a computer readable storage medium storing programming for execution by the
processor, the programming including instructions to

transmit (132) a null data packet (NDP) PS-Poll frame comprising

a short training field,

a long training field, and

a signaling field comprising

a message type indicator,

5 a receiver address (RA),

a transmitter address (TA)

a cyclic redundancy check (CRC),

wherein the signaling field further comprises a preferred modulation

and coding scheme (MCS) subfield; and

10 receive (140) buffered data in accordance with the NDP PS-Poll frame.

14. The station of claim 13, wherein the signaling field has fewer than 37 bits.

15. The station of claim 13, wherein the TA is generated in accordance with a portion of an association ID (AID).

16. The station of claim 13, wherein the RA is generated in accordance with a portion
15 of a basic service set ID (BSSID).

17. An access point comprising:

a processor; and

a computer readable storage medium storing programming for execution by the processor, the programming including instructions to

receive (132) a null data packet (NDP) PS-Poll frame comprising

- a short training field,
- a long training field, and
- a signaling field comprising

5 a message type indicator,

 a receiver address (RA),

 a transmitter address (TA), and

 a cyclic redundancy check (CRC);

 wherein the signaling field further comprises a preferred modulation

10 and coding scheme (MCS) subfield;

 decode the null data packet, and

 transmit (140) buffered data in accordance with the NDP PS-Poll frame.

18. The access point of claim 17, wherein the signaling field has fewer than 37 bits.

19. The access point of claim 17, wherein the TA is generated in accordance with a

15 portion of an association ID (AID).

20. The access point of claim 17, wherein the RA is generated in accordance with a

 portion of a basic service set ID (BSSID).