US 20160065466A1

(19) United States

(12) Patent Application Publication

Abraham et al.

(10) Pub. No.: US 2016/0065466 A1

(43) Pub. Date: Mar. 3, 2016

(54) **SYSTEMS AND METHODS FOR SIGNALING MULTI-DESTINATION AGGREGATED MULTI-USER MEDIA ACCESS CONTROL PROTOCOL DATA UNITS IN A WIRELESS NETWORK**

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(21) Appl. No.: **14/836,899**

(22) Filed: **Aug. 26, 2015**

Related U.S. Application Data

(60) Provisional application No. 62/043,061, filed on Aug. 28, 2014.

Publication Classification

(51) **Int. Cl.**

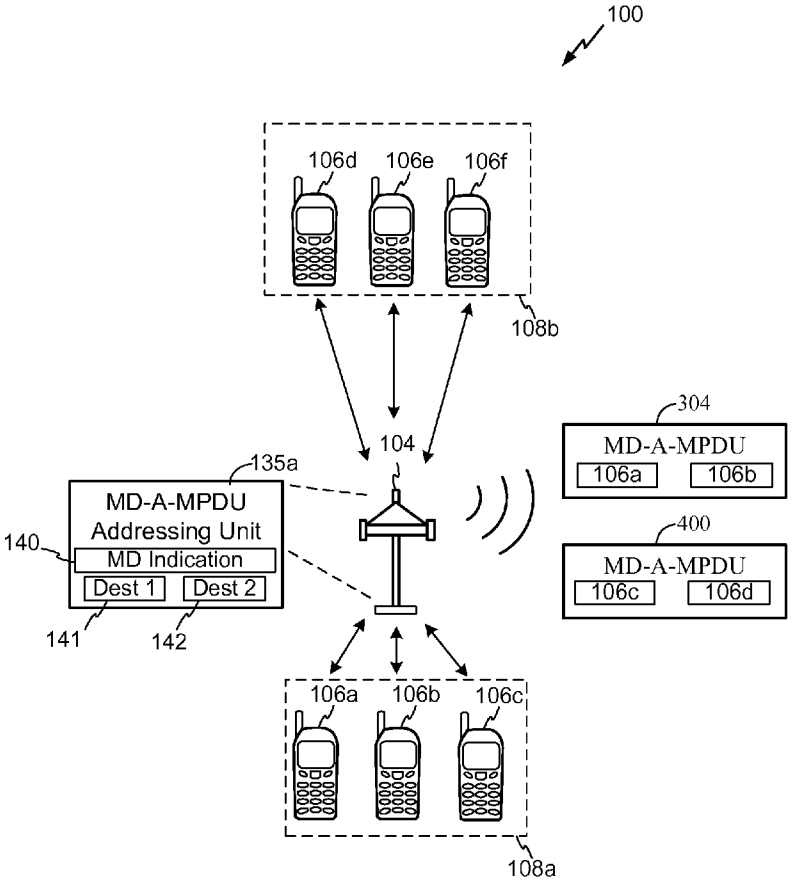
H04L 12/741	(2006.01)
H04L 29/12	(2006.01)
H04L 29/06	(2006.01)

(52) **U.S. Cl.**

CPC ***H04L 45/74*** (2013.01); ***H04L 69/22*** (2013.01); ***H04L 61/6022*** (2013.01)

(57) **ABSTRACT**

Systems, methods, and apparatuses for aggregating multi-user media access control protocol data units (MPDU) in a wireless network are provided. One aspect of this disclosure provides a method of wireless communication. The method includes generating, by an apparatus, an aggregated media access control protocol data unit (A-MPDU) frame comprising a plurality of A-MPDU sub-frames, wherein at least one sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device. The method comprises inserting an indication that the A-MPDU frame is addressed to at least the first and second devices into a physical layer convergence procedure (PLCP) protocol data unit (PPDU) field.



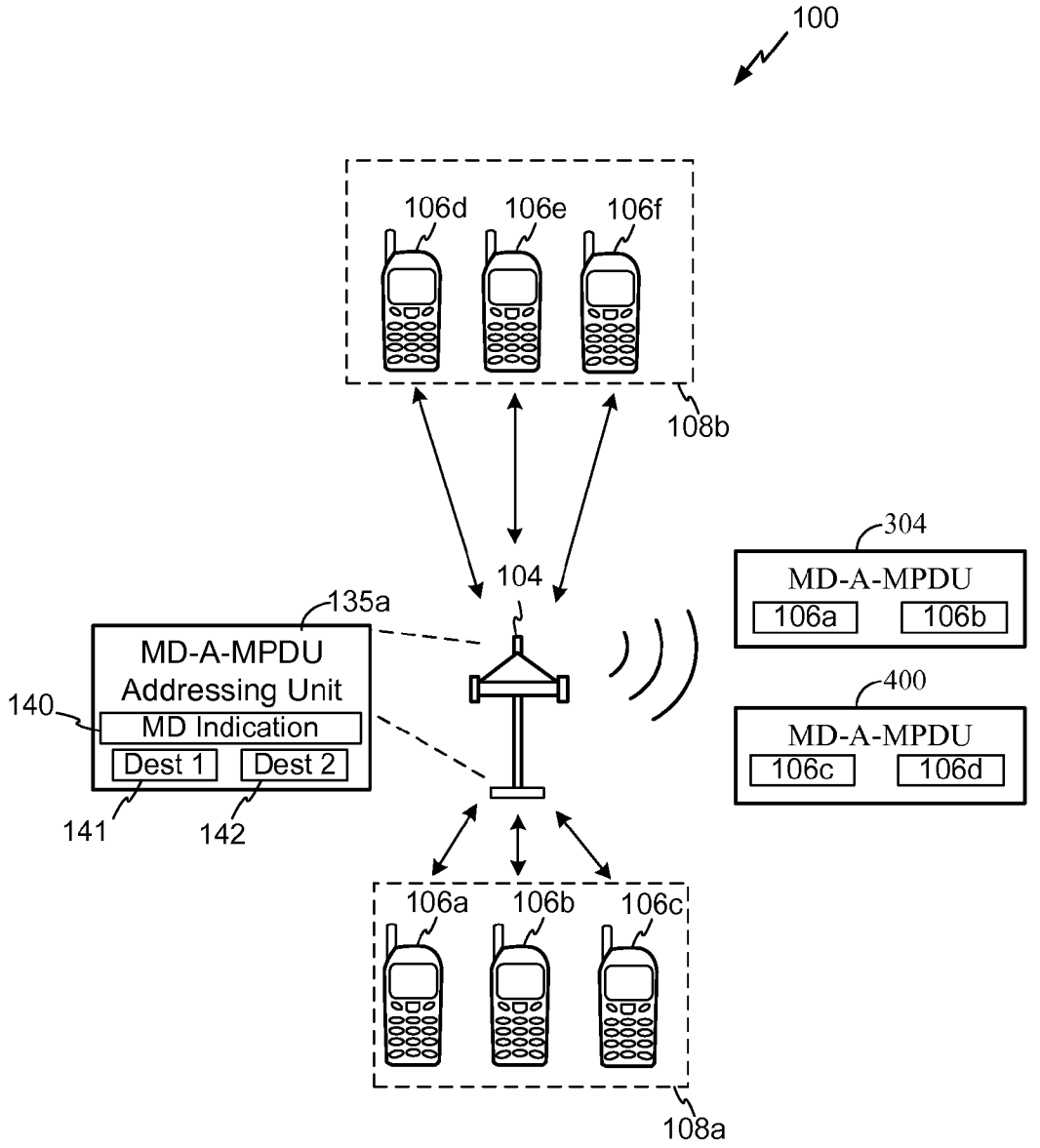

100
106d
106e
106f
108b
104
135a
MD-A-MPDU
Addressing Unit
140
MD Indication
Dest 1
Dest 2
141
142
304
MD-A-MPDU
106a
106b
400
MD-A-MPDU
106c
106d
106a
106b
106c
108a

FIG. 1

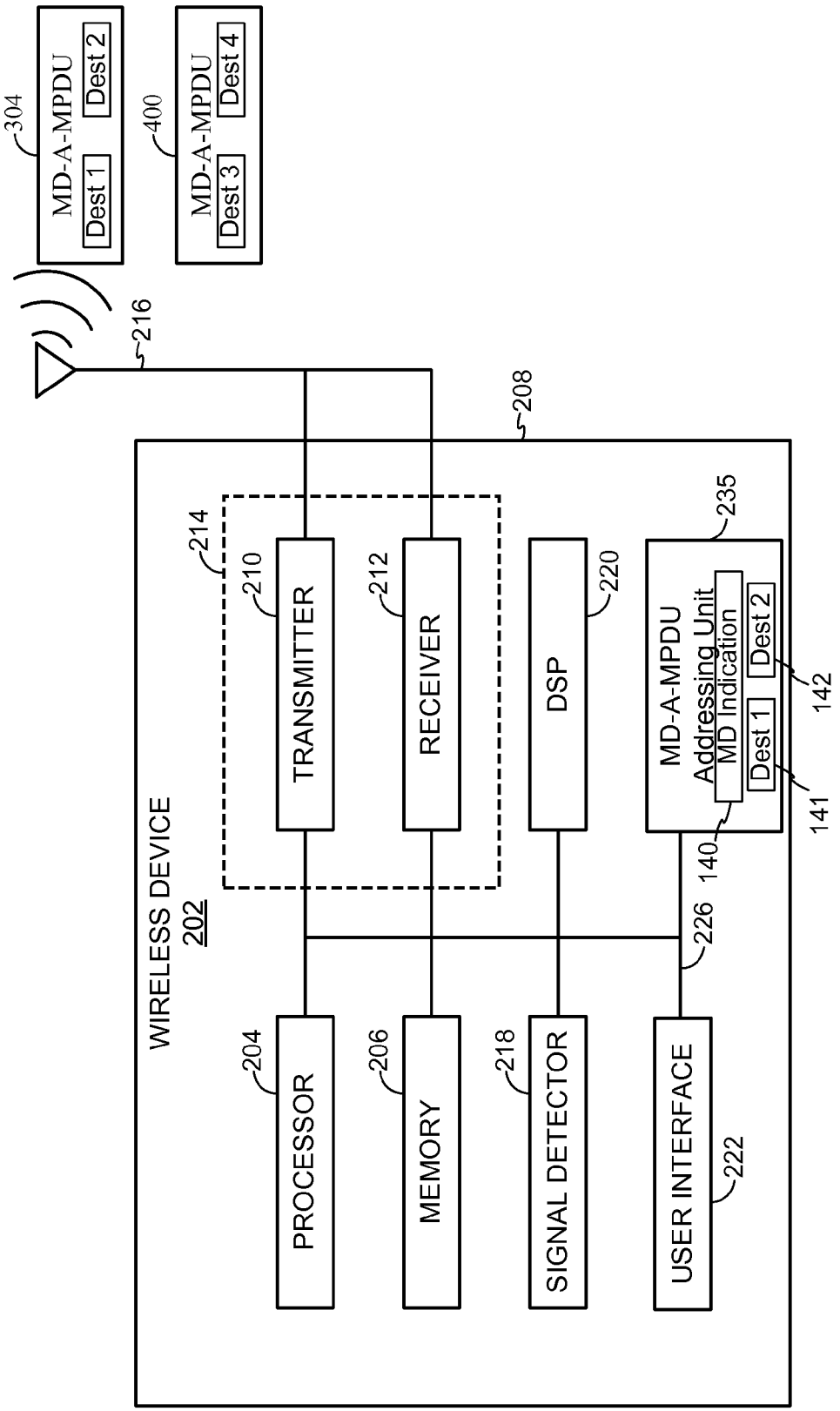

304
MD-A-MPDU
Dest 1
Dest 2
400
MD-A-MPDU
Dest 3
Dest 4
216
208
WIRELESS DEVICE
202
214
210
TRANSMITTER
212
RECEIVER
220
DSP
235
MD-A-MPDU
Addressing Unit
MD Indication
Dest 1
Dest 2
142
141
140
226
204
PROCESSOR
206
MEMORY
218
SIGNAL DETECTOR
USER INTERFACE
222

FIG. 2

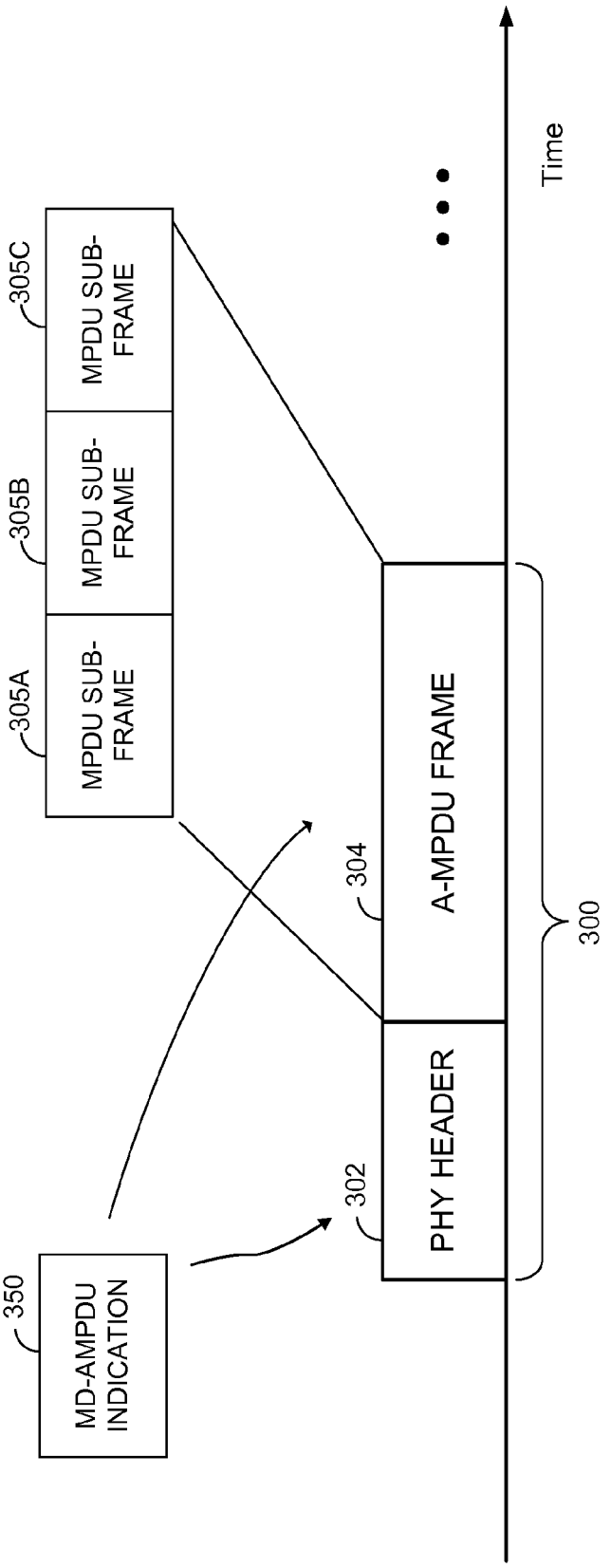

350
MD-AMPDU INDICATION
305A
MPDU SUB-FRAME
305B
MPDU SUB-FRAME
305C
MPDU SUB-FRAME
302
PHY HEADER
304
A-MPDU FRAME
300
Time

FIG. 3

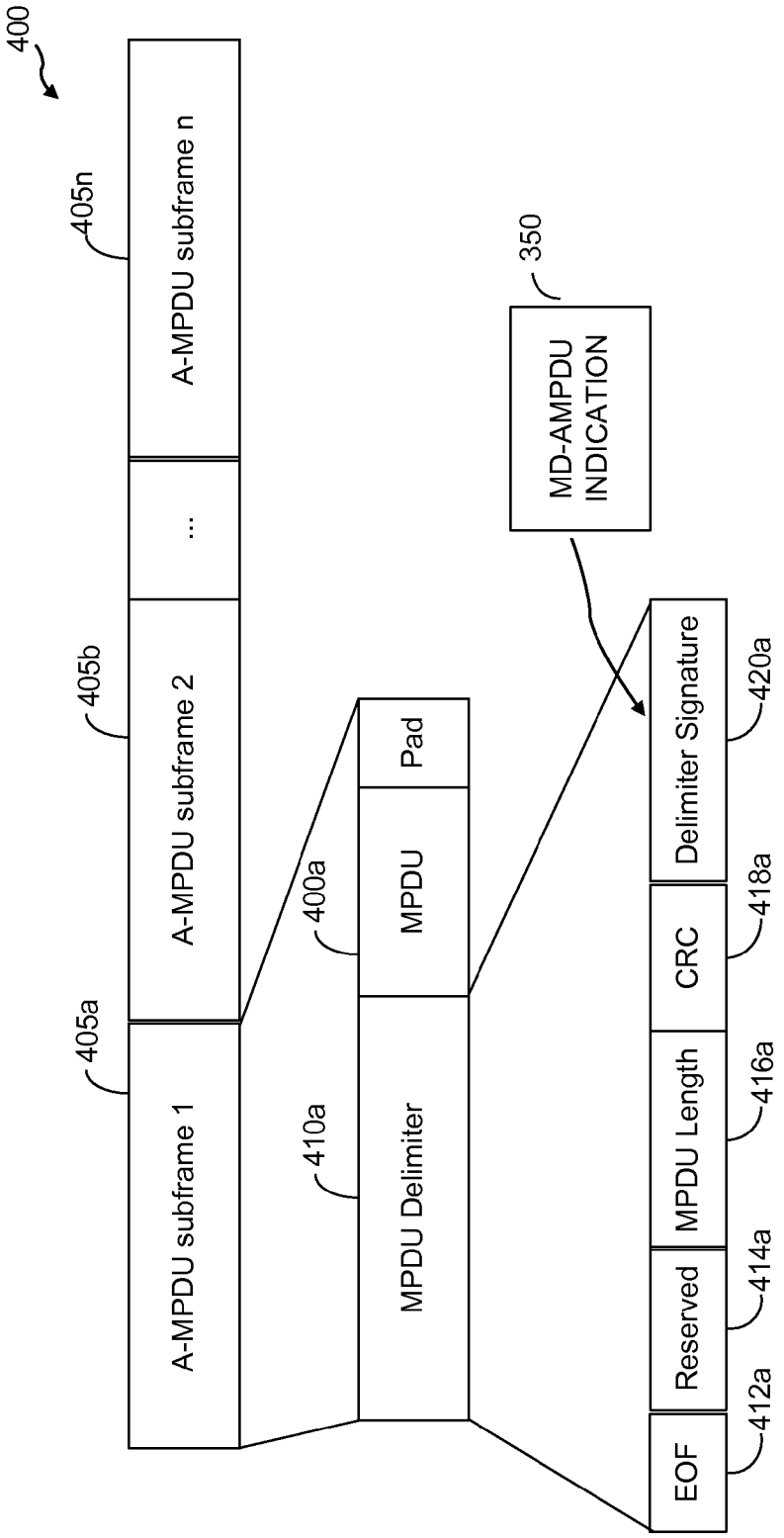

400
405n
A-MPDU subframe n
...
405b
A-MPDU subframe 2
405a
A-MPDU subframe 1
400a
MPDU
Pad
410a
MPDU Delimiter
350
MD-AMPDU INDICATION
Delimiter Signature
420a
CRC
418a
MPDU Length
416a
Reserved
414a
EOF
412a

FIG. 4A

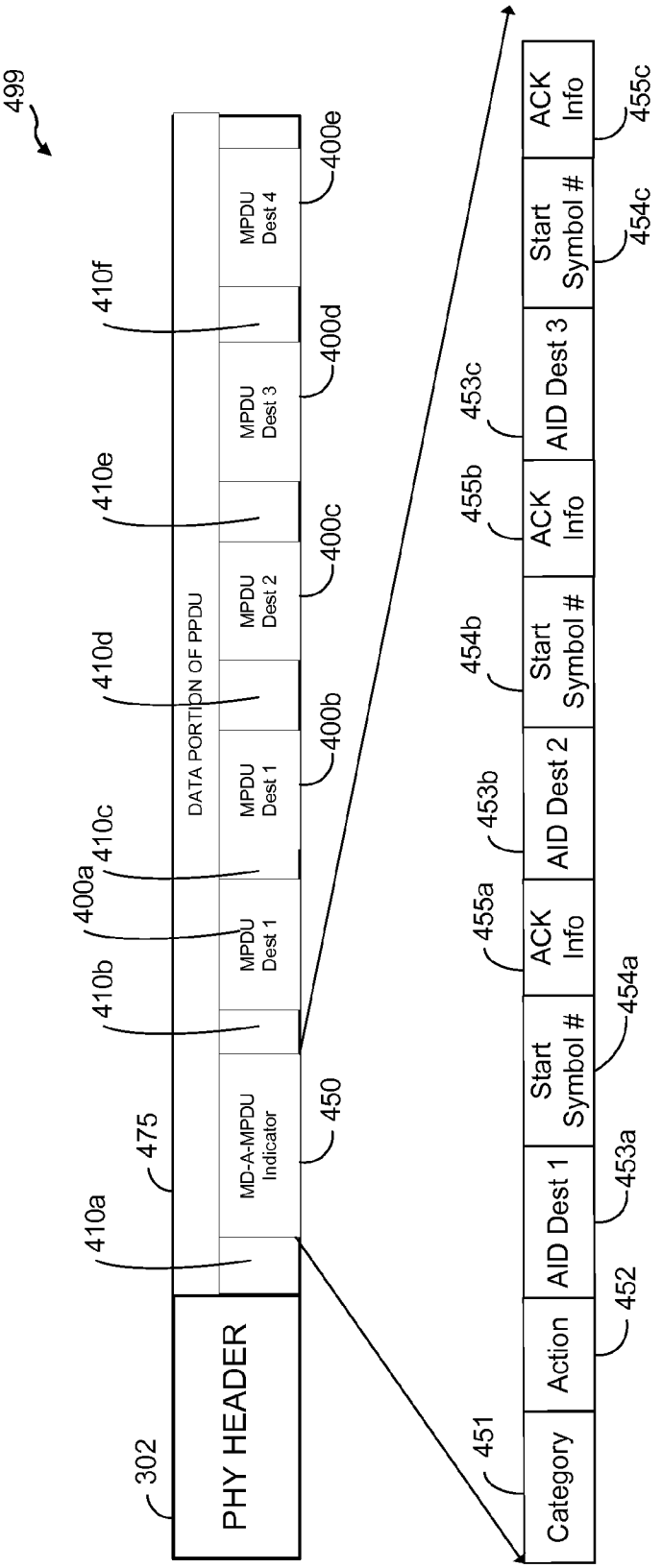

499
PHY HEADER
302
410a
475
MD-A-MPDU Indicator
450
410b
400a
MPDU Dest 1
410c
DATA PORTION OF PPDU
MPDU Dest 1
400b
410d
MPDU Dest 2
400c
410e
MPDU Dest 3
400d
410f
MPDU Dest 4
400e
Category
451
Action
452
AID Dest 1
453a
Start Symbol #
454a
ACK Info
455a
AID Dest 2
453b
Start Symbol #
454b
ACK Info
455b
AID Dest 3
453c
Start Symbol #
454c
ACK Info
455c

FIG. 4B

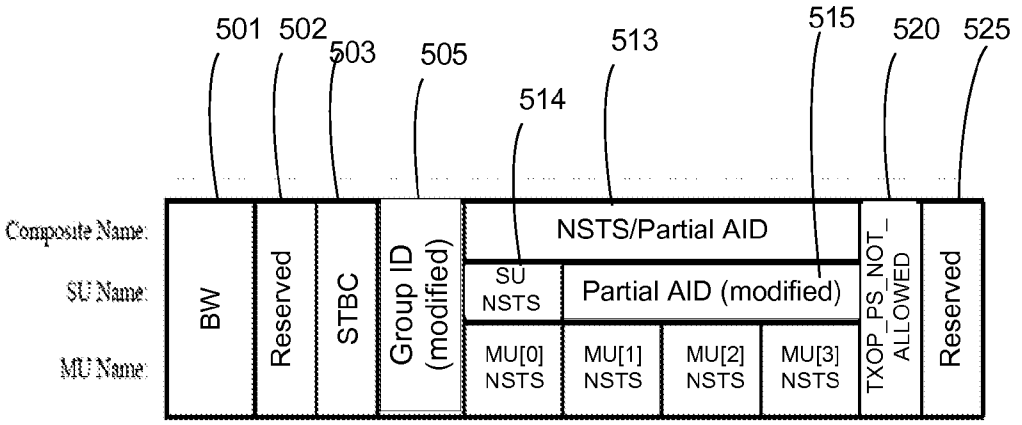

501
502
503
505
513
514
515
520
525
Composite Name:
SU Name:
MU Name:
BW
Reserved
STBC
Group ID (modified)
NSTS/Partial AID
SU NSTS
Partial AID (modified)
MU[0] NSTS
MU[1] NSTS
MU[2] NSTS
MU[3] NSTS
TXOP_PS_NOT_ALLOWED
Reserved

FIG. 5

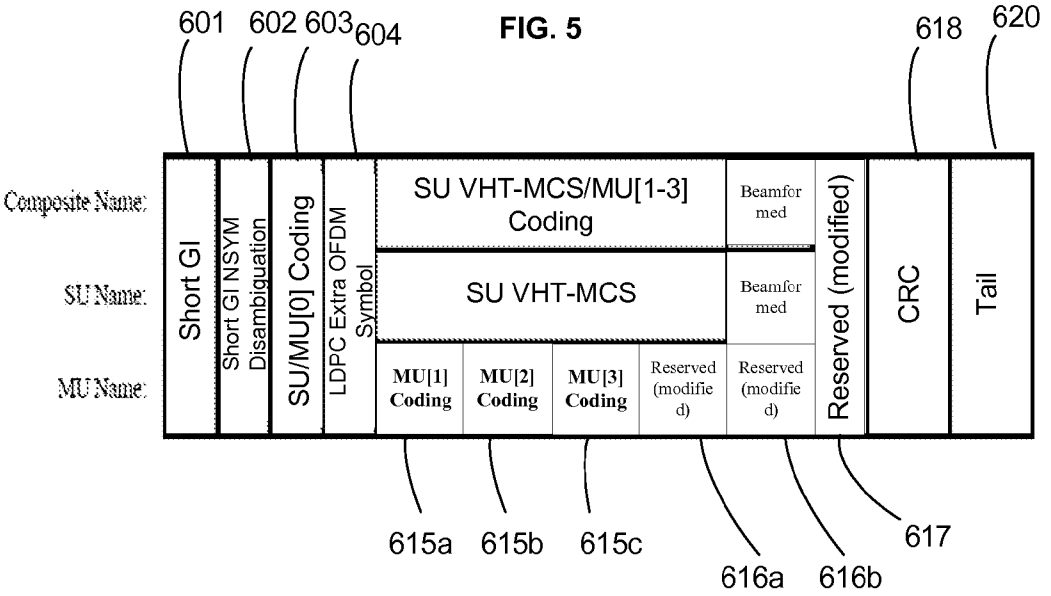

601
602
603
604
618
620
Composite Name:
SU Name:
MU Name:
Short GI
Short GI NSYM Disambiguation
SU/MU[0] Coding
LDPC Extra OFDM Symbol
SU VHT-MCS/MU[1-3] Coding
SU VHT-MCS
Beamformed
Beamformed
MU[1] Coding
MU[2] Coding
MU[3] Coding
Reserved (modified)
Reserved (modified)
Reserved (modified)
CRC
Tail
615a
615b
615c
616a
616b
617

FIG. 6

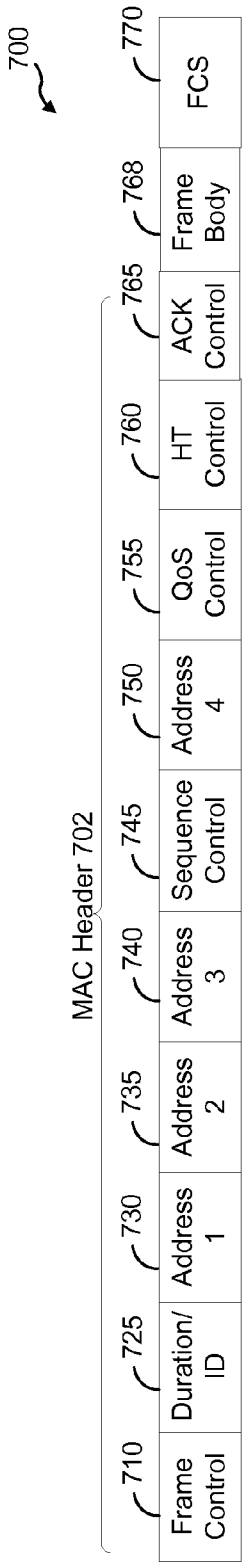

700
MAC Header 702
710
Frame Control
725
Duration/ ID
730
Address 1
735
Address 2
740
Address 3
745
Sequence Control
750
Address 4
755
QoS Control
760
HT Control
765
ACK Control
768
Frame Body
770
FCS

FIG. 7

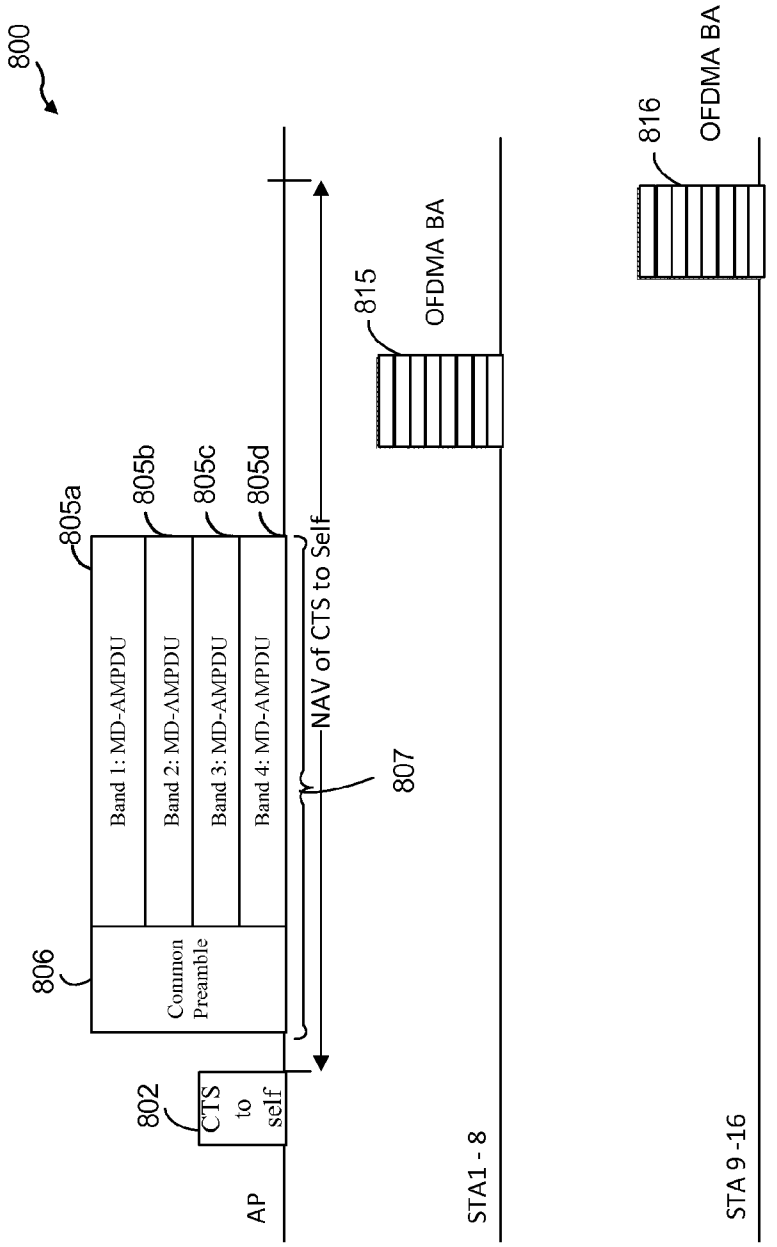

800
AP
802
CTS to self
806
Common Preamble
805a
Band 1: MD-AMPDU
805b
Band 2: MD-AMPDU
805c
Band 3: MD-AMPDU
805d
Band 4: MD-AMPDU
NAV of CTS to Self
807
STA1 - 8
815
OFDMA BA
STA 9 -16
816
OFDMA BA

FIG. 8

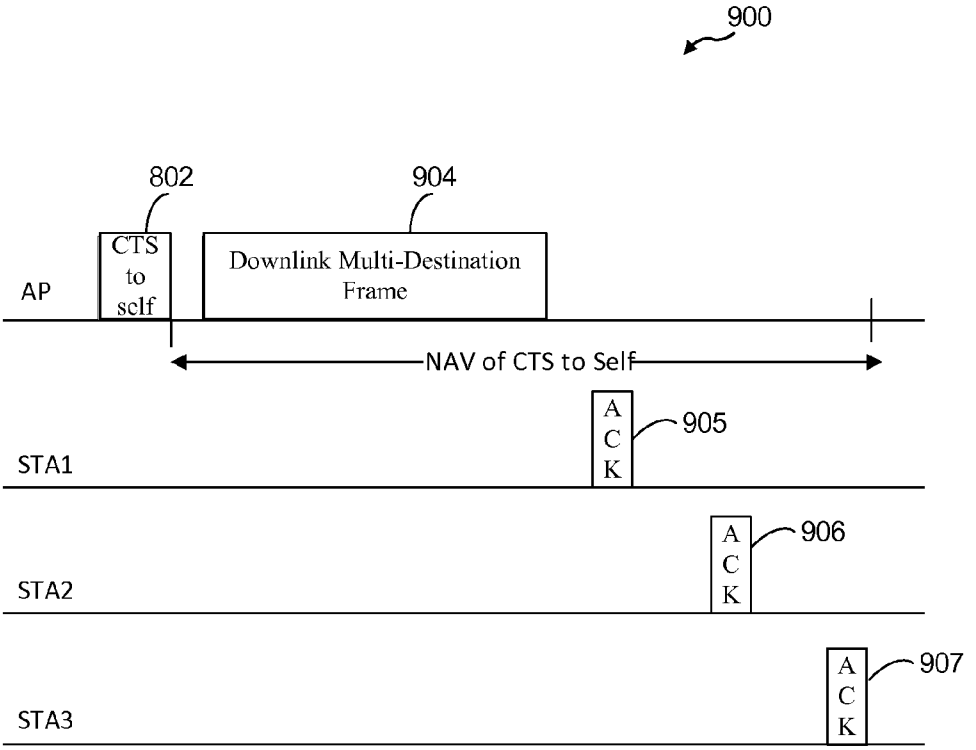

900
802
904
CTS to self
Downlink Multi-Destination Frame
AP
NAV of CTS to Self
A C K
905
STA1
A C K
906
STA2
A C K
907
STA3

FIG. 9

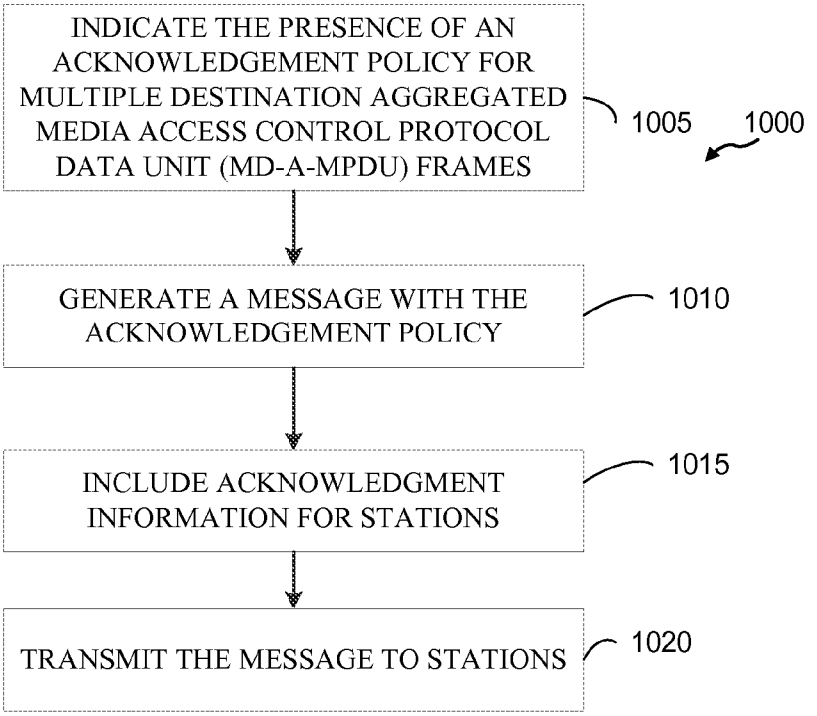

INDICATE THE PRESENCE OF AN ACKNOWLEDGEMENT POLICY FOR MULTIPLE DESTINATION AGGREGATED MEDIA ACCESS CONTROL PROTOCOL DATA UNIT (MD-A-MPDU) FRAMES
1005
1000
GENERATE A MESSAGE WITH THE ACKNOWLEDGEMENT POLICY
1010
INCLUDE ACKNOWLEDGMENT INFORMATION FOR STATIONS
1015
TRANSMIT THE MESSAGE TO STATIONS
1020

FIG. 10

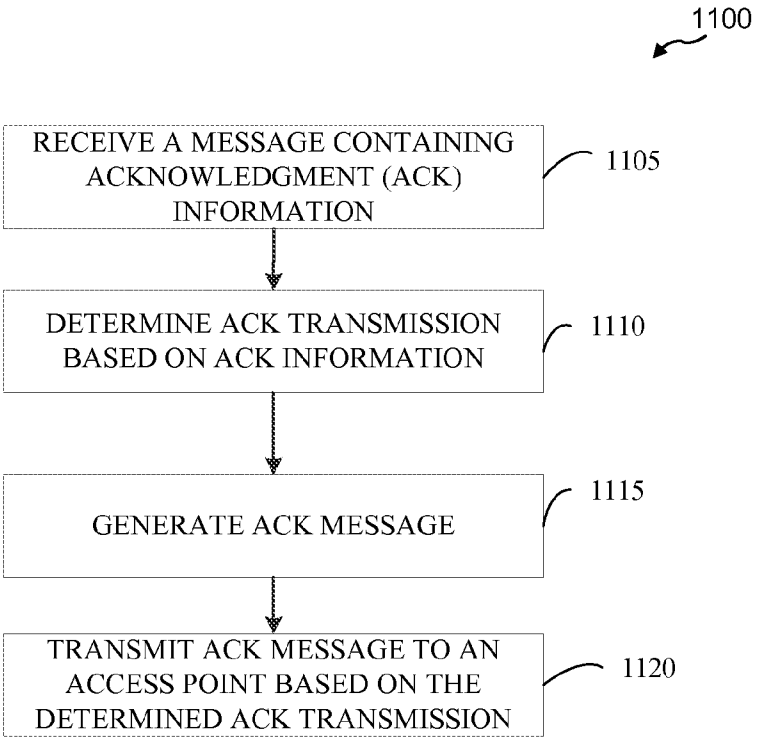

1100
RECEIVE A MESSAGE CONTAINING ACKNOWLEDGMENT (ACK) INFORMATION
1105
DETERMINE ACK TRANSMISSION BASED ON ACK INFORMATION
1110
GENERATE ACK MESSAGE
1115
TRANSMIT ACK MESSAGE TO AN ACCESS POINT BASED ON THE DETERMINED ACK TRANSMISSION
1120

FIG. 11

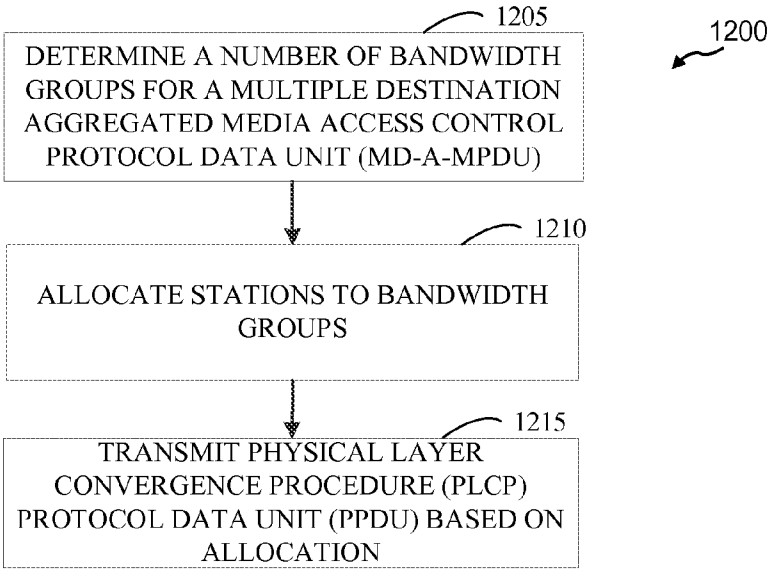

1200
1205
DETERMINE A NUMBER OF BANDWIDTH GROUPS FOR A MULTIPLE DESTINATION AGGREGATED MEDIA ACCESS CONTROL PROTOCOL DATA UNIT (MD-A-MPDU)
1210
ALLOCATE STATIONS TO BANDWIDTH GROUPS
1215
TRANSMIT PHYSICAL LAYER CONVERGENCE PROCEDURE (PLCP) PROTOCOL DATA UNIT (PPDU) BASED ON ALLOCATION

FIG. 12

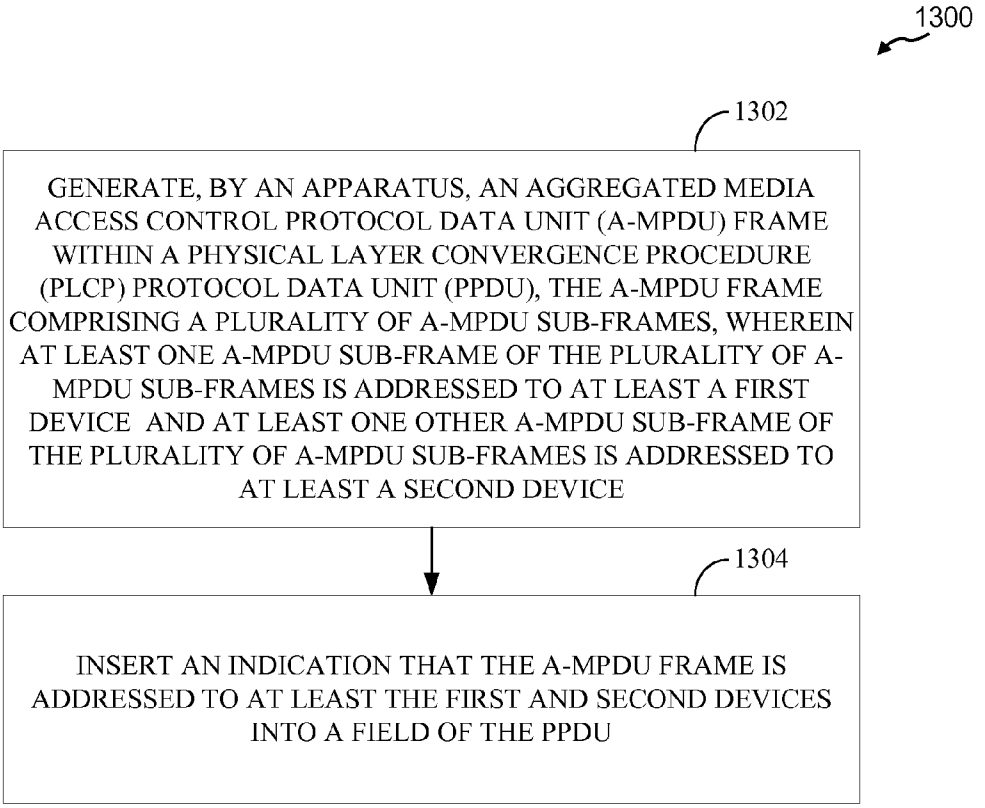

1300
1302
GENERATE, BY AN APPARATUS, AN AGGREGATED MEDIA ACCESS CONTROL PROTOCOL DATA UNIT (A-MPDU) FRAME WITHIN A PHYSICAL LAYER CONVERGENCE PROCEDURE (PLCP) PROTOCOL DATA UNIT (PPDU), THE A-MPDU FRAME COMPRISING A PLURALITY OF A-MPDU SUB-FRAMES, WHEREIN AT LEAST ONE A-MPDU SUB-FRAME OF THE PLURALITY OF A-MPDU SUB-FRAMES IS ADDRESSED TO AT LEAST A FIRST DEVICE AND AT LEAST ONE OTHER A-MPDU SUB-FRAME OF THE PLURALITY OF A-MPDU SUB-FRAMES IS ADDRESSED TO AT LEAST A SECOND DEVICE
1304
INSERT AN INDICATION THAT THE A-MPDU FRAME IS ADDRESSED TO AT LEAST THE FIRST AND SECOND DEVICES INTO A FIELD OF THE PPDU

FIG. 13

SYSTEMS AND METHODS FOR SIGNALING MULTI-DESTINATION AGGREGATED MULTI-USER MEDIA ACCESS CONTROL PROTOCOL DATA UNITS IN A WIRELESS NETWORK

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. §119(e) to U.S. Provisional Patent Application No. 62/043,061 entitled "SYSTEMS AND METHODS FOR SIGNALING MULTI-DESTINATION AGGREGATED MULTI-USER MEDIA ACCESS CONTROL PROTOCOL DATA UNITS IN A WIRELESS NETWORK" filed on Aug. 28, 2014, which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] 1. Field

[0003] The present application relates generally to wireless communications, and more specifically to systems, methods, and devices for signaling aggregated multi-user media access control protocol data units (A-MPDUs) in a wireless network.

[0004] 2. Background

[0005] In many telecommunication systems, communications networks are used to exchange messages among several interacting spatially-separated devices. Networks may be classified according to geographic scope, which could be, for example, a metropolitan area, a local area, or a personal area. Such networks would be designated respectively as a wide area network (WAN), metropolitan area network (MAN), local area network (LAN), wireless local area network (WLAN), or personal area network (PAN).

[0006] As wireless communications continue to advance, communication schemes continue to grow more complicated, prompting the aggregation of medium access control (MAC) protocol data units (MPDUs) into a single physical layer convergence procedure (PLCP) protocol data unit (PPDU). There may be a need to more efficiently transmit messages and frames across various communication schemes.

SUMMARY

[0007] The systems, methods, and devices of the invention each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this invention as expressed by the claims which follow, some features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled "Detailed Description" one will understand how the features of this invention provide advantages that include improved communications between access points and stations in a wireless network.

[0008] One aspect of the present application provides a method for wireless communication. The method comprises generating, by an apparatus, an aggregated media access control protocol data unit (A-MPDU) frame comprising a plurality of A-MPDU sub-frames, wherein at least one sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device. The method further comprises inserting an indication that the A-MPDU frame is addressed to at least the first and second devices into a PLCP protocol data unit (PPDU) field.

[0009] Another aspect of the present application provides an apparatus for wireless communication. The apparatus comprises a processor configured to generate an aggregated media access control protocol data unit (A-MPDU) frame comprising a plurality of A-MPDU sub-frames, wherein at least one sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device. The processor further configured to insert an indication that the A-MPDU frame is addressed to at least the first and second devices into a PLCP protocol data unit (PPDU) field. The apparatus further includes a transmitter configured to transmit the A-MPDU frame.

[0010] Yet another aspect of the present application provides a non-transitory computer-readable medium comprising code that, when executed, causes the apparatus to generate an aggregated media access control protocol data unit (A-MPDU) frame comprising a plurality of A-MPDU sub-frames, wherein at least one sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device. The medium further comprises code that, when executed, causes the apparatus to insert an indication that the A-MPDU frame is addressed to at least the first and second devices into a PLCP protocol data unit (PPDU) field.

[0011] Yet another aspect of the present application provides an apparatus for wireless communication. The apparatus comprises means for generating an aggregated media access control protocol data unit (A-MPDU) frame comprising a plurality of A-MPDU sub-frames, wherein at least one sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device. The apparatus further comprises means for inserting an indication that the A-MPDU frame is addressed to at least the first and second devices into a PLCP protocol data unit (PPDU) field. The apparatus further includes means for transmitting the A-MPDU frame.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. **1** illustrates an example of a wireless communication system in which aspects of the present disclosure may be employed.

[0013] FIG. **2** illustrates various components that may be utilized in a wireless device that may be employed within the wireless communication system of FIG. **1**.

[0014] FIG. **3** illustrates a physical layer data unit including an aggregated media access control protocol data unit as may be transmitted in the wireless communication system of FIG. **1**.

[0015] FIG. **4**A shows an exemplary structure of an aggregated MPDU (A-MPDU) frame.

[0016] FIG. **4**B shows an exemplary structure of a PLCP protocol data unit (PPDU).

[0017] FIG. **5** shows an exemplary structure of a very high throughput (VHT) signal (SIG) field.

[0018] FIG. **6** shows an exemplary structure of another very high throughput (VHT) signal (SIG) field.

[0019] FIG. **7** shows an exemplary structure of a media access control (MAC) protocol data unit (MPDU) frame.

[0020] FIG. **8** shows an exemplary frame exchange between an access point and multiple stations using orthogonal frequency-division multiplexing (OFDM) and a multi-destination (MD) A-MPDU.

[0021] FIG. **9** is a timing diagram of an exemplary frame exchange for scheduling acknowledgments in response to a downlink (DL) multi-destination frame.

[0022] FIG. **10** is a flowchart of a method of wireless communication, in accordance with an implementation.

[0023] FIG. **11** is a flowchart of a method of wireless communication, in accordance with an implementation.

[0024] FIG. **12** is a flowchart of a method of wireless communication, in accordance with an implementation.

[0025] FIG. **13** is a flowchart of a method of wireless communication, in accordance with an implementation.

DETAILED DESCRIPTION

[0026] Various aspects of the novel apparatuses and methods are described more fully hereinafter with reference to the accompanying drawings. The teachings disclosure may, however, be embodied in many different forms and should not be construed as limited to any specific structure or function presented throughout this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Based on the teachings herein one skilled in the art should appreciate that the scope of the disclosure is intended to cover any aspect of the novel systems, apparatuses, and methods disclosed herein, whether implemented independently of or combined with any other aspect of the invention. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the invention is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the invention set forth herein. It should be understood that any aspect disclosed herein may be embodied by one or more elements of a claim.

[0027] Although particular aspects are described herein, many variations and permutations of these aspects fall within the scope of the disclosure. Although some benefits and advantages of the preferred aspects are mentioned, the scope of the disclosure is not intended to be limited to particular benefits, uses, or objectives. Rather, aspects of the disclosure are intended to be broadly applicable to different wireless technologies, system configurations, networks, and transmission protocols, some of which are illustrated by way of example in the figures and in the following description of the preferred aspects. The detailed description and drawings are merely illustrative of the disclosure rather than limiting, the scope of the disclosure being defined by the appended claims and equivalents thereof.

[0028] Wireless network technologies may include various types of wireless local area networks (WLANs). A WLAN may be used to interconnect nearby devices together, employing widely used networking protocols. The various aspects described herein may apply to any communication standard, such as WiFi or, more generally, any member of the IEEE 802.11 family of wireless protocols. For example, the various aspects described herein may be used as part of the IEEE 802.11ax, 801.11ac, 802.11n, 802.11g, and/or 802.11b protocols.

[0029] In some aspects, wireless signals may be transmitted according to an 802.11 protocol using orthogonal frequency-division multiplexing (OFDM), direct-sequence spread spectrum (DSSS) communications, a combination of OFDM and DSSS communications, or other schemes. Implementations of 802.11 protocols may be used for sensors, metering, and smart grid networks. Advantageously, aspects of certain devices implementing 802.11 protocols may consume less power or provide higher communication speeds than devices implementing other wireless protocols, such as 802.11b, 802.11g, 802.11n or 802.11ac for example.

[0030] Certain of the devices described herein may further implement Multiple Input Multiple Output (MIMO) technology. This may also be implemented as part of 802.11 protocols. A MIMO system employs multiple (N_T) transmit antennas and multiple (N_R) receive antennas for data transmission. A MIMO channel formed by the N_T transmit and N_R receive antennas may be decomposed into N_S independent channels, which are also referred to as spatial channels or streams, where $N_S \leq \min\{N_T, N_R\}$. Each of the N_S independent channels corresponds to a dimension. The MIMO system can provide improved performance (e.g., higher throughput and/or greater reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

[0031] In some implementations, a WLAN includes various devices which are the components that access the wireless network. For example, there may be two types of devices: access points ("APs") and clients (also referred to as stations, or "STAB"). In general, an AP serves as a hub or base station for the WLAN and an STA serves as a user of the WLAN. For example, an STA may be a laptop computer, a personal digital assistant (PDA), a mobile phone, etc. In an example, an STA connects to an AP via a WiFi (e.g., IEEE 802.11 protocol such as 802.11ax) compliant wireless link to obtain general connectivity to the Internet or to other wide area networks. In some implementations an STA may also be used as an AP.

[0032] An access point ("AP") may also comprise, be implemented as, or known as a NodeB, Radio Network Controller ("RNC"), eNodeB, Base Station Controller ("BSC"), Base Transceiver Station ("BTS"), Base Station ("BS"), Transceiver Function ("TF"), Radio Router, Radio Transceiver, or some other terminology.

[0033] A station "STA" may also comprise, be implemented as, or known as an access terminal ("AT"), a subscriber station, a subscriber unit, a mobile station, a remote station, a remote terminal, a user terminal, a user agent, a user device, user equipment, or some other terminology. In some implementations an access terminal may comprise a cellular telephone, a cordless telephone, a Session Initiation Protocol ("SIP") phone, a wireless local loop ("WLL") station, a personal digital assistant ("PDA"), a handheld device having wireless connection capability, or some other suitable processing device connected to a wireless modem. Accordingly, one or more aspects taught herein may be incorporated into a phone (e.g., a cellular phone or smartphone), a computer (e.g., a laptop), a portable communication device, a headset, a portable computing device (e.g., a personal data assistant), an entertainment device (e.g., a music or video device, or a satellite radio), a gaming device or system, a global positioning system device, or any other suitable device that is configured to communicate via a wireless medium.

[0034] As discussed above, certain of the devices described herein may implement 802.11 protocols. Such devices,

whether used as an STA or AP or other device, may be used for smart metering or in a smart grid network. Such devices may provide sensor applications or be used in home automation. The devices may instead or in addition be used in a healthcare context, for example for personal healthcare. They may also be used for surveillance, to enable extended-range Internet connectivity (e.g. for use with hotspots), or to implement machine-to-machine communications. Aggregated MPDUs (A-MPDUs) for multiple destinations may be efficient for transferring amounts of data to several devices without incurring large overhead. Techniques are needed to indicate the presence of multi destination A-MPDUs in a PPDU and the timing of the corresponding acknowledgments.

[0035] FIG. **1** illustrates an example of a wireless communication system **100** in which aspects of the present disclosure may be employed. The wireless communication system **100** may operate pursuant to a wireless standard, for example at least one of the the 802.11ac, 802.11n, 802.11g and 802.11b standards. The wireless communication system **100** may include an AP **104**, which communicates with STAs **106***a*-**106***f*. In some embodiments, the AP **104** may comprise a MD-A-MPDU Addressing Unit **135***a*. The MD-A-MPDU Addressing Unit **135***a* may be configured to address MPDUs of an A-MPDU frames to different stations. For example, as shown in FIG. **1**, the MD-A-MPDU Addressing Unit **135***a* may be configured to address a first MPDU of the MD-A-MPDU frame to a first destination **141** and to address a second MPDU of the MD-A-MPDU frame to a second destination **142**. The MD-A-MPDU Addressing Unit **135***a* may also be configured to indicate that the AP **104** is transmitting a multiple destination (MD) A-MPDU. For example, as shown in FIG. **1**, the MD-A-MPDU Addressing Unit **135**a may be configured to insert an MD indication **140** to indicate that AP **104** is transmitting a MD-A-MPDU frame (e.g., MD-A-MPDU **304** and MD-A-MPDU **400** described below). In some aspects, the MD indication **140** may indicate that the AP **104** is transmitting a single destination A-MPDU frame.

[0036] A variety of processes and methods may be used for transmissions in the wireless communication system **100** between the AP **104** and the STAs **106***a*-**106***f*. For example, signals may be transmitted and received between the AP **104** and the STAs **106***a*-**106***f* in accordance with OFDM/OFDMA techniques. If this is the case, the wireless communication system **100** may be referred to as an OFDM/OFDMA system. Alternatively, signals may be transmitted and received between the AP **104** and the STAs **106***a*-**106***f* in accordance with CDMA techniques. If this is the case, the wireless communication system **100** may be referred to as a CDMA system.

[0037] In FIG. **1**, the STAs **106***a*-**106***c* may comprise high efficiency (HEW) wireless stations (e.g., stations that operate according to 802.11ax or later developed communication protocols), while the STAs **106***d*-**106***f* may comprise "legacy" wireless stations (e.g., stations that operate according to one or more of 802.11a/b/g/n/ac communication protocols). For example, any of the STAs **106***a*-**106***c* may be configured to communicate at higher data rates and/or to utilize less energy during communication or operation as compared to the legacy wireless STAs **106***d*-**106***f*. Thus, for the purposes of this disclosure, the STAs **106***a*-**106***c* may be considered part of a first group of STAs **108***a*, while the STAs **106***d*-**106***f* may be considered part of a second group of STAs **108***b*. As illustrated, the AP **104** may transmit MD-A-MPDU frames such as frames **304** or **400** (described in further detail below) to multiple stations. For example, the AP **104** may transmit the MD-A-MPDU frame **304** to STAs **106***a* and **106***b* and may transmit the MD-A-MPDU frame **400** to STAs **106***c* and **106***d*.

[0038] It should be noted that the wireless communication system **100** may not have a central AP **104**, but rather may function as a peer-to-peer network between the STAs **106***a*-**106***f*. Accordingly, the functions of the AP **104** described herein may alternatively be performed by one or more of the STAs **106***a*-**106***f*.

[0039] FIG. **2** illustrates various components that may be utilized in a wireless device **202** that may be employed within the wireless communication system **100**. The wireless device **202** is an example of a device that may be configured to implement the various methods described herein. For example, the wireless device **202** may comprise the AP **104** or one of the STAs **106***a*-**106***f*.

[0040] The wireless device **202** may include a processor **204** which controls operation of the wireless device **202**. The processor **204** may also be referred to as a central processing unit (CPU). Memory **206**, which may include both read-only memory (ROM) and random access memory (RAM), provides instructions and data to the processor **204**. A portion of the memory **206** may also include non-volatile random access memory (NVRAM). The processor **204** typically performs logical and arithmetic operations based on program instructions stored within the memory **206**. The instructions in the memory **206** may be executable to implement the methods described herein.

[0041] The processor **204** may comprise or be a component of a processing system implemented with one or more processors. The one or more processors may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that can perform calculations or other manipulations of information.

[0042] The processing system may also include non-transitory machine-readable media for storing code or software. Software shall be construed broadly to mean any type of instructions, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Instructions may include code (e.g., in source code format, binary code format, executable code format, or any other suitable format of code). The instructions, when executed by the one or more processors, cause the processing system to perform the various functions described herein.

[0043] The wireless device **202** may also include a housing **208** that may include a transmitter **210** and a receiver **212** to allow transmission and reception of data between the wireless device **202** and a remote location. The transmitter **210** and receiver **212** may be combined into a transceiver **214**. An antenna **216** may be attached to the housing **208** and electrically coupled to the transceiver **214**. The wireless device **202** may also include (not shown) multiple transmitters, multiple receivers, multiple transceivers, and/or multiple antennas, which may be utilized during MIMO communications, for example.

[0044] The wireless device **202** may also include a signal detector **218** that may be used in an effort to detect and quantify the level of signals received by the transceiver **214**. The signal detector **218** may detect such signals as total

energy, energy per subcarrier per symbol, power spectral density and other signals. The wireless device **202** may also include a digital signal processor (DSP) **220** for use in processing signals. The DSP **220** may be configured to generate a data unit for transmission. In some aspects, the data unit may comprise a PPDU. In some aspects, the PPDU may be referred to as a frame or packet. In some aspects, the PPDU may comprise an aggregated MPDU comprising a plurality of MPDUs.

[0045] The wireless device **202** may further comprise a user interface **222** in some aspects. The user interface **222** may comprise a keypad, a microphone, a speaker, and/or a display. The user interface **222** may include any element or component that conveys information to a user of the wireless device **202** and/or receives input from the user.

[0046] In some aspects, the wireless device **202** may further comprise a MD-A-MPDU Addressing Unit **235**. The MD-A-MPDU Addressing Unit **235** may be configured to address each MPDU of an A-MPDU frames to a different station. The MD-A-MPDU Addressing Unit **235** may also be configured to indicate that the AP **104** is transmitting a multiple destination A-MPDU. In some aspects, the MD-A-MPDU Addressing Unit **235** is similar to and performs similar functions as the MD-A-MPDU Addressing Unit **135***a* of FIG. **1**. For example, as shown in FIG. **2**, the MD-A-MPDU Addressing Unit **235** may be configured to address a first MPDU of the MD-A-MPDU frame to a first destination **141** and to address a second MPDU of the MD-A-MPDU frame to a second destination **142**. Additionally, as shown in FIG. **2**, the MD-A-MPDU Addressing Unit **135***a* may be configured to insert an MD indication **140** to indicate that AP **104** is transmitting a MD-A-MPDU frame (e.g., MD-A-MPDU **304** and MD-A-MPDU **400** described below) or transmitting a single destination A-MPDU. As illustrated, antenna **216** may be used to transmit MD-A-MPDU frames such as frames **304** or **400** (described in further detail below). MD-A-MPDU frames **304** and **400** may each contain information more two or more devices. For example, the MD-A-MPDU frame **304** may contain data for a first destination (Dest **1**) and a second destination (Dest **2**). Additionally, the MD-A-MPDU frame **400** may contain data for a third destination (Dest **3**) and a fourth destination (Dest **4**). In some aspects, the destinations (Dest **1**-**4**) may comprise one or more of the STAs **106***a*-*f* and/or the AP **104** of FIG. **1**. In some aspects, transmitting MD-A-MPDU frames can allow for efficient use of the wireless medium and reduce overhead.

[0047] The various components of the wireless device **202** may be coupled together by a bus system **226**. The bus system **226** may include a data bus, for example, as well as a power bus, a control signal bus, and a status signal bus in addition to the data bus. Those of skill in the art will appreciate the components of the wireless device **202** may be coupled together or accept or provide inputs to each other using some other mechanism.

[0048] Although a number of separate components are illustrated in FIG. **2**, those of skill in the art will recognize that one or more of the components may be combined or commonly implemented. For example, the processor **204** may be used to implement not only the functionality described above with respect to the processor **204**, but also to implement the functionality described above with respect to the signal detector **218** and/or the DSP **220**. Further, each of the components illustrated in FIG. **2** may be implemented using a plurality of separate elements.

[0049] As discussed above, the wireless device **202** may comprise an AP **104** or an STA **106***a*-**106***f*, and may be used to transmit and/or receive communications. The communications exchanged between devices in a wireless network may include data units which may comprise packets or frames. In some aspects, the data units may include data frames, control frames, and/or management frames. Data frames may be used for transmitting data from an AP and/or a STA to other APs and/or STAs. Control frames may be used together with data frames for performing various operations and for reliably delivering data (e.g., acknowledging receipt of data, polling of APs, area-clearing operations, channel acquisition, carrier-sensing maintenance functions, etc.). Management frames may be used for various supervisory functions (e.g., for joining and departing from wireless networks, etc.).

[0050] An aggregate media access control protocol data unit (A-MPDU) frame allows a device to send multiple data frames in a single physical layer frame. Typically a physical layer frame (e.g., A-MPDU) is intended only for a single destination. Each physical layer frame transmission, however, requires a certain amount of overhead (e.g., preamble overhead, sounding, and channel state information feedback). In many downlink traffic situations, frames may be sent to multiple destinations. Some examples for downlink traffic sources for frames include downlink transmission control protocol (TCP) acknowledgments (e.g., in response to audio/video/data uploads, http get etc.), phone applications (e.g., receiving posts via Facebook or Twitter, ad push notifications, email notifications), and VoIP sessions. In such situations where multiple frames are sent to multiple destinations, it may be desirable to send a single A-MPDU containing frames for multiple destinations. In some aspects, this may be desirable when transmitting small frames (e.g., less than 50 bytes) where a physical layer preamble overhead may be large compared to the size of the frame. For example, for a 50 byte frame at 80 MHz transmitted with an MCS 7 as defined in the 802.11ac standard, there may be 10 OFDM symbols of preamble for 1 OFDM symbol of data. Accordingly, one non-limiting method of reducing such overhead may be to aggregate frames for multiple destinations in a single PPDU. Embodiments described herein relate to transmitting and signaling the presence of multiple destination (MD) A-MPDUs and relate to acknowledgments by stations receiving the MD-AMPDU.

[0051] FIG. **3** illustrates a physical layer data unit **300** including a physical layer (PHY) header **302** and an aggregated media access control protocol data unit **304** as may be transmitted in the wireless communication system **100** of FIG. **1**. As shown, time increases horizontally across the page on the x-axis. If the AP **104** of FIG. **1** has buffered units to send to more than one of the STAs **106***a*-**106***f*, instead of transmitting multiple wireless messages, the AP **104** may transmit a single aggregated MPDU frame **304**. The A-MPDU frame **304** may include multiple A-MPDU sub-frames **305**A-**305**C. One or more of the multiple A-MPDU sub-frames **305**A-**305**C may be addressed to a different STA than one or more of the multiple A-MPDU sub-frames **305**A-**305**C. In some embodiments, the A-MPDU Addressing Unit **235** of FIG. **2** may be configured to address the A-MPDU sub-frames **305**A-**305**C to each of the different STAs (e.g., STAs **106***a*-**106***f*).

[0052] However, the 802.11a/b/g/n/ac wireless communication protocols prescribe that all MPDU frames in a PPDU comprising an A-MPDU are addressed to the same STA.

Thus, the legacy STAs **106***d*-**106***f*, operating according to one or more of the 802.11a/b/g/n/ac wireless communication protocols may discontinue processing the A-MPDU frame **304** (or transition to a power save mode) if the first MPDU subframe **305**A is not addressed to the particular legacy STA **106***d*-**106***f* receiving the PPDU **300**. HEW STAs **106***a*-**106***c* however, may require a particular indication that the A-MPDU frame **304** is meant for multiple destinations to properly decode the A-MPDU frame **304**. In some embodiments, the indication that the A-MPDU frame **304** is meant for multiple destinations may comprise MD-AMPDU indication **350** which may be included in either the PHY header **302** portion or the A-MPDU frame **304** portion of the PPDU **300**.

[0053] FIG. **4**A shows an exemplary structure of an aggregated MPDU (A-MPDU) frame **400**. As shown, the A-MPDU frame **400** includes a variable number (n) of A-MPDU subframes, as shown **405***a*, **405***b*, and **405***n*. In some embodiments each of the A-MPDU sub-frames **405***a*, **405***b*, and **405***n* may be intended for different stations. Each of the A-MPDU sub-frames **405***a*, **405***b*, and **405***n* may in some aspects be comprised of an MPDU delimiter field **410***a*, an MPDU frame **400***a*, and zero or more pad bytes. The MPDU frames **300***a* may in some aspects conform substantially with the MPDU frames **305***a*-**305***c* illustrated in FIG. **3**.

[0054] Each of the MPDU delimiter fields, for example, MPDU delimiter field **410***a*, may include an end of frame (EOF) field **412***a*, a reserved field **414***a*, an MPDU length field **416***a*, a CRC field **418***a*, and a delimiter signature field **420***a*. The delimiter signature field **420***a* may to indicate a difference between two MSDU subframe delimiter signature fields. Typically, this field is set to the hexidecimal value **7**E.

[0055] In some embodiments, the delimiter signature field **420***a* may indicate to stations equipped with a protocol to decode MD-AMPDUs (e.g., HEW stations) that the A-MPDU is a MD-AMPDU. For example, in MD-AMPDU frames, the delimiter signature field **420***a* may comprise the MD-AMPDU indication **350** to indicate the presence of the MD-AMPDU frame **400**. In some embodiments, the delimiter signature field **420***a* may be set a different value than **7**E, such as **7**D, and that different value is specified and known to all HEW stations. Legacy stations (e.g., STAs **106***d*-**106***f*) that receive and decode the delimiter signature field **420***a* as **7**D will drop the frame, whereas HEW stations (e.g., STAs **106***a*-**106***c*) will decode the delimiter signature field **420***a* as **7**D will know that the A-MPDU frame **400** is a MD-AMPDU. In some embodiments, the A-MPDU Addressing Unit **235** of FIG. **2** may be configured to address each of the A-MPDU sub-frames **405***a*-**405***n* to different STAs (e.g., STAs **106***a*-**106***f*).

[0056] FIG. **4**B shows an exemplary structure of a MD PPDU **499**. The MD PPDU frame **499** comprises the PHY header **302** and the data portion of the PPDU **475**. In some embodiments, the data portion of the PPDU **475** may comprise the A-MPDU frame **304** of FIG. **3**. As shown, the data portion of the PPDU **475** comprises MPDU delimiters **410***a*-**410***f*, a MD-AMPDU indicator field **450** and MPDUs **400***a*-**400***e*. The MD-AMPDU indicator field **450** may comprise a single management MPDU as the first MPDU which indicates that the MD PPDU **499** comprises a MD-AMPDU frame and indicates the destinations of MPDUs **400** that are included in the data portion of the PPDU **300**. As shown, the MD-AMPDU indicator **450** comprises a category field **451** which indicates the category for the MD-AMPDU indicator field **450**, an action field **452** to specify certain actions for the stations receiving the MD PPDU **499**, an address identifier (AID) field (e.g., **453***a*-**453***c*) of destination STAs, an approximate symbol start field (e.g., **454***a*-**454***c*) of the destination STAs, and an acknowledgement information (ACK Info) field (e.g., **455***a*-**455***c*) which includes information on how the uplink acknowledgement should be sent for the destination STAs.

[0057] In some embodiments, a very high throughput (VHT) signal (SIG) field of a physical layer header field (e.g., PHY header **302**) may indicate to stations equipped with a protocol to decode MD-AMPDUs (e.g., HEW stations) that an A-MPDU is a MD-AMPDU. FIG. **5** shows an exemplary VHT-SIG-A field **500**. In some embodiments, the name of sub-fields of the VHT-SIG-A field **500** may depend on the type of transmission. For example, as shown in FIG. **5** (and similarly in FIG. **6**), the name of certain subfields depends on whether the VHT-SIG-A field **500** is transmitted under a composite transmission (e.g., composite name), a single user transmission (e.g., SU name), or a multi-user transmission (e.g., MU name). The names of sub-fields for the different transmissions correspond to rows of FIG. **5** and FIG. **6** indicating the transmission type.

[0058] As shown in FIG. **5**, the VHT-SIG-A field **500** comprises bandwidth field **501**, a reserved field **502**, a space-time block coding field **503**, a group identifier field (ID) **505**, a transmission opportunity power save not allowed field **520**, and a second reserved field **525**. Under the composite name for the VHT-SIG-A field **500**, the VHT-SIG-A field **500** comprises a number of space time streams (NSTS)/partial address identifier field **513**. Under a single user transmission, the VHT-SIG-A field **500** comprises single user NSTS field **514** and a partial address identifier (AID) field **515**. In some embodiments, the AP **104** may determine and communicate to stations associated with the AP **104** that a certain partial AID value is reserved to indicate that an A-MPDU with that particular partial AID is a MD-AMPDU. The partial AID field **515** may be modified to indicate the presence of a MD-AMPDU. In some aspects, the MD-A-MPDU Addressing Unit **135***a* of FIG. **1** may be configured to indicate that an A-MPDU with that particular partial AID is a MD-AMPDU. Stations not associated with the AP **104** may read and drop the MD-AMPDU because the partial AID field **515** does not match their AID or partial AID. In some embodiments, the partial AID field **515** may comprise 9 bits.

[0059] The group ID field **505** may identify a group of stations that should receive the A-MPDU. In some embodiments, the group ID field **505** may be configured or modified to indicate the presence of a MD-AMPDU frame. For example, the AP **104** may determine and communicate that a certain group ID, or a set of group IDs, is reserved to indicate to receiving stations that the frame is a MD-AMPDU frame. In some embodiments, the reserved group ID may be in the range of 01 to 62. In some aspects, the use of a group ID to indicate the presence of a MD-AMPDU frame can help some devices to shutoff receiver circuitry when the A-MPDU does not contain MPDUs for them. In some aspects, the MD-A-MPDU Addressing Unit **135***a* of FIG. **1** may be configured to indicate that an A-MPDU with a particular group ID value is a MD-AMPDU. In some embodiments, the group ID field may comprise 6 bits.

[0060] In other embodiments, a reserved bit of the VHT-SIG-A field may indicate that a A-MPDU is a MD-AMPDU. FIG. **6** is a diagram of an exemplary VHT-SIG-A2 field **600**

structure. The VHT-SIG-A2 field **600** comprises a short guard interval (GI) field **601**, a short GI number of transmission symbols (NSYM) disambiguation field **602**, a single/multi-user (SU/MU) coding field **603**, a low-density parity check (LDPC) extra OFDM symbol field **604**, a reserve field **617**, a cyclic redundancy check (CRC) field **618**, and a tail field **620**. Under multiple user transmissions, the VHT-SIG-A2 field **600** comprises MU coding fields **615***a*, **615***b*, **615***c* and reserve bits **616***a* and **616***b*. Typically, if a bit is marked reserved, the bit is set to zero. In some embodiments, in order to indicate the presence of a MD-AMPDU frame, one or more of the reserved bits may modified and/or set to 1. In these embodiments, legacy stations (e.g., stations (e.g., STAs **106***d*-**106***f*) that receive and decode the VHT-SIG-A2 field **600** with one or more of the reserve bits **616***a*, **616***b* and **617** set to 1 will be unable to decode the frame and will drop the rest of the frame. HEW stations (e.g., STAs **106***a*-**106***c*) will be equipped with the protocol to know which reserve bits indicate the presence of the MD-A-MPDU frame and will decode the remainder of the frame. In some aspects, the MD-A-MPDU Addressing Unit **135***a* of FIG. **1** may be configured to indicate that an A-MPDU with one or more of the reserved bits **616***a*, **616***b* and **617** set to 1 is a MD-AMPDU.

[0061] In some embodiments, a SIG field with a different frame format than those shown in FIGS. **5** and **6** may be used. This SIG field may be used for all MD-A-MPDUs and may be decodable only by HEW stations. In some aspects, the same indications described above may be applied to PPDUs using this SIG field with a different frame format. Additionally, the indication that the A-MPDU frame (e.g., A-MPDU **304** or **400**) is meant for multiple destinations may be located in any other preamble field (e.g., a signal (SIG) field, long training field (LTF), short training field (STF), etc.). In some aspects, the preamble field may be located within the PHY header portion **302**.

[0062] In some embodiments, the AP **104** may set an acknowledgment policy for stations receiving MD-AMPDUs (e.g., A-MPDU **400**). To coordinate acknowledgements from each of the STAs, one or more of the A-MPDU sub-frames **305***a*-**305***c* or **405***a*-**405***n* (See FIGS. **3** and **4**) may include one or more fields defining an acknowledgement policy (e.g., transmission parameters of acknowledgment frames transmitted from each of the STAs in response to the A-MPDU **400**) for the A-MPDU sub-frame. For example, the acknowledgement policy may indicate whether an acknowledgement for the A-MPDU sub-frame should be transmitted by an addressed receiver, the type of acknowledgement that should be transmitted (e.g., whether an acknowledgement or block acknowledgement should be transmitted) and/or a delay time period between when the A-MPDU frame **304** is received and when an acknowledgement to any MPDU sub-frame included in the A-MPDU frame **304** is transmitted. The indicated acknowledgement policy of each A-MPDU sub-frame **305***a*-*c*, **405***a*-**405***n* functions to coordinate acknowledgements of each of the MPDU sub-frames **305***a*-**305***c*, **405***a*-**405***n* so as to reduce the probability of collisions occurring if each of the MPDU sub-frames **305***a*-**305***c*, **405***a*-**405***n* is acknowledged.

[0063] In order to set the acknowledgment, the AP **104** may include an indication of the acknowledgment policy in the MAC header portion of a frame. FIG. **7** shows an exemplary structure of a media access control protocol data unit (MPDU) frame **700**. The MPDU frame **700** may correspond to any of the MPDU sub-frames **305**A-**305**C or **405**A-**406**N, as previously described in connection with FIGS. **3** and **4**, respectively. As shown, the MPDU frame **700** includes 12 different fields: a frame control (fc) field **710**, a duration/identification (dur) field **725**, a receiver address (a**1**) field **730**, a transmitter address (a**2**) field **735**, a destination address (a**3**) field **740**, a sequence control (sc) field **745**, a fourth address (a**4**) field **750**, a quality of service (QoS) control (qc) field **755**, a High Throughput (HT)/VHT control field **760**, an acknowledgment (ACK) control field **765**, a frame body **768**, and a frame check sequence (FCS) field **770**. Some or all of the fields **710**-**765** make up the MAC header **702**.

[0064] The ACK control field **765** may indicate to a station receiving the MPDU frame **700** when and how a BA is sent and a time gap (or frequency offset or spatial stream gap) between successive BAs (e.g., transmission parameters of block acknowledgment frames transmitted from each of the STAs in response to the MPDU frame **700**). For example, ACK control field **765** may indicate that one or more stations should send a BA a Short Interframe Space (SIFS) time period after the PPDU carrying the MPDU frame **700**. In some embodiments, the presence of the ACK control field **765** may be indicated using a reserved bit/bit combination in the frame control field **710**, QoS control field **755** or the HT/VHT control field **760**. Information that may be included in the ACK control field **765** may include: BA modulation and coding scheme (MCS); bandwidth and/or spatial stream information such as total uplink bandwidth, per STA bandwidth for BA, or the total number of uplink spatial streams; and BA index in which each STA determines the time, exact bandwidth and spatial stream index from its BA index and the bandwidth and spatial stream information.

[0065] In some embodiments, any two octet field may be sufficient to create the ACK control field **765**. In some embodiments, ten (10) bits of the ACK control field **765** may be partitioned as follows: 3 bits to indicate a number of spatial streams (e.g, one of 8 spatial stream indices), 4 bits to indicate a number of frequency bands (e.g., one of 16 frequency bands), and 3 bits to indicate a time position for the BA. From the 10 bits of the ACK control field **765**, a device can determine exactly how and when to send the BA. In some embodiments, the BA MCS is to be set to MCS of the downlink PPDU.

[0066] In some embodiments, OFDMA and MD-AMPDU can be combined to optimize the time taken for the entire PPDU transmission. OFDMA allows different data rates per STA because with OFDMA, each STA is not restricted to the minimum MCS across all STAs. In some embodiments, STAs located further away from the AP **104** may have lower a MCS than STAs located closer to the AP **104**. In some embodiments, STAs having higher MCSs can be combined using MD-AMPDU and this further combined with OFDMA, to transmit the higher MCSs on a specific frequency bandwidth. In some embodiments, the STAs with lower MCSs can be combined using MD-AMPDU and transmitted on a different bandwidth using OFDMA to attain an overall lower length PPDU to be transmitted and increase the data rate of the system.

[0067] FIG. **8** is a timing diagram of an exemplary frame exchange using OFDMA and MD-AMPDU. In FIG. **8**, the AP **104** sends a clear to send (CTS) to self message **802** to reserve the medium for the MD-AMPDU transmission and the corresponding uplink acknowledgments from the STAs receiving the MD-AMPDU. The AP **104** next transmits a PPDU **807** which comprises a common preamble portion **806** and MD-AMPDU messages **805***a*-*d*. In some embodiments,

the MD-AMPDU message **805***a* transmitted over a first bandwidth may comprise the MD-AMPDU frames **304**, **400**, and **475** of FIGS. **3**, **4**A and **4**B. In some embodiments, the common preamble portion **806** may comprise the PHY header portion **302** of FIG. **3**. Additionally each MD-AMPDU **805***a-d* is transmitted over a different frequency bandwidth. In some embodiments, the MD-AMPDU message **805***a* may be addressed to STAs having a higher MCS than the STAs addressed in the MD-AMPDU messages **805***b*-**805***d*

[0068] The MD-AMPDUs **805***a-d* may also include an indication of which STAs should send an acknowledgment and at what time, as discussed above. For example, the MD-AMPDU messages **805***a* and **805***b* may be addressed to STAs **1-8** and may have an indication in a MAC header of a MDPU that indicates that the STAs **1-8** should send their ACK messages over different frequencies a SIFS time after receiving the MD-AMPDU messages **805***a* and **805***b*. The MD-AMPDU messages **805***c* and **805***d* may be addressed to STAs **9-16** and may have an indication in a MAC header of a MDPU that indicates that the STAs **9-16** should send their ACK messages over different frequencies a specific time after receiving the MD-AMPDU messages **805***c* and **805***d*. The specific time may be determined by the AP **104** by calculating the transmission time for the PPDU **810** based on the MCS of the STAs and based on the estimated transmission time of the ACK messages from STAs **1-8**. As shown, 8 STAs (e.g., STAs **1-8**) send uplink BAs **815** over 8 different bandwidths a short time (e.g., SIFS) after receiving MD-AMPDUs **805***a-d*. A short time after the uplink BAs **815**, 8 more STAs (e.g., STAs **9-16**) send uplink BAs **816** over 8 different bandwidths to the AP **104**.

[0069] This combination of OFDMA and MD-AMPDU may require that the AP **104** indicate to each station the particular frequency band and the particular MCS for the combined OFDMA and MD-AMPDU transmission. Accordingly, AP **104** may indicate one or more groups of STAs to participate in the combined OFDMA and MD-AMPDU transmission and may indicate the particular frequency bandwidth for each group. In some embodiments, the indication of how the bandwidth is allocated may comprise two bits. For example, if both bits are set to zero, then the bandwidth is not divided and 8 stations may share that frequency bandwidth. If the bits are set to "01" the bandwidth may be divided into two different frequency bandwidths and 4 stations may be assigned to each bandwidth. In some embodiments, if the bits are set to "10" then the frequency may be split into 4 different bandwidths with 2 STAs assigned to each bandwidth. In some embodiments, if the bits are set to "11" then the frequency may be split into 8 different bandwidths with a single STA assigned to each bandwidth.

[0070] In some embodiments, a six bit group identifier (ID) is used to indicate a particular bandwidth for a STA in the PPDU according to the bandwidth allocation. In these embodiments, in each group ID a STA is assigned a position in the bandwidth according to the highest bandwidth division. In embodiments that have fewer frequency bandwidth divisions, the STA position may be determined according to its position in the highest bandwidth division For example, if a STA is allocated a position in the third bandwidth of the eight bandwidths, then if the bandwidth is divided into 4 different bandwidths, it would allocated a position in the second bandwidth position. If the bandwidth is divided into 2 different bandwidths, the STA would be allocated a position in the first bandwidth group.

[0071] FIG. **9** is a timing diagram of an exemplary frame exchange **900** for scheduling acknowledgments in response to a downlink (DL) MD frame. As shown, the AP **104** sends a CTS to self message **802** which reserves the medium for the transmission of the downlink frame and the subsequent acknowledgment frames. The AP **104** then transmits the DL MD frame **904** to the STAs **1-3**. The DL MD frame **904** may comprise a MD-AMPDU. In some embodiments, the DL MD frame **904** comprises the ACK control field **765** or other indication of the ACK policy. Using the information in the ACK control field **765** (e.g., BA MCS, total uplink bandwidth, per STA bandwidth, total uplink spatial streams, BA index, etc.) the STAs **1-3** can determine when to send ACK messages **905**, **906**, and **907** so that they don't interfere with each other and fit within the time reserved by the network allocation vector (NAV) of the CTS to self **802**. In some aspects, one or more of the ACK messages **905**, **906**, and **907** may comprise a block acknowledgement (BA) message.

[0072] FIG. **10** is a flowchart of a method **1000** for wireless communication, in accordance with an implementation. In some aspects, the method **1000** may be performed by the wireless device **202**, shown above with respect to FIG. **2**. In some aspects, method **1000** may be performed by the AP **104** or any suitable device. At block **1005**, the AP **104** indicates the presence of an acknowledgment (ACK) policy for responding to MD-AMPDU frames. In some embodiments, AP **104** may include this indication in the ACK control field **765**. In some embodiments, the indication may be included in a portion of the FC field **710**, QoS control field **755**, or the HT control field **760**. In some aspects, the indication may be included in the MD-AMPDU indicator **450**. At block **1010**, the AP **104** may generate a message with the ACK policy for responding to the MD-AMPDU. In some embodiments, the message may comprise the PPDU **300** which may comprise the A-MPDU frame **304** and MPDU **700**.

[0073] At block **1015**, the AP **104** may include ACK information for each of the STAs receiving the MD-AMPDU. In some embodiments, the ACK information may comprise BA MCS, total uplink bandwidth, per STA bandwidth, total uplink spatial streams, BA index, or any other information facilitate the STA determining when and how to send its ACK to the AP **104**. At block **1020**, the AP **104** may then transmit the message to the different STAs.

[0074] FIG. **11** is a flowchart of a method **1100** for wireless communication, in accordance with an implementation. In some aspects, the method **1100** may be performed by the wireless device **202**, shown above with respect to FIG. **2**. In some aspects, method **1100** may be performed by the STA **106***a* or any suitable device. At block **1105**, the STA **106***a* may receive a message containing ACK information. In some embodiments, the message may comprise a MD-AMPDU frame from the AP **104** which comprises the ACK control field **765**. At block **1110**, the STA **106***a* may then determine when and how to send its ACK message transmission based on the ACK information. For example, the ACK control field **765** may include a MCS, a bandwidth allocated to the STA **106***a*, and an order of when the STA should send its ACK message. The STA **106***a* may then determine based on such information the specific time to transmit the ACK and type of transmission (e.g., BA, MU-MIMO, FDMA, OFDMA, etc.). At block **1115**, the STA **106***a* may then generate the ACK message. In some embodiments, the ACK message is generated based on the determination in block **1110**. At block **1120**,

the STA **106***a* transmits to the ACK message to the AP **104** based on the determined transmission.

[0075] FIG. **12** is a flowchart of a method **1200** for wireless communication, in accordance with an implementation. In some aspects, the method **1200** may be performed by the wireless device **202**, shown above with respect to FIG. **2**. In some aspects, method **1200** may be performed by the AP **104** or any suitable device. At block **1205**, the AP **104** may determine a number of bandwidth groups for a MD-AMPDU message. For example, with reference to FIG. **8**, the AP **104** determines that the bandwidth for the PPDU **807** transmission should be divided into 4 different bandwidths. At block **1210**, the AP **104** then allocates STA to each bandwidth group. As discussed above with reference to FIG. **8**, in some embodiments, the AP **104** may allocate STAs **1-8** to bandwidth groups **1** and **2** (e.g., MD-AMPDU messages **805***a-b*) and may allocate STAs **9-16** to bandwidth groups **3** and **4** (e.g., MD-AMPDU messages **805***c-d*). At block **1215**, the AP **104** may then transmit the PPDU based on the bandwidth allocation. For example, the AP **104** may transmit PPDU **807** of FIG. **8** based on the bandwidth allocation of the 4 different bandwidths shown.

[0076] FIG. **13** is a flowchart of a method **1300** of wireless communication, in accordance with an implementation. In some aspects, the method **1300** may be performed by the wireless device **202**, shown above with respect to FIG. **2**. In some aspects, method **1300** may be performed by the AP **104**. The method **1300** may correspond to one or more implementations, as previously described in connection with FIGS. **3-9**.

[0077] Block **1302** includes generating, by an apparatus, an aggregated media access control protocol data unit (A-MPDU) frame within a PLCP protocol data unit (PPDU), the A-MPDU frame comprising a plurality of A-MPDU sub-frames, wherein at least one A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device. For example, as previously described in connection with FIG. **4**, the A-MPDU **400** comprises a plurality of A-MPDU sub-frames **405***a*-**405***n*. As previously described, the plurality of A-MPDU sub-frames are intended for one or more devices. In one aspect, the A-MPDU **405***a* may be addressed to a first device (e.g., STA **106***a* of FIG. **1**) and the A-MPDU **405***b* may be addressed to a second device (e.g., STA **106***d* of FIG. **1**).

[0078] Block **1304** includes inserting an indication that the A-MPDU frame is addressed to at least the first and second devices into a field of the PPDU. For example, as previously described in connection with FIG. **4**, a value may be inserted into the delimiter signature field **420***a* of the media access control protocol data unit (MPDU) delimiter field **410***a* of at least a first A-MPDU sub-frame **405***a*, to indicate that the A-MPDU **405***a* is intended for the legacy STA **106***a*. In some implementations of FIG. **5**, a value may be inserted into the partial AID field **515** to indicate that the A-MPDU frame that follows (e.g., the A-MPDU frame **304** of FIG. **3**) is a multi-destination A-MPDU with the MPDU **305***a* addressed to a first device (e.g., STA **106***a* of FIG. **1**) and the MPDU **305***b* addressed to a second device (e.g., STA **106***d* of FIG. **1**). In some embodiments, the delimiter signature field **420***a* may comprise 8 bits.

[0079] As used herein, the term "determining" encompasses a wide variety of actions. For example, "determining" may include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, "determining" may include resolving, selecting, choosing, establishing and the like. Further, a "channel width" as used herein may encompass or may also be referred to as a bandwidth in certain aspects.

[0080] As used herein, a phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover: a, b, c, a-b, a-c, b-c, and a-b-c.

[0081] The various operations of methods described above may be performed by any suitable means capable of performing the operations, such as various hardware and/or software component(s), circuits, and/or module(s). Generally, any operations illustrated in the Figures may be performed by corresponding functional means capable of performing the operations.

[0082] As used herein, the term interface may refer to hardware or software configured to connect two or more devices together. For example, an interface may be a part of a processor or a bus and may be configured to allow communication of information or data between the devices. The interface may be integrated into a chip or other device. For example, in some embodiments, an interface may comprise a receiver configured to receive information or communications from a device at another device. The interface (e.g., of a processor or a bus) may receive information or data processed by a front end or another device or may process information received. In some embodiments, an interface may comprise a transmitter configured to transmit or communicate information or data to another device. Thus, the interface may transmit information or data or may prepare information or data for outputting for transmission (e.g., via a bus).

[0083] The various illustrative logical blocks, modules and circuits described in connection with the present disclosure may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array signal (FPGA) or other programmable logic device (PLD), discrete gate or transistor logic, discrete hardware components or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any commercially available processor, controller, microcontroller or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0084] In one or more aspects, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or

any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Thus, in some aspects, computer readable medium may comprise non-transitory computer readable medium (e.g., tangible media). In addition, in some aspects computer readable medium may comprise transitory computer readable medium (e.g., a signal). Combinations of the above should also be included within the scope of computer-readable media.

[0085] Thus, certain aspects may comprise a computer program product for performing the operations presented herein. For example, such a computer program product may comprise a computer readable medium having instructions stored (and/or encoded) thereon, the instructions being executable by one or more processors to perform the operations described herein. For certain aspects, the computer program product may include packaging material.

[0086] The methods disclosed herein comprise one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is specified, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0087] Software or instructions may also be transmitted over a transmission medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of transmission medium.

[0088] Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein can be downloaded and/or otherwise obtained by a user terminal and/or base station as applicable. For example, such a device can be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via storage means (e.g., RAM, ROM, a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a user terminal and/or base station can obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

[0089] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the methods and apparatus described above without departing from the scope of the claims.

[0090] While the foregoing is directed to aspects of the present disclosure, other and further aspects of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A method of wireless communication, comprising:

generating, by an apparatus, an aggregated media access control protocol data unit (A-MPDU) frame within a physical layer convergence procedure (PLCP) protocol data unit (PPDU), the A-MPDU frame comprising a plurality of A-MPDU sub-frames, wherein at least one A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device; and

inserting an indication that the A-MPDU frame is addressed to at least the first and second devices into a field of the PPDU.

2. The method of claim **1**, wherein the at least one A-MPDU sub-frame comprises a media access control protocol data unit (MPDU) delimiter field, wherein the indication comprises a value in the MPDU delimiter field.

3. The method of claim **2**, wherein MPDU delimiter field comprises a delimiter signature field, wherein the indication comprises a value in the delimiter signature field.

4. The method of claim **1**, wherein the PPDU comprises a physical layer header field, wherein the indication is a value in the physical layer header field.

5. The method of claim **4**, wherein the physical layer header field comprises a very high throughput (VHT) signal (SIG) field, wherein the indication is a value in the VHT-SIG field.

6. The method of claim **5**, wherein the VHT-SIG field comprises a partial address identifier (AID) field, wherein the indication comprises a value in the partial AID field.

7. The method of claim **5**, wherein the VHT-SIG field comprises a group identifier field, wherein the indication comprises a value in the group identifier field.

8. The method of claim **5**, wherein the VHT-SIG field comprises a reserve field, wherein the indication comprises a value in the reserve field.

9. The method of claim **1**, wherein the at least one A-MPDU sub-frame comprises a media access control (MAC) header, the MAC header comprising an acknowledgement control field.

10. The method of claim **9**, wherein the acknowledgement control field comprises ten bits for indicating a number of spatial streams allocated, a number of frequency bands, or a time position for acknowledgment frames.

11. The method of claim **9**, wherein the acknowledgement control field indicates an acknowledgment modulation and coding scheme (MCS).

12. The method of claim **9**, wherein the acknowledgement control field indicates a bandwidth allocated to the first device and second device for sending an acknowledgment message in response to the A-MPDU frame.

13. The method of claim **9**, further comprising inserting an indication of the acknowledgement control field into one or

more of a frame control field, a very high throughput (VHT) control field, or a quality of service (QoS) control field.

14. An apparatus for wireless communication, comprising:

a processor configured to:

generate an aggregated media access control protocol data unit (A-MPDU) frame within a physical layer convergence procedure (PLCP) protocol data unit (PPDU), the A-MPDU frame comprising a plurality of A-MPDU sub-frames, wherein at least one A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device;

insert an indication that the A-MPDU frame is addressed to at least the first and second devices into a field of the PPDU; and

a transmitter configured to transmit the A-MPDU frame.

15. The apparatus of claim **14**, wherein the at least one A-MPDU sub-frame comprises a media access control protocol data unit (MPDU) delimiter field, wherein the indication comprises a value in the MPDU delimiter field.

16. The apparatus of claim **15**, wherein MPDU delimiter field comprises a delimiter signature field, wherein the indication comprises a value in the delimiter signature field.

17. The apparatus of claim **14**, wherein the PPDU comprises a physical layer header field, wherein the indication is a value in the physical layer header field.

18. The apparatus of claim **17**, wherein the physical layer header field comprises a very high throughput (VHT) signal (SIG) field, wherein the indication is a value in the VHT-SIG field.

19. The apparatus of claim **18**, wherein the VHT-SIG field comprises one or more of a group identifier field, a partial address identifier (AID) field, and a reserve field, wherein the indication comprises a value in the group identifier field, the partial address identifier (AID) field, or the reserve field.

20. The apparatus of claim **14**, wherein the at least one A-MPDU sub-frame comprises a media access control (MAC) header, the MAC header comprising an acknowledgement control field.

21. The apparatus of claim **20**, wherein the acknowledgement control field comprises ten bits for indicating a number of spatial streams allocated, a number of frequency bands, or a time position for acknowledgment frames.

22. The apparatus of claim **20**, wherein the acknowledgement control field indicates an acknowledgment modulation and coding scheme (MCS).

23. The apparatus of claim **20**, wherein the acknowledgement control field indicates a bandwidth allocated to the first device and second device for sending an acknowledgment message in response to the A-MPDU frame.

24. A non-transitory computer-readable medium comprising code that, when executed, causes an apparatus to:

generate an aggregated media access control protocol data unit (A-MPDU) frame within a physical layer convergence procedure (PLCP) protocol data unit (PPDU), the A-MPDU frame comprising a plurality of A-MPDU sub-frames, wherein at least one A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device; and

insert an indication that the A-MPDU frame is addressed to at least the first and second devices into a field of the PDDU.

25. The non-transitory computer-readable medium of claim **24**, wherein the A-MPDU sub-frame comprises a media access control protocol data unit (MPDU) delimiter field, wherein MPDU delimiter field includes a delimiter signature field, wherein the indication comprises a value in the delimiter signature field.

26. The non-transitory computer-readable medium of claim **24**, wherein the PPDU comprises a physical layer header field, the physical layer header field including a very high throughput (VHT) signal (SIG) field, and wherein the indication is a value in the VHT-SIG field.

27. The non-transitory computer-readable medium of claim **26**, wherein the VHT-SIG field comprises one or more of a group identifier field, a partial address identifier (AID) field, and a reserve field, wherein the indication comprises a value in the group identifier field, the partial address identifier (AID) field, or the reserve field.

28. The non-transitory computer-readable medium of claim **24**, wherein the at least one A-MPDU sub-frame comprises a media access control (MAC) header, the MAC header comprising an acknowledgement control field for indicating an acknowledgment modulation and coding scheme (MCS).

29. An apparatus for wireless communication, comprising:

means for generating an aggregated media access control protocol data unit (A-MPDU) frame within a physical layer convergence procedure (PLCP) protocol data unit (PPDU), the A-MPDU frame comprising a plurality of A-MPDU sub-frames, wherein at least one A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device;

means for inserting an indication that the A-MPDU frame is addressed to at least the first and second devices into a field of the PDDU; and

means for transmitting the A-MPDU frame.

30. The apparatus of claim **29**, wherein the at least one A-MPDU sub-frame comprises a media access control (MAC) header, the MAC header comprising an acknowledgement control field for indicating a bandwidth allocated to the first device and second device for sending an acknowledgment message in response to the A-MPDU frame.

31. An apparatus for wireless communication, comprising:

a processor configured to generate an aggregated media access control protocol data unit (A-MPDU) frame comprising a plurality of A-MPDU sub-frames, wherein at least one A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a first device and at least one other A-MPDU sub-frame of the plurality of A-MPDU sub-frames is addressed to at least a second device, wherein the A-MPDU frame comprises an acknowledgement control field for indicating transmission parameters of acknowledgment frames transmitted from the first device and the second device in response to the A-MPDU frame; and

a transmitter configured to transmit the A-MPDU frame.

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