

DESCRIPTION

COMMUNICATION APPARATUS AND COMMUNICATION METHOD FOR POLLING STAS

TECHNICAL FIELD

[0001] The present disclosure relates generally to communication apparatuses and communication methods, and more particularly, communication apparatuses and communication methods for polling stations (STAs).

BACKGROUND

[0002] The Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard specifies the transmission of a Trigger frame, such as a multi-user request-to-send (MU-RTS) or buffer status report poll (BSRP), by an access point (AP) to solicit responses from multiple stations (STAs). The Trigger frame also allocates resource units (RUs) for each STA to use for transmitting a response.

[0003] Conventionally, a Trigger frame solicits responses from multiple STAs on allocated RUs. However, efficient use of frequency resources is crucial, particularly when an AP solicits responses from multiple STAs using a single frame.

[0004] Accordingly, there exists a need to provide a novel communication apparatus and communication method for polling STAs that can address the above issues.

[0005] Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY

[0006] Non-limiting and exemplary embodiments facilitate providing communication apparatuses and communication methods for polling STAs.

[0007] In a first aspect, the present disclosure provides a first communication apparatus comprising: circuitry, which in operation, generates a frame comprising information for

allocating a frequency resource to one or more second communication apparatuses for transmitting a response; and a transmitter, which in operation, transmits the frame to the one or more second communication apparatuses.

[0008] In a second aspect, the present disclosure provides a second communication apparatus comprising: a receiver, which in operation, receives a frame from a first communication apparatus, the frame comprising information for allocating a frequency resource to the second communication apparatus for transmitting a response; and circuitry, which in operation, determines the frequency resource for transmitting a response to the first communication apparatus based on the information.

[0009] In a third aspect, the present disclosure provides a communication method implemented by a first communication apparatus comprising: generating a frame comprising information for allocating a frequency resource to one or more second communication apparatuses for transmitting a response; and transmitting the frame to the one or more second communication apparatuses.

[0010] In a fourth aspect, the present disclosure provides a communication method implemented by a second communication apparatus comprising: receiving a frame from a first communication apparatus, the frame comprising information for allocating a frequency resource to the second communication apparatus for transmitting a response; and determining the frequency resource for transmitting a response to the first communication apparatus based on the information.

[0011] It should be noted that general or specific embodiments may be implemented as a system, a method, an integrated circuit, a computer program, a storage medium, or any selective combination thereof. Additional benefits and advantages of the disclosed embodiments will become apparent from the specification and drawings. The benefits and/or advantages may be individually obtained by the various embodiments and features of the specification and drawings, which need not all be provided in order to obtain one or more of such benefits and/or advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views and which together with the detailed description below are incorporated in and form part of the specification, serve to

illustrate various embodiments and to explain various principles and advantages in accordance with present embodiments.

[0013] Figure 1 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a first embodiment of the present disclosure.

[0014] Figure 2 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a first implementation of the first embodiment of the present disclosure.

[0015] Figures 3 to 5 show exemplary formats of a BSRP Trigger frame according to the first implementation of the first embodiment of the present disclosure.

[0016] Figure 6 shows an exemplary format of a Basic Trigger frame according to the first implementation of the first embodiment of the present disclosure.

[0017] Figure 7 shows an exemplary format of an MU-RTS Trigger frame according to the first implementation of the first embodiment of the present disclosure.

[0018] Figure 8 shows a diagram illustrating an exemplary RU allocation encoding in an MU-RTS Trigger frame according to the first implementation of the first embodiment of the present disclosure.

[0019] Figure 9 shows an exemplary format of a Multi-User Block Acknowledgement Request (MU-BAR) Trigger frame according to the first implementation of the first embodiment of the present disclosure.

[0020] Figure 10 shows an exemplary format of a Conditional Report Poll (CRP) Trigger frame according to the first implementation of the first embodiment of the present disclosure.

[0021] Figure 11 shows an exemplary format of a CRP Parameter Set element according to the first implementation of the first embodiment of the present disclosure.

[0022] Figure 12 shows an exemplary format of a Null Data Packet (NDP) Feedback Report Poll (NFRP) Trigger frame according to the first implementation of the first embodiment of the present disclosure.

[0023] Figure 13 shows an exemplary format of a Multi-STA block acknowledgement (BlockAck) frame according to the first implementation of the first embodiment of the present disclosure.

[0024] Figure 14 shows an exemplary format of an Acknowledgment (Ack) frame according to the first implementation of the first embodiment of the present disclosure.

[0025] Figure 15 shows an exemplary format of a High Efficiency (HE) Trigger-Based (TB) Feedback NDP Physical Layer (PHY) Protocol Data Unit (PPDU) according to the first implementation of the first embodiment of the present disclosure.

[0026] Figure 16 shows an exemplary format of a Clear-to-Send (CTS) frame according to the first implementation of the first embodiment of the present disclosure.

[0027] Figures 17A and 17B show exemplary formats of a PHY sequence according to the first implementation of the first embodiment of the present disclosure.

[0028] Figure 18 shows a flowchart illustrating a process implemented by an AP according to various embodiments of the present disclosure.

[0029] Figure 19 shows a flowchart illustrating a process implemented by a STA according to various embodiments of the present disclosure.

[0030] Figure 20 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a second implementation of the first embodiment of the present disclosure.

[0031] Figure 21 shows an exemplary format of a TB PPDU according to the second implementation of the first embodiment of the present disclosure.

[0032] Figure 22 shows an exemplary format of a Quality of Service (QoS) Null frame according to the second implementation of the first embodiment of the present disclosure.

[0033] Figure 23 shows an exemplary format of a QoS Data frame according to the second implementation of the first embodiment of the present disclosure.

[0034] Figure 24 shows an exemplary format of a Multi-STA BlockAck frame according to the second implementation of the first embodiment of the present disclosure.

[0035] Figure 25 shows a flowchart illustrating another process implemented by an AP according to various embodiments of the present disclosure.

[0036] Figure 26 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a third implementation of the first embodiment of the present disclosure.

[0037] Figure 27 shows an exemplary format of a PPDU with additional sequence according to the third implementation of the first embodiment of the present disclosure.

[0038] Figure 28 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a fourth implementation of the first embodiment of the present disclosure.

[0039] Figure 29 shows an exemplary format of an Association Response frame according to the fourth implementation of the first embodiment of the present disclosure.

[0040] Figure 30 shows an exemplary format of a Beacon frame according to the fourth implementation of the first embodiment of the present disclosure.

[0041] Figure 31 shows an exemplary format of a Polling Response Resource Allocation frame according to the fourth implementation of the first embodiment of the present disclosure.

[0042] Figure 32 shows an exemplary format of a Trigger frame according to the fourth implementation of the first embodiment of the present disclosure.

[0043] Figure 33 shows an exemplary format of another Trigger frame according to the fourth implementation of the first embodiment of the present disclosure.

[0044] Figure 34 shows an exemplary format of a QoS Null frame according to the fourth implementation of the first embodiment of the present disclosure.

[0045] Figure 35 shows an exemplary format of a QoS Data frame according to the fourth implementation of the first embodiment of the present disclosure.

[0046] Figure 36 shows an exemplary format of a Multi-STA BlockAck frame according to the fourth implementation of the first embodiment of the present disclosure.

[0047] Figure 37 shows an exemplary format of a PPDU according to the fourth implementation of the first embodiment of the present disclosure.

[0048] Figure 38 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a fifth implementation of the first embodiment of the present disclosure.

[0049] Figure 39 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a sixth implementation of the first embodiment of the present disclosure.

[0050] Figure 40 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a seventh implementation of the first embodiment of the present disclosure.

[0051] Figure 41 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a second embodiment of the present disclosure.

[0052] Figure 42 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a first implementation of the second embodiment of the present disclosure.

[0053] Figure 43 shows an exemplary format of a Trigger frame according to the first implementation of the second embodiment of the present disclosure.

[0054] Figure 44 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a second implementation of the second embodiment of the present disclosure.

[0055] Figure 45 shows an exemplary format of an Association Response frame according to the second implementation of the second embodiment of the present disclosure.

[0056] Figure 46 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a third implementation of the second embodiment of the present disclosure.

[0057] Figure 47 shows a sequence diagram illustrating a polling procedure involving an AP and multiple STAs according to a fourth implementation of the second embodiment of the present disclosure.

[0058] Figure 48 shows a sequence diagram illustrating another polling procedure involving an AP and multiple STAs according to the fourth implementation of the second embodiment of the present disclosure.

[0059] Figure 49 shows a flowchart illustrating a communication method according to various embodiments of the present disclosure.

[0060] Figure 50 shows a flowchart illustrating another communication method according to various embodiments of the present disclosure.

[0061] Figure 51 shows a schematic view of a communication apparatus according to various embodiments of the present disclosure.

[0062] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale.

DETAILED DESCRIPTION

[0063] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention that the embodiments and examples herein are bound by any theory presented in the preceding background of the invention or the following detailed description.

[0064] Some embodiments of the present disclosure will be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements or equivalents.

[0065] In the following paragraphs, certain exemplifying embodiments are explained with reference to an access point (AP) and one or more stations (STAs).

[0066] In the context of IEEE 802.11 (Wi-Fi) technologies, a station, which is interchangeably referred to as a STA, is a communication apparatus that has the capability to use the IEEE 802.11 protocol. Based on the IEEE 802.11-2020 definition, a STA can be any device that contains an IEEE 802.11-conformant media access control (MAC) and physical layer (PHY) interface to the wireless medium (WM).

[0067] For example, a STA may be any device such as laptop, a desktop personal computer (PC), a personal digital assistant (PDA), either an access point or not (e.g., either an AP STA or a non-AP STA), or a Wi-Fi phone in a wireless local area network (WLAN) environment. The station may be fixed or mobile. In the WLAN environment, the terms "STA", "non-AP STA", "client", "wireless client", "user", "user device", and "mobile terminal" are often used interchangeably.

[0068] Likewise, an AP, which may be interchangeably referred to as a wireless access point (WAP) in the context of IEEE 802.11 (Wi-Fi) technologies, is a communication apparatus that allows STAs in a WLAN to connect to a wired network. The AP usually connects to a router (via a wired network) as a standalone device, but it can also be integrated with or employed in the router. The AP may be a part of a basic service set (BSS), which consists of the AP and one or more STAs, facilitating communication between the STAs in the BSS.

[0069] As mentioned above, a STA in a WLAN may work as an AP at different occasions, and vice versa. This is because communication apparatuses in the context of IEEE 802.11 (Wi-Fi) technologies may include both STA hardware components and AP hardware components. In this manner, the communication apparatuses may switch between a non-AP STA mode and an AP mode, based on actual WLAN conditions and/or requirements.

[0070] Unless explicitly indicated otherwise, it will be appreciated that, the disclosure should be applicable to various generations of IEEE 802.11 protocols and other standards and/or technologies in wireless communication involving similar features. In various embodiments below, each of the terms "channel" and "subchannel" may be used interchangeably with any one of "band", "subband" and "frequency segments". The term "circuitry" may be used interchangeably with "module".

[0071] According to various embodiments of the present disclosure, an AP may allocate a same frequency resource to one or more STAs for transmission of responses. A frame may be used to solicit the responses from the one or more STAs. Then, the AP may listen on the

allocated frequency resource and may determine information about the one or more STAs based on the responses and non-responses of the one or more STAs.

[0072] Advantageously, this approach allows an AP to obtain information about one or more STAs using fewer frequency resources.

[0073] According to a first embodiment, the AP may allocate the same frequency resource for a single transmission time (TT) to one or more STAs. Responses using the frequency resource may be conditional and may be decoded at least in part during simultaneous transmissions.

[0074] Figure 1 illustrates a polling procedure 100 involving an AP and multiple STAs according to the first embodiment.

[0075] In the first embodiment, the AP may allocate frequency resources 108, 110 (e.g., FR1, FR2) to multiple STAs (e.g., STA1 to STA4) for transmission of responses (e.g., Rsp 104, 106) by transmitting one or more resource allocation frames 102. At least one same frequency resource may be allocated to a subset of the multiple STAs. For example, a first same frequency resource 108 (FR1) may be allocated to a first subset comprising STA1 and STA2, while a second same frequency resource 110 (FR2) may be allocated to a second subset comprising STA3 and STA4. The number of STAs in the subset may be fewer than or the same as the total number of STAs of the multiple STAs.

[0076] Each STA in the subset may determine whether to transmit a response based on one or more conditions associated with the poll. For example, STA1 and STA2 may determine to and transmit responses 104, 106, while STA3 and STA4 may determine not to respond. The one or more conditions may be related to such as link measurement (e.g., whether the STA has poor link quality), or traffic status (e.g., whether the STA has queued low-latency (LL) traffic). The one or more conditions may, herein, also be referred to as response conditions or conditions for responding. The response from each STA may be transmitted on the allocated frequency resource while using the same spatial domain resource. The AP may determine information about one or more STAs in the subset based on responses and non-responses on the allocated frequency resources. For example, based on the responses 104, 106 on allocated frequency resource FR1 108, the AP may determine that at least one of STA1 and STA2 satisfied the response conditions, and, based on the non-response on allocated frequency resource FR2 110, the AP may determine that none of STA3 and STA4 satisfied the response conditions.

[0077] Figure 2 illustrates a polling procedure 200 involving an AP and multiple STAs according to a first implementation of the first embodiment.

[0078] In this first implementation, a single frame (e.g., request (Req) frame 202) may be used to both allocate frequency resources for response transmissions and solicit the responses. The Req frame 202 in Figure 2 may be an example of a resource allocation frame 102 in Figure 1. The frame 202 (e.g., Req frame) transmitted during a first poll (e.g., Poll1) to allocate frequency resources 208, 210 (e.g., RU1, RU2) to multiple STAs (e.g., STA1 to STA4) for transmission of responses may also solicit the responses. The frame 202 may be a Trigger frame, such as a BSRP Trigger frame, a Basic Trigger frame, an MU-BAR Trigger frame, an MU-RTS Trigger frame, or a new Trigger frame.

[0079] The same RU 208, 210 (e.g., RU1 or RU2) may be allocated to each STA in a subset (e.g., STA1 and STA2 or STA3 and STA4 respectively), and responses (e.g., response (Rsp) 204, 206) transmitted on the same RU may be identical such that when simultaneous transmission of responses 204, 206 occurs on the same RU 208 (e.g., RU1), the AP may still successfully decode the responses 204, 206. The response may be a TB PPDU (e.g., Multi-STA BlockAck, Ack), a TB Feedback NDP PPDU, a non-High Throughput (non-HT) PPDU (e.g., CTS, Multi-STA BlockAck), or a PHY sequence.

[0080] The AP, based on receiving a response on the same RU, may determine that at least one STA in the subset met the conditions for responding. The AP may then transmit another frame (e.g., Req frame 212) to one or more STAs in the subset with at least one STA meeting the conditions for responding (e.g., STA1 and STA2). The frame 212 may be used to trigger a second poll (e.g., Poll2) to solicit responses 214, 216 (e.g., containing STA-specific information) from individual STAs in the subset. For example, the second poll (e.g., Poll2) may solicit non-conditional responses (i.e., responses that are not based on specific conditions).

[0081] Advantageously, this approach allows the AP to efficiently allocate frequency resources and solicit responses within a single transmission. Furthermore, the AP may narrow down from multiple STAs to a subset, allowing it to identify one or more STAs that meet specific conditions.

[0082] In an example, the resource allocation frame from the AP (e.g., Req frame 202) may be a Trigger frame, such as a BSRP Trigger frame.

[0083] Figures 3 to 5 show exemplary formats of a BSRP Trigger frame 300, 400, 500 according to the first implementation of the first embodiment. The BSRP Trigger frame 300, 400, 500 in Figures 3 to 5 may be examples of the Req frame 202 in Figure 2. As shown in Figures 3 to 5, the BSRP Trigger frame 300, 400, 500 may comprise a Frame Control field, a Duration field, a Receiver Address (RA) field, a Transmitter Address (TA) field, a Common Info field 302, a User Info List field 304, 402, 502, a Padding field, and an FCS field. The RA field may be set to the broadcast address, and the TA field may be set to the MAC address of the transmitting AP.

[0084] In the example shown in Figure 3, the Common Info field 302 may comprise a Trigger Type subfield 306, a More TF subfield 308, a UL BW subfield 310, a CRP Type subfield 312, and a CRP Parameters subfield 314; while the User Info List field 304 may comprise multiple (e.g., N) User Info fields 316. Each User Info field 316 may comprise an AID12 subfield 318 and an RU Allocation subfield 320. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0085] The Trigger Type subfield 306 in the Common Info field 302 may be set to a value of '4' to indicate a BSRP Trigger frame. The same frequency resource may be allocated to multiple STAs individually (e.g., based on each STA's AID). For example, the User Info List field 304 may contain multiple User Info fields 316, one for each STA, identified individually in the AID12 subfield 318. The UL BW subfield 310 and RU Allocation subfield 320 may be set to indicate the size and location of the allocated RU respectively.

[0086] A poll with conditions for responding may, herein, also be referred to as a conditional report poll (CRP). A new field (e.g., Conditional Report Poll (CRP) Type subfield 312) may be included to indicate the CRP type, which may be associated with one or more specific predetermined response conditions. Examples of the specific predetermined response conditions may include a presence of queued LL traffic or poor link quality. As an example, there may be only a single type of poll and the CRP type may be indicated by a single bit (e.g., value of '0' indicates none, while value of '1' indicates the specific CRP type). The new field may use reserved bit(s) or reuse an existing field in the Common Info field 302, e.g., reserved or existing in the IEEE 802.11be specification (e.g., based on IEEE P802.11be/D7.0). For example, the existing More TF subfield 308 may be reused to indicate CRP type when transmitted outside a Target Wake Time (TWT) Service Period (SP).

[0087] Another new field (e.g., CRP Parameters subfield 314) may be included to indicate additional parameters (e.g., relating to the response conditions), such as a threshold for delay

bound (or expiration time) of the queued LL traffic or a threshold for link measurement to determine poor link quality (e.g., based on RSSI). The CRP Parameters subfield 314 may use reserved bit(s) or reuse an existing field in the Common Info field, e.g., reserved or existing in the IEEE 802.11be specification. For example, the More TF subfield 308 may be reused to indicate CRP parameters when the BSRP frame 300 is not transmitted during TWT SP or ranging. If additional CRP parameters (e.g., CRP Parameters subfield 314) are not included, the response conditions may be determined based on the type of CRP (e.g., indicated by the CRP Type subfield 312).

[0088] Alternatively, one or both new fields (e.g., CRP Type subfield 412 and CRP Parameters subfield 414) may be included in a User Info field 404, as shown in Figure 4.

[0089] In the example shown in Figure 4, the User Info List field 402 may comprise multiple (e.g., N) User Info fields 404. Each User Info field 404 may comprise an AID12 subfield 406, an RU Allocation subfield 408, an SS Allocation(/RA-RU Information) subfield 410, a CRP Type subfield 412, and a CRP Parameters subfield 414. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0090] Advantageously, this approach allows the Trigger frame to apply different response conditions for different subsets of STAs (e.g., in different RUs). The CRP Type subfield 412, CRP Parameters subfield 414 may use reserved bit(s) or reuse an existing field (e.g., SS Allocation(/RA-RU Information) subfield 410), e.g., reserved or existing in the IEEE 802.11be specification. For example, SS Allocation(/RA-RU Information) subfield 410 may be reused to indicate CRP parameters when used for CRP (e.g., when a specific CRP type is indicated).

[0091] As another example, one or both new fields (e.g., CRP Type subfield 510 and CRP Parameters subfield 512) may be included in a Special User Info field, which may be indicated by a User Info field 504 with AID12 subfield 506 set to '2007'. Alternatively, the value of the AID12 subfield 514 in the User Info field 504 may be set to another predetermined value (e.g., a reserved value such as '2047', e.g., reserved in the IEEE 802.11be specification) to indicate that it is used for CRP. Alternatively, specific AID12 values may be used for indicating different types of CRP instead of explicitly including a CRP Type subfield 516.

[0092] In the example shown in Figure 5, the User Info List field 502 may comprise multiple (e.g., N) User Info fields 504. One or more User Info fields 504 may comprise an AID12 subfield 506, a PHY Version Identifier subfield 508, a CRP Type subfield 510, and a CRP

Parameters subfield 512. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted). Alternatively, one or more User Info fields 504 may comprise an AID12 subfield 514, a CRP Type subfield 516, and a CRP Parameters subfield 518. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0093] Advantageously, use of special or predetermined AID12 values allows for conservation of the limited reserved bits in the Common Info and User Info general formats.

[0094] In another example, the resource allocation frame from the AP (e.g., Req frame 202) may be a Trigger frame that includes a Trigger Dependent User Info field, such as a Basic Trigger frame.

[0095] Figure 6 shows an exemplary format of a Basic Trigger frame 600 according to the first implementation of the first embodiment. The Basic Trigger frame 600 in Figure 6 may be an example of the Req frame 202 in Figure 2. As shown in Figure 6, the Basic Trigger frame 600 may comprise a Frame Control field, a Duration field, an RA field, a TA field, a Common Info field 602, a User Info List field 604, a Padding field, and an FCS field. The Common Info field 602 may comprise a Trigger Type subfield 606, a More TF subfield, and a UL BW subfield; while the User Info List field 604 may comprise multiple (e.g., N) User Info fields 608. Each User Info field 608 may comprise an AID12 subfield, an RU Allocation subfield, and a Trigger Dependent User Info subfield 610. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0096] In this example, one or both new fields (e.g., CRP Type subfield 612 and CRP Parameters subfield 614) may be included in a Trigger Dependent User Info subfield 610, which increases the available bits which may be used. The Trigger Type subfield 606 in the Common Info field 602 may be set to a value of '0' to indicate a Basic Trigger frame.

[0097] In another example, the resource allocation frame from the AP (e.g., Req frame 202) may be an MU-RTS Trigger frame.

[0098] Figure 7 shows an exemplary format of an MU-RTS Trigger frame 700 according to the first implementation of the first embodiment. The MU-RTS Trigger frame 700 in Figure 7 may be an example of the Req frame 202 in Figure 2. As shown in Figure 7, the MU-RTS Trigger frame 700 may comprise a Frame Control field, a Duration field, an RA field, a TA field, a Common Info field 702, a User Info List field 704, a Padding field, and an FCS field. The

Common Info field 702 may comprise a Trigger Type subfield 706, a More TF subfield, and a UL BW subfield 708; while the User Info List field 704 may comprise multiple (e.g., N) User Info fields 708. Each User Info field 710 may comprise an AID12 subfield and an RU Allocation subfield 712. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0099] In this example, the Trigger Type subfield 706 in the Common Info field 702 may be set to a value of '3' to indicate the frame 700 is an MU-RTS Trigger frame. The UL BW subfield 708 may indicate the bandwidth of the PPDU carrying the MU-RTS Trigger frame, while the RU allocation subfield 712 may indicate the channel to be used for transmission of the response. The RU allocation encoding may be modified from the current IEEE 802.11 specification (e.g., based on IEEE P802.11-REVme/D7.0) to allow responses also on just non-primary channels. For example, to solicit responses on a specific non-primary 20 MHz channel. The new fields, (e.g., CRP Type subfield and CRP Parameters subfield) (not depicted) may be included in a similar manner as the examples as shown in Figures 3 to 6.

[0100] Table 1 shows an encoding of the RU Allocation subfield 712 in Figure 7.

B7-B1 of the RU Allocation subfield	RU allocated
1	The second lowest 20 MHz channel, and the primary 20 MHz channel is the lowest frequency 20 MHz channel in the primary 40/80 MHz channel
2	The third lowest 20 MHz channel, and the primary 20 MHz channel is the lowest frequency 20 MHz channel in the primary 80 MHz channel
3	The fourth lowest 20 MHz channel, and the primary 20 MHz channel is the lowest frequency 20 MHz channel in the primary 80 MHz channel
4	The lowest 20 MHz channel, and the primary 20 MHz channel is the second lowest frequency 20 MHz channel in the primary 40/80 MHz channel
5	The third lowest 20 MHz channel, and the primary 20 MHz channel is the second lowest frequency 20 MHz channel in the primary 80 MHz channel
6	The fourth lowest 20 MHz channel, and the primary 20 MHz channel is the second lowest frequency 20 MHz channel in the primary 80 MHz channel
7, 8, 9	<The lowest, second lowest, and fourth lowest 20 MHz channels, respectively, and the primary 20 MHz channel is the third lowest frequency 20 MHz channel in the primary 80 MHz channel>
10, 11, 12	<The lowest, second lowest, and third lowest 20 MHz channels, respectively, and the primary 20 MHz channel is the fourth

	lowest frequency 20 MHz channel in the primary 80 MHz channel>
61 to 68	<The 20/40/80/80+80 primary channels as defined in the current IEEE 802.11 specification>

Table 1

[0101] Figure 8 illustrates an exemplary RU allocation encoding 800 in MU-RTS Trigger frame 700 according to the first implementation of the first embodiment, modified to include non-primary 20 MHz channels for primary channel up to 80 MHz, based on the encoding shown in Table 1. In particular, Figure 8 illustrates the RU allocation when the value of the RU Allocation subfield 712 is '1', '2', '3', '61' or '10', '11', '12', '64'.

[0102] In another example, values for RU allocation of non-primary channels in the secondary 80 MHz channel may also be included. For example, the fifth to eighth lowest channel when the primary 20 MHz channel is the second to fourth lowest frequency 20 MHz channel in the primary 80/160 MHz channel. In another example, values for RU allocation of non-primary 40 MHz and non-primary 80 MHz channels may also be included.

[0103] In another example, the resource allocation frame from the AP (e.g., Req frame 202) may be an MU-BAR Trigger frame.

[0104] Figure 9 shows an exemplary format of an MU-BAR Trigger frame 900 according to the first implementation of the first embodiment. The MU-BAR Trigger frame 900 in Figure 9 may be an example of the Req frame 202 in Figure 2. As shown in Figure 9, the MU-BAR Trigger frame 900 may comprise a Frame Control field, a Duration field, an RA field, a TA field, a Common Info field 902, a User Info List field 904, a Padding field, and an FCS field. The Common Info field 902 may comprise a Trigger Type subfield 906; while the User Info List field 904 may comprise multiple (e.g., N) User Info fields 908. Each User Info field 908 may comprise an AID12 subfield, an RU Allocation subfield, and a Trigger Dependent User Info subfield 910. The Trigger Dependent User Info subfield 910 may comprise BAR Control subfield 912 and BAR Information subfield 914, where the BAR Information subfield 914 may further comprise a CRP Type subfield 916 and a CRP Parameters subfield 918. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0105] In this Example, the Trigger Type subfield 906 in the Common Info field 902 may be set to a value of '2' to indicate the frame is an MU-BAR Trigger frame. In the User Info field 908, the BAR Control subfield 912 may be set to a predetermined value (e.g., '11', which is a reserved value, e.g., reserved in the current IEEE 802.11 specification) to indicate it is used for CRP, and the BAR Information subfield 914 may include CRP Type subfield 916 and CRP Parameters subfield 918. Alternatively, the predetermined value (e.g., '11') may be used to indicate a specific CRP type and the CRP Type subfield 916 may not be present.

[0106] In another example, the resource allocation frame from the AP (e.g., Req frame 202) may be a new type of Trigger frame used primarily for CRP, such as a CRP Trigger frame.

[0107] Figure 10 shows an exemplary format of a CRP Trigger frame 1000 according to the first implementation of the first embodiment. The CRP Trigger frame 1000 in Figure 10 may be an example of the Req frame 202 in Figure 2. As shown in Figure 10, the CRP Trigger frame 1000 may comprise a Frame Control field, a Duration field, an RA field, a TA field, a Common Info field 1002, a User Info List field 1004, a Padding field, and an FCS field. The Common Info field 1002 may comprise a Trigger Type subfield 1006 and a UL BW subfield; while the User Info List field 1004 may comprise multiple (e.g., N) User Info fields 1008. Each User Info field 1008 may comprise an AID12 subfield and an RU Allocation subfield. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0108] The Trigger Type subfield 1006 in the Common Info subfield 1002 may be set to a predetermined value (e.g., '9', which is a reserved value, e.g., reserved in the IEEE 802.11be specification) to indicate a CRP Trigger frame. One or both CRP Type subfield 1010 and CRP Parameters subfield 1012 may be included in the Common Info field 1002 to provide information on the poll. Alternatively, the CRP Type subfield 1010 and the CRP Parameters subfield 1012 may be included in the User Info field 1008.

[0109] Alternatively, the CRP parameters may be informed in a separate frame using an element (e.g., a new CRP Parameter Set element) carried in an earlier transmitted frame (e.g., Beacon frame, Probe Response frame, or Association Response frame), in which case the CRP Parameters subfield may not be present in the resource allocation frame. Alternatively, some CRP parameters may still be included in the resource allocation frame.

[0110] Figure 11 shows an exemplary format of a CRP Parameter Set element 1100 according to the first implementation of the first embodiment. As shown in Figure 11, the CRP

Parameter Set element 1100 may comprise an Element ID field 1102, a Length field, an Element ID Extension field 1104, and CRP Parameters field 1106. The Element ID field 1102 may be set to a value of '255' to indicate that Element ID Extension is present and the Element ID Extension field 1104 may be set to a value of '144', which is a reserved value, e.g., reserved in the IEEE 802.11be specification, to indicate a CRP Parameter Set element.

[0111] As a variation, the allocation of the same frequency resource to one or more of the multiple STAs individually may be based on a secondary AID (or an additional identifier besides a STA's AID). The AP may assign one or more secondary AIDs to a STA in addition to the STA's primary AID assigned during association. The same frequency resource may then be allocated to a STA by indicating its secondary AID, such as in the AID12 subfield within the User Info field of a Trigger frame. Alternatively, a same secondary AID may be assigned to multiple STAs, functioning as a group ID. The resource may be allocated using the secondary AID by indicating the AID individually (e.g., in the AID12 subfield) or by including the AID in a range of AIDs (e.g., based on an indication of a starting AID).

[0112] The secondary AID may be dynamically assigned in advance, for example, by means of a management frame exchange (e.g., via an Action frame or using an element) (not depicted). The CRP type, response conditions or CRP parameters may be indicated for a secondary AID by including the information during the frame exchange when assigning the secondary AID. Additionally or alternatively, the secondary AID may be assigned for a specific CRP Type, such that polling using the secondary AID corresponds to specific response conditions (e.g., a presence of queued LL traffic).

[0113] Advantageously, use of a secondary AID enhances the flexibility of resource allocation schemes as compared to using only the STA's primary AID.

[0114] As a variation, the allocation of the same frequency resource to multiple STAs may be based on a predetermined grouping. In this approach, a subset of STAs may be automatically determined based on predefined classifications or capabilities of the STAs. For example, STAs may recognise their inclusion in a subset by their device type or advertised capabilities. The subset may be associated with a predetermined AID12 value (e.g., using a value that is a reserved value, e.g., reserved in the IEEE 802.11be specification) that corresponds to a predefined group. The AP may use this predetermined AID12 value in the AID12 subfield of the User Info field to address the subset. Additionally, the frequency resource allocated to the predetermined group may be predetermined or dynamically assigned (e.g., by indicating the

frequency resource for the predetermined or dynamically assigned AID12 value for the group in the resource allocation frame).

[0115] Advantageously, the use of predefined subsets and allocations may simplify resource allocation.

[0116] As an alternative to allocating the same frequency resource to each STA in a subset individually (e.g., based on each STA's AID (e.g., AID12 values)), resource allocation may be based on a range of AIDs. In an example, a set of frequency resources may be allocated based on the formula: Frequency resource index = $1 + \text{<AID index> MOD (<number of allocated resources>)}$, where the AID index starts from value '0' and may be derived from the position of a STA's AID relative to the range of AIDs (e.g., AID index may be determined using the formula (STA's AID - Starting AID), where the Starting AID is the lowest AID value of a STA in the range of AIDs and all the AIDs in the range are in a sequence of consecutive integers). For instance, given 11 AIDs with indexes '0' through '10', and where the number of allocated resources is 2, a first resource may be allocated to AID indexes '0','2','4','6','8', and '10', while a second resource may be allocated to AID indexes '1','3','5','7', and '9', resulting in two subsets. The frequency resource index may correspond to a predetermined frequency resource (e.g., an RU or an RU tone set). Alternatively, the resource allocation frame may indicate (e.g., in a User Info field of a Trigger frame) for each frequency resource index (e.g., in a new field indicating the index), corresponding frequency resource information (e.g., RU Allocation subfield in the User Info field) (not depicted).

[0117] Alternatively, the frequency resources may be allocated based on the formula: Frequency resource index = $\text{FLOOR (<AID index> / <maximum number of STAs in subset>)}$. For example, given AID indexes '0' through '10', for the maximum number of STAs in subset set to 6, a first resource may be allocated to AID indexes '0' to '5', while a second resource may be allocated to AID indexes '6' to '10', resulting in two subsets.

[0118] In some implementations, the frequency resources index may be an RU tone set index based on use of the NFRP Trigger frame in NDP feedback reporting. The resource allocation signalling may indicate a starting AID (e.g., in a Starting AID subfield) instead of individual target AID(s).

[0119] Advantageously, this approach reduces signalling for resource allocation, thereby improving efficiency of resource allocation.

[0120] In an example of allocating frequency resources based on a range of AIDs, the resource allocation frame from the AP (e.g., Req frame 202) may be an NFRP Trigger frame.

[0121] Figure 12 shows an exemplary format of an NFRP Trigger frame 1200 according to the first implementation of the first embodiment. The NFRP Trigger frame 1200 in Figure 12 may be an example of the Req frame 202 in Figure 2. As shown in Figure 12, the NFRP Trigger frame 1200 may comprise a Frame Control field, a Duration field, an RA field, a TA field, a Common Info field 1202, a User Info List field 1204, a Padding field, and an FCS field. The Common Info field 1202 may comprise a Trigger Type subfield 1206, a More TF subfield, and a UL BW subfield; while the User Info List field 1204 may comprise multiple (e.g., N) User Info fields 1208. Each User Info field 1208 may comprise a Starting AID subfield 1210 and a Feedback Type subfield 1212. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0122] In an example, the resource allocation signalling may be contained in a Special User Info field, such as User Info field with a special or predetermined AID12 value (e.g., using a value which is a reserved value, e.g., reserved in the IEEE 802.11be specification) (not depicted). The number of allocated resources or maximum number of STAs in a subset 1214 may be indicated in the Common Info field 1220 or User Info field 1208 (e.g., Special User Info field). Alternatively, this information may have been indicated in an earlier frame transmission. The CRP type may be indicated by the Feedback Type subfield 1212. Alternatively, an additional field may be used to indicate the CRP type or to indicate that the Feedback Type indicates the CRP type (not depicted). CRP parameters may be included (e.g., CRP Parameters field 1216) to provide conditions or parameters for responding. Alternatively, the parameters may be expressed in a new element (e.g., CRP Parameter Set element (e.g., 1100) as exemplified in Figure 11) sent separately from the resource allocation.

[0123] Alternatively, for allocating frequency resources based on a range of AIDs, the resource allocation frame may be another Trigger frame (e.g., BSRP Trigger frame) or a new Trigger frame (e.g., CRP Trigger frame) comprising an indication of a range of AIDs (e.g., by indicating a starting AID and related parameters, e.g., in a User Info field (e.g., a Special User Info field)) (not depicted).

[0124] In an example, the response transmitted from the STAs (e.g., Rsp 204, 206) may be a TB PPDU, such as a Multi-STA BlockAck, which may be transmitted in response to a Trigger frame (e.g., BSRP, Basic, MU-BAR, or CRP Trigger frame).

[0125] Figure 13 shows an exemplary format of a Multi-STA BlockAck frame 1300 according to the first implementation of the first embodiment. The Multi-STA BlockAck frame 1300 in Figure 13 may be an example of the Rsp 204, 206 in Figure 2. As shown in Figure 13, the Basic Trigger frame 1300 may comprise a Frame Control field, a Duration field, an RA field, a TA field, a BA Control field 1302, a BA Information field 1304, and an FCS field. The BA Control field 1302 may comprise a BA Type subfield 1306; while the BA Information field 1304 may comprise a Per AID TID Info subfield 1308. The Per AID TID Info subfield 1308 may comprise an AID11 subfield, an Ack Type subfield, and a TID subfield.

[0126] The RA field may be set to the MAC address of the AP, and the TA field may be set to the MAC address of the AP or a predetermined address such as the broadcast address. The BA Type subfield 1306 in the BA Control field 1302 may be set to a value of '11' to indicate a Multi-STA BlockAck frame. The Per AID TID Info subfield 1308 may include a single Per AID TID field with predetermined values (e.g., AID11 subfield 1310 set to '0' or a predetermined value, such as '2046', which is an unused value, e.g., unused in the IEEE 802.11be specification, Ack Type subfield 1312 set to '0', TID subfield 1314 set to '15'). Alternatively, it may contain zero Per AID TID fields. Alternatively, another predetermined value for BA Type subfield 1306 (e.g., '12', which is a reserved value, e.g., reserved in the current IEEE 802.11 specification) may be used to indicate a response to the CRP.

[0127] In another example, the response transmitted from the STAs (e.g., Rsp 204, 206) may be an Ack frame (e.g., in a TB PPDU), which may be transmitted in response to a Trigger frame (e.g., BSRP, Basic, MU-BAR, or CRP Trigger frame).

[0128] Figure 14 shows an exemplary format of an Ack frame 1400 according to the first implementation of the first embodiment. The Ack frame 1400 in Figure 14 may be an example of the Rsp 204, 206 in Figure 2. As shown in Figure 14, the Ack frame 1400 may comprise a Frame Control field, a Duration field, an RA field 1402, and an FCS field. The RA field 1402 may be set to the MAC address of the AP.

[0129] In another example, the response transmitted from the STAs (e.g., Rsp 204, 206) may be a TB PPDU without a Data field, such as a high-efficiency (HE) TB Feedback Null Data Packet (NDP), which may be transmitted in response to a Trigger frame (e.g., BSRP, Basic, MU-BAR, or CRP Trigger frame).

[0130] Figure 15 shows an exemplary format of an HE TB Feedback NDP PPDU 1500 according to the first implementation of the first embodiment. The HE TB Feedback NDP

PPDU 1500 in Figure 15 may be an example of the Rsp 204, 206 in Figure 2. As shown in Figure 15, the HE TB Feedback NDP PPDU 1500 may comprise an L-STF field, an L-LTF field, an L-SIG field, an RL-SIG field, an HE-SIG-A field, an HE-STF field, an HE-LTF field, and a PE field.

[0131] In another example, the response transmitted from the STAs (e.g., Rsp 204, 206) may be a non-HT PPDU, such as a CTS frame or a Multi-STA BlockAck frame, which may be sent in response to an MU-RTS Trigger frame.

[0132] Figure 16 shows an exemplary format of a CTS frame 1600 according to the first implementation of the first embodiment. The CTS frame 1600 in Figure 16 may be an example of the Rsp 204, 206 in Figure 2. As shown in Figure 16, the CTS frame 1600 may comprise a Frame Control field, a Duration field, an RA field 1602, and an FCS field. The RA field 1602 may be set to the MAC address of the AP.

[0133] Advantageously, the CTS frame offers better network allocation vector (NAV) protection of the channel.

[0134] In another example, the response transmitted from the STAs (e.g., Rsp 204, 206) may be a PHY sequence, such as a part of a PPDU preamble (e.g., functioning as a chirp), which may be transmitted only on the allocated frequency resource. In an example, it may be a whole or part of a short training sequence (e.g., an HE-STF). Additionally, the response may begin with legacy preamble fields for medium protection over the full bandwidth.

[0135] Figures 17A and 17B show exemplary formats of a PHY sequence 1700, 1702 according to the first implementation of the first embodiment. The PHY sequence 1700, 1702 in Figures 17A and 17B may be an example of the Rsp 204, 206 in Figure 2. As shown in Figure 17A, the PHY sequence 1700 may consist of a Short HE-STF field. Alternatively, as shown in Figure 17B, the PHY sequence 1702 may comprise an L-STF field, an L-LTF field, an L-SIG field, an RL-SIG field, and a Short HE-STF field.

[0136] Table 2 shows the potential effects for different response scenarios when responses (e.g., Rsp 204, 206) on the same frequency resource are identical according to the first implementation of the first embodiment.

Scenario	Example effect
Only one STA in the subset transmits a response in the same RU	The AP may determine that at least one STA in the subset met the conditions for responding, and may proceed with a further transmission to STAs in the subset (e.g., Req frame 212 for Poll2)
Multiple STAs in the subset transmit a response in the same RU (i.e., simultaneous transmission of responses)	
No STAs in the subset transmit a response in the same RU	The AP may determine that no STAs in the subset met the conditions for responding, and may not proceed with a further transmission to STAs in the subset.

Table 2

[0137] In an example, the another frame (e.g., Req frame 212) transmitted by the AP may be a frame (e.g., a BSRP Trigger frame or other Trigger frame) to solicit information individually from the STAs in the subset (e.g., STA1 and STA2 in Figure 2). In an alternative, the frame may poll a smaller subset of the first subset using a same RU. In another example, the transmission of the another frame (e.g., Req frame 212) may initiate an action in response to the response conditions, such as initiating a radio measurement or link improvement procedure (e.g., beamforming) in response to an indication of poor link quality from STAs in the subset.

[0138] Figure 18 shows a flowchart illustrating a process 1800 implemented by an AP according to various embodiments of the present disclosure. In step 1802, the AP may transmit a Req frame (e.g., Req frame 202), which allocates a same RU to a subset of STAs (e.g., RU1 allocated to STA1 and STA2 or RU2 allocated to STA3 and STA4). Then, the AP waits to receive responses (e.g., Rsp 204, 206) on the RU allocated to the subset of STAs in step 1804. Next, the AP may carry out step 1806 to determine whether a response is received on the allocated RU. If a response is received, the process moves to step 1808, where the AP may transmit another frame (e.g., Req frame 212) to one or more STAs in the subset of STA. Otherwise, the process ends.

[0139] Figure 19 shows a flowchart illustrating a process 1900 implemented by a STA according to various embodiments of the present disclosure. In response to receiving a Req frame (e.g., Req frame 202) from an AP in step 1902, the STA may carry out step 1904 to determine if there is a need to respond based on specific conditions. If the STA is to respond,

the process moves to step 1906, where the STA then transmits the response to the AP on the allocated RU. Otherwise, the process ends.

[0140] As a variation, a second implementation of the first embodiment may be applied independently or in combination with one or more other implementations of the first embodiment. In this second implementation, responses transmitted on the same frequency resource may be partially identical (e.g., the responses comprise at least an identical part and a non-identical part). For example, a non-identical part of the responses may be information specific to the responding STAs.

[0141] Advantageously, this approach allows additional information about the responding STA or subset to be determined by the AP.

[0142] Figure 20 illustrates a polling procedure 2000 involving an AP and multiple STAs according to the second implementation of the first embodiment.

[0143] Similar to polling procedure 200, in polling procedure 2000, a single frame (e.g., Req frame 2002) may be used to both allocate frequency resources for response transmission and solicit responses in polling procedure 2000. The Req frame 2002 in Figure 20 may be an example of a resource allocation frame 102 in Figure 1. The frame 2002 (e.g., Req frame) transmitted during a first poll (e.g., Poll1) to allocate frequency resources 2008, 2012 (e.g., RU1, RU2) to multiple STAs (e.g., STA1 to STA4) for transmission of responses may also solicit the responses.

[0144] However, in polling procedure 2000, the responses (e.g., Rsp 2004, 2006) are only partially identical and may include information specific to the responding STAs.

[0145] When simultaneous transmission of responses occurs on the same RU, part of the response may be decoded by the AP, while another part of the response, e.g., the STA-specific information, cannot be decoded (e.g., Rsp 2004, 2006 on RU1 2008 from STA1 and STA2). When non-simultaneous transmission of response occurs on the same RU (e.g., Rsp 2010 on RU2 2012 from STA3), the whole response, including the STA-specific information, may be decoded by the AP. The response 2004, 2006, 2010 may be a TB PPDU (e.g., BSR, Multi-STA BlockAck).

[0146] The AP, based on receiving only a part of the response on the same RU (e.g., RU1 2008), may partially decode the response and determine that at least two STAs in the subset

met the conditions for responding. The AP may then transmit another frame (e.g., Req frame 2014) to one or more STAs in the subset (e.g., STA1 and STA2). The Req frame 2014 may be used to trigger a second poll (e.g., Poll2) to solicit additional (e.g., STA-specific) responses 2016, 2018 from STAs in the subset (e.g., STA1 and STA2). For example, the second poll (e.g., Poll2) may solicit non-conditional responses (i.e., responses that are not based on specific conditions).

[0147] The AP, based on receiving the whole of a response on the same RU (e.g., RU2 2012), may decode the whole response and determine specific information (e.g., presence of queued LL traffic) about the STA (e.g., STA3). Then, the AP may take corresponding action for the STA (not depicted), such as allocating time (e.g., before or after Poll2) for the STA (e.g., STA3) to transmit data after determining a STA has LL traffic queued. The AP may also determine based on receiving the whole response of a STA (e.g., STA3) that the other STAs in the subset (e.g., STA4) did not meet the response conditions.

[0148] Advantageously, the AP may obtain STA-specific information particularly when there is only one responding STA.

[0149] The format of the resource allocation frame from the AP (e.g., Req frame 2002) in the second implementation of the first embodiment may be the same as that of the resource allocation frame from the AP (e.g., Req frame 202) in the first implementation of the first embodiment and as exemplified in Figures 3 to 12.

[0150] In an example, the response transmitted from the STAs (e.g., Rsp 2004, 2006, 2010) may be a TB PPDU, such as a buffer status report (BSR) (e.g., a QoS Null or QoS Data frame with BSR Control), which may be transmitted in response to a Trigger frame (e.g., BSRP, Basic, MU-BAR, or CRP Trigger frame). The identical part of the response may be in the PHY preamble (e.g., particularly the parts transmitted only on the allocated resource) and the STA-specific information may be in the Data field carrying the PHY layer convergence procedure (PLCP) service data unit (PSDU).

[0151] Figure 21 shows an exemplary format of a TB PPDU 2100 according to the second implementation of the first embodiment. The TB PPDU 2100 in Figure 21 may be an example of the Rsp 2004, 2006, 2010 in Figure 20. As shown in Figure 21, the TB PPDU 2100 may comprise a PHY Preamble field, a Data (e.g., comprising QoS Null/Data) field, and a PE field. The identical part of the response may be in the PHY Preamble field 2102 and the STA-specific information may be in the Data (e.g., comprising QoS Null/Data) field 2104.

[0152] Figure 22 shows an exemplary format of a QoS Null frame 2200 according to the second implementation of the first embodiment. The QoS Null frame 2200 in Figure 22 may be an example of the Rsp 2004, 2006, 2010 in Figure 20. As shown in Figure 22, the QoS Null frame 2200 may comprise a Frame Control field 2202, a Duration field, three Address fields (Address 1 field, Address 2 field, and Address 3 field), a Sequence Control field, a QoS Control field, an HT Control field 2204, and an FCS field. The Frame Control field 2202 may comprise a Type subfield 2206 and a Subtype subfield 2208. The HT Control field 2204 may comprise an A-Control subfield, which further comprises a Control ID subfield 2212 and a Control Information subfield. The Type subfield 2206 may be set to a value of '10', the Subtype subfield 2208 may be set to a value of '1100' and the Control ID subfield 2212 may be set to a value of '3' to indicate a QoS Null frame with BSR Control. STA-specific information may be included in the Control Information subfield. Alternatively, the Control ID subfield 2212 may be set to another value to indicate a different type.

[0153] Figure 23 shows an exemplary format of a QoS Data frame 2300 according to the second implementation of the first embodiment. The QoS Data frame 2300 in Figure 23 may be an example of the Rsp 2004, 2006, 2010 in Figure 20. As shown in Figure 23, the QoS Data frame with 2300 may comprise a Frame Control field 2302, a Duration field, three Address fields (Address 1 field, Address 2 field, and Address 3 field), a Sequence Control field, another Address field (Address 4 field), a QoS Control field, an HT Control field 2304, a Frame Body field, and an FCS field. The Frame Control field 2302 may comprise a Type subfield 2306 and a Subtype subfield 2308. The HT Control field 2304 may comprise an A-Control subfield, which further comprises a Control ID subfield 2312 and a Control Information subfield. The Type subfield 2306 may be set to a value of '10', the Subtype subfield 2308 may be set to a value of '1000' and the Control ID subfield 2312 may be set to a value of '3' to indicate a QoS Data frame with BSR Control. STA-specific information may be included in the Control Information subfield. Alternatively, the Control ID subfield 2312 may be set to another value to indicate a different type.

[0154] In another example, the response transmitted from the STAs (e.g., Rsp 2004, 2006, 2010) may be a Multi-STA BlockAck, which may be transmitted in response to a Trigger frame (e.g., BSRP, Basic, MU-BAR, or CRP Trigger frame).

[0155] Figure 24 shows an exemplary format of a Multi-STA BlockAck frame 2400 according to the second implementation of the first embodiment. The Multi-STA BlockAck frame 2400 in Figure 24 may be an example of the Rsp 2004, 2006, 2010 in Figure 20. As shown in Figure 24, the Multi-STA BlockAck frame 2400 may comprise a Frame Control field, a Duration field,

an RA field, a TA field, a BA Control field 2402, a BA Information field 2404, and an FCS field. The BA Control field 2402 may comprise a BA Type subfield 2406; while the BA Information field 2404 may comprise a Per AID TID Info subfield 2408. The Per AID TID Info subfield 2408 may comprise an AID11 subfield 2410, and STA-specific information 2412.

[0156] The BA Type subfield 2406 may be set to a value of '11' to indicate a Multi-STA BlockAck frame, The AID11 subfield 2410 in the Per AID TID Info subfield 2408 may be set to a special value (e.g., '2046', which is an unused value, e.g., unused in the current IEEE 802.11 specification) to indicate a CRP response. The STA-specific information 2412 may be contained in the remaining field(s). Alternatively, another predetermined value for BA Type subfield 2406 (e.g., '12', which is a reserved value, e.g., reserved in the current IEEE 802.11 specification) may be used to indicate a response to the CRP.

[0157] Table 3 shows the potential effects for different response scenarios when responses (e.g., Rsp 2004, 2006, 2010) on the same frequency resource are partially identical.

Scenario	Example effect
Only one STA in the subset transmits a response in the same RU	The AP may obtain specific information about the STA that responded, and may take further action to serve the STA based on the STA-specific information.
Multiple STAs in the subset transmit a response in the same RU (i.e., simultaneous transmission of responses)	The AP may determine that at least two STAs in the subset met the conditions for responding, and may proceed with a further transmission to STAs in the subset. (e.g., Req frame 2014 for Poll2)
No STAs in the subset transmit a response in the same RU	The AP may determine that no STAs in the subset met the conditions for responding, and, may not proceed with a further transmission to STAs in the subset.

Table 3

[0158] Figure 25 shows a flowchart illustrating another process implemented by an AP according to various embodiments. In step 2502, the AP may transmit a Req frame (e.g., Req frame 2002), which allocates a same RU to a subset of STAs (e.g., RU1 allocated to STA1 and STA2 or RU2 allocated to STA3 and STA4). Then, the AP waits to receive responses (e.g., Rsp 2004, 2006, 2010) on the RU allocated to the subset of STAs in step 2504. Next, the AP may carry out step 2506 to determine whether a response is received on the allocated

RU. If a response is received, the process moves to step 2508, where the AP may determine whether the response contains STA-specific content. If so, the AP takes a corresponding action based on the STA-specific information in step 2510. Otherwise, the process moves to step 2512, where the AP may transmit another frame (e.g., Req frame 2014) to one or more STAs in the subset of STA. If no response is received in step 2506, the process ends.

[0159] As a variation, a third implementation of the first embodiment may be applied independently or in combination with one or more other implementations of the first embodiment. In this third implementation, responses transmitted on the same frequency resource may include an additional part which may be included by the responding STAs based on one or more additional conditions.

[0160] Advantageously, this approach allows additional information about the responding STA or subset to be determined by the AP.

[0161] Figure 26 illustrates a polling procedure 2600 involving an AP and multiple STAs according to the third implementation of the first embodiment.

[0162] Similar to polling procedure 200, in polling procedure 2600, a single frame (e.g., Req frame 2602) may be used to both allocate frequency resources for response transmission and solicit responses in polling procedure 2600. The Req frame 2602 in Figure 26 may be an example of a resource allocation frame 102 in Figure 1. The frame 2602 (e.g., Req frame) transmitted during a first poll (e.g., Poll1) to allocate frequency resources 2608, 2612 (e.g., RU1, RU2) to multiple STAs (e.g., STA1 to STA4) for transmission of responses may also solicit the responses.

[0163] However, in polling procedure 2600, the responses (e.g., Rsp 2604, 2606) may include an additional part which may be included by the STAs based on additional conditions. For example, the response 2606 may include an additional part 2607 when additional conditions are met, such as presence of queued LL traffic and additionally, it is very urgent, or has poor link quality and additionally, needs immediate attention.

[0164] The additional part may be added to an identical (e.g., according to examples of the response frame to the AP (e.g., Rsp 204, 206) in the first implementation as described in Figures 13 to 17), or to a partially identical (e.g., according to examples of the response frame to the AP (e.g., Rsp 2004, 2006, 2010) in the second implementation as described in Figures 21 to 24). The additional part of the response may be a PHY sequence.

[0165] The AP, based on receiving, or partially receiving, a response (e.g., Rsp 2606) including an additional part (e.g., 2607) on the same RU (e.g., RU1 2608), may determine that at least one STA in the subset met additional conditions for responding. Then, the AP may take a corresponding action for the STA, such as prioritising polling towards the STAs in the subset that was allocated the RU on which the response with additional part was received. For example, transmitting another frame (e.g., Req frame 2614) to trigger a second poll (e.g., Poll2) to solicit STA-specific responses 2616, 2618 from individual STAs in the subset. For example, the second poll (e.g., Poll2) may solicit non-conditional responses (i.e., responses are not based on specific conditions). Alternatively, if the response does not include an additional part, the AP may determine the corresponding action based on whether the response is received in part or whole as described for the first and second implementation.

[0166] Advantageously, the AP may prioritise or take appropriate action for a STA or subset based on the meeting of additional response conditions.

[0167] The format of the resource allocation frame from the AP (e.g., Req frame 2602) in the third implementation of the first embodiment may be the same as that of the resource allocation frame from the AP (e.g., Req frame 202) in the first implementation of the first embodiment and as exemplified in Figures 3 to 12. Support or enablement of responses with an additional part may be indicated in the resource allocation frame (e.g., Req frame 2602) (e.g., in the CRP parameters or based on the CRP type) or in a prior exchange (e.g., advertised in a Beacon frame as a capability).

[0168] The format of the response (e.g., Rsp 2604, 2606) may be the same as any one of the exemplary formats described Figures 13 to 17 and 21 to 24, including (e.g., followed by) an additional sequence.

[0169] As an example, the additional sequence may be a PHY sequence, such as a part of a PPDU preamble (e.g., HE-STF). As another example, the additional sequence may be the packet extension (PE) field of the PPDU.

[0170] Figure 27 shows an exemplary format of a PPDU with additional sequence 2700 according to the third implementation of the first embodiment. The PPDU with additional sequence 2700 in Figure 27 may be an example of the Rsp 2604, 2606 in Figure 26. As shown in Figure 27, the PPDU 2700 may comprise a PHY Preamble field, a Data field, and an additional sequence 2702. The additional sequence 2702 may be in a PE subfield 2704 or a

Short HE-STF subfield 2706. A Short HE-STF may comprise a short training sequence similar to or based on an STF field (e.g., HE-STF).

[0171] Alternatively, more than one additional part (e.g., PHY sequence 2702) that may be added to a response and the number of additional sequences received may provide further information about the STA or subset to the AP (e.g., including two sequences may indicate higher priority than a single sequence) and the AP may determine a corresponding action based on the number of additional parts received (not depicted).

[0172] As a variation, a fourth implementation of the first embodiment may be applied independently or in combination with one or more other implementations of the first embodiment. In this fourth implementation, the AP may transmit a separate frame to solicit responses.

[0173] Figure 28 illustrates a polling procedure 2800 involving an AP and multiple STAs according to the fourth implementation of the first embodiment.

[0174] In the fourth implementation, a frame (e.g., allocation (Alloc) frame 2802) is first transmitted to allocate frequency resources 2810, 2812 (e.g., RU1 and RU2) for response transmission. The frame may be a Management frame, such as an Association Response frame, a Beacon frame, or an Action frame. The frame may be transmitted individually or group/broadcast to the multiple STAs. The Alloc frame 2802 in Figure 28 may be an example of a resource allocation frame 102 in Figure 1. The AP may then send a separate frame (e.g., Req frame 2804) to solicit the responses. The separate frame 2804 may be a QoS Data frame, a QoS Null frame, a Multi-STA BlockAck frame, an Ack frame, a Trigger frame (e.g., a BSRP Trigger frame, Basic Trigger frame, MU-BAR Trigger frame, MU-RTS Trigger frame, or new Trigger frame), an NDP or a PHY sequence. The frame 2804 may be addressed to all, some, one or none of the STAs from which the response is being solicited. For example, a non-addressee STA may be a responder.

[0175] Advantageously, this approach allows the AP to allocate resources in advance, thereby reducing signalling overhead when soliciting responses.

[0176] In an example, the resource allocation frame from the AP (e.g., Alloc frame 2802) may be an individually-addressed Management frame, such as an Association Response frame.

[0177] Figure 29 shows an exemplary format of an Association Response frame 2900 according to the fourth implementation of the first embodiment. The Association Response frame 2900 in Figure 29 may be an example of the Alloc frame 2802 in Figure 28. As shown in Figure 29, the Association Response frame 2900 may comprise a Frame Control field, a Duration field, three Address fields (Address 1 field, Address 2 field, and Address 3 field), a Sequence Control field, an HT Control field, a Frame Body field 2902, and an FCS field. The Frame Body field 2902 may comprise an element with an Element ID subfield 2904, a Length subfield 2906, a CRP Type subfield 2908, a CRP Parameters subfield 2910, a Resource Allocation ID subfield 2912, a UL BW subfield 2914, an RU Allocation subfield 2916, and transmit parameters 2918.

[0178] The Address 1 field may be set to the receiver's address, the Address 2 field may be set to the transmitter's address, and the Address 3 field may be set to the BSS identifier (BSSID) of the AP's BSS. Similar to the resource allocation frame described in Figures 3 to 12, the same frequency resource may be allocated based on individual AID, secondary AID, predetermined group or based on a range of AIDs. The Frame Body field 2902 may comprise an element (e.g., a new Polling Response Resource Allocation element) which indicates the allocated resource for the STA's response. The Element ID subfield 2904 may indicate the element (e.g., using a reserved value for the element, e.g., reserved in the IEEE 802.11be specification), the Length subfield 2906 may indicate the size of the element following the Length subfield 2906.

[0179] The CRP type may be included (e.g., CRP Type subfield 2908) to indicate the type of poll for which the resources are being allocated. Alternatively, the element ID may indicate the CRP type and the CRP Type subfield 2908 may not be present. Alternatively, a Resource Allocation ID subfield 2912 may be included to identify this resource allocation. The AP may subsequently reference this identifier when soliciting a response to apply this resource allocation.

[0180] CRP parameters may be included (e.g., CRP Parameters subfield 2910) to indicate conditions or parameters for responding, such as a threshold for delay bound of the LL traffic or a threshold for poor link quality.

[0181] The UL BW subfield 2914 and RU Allocation subfield 2916 may be set to indicate the size and location of the allocated resource unit (RU) respectively. Transmit parameters 2918 may be included to inform parameters for transmission of the CRP response.

[0182] In another example, the resource allocation frame from the AP (e.g., Alloc frame 2802) may be a group-addressed Management frame such as a Beacon frame.

[0183] Figure 30 shows an exemplary format of a Beacon frame 3000 according to the fourth implementation of the first embodiment. The Beacon frame 3000 in Figure 30 may be an example of the Alloc frame 2802 in Figure 28. As shown in Figure 30, the Beacon frame 3000 may comprise a Frame Control field, a Duration field, three Address fields (Address 1 field, Address 2 field, and Address 3 field), a Sequence Control field, a Frame Body field 3002, and an FCS field. The Frame Body field 3002 may comprise an element with an Element ID subfield, a Length subfield, a CRP Type subfield, a CRP Parameters subfield, a Resource Allocation ID subfield, a UL BW subfield, a User Info List field 3004. The User Info List field may comprise multiple (e.g., N) User Info fields 3006. Each User Info field 3006 may comprise an AID12 subfield 3008, and an RU Allocation subfield 3010. The User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0184] The Address 1 field may be set to the broadcast address, the Address 2 field may be set to the transmitter's address, and the Address 3 field may be set to the BSSID of the AP's BSS. The Frame Body field 3102 may comprise an element (e.g., a new Polling Response Resource Allocation element) which indicates the allocated resource for the STA's response. The Element ID subfield may indicate the element (e.g., using a reserved value for the element, e.g., reserved in the IEEE 802.11be specification), the Length subfield may indicate the size of the element following the Length subfield.

[0185] The CRP type may be included (e.g., CRP Type subfield) to indicate the type of poll for which the resources are being allocated. Alternatively, the element ID may indicate the CRP type and the CRP Type subfield may not be present. Alternatively, a Resource Allocation ID subfield may be included to identify this resource allocation. The AP may subsequently reference this identifier when soliciting a response to apply this resource allocation.

[0186] CRP parameters may be included (e.g., CRP Parameters subfield) to indicate conditions or parameters for responding, such as a threshold for delay bound of the LL traffic or a threshold for poor link quality.

[0187] The User Info List field 3004 may contains multiple User Info fields 3006, one for each STA, identified individually in the AID12 subfield 3008. The UL BW subfield and RU Allocation

subfield may be set to indicate the size and location of the allocated resource unit (RU) respectively for the STA(s) identified by the AID12.

[0188] In another example, the resource allocation frame from the AP (e.g., Alloc frame 2802) may be a new frame (e.g., Polling Response Resource Allocation frame), which may be an Action or Action No Ack frame.

[0189] Figure 31 shows an exemplary format of a Polling Response Resource Allocation frame 3100 according to the fourth implementation of the first embodiment. The Polling Response Resource Allocation frame 3100 in Figure 31 may be an example of the Alloc frame 2802 in Figure 28. As shown in Figure 31, the Polling Response Resource Allocation frame 3100 may comprise a Frame Control field, a Duration field, three Address fields (Address 1 field, Address 2 field, and Address 3 field), a Sequence Control field, an HT Control field, a Frame Body field 3102, and an FCS field. The Frame Body field 3102 may comprise a CRP Type subfield, a CRP Parameters subfield, a Resource Allocation ID subfield, a UL BW subfield, and an RU Allocation subfield. The Frame Body field may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted). Alternatively, the Frame Body field 3102 may comprise a CRP Type subfield, a CRP Parameters subfield, a Resource Allocation ID subfield, a UL BW subfield, and a User Info List field. The User Info List field may comprise multiple (e.g., N) User Info fields. Each User Info field may comprise AID12 subfield, and RU Allocation subfield. Each User Info field(s) may also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0190] The Polling Response Resource Allocation frame 3100 may be addressed to individual or group (e.g., broadcast). The content of the example elements from the exemplary frames illustrated in Figures 29 and 30 may be included in the body of the frame directly. The User Info List may be included for group-addressed case.

[0191] In another example, the resource allocation frame from the AP (e.g., Alloc frame 2802) may be a new frame (e.g., a new Polling Response Resource Allocation Trigger frame) or an existing Trigger frame (e.g., Basic Trigger frame, NFRP Trigger frame) with added indication that the resource is to be used for the future poll.

[0192] Figure 32 shows an exemplary format of a Trigger frame 3200 according to the fourth implementation of the first embodiment. The Trigger frame 3200 in Figure 32 may be an example of the Alloc frame 2802 in Figure 28. As shown in Figure 32, the Trigger frame 3200

may comprise a Frame Control field, a Duration field, an RA field, a TA field, a Common Info field 3202, a User Info List field 3204, a Padding field, and an FCS field. The Common Info field 3202 may comprise a Trigger Type subfield 3206, while the User Info List field 3204 may comprise multiple (e.g., N) User Info fields 3208. The Trigger frame 3200 may also include indication that the resource is to be used for the future poll 3210.

[0193] In an example, the separate frame from the AP to solicit the response (e.g., Req frame 2804) may be a Trigger frame, such as a BSRP Trigger frame, a Basic Trigger frame, an MU-BAR Trigger frame, an MU-RTS Trigger frame, or a new Trigger frame.

[0194] Figure 33 shows an exemplary format of another Trigger frame 3300 according to the fourth implementation of the first embodiment. The Trigger frame 3300 in Figure 33 may be an example of the Req frame 2804 in Figure 28. As shown in Figure 33, the Trigger frame 3300 may comprise a Frame Control field, a Duration field, an RA field, a TA field, a Common Info field 3302, a User Info List field 3304, a Padding field, and an FCS field. The Common Info field 3302 may comprise a Trigger Type subfield; while the User Info List field 3304 may comprise multiple (e.g., N) User Info fields 3306. Each User Info field 3306 may comprise an AID12 subfield. The Trigger frame 3300 may also include indication of use of a prior resource allocation.

[0195] The frame may indicate use of prior allocated resources for the response (e.g., indicated by one or more fields in the Common Info field 3302 or User Info field 3306). The Trigger Type field is set to indicate the type of Trigger frame, which may also indicate the CRP type.

[0196] A field may be used to indicate use of a prior resource allocation. For example, a bit in the Common Info field 3302 or in a User Info field (e.g., a User Info field with a special or predetermined AID12 value) may be used to indicate use of a prior resource allocation. In another example, the indication may be implicit (e.g., based on the frame soliciting a CRP response). In another example, the field may indicate use of one of one or more prior resource allocations identified by a resource allocation ID, such as a Resource Allocation ID field (not depicted). Alternatively, the indication of which prior resource allocation to use may be implicitly informed (e.g., based on the frame soliciting a CRP response (e.g., soliciting a preemption request based on a preemption allowed indication)). Alternatively, CRP parameters may be included in the separate frame (e.g., Req frame 2804) instead of in the resource allocation frame (e.g., Req frame 2802).

[0197] In another example, the separate frame (e.g., Req frame 2804) from the AP to solicit the response may be a QoS Data frame or a QoS Null frame. The soliciting of responses using the prior allocated resources may be indicated within the A-Control field. In another example, the indication may be implicit (e.g., based on the frame soliciting a CRP response (e.g., soliciting a preemption request based on a preemption allowed indication)). In another example, the field may indicate use of one of one or more prior resource allocations identified by a resource allocation ID value.

[0198] Figure 34 shows an exemplary format of a QoS Null frame 3400 according to the fourth implementation of the first embodiment. The QoS Null frame 3400 in Figure 34 may be an example of the Req frame 2804 in Figure 28. As shown in Figure 34, the QoS Null frame 3400 may comprise a Frame Control field 3402, a Duration field, three Address fields (Address 1 field, Address 2 field, and Address 3 field), a Sequence Control field, a QoS Control field, an HT Control field 3404, and an FCS field. The Frame Control field 3402 may comprise a Type subfield 3406 and a Subtype subfield 3408. The HT Control field 3404 may comprise an A-Control subfield 3410 (e.g., for BSR Control), which may indicate use of a prior resource allocation. The Type subfield 3406 may be set to a value of '10', and the Subtype subfield 3408 may be set to a value of '1100' to indicate a QoS Null frame.

[0199] Figure 35 shows an exemplary format of a QoS Data frame 3500 according to the fourth implementation of the first embodiment. The QoS Null frame 3500 in Figure 35 may be an example of the Req frame 2804 in Figure 28. As shown in Figure 35, the QoS Null frame 3500 may comprise a Frame Control field 3502, a Duration field, three Address fields (Address 1 field, Address 2 field, and Address 3 field), a Sequence Control field, another Address field (Address 4 field), a QoS Control field, an HT Control field 3504, a Frame Body field, and an FCS field. The Frame Control field 3502 may comprise a Type subfield 3506 and a Subtype subfield 3508. The HT Control field 3504 may comprise an A-Control subfield 3510 (e.g., for BSR Control), which may indicate use of a prior resource allocation. The Type subfield 3506 may be set to a value of '10', and the Subtype subfield 3508 may be set to a value of '1000' to indicate a QoS Data frame.

[0200] In another example, the separate frame from the AP to solicit the response (e.g., Req frame 2804) may be a Multi-STA BlockAck. The soliciting of responses using the prior allocated resources may be indicated in the frame body. For a Multi-STA BlockAck, the indication may consist of setting the AID11 subfield in a Per AID TID Info subfield to a predetermined value (e.g., '2046', which is an unused value, e.g., unused in the current IEEE 802.11 specification). In another example a CRP type may also be indicated (e.g., CRP Type

subfield). In another example, a field may be included to indicate use of one of one or more prior resource allocations identified by a resource allocation ID value.

[0201] Figure 36 shows an exemplary format of a Multi-STA BlockAck frame 3600 according to the fourth implementation of the first embodiment. The Multi-STA BlockAck frame 3600 in Figure 36 may be an example of the Req frame 2804 in Figure 28. As shown in Figure 36, the Multi-STA BlockAck frame 3600 may comprise a Frame Control field, a Duration field, an RA field, a TA field, a BA Control field 3602, a BA Information field 3604, and an FCS field. The BA Control field 3602 may comprise a BA Type subfield 3606; while the BA Information field 3604 may comprise a Per AID TID Info subfield 3608. The Per AID TID Info subfield 3608 may comprise an AID11 subfield 3610, a CRP Type subfield, and an indication of use of a prior resource allocationsubfield. The BA Type subfield 3606 in the BA Control field 3602 may be set to a value of '11' to indicate a Multi-STA BlockAck frame and the AID11 subfield 3610 in a Per AID TID Info subfield 3608 may be set to a predetermined value (e.g., '2046', which is an unused value, e.g., unused in the current IEEE 802.11 specification).

[0202] In another example, the separate frame from the AP to solicit the response (e.g., Req frame 2804) may be a PPDU (e.g., a QoS Null, QoS Data, Ack, or Multi-STA BlockAck) and the indication of using a prior resource allocation may be in the PHY preamble.

[0203] Figure 37 shows an exemplary format of a PPDU 3700 according to the fourth implementation of the first embodiment. The PPDU 3700 in Figure 37 may be an example of the Req frame 2804 in Figure 28. As shown in Figure 37, the PPDU 3700 may comprise a PHY Preamble field 3702, a Data field (e.g., comprising a QoS Null, QoS Data, Ack, or Multi-STA BlockAck), and a PE field.

[0204] The PHY Preamble field 3702 may include indication of use of a prior resource allocation. The indication may be a field in a signal (SIG) field. In another example, the indication may be implicit (e.g., based on the frame soliciting a CRP response (e.g., soliciting a preemption request based on a preemption allowed indication)). In another example, the indication may be based on the use of a specific predetermined PHY sequence in the PHY preamble.

[0205] In another example, the separate frame from the AP to solicit the response (e.g., Req frame 2804) may be an NDP or a PHY sequence (e.g., a part of an STF) (not depicted) and may be associated with soliciting for a specific (e.g., predetermined) CRP type or implying a specific resource allocation.

[0206] The format of the response transmitted from the STAs (e.g., Rsp 2806, 2808) in the fourth implementation of the first embodiment may be the same as that of the response from the STAs (e.g., Rsp 204, 206 and Rsp 2004, 2006, 2010 and 2604, 2606, 2610) in the first, second, and third implementations of the first embodiment and as exemplified in Figures 13 to 17, 21 to 24, and 27.

[0207] As a variation, a fifth implementation of the first embodiment may be applied independently or in combination with one or more other implementations of the first embodiment. In this fifth implementation, a STA may transmit a separate frame to solicit responses.

[0208] Advantageously, this approach allows the responses to be solicited by an uplink or peer to peer transmission.

[0209] Figure 38 illustrates a polling procedure 3800 involving an AP and multiple STAs according to the fifth implementation of the first embodiment.

[0210] Similar to polling procedure 2800, in polling procedure 3800, a frame (e.g., Alloc frame 3802) is first transmitted to allocate frequency resources 3810, 3812 (e.g., RU1 and RU2) for response transmission. The frame may be a Management frame, such as an Association Response frame, a Beacon frame, or an Action frame. The frame may be transmitted individually or group/broadcast to the multiple STAs. The Alloc frame 3802 in Figure 38 may be an example of a resource allocation frame 102 in Figure 1.

[0211] However, in polling procedure 3800, the separate frame (e.g., Req frame 3804) is sent by another STA (e.g., STA0), instead of the AP, to solicit the responses. The separate frame 3804 may be a QoS Data frame, a QoS Null frame, a Multi-STA BlockAck frame, or an Ack frame. The frame 3804 may be addressed to all, some, one or none of the STAs from which the response is being solicited. For example, a non-addressee STA may be a responder. The frame 3804 may also be addressed to the AP. In another example, the STA may transmit the separate frame based on instruction from the AP, such as receiving a frame with a preemption indication (not depicted). In another example, the STA (e.g., STA0) transmitting the separate frame (e.g., Req frame 3804) may also be allocated a same RU (e.g., RU1 3810) and may also transmit a response (e.g., Rsp frame) during the poll (not depicted).

[0212] The format of the resource allocation frame from the AP (e.g., Alloc frame 3802) in the fifth implementation of the first embodiment may be the same as that of the resource allocation

frame from the AP (e.g., Req frame 2802) in the fourth implementation of the first embodiment and as exemplified in Figures 29 to 32.

[0213] The format of the separate frame from the AP to solicit the response (e.g., Req frame 3804) in the fifth implementation of the first embodiment may be the same as that of the separate frame from the AP (e.g., Req frame 2804) in the fourth implementation of the first embodiment and as exemplified in Figures 33 to 37, except that the separate frame is sent by the STA (e.g., STA0).

[0214] The format of the response transmitted from the STAs (e.g., Rsp 3806, 3808) in the fifth implementation of the first embodiment may be the same as that of the response from the STAs (e.g., Rsp 204, 206 and Rsp 2004, 2006, 2010 and 2604, 2606, 2610) in the first, second, and third implementations of the first embodiment and as exemplified in Figures 13 to 17, 21 to 24, and 27.

[0215] As a variation, a sixth implementation of the first embodiment may be applied independently or in combination with one or more other implementations of the first embodiment. In this sixth implementation, the AP may allocate another RU (e.g., RU2) to a STA (e.g., STA4) included in the subset, in addition to the same RU (e.g., RU1).

[0216] Figure 39 illustrates a polling procedure 3900 involving an AP and multiple STAs according to the sixth implementation of the first embodiment.

[0217] In this sixth implementation, a single frame (e.g., Req frame 3902) may be used to both allocate frequency resources for response transmission and solicit responses. The Req frame 3902 in Figure 39 may be an example of a resource allocation frame 102 in Figure 1. The frame 3902 (e.g., Req frame) transmitted during a first poll (e.g., Poll1) to allocate frequency resources 3906, 3908 (e.g., RU1, RU2) to multiple STAs (e.g., STA1 to STA4) for transmission of responses may also solicit the responses. Additionally, the AP may allocate an RU (e.g., RU2) dedicated to a STA (e.g., STA4) included in the subset, in addition to the same RU.

[0218] In an example, the same RU (e.g., RU1) may have been allocated such as based on a group ID, device capability or an AID range. The STA may determine to send a response in the dedicated RU and not the same RU. Additionally, the response transmitted on the dedicated RU may include STA-specific information.

[0219] Advantageously, this approach allows the response of a specific STA of the subset to be prioritised.

[0220] In another example, the AP may allocate another same RU of another subset of STAs to a STA (e.g., a STA may be in multiple subsets) and the STA may determine to respond in only one of the same RUs (e.g., based on determining a priority of the subset such as by the grouping or information related to the CRP or resource allocation).

[0221] As a variation, a seventh implementation of the first embodiment may be applied independently or in combination with one or more other implementations of the first embodiment. In this seventh implementation, an AP may determine that no response is being transmitted for a certain time period (e.g., a priority interframe space (PIFS)) after a poll is solicited, and may proceed with another action (e.g., to transmit another frame).

[0222] Figure 40 illustrates a polling procedure 4000 involving an AP and multiple STAs according to the seventh implementation of the first embodiment.

[0223] In this seventh implementation, a frame (e.g., Req frame 4002) may be used to both allocate frequency resources for response transmission and solicit responses. The Req frame 4002 in Figure 40 may be an example of a resource allocation frame 102 in Figure 1. The frame 4002 (e.g., Req frame) transmitted during a first poll (e.g., Poll1) to allocate frequency resources 4004, 4006 (e.g., RU1, RU2) to multiple STAs (e.g., STA1 to STA4) for transmission of responses may also solicit the responses. The responses may be transmitted after a certain time period (e.g., a short interframe space (SIFS) 4008) following the Req frame 4002.

[0224] After the poll is solicited, if the AP determines that no response is being transmitted for a certain time period 4010 (e.g., priority interframe space (PIFS)), the AP may proceed to transmit another frame (e.g., Data frame 4012).

[0225] Advantageously, this approach allows the AP to reduce the chance of losing medium control to another STA when no responses are transmitted on the allocated resource.

[0226] As a variation, an eighth implementation of the first embodiment may be applied independently or in combination with one or more other implementations of the first embodiment. In this eighth implementation, one or more STAs (e.g., STA1 and STA2 or STA3 and STA4) being allocated the same frequency resource (e.g., RU1 or RU2, respectively) for responding may be an AP (e.g., of an overlapping BSS). The AID (e.g., in the AID12 subfield

in the User Info field) used for allocating the resource may indicate an ID of the target AP, such as an AP ID which can be used to uniquely identify an AP among a plurality of APs. Alternatively, the AP may be contained in an alternative ID subfield (e.g., in addition to or in replacement of the AID12 subfield, e.g., an AP ID subfield).

[0227] Advantageously, this approach allows polling multiple APs, such as for multiple AP coordination, with fewer resources.

[0228] According to a second embodiment, the AP may allocate the same frequency resource for multiple transmission times to one or more STAs.

[0229] Figure 41 illustrates a polling procedure 4100 involving an AP and multiple STAs according to a second embodiment.

[0230] In the second embodiment, the AP may allocate frequency resources 4108, 4110 (e.g., FR1, FR2) over multiple transmission times 4116, 4118 (e.g., TT1, TT2) to multiple STAs (e.g., STA1 to STA4) for transmission of responses 4104, 4106, 4112, 4114 by transmitting one or more resource allocation frames 4102. At least one same frequency resource may be allocated to a subset of the multiple STAs over multiple transmission times. The number of STAs in the subset may be fewer than or the same as the total number of STAs of the multiple STAs.

[0231] For example, a first frequency resource 4108 (FR1) may be allocated to a subset comprising STA1 and STA2 during a first transmission time 4116 (TT1) and a second transmission time 4118 (TT2), while a second frequency resource 4110 (FR2) may be allocated to another subset comprising STA3 and STA4 during the first transmission time 4116 (TT1) and the second transmission time 4118 (TT2). The response from each STA may be sent on the allocated frequency resource and transmission time and using the same spatial domain resource. The AP may determine information about STAs in the subset based on the responses received on the allocated frequency resource and transmission time.

[0232] Figure 42 illustrates a polling procedure 4200 involving an AP and multiple STAs according to a first implementation of the second embodiment.

[0233] In this first implementation, a single frame (e.g., Req frame 4202) may be used to both allocate frequency resources (e.g., RU1 4208, or RU2 4210) and transmission times 4216, 4218 for response transmission, and also solicit responses. The Req frame 4202 may be an

example of a resource allocation frame 4102 in Figure 41. The frame 4202 may be a Trigger frame, such as a BSRP Trigger frame, a Basic Trigger frame, an MU-BAR Trigger frame, an MU-RTS Trigger frame, or a new Trigger frame.

[0234] The RUs and TTs for responses may be allocated to each STA of the subset based on individually AIDs (e.g., AID12s). Responses allocated the same RU may be allocated different transmission times 4216, 4218. For example, Rsp 4204, 4212 by STA1 and STA2 in RU1 for TT1 4216 and TT2 4218 respectively, or Rsp 4206, 4214 by STA3 and STA4 in RU2 for TT1 4216 and TT2 4218 respectively. Each transmission time 4216, 4218 may be separated by a predetermined time interval, which may be determined such as based on a transmit duration of the response frame and a short interframe space (SIFS). Responses may include STA-specific information. The response may be a TB PPDU (e.g., BSR, Multi-STA BlockAck), a TB feedback NDP PPDU, a non-HT PPDU (e.g., Multi-STA BlockAck), or a PHY sequence.

[0235] The AP, based on the responses received, may determine information about each responding STA.

[0236] Advantageously, this approach allows the AP to efficiently allocate resources and solicit the response within a single transmission. The AP may obtain multiple responses with a single request with fewer frequency resources.

[0237] In an example, the resource allocation frame from the AP (e.g., Req frame 4202) may be a Trigger frame according to examples of the resource allocation frame from the AP in the first implementation of the first embodiment as described in Figures 3 to 12. The frame additionally includes TT allocation information.

[0238] Figure 43 shows an exemplary format of a Trigger frame 4300 according to the first implementation of the second embodiment. The Trigger frame 4300 in Figure 43 may be an example of the Req frame 4202 in Figure 42. As shown in Figure 43, the Trigger frame 4300 may comprise a Frame Control field, a Duration field, an RA field, a TA field, a Common Info field 4302, a User Info List field 4304, a Padding field, and an FCS field. The Common Info field 4302 may comprise a Trigger Type subfield, a More TF subfield, and a UL BW subfield; while the User Info List field 4304 may comprise multiple (e.g., N) User Info fields 4306. Each User Info field 4306 may comprise an AID12 subfield, and an RU Allocation subfield. Additionally, each User Info field includes a TT Allocation subfield. The User Info field(s) may

also comprise transmit parameters to inform parameters for transmission of the CRP response (not depicted).

[0239] The RUs and TTs may be allocated to each STA individually (e.g., based on each STA's AID). Similar to the first embodiment as described in Figures 3 to 12, the RU and TT may also be allocated based on a secondary AID, predetermined group or based on a range of AIDs. An additional field (e.g., transmission time (TT) Allocation) may be included in the User Info field and may indicate a transmission time for the response. This field may consist of a single bit indicating a first or second TT (e.g., '0' for the first TT and '1' for the second TT). Alternatively, the field may consist of multiple bits indicating an index of the TT (e.g., '0', '1', '2', for first TT, second TT, and third TT respectively). In another variation, the field may indicate a time (i.e., actual or relative time (e.g., part of a time synchronization function (TSF))) or delay (i.e., a duration until the transmission time (e.g., in microseconds or a multiple of some unit of time) for the response.

[0240] As an alternative to using the TT Allocation subfield, the transmission time may be indicated by repetition of an allocated RU (not depicted). For example, a first instance of User Info field for an RU (e.g., RU1) allocation may be determined to be for TT1, while a second instance of User Info field for the same RU, (e.g., RU1) allocation may be determined to be for TT2. Further, to reduce complexity of implementation, the same RUs may be allocated consecutively, such as in the sequence RU1-TT1 (e.g., first instance of RU1, for TT1), RU1-TT2 (e.g., second instance of RU1, for TT2), RU2-TT1 (e.g., first instance of RU2, for TT1), RU2-TT2 (e.g., first instance of RU2, for TT2).

[0241] As an alternative to allocating the same frequency resource for different TTs to each STA of the subset individually (e.g., based on each STA's AID (e.g., AID12)), resource allocation may be based on a range of AIDs. The resource allocation signalling may indicate a starting AID (e.g., in a Starting AID subfield) instead of individual target AID(s). In an example, a set of frequency resources and transmission times may be allocated based on the following formula which are based on formula from the current IEEE 802.11 specification:

- Frequency resource index = $1 + \text{<AID index> MOD } (18 \times 2^{\text{BW}} / \text{<number of transmission times>})$
- TT index = $1 + \text{FLOOR } (\text{<AID index>} / 18 \times 2^{\text{BW}} / \text{<number of transmission times>})$
- Where the AID index starts from value '0' and may be derived from the position of a STA's AID relative to the range of AIDs (e.g., AID index may be determined using the formula (STA's AID - Starting AID), where the Starting AID is the lowest AID value of

a STA in the range of AIDs and all the AIDs in the range are in a sequence of consecutive integers).

[0242] For example, given AIDs '0' to '17' and the number of transmission times as 2, for a first transmission time (e.g., TT1), frequency resource index '1' to '9' may be allocated to AIDs '0' to '8', while for a second transmission time (e.g., TT2), frequency resource index '1' to '9' may be allocated to AIDs '9' to '17'. The frequency resource index may correspond to a predetermined frequency resource (e.g., an RU or an RU tone set). Alternatively, the resource allocation frame may indicate (e.g., in a User Info field of a Trigger frame) for each frequency resource index (e.g., in a new field indicating the index), corresponding frequency resource information (e.g., RU Allocation subfield in the User Info field) (not depicted). In this example, the resource allocation frame from the AP (e.g., Req frame 4202) may be an NFRP Trigger frame and the frequency resource index may be the RU tone set index.

[0243] In an example, the resource allocation signalling may be contained in a Special User Info field, such as a User Info field 4306 with a predetermined AID12 value (e.g., using a value that is a reserved value, e.g., reserved in the IEEE 802.11be specification) (not depicted). The number of transmission times may be signalled in the Common Info field 4302 or User Info field 4306 (e.g., Special User Info field). Alternatively, it may have been indicated in an earlier frame transmission.

[0244] Alternatively, for allocating resources based on a range of AIDs, the resource allocation frame from the AP (e.g., Req frame 4202) may be another Trigger frame (e.g., BSRP Trigger frame or a new Trigger frame (e.g., CRP Trigger frame)) comprising an indication of a range of AIDs (e.g., by indicating a starting AID and related parameters in a User Info field 4306 (e.g., a Special User Info field)).

[0245] Advantageously, this approach reduces signalling required for allocation of resources and transmission times, thereby improving efficiency of resource allocation.

[0246] The format of the response transmitted from the STAs (e.g., Rsp 4204, 4206, 4212, 4214) in the first implementation of the second embodiment may be the same as that of the response from the STAs (e.g., Rsp 204, 206, 2004, 2006, 2010, 2604, 2606, 2610, 2616, 2618) in the first, second, and third implementations of the first embodiment and as exemplified in Figures 13 to 17, 21 to 24, and 27. For instance, the response transmitted from the STAs (e.g., Rsp 4204, 4206, 4212, 4214) may be a TB PPDU (e.g., BSR, Multi-STA BlockAck), a TB Feedback NDP PPDU, or a non-HT PPDU (e.g., Multi-STA BlockAck).

[0247] As a variation, a second implementation of the second embodiment may be applied independently or in combination with one or more other implementations of the second embodiment. In this second implementation, the AP may transmit a separate frame to solicit responses.

[0248] Figure 44 illustrates a polling procedure 4400 involving an AP and multiple STAs according to the second implementation of the second embodiment.

[0249] In the second implementation the frame (e.g., Alloc frame 4402) is first transmitted to allocate frequency resources 4410, 4412 (e.g., RU1 and RU2) for transmission times 4418, 4420 (e.g., TT1, TT2) to multiple STAs (e.g., STA1 to STA4). In an example, the frame may be a Management frame, such as an Association Response frame, a Beacon frame, an Action frame, or a Trigger frame. The frame may be transmitted individually or group/broadcast to the multiple STAs. The Alloc frame 4402 in Figure 44 may be an example of a resource allocation frame 4102 in Figure 41. The AP may then send a separate frame (e.g., Req frame 4404) to solicit the responses. The separate frame 4404 may be a QoS Data frame, a QoS Null frame, a Multi-STA BlockAck frame, an Ack frame, a Trigger frame, (e.g., a BSRP Trigger frame, Basic Trigger frame, MU-BAR Trigger frame, MU-RTS Trigger frame, or new Trigger frame), an NDP or a PHY sequence. The frame 4404 may be addressed to all, some, one or none of the STAs from which the response is being solicited. For example, a non-addressee STA may be a responder.

[0250] In an alternative, the transmission times 4418, 4420 may be allocated in the separate frame 4404 (e.g., Trigger frame) instead of the frame 4402. For example, RU allocated by frame 4402 may be assigned a resource allocation ID and the separate frame 4404 allocates transmission times 4418, 4420 for the specific resource allocation ID (not depicted).

[0251] Advantageously, this approach allows the AP to allocate resources in advance, thereby reducing signalling overhead when soliciting responses.

[0252] In an example, the resource allocation frame from the AP (e.g., Alloc frame 4402) may be an individual or group addressed Management frame, such as an Association Response frame, a Beacon frame, an Action frame, a Trigger frame, similar to the description for the resource allocation frame 2802 as described in Figures 29 to 32, with the frame additionally comprising TT allocation information in the frame, and alternative formula for determining the frequency resource index and TT index when allocating for a range of AIDs.

[0253] Figure 45 shows an exemplary format of an Association Response frame 4500 according to the second implementation of the second embodiment. The Association Response frame 4500 in Figure 45 may be an example of the Alloc frame 4402 in Figure 44. As shown in Figure 45, the Association Response frame 4500 may comprise a Frame Control field, a Duration field, three Address fields (Address 1 field, Address 2 field, and Address 3 field), a Sequence Control field, an HT Control field, a Frame Body field 4502, and an FCS field. The Frame Body field 4502 may comprise an element with an Element ID subfield, a Length subfield, a CRP Type subfield, a CRP Parameters subfield, a Resource Allocation ID subfield, a UL BW subfield, an RU Allocation subfield, transmit parameters, and a TT Allocation subfield.

[0254] As an example, the format of Association Response frame 4500 is similar to that of Association Response frame 2900. Additionally, the frame may include a TT Allocation subfield in the Frame Body field 4502 to indicate a transmission time. This additional field may consist of a single bit indicating a first or second TT (e.g., '0' for the first TT and '1' for the second TT). Alternatively, the additional field may consist of multiple bits indicating an index of the TT index (e.g., '0', '1', '2', for first TT, second TT, and third TT respectively). In another variation, the field may indicate a time (i.e., actual or relative time (e.g., part of a time synchronization function (TSF))) or delay (i.e., a duration until the transmission time (e.g., in microseconds or a multiple of some unit of time) for the response. A similar description of the adding of TT allocation information may be applied for other examples of the Alloc frame 4402.

[0255] The format of the separate frame from the AP to solicit the response (e.g., Req frame 4404) in the second implementation of the second embodiment may be the same as that of the separate frame from the AP (e.g., Req frame 2804) in the fourth implementation of the first embodiment and as exemplified in Figures 33 to 37.

[0256] The format of the response transmitted from the STAs (e.g., Rsp 4406, 4408, 4414, 4416) in the second implementation of the second embodiment may be the same as that of the response from the STAs (e.g., Rsp 204, 206, 2004, 2006, 2010, 2604, 2606, 2610) in the first, second, and third implementations of the first embodiment and as exemplified in Figures 13 to 17, 21 to 24, and 27. For instance, the response transmitted from the STAs (e.g., Rsp 4406, 4408, 4414, 4416) may be a TB PPDU (e.g., BSR, Multi-STA BlockAck), a TB Feedback NDP PPDU, or a non-HT PPDU (e.g., Multi-STA BlockAck).

[0257] As a variation, a third implementation of the second embodiment may be applied independently or in combination with one or more other implementations of the second

embodiment. In this third implementation, a STA may transmit a separate frame to solicit responses.

[0258] Advantageously, this approach allows the responses to be solicited by an uplink or peer to peer transmission.

[0259] Figure 46 illustrates a polling procedure 4600 involving an AP and multiple STAs according to the third implementation of the second embodiment.

[0260] Similar to polling procedure 4200, in polling procedure 4600, a frame (e.g., Alloc frame 4602) is first transmitted to allocate frequency resources 4610, 4612 (e.g., RU1 and RU2) and transmission times 4618, 4620 (e.g., TT1, TT2) for response transmission. The frame may be a Management frame, such as an Association Response frame, a Beacon frame, or an Action frame. The frame may be transmitted individually or group/broadcast to the multiple STAs. The Alloc frame 4602 in Figure 46 may be an example of a resource allocation frame 4402 in Figure 44.

[0261] However, in polling procedure 4600, the separate frame (e.g., Req frame 4604) is sent by another STA (e.g., STA0), instead of the AP, to solicit the responses. The separate frame 4604 may be a QoS Data frame, a QoS Null frame, a Multi-STA BlockAck frame, or an Ack frame. The frame 4604 may be addressed to all, some, one or none of the STAs from which the response is being solicited. For example, a non-addressee STA may be a responder. The frame 4604 may also be addressed to the AP. In another example, the STA may transmit the separate frame based on instruction from the AP, such as receiving a frame with a preemption indication (not depicted). In another example, the STA (e.g., STA0) transmitting the separate frame (e.g., Req frame 4604) may also be allocated a TT and RU (e.g., TT1 4618 and RU1 4610) and may also transmit a response (e.g., Rsp frame) during the poll (not depicted).

[0262] The format of the resource allocation frame from the AP (e.g., Alloc frame 4602) in the third implementation of the second embodiment may be the same as that of the resource allocation frame from the AP (e.g., Alloc frame 4402) in the second implementation of the second embodiment and as exemplified in Figures 44 and 45.

[0263] The format of the separate frame from the AP to solicit the response (e.g., Req frame 4604) in the third implementation of the second embodiment may be the same as that of the separate frame from the AP (e.g., Req frame 2804) in the fourth implementation of the first

embodiment and as exemplified in Figures 33 to 37, except that the separate frame is sent by a STA (e.g., STA0).

[0264] The format of the response transmitted from the STAs (e.g., Rsp 4606, 4608, 4614, 4616) in the third implementation of the second embodiment may be the same as that of the response from the STAs (e.g., Rsp 204, 206, 2004, 2006, 2010, 2604, 2606, 2610, 2616, 2618) in the first, second, and third implementations of the first embodiment and as exemplified in Figures 13 to 17, 21 to 24, and 27.

[0265] As a variation, a fourth implementation of the second embodiment may be applied independently or in combination with one or more other implementations of the second embodiment. In this fourth implementation, a same frequency resource for a same transmission time (e.g., TT1-RU1 or TT2-RU1) may be allocated to a subset of STAs (e.g., STA1 and STA3 or STA2 and STA4). The subset of STAs may respond based on specific conditions.

[0266] Figure 47 illustrates a polling procedure 4700 involving an AP and multiple STAs according to the fourth implementation of the second embodiment.

[0267] In this fourth implementation, a single frame (e.g., Req 4702) may be used to both allocate frequency resource 4708 and transmission times 4712, 4714 for response transmission and also solicit responses in polling procedure 4700. The Req frame 4702 in Figure 47 may be an example of a resource allocation frame 4102 in Figure 41.

[0268] The responses sent on the same RU and TT (e.g., responses (e.g., Rsp) by STA1 and STA3 or by STA2 and STA4) may be identical (similar to the first implementation of the first embodiment illustrated in Figure 3) or partially identical (similar to the second implementation of the first embodiment illustrated in Figures 20 and 26).

[0269] When simultaneous transmission of responses occurs on the same RU, the whole or part of the response may be successfully decoded by the AP. The AP, based on receiving a whole or part of the response on the same RU (e.g., RU1, RU2), may determine information about one or more STAs in the subset. The AP may then transmit another frame to one or more STAs in the subset whose response was received. The another frame (e.g., Req in Poll2 in the first embodiment) may be used to trigger a second poll (e.g., Poll2 in the first embodiment) to solicit STA-specific responses from individual STAs in the subset (not

depicted). For example, the second poll (e.g., Poll2 in the first embodiment) may solicit non-conditional responses (i.e., responses are not based on specific conditions)

[0270] Advantageously, the AP may can poll multiple STAs by using fewer frequency resources over multiple transmission times.

[0271] Figure 48 illustrates another polling procedure 4800 involving an AP and multiple STAs according to the fourth implementation of the second embodiment.

[0272] Similar to polling procedure 4700, in polling procedure 4800, a single frame (e.g., Req 4802) may be used to both allocate frequency resources 4808, 4810 and transmission times 4814, 4816 for response transmission and also solicit responses. The Req frame 4802 in Figure 48 may be an example of a resource allocation frame 4102 in Figure 41.

[0273] The responses transmitted from the STAs on the same frequency resource and transmission time may be according to the first and second implementations of the first embodiment. For example, the response is transmitted based on specific conditions. Also, in certain implementations, the response may be identical or partially identical to the responses in the subset, allowing the whole or partial reception of the response by the AP in different transmission scenarios as has been described in the present disclosure.

[0274] Alternatively, in polling procedure 4800, the allocation with same frequency resource and transmission time (e.g., RU1-TT2) only occurs in the latest allocated transmission time 4816 (e.g., TT2). In an example, similar to the eighth implementation of the first embodiment, the AP may transmit another frame (e.g., Data frame) if no response is received for a certain duration (e.g., (PIFS - SIFS) value, based on a (response frame transmit duration + SIFS) time interval between TT) from the start of the TT 4816 (e.g., TT2) with the same allocation responses (not depicted). The response may further comprise an additional part according to the third implementation of the first embodiment. Support or enablement of responses with an additional part may be indicated in the resource allocation frame (e.g., Req frame 4802) (e.g., in the CRP parameters or based on the CRP type) or in a prior exchange (e.g., advertised in a Beacon frame as a capability).

[0275] The format of the response transmitted from the STAs (e.g., Rsp 4704, 4706, 4710, 4804, 4806, 4812) in the fourth implementation of the second embodiment may be the same as that of the response from the STAs (e.g., Rsp 204, 206, 2004, 2006, 2010, 2604, 2606,

2610, 2616, 2618) in the first, second, and third implementations of the first embodiment and as exemplified in Figures 13 to 17, 21 to 24, and 27.

[0276] Advantageously, the AP may maintain control of medium even when there are no responses transmitted on the allocated resource.

[0277] As a variation, a fifth implementation of the second embodiment may be applied independently or in combination with one or more other implementations of the second embodiment. In this fifth implementation, one or more STAs (e.g., STA1 and STA2 or STA3 and STA4) being allocated the same frequency resource (e.g., RU1 or RU2, respectively) for responding may be an AP (e.g., of an overlapping BSS). The AID (e.g., in the AID12 subfield in the User Info field) used for allocating the resource may indicate an ID of the target AP, such as an AP ID which can be used to uniquely identify an AP among a plurality of APs. Alternatively, the AP may be contained in an alternative ID subfield (e.g., in addition to or in replacement of the AID12 subfield, e.g., an AP ID subfield).

[0278] Advantageously, this approach allows to polling multiple APs, such as for multiple AP coordination, with fewer resources.

[0279] Figure 49 shows a flowchart illustrating a communication method according to various embodiments of the present disclosure. The communication method 4900 may be implemented by a first communication apparatus (e.g., an AP). At step 4902, the first communication apparatus may generate a frame comprising information for allocating a frequency resource to one or more second communication apparatuses for transmitting a response. At step 4904, the first communication apparatus may transmit the frame to the one or more second communication apparatuses.

[0280] Figure 50 shows a flowchart illustrating another communication method according to various embodiments of the present disclosure. The communication method 5000 may be implemented by a second communication apparatus (e.g., a STA). At step 5002, the second communication apparatus may receive a frame from a first communication apparatus, the frame comprising information for allocating a frequency resource to the second communication apparatus for transmitting a response. At step 5004, the second communication apparatus may determine the frequency resource for transmitting a response to the first communication apparatus based on the information.

[0281] Figure 51 shows a schematic view of a communication apparatus 5100 according to various embodiments of the present disclosure. The communication apparatus 5100 may be implemented as an AP or a STA.

[0282] Various functions and operations of the communication apparatus 5100 are arranged into layers in accordance with a hierarchical model. In the model, lower layers report to higher layers and receive instructions therefrom in accordance with IEEE specifications. For the sake of simplicity, details of the hierarchical model are not discussed in the present disclosure.

[0283] As shown in Figure 51, the communication apparatus 5100 may include circuitry 5114, at least one radio transmitter 5102, at least one radio receiver 5104, and at least one antenna 5112 (for the sake of simplicity, only one antenna is depicted in Figure 51 for illustration purposes). The circuitry 5114 may include at least one controller 5106 for use in software and/or hardware aided execution of tasks that the at least one controller 5106 is designed to perform, including control of communications with one or more other devices in a wireless network. The circuitry 5114 may further include at least one transmission signal generator 5108 and at least one receive signal processor 5110. The at least one controller 5106 may control the at least one transmission signal generator 5108 for generating frames (e.g., NFRP Trigger frame, NDP feedback report response frame) to be sent through the at least one radio transmitter 5102 to one or more other communication apparatuses (e.g., STAs or APs). The at least one controller 5106 may control the at least one receive signal processor 5110 for processing frames received through the at least one radio receiver 5104 from the one or more other communication apparatuses. The at least one transmission signal generator 5108 and the at least one receive signal processor 5110 may be stand-alone modules of the communication apparatus 5100 that communicate with the at least one controller 5106 for the above-mentioned functions. Alternatively, the at least one transmission signal generator 5108 and the at least one receive signal processor 5110 may be included in the at least one controller 5106. It is appreciable to those skilled in the art that the arrangement of these functional modules is flexible and may vary depending on the practical needs and/or requirements. The data processing, storage and other relevant control apparatus can be provided on an appropriate circuit board and/or in chipsets.

[0284] In various embodiments, when in operation, the at least one radio transmitter 5102, at least one radio receiver 5104, and at least one antenna 5112 may be controlled by the at least one controller 5106. Furthermore, while only one radio transmitter 5102 is shown, it will be appreciated that there can be more than one of such transmitters.

[0285] In various embodiments, when in operation, the at least one radio receiver 5104, together with the at least one receive signal processor 5110, forms a receiver of the communication apparatus 5100. The receiver of the communication apparatus 5100, when in operation, provides functions required for processing an information container. While only one radio receiver 5104 is shown, it will be appreciated that there can be more than one of such receivers.

[0286] The communication apparatus 5100, when in operation, provides functions required for polling STAs. In an example, the communication apparatus 5100 may be a first communication apparatus (e.g., an AP), and the circuitry 5114 may, in operation, generate a frame comprising information for allocating a frequency resource to one or more second communication apparatuses for transmitting a response. The transmitter 5102 may, in operation, transmit the frame to the one or more second communication apparatuses.

[0287] Additionally or alternatively, the information may indicate the frequency resource allocated to the one or more second communication apparatuses for transmitting a response during a single time interval. The information may indicate the frequency resource allocated to each of the one or more second communication apparatuses for transmitting a response. The information may indicate the frequency resource allocated to each of the one or more second communication apparatuses based on a range of identifiers. The information may indicate an additional frequency resource allocated to at least one of the one or more second communication apparatuses for transmitting a response.

[0288] Additionally or alternatively, the information may indicate the frequency resource allocated to the one or more second communication apparatuses for transmitting a response during a plurality of time intervals. The information may indicate the frequency resource allocated to the one or more second communication apparatuses for transmitting a response during one of the plurality of time intervals.

[0289] Additionally or alternatively, the one or more second communication apparatuses may belong to a predetermined group, and the information may indicate the frequency resource allocated to the one or more second communication apparatuses for the predetermined group.

[0290] Additionally or alternatively, the circuitry 5114 may assign an identifier to at least one of the one or more second communication apparatuses and the information may indicate the frequency resource allocated to the one or more second communication apparatuses based on the identifier. The identifier may be a unique identifier corresponding to a second

communication apparatus or may be a group identifier corresponding to the one or more second communication apparatuses.

[0291] Additionally or alternatively, the circuitry 5114 may determine a condition associated with the one or more second communication apparatuses based on whether a response is received from the one or more second communication apparatuses. The transmitter 5102 may transmit another frame to the one or more second communication apparatuses based on the condition. The condition may include at least one of: a link quality, a traffic status, and a traffic priority level of the one or more second communication apparatuses.

[0292] Additionally or alternatively, the response received from the one or more second communication apparatuses may comprise information based on the one or more second communication apparatuses. The response received from at least one of the one or more second communication apparatuses may comprise an additional component indicative of another condition associated with the one or more second communication apparatuses.

[0293] Additionally or alternatively, the frame may request for the response from the one or more second communication apparatuses.

[0294] Additionally or alternatively, the transmitter 5102 may transmit another frame to request for the response from the one or more second communication apparatuses.

[0295] Additionally or alternatively, the transmitter 5102 may transmit an indication to a third communication apparatus to transmit another frame requesting the response from the one or more second communication apparatuses.

[0296] Additionally or alternatively, the one or more second communication apparatuses may include an access point.

[0297] Additionally or alternatively, the transmitter 5102 may transmit another frame when no response is received within a predetermined time period after transmission of the frame.

[0298] Additionally or alternatively, the frame may further comprise information for allocating another frequency resource to another one or more second communication apparatuses.

[0299] In another example, the communication apparatus 5100 may be a second communication apparatus (e.g., a STA). The receiver 5104 may, in operation, receive a frame

from a first communication apparatus, the frame comprising information for allocating a frequency resource to the second communication apparatus for transmitting a response. The circuitry 5114 may, in operation, determine the frequency resource for transmitting a response to the first communication apparatus based on the information.

[0300] Additionally or alternatively, the circuitry 5114 may determine whether to transmit the response based on one or more conditions associated with the second communication apparatus. The one or more conditions may include at least one of: a link quality, a traffic status, and a traffic priority level of the second communication apparatus.

[0301] The present disclosure can be realised by software, hardware, or software in cooperation with hardware. Each functional block used in the description of each embodiment described above can be partly or entirely realised by an LSI such as an integrated circuit, and each process described in each embodiment may be controlled partly or entirely by the same LSI or a combination of LSIs. The LSI may be individually formed as chips, or one chip may be formed so as to include a part or all of the functional blocks. The LSI may include a data input and output coupled thereto. The LSI here may be referred to as an IC, a system on a chip (SoC), a system LSI, a super LSI, or an ultra LSI depending on a difference in the degree of integration. However, the technique of implementing an integrated circuit is not limited to the LSI and may be realised by using a dedicated circuit, a general-purpose processor, or a special-purpose processor. In addition, an FPGA (Field Programmable Gate Array) that can be programmed after the manufacture of the LSI or a reconfigurable processor in which the connections and the settings of circuit cells disposed inside the LSI can be reconfigured may be used. The present disclosure can be realised as digital processing or analogue processing. If future integrated circuit technology replaces LSIs as a result of the advancement of semiconductor technology or other derivative technology, the functional blocks could be integrated using the future integrated circuit technology. Biotechnology can also be applied.

[0302] The present disclosure can be realised by any kind of apparatus, device or system having a function of communication, which is referred to as a communication apparatus.

[0303] Some non-limiting examples of such a communication apparatus include a phone (e.g., cellular (cell) phone, smart phone), a tablet, a personal computer (PC) (e.g., laptop, desktop, netbook), a camera (e.g., digital still/video camera), a digital player (digital audio/video player), a wearable device (e.g., wearable camera, smart watch, tracking device), a game console, a digital book reader, a telehealth/telemedicine (remote health and medicine)

device, and a vehicle providing communication functionality (e.g., automotive, airplane, ship), and various combinations thereof.

[0304] The communication apparatus is not limited to be portable or movable, and may also include any kind of apparatus, device or system being non-portable or stationary, such as a smart home device (e.g., an appliance, lighting, smart meter, control panel), a vending machine, and any other "things" in a network of an "Internet of Things (IoT)".

[0305] The communication may include exchanging data through, for example, a cellular system, a wireless LAN system, a satellite system, etc., and various combinations thereof.

[0306] The communication apparatus may comprise a device such as a controller or a sensor which is coupled to a communication device performing a function of communication described in the present disclosure. For example, the communication apparatus may comprise a controller or a sensor that generates control signals or data signals which are used by a communication device performing a communication function of the communication apparatus.

[0307] The communication apparatus also may include an infrastructure facility, such as a base station, an access point, and any other apparatus, device or system that communicates with or controls apparatuses such as those in the above non-limiting examples.

[0308] It will be understood that while some properties of the various embodiments have been described with reference to a device, corresponding properties also apply to the methods of various embodiments, and vice versa.

[0309] In the following paragraphs, certain exemplifying embodiments are explained with reference to terms related to wireless communication and the present disclosure regarding communication apparatuses and communication methods for polling STAs, namely:

Example 1. A first communication apparatus comprising:

circuitry, which in operation, generates a frame comprising information for allocating a frequency resource to one or more second communication apparatuses for transmitting a response; and

a transmitter, which in operation, transmits the frame to the one or more second communication apparatuses.

Example 2. The first communication apparatus of example 1, wherein the information indicates the frequency resource allocated to the one or more second communication apparatuses for transmitting a response during a single time interval.

Example 3. The first communication apparatus of example 1, wherein the information indicates the frequency resource allocated to the one or more second communication apparatuses for transmitting a response during a plurality of time intervals.

Example 4. The first communication apparatus of example 3, wherein the information indicates the frequency resource allocated the one or more second communication apparatuses for transmitting a response during one of the plurality of time intervals.

Example 5. The first communication apparatus of any one of examples 1 to 4, wherein the information indicates the frequency resource allocated to each of the one or more second communication apparatuses for transmitting a response.

Example 6. The first communication apparatus of any one of examples 1 to 5, wherein the one or more second communication apparatuses belong to a predetermined group, and wherein the information indicates the frequency resource allocated to the one or more second communication apparatuses for the predetermined group.

Example 7. The first communication apparatus of any one of claims 1 to 6, wherein the circuitry assigns an identifier to at least one of the one or more second communication apparatuses and the information indicates the frequency resource allocated to the one or more second communication apparatuses based on the identifier.

Example 8. The first communication apparatus of example 7, wherein the identifier is a unique identifier corresponding to a second communication apparatus or is a group identifier corresponding to the one or more second communication apparatuses.

Example 9. The first communication apparatus of any one of examples 1 to 8, wherein the information indicates the frequency resource allocated to each of the one or more second communication apparatuses based on a range of identifiers.

Example 10. The first communication apparatus of any one of examples 1 to 9, wherein the circuitry determines a condition associated with the one or more second communication

apparatuses based on whether a response is received from the one or more second communication apparatuses.

Example 11. The first communication apparatus of example 10, wherein the transmitter transmits another frame to the one or more second communication apparatuses based on the condition.

Example 12. The first communication apparatus of example 10 or 11, wherein the condition includes at least one of: a link quality, a traffic status, and a traffic priority level of the one or more second communication apparatuses.

Example 13. The first communication apparatus of any one of examples 1 to 12, wherein the response received from the one or more second communication apparatuses comprises information based on the one or more second communication apparatuses.

Example 14. The first communication apparatus of any one of examples 1 to 13, wherein the response received from at least one of the one or more second communication apparatuses comprises an additional component indicative of another condition associated with the one or more second communication apparatuses.

Example 15. The first communication apparatus of any one of examples 1 to 14, wherein the frame requests for the response from the one or more second communication apparatuses.

Example 16. The first communication apparatus of any one of examples 1 to 14, wherein the transmitter transmits another frame to request for the response from the one or more second communication apparatuses.

Example 17. The first communication apparatus of any one of examples 1 to 14, wherein the transmitter transmits an indication to a third communication apparatus to transmit another frame requesting the response from the one or more second communication apparatuses.

Example 18. The first communication apparatus of any one of examples 1 to 17, wherein the one or more second communication apparatuses include an access point.

Example 19. The first communication apparatus of any one of examples 1 to 18, wherein the information indicates an additional frequency resource allocated to at least one of the one or more second communication apparatuses for transmitting a response.

Example 20. The first communication apparatus of any one of examples 1 to 19, wherein the transmitter transmits another frame when no response is received within a predetermined time period after transmission of the frame.

Example 21. The first communication apparatus of any one of examples 1 to 20, wherein the frame further comprises information for allocating another frequency resource to another one or more second communication apparatuses.

Example 22. A second communication apparatus comprising:

a receiver, which in operation, receives a frame from a first communication apparatus, the frame comprising information for allocating a frequency resource to the second communication apparatus for transmitting a response; and

circuitry, which in operation, determines the frequency resource for transmitting a response to the first communication apparatus based on the information.

Example 23. The second communication apparatus of example 22, wherein the circuitry determines whether to transmit the response based on a condition associated with the second communication apparatus.

Example 24. The second communication apparatus of example 23, wherein the condition includes at least one of: a link quality, a traffic status, and a traffic priority level of the second communication apparatus.

Example 25. A communication method implemented by a first communication apparatus comprising:

generating a frame comprising information for allocating a frequency resource to one or more second communication apparatuses for transmitting a response; and

transmitting the frame to the one or more second communication apparatuses.

Example 26. A communication method implemented by a second communication apparatus comprising:

receiving a frame from a first communication apparatus, the frame comprising information for allocating a frequency resource to the second communication apparatus for transmitting a response; and

determining the frequency resource for transmitting a response to the first communication apparatus based on the information.

[0310] While exemplary embodiments have been presented in the foregoing detailed description of the present embodiments, it should be appreciated that a vast number of variations exist. It should further be appreciated that the exemplary embodiments are examples, and are not intended to limit the scope, applicability, operation, or configuration of this disclosure in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing exemplary embodiments, it being understood that various changes may be made in the function and arrangement of steps and method of operation described in the exemplary embodiments and modules and structures of devices described in the exemplary embodiments without departing from the scope of the subject matter as set forth in the appended claims.

CLAIMS

1. A first communication apparatus comprising:
circuitry, which in operation, generates a frame comprising information for allocating a frequency resource to one or more second communication apparatuses for transmitting a response; and
a transmitter, which in operation, transmits the frame to the one or more second communication apparatuses.
2. The first communication apparatus of claim 1, wherein the information indicates the frequency resource allocated to the one or more second communication apparatuses for transmitting a response during a single time interval.
3. The first communication apparatus of claim 1, wherein the information indicates the frequency resource allocated to the one or more second communication apparatuses for transmitting a response during a plurality of time intervals.
4. The first communication apparatus of claim 3, wherein the information indicates the frequency resource allocated to the one or more second communication apparatuses for transmitting a response during one of the plurality of time intervals.
5. The first communication apparatus of claim 1, wherein the information indicates the frequency resource allocated to each of the one or more second communication apparatuses for transmitting a response.
6. The first communication apparatus of claim 1, wherein the one or more second communication apparatuses belong to a predetermined group, and wherein the information indicates the frequency resource allocated to the one or more second communication apparatuses for the predetermined group.
7. The first communication apparatus of claim 1, wherein the circuitry assigns an identifier to at least one of the one or more second communication apparatuses and the information indicates the frequency resource allocated to the one or more second communication apparatuses based on the identifier.

8. The first communication apparatus of claim 1, wherein the information indicates the frequency resource allocated to each of the one or more second communication apparatuses based on a range of identifiers.
9. The first communication apparatus of claim 1, wherein the circuitry determines a condition associated with the one or more second communication apparatuses based on whether a response is received from the one or more second communication apparatuses.
10. The first communication apparatus of claim 9, wherein the transmitter transmits another frame to the one or more second communication apparatuses based on the condition.
11. The first communication apparatus of claim 9, wherein the condition includes at least one of: a link quality, a traffic status, and a traffic priority level of the one or more second communication apparatuses.
12. The first communication apparatus of claim 1, wherein the response received from the one or more second communication apparatuses comprises information based on the one or more second communication apparatuses.
13. The first communication apparatus of claim 1, wherein the response received from at least one of the one or more second communication apparatuses comprises an additional component indicative of another condition associated with the one or more second communication apparatuses.
14. The first communication apparatus of claim 1, wherein the transmitter transmits another frame to request for the response from the one or more second communication apparatuses.
15. The first communication apparatus of claim 1, wherein the transmitter transmits an indication to a third communication apparatus to transmit another frame requesting the response from the one or more second communication apparatuses.
16. The first communication apparatus of claim 1, wherein the transmitter transmits another frame when no response is received within a predetermined time period after transmission of the frame.
17. A second communication apparatus comprising:

a receiver, which in operation, receives a frame from a first communication apparatus, the frame comprising information for allocating a frequency resource to the second communication apparatus for transmitting a response; and

circuitry, which in operation, determines the frequency resource for transmitting a response to the first communication apparatus based on the information.

18. The second communication apparatus of claim 17, wherein the circuitry determines whether to transmit the response based on a condition associated with the second communication apparatus.

19. A communication method implemented by a first communication apparatus comprising:

generating a frame comprising information for allocating a frequency resource to one or more second communication apparatuses for transmitting a response; and

transmitting the frame to the one or more second communication apparatuses.

20. A communication method implemented by a second communication apparatus comprising:

receiving a frame from a first communication apparatus, the frame comprising information for allocating a frequency resource to the second communication apparatus for transmitting a response; and

determining the frequency resource for transmitting a response to the first communication apparatus based on the information.