

Description

Title of Invention: COMMUNICATION APPARATUS AND COMMUNICATION METHOD FOR MULTIPLE STAS PREEMPTION

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TECHNICAL FIELD

[001] The present disclosure relates to communication methods and apparatuses, and more particularly relates to methods and apparatuses for preemption of multiple STAs (stations).

10 BACKGROUND

[002] Low latency is considered as an important feature for related IEEE 802.11 standards. Preemption is a method to transmit low latency data by stopping a current ongoing transmission.

[003] Although there have been discussions about reducing delays for low latency data by using preemption, preemption for multiple STAs is not well studied, and may lead to potential problems such as low latency data collisions. A preemption method for multiple STAs is needed for reliable and efficient low latency data transmission.

[004] There is thus a need for communication apparatuses and methods that can solve the above-mentioned issue. 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

[005] Non-limiting and exemplary embodiments facilitate providing communication apparatuses and communication methods for preemption of multiple STAs.

[006] According to an aspect of the present disclosure, there is provided a first communication apparatus comprising: circuitry, which in operation, generates a frame comprising information for transmission of a preemption request (PR) frame by a second communication apparatus prior to performing a low latency (LL) transmission by the second communication apparatus; and; and a transceiver, which in operation, transmits the frame to the second communication apparatus.

[007] According to another aspect of the present disclosure, there is provided a second communication apparatus comprising: circuitry, which in operation, a preemption request (PR) frame indicating a request for a first communication apparatus to suspend an ongoing transmission for the second communication apparatus to perform a low latency (LL) transmission; and a transceiver, which in operation, transmits, prior to performing the LL transmission, the PR frame to the first communication apparatus based on resource allocation information indicated in a frame received from the first communication apparatus.

[008] According to another aspect of the present disclosure, there is provided a communication method implemented by a first communication apparatus comprising: generating a frame comprising information for transmission of a preemption request (PR) frame prior to a second communication apparatus performing a low latency (LL) transmission; and transmitting the frame to the second communication apparatus.

[009] According to another aspect of the present disclosure, there is provided a communication method implemented by a second communication apparatus comprising: generating a preemption request (PR) frame indicating a request for a first communication apparatus to suspend an ongoing transmission for the second communication apparatus to perform a low latency (LL) transmission; and transmitting, prior to performing the LL transmission, the PR frame to the first communication apparatus based on resource allocation information indicated in a frame received from the first communication apparatus.

[0010] 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

[0011] 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.

5 **[0012]** FIG. 1 depicts an exemplary illustration of an access point (AP) notifying neighbouring STAs of Resource Unit (RU) Allocation for transmitting preemption request (PR) frames prior to low latency (LL) data transmission according to various embodiments of the present disclosure.

10 **[0013]** FIG. 2 depicts an exemplary illustration of a preemption procedure according to an embodiment of the present disclosure.

15 **[0014]** FIG. 3 depicts an exemplary illustration of an AP sending a multi-user request to send (MU-RTS) frame to multiple STAs prior to sending an RU allocation frame according to various embodiments of the present disclosure.

20 **[0015]** FIG. 4 depicts an exemplary illustration of an AP sending a Buffer Status Report Poll (BSRP) frame to multiple STAs prior to sending an RU allocation frame according to various embodiments of the present disclosure.

25 **[0016]** FIG. 5 depicts an exemplary illustration of a BSRP Trigger frame according to various embodiments of the present disclosure.

30 **[0017]** FIG. 6 depicts an exemplary illustration of a Control Information subfield format in a Buffer Status Report (BSR) Control subfield according to various embodiments of the present disclosure.

35 **[0018]** FIG. 7 depicts an exemplary illustration of an RU Allocation frame format according to various embodiments of the present disclosure.

40 **[0019]** FIG. 8 depicts an exemplary illustration of a PR frame according to various embodiments of the present disclosure.

[0020] FIG. 9 depicts an exemplary illustration of a BSR format contained in or appended to a PR frame according to various embodiments of the present disclosure.

[0021] FIG. 10 depicts an exemplary illustration of a Quality of Service (QoS) Null frame used as a PR frame according to various embodiments of the present disclosure.

[0022] FIG. 11 depicts an exemplary illustration of Control ID values for an A-Control subfield used in a PR frame according to various embodiments of the present disclosure.

[0023] FIG. 12 depicts an exemplary illustration of a Control Information subfield in a PR Control subfield according to various embodiments of the present disclosure.

[0024] FIG. 13 depicts an exemplary illustration of a downlink (DL) physical layer protocol data unit (PPDU) format according to various embodiments of the present disclosure.

[0025] FIG. 14 depicts an exemplary illustration of an AP transmitting a Control frame that contains preemption information for a transmission opportunity (TXOP) according to various embodiments of the present disclosure.

[0026] FIG. 15 depicts an exemplary illustration of an MU-RTS Trigger frame format comprising a PR RU Allocation subfield according to various embodiments of the present disclosure.

[0027] FIG. 16 depicts an exemplary illustration of an MU-RTS Trigger frame format in which RU Allocation subfield is reused for PR RU allocation according to various embodiments of the present disclosure.

[0028] FIG. 17 depicts an exemplary illustration of a BSRP Trigger frame being used as an initial control frame (ICF) according to various embodiments of the present disclosure.

[0029] FIG. 18 depicts an exemplary illustration of preemption when an AP shares a TXOP with a STA according to various embodiments of the present disclosure.

[0030] FIG. 19 depicts an exemplary illustration of a Preemption Enable (PE) frame according to various embodiments of the present disclosure.

[0031] FIG. 20 depicts an exemplary illustration of a trigger-based (TB) PPDU format according to various embodiments of the present disclosure.

[0032] FIG. 21 depicts an exemplary illustration of a PE frame notifying an end of preemption according to various embodiments of the present disclosure.

[0033] FIG. 22 depicts an exemplary illustration of a PE frame being a BlockAck (BA) frame with indication for preemption according to various embodiments of the present disclosure.

[0034] Fig. 23 shows an exemplary flowchart illustrating a communication method according to various embodiments of the present disclosure.

[0035] FIG. 24 shows an exemplary flowchart illustrating another communication method according to various embodiments of the present disclosure.

[0036] FIG. 25 shows an exemplary schematic view of a communication apparatus that can be implemented for preemption of multiple STAs according to various embodiments of the present disclosure.

[0037] 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

[0038] The following detailed description is merely exemplary in nature and is not intended to limit the embodiments or the application and uses of the embodiments. There is no intention that the embodiments and examples herein are bound by any theory presented in the preceding background or this detailed description. 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 background of the disclosure.

[0039] 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.

5 **[0040]** In the following paragraphs, certain exemplifying embodiments are explained with reference to one or more mobile terminals (also referred to herein as devices, peer devices, communication apparatuses, STAs (stations) or other similar terms) which may operate as an access point (AP) or a non-AP STA.

10 **[0041]** In the context of IEEE 802.11 (Wi-Fi) technologies, a mobile terminal is a communication apparatus that has the capability to use the IEEE 802.11 protocol. Based on the IEEE 802.11-2020 definition, a mobile terminal 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).

15 **[0042]** For example, a mobile terminal may be any device such as a laptop, a desktop personal computer (PC), a personal digital assistant (PDA), an access point or a mobile phone in a wireless local area network (WLAN) environment. The mobile terminal here may be fixed or mobile.

[0043] Likewise, an AP, which may be interchangeably referred to as a wireless access
20 point (WAP) or AP multi-link device (AP MLD) in the context of IEEE 802.11 (Wi-Fi) technologies, is a communication apparatus that allows mobile terminals in a WLAN to connect to a wired or another wireless network. The AP may be connected to a router (e.g., via a wired network) as a standalone device, but it can also be integrated with or employed in the router.

25 **[0044]** A mobile terminal in a WLAN may operate 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 non-AP hardware components and AP hardware components. In this manner, the communication apparatuses may switch between a non-AP mode and an AP mode, based on actual WLAN conditions and/or requirements.

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[0045] 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.

[0046] In the present disclosure, an AP may be configured to transmit a preemptable physical layer protocol data unit (PPDU) to a STA, and receive one or more preemption request (PR) or low latency data frames from one or more STAs. A preemptable PPDU is PPDU that is allowed to be preempted. Advantageously, the AP can receive low latency (LL) and/or urgent data from STAs earlier, and latency for LL/urgent traffic can be reduced. In an implementation, an AP may be configured to transmit, prior to a transmission of a preemptable PPDU, a frame to one or more STAs to inform frequency resource information for the transmission of PR frames (e.g., information for transmission of a PR frame prior to performing a LL transmission by the second and third STA). Advantageously, the AP can identify which STA transmits the PR frame, and the STA transmitting the PR frame can perform preemption with a small number of frame exchanges. In another implementation, an AP may be configured to transmit, after receiving a PR frame, a Trigger frame to allocate resources for STAs that sent the PR frame to perform preemption. This advantageously enables multiple STAs to obtain an opportunity to transmit low latency data. In another implementation, an AP may be configured to transmit a Control frame that contains information for preemption, at least to a STA (e.g., a transmission opportunity (TXOP) responder) during a TXOP in which the AP transmits a preemptable PPDU. Advantageously, this enables the STA to know whether preemption will be enabled.

[0047] FIG. 1 depicts an exemplary illustration 100 of an AP 102 notifying neighbouring STAs 104, 106 and 108 of Resource Unit (RU) Allocation 110 for transmitting PR frames 116 and 118 prior to LL data transmission 126 according to various embodiments of the present disclosure. A PR frame is sent by STA(s) with LL data arrival to request preemption. PR frame may contain indication for LL data arrival, and data urgency level information. STAs 106 and 108 with LL data arrival 112 and 114 respectively send PR frames 116 and 118 respectively to the AP 102, using RUs allocated during RU Allocation 110, during a time gap 124 following the preemptable non-LL data PPDU 122. In this example, the AP 102 may own or have been allocated the TXOP. After receiving the PR frames 116 and 118, the AP may suspend or defer a start of a next PPDU transmission (e.g., downlink (DL)), enabling LL data transmission 126.

[0048] FIG. 2 depicts an exemplary illustration 200 of a preemption procedure according to an embodiment of the present disclosure. In this example, AP 202 is a TXOP holder, and has DL transmission (e.g., AP 202 to STA1 204). LL data 212 and 214 for AP arrives during the DL PPDU transmission at STA2 206 and STA3 208 respectively (e.g., uplink ((UL) LL). STA1 204 may also have LL data arrival and may follow the same preemption procedures as STA2 206 and STA3

208 (not shown). The preemption procedure is as follows. AP 202 may be configured to announce RU Allocation 210 to all STAs 204, 206 and 208 before sending the DL PPDUs. The STAs 206 and 208 use the allocated RU to transmit PR frames 216 and 218 respectively after LL data (212 and 214 respectively) arrives. The AP 202 divides large DL PPDUs into multiple DL PPDUs (e.g., DL PPDUs 220, 222 and 232) separated with XIFS (e.g., PIFS or (SIFS + μ s), also referred to herein as an interframe spacing) time 224 and 226 to enable preemption for LL data. It will be appreciated that a PPDU need not be divided if the PPDU is already small enough to follow the preemption procedure. The multiple DL PPDUs may contain indication whether the PPDU is allowed to be preempted, and whether this PPDU is the last PPDU divided from the large PPDU.

STA2 206 and STA3 208 sends PR frames 216 and 218 respectively to AP 202 using allocated RUs after a current preemptable PPDU (e.g., small PPDU) transmission 222 of AP finishes (e.g., after a SIFS time, which is smaller than the XIFS 226), and before the end of the XIFS 226, to request preemption for LL data. AP 202 suspends ongoing transmission after receiving the PR frames 216 and 218, and triggers STA2 206 and STA3 208 to send LL data (228 and 230 respectively). It will be appreciated that “suspend” and “stop” may be used interchangeably. In an implementation, data urgency level may be indicated in the PR frames 216 and 218, and the AP 202 may be configured to trigger STAs with more urgent data first. After successful reception of LL data 228 and 230, AP may proceed with remaining small DL PPDU(s) transmission (e.g., PPDU transmission 232). Advantageously, it is possible for LL data from multiple STAs to be sent in different RUs to reduce collisions and latency.

[0049] FIG. 3 depicts an exemplary illustration 300 of an AP 302 sending a multi-user request to send (MU-RTS) frame 310 to multiple STAs 304, 306 and 308 prior to sending an RU allocation frame 318 according to various embodiments of the present disclosure. STA1 304, STA2 306 and STA3 308 may then send clear to send (CTS) frames 312, 314 and 316 respectively to the AP 302. Advantageously, transmission of the CTS frames 312, 314 and 316 can be protected against collisions during transmission of PR frames.

[0050] Instead of utilizing an MU-RTS – CTS exchange, an AP may be configured to send a Buffer Status Report Poll (BSRP) Trigger frame to STAs. The BSRP Trigger frame may contain indication of AP to poll each STA's potential preemption intent. FIG. 4 depicts an exemplary illustration 400 of an AP 402 sending a BSRP Trigger frame 410 to STAs 404, 406 and 408 prior to sending an RU allocation frame 418 according to various embodiments of the present disclosure. Upon receiving the BSRP Trigger frame 410, the STAs 404, 406 and 408 may be

configured to respond by transmitting Buffer Status Reports (BSRs) 412, 414 and 416 respectively to the AP 402. This advantageously enables the AP 402 to decide scheduling for transmission of PPDUs including a decision for whether or not preemption is allowed for the PPDUs. The BSRs 414 and 416 transmitted by STAs 406 and 408 respectively may include an indication for an intent of potential preemption by the STAs 406 and 408 during this TXOP. This advantageously enables the AP 402 to identify which STA will potentially perform preemption. The AP 402 can thus determine RU allocation efficiently based on the received indication. The AP 402 can also avoid splitting large PPDUs into small PPDUs unnecessarily.

10 **[0051]** FIG. 5 depicts an exemplary illustration of a BSRP Trigger frame 500 according to various embodiments of the present disclosure. A User Info List field 502 contains one or more User Info fields for one or more STAs. The User Info field may contain preemption information. Preemption Indicator field 504 in a User Info field of the BSRP Trigger frame 500 may be set to 1 to indicate a potential preemption intent of an STA or set to 0 otherwise. Reserved bits or bits for other field(s) in User Info field may be used for the Preemption Indicator field. The field is interpreted as Preemption Indicator if transmitted to a UHR STA, and Reserved otherwise (e.g., when transmitted to EHT STA).

20 **[0052]** FIG. 6 depicts an exemplary illustration of a Control Information subfield 600 format in a Buffer Status Report (BSR) Control subfield according to various embodiments of the present disclosure. The Control Information subfield 600 in a BSR Control subfield is extended to indicate preemption intent. Preemption enablement request indicates whether the STA requests the AP to enable preemption, and may be indicated by setting an adjacent channel interference (ACI) High subfield 602 to a value indicating low latency AC, and a Queue Size High subfield 604 to 0. 25 A BSR Control subfield comprising the Control Information subfield 600 may be included in quality of service (QoS) Null frame or Management frame. Alternatively, an indication for request for preemption enablement may be included in a Control Information subfield with a control type other than BSR Control, or other frame type, such as a Multi-STA BlockAck frame. For example, the indication for Preemption enablement request may be provided in a Reserved field in the BA 30 Control field of the Multi-STA BlockAck frame.

[0053] FIG. 7 depicts an exemplary illustration of an RU Allocation frame 700 format according to various embodiments of the present disclosure. A new Management frame may be defined for RU Allocation, such as a new Public Action frame. For example, a Public Action field 702 of value

54, which was Reserved, may be used to indicate RU Allocation. In the RU Allocation frame 700 format, RU Allocation Info List field 704 may be configured to contain RU Allocation information for each STA (e.g., in RU Allocation field 706 in each of one or more RU Allocation Info fields 708), transmit parameters for PR frames (e.g., in transmit parameters field 710), and other similar information.

[0054] FIG. 8 depicts an exemplary illustration of a PR frame 800 according to various embodiments of the present disclosure. In an option, PR frame 800 may be carried in a trigger-based (TB) PPDU and transmitted, for example, to a STA in an RU allocated by an AP for the STA. The U-SIG field 802 may contain indication whether this TB PPDU is a PR frame. Bit B20 in U-SIG-1 of the U-SIG field 802 may be set as a Preemption Request field 804 (e.g., disregard bits or bits for other field(s) in U-SIG field 802 may be used for the Preemption Request field) for indicating whether the TB PPDU is a PR frame. The field is interpreted as Preemption Request if transmitted by a UHR STA, and Disregard otherwise (e.g., transmitted by EHT STA) For example, the Preemption Request field 804 may be set to 1 to indicate that the TB PPDU is used as a PR frame.

[0055] In an option, the PR frame may be a frame that contains or is appended with a Buffer Status Report (BSR). FIG. 9 depicts an exemplary illustration of a BSR format 900 contained in or appended to a PR frame according to various embodiments of the present disclosure. The BSR format 900 may be a Control Information subfield format in a BSR Control subfield according to the 802.11 TGbe specification. In an implementation, an STA may send an unsolicited BSR in an allocated RU as a PR (e.g., containing BSR format 900) to an AP, to indicate to the AP that there is LL data arrival at the STA and the STA thus needs preemption.

[0056] FIG. 10 depicts an exemplary illustration of a Quality of Service (QoS) Null frame 1000 used as a PR frame according to various embodiments of the present disclosure. For high-throughput (HT) Control subfield 1002, there are three variants (e.g., shown in Variant subfield 1004 as HE in this case): HT, very high throughput (VHT), and high efficiency (HE). These variants are differentiated by the value of B0 1006 and B1 1008. Preemption Request (PR) may be indicated in an A-Control subfield 1010 of the HT Control subfield 1002, and no acknowledgement (ACK) may be indicated in QoS Control field 1012.

[0057] PR Control may be defined as a new A-Control subfield. For example, table 1100 of FIG. 11 shows Control ID values for an A-Control subfield used as a PR Control frame according to various embodiments of the present disclosure. Control ID subfield indicates the type of information carried in a Control Information subfield, and the values of the Control ID subfield is defined in the table 1100. For example, Reserved bits such as Control ID with value 10 (see row 1102) or bits for other field(s) in Control Information subfield may be used for Preemption Request (PR). The field is interpreted as Preemption Request if transmitted by a UHR STA, and Reserved otherwise (e.g., transmitted by EHT STA). Further referring to FIG. 12, Control Information subfield 1200 of a PR Control subfield may comprise an ACI Bitmap field 1202 for indicating data urgency level, and a Reserved field 1204 for other information to be included.

[0058] FIG. 13 depicts an exemplary illustration of a small DL PPDU 1300 format according to various embodiments of the present disclosure. Bit B20 in U-SIG-1 of the U-SIG field 1302 may be defined as a Preemption Allowed field (see row 1304) to indicate whether the DL PPDU 1300 is allowed to be preempted. For example, the Preemption Allowed field may be set to 1 to indicate that the DL PPDU 1300 is allowed to be preempted, or set to 0 otherwise. The field is interpreted as Preemption Allowed if transmitted to a UHR STA, and Disregard otherwise (e.g., when transmitted to EHT STA). Further, bit B21 in U-SIG-1 of the U-SIG field 1302 may be implemented as an End PPDU Flag field (see row 1306) for indicating whether the DL PPDU 1300 is a last small PPDU divided from a large PPDU. For example, the End PPDU Flag field may be set to 1 to indicate that the DL PPDU 1300 is the last small PPDU divided from the large PPDU, or set to 0 otherwise. The field is interpreted as End PPDU Flag if transmitted to a UHR STA, and Disregard otherwise (e.g., when transmitted to EHT STA).

[0059] In an implementation, a Control frame comprising preemption information for a TXOP may be transmitted by an AP. The Control frame may be an MU-RTS Trigger frame or BSRP Trigger frame. The preemption information may include indication that the AP may transmit one or more preemptable PPDUs during the TXOP. A STA that receives the Control frame may send a response frame such as a BSR or a Multi-STA BlockAck frame that contains an indication for STA's intent for preemption. The Control frame may be referred to as an initial control frame (ICF), and the response frame to the ICF may be referred to as an initial control response (ICR).

[0060] FIG. 14 depicts an exemplary illustration 1400 of an AP 1402 transmitting a Control frame 1410 (in this case, an MU-RTS frame) comprising preemption information for a TXOP 1412 according to various embodiments of the present disclosure. The Control frame 1410 may be transmitted at the beginning of TXOP 1412. In other words, the Control frame 1410 may be referred to as an initial control frame (ICF). The preemption information may indicate that the AP 1402 may transmit one or more PPDU(s) (e.g., transmitting PPDU(s) 1414 and 1416 to STA1 1404) that are preemptable during the TXOP 1412. Alternatively or additionally, each of the PPDU(s) 1414, 1416 and 1418 may contain indication of whether preemption is allowed after the end of the PPDU, and the preemption information in the MU-RTS frame may indicate existence of one or more PPDU(s) for which preemption is allowed during the TXOP. Alternatively or additionally, the information may be regarding STAs for which preemption is allowed, such as STA2 1406 and STA3 1408. For example, the Control frame may include one or more User Info field(s) with AID(s) for potential preempting STA(s). Further, the Control frame 1410 (being an MU-RTS frame) may also comprise PR RU Allocation information (e.g., RU Allocation for the PR frame).

[0061] One or more STAs (e.g., STA2 1406, STA3 1408) may perform preemption based on the preemption information during the TXOP. The STA(s) may transmit a preemption request frame over a predetermined frequency resource (channel or RU) or a frequency resource indicated in the preemption information in the Control frame 1410. For example, the predetermined frequency resource may be the primary channel, the channel or subband over which the Control frame (e.g., MU-RTS 1410) is transmitted, or the channel over which the response frame (e.g., CTS frame 1418, 1420, 1422) is transmitted, etc.

[0062] FIG. 15 depicts an exemplary illustration of an MU-RTS Trigger frame 1500 format according to various embodiments of the present disclosure. The MU-RTS Trigger frame 1500 may comprise a User Info List field 1502 and a Common Info field 1508. The User Info List field 1502 comprises one or more User Info fields for one or more STAs. The Common Info field 1508 or each of the one or more User Info fields may contain a preemption indication (not depicted) that informs that the frame contains preemption information in the Common Info field 1508 and/or User Info fields. When the preemption indication indicates that the frame 1500 contains preemption information, the STA(s) identified in the AID12 field(s) 1506 in the User Info field(s) are allowed for preemption.

[0063] The User Info field may further contain preemption information. A PR RU Allocation subfield 1504 may be included in the User Info field for a STA for which preemption is allowed and contain RU Allocation information for the STA to transmit PR frames. The PR RU allocation subfield 1504 may be included in the User Info field only when the preemption indication indicates the frame or the User Info field includes the preemption information. Otherwise, the bits where the PR RU Allocation is located may be used for other purpose(s) (e.g., interpreted as another subfield or reserved).

[0064] FIG. 16 depicts an exemplary illustration of an MU-RTS Trigger frame 1600 format in which the RU Allocation subfield, which is used when the frame is used as MU-RTS TXOP Sharing (TXS) frame, is reused for PR RU allocation according to various embodiments of the present disclosure. In a User Info field (not shown) in the User Info List 1602, an existing RU Allocation field 1604 may be reused for PR RU allocation. Further, Preemption Allowed field 1606 may indicate whether preemption is allowed for a STA that is indicated by the AID12 field during the TXOP. For example, the Preemption Allowed field 1606 may be set to 1 to indicate that preemption is allowed, or set to 0 otherwise. The Preemption Allowed field 1606 may be located on (or replace) a bit that is a Reserved bit or a part of Allocation Duration subfield for an EHT variant User Info field. The Preemption Allowed field 1606 may be included in the User Info field when a TXS Mode subfield in the Common Info field 1608 indicates the MU-RTS frame does not initiate TXS procedure (e.g., TXS Mode subfield value is 0 or 3).

[0065] FIG. 17 depicts an exemplary illustration 1700 of an AP 1702 transmitting a Control frame (in this case, a BSRP Trigger frame) comprising preemption information for a TXOP according to various embodiments of the present disclosure. For example, AP 1702 (being a TXOP holder) may transmit BSRP Trigger frame 1710 comprising preemption information to STAs 1704, 1706 and 1708 which, in response, transmits response frames (Resp) 1712, 1714 and 1716 respectively to the AP 1702. The response may be a frame with BSR or Multi-STA BlockAck frame. The response may include an indication for the STA's intent of preemption during the TXOP. The fields and/or subfields for preemption information in the MU-RTS frame 1410, 1500, 1600 may be included in the BSRP Trigger frame 1710.

[0066] The STA(s) 1706 and/or 1708 may transmit PR frame(s) 1718 and/or 1720 without frequency multiplexing (e.g., using non-OFDMA PPDU or non-HT duplicate PPDU) over

predetermined frequency resource (not depicted, similarly to transmission of the PR frames 1424 and 1426 in Figure 14), or with frequency multiplexing as shown in FIG. 17.

[0067] The BSRP Trigger frame 1710 may include RU Allocation information for frequency multiplexing for preemption for one or more STAs 1706 and 1708 for which preemption is allowed. The STAs 1706 and 1708 may then transmit PR frames 1718 and 1720 respectively based on the RU Allocation after a certain IFS from the end of PPDU transmission by the AP 1702. Alternatively, the STAs 1706 and 1708 may be configured to transmit the PR frames 1718 and 1720 using a same resource as for transmission of the responses (Resp) 1714 and 1716 sent in response to the BSRP Trigger frame 1710. In other words, the RU Allocation field in the BSRP Trigger frame 1710 indicates resource allocation for transmission of the response frame, as well as transmission of the PR frame.

[0068] FIG. 18 depicts an exemplary illustration 1800 of preemption when an AP shares a TXOP with a STA according to various embodiments of the present disclosure. For example, STA1 1804 is shared a portion of a TXOP 1836 by AP 1802, and has uplink (UL) transmission (e.g., STA1 1804 to AP 1802). There is LL data 1820 and 1822 for AP arrival during the UL PPDU transmission at STA2 1806 and STA3 1808 respectively (UL LL). STA1 1804 may also have LL data arrival and may follow the same preemption procedures as STA2 1806 and STA3 1808 (not shown). AP 1802 announces RU Allocation 1810 to all STAs 1804, 1806 and 1808 before sharing the TXOP with STA1 1804. STAs 1806 and 1808 use the allocated RUs to transmit PR frames 1824 and 1826 respectively. AP 1802 may transmit an MU-RTS TXS Trigger (MRTT) frame 1812 (e.g., same format as in the 11be specification) to STA1 1804 for the UL transmission. STA1 1804 may divide one or more large PPDUs into a plurality of small PPDUs (e.g., UL PPDUs 1814, 1816 and 1818) with time gap of XIFS (e.g., PIFS or (SIFS + μ s)) time following preemptable UL PPDUs (e.g., UL PPDUs 1814 and 1816) to enable preemption for transmission of LL data. STA2 1806 and STA3 1808 may send PR frames 1824 and 1826 respectively to AP 1802 using the allocated RU after a current preemptable PPDU (e.g., small PPDU) transmission (e.g., after transmission of PPDU 1816) of STA1 1804 finishes (e.g., after SIFS time, which is smaller than XIFS 1828), and before the end of the XIFS 1828, to request preemption for LL data. AP 1802 receives the PR frames 1824 and 1826, and sends a Preemption Enable (PE) frame 1830 to STA1 1804. The PE frame 1830 may contain an indication to enable preemption. After receiving the PE frame 1830, STA1 1804 suspends the ongoing UL PPDU transmission. STA2 1806 and STA3 1808 starts backoff to contend for sending LL data (e.g., LL data 1832 and 1834

respectively) to the AP 1802. After successful reception of the LL data 1832 and 1824 by the AP 1802, STA1 1804 may continue its non-LL data transmission (e.g., next UL PPDU transmission 1818) after the channel becomes idle after a predetermined duration.

5 **[0069]** In an implementation, a PE frame may be a BlockAck (BA) frame with indication for preemption, such as frame 1900 as shown in Fig. 19. A Preemption Enable field 1904 in BA Control field 1902 may indicate whether the BA frame 1900 is used for enabling preemption. For example, it may be set to 1 to indicate that the BA frame 1900 is used for enabling preemption (e.g., a STA (e.g., 1804) receiving the frame will suspend ongoing UL data transmission (e.g., non-LL)), or set to 0 otherwise. Reserved bits or bits for other field(s) in User Info field may be used for the Preemption Enable field. The field is interpreted as Preemption Enable if transmitted to a UHR STA, and Reserved otherwise (e.g., when transmitted to EHT STA).

15 **[0070]** FIG. 20 depicts an exemplary illustration of a PPDU (e.g., small UL PPDU 1814, 1816 and 1818) with a TB PPDU format 2000 according to various embodiments of the present disclosure. The U-SIG field 2002 may contain indication of whether this TB PPDU is allowed to be preempted and whether the PPDU is the last small TB PPDU divided from a large PPDU. In an implementation, bit B20 of U-SIG field 2002 may be used as a Preemption Allowed field (see row 2004) for indicating whether the TB PPDU is allowed to be preempted. For example, the
20 Preemption Allowed field may be set to 1 to indicate this TB PPDU is allowed to be preempted, or set to 0 otherwise. Further, bit B21 of U-SIG field 2002 may be used as an End PPDU Flag field (see row 2006) for indicating whether the PPDU is the last small PPDU divided from a large PPDU. For example, the End PPDU Flag field may be set to 1 to indicate the PPDU is the last small PPDU divided from a large PPDU, or set to 0 otherwise. Reserved bits or bits for other
25 field(s) in U-SIG field 2002 may be used for Preemption Allowed field and End PPDU Flag field. The fields are interpreted as Preemption Allowed and End PPDU Flag respectively if transmitted by a UHR STA, and Disregard otherwise (e.g., transmitted by EHT STA).

30 **[0071]** Another option to enable a STA to continue small UL PPDU transmission (e.g., non-LL) is for an AP to send a PE frame to the STA indicating that preemption has ended. FIG. 21 depicts an exemplary illustration 2100 of a PE frame notifying an end of preemption according to various embodiments of the present disclosure. For example, AP 2102 may transmit a PE frame 2110 to STA 2104 to notify an end of preemption (e.g., after transmission of LL data 2112 and 2114 are

completed by STAs 2106 and 2108 respectively). The STA1 2104 may then start sending (the remaining) small PPDU(s) (e.g., UL PPDU 2116) after receiving the PE frame 2110.

[0072] FIG. 22 depicts an exemplary illustration of a PE frame being a BlockAck (BA) frame 2200 with indication for preemption according to various embodiments of the present disclosure. For example, a Preemption Enable field 2204 in BA Control field 2202 may be configured to indicate whether the BA frame 2200 is used for enabling preemption. The Preemption Enable field 2204 may be set to 1 to indicate the BA frame is used for enabling preemption (e.g., a STA receiving the frame 2200 with Preemption Enable field 2204 set to 1 will suspend any ongoing UL data transmission (e.g., non-LL)), or set to 0 indicating preemption has ended (e.g., the STA receiving the BA frame 2200 with Preemption Enable field 2204 set to 0 may start sending (the remaining) data (e.g., non-LL)). Reserved bits or bits for other field(s) in BA Control field 2202 may be used for the Preemption Enable field. The field is interpreted as Preemption Enable if transmitted to a UHR STA, and Reserved otherwise (e.g., when transmitted to EHT STA).

[0073] Fig. 23 shows an exemplary flowchart 2300 illustrating a communication method according to various embodiments of the present disclosure. In step 2302, a frame may be generated by a first communication apparatus comprising information for transmission of a preemption request (PR) frame by a second communication apparatus prior to performing a low latency (LL) transmission by the second communication apparatus. In step 2304, the frame may be transmitted to the second communication apparatus.

[0074] FIG. 24 shows an exemplary flowchart 2400 illustrating another communication method according to various embodiments of the present disclosure. In step 2402, a preemption request (PR) frame may be generated by a second communication apparatus indicating a request for a first communication apparatus to suspend an ongoing transmission for the second communication apparatus to perform a low latency (LL) transmission. In step 2404, the PR frame may, prior to performing the LL transmission, be transmitted to the first communication apparatus based on resource allocation information indicated in a frame received from the first communication apparatus.

[0075] FIG. 25 shows an exemplary schematic view of a communication apparatus 2500 that can be implemented for preemption of multiple STAs according to various embodiments of the present disclosure. The communication apparatus 2500 may be implemented as a mobile terminal, application host, router, server, non-AP or AP according to various embodiments.

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[0076] Various functions and operations of the communication apparatus 2500 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.

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[0077] As shown in FIG. 25, the communication apparatus 2500 may include circuitry 2514, at least one radio transmitter 2502, at least one radio receiver 2504 and at least one antenna 2512 (for the sake of simplicity, only one radio receiver and only one antenna is depicted in FIG. 25 for illustration purposes). The circuitry may include at least one controller 2506 for use in software and/or hardware aided execution of tasks it is designed to perform, including control of communications with one or more other devices in a wireless network. The at least one controller 2506 may control at least one transmission signal generator 2508 for generating frames to be sent through the at least one radio transmitter 2502 to one or more other non-APs or APs and at least one receive signal processor 2510 for processing frames received through the at least one radio receiver 2504 from the one or more other non-APs or APs. The at least one transmission signal generator 2508 and the at least one receive signal processor 2510 may be stand-alone modules of the communication apparatus 2500 that communicate with the at least one controller 2506 for the above-mentioned functions. Alternatively, the at least one transmission signal generator 2508 and the at least one receive signal processor 2510 may be included in the at least one controller 2506. 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.

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[0078] In various embodiments, when in operation, the at least one radio transmitter 2502, at least one radio receiver 2504, and at least one antenna 2512 may be controlled by the at least one controller 2506. Furthermore, while only one radio transmitter 2502 is shown, it will be appreciated that there can be more than one of such transmitters.

[0079] In various embodiments, when in operation, the at least one radio receiver 2504, together with the at least one receive signal processor 2510, forms a receiver of the communication apparatus 2500. The receiver of the communication apparatus 2500, when in operation, provides functions required for receiving data, a signal, a frame such as a TR frame or other similar frame, or other similar transmission. While only one radio receiver 2504 is shown, it will be appreciated that there can be more than one of such receivers. Furthermore, the functions of both the radio receiver 2504 and radio transmitter 2502 may also be performed by a transceiver (not shown).

[0080] The communication apparatus 2500, when in operation, provides functions required for preemption of multiple STAs. For example, the communication apparatus 2500 may be a first communication apparatus, and the circuitry 2514 may, in operation, generate a frame comprising information for transmission of a preemption request (PR) frame by a second communication apparatus prior to performing a low latency (LL) transmission by the second communication apparatus. The transceiver may, in operation, transmit the frame to the second communication apparatus.

[0081] The information may indicate resource unit (RU) allocation for transmission of the PR frame from the second communication apparatus, and the transceiver may be configured to receive the PR frame transmitted based on the RU allocation by the second communication apparatus. The circuitry 2514 may be configured to divide a physical layer protocol data unit (PPDU) into a plurality of smaller PPDU's transmitted with one or more interframe spacings, and the transceiver may be configured to receive the PR frame within one of the one or more interframe spacings. Each of the plurality of smaller PPDU's comprises a field indicating whether the corresponding smaller PPDU is allowed to be preempted, and another field indicating whether the corresponding smaller PPDU is a last smaller PPDU divided from the PPDU. The circuitry 2514 may be configured to suspend transmission of a next smaller PPDU after receiving the PR frame. The PR frame may be a Trigger-based (TB) PPDU comprising a field indicating that the TB PPDU is a PR frame. The PR frame may be a BSR comprising a field indicating a request for the first communication apparatus to suspend an ongoing transmission for the second communication apparatus to perform an LL transmission. The PR frame may be a quality of service (QoS) Null frame comprising a field indicating a request for the first communication apparatus to suspend an ongoing transmission for the second communication apparatus to perform an LL transmission.

[0082] Prior to transmitting the frame, the transceiver may be configured to transmit a multi-user request-to-send (MU-RTS) frame to the second communication apparatus and, in response, receive a clear to send (CTS) frame from the second communication apparatus. Prior to transmitting the frame, the transceiver may be configured to transmit a Buffer Status Report Poll (BSRP) Trigger frame to the second communication apparatus and, in response, receive a Buffer Status Report (BSR) from the second communication apparatus. The BSRP Trigger frame may comprise a subfield indicating a request for the second communication apparatus to indicate an intention to send the PR frame. The BSR may comprise a subfield indicating a request for the first communication apparatus to transmit a PPDU that is allowed to be preempted.

[0083] The frame may be an MU-RTS Trigger frame comprising a field indicating the information, and the transceiver is configured to receive, in response, a CTS frame from the second communication apparatus. The frame may further comprise a preemption allowed field indicating whether a transmission opportunity (TXOP) allows an ongoing transmission to be suspended for the second communication apparatus to perform an LL transmission. The frame may be a BSRP Trigger frame comprising a field indicating the information, and the transceiver may be configured to receive, in response, a BSR frame or a Multi-STA Block Acknowledgement (BlockAck) frame from the second communication apparatus. The transceiver may be configured to receive the PR frame from the second communication apparatus, and transmits, in response, a preemption enable frame (PE) frame to a third communication apparatus indicating to the third communication apparatus to suspend an ongoing transmission to the first communication apparatus. The transceiver may be further configured to transmit another PE frame to the third communication apparatus indicating the third communication apparatus to continue the ongoing uplink transmission to the first communication apparatus.

[0084] The communication apparatus 2500 may be a second communication apparatus. The circuitry 2514 may, in operation, generate a preemption request (PR) frame indicating a request for a first communication apparatus to suspend an ongoing transmission for the second communication apparatus to perform a low latency (LL) transmission. The transceiver may, in operation, transmit, prior to performing the LL transmission, the PR frame to the first communication apparatus based on resource allocation information indicated in a frame received from the first communication apparatus.

[0085] The present disclosure can be realized 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 realized by an integrated circuit (IC) such as LSI (Large Scale Integration), and each process described in each embodiment may be controlled partly or entirely by a 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 LSI, a super LSI, an ultra-LSI, a very-large-scale integration (VLSI), or a system on a chip (SoC) depending on the integration scales. However, the technique of implementing an integrated circuit is not limited to the LSI and may be realized by using a dedicated circuit, a general-purpose processor, or a special-purpose processor. In addition, a 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 realized as digital processing and/or analogue processing. The functional blocks could be integrated with various integrated circuit technologies which are not limited to those mainly used at present. Biotechnology can also be applied.

[0086] The present disclosure can be realized by any kind of apparatus, device or system having a function of communication, which is referred to as a communication apparatus.

[0087] Some non-limiting examples of such communication apparatus may 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, head mounted display (HMD), smart glasses), 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.

[0088] 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)”.

[0089] The communication may include exchanging data through, for example, a cellular system, a wireless LAN system, a satellite system, etc., and various combinations thereof.

[0090] The communication apparatus may comprise a device such as a controller or a sensor which is coupled to a communication apparatus 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 apparatus performing a communication function of the communication apparatus.

[0091] 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.

[0092] Thus, it can be seen that the present embodiments provide communication apparatuses and methods for multiple STAs preemption.

[0093] 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 transmission
 5 of a preemption request (PR) frame by a second communication apparatus prior to performing a
 low latency (LL) transmission by the second communication apparatus; and
 a transceiver, which in operation, transmits the frame to the second communication
 apparatus.
- 10 2. The first communication apparatus of claim 1, wherein the information indicates resource
 unit (RU) allocation for transmission of the PR frame from the second communication
 apparatus, and the transceiver is configured to receive the PR frame transmitted based
 on the RU allocation by the second communication apparatus.
- 15 3. The first communication apparatus of claim 2, wherein the circuitry is configured to
 divide a physical layer protocol data unit (PPDU) into a plurality of smaller PPDU
 transmitted with one or more interframe spacings, and the transceiver is configured to
 receive the PR frame within one of the one or more interframe spacings.
- 20 4. The first communication apparatus of claim 3, wherein each of the plurality of smaller
 PPDU comprises a field indicating whether the corresponding smaller PPDU is allowed
 to be preempted, and another field indicating whether the corresponding smaller PPDU
 is a last smaller PPDU divided from the PPDU.
- 25 5. The first communication apparatus of claim 3, wherein the circuitry is configured to
 suspend transmission of a next smaller PPDU after receiving the PR frame.
- 30 6. The first communication apparatus of claim 1, wherein, prior to transmitting the frame,
 the transceiver is configured to transmit a multi-user request-to-send (MU-RTS) frame to
 the second communication apparatus and, in response, receive a clear to send (CTS)
 frame from the second communication apparatus.

7. The first communication apparatus of claim 1, wherein, prior to transmitting the frame, the transceiver is configured to transmit a Buffer Status Report Poll (BSRP) Trigger frame to the second communication apparatus and, in response, receive a Buffer Status Report (BSR) from the second communication apparatus.
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8. The first communication apparatus of claim 7, wherein the BSRP Trigger frame comprises a subfield indicating a request for the second communication apparatus to indicate an intention to send the PR frame.
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9. The first communication apparatus of claim 7, wherein the BSR comprises a subfield indicating a request for the first communication apparatus to transmit a PPDU that is allowed to be preempted.
10. The first communication apparatus of claim 2, wherein the PR frame is a Trigger-based (TB) PPDU comprising a field indicating that the TB PPDU is a PR frame.
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11. The first communication apparatus of claim 2, wherein the PR frame is a BSR comprising a field indicating a request for the first communication apparatus to suspend an ongoing transmission for the second communication apparatus to perform an LL transmission.
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12. The first communication apparatus of claim 2, wherein the PR frame is a quality of service (QoS) Null frame comprising a field indicating a request for the first communication apparatus to suspend an ongoing transmission for the second communication apparatus to perform an LL transmission.
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13. The first communication apparatus of claim 1, wherein the frame is an MU-RTS Trigger frame comprising a field indicating the information, and the transceiver is configured to receive, in response, a CTS frame from the second communication apparatus.
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14. The first communication apparatus of claim 13, wherein the frame further comprises a preemption allowed field indicating whether a transmission opportunity (TXOP) allows an

ongoing transmission to be suspended for the second communication apparatus to perform an LL transmission.

- 5 15. The first communication apparatus of claim 1, wherein the frame is a BSRP Trigger frame comprising a field indicating the information, and the transceiver is configured to receive, in response, a BSR frame or a Multi-STA Block Acknowledgement (BlockAck) frame from the second communication apparatus.
- 10 16. The first communication apparatus of claim 1, wherein the transceiver is configured to receive the PR frame from the second communication apparatus, and transmits, in response, a preemption enable frame (PE) frame to a third communication apparatus indicating to the third communication apparatus to suspend an ongoing transmission to the first communication apparatus.
- 15 17. The first communication apparatus of claim 16, wherein the transceiver is further configured to transmit another PE frame to the third communication apparatus indicating the third communication apparatus to continue the ongoing transmission to the first communication apparatus.
- 20 18. A second communication apparatus comprising:
 circuitry, which in operation, generates a preemption request (PR) frame indicating a request for a first communication apparatus to suspend an ongoing transmission for the second communication apparatus to perform a low latency (LL) transmission; and
- 25 a transceiver, which in operation, transmits, prior to performing the LL transmission, the PR frame to the first communication apparatus based on resource allocation information indicated in a frame received from the first communication apparatus.
- 30 19. A communication method performed by a first communication apparatus, comprising:
 generating a frame comprising information for transmission of a preemption request (PR) frame prior to a second communication apparatus performing a low latency (LL) transmission; and
 transmitting the frame to the second communication apparatus.

20. A communication method performed by a second communication apparatus, comprising:
generating a preemption request (PR) frame indicating a request for a first
communication apparatus to suspend an ongoing transmission for the second
5 communication apparatus to perform a low latency (LL) transmission; and
transmitting, prior to performing the LL transmission, the PR frame to the first
communication apparatus based on resource allocation information indicated in a frame
received from the first communication apparatus.