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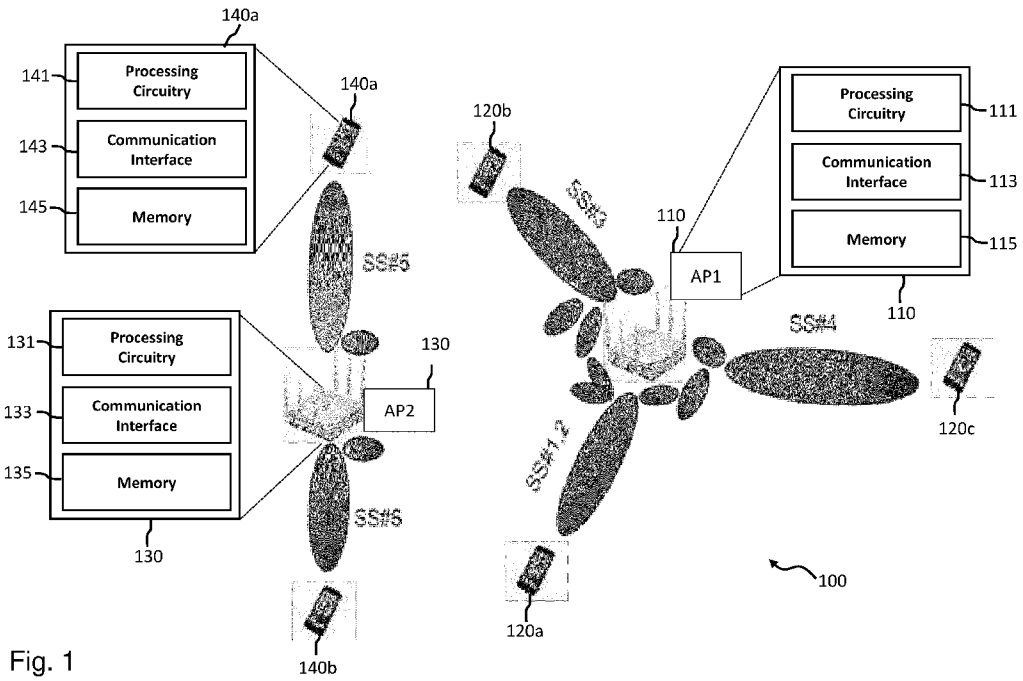

Fig. 1

(57) Abstract: A sharing access point, AP, (110) is disclosed configured to share at least a portion of a transmission opportunity, TXOP, with at least one shared AP (130) within a Multi-AP, M-AP, set for participating in a coordinated transmission, wherein at least one OBSS non-AP station (140a-c) is associated with the shared AP (130). The sharing AP (110) comprises a processing circuitry (111) configured to generate a trigger frame and a communication interface (113) configured to transmit the trigger frame (501) to the at least one OBSS non-AP station (140a-c) for triggering a power control report frame from the at least one OBSS non-AP station (140a-c). The communication interface (113) is further configured to receive the power control report frame from the at least one OBSS non-AP station (140a-c), wherein the power control report frame comprises power control information associated with the at least one OBSS non-AP station (140a-c) for adjusting the transmission power of the at least one OBSS non-AP station by the sharing AP (110).

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POWER CONTROL FOR WIRELESS COMMUNICATION DEVICES AND METHODS

TECHNICAL FIELD

The present disclosure relates to wireless communications. More specifically, the present disclosure relates to power control for wireless communication devices and methods in a wireless communication network, in particular an IEEE 802.11-based WLAN.

BACKGROUND

IEEE 802.11-based WLANs (also referred to as Wi-Fi networks) have become popular at an unprecedented rate. The 802.11 family of standards is constantly expanded by amendments and new generations of previous 802.11 standards to provide WLAN technology with new and improved technical features.

802.11be (also referred to as "Wi-Fi 7") introduces so called Multi-AP (M-AP) coordinated transmission operations, where multiple access points (APs) share resources in order to allow parallel transmissions so that their resources are utilized more efficiently. Some coordinated schemes involve UL PPDU transmissions where stations (STAs) may transmit frames that are addressed to an OBSS AP. One of the issues that needs to be addressed by the AP, when it is soliciting a UL trigger based (TB) transmission, is power control for all the STAs that participate in a current UL transmission. The control of the power per STA allows each STA to transmit using the optimal modulation and coding scheme (MCS) and also allows an alignment between the different STAs participating in the UL transmission. This ensures efficient transmission and reception of UL PPDUs. However, power control mechanisms are designed for AP and non-PA STAs within the same BSS and assume continuous (or at least frequent) communication between the AP and STAs.

SUMMARY

It is an objective to provide improved wireless devices for wireless communication in a wireless network, in particular an IEEE 802.11 based wireless communication network, i.e. a Wi-Fi network, as well as corresponding methods allowing for an efficient power control.

The foregoing and other objectives are achieved by the subject matter of the independent claims. Further implementation forms are apparent from the dependent claims, the description and the figures.

According to a first aspect a sharing access point, AP, is configured to share at least a portion of a transmission opportunity, TXOP, with at least one shared AP within a Multi-AP, M-AP, set for participating in a coordinated transmission, wherein at least one non-AP station is associated with the shared AP (this at least one non-AP station associated with the shared AP will be referred to in the following as at least one OBSS non-AP station when described with respect to the sharing AP, because relative to the sharing AP the at least one non-AP station associated with the shared AP is an OBSS non-AP station). The sharing AP comprises a processing circuitry configured to generate a trigger frame and a communication interface configured to transmit the trigger frame to the at least one OBSS non-AP station for triggering a power control report frame from the at least one OBSS non-AP station. The communication interface is further configured to receive, in response to transmitting the trigger frame, the power control report frame from the at least one OBSS non-AP station. The power control report frame comprises power control information associated with the at least one OBSS non-AP station for adjusting the transmission power of the at least one OBSS non-AP station by the sharing AP.

In a further possible implementation form, the communication interface is configured to receive an uplink physical protocol data unit, PPDU, from the at least one OBSS non-AP station, wherein the power control information comprises a power headroom value for each of a plurality of modulation and coding schemes, MCSs, that may be used by the at least one OBSS non-AP station.

In a further possible implementation form, the trigger frame comprises a M-AP set identifier indicative of the M-AP set.

In a further possible implementation form, the trigger frame comprises a coordination agreement identifier within the M-AP set, wherein the coordination agreement identifier identifies one coordination agreement of a plurality of coordination agreements within the M-AP set and wherein the sharing AP and the shared AP both operate under the coordination agreement identified by the coordination agreement identifier within the M-AP set.

In a further possible implementation form, the trigger frame comprises information for identifying the at least one OBSS non-AP station. In case of several OBSS non-AP stations the information may comprise, for instance, a list of identifiers and/or addresses of the several OBSS non-AP stations.

In a further possible implementation form, the trigger frame further comprises at least, an allocated resource unit, RU, a target received signal strength indicator, RSSI, and/or a target modulation and coding scheme, MCS, to be used by the at least one OBSS non-AP station in an upcoming uplink transmission from the at least one OBSS non-AP station to the sharing AP.

In a further possible implementation form, the trigger frame is a beamforming report poll trigger frame for OBSS non-AP stations within the M-AP set, including the at least one OBSS non-AP station, wherein the beamforming report poll trigger frame includes an additional indication for triggering the at least one OBSS non-AP station (as well as any other OBSS non-AP stations within the M-AP set) to transmit both a coordinated beamforming sounding report and the power control information, which may be aggregated in the same PPDU.

In a further possible implementation form, the communication interface is further configured to transmit a M-AP trigger frame to the at least one shared AP (that is under the same coordination agreement as the sharing AP and that is going to participate in the upcoming coordinated transmission) for triggering the shared AP to transmit a further trigger frame (for instance, a power control information request frame) to at least one further OBSS non-AP station for triggering the at least one further OBSS non-AP station to transmit a further power control report frame to the shared AP. The at least one further OBSS non-AP station may be associated with a further shared AP or with the sharing AP.

In a further possible implementation form, the M-AP trigger frame comprises an identifier of the shared AP.

In a further possible implementation form, the M-AP trigger frame comprises a M-AP set identifier indicative of the M-AP set.

In a further possible implementation form, the M-AP trigger frame comprises a coordination agreement identifier within the M-AP set, wherein the coordination agreement identifier

identifies one coordination agreement of a plurality of coordination agreements within the M-AP set and wherein the sharing AP and the shared AP both operate under the coordination agreement identified by the coordination agreement identifier within the M-AP set.

In a further possible implementation form, the M-AP trigger frame comprises an indication, for instance, one or more flag bits configured to trigger the shared AP to invoke the power control information procedure with the at least one further OBSS non-AP station, e.g. one or more OBSS non-AP stations associated with OBSS APs under the same coordination agreement within the M-AP set.

In a further possible implementation form, the communication interface is further configured, to receive from the shared AP a power control report complete frame for informing the sharing AP that the shared AP has received the power control report frame from the at least one further OBSS non-AP station and completed its stage in the sequential procedure. Consequently, the sharing AP can initiate the same procedure defined by the above implementation forms with another shared AP operating under the same coordination agreement and participating in the next coordinated transmission.

In a further possible implementation form, the M-AP trigger frame further comprises an indication for triggering the shared AP to initiate an EHT sequential sounding procedure and to invoke the power control information procedure with the at least one OBSS non-AP station and/or the one or more further OBSS non-AP stations under the same coordination agreement within the M-AP set, provided that the OBSS non-AP stations are included in the EHT sequential sounding procedure.

In a further possible implementation form, the indication of the M-AP trigger frame for triggering the shared AP to initiate the EHT sequential sounding procedure comprises an indication for triggering the shared AP to transmit a beamforming report poll to the at least one OBSS non-AP station and/or the one or more further OBSS non-AP stations under the same coordination agreement within the M-AP set, wherein the beamforming report poll comprises information configured to trigger the at least one further OBSS non-AP station to provide one or more portions of a beamforming report (i.e. any part thereof) and the power control information.

In a further possible implementation form, the beamforming report poll comprises information configured to trigger the at least one further OBSS non-AP station to transmit one or more beamforming report portions that were already transmitted and/or one or more beamforming report portions which have not been transmitted yet by the at least one further OBSS non-AP station.

In a further possible implementation form, the information configured to trigger the at least one further OBSS non-AP station to transmit the one or more beamforming report portions not transmitted yet and/or the one or more beamforming report portions already transmitted comprises an indication, for instance, a bitmap for identifying the one or more beamforming report portions not transmitted yet and/or the one or more beamforming report portions already transmitted.

In a further possible implementation form, the one or more already transmitted beamforming report portions comprise the most recent transmitted beamforming report portion.

According to a second aspect a method is provided for operating a sharing AP configured to share at least a portion of a TXOP with at least one shared AP within a M-AP set for participating in a coordinated transmission, wherein at least one OBSS non-AP station is associated with the shared AP. The method comprises:
generating a trigger frame for polling power control information from the at least one OBSS non-AP station;
transmitting the trigger frame to the at least one OBSS non-AP station; and
receiving, in response to transmitting the trigger frame for polling the power control information, a power control report frame from the at least one OBSS non-AP station, wherein the power control report frame comprises power control information associated with the at least one OBSS non-AP station for adjusting the transmission power of the at least one OBSS non-AP station by its associated AP, i.e. the shared AP. The power control information may comprise one or more power headroom values per MCS.

The method according to the second aspect of the present disclosure may be performed by the sharing AP according to the first aspect of the present disclosure. Thus, further features of the method according to the second aspect of the present disclosure result directly from the functionality of the sharing AP according to the first aspect of the present disclosure as well as its different implementation forms described above and below.

According to a third aspect a shared AP is configured to participate in a coordinated transmission making use of at least a portion of a transmission opportunity, TXOP, shared by a sharing AP within a M-AP set, wherein the shared AP is associated with at least one non-AP station (which is an OBSS non-AP station for the sharing AP). The shared AP comprises a communication interface configured to receive a M-AP trigger frame from the sharing AP to invoke a power control information procedure with at least one OBSS non-AP station not associated with the shared AP. Thus, the at least one OBSS non-AP station is associated with an AP different from the shared AP. The at least one OBSS non-AP station may be associated with the sharing AP or a different shared AP operating under the same coordination agreement within the same M-AP set. The communication interface is further configured to transmit, in response to receiving the M-AP trigger frame from the sharing AP, a further trigger frame, in particular a power control information request frame to the at least one OBSS non-AP station not associated with the shared AP (which is one of one or more OBSS APs under the same coordination agreement within the M-AP set) for soliciting the at least one OBSS non-AP station to transmit a power control report frame to the shared AP. The power control report frame comprises power control information associated with the at least one OBSS non-AP station for adjusting the transmission power of the at least one OBSS non-AP station by the shared AP.

In a further possible implementation form, in response to receiving the power control report frame from the at last one OBSS non-AP station, the communication interface is further configured to transmit a power control report complete frame to the sharing AP for informing the sharing AP that the power control report frame from the at least one OBSS non-AP station has been successfully received by the shared AP.

In a further possible implementation form, the power control information request frame comprises a M-AP set identifier indicative of the M-AP set, which includes the sharing AP, the shared AP and possibly one or more further shared APs.

In a further possible implementation form, the power control information request frame comprises a coordination agreement identifier within the M-AP set, wherein the coordination agreement identifier identifies one coordination agreement of a plurality of coordination agreements within the M-AP set and wherein the sharing AP and the shared AP both operate under the coordination agreement identified by the coordination agreement identifier within the M-AP set. For instance, the sharing AP and the shared AP might use

the same parameters and/or settings defined by the coordination agreement identified by the coordination agreement identifier within the M-AP set.

In a further possible implementation form, the power control information request frame comprises information, such as an address or an identifier for identifying the at least one OBSS non-AP station.

In a further possible implementation form, the power control information request frame further comprises at least an allocated resource unit, RU, a target received signal strength indicator, RSSI, and/or a target modulation and coding scheme, MCS, to be used by the at least one OBSS non-AP station associated with an AP which is different from that shared AP and is operating under the same coordination agreement within the same M-AP set in an upcoming uplink transmission from the at least one OBSS non-AP station to the shared AP.

In a further possible implementation form, the power control information comprises a power headroom value associated with the at least one OBSS non-AP station for each of a plurality of modulation and coding schemes, MCSs.

In a further possible implementation form, the M-AP trigger frame received from the sharing AP is a EHT sequential sounding trigger frame for further triggering the shared AP to invoke an EHT sequential sounding procedure (which may include the transmission of a NDPA frame and a sounding NDP) and to invoke the power control information procedure with the at least one OBSS non-AP station, e.g. one or more OBSS non-AP stations associated with OBSS APs operating under the same coordination agreement within the M-AP set (provided that these OBSS non-AP stations are included in the EHT sequential sounding procedure).

In a further possible implementation form, the M-AP trigger frame comprises an indication, for instance, a flag bit, configured to trigger the shared AP to invoke the power control information procedure with the at least one OBSS non-AP station, e.g. the one or more OBSS non-AP stations associated with OBSS APs operating under the same coordination agreement within the M-AP set.

In a further possible implementation form, as part of the EHT sequential sounding procedure the communication interface is configured to transmit a beamforming report poll to the at least one OBSS non-AP station, e.g. the one or more OBSS non-AP stations associated

with the OBSS APs operating under the same coordination agreement within the M-AP set, wherein the beamforming report poll comprises information configured to trigger the one or more OBSS non-AP stations to provide one or more portions of a beamforming report and the power control information.

In a further possible implementation form, the beamforming report poll comprises information configured to trigger the at least one OBSS non-AP station, e.g. the one or more OBSS non-AP stations to transmit one or more beamforming report portions that were already transmitted and/or one or more beamforming report portions which have not been transmitted yet.

In a further possible implementation form, the information configured to trigger the one or more OBSS non-AP stations to transmit the one or more beamforming report portions not transmitted yet and/or the one or more beamforming report portions already transmitted comprises an indication, for instance, a bitmap, for identifying the one or more beamforming report portions not transmitted yet and/or the one or more beamforming report portions already transmitted.

In a further possible implementation form, the one or more already transmitted beamforming report portions comprise the most recent transmitted beamforming report portion.

According to a fourth aspect a method is provided for operating a shared AP configured to participate in a coordinated transmission making use of at least a portion of a transmission opportunity, TXOP, shared by a sharing AP within a M-AP set, wherein the shared AP is associated with at least one non-AP station (which for the sharing AP is an OBSS non-AP station). The method comprises the steps of:

receiving a M-AP trigger frame from the sharing AP to invoke a power control information procedure with at least one OBSS non-AP station not associated with the shared AP; and

transmitting, in response to receiving the M-AP trigger frame from the sharing AP, a further trigger frame, in particular a power control information request frame to the at least one OBSS non-AP station not associated with the shared AP for soliciting the at least one OBSS non-AP station to transmit a power control report frame to the shared AP, wherein the power control report frame comprises power control information associated with the at least one OBSS non-AP station for adjusting the transmission power of the at least one OBSS non-AP station by the shared AP. The at least one OBSS non-AP station not associated with

the shared AP may be associated with the sharing AP or a different shared AP operating under the same coordination agreement within the same M-AP set.

The method according to the fourth aspect of the present disclosure may be performed by the shared AP according to the third aspect of the present disclosure. Thus, further features of the method according to the fourth aspect of the present disclosure result directly from the functionality of the shared AP according to the third aspect of the present disclosure as well as its different implementation forms described above and below.

According to a fifth aspect a non-AP station is provided, wherein the non-AP station is associated with an AP within a M-AP set and wherein the associated AP is configured to participate in a coordinated transmission making use of at least a portion of a transmission opportunity, TXOP, shared by a sharing AP within the M-AP set. As will be appreciated, the associated AP of the non-AP station is one shared AP of a plurality of shared APs within the M-AP set and for the sharing AP the non-AP station is an OBSS non-AP station associated with one shared AP. The non-AP station comprises a communication interface configured to receive a trigger frame, in particular a power control report request frame from the sharing AP or a further shared AP within the M-AP set. The non-AP station further comprises a processing circuitry configured to generate, in response to receiving that trigger frame, a power control report frame, wherein the power control report frame comprises power control information associated with the non-AP station. The communication interface of the non-AP station is further configured to transmit the power control report frame to the soliciting AP, which may be either the sharing AP or the further shared AP.

In a further possible implementation form, the power control information comprises a power headroom value of the non-AP station for each of a plurality of modulation and coding scheme, MCS, indexes.

In a further possible implementation form, the power control report frame comprises a M-AP set identifier indicative of the M-AP set.

In a further possible implementation form, the power control report frame comprises a coordination agreement identifier within the M-AP set, wherein the coordination agreement identifier identifies one coordination agreement of a plurality of coordination agreements within the M-AP set and wherein the sharing AP and the shared AP both operate under the

coordination agreement identified by the coordination agreement identifier within the M-AP set.

In a further possible implementation form, the power control report request frame comprises information, such as an identifier or an address for identifying the non-AP station.

In a further possible implementation form, the trigger frame, in particular the power control report request frame further comprises at least an allocated resource unit, RU, a target received signal strength indicator, RSSI, and/or a target modulation and coding scheme, MCS, to be used by the non-AP station in an upcoming uplink transmission to the soliciting AP, i.e. the sharing AP or the further shared AP.

In a further possible implementation form, the power control report request frame comprises an identifier of the soliciting AP, i.e. the sharing AP or the further shared AP within the M-AP set.

In a further possible implementation form, the communication interface is configured to transmit the power control report frame to the soliciting AP, i.e. the sharing AP or the further shared AP as a trigger based physical protocol data unit, PPDU, using an OFDMA and/or MU-MIMO scheme.

In a further possible implementation form, the power control report request frame is part of a beamforming report poll received from the further shared AP, wherein the beamforming report poll comprises an indication to transmit the power control report frame (in addition to a beamforming report frame as a part of the received PPDU).

In a further possible implementation form, the beamforming report poll further comprises information configured to trigger the non-AP station to provide one or more portions of a beamforming report frame and the power control information as a part thereof.

In a further possible implementation form, the beamforming report poll comprises information configured to trigger the non-AP station to transmit one or more beamforming report portions that were already transmitted and/or one or more beamforming report portions which have not been transmitted yet.

In a further possible implementation form, the information configured to trigger the non-AP station to transmit the one or more beamforming report portions not transmitted yet and/or the one or more beamforming report portions already transmitted comprises an indication, for instance, a bitmap for identifying the one or more beamforming report portions not transmitted yet and/or the one or more beamforming report portions already transmitted.

In a further possible implementation form, the information configured to trigger the non-AP station to transmit the one or more beamforming report portions comprises an indication for indicating whether the currently transmitted beamforming report portion is the last portion to transmit.

In a further possible implementation form, the one or more already transmitted beamforming report portions comprise the most recent transmitted beamforming report portion.

According to a sixth aspect a method is provided for operating a non-AP station associated with an AP within a M-AP set, wherein the associated AP is configured to participate in a coordinated transmission making use of at least a portion of a transmission opportunity, TXOP, shared by a sharing AP within the M-AP set. The method comprises the steps of:
receiving a trigger frame, in particular a power control report request frame from the sharing AP or a further shared AP that the non-AP station is not associated with within the M-AP set;
generating, in response to receiving the trigger frame, a power control report frame, wherein the power control report frame comprises power control information associated with the non-AP station; and
transmitting the power control report frame to the soliciting AP, which may be either the sharing AP or the further shared AP within the same M-AP set.

The method according to the sixth aspect of the present disclosure may be performed by the non-AP station according to the fifth aspect of the present disclosure. Thus, further features of the method according to the sixth aspect of the present disclosure result directly from the functionality of the non-AP station according to the fifth aspect of the present disclosure as well as its different implementation forms described above and below.

According to a seventh aspect a computer program product is provided, comprising a computer-readable storage medium for storing program code which causes a computer or a processor to perform the method according to the second aspect, the method according

to the fourth aspect and/or the method according to the sixth aspect, when the program code is executed by the computer or the processor.

Details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description, drawings, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, embodiments of the present disclosure are described in more detail with reference to the attached figures and drawings, in which:

Fig. 1 shows an exemplary wireless communication network including a sharing AP according to an embodiment, a shared AP according to an embodiment and a plurality of OBSS non-AP stations according to an embodiment;

Fig. 2 shows a timing diagram illustrating several iterations of a power control procedure between an AP and associated non-AP stations;

Fig. 3 shows a diagram illustrating different exemplary power levels defined for a non-AP station;

Fig. 4 shows a timing diagram illustrating a coordinated beamforming sounding procedure between an AP, a BSS non-AP station and an OBSS non-AP station;

Fig. 5 shows a timing diagram illustrating aspects of a power control report protocol implemented by a sharing AP, a shared AP and an OBSS non-AP station according to an embodiment;

Fig. 6 shows a diagram illustrating a portion of a M-AP trigger frame transmitted by a sharing AP according to an embodiment to a shared AP according to an embodiment as part of the protocol of figure 5;

Fig. 7 shows a timing diagram illustrating aspects of a power control report protocol implemented by a sharing AP, a shared AP and an OBSS non-AP station according to an embodiment as part of a coordinated beamforming sequential sounding protocol;

Fig. 8 shows a diagram illustrating a portion of a BFRP trigger frame transmitted by a sharing AP according to an embodiment to an OBSS non-AP STA according to an embodiment as part of the protocol of figure 7;

Fig. 9 shows a timing diagram illustrating aspects of a power control report protocol implemented by a sharing AP, a shared AP and an OBSS non-AP station according to an embodiment as part of a coordinated beamforming sequential sounding protocol with a fragmented beamforming report;

Fig. 10 shows a diagram illustrating a portion of a trigger frame transmitted by a sharing AP or shared AP according to an embodiment to an OBSS non-AP STA according to an embodiment as part of the protocol of figure 9;

Fig. 11 shows a timing diagram illustrating aspects of a power control report protocol implemented by a sharing AP, a shared AP and an OBSS non-AP station according to an embodiment;

Fig. 12 shows a diagram illustrating a portion of a power control report frame transmitted by an OBSS non-AP station according to an embodiment;

Fig. 13 shows a timing diagram illustrating aspects of a power control report protocol implemented by a sharing AP, a shared AP and OBSS non-AP stations according to an embodiment using OFDMA;

Fig. 14 shows a flow diagram illustrating steps of a method for operating a sharing AP according to an embodiment;

Fig. 15 shows a flow diagram illustrating steps of a method for operating a shared AP according to an embodiment; and

Fig. 16 shows a flow diagram illustrating steps of a method for operating an OBSS non-AP station according to an embodiment.

In the following, identical reference signs refer to identical or at least functionally equivalent features.

DETAILED DESCRIPTION OF THE EMBODIMENTS

In the following description, reference is made to the accompanying figures, which form part of the disclosure, and which show, by way of illustration, specific aspects of embodiments of the present disclosure or specific aspects in which embodiments of the present disclosure may be used. It is understood that embodiments of the present disclosure may be used in other aspects and comprise structural or logical changes not depicted in the figures. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims.

For instance, it is to be understood that a disclosure in connection with a described method may also hold true for a corresponding device or system configured to perform the method and vice versa. For example, if one or a plurality of specific method steps are described, a corresponding device may include one or a plurality of units, e.g. functional units, to perform the described one or plurality of method steps (e.g. one unit performing the one or plurality of steps, or a plurality of units each performing one or more of the plurality of steps), even if such one or more units are not explicitly described or illustrated in the figures. On the other hand, for example, if a specific apparatus is described based on one or a plurality of units, e.g. functional units, a corresponding method may include one step to perform the functionality of the one or plurality of units (e.g. one step performing the functionality of the one or plurality of units, or a plurality of steps each performing the functionality of one or more of the plurality of units), even if such one or plurality of steps are not explicitly described or illustrated in the figures. Further, it is understood that the features of the various exemplary embodiments and/or aspects described herein may be combined with each other, unless specifically noted otherwise.

Figure 1 shows an exemplary wireless communication network 100 including a sharing AP 110 and a shared AP 130 for a coordinated transmission, such as a coordinated beamforming (CoBF) transmission.

The sharing AP 110 illustrated in figure 1 is configured to share at least a portion of a transmission opportunity, TXOP, with the shared AP 130 under the same coordination agreement within a Multi-AP set (also referred to as M-AP set) for participating in a coordinated transmission. In the exemplary embodiment shown in figure 1, the sharing AP 110 is configured to communicate with its associated BSS stations 120a, 120b and 120c,

while the shared AP 120 is configured to communicate with its associated stations 140a, 140b, which are OBSS stations for the sharing AP 110.

As illustrated in figure 1, the sharing AP 110 comprises a processing circuitry 111 and a communication interface 113, in particular a wireless communication interface 113 in accordance with the IEEE 802.11 framework of standards. The processing circuitry 111 may be implemented in hardware and/or software and may comprise digital circuitry, or both analog and digital circuitry. Digital circuitry may comprise components such as application-specific integrated circuits (ASICs), field-programmable arrays (FPGAs), digital signal processors (DSPs), or general-purpose processors. The sharing AP 110 may further comprise a memory 115 configured to store executable program code which, when executed by the processing circuitry 111, causes the sharing AP 110 to perform the functions and methods described herein.

Likewise, the shared AP 130 illustrated in figure 1 comprises a processing circuitry 131 and a communication interface 133, in particular a wireless communication interface 133 in accordance with the IEEE 802.11 framework of standards. The processing circuitry 131 may be implemented in hardware and/or software and may comprise digital circuitry, or both analog and digital circuitry. Digital circuitry may comprise components such as application-specific integrated circuits (ASICs), field-programmable arrays (FPGAs), digital signal processors (DSPs), or general-purpose processors. The shared AP 130 may further comprise a memory 135 configured to store executable program code which, when executed by the processing circuitry 131, causes the shared AP 130 to perform the functions and methods described herein.

Likewise, the exemplary OBSS non-AP station 140a illustrated in figure 1 comprises a processing circuitry 141 and a communication interface 143, in particular a wireless communication interface 143 in accordance with the IEEE 802.11 framework of standards. The processing circuitry 141 may be implemented in hardware and/or software and may comprise digital circuitry, or both analog and digital circuitry. Digital circuitry may comprise components such as application-specific integrated circuits (ASICs), field-programmable arrays (FPGAs), digital signal processors (DSPs), or general-purpose processors. The exemplary OBSS non-AP station 140a may further comprise a memory 145 configured to store executable program code which, when executed by the processing circuitry 141, causes the OBSS non-AP station 140a to perform the functions and methods described herein.

Before describing different embodiments of the sharing AP 110, the shared AP 130 and the exemplary OBSS non-AP station 140a in more detail, in the following some technical background as well as terminology concerning wireless devices in accordance with the IEEE 802.11 WLAN framework of standards will be introduced making use of one or more of the following abbreviations:

AP	Access Point
BSS	Basic Serving Set
BW	Bandwidth
CoBF	Coordinated Beamforming
MAC	Medium Access Control
M-AP	Multi-AP
MCS	Modulation and Coding Scheme
MRU	Multiple Resource Unit
OBSS	Overlapping BSS
OFDMA	Orthogonal Frequency Division Multiple Access
PHY	Physical Layer
PPDU	PHY Protocol Data Unit
PSD	Power Spectral Density
RU	Resource Unit
STA	Station (in general, can be either an AP STA or a non-AP STA)
TB	Trigger based
TF	Trigger Frame – in 802.11ax, the Trigger Frame was introduced as a means to trigger a non-AP STA or multiple non-AP STAs to transmit simultaneously and in a synchronized manner to the triggering AP

As already described above, 802.11be (also referred to as “Wi-Fi 7”) introduces so called Multi-AP (M-AP) coordinated transmission operations, where multiple access points (APs) share resources in order to allow parallel transmissions and utilize their resources more efficiently. Some coordinated schemes involve trigger based (TB) UL PPDU transmissions where stations (STAs) may transmit frames that are addressed to an OBSS AP. For example, the exemplary coordinated beamforming scheme illustrated in figure 1 may require a sequential sounding procedure where a station, such as the exemplary OBSS non-AP station 140a, may need to transmit a respective sounding feedback report to its associated AP 130 and OBSS AP 110 as well.

Conventionally, an AP applies a long-term adaptation to control the transmit power and MCS per associated STA in triggered UL transmissions using the following scheme. Upon transmission, the AP sets a target RSSI and MCS for each non-AP STA solicited in the trigger frame. Upon reception of an EHT/HE TB PPDU from the respective non-AP STA, the AP measures the actual value of the RSSI and may read (if reported by the STA) the power headroom value relative to maximum available power at current working point (maximum power value is different for different MCSs). These values allow the AP to adjust the target RSSI and MCS for the next UL transmissions for that particular STA. Assuming continuous communication between AP and a given STA within a certain time period, the AP may iteratively optimize and improve the system efficiency in UL transmissions by a better adjustment of the target RSSI, allocated RU size and selected MCS for UL MU PPDUs (including MU-MIMO). This is illustrated by the example shown in figure 2, where non-AP STA2 is required to initially pad the UL TB PPDUs 230a,b (compared with the UL PPDUs 220a,b of non-AP STA1) due to higher MCS than is set for STA1 by the AP in the respective trigger frame (TF) 210a-c. However, after two iterations the AP has adjusted the target RSSI values and MCS values of STA1 and thus the padding part of STA2 may be eliminated (see UL TB PPDUs 220c and 230c).

It is known that based on the RF conditions a STA sets the maximum available transmit power value per MCS. This value depends on the back-off (a gap between absolute maximum transmit power and actual maximum transmit power for that MCS) needed to achieve the EVM requirements for each MCSs. Usually a higher MCS requires a larger back-off and, thus, the maximum transmit power for higher values of MCS will be lower compared to those of lower values of MCS. When an AP sets the target RSSI, a STA computes the required transmitted power and derives the gap between the maximum power for the indicated MCS and the transmitted power required to achieve that target RSSI. This gap is called the power headroom.

Figure 3 shows an example for different power levels defined for a station, where, by way of example, the absolute maximum available transmit power of the STA is 20dBm. When the STA transmits with MCS4 it needs to reduce the maximum power by 10dB (this is the back-off value). In order to achieve target RSSI of -70dBm using MCS4, a STA will transmit with 7dBm which is 3dB lower than the maximum power for MCS4. Thus, in case of a target RSSI of -70dBm, the power headroom value for MCS4 would be 3dB.

When a STA transmits a UL PPDU to its associated AP it may report the power headroom value for the MCS value specified in the preceding TF. In the example shown in figure 3 the STA may report a power headroom value of 3dB for MCS 4. This provides the associated AP with information about which power changes may be possible when triggering this STA for the next time. Usually, the STA will not report the absolute power but only the headroom value with respect to the maximum power of the currently used MCS and the specific target RSSI indicated by the AP (in the preceding TF). Usually the power headroom value is reported to the associated AP within the Uplink Power Headroom (UPH) Control Field of a single byte defined by the 802.11-2020 WLAN standard. Reporting a single headroom value with respect to a current working point allows the associated AP to make small changes concerning the MCS and the target RSSI. However, a STA may not include the UPH Control field in a specific UL PPDU in case it does not contain data frames. Thus, this conventional scheme only works well for a long-term communication between a specific STA and its associated AP.

However, in the coordinated transmission scenarios described above, for instance, the sharing AP 110 is not communicating often with the OBSS stations 140a,b. In the case of CoBF, for instance, the frame exchange with the OBSS stations 140a,b is done only during the preceding sequential sounding procedure. Moreover, the same station may not be scheduled for the next coordinated transmission with the same AP and thus any obtained power control information will be not relevant anymore. Thus, each time an AP triggers an OBSS station to transmit an UL PPDU, it should be treated, as if it is the first time the AP triggers this station and has no previous information regarding the headroom value and the expected Rx RSSI on the allocated channel.

Figure 4 shows a timing diagram of a coordinated beamforming sounding procedure between an AP, a BSS (i.e. an associated) non-AP station and a OBSS non-AP station illustrating an issue addressed by embodiments disclosed herein. In the example shown in figure 4, the AP transmits a NDPA 401, a Sounding NDP 403 and then a beamforming report poll (BFRP) 405. As will be appreciated, in the example shown in figure 4 these frames are special frames that allow triggering both BSS and OBSS STAs. Thus, the AP triggers BSS and OBSS STAs to transmit a respective beamforming report (BFR) 407, 409 within the same UL PPDU. Although BSS STA may transmit with high MCS (due to previous knowledge of the link parameters for the associated STA), the duration of the TB PPDU containing the BFR is actually defined by OBSS STA link parameters, which results in a long duration sounding procedure that is rather inefficient.

To address at least some of the issues described above embodiments described in the following in more detail enable an AP, such as the sharing AP 110 indicated in figure 1, to obtain power headroom values from OBSS stations, such as the OBSS station 140a illustrated in figure 1. According to embodiments described in the following in more detail, the power headroom value may be obtained for all usable MCSs. Moreover, according to embodiments described in the following in more detail, the power headroom value(s) may be always reported per AP request (regardless of reported UPH A-Control availability).

Embodiments disclosed herein provide a power control information procedure or protocol that allows an AP, such as the sharing AP 110 or the shared AP 130 illustrated in figure 1, to request power control information from a specific OBSS station, such as an OBSS station of a further shared AP not shown in figure 1 or one of the stations 120a-c associated with the sharing AP 110 (which is an OBSS station for the shared AP 130). According to embodiments disclosed herein the OBSS station that is solicited to transmit power control information, such as the OBSS station 120a illustrated in figure 1, may reply with power control information for all the MCSs with respect to a specific target RSSI indicated by the soliciting AP in the request. In the following embodiments will be described with the OBSS station being one of the stations 120a-c associated with the sharing AP 110 (which is an OBSS station for the shared AP 130) with the understanding that the OBSS station may also be a station associated with a further AP within the M-AP set.

Figure 5 shows a timing diagram illustrating aspects of a power control information protocol implemented by the sharing AP 110, the shared AP 130 and the exemplary OBSS non-AP station 120a according to an embodiment. In a first stage illustrated in figure 5 the shared AP 130 is triggered by the sharing AP 110 to transmit a power control information request frame 503 to the exemplary OBSS station 120a. In an embodiment, as illustrated in figure 5, the sharing AP 110 may use a special M-AP trigger frame 501 to solicit the shared AP 130 to invoke the power control information protocol. In a second stage the power control information request frame 503 may be transmitted by the shared AP 130 to the exemplary OBSS station 120a. In a third stage the exemplary OBSS station 120a may transmit in response to the soliciting request 503 a power control information report frame 505 to the soliciting AP, i.e. the shared AP 130. As will be appreciated, although in figure 5 for the sake of clarity it is only illustrated with a single OBSS station, the power control information protocol implemented by sharing APs and shared APs according to embodiments disclosed herein may involve multiple OBSS stations associated with different APs.

More specifically, the sharing AP 110 is configured to share at least a portion of a transmission opportunity, TXOP, with the at least one shared AP 130 within a M-AP set for participating in a coordinated transmission, wherein, as already described above, the non-AP station 140a is associated with the shared AP 130. The processing circuitry 111 of the sharing AP 110 is configured to generate a trigger frame (such as the power control information request frame 503 illustrated in figure 5) and the communication interface 113 is configured to transmit the trigger frame to the OBSS non-AP station 140a for soliciting the OBSS non-AP station 140a to transmit the power control report frame 505 back to the sharing AP 110. Thus, the communication interface 113 is further configured to receive, in response to transmitting the trigger frame, the power control report frame 505 from the OBSS non-AP station 140a. The power control report frame comprises power control information corresponding to the OBSS non-AP station 140a for adjusting the transmission power of the OBSS non-AP station 140a by the sharing AP 110. In an embodiment, the power control information contained in the power control report frame 505 may comprise a respective power headroom value for each of a plurality of modulation and coding schemes, MCSs, that may be used by the OBSS non-AP station 140a.

Complementary to the sharing AP 110, the shared AP 130 is configured to participate in a coordinated transmission making use of at least a portion of a TXOP shared by the sharing AP 110 within the M-AP set. The communication interface 133 of the shared AP 130 is configured to receive a M-AP trigger frame (such as the frame 501 illustrated in figure 5) from the sharing AP 110 to invoke the power control information procedure with the exemplary OBSS non-AP station 120a. The communication interface 133 is further configured to transmit, in response to receiving the M-AP trigger frame 501 from the sharing AP 110, a further trigger frame, in particular the power control information request frame 503 illustrated in figure 5 to the exemplary OBSS non-AP station 120a (which is one of one or more OBSS APs under the same coordination agreement within the M-AP set) for soliciting the exemplary OBSS non-AP station 120a to transmit the power control report frame 505 to the shared AP 130. As already described above, the power control report frame 505 comprises power control information corresponding to the exemplary OBSS non-AP station 120a for adjusting the transmission power of the OBSS non-AP station 120a by its soliciting (OBSS) AP, namely the shared AP 130. In an embodiment, the power control information contained in the power control report frame 505 may comprise a respective power headroom value for each of a plurality of modulation and coding schemes, MCSs, that may be used by the exemplary OBSS non-AP station 120a.

Complementary to the sharing AP 110 and the shared AP 130, the communication interface 143 of the OBSS station 140a is configured to receive a trigger frame, in particular the power control report request frame 503 from the sharing AP 110 or any other shared AP within the same M-AP Set but the shared AP 130. The processing circuitry 141 is configured to generate, in response to receiving the trigger frame 503, the power control report frame 505, wherein, as already described above, the power control report frame 505 comprises the power control information associated with the non-AP station 140a. The communication interface 143 of the non-AP station 140a is further configured to transmit the power control report frame 505 to the soliciting AP, which may be either the sharing AP 110 or any other shared AP within the same M-AP Set but the shared AP 130.

In the following further embodiments of the sharing AP 110, the shared AP 130 and the exemplary OBSS non-AP station 140a will be described in more detail.

According to embodiments disclosed herein, the sharing AP 110 may solicit the power control information procedure/protocol by at least two options. According to a first option, the power control information procedure/protocol may be implemented as a part of another sequential pre-coordinated transmission procedure, such as the CoBF sounding procedure. In this case, the sharing AP 110 may use a trigger frame variant that may be designed for a specific coordination procedure and a dedicated indication 601 may be added in a trigger dependent common info field of the trigger frame 501 illustrated in figure 6. According to a second option the sharing AP 110 may use a dedicated trigger frame 501 for soliciting the power control information procedure/protocol. In both options the trigger frame variant 501 may include: a M-AP set identifier, a coordination agreement identifier, a shared AP 130 identifier (i.e. an identifier of the AP 130 that is solicited to transmit the power control information request frame 503), and/or a list of unique station identifiers within the M-AP set indicating the OBSS stations 120a, 120b , 120c that the solicited AP 130 should request power control information from. As will be appreciated, the trigger frame variant 501 usually will include the shared AP identifier, if the trigger frame variant 501 is initiated by the sharing AP 110 for any of the shared APs to initiate a sequential procedure of CoBF sounding or Power control information.

As already described above, according to embodiments disclosed herein, the sharing AP 110 may be configured to solicit the power control information procedure/protocol as a part of another coordination procedure/protocol. In the embodiments described in the following the other coordination procedure/protocol is, by way of example, the CoBF sounding

procedure. It will be appreciated, however, that the power control information procedure/protocol disclosed herein may be implemented as a part of other coordination procedures/protocols as well.

Figure 7 shows a timing diagram illustrating aspects of the power control information protocol implemented by the sharing AP 110, the shared AP 130 and the exemplary OBSS non-AP station 120a according to an embodiment as part of a coordinated beamforming sounding protocol. As illustrated in figure 7, in this case, the sharing AP 110 may indicate that the power control information frame is requested within the trigger frame 501 that solicits the CoBF sounding procedure, namely the CoBF sounding trigger frame 501. In response to the trigger frame 501 the shared AP 130 may transmit a OBSS NDPA 502a, a Sounding NDP 502b and a OBSS beamforming report poll frame 503 including the request for the power control information from the exemplary OBSS non-AP station 120a. This power control information may be provided by the exemplary OBSS non-AP station 120a as part of the response PPDU (which will include both BFR frame and Power Control Report frame) 505. As will be appreciated, in the sequence invoked by the shared AP 130 according to an embodiment for OBSS STAs, such as the exemplary OBSS STA 120a, a special type of NDPA and BFRP frames may be used (referred to herein an OBSS NDPA, OBSS BFRP), which may include additional parameters such as the M-AP Set identifier, the coordination agreement identifier, and/or a unique identifier for the OBSS STAs within the M-AP set.

Similar to the embodiment shown in figure 6, in an embodiment, the shared AP 130 may indicate in the trigger frame 503 that the power control Report Poll is requested. As illustrated in figure 8, such an indication 801 may be provided in the trigger dependent common info field of the BFRP frame 503. In this case, the BFRP frame 503 may include the M-AP set identifier and the coordination agreement identifier. In an embodiment, the solicited OBSS station 120a aggregates the requested power control Report frame with the BFR frame 505 (within a single PPDU).

In order to achieve a higher efficiency for the transmission of the response PPDU 505 from the OBSS STA 120a (including the power control report frame) according to embodiments disclosed herein the response PPDU 505 may sent in several fragments or portions 505a,b as illustrated in figure 9. In an embodiment, each portion 505a,b may have a size indicated by the soliciting AP, i.e. the shared AP 130. As illustrated in figure 9, the shared AP 130 may request first a short response PPDU portion 505a including the power control report

frame (or part of thereof) and then subsequent further response PPDU portions 505b (with further parts of the power control information report frame and/or BFR frame).

In an embodiment, the shared AP 130 may be configured to repeat the request for power control information from the same exemplary OBSS station 120a at least once in order to improve the power adjustment. In this case, the sharing AP 130 may request several response PPDU fragments or portions with the BFRP frame 503a including the request for power control report frame. In order to inform the solicited OBSS station 120a which BFR portions are requested by the current BFRP frame 503a according to an embodiment a bitmap 1001 of N bits may be added to the BFRP frame 503a, wherein each bit of the bitmap indicates a specific response PPDU portion 505a,b among N BFR portions, such as, for instance, 8 BFR portions. As illustrated in figure 10, this bitmap 1001 may be added to the trigger dependent common info field of the BFRP frame 503a or 503b.

As already described above, according to embodiments disclosed herein the power control information protocol may be implemented as a stand-alone protocol and not as part of another sequential pre-coordinated transmission procedure, such as the CoBF sounding procedure for the embodiments described above. For such a stand-alone implementation, the sharing AP 110 and/or the shared AP 130 may be configured to generate and transmit a trigger frame variant referred to as power control report poll frame 503 herein and illustrated in figure 11. In this case it may be transmitted by either the sharing AP 110 or the shared AP 130 that is solicited to perform the power control information protocol by the sharing AP 110 using the dedicated trigger frame 501 (which is herein also referred to as M-AP trigger frame 501). In an embodiment, the power control report poll frame 503 may include a M-AP set identifier, a coordination agreement identifier, a list of unique station identifiers within the M-AP set (indicating the OBSS stations that are solicited to transmit the power control report frame 505), and/or transmission parameters per stations, such as allocated RU, MCS, NSS, target RSSI.

As already described above, according to embodiments disclosed herein, upon receiving the power control report poll frame 503, the exemplary OBSS station 120a is configured to reply with the power control report frame 505, which may include a M-AP set identifier, a coordination agreement identifier, and/or additional Information, such as the number of spatial streams that the exemplary OBSS station 120a can decode. As illustrated in figure 12, the power control report frame 505 may further comprise uplink headroom control fields

1201-0 ... 1201-N including the headroom values for all the MCS, from MCS0 to MCSN (highest MCS index that can be used by the OBSS STA).

Figure 13 shows a further embodiment, where the power control report frame 505 may be transmitted in a TB PPDU format, where several OBSS stations transmit in parallel using OFDMA or/and MU-MIMO methods.

Figure 14 is a flow diagram illustrating a method 1400 for operating a sharing AP (such as the sharing AP 110 of figure 1). The method 1400 comprises a step 1401 of generating an OBSS trigger frame for polling power control information from the OBSS non-AP station 140a. Moreover, the method 1400 comprises a step 1403 of transmitting the trigger frame to the OBSS non-AP station 140a (provided that the trigger frame is invoked by the sharing AP 110). The method 1400 further comprises a step 1405 of receiving, in response to transmitting the OBSS trigger frame for polling the power control information, a power control report frame 505 from the OBSS non-AP station 140a, wherein the power control report frame 505 comprises power control information corresponding to the OBSS non-AP station 140a for adjusting the transmission power of the OBSS non-AP station 140a by the soliciting AP, i.e. the sharing AP 110.

Figure 15 is a flow diagram illustrating a method 1500 for operating a shared AP (such as the shared AP 130 of figure 1) configured to participate in a coordinated transmission making use of at least a portion of a TXOP shared by a sharing AP (such as the sharing AP 110 of figure 1) within a M-AP set, wherein the shared AP 130 requests the Power Information from one or more its OBSS STAs (such as the exemplary OBSS station 120a of figure 1). The method 1500 comprises a step 1501 of receiving a M-AP trigger frame 501 from the sharing AP 110 to invoke a power control information procedure with the at least one exemplary OBSS non-AP station 120a. Moreover, the method 1500 comprises a step 1503 of transmitting, in response to receiving the M-AP trigger frame 501 from the sharing AP 110, a further OBSS trigger frame, in particular a power control information request frame 503 to the at least one exemplary OBSS non-AP station 120a for soliciting the at least one exemplary OBSS non-AP station 120a to transmit a power control report frame 505 to the shared AP 130, wherein the power control report frame comprises power control information corresponding to the at least one exemplary OBSS non-AP station 120a for adjusting the transmission power of the at least one exemplary OBSS non-AP station 120a by the shared AP 130.

Figure 16 is a flow diagram illustrating a method 1600 for operating a non-AP station (such as the exemplary OBSS station 120a of figure 1). The method 1600 comprises a step 1601 of receiving a power control report request frame 503 from the sharing AP 110 or an OBSS trigger frame 503, in particular a power control report request frame from the shared AP 130 within the M-AP set. Moreover, the method 1600 comprises a step 1603 of generating, in response to receiving the trigger frame, 503, a power control report frame 505, wherein the power control report frame 505 comprises power control information corresponding to the non-AP station 120a. The method 1600 further comprises a step 1605 of transmitting the power control report frame 505 to the soliciting AP, which may be either the sharing AP 110 or the shared AP 130.

Embodiments disclosed herein allow an AP to select an optimal MCS and/or target RSSI for OBSS stations. Moreover, an AP can ensure an accurate power alignment for UL MU/MU-MIMO PPDUs (for example when BSS and OBSS are triggered to transmit within the same TB PPDU). The UL PPDU may reduce overhead of transmissions by OBSS stations.

The person skilled in the art will understand that the "blocks" ("units") of the various figures (method and apparatus) represent or describe functionalities of embodiments of the present disclosure (rather than necessarily individual "units" in hardware or software) and thus describe equally functions or features of apparatus embodiments as well as method embodiments (unit = step).

In the several embodiments provided in the present application, it should be understood that the disclosed system, apparatus, and method may be implemented in other manners. For example, the described embodiment of an apparatus is merely exemplary. For example, the unit division is merely logical function division and may be another division in an actual implementation. For example, a plurality of units or components may be combined or integrated into another system, or some features may be ignored or not performed. In addition, the displayed or discussed mutual couplings or direct couplings or communication connections may be implemented by using some interfaces. The indirect couplings or communication connections between the apparatuses or units may be implemented in electronic, mechanical, or other forms.

The units described as separate parts may or may not be physically separate, and parts displayed as units may or may not be physical units, may be located in one position, or may

be distributed on a plurality of network units. Some or all of the units may be selected according to actual needs to achieve the objectives of the solutions of the embodiments.

In addition, functional units in the embodiments disclosed herein may be integrated into one processing unit, or each of the units may exist alone physically, or two or more units are integrated into one unit.

CLAIMS

1. A sharing access point, AP, (110) configured to share at least a portion of a transmission opportunity, TXOP, with at least one shared AP (130) within a Multi-AP, M-AP, set for participating in a coordinated transmission, wherein at least one OBSS non-AP station (120a-c) related to the shared AP (130) is associated with the sharing AP (110) and at least one OBSS non-AP station (140a-b) related to the sharing AP (110) is associated with the shared AP (130), wherein the sharing AP (110) comprises:

a processing circuitry (111) configured to generate a trigger frame; and

a communication interface (113) configured to transmit the trigger frame to the at least one OBSS non-AP station (140a,b) for triggering a power control report frame (505) from the at least one OBSS non-AP station (140a,b),

wherein the communication interface (113) is further configured to receive the power control report frame (505) from the at least one OBSS non-AP station (140a,b), wherein the power control report frame (505) comprises power control information associated with the at least one OBSS non-AP station (140a,b).

2. The sharing AP (110) of claim 1, wherein the communication interface (113) is configured to receive an uplink physical protocol data unit, PPDU, (505) from the at least one OBSS non-AP station (140a,b) and wherein the power control information comprises a power headroom value for each of a plurality of modulation and coding schemes, MCSs.

3. The sharing AP (110) of any one of the preceding claims, wherein the trigger frame comprises a M-AP set identifier indicative of the M-AP set.

4. The sharing AP (110) of any one of the preceding claims, wherein the trigger frame comprises a coordination agreement identifier within the M-AP set, wherein the coordination agreement identifier identifies one coordination agreement of a plurality of coordination agreements within the M-AP set and wherein the sharing AP (110) and the shared AP (130) both operate under the coordination agreement identified by the coordination agreement identifier within the M-AP set.

5. The sharing AP (110) of any one of the preceding claims, wherein the trigger frame comprises information for identifying the at least one OBSS non-AP station (140a,b) within the M-AP set.

6. The sharing AP (110) of any one of the preceding claims, wherein the trigger frame further comprises at least, an allocated resource unit, RU, a target received signal strength indicator, RSSI, and/or a target modulation and coding scheme, MCS, to be used by the at least one OBSS non-AP station (140a,b) in an upcoming uplink transmission from the at least one OBSS non-AP station (140a,b) to the sharing AP (110).

7. The sharing AP (110) of any one of the preceding claims, wherein the trigger frame is a beamforming report poll trigger frame for OBSS non-AP STAs within the M-AP set which includes an additional indication for triggering the at least one OBSS non-AP STA (140a,b) to send both a coordinated beamforming sounding report and a power control information report.

8. The sharing AP (110) of any one of the preceding claims, wherein the communication interface (113) is further configured to transmit a M-AP trigger frame (501) to the shared AP (130) for triggering the shared AP (130) to transmit a further trigger frame (503) to at least one further OBSS non-AP station (120a-c) for triggering the at least one further OBSS non-AP station (120a-c) to transmit the power control report frame (505).

9. The sharing AP (110) of claim 8, wherein the M-AP trigger frame (501) comprises an identifier of the shared AP (130).

10. The sharing AP (110) of claim 8 or 9, wherein the M-AP trigger frame (501) comprises a M-AP set identifier indicative of the M-AP set.

11. The sharing AP (110) of any one of claims 8 to 10, wherein the M-AP trigger frame (501) comprises a coordination agreement identifier within the M-AP set, wherein the coordination agreement identifier identifies one coordination agreement of a plurality of coordination agreements within the M-AP set and wherein the sharing AP (110) and the shared AP (130) both operate under the coordination agreement identified by the coordination agreement identifier within the M-AP set.

12. The sharing AP (110) of any one of claims 8 to 11, wherein the M-AP trigger frame (501) comprises an indication configured to trigger the shared AP (130) to invoke the power control information procedure with the at least one further OBSS non-AP station (120a-c) associated with OBSS APs under the same coordination agreement within the M-AP set.

13. The sharing AP (110) of any one of claims 8 to 12, wherein the communication interface (113) is further configured, to receive from the shared AP (130) a power control report complete frame for informing the sharing AP (110) that the shared AP (130) has received the power control report frame (505) from the at least one further OBSS non-AP station (120a-c) and completed its stage in the sequential procedure.

14. The sharing AP (110) of any one of claims 8 to 13, wherein the M-AP trigger frame (501) further comprises an indication for triggering the shared AP (130) to initiate a sequential sounding procedure and to invoke the power control information procedure with the at least one further OBSS non-AP station (120a-c) under the same coordination agreement within the M-AP set.

15. The sharing AP (110) of claim 14, wherein the indication of the M-AP trigger frame (501) for triggering the shared AP (130) to initiate the sequential sounding procedure comprises an indication for triggering the shared AP (130) to transmit a beamforming report poll (503, 503a,b) to the at least one further OBSS non-AP station (120a-c) associated with OBSS AP (110) under the same coordination agreement within the M-AP set, wherein the beamforming report poll (503, 503a,b) comprises information configured to trigger the at least one further OBSS non-AP station (120a-c) to provide one or more portions (505a,b) of a beamforming report and the power control information.

16. The sharing AP (110) of claim 15, wherein the beamforming report poll (503, 503a,b) comprises information configured to trigger the at least one further OBSS non-AP station (120a-c) to transmit one or more beamforming report portions (505a,b) that were already transmitted and/or one or more beamforming report portions (505a,b) which have not been transmitted yet.

17. The sharing AP (110) of claim 15, wherein the information configured to trigger the at least one further OBSS non-AP station (120a-c) to transmit the one or more beamforming report portions (505a,b) not transmitted yet and/or the one or more beamforming report portions (505a,b) already transmitted comprises an indication (1010) for identifying the one

or more beamforming report portions (505a,b) not transmitted yet and/or the one or more beamforming report portions (505a,b) already transmitted.

18. The sharing AP (110) of claim 16 or 17, wherein the one or more already transmitted beamforming report portions (505a,b) comprise the most recent transmitted beamforming report portion.

19. A method (1400) for operating a sharing access point, AP, (110) configured to share at least a portion of a transmission opportunity, TXOP, with at least one shared AP (130) within a Multi-AP, M-AP, set for participating in a coordinated transmission, wherein at least one OBSS non-AP station (140a,b) is associated with the shared AP (130), wherein the method (1400) comprises:

generating (1401) a trigger frame for polling power control information from the at least one OBSS non-AP station (140a,b);

transmitting (1403) the trigger frame to the at least one OBSS non-AP station (140a,b); and

receiving (1405) a power control report frame (505) from the at least one OBSS non-AP station (140a,b), wherein the power control report frame (505) comprises power control information associated with the at least one OBSS non-AP station (140a,b).

20. A shared access point, AP, (130) configured to participate in one or more coordinated transmissions making use of at least a portion of a transmission opportunity, TXOP, shared by a sharing AP (110) under the same coordination agreement within a Multi-AP, M-AP, set, wherein the shared AP (130) comprises:

a communication interface (131) configured to receive a M-AP trigger frame (501) from the sharing AP (110),

wherein the communication interface (131) is configured to transmit, in response to receiving the M-AP trigger frame (501) from the sharing AP (110), a power control information request frame (503) to at least one OBSS non-AP station (120a-c) for triggering the at least one OBSS non-AP station (120a-c) to transmit a power control report frame (505) to the shared AP (130), wherein the power control report frame (505) comprises power control information associated with the at least one OBSS non-AP station (120a-c).

21. The shared AP (130) of claim 20, wherein, in response to receiving the power control report frame (505) from the at last one OBSS non-AP station (120a-c), the communication interface (133) is further configured to transmit a power control report complete frame to the sharing AP (110).

22. The shared AP (130) of claim 20 or 21, wherein the power control information request frame (503) comprises a M-AP set identifier indicative of the M-AP set.

23. The shared AP (130) of any one of claims 20 to 22, wherein the power control information request frame (503) comprises a coordination agreement identifier within the M-AP set, wherein the coordination agreement identifier identifies one coordination agreement of a plurality of coordination agreements within the M-AP set and wherein the sharing AP (110) and the shared AP (130) both operate under the coordination agreement identified by the coordination agreement identifier within the M-AP set.

24. The shared AP (130) of any one of claims 20 to 23, wherein the power control information request frame (503) comprises information for identifying the at least one OBSS non-AP station (120a-c) within the M-AP set.

25. The shared AP (130) of any one of claims 20 to 24, wherein the power control information request frame (503) further comprises at least an allocated resource unit, RU, a target received signal strength indicator, RSSI, and/or a target modulation and coding scheme, MCS, to be used by the at least one OBSS non-AP station (120a-c) in an upcoming uplink transmission from the at least one OBSS non-AP station (120a-c) to the shared AP (130).

26. The shared AP (130) of any one of claims 20 to 25, wherein the power control information comprises a power headroom value for the at least one OBSS non-AP station (120a-c) for each of a plurality of modulation and coding schemes, MCSs.

27. The shared AP (130) of any one of claims 19 to 26, wherein the received M-AP trigger frame (501) is a EHT sequential sounding trigger frame (501) for further triggering the shared AP (130) to invoke an EHT sequential sounding procedure and to invoke the power control information procedure with the at least one OBSS non-AP station (120a-c).

28. The shared AP (130) of any one of claims 19 to 27, wherein the M-AP trigger frame (501) comprises an indication configured to trigger the shared AP (130) to invoke the power control information procedure with the at least one OBSS non-AP station (120a-c).

29. The shared AP (130) of claim 27, wherein as part of the EHT sequential sounding procedure the communication interface (133) is configured to transmit a beamforming report poll (503, 503a,b) to the at least one OBSS non-AP station (120a-c) and wherein the beamforming report poll (503, 503a,b) comprises information configured to trigger the at least one OBSS non-AP station (120a-c) to provide one or more portions (505a,b) of a beamforming report and the power control information.

30. The shared AP (130) of claim 29, wherein the beamforming report poll (503, 503a,b) comprises information configured to trigger the at least one OBSS non-AP station (120a-c) to transmit one or more beamforming report portions (505a,b) that were already transmitted and/or one or more beamforming report portions (505a,b) which have not been transmitted yet.

31. The shared AP (130) of claim 30, wherein the information configured to trigger the at least one OBSS non-AP station (120a-c) to transmit the one or more beamforming report portions (505a,b) not transmitted yet and/or the one or more beamforming report portions (505a,b) already transmitted comprises an indication (1001) for identifying the one or more beamforming report portions (505a,b) not transmitted yet and/or the one or more beamforming report portions (505a,b) already transmitted.

32. The shared AP (130) of claim 30 or 31, wherein the one or more already transmitted beamforming report portions (505a,b) comprise the most recent transmitted beamforming report portion.

33. A method (1500) for operating a shared access point, AP, (130) configured to participate in one or more coordinated transmissions making use of at least a portion of a transmission opportunity, TXOP, shared by a sharing AP (110) within a Multi-AP, M-AP, set, wherein the method (1500) comprises:

receiving (1501) a M-AP trigger frame (501) from the sharing AP (110) to invoke a power control information procedure with at least one OBSS non-AP station (120a-c); and

transmitting (1503), in response to receiving the M-AP trigger frame (501) from the sharing AP (110), a power control information request frame (503) to the at least one OBSS non-AP station (120a-c) soliciting the at least one OBSS non-AP station (120a-c) to respond with a power control report frame (505), wherein the power control report frame (505) comprises power control information associated with the at least one OBSS non-AP station (120a-c).

34. A non-AP station (140a-c) associated with an AP (130) within a Multi-AP, M-AP, set, wherein the associated AP (130) is configured to participate in a coordinated transmission making use of at least a portion of a transmission opportunity, TXOP, shared by a sharing AP (110) within the M-AP set, wherein the non-AP station (140a-c) comprises:

a communication interface (143) configured to receive a power control report request frame (503) from a further OBSS shared AP within the M-AP set and operating under the same coordination agreement () or the sharing AP (110); and

a processing circuitry (141) configured to generate a power control report frame (505), wherein the power control report frame (505) comprises power control information associated with the non-AP station (140a-c),

wherein the communication interface (143) is further configured to transmit the power control report frame (505) to the soliciting AP (, 110).

35. The non-AP station (140a-c) of claim 34, wherein the power control information comprises a power headroom value of the non-AP station (140a-c) for each of a plurality of modulation and coding scheme, MCS, indexes.

36. The non-AP station (140a-c) of any one of claims 34 to 35, wherein the power control report frame (505) comprises a M-AP set identifier indicative of the M-AP set.

37. The non-AP station (140a-c) of any one of claims 34 to 36, wherein the power control report frame (505) comprises a coordination agreement identifier within the M-AP set, wherein the coordination agreement identifier identifies one coordination agreement of a plurality of coordination agreements within the M-AP set and wherein the sharing AP (110) and the shared AP (130) both operate under the coordination agreement identified by the coordination agreement identifier within the M-AP set.

38. The non-AP station (140a-c) of any one of claims 34 to 37, wherein the power control request frame (503) comprises information for identifying the non-AP station (140a-c) within the M-AP set.

39. The non-AP station (140a-c) of any one of claims 34 to 38, wherein the power control request frame (503) further comprises at least an allocated resource unit, RU, a target received signal strength indicator, RSSI, and/or a target modulation and coding scheme, MCS, to be used by the non-AP station (140a-c) in an upcoming uplink transmission to the soliciting AP (110).

40. The non-AP station (140a-c) of any one of claims 34 to 39, wherein the power control request frame (503) comprises an identifier of the soliciting AP (110) within the M-AP set.

41. The non-AP station (140a-c) of any one of claims 34 to 40, wherein the communication interface (143) is configured to transmit the power control report frame (505) to the soliciting AP (110) as a trigger based physical protocol data unit, PPDU, using an OFDMA and/or MU-MIMO scheme.

42. The non-AP station (140a-c) of any one of claims 34 to 41, wherein the power control request is part of a beamforming report poll frame (503), which includes an indication to transmit the power control information report frame (505).

43. The non-AP station (140a-c) of claim 41, wherein the beamforming report poll frame (503, 503a,b) further comprises information configured to trigger the non-AP station (140a-c) to provide one or more portions (505a,b) of a beamforming report and the power control information.

44. The non-AP station (140a-c) of claim 43, wherein the beamforming report poll frame (503, 503a,b) comprises information configured to trigger the non-AP station (140a-c) to transmit one or more beamforming report portions (505a,b) that were already transmitted and/or one or more beamforming report portions (505a,b) which have not been transmitted yet.

45. The non-AP station (140a-c) of claim 44, wherein the information configured to trigger the non-AP station (140a-c) to transmit the one or more beamforming report portions (505a,b) not transmitted yet and/or the one or more beamforming report portions (505a,b)

already transmitted comprises an indication (1001) for identifying the one or more beamforming report portions (505a,b) not transmitted yet and/or the one or more beamforming report portions (505a,b) already transmitted.

46. The non-AP station (140a-c) of claim 44 or 45, wherein the information configured to trigger the non-AP station (140a-c) to transmit the one or more beamforming report portions (505a,b) comprises an indication for indicating whether the currently transmitted beamforming report portion (505a,b) is the last portion to transmit.

47. The non-AP station (140a-c) of any one of claims 44 to 46, wherein the one or more already transmitted beamforming report portions (505a,b) comprise the most recent transmitted beamforming report portion.

48. A method (1600) for operating a non-AP station (140a-c) associated with an AP (130) under a specific coordination agreement within a specific Multi-AP, M-AP set, wherein the associated AP (130) is configured to participate in a coordinated transmission making use of at least a portion of a transmission opportunity, TXOP, shared by a sharing AP (110) within the M-AP set, wherein the method (1600) comprises:

receiving (1601) a power control report request frame (503) from a further shared AP within the M-AP set and operating under the same coordination agreement () or the sharing AP (110);

generating (1603) a power control report frame (505), wherein the power control report frame (505) comprises power control information associated with the non-AP station (140a-c); and

transmitting (1605) the power control report frame (505) to the soliciting AP (110).

49. A computer program product comprising a computer-readable storage medium for storing program code which causes a computer or a processor to perform the method (1400) of claim 19, the method (1500) of claim 33 or the method (1600) of claim 48, when the program code is executed by the computer or the processor.

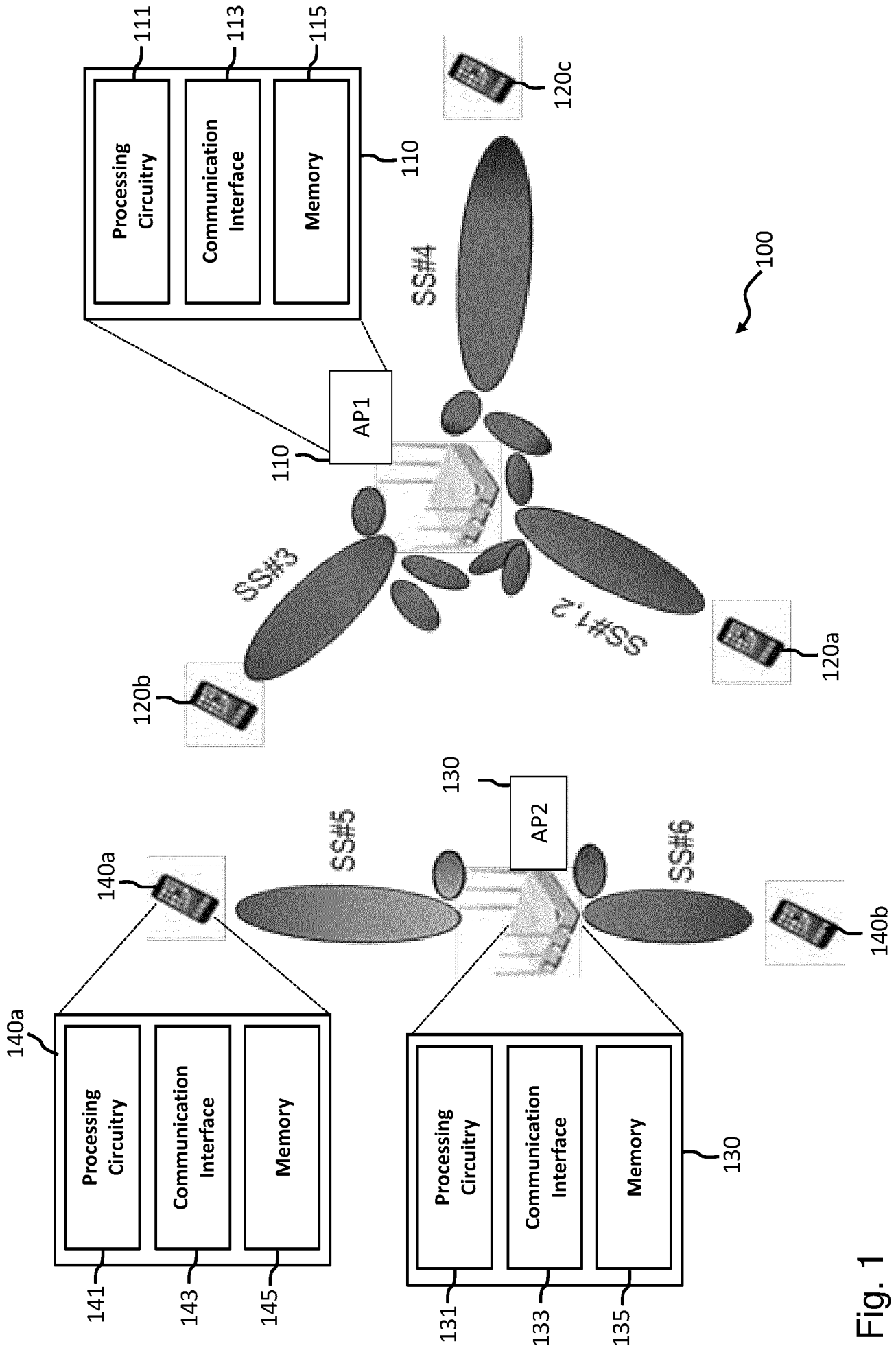
111
113
115
Processing Circuitry
Communication Interface
Memory
110
120c
100
SS#4
AP1
110
SS#3
SS#1,2
120b
120a
130
AP2
SS#5
SS#6
140a
140b
140a
Processing Circuitry
Communication Interface
Memory
141
143
145
130
Processing Circuitry
Communication Interface
Memory
131
133
135

Fig. 1

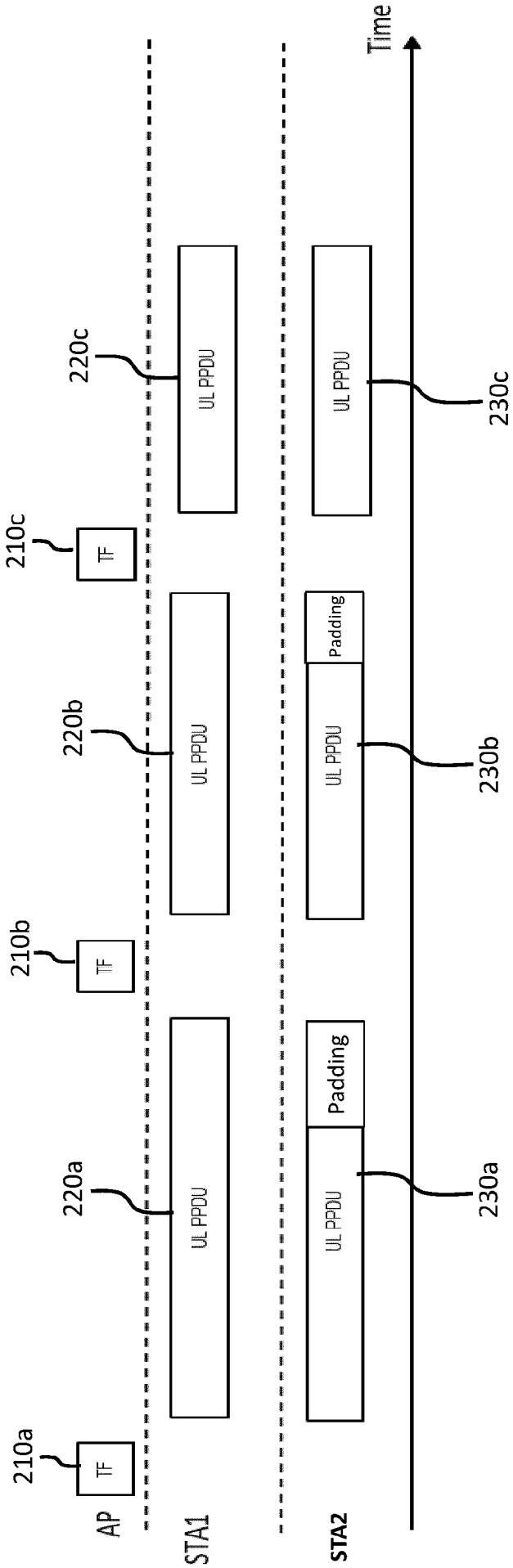
Time
AP
STA1
STA2
TF
UL PPDU
Padding
210a
210b
210c
220a
220b
220c
230a
230b
230c

Fig. 2

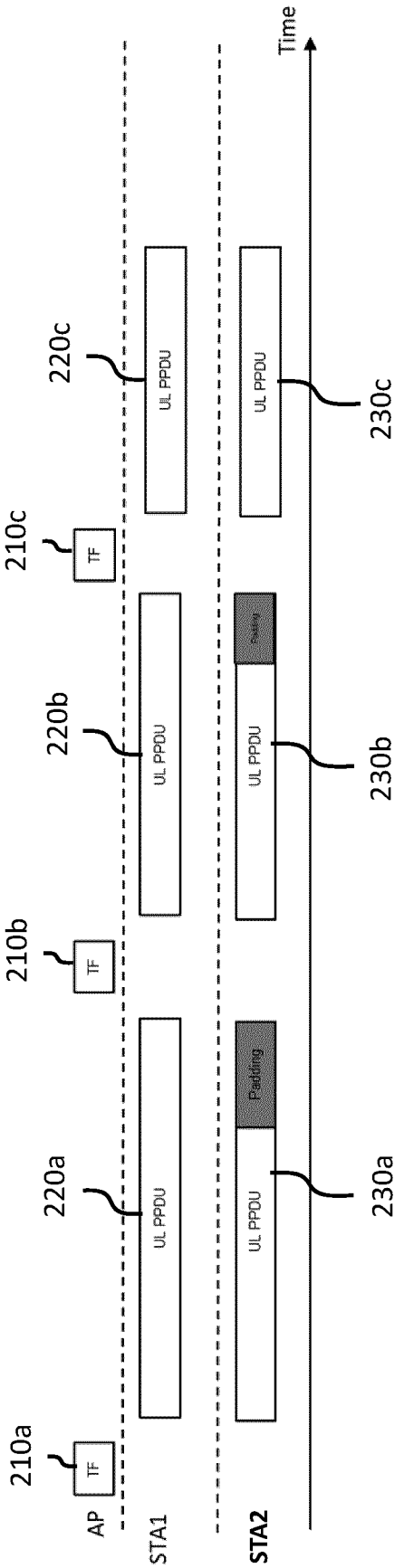
Time
AP
STA1
STA2
TF
UL PPDU
Padding
210a
210b
210c
220a
220b
220c
230a
230b
230c

Fig. 2

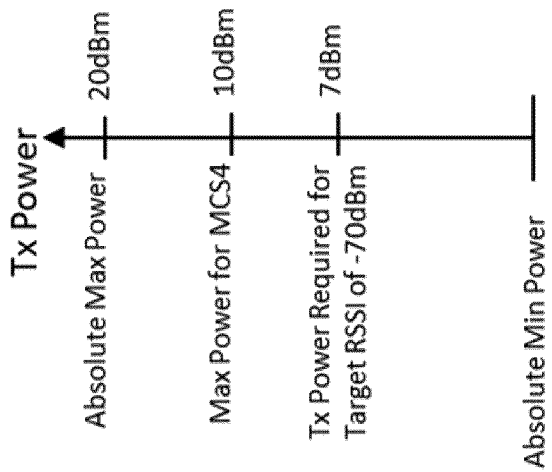
Tx Power
20dBm
Absolute Max Power
10dBm
Max Power for MCS4
7dBm
Tx Power Required for
Target RSSI of -70dBm
Absolute Min Power

Fig. 3

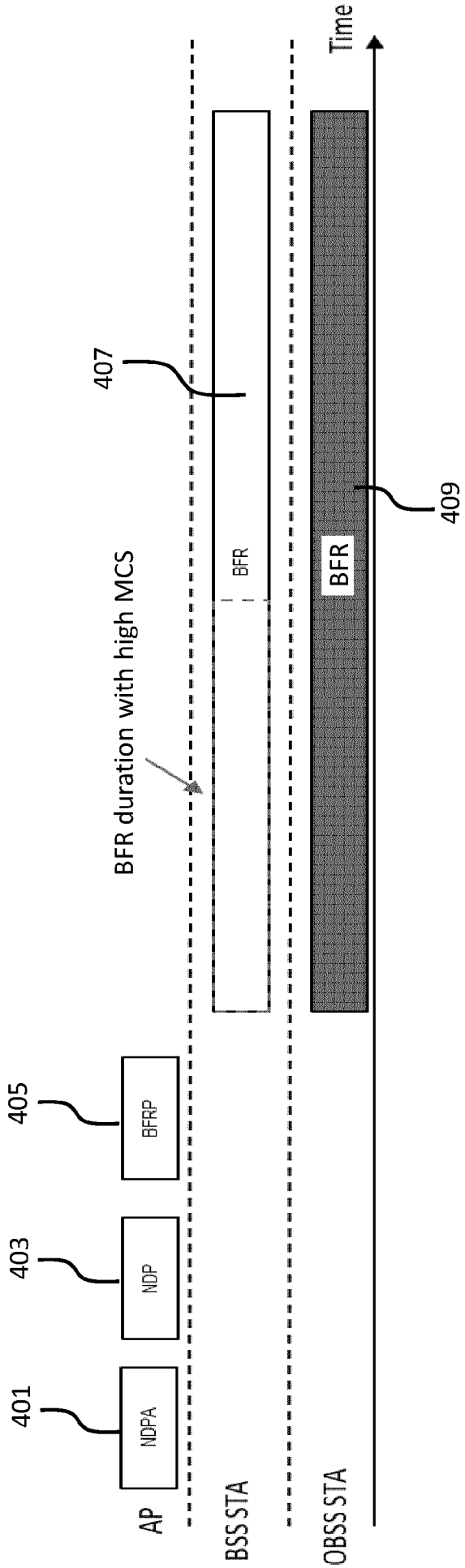
Time
AP
BSS STA
OBSS STA
NDPA
NDP
BFRP
BFR
BFR
401
403
405
407
409
BFR duration with high MCS

Fig. 4

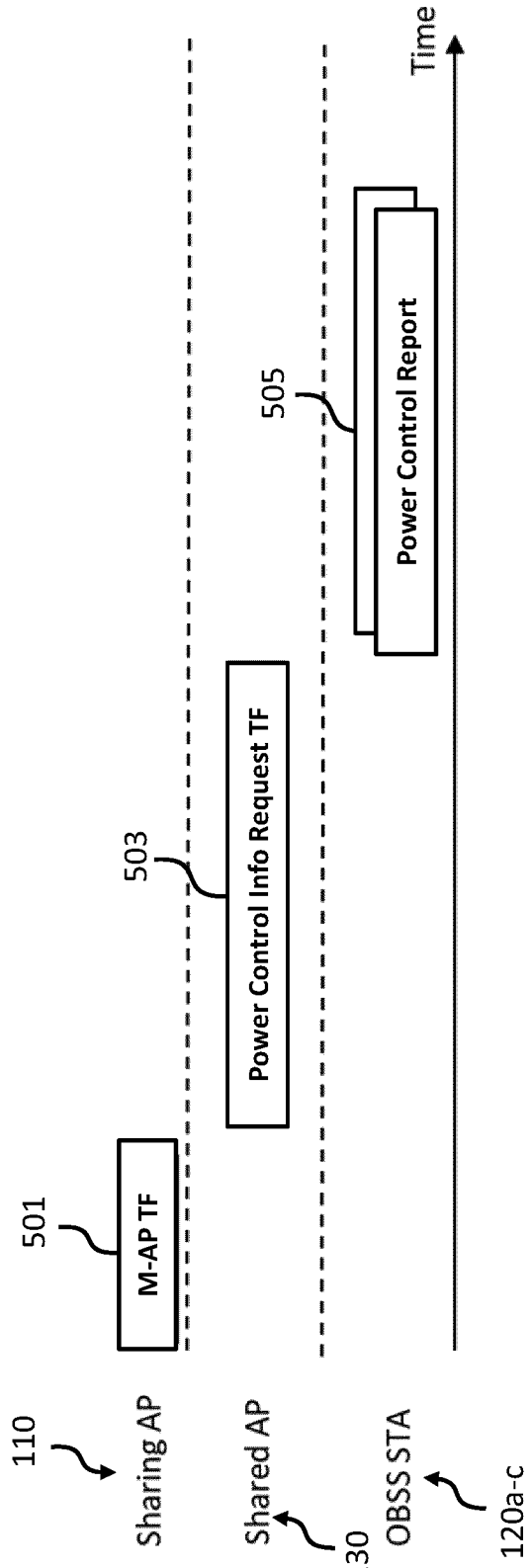
Time
501
M-AP TF
503
Power Control Info Request TF
505
Power Control Report
110
Sharing AP
Shared AP
130
OBSS STA
120a-c

Fig. 5

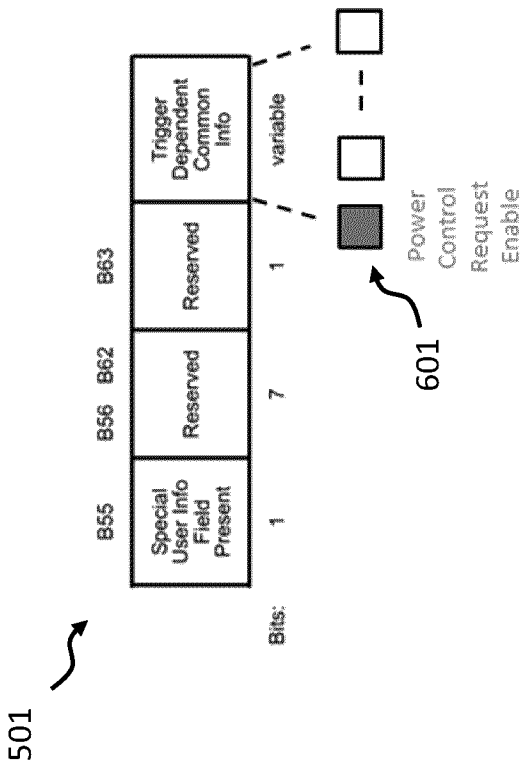
501
Bits:
B55
B56
B62
B63
Special User Info Field Present
Reserved
Reserved
Trigger Dependent Common Info
1
7
1
variable
601
Power Control Request Enable

Fig. 6

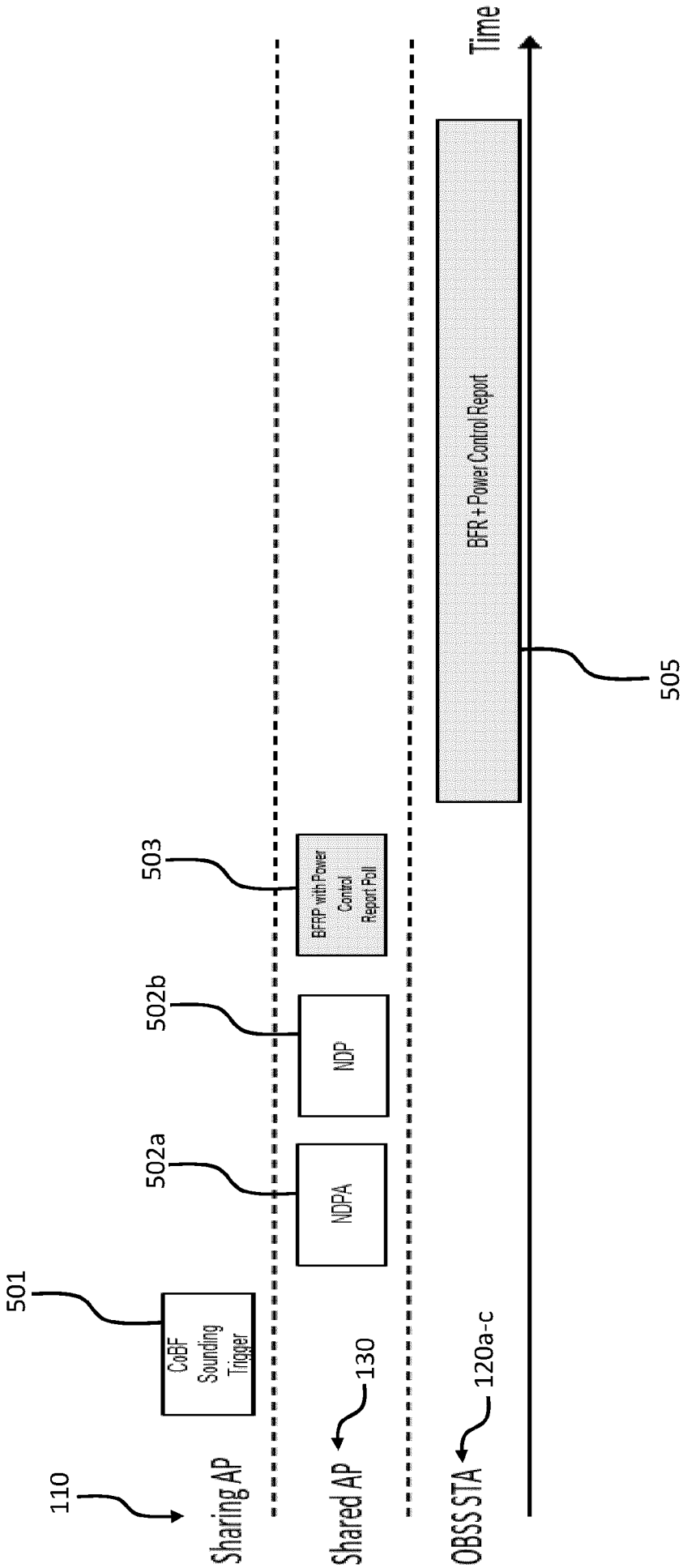
Time
BFR + Power Control Report
505
BFRP with Power Control Report Poll
503
NDP
502b
NDPA
502a
CoBF Sounding Trigger
501
110
Sharing AP
Shared AP
130
OBSS STA
120a-c

Fig. 7

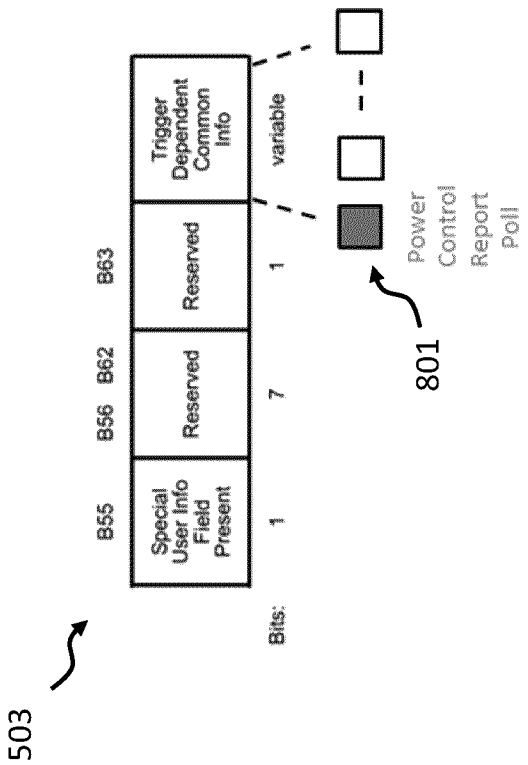
503
Bits:
B55
B56
B62
B63
Special User Info Field Present
Reserved
Reserved
Trigger Dependent Common Info
1
7
1
variable
801
Power Control Report Poll

Fig. 8

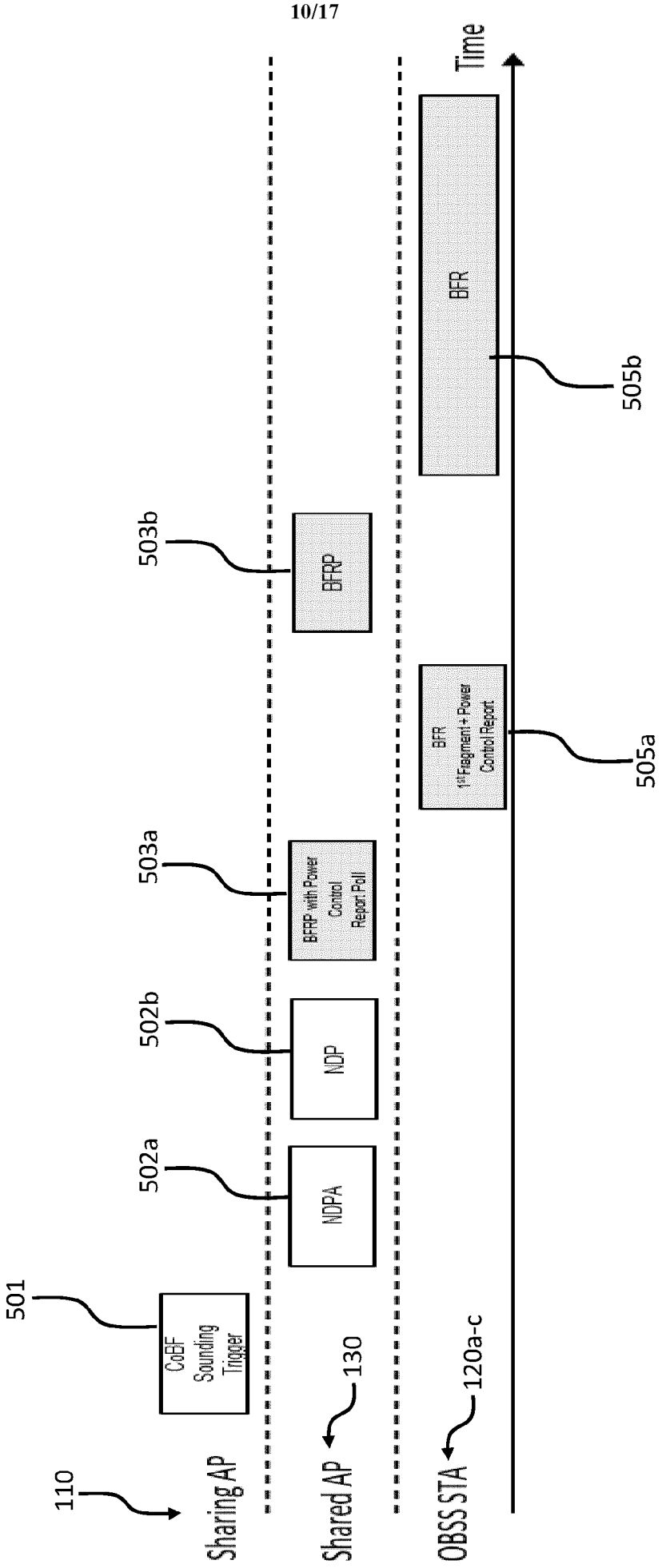
Time
BFR
505b
BFRP
503b
BFRP with Power Control Report Poll
503a
NDP
502b
NDPA
502a
CoBF Sounding Trigger
501
BFR 1st Fragment + Power Control Report
505a
Sharing AP
110
Shared AP
130
OBSS STA
120a-c

Fig. 9

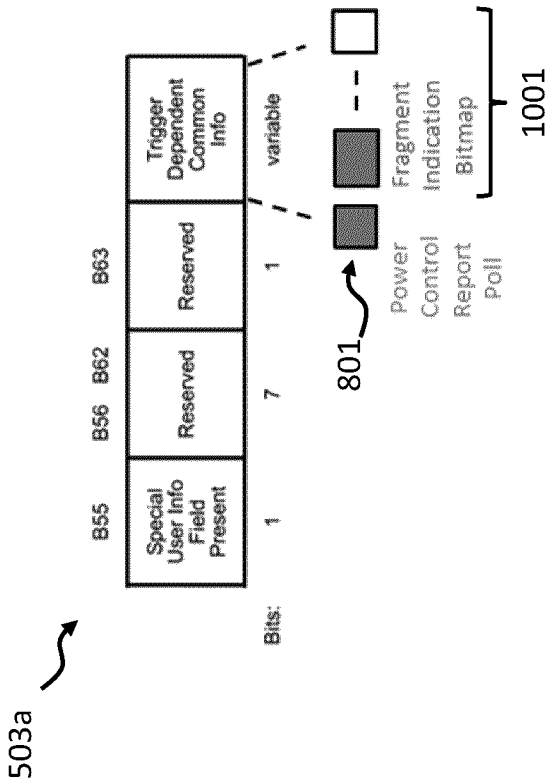
503a
Bits:
B55
B56
B62
B63
Special User Info Field Present
Reserved
Reserved
Reserved
Trigger Dependent Common Info
1
7
1
variable
801
Power Control Report Poll
Fragment Indication Bitmap
1001

Fig. 10

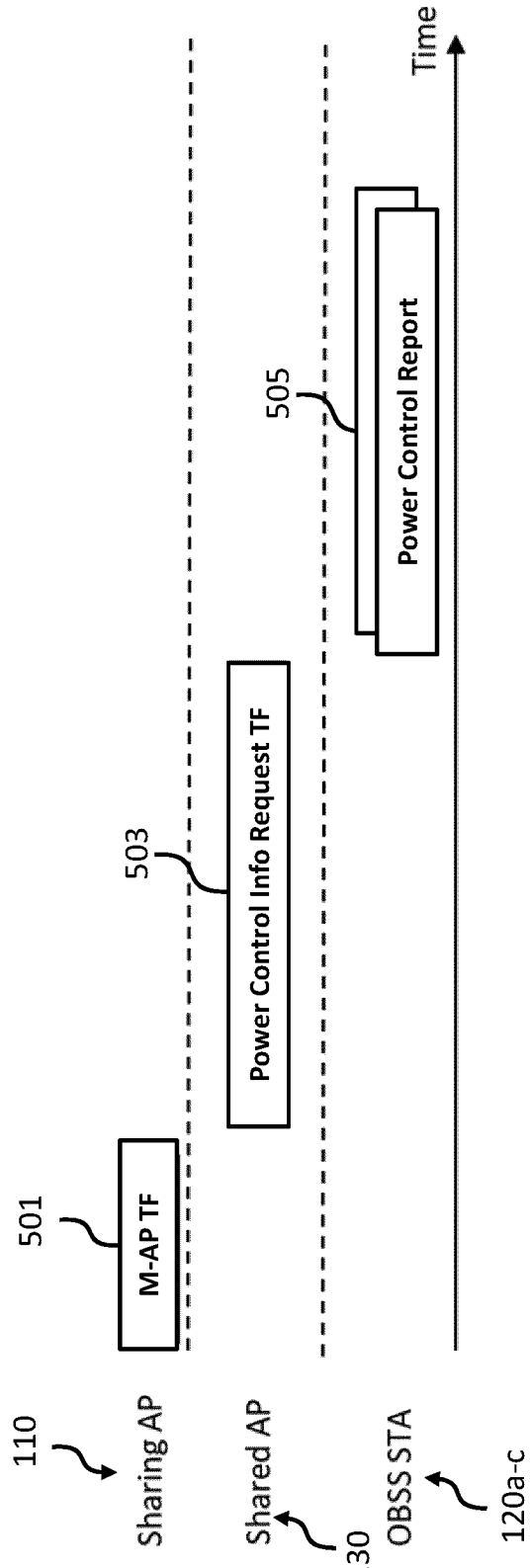
Time
110
Sharing AP
501
M-AP TF
503
Power Control Info Request TF
Shared AP
130
OBSS STA
120a-c
505
Power Control Report

Fig. 11

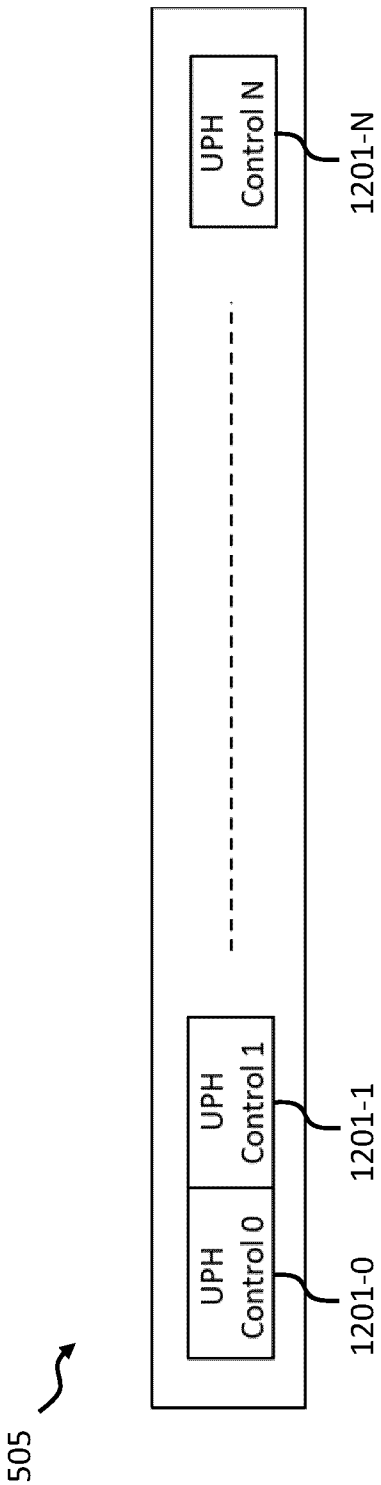
505
UPH Control 0
UPH Control 1
UPH Control N
1201-0
1201-1
1201-N

Fig. 12

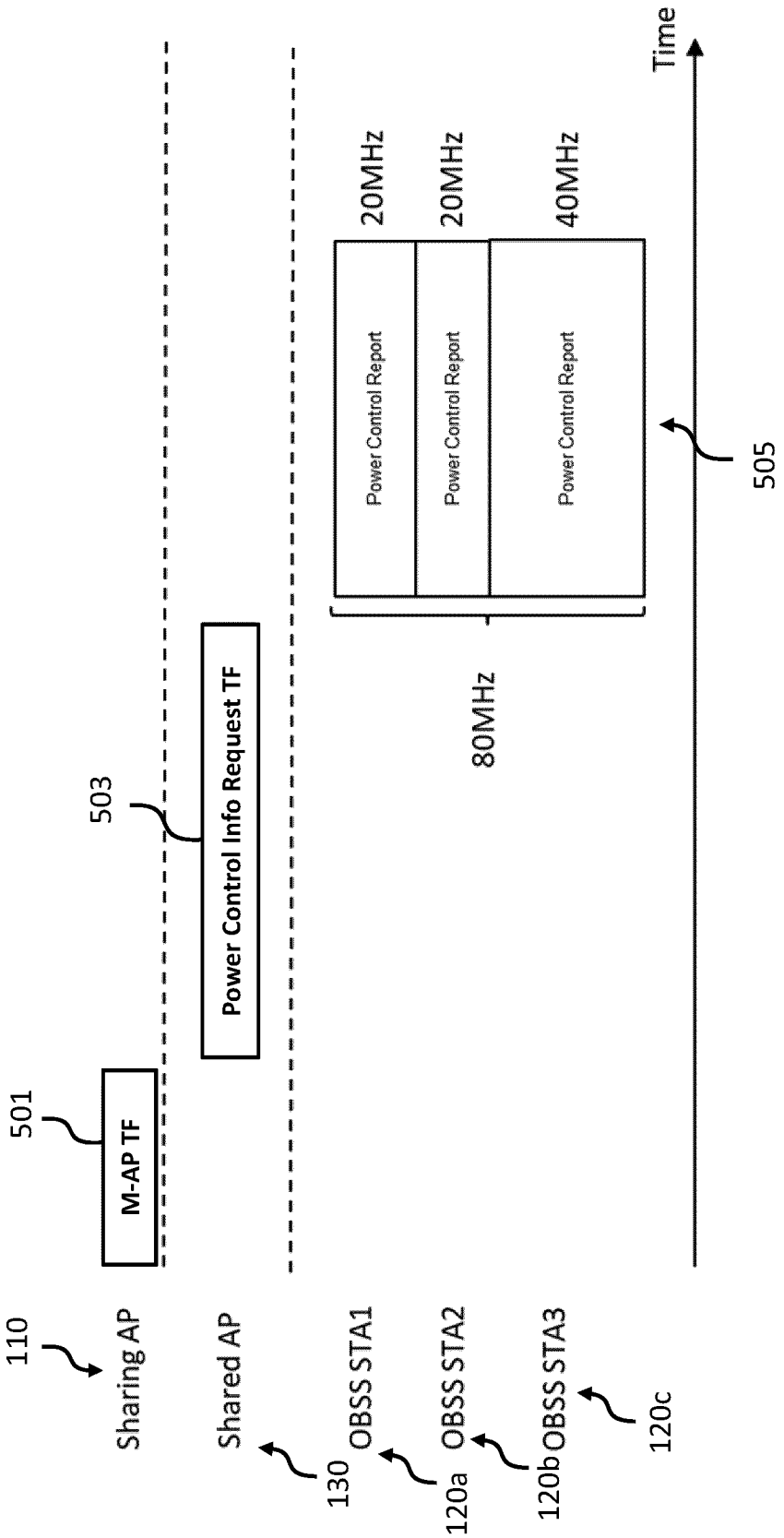
110
Sharing AP
501
M-AP TF
503
Power Control Info Request TF
Shared AP
130
OBSS STA1
120a
OBSS STA2
120b
OBSS STA3
120c
80MHz
20MHz
20MHz
40MHz
Power Control Report
Power Control Report
Power Control Report
505
Time

Fig. 13

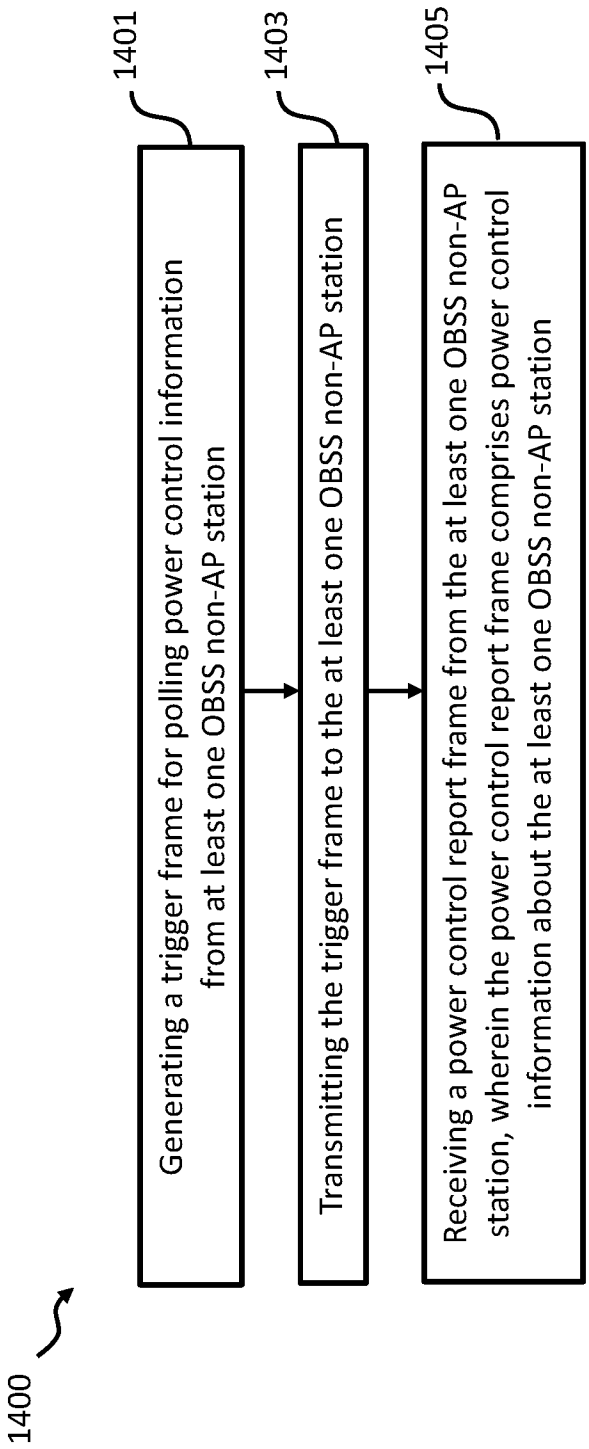
1400
1401
Generating a trigger frame for polling power control information from at least one OBSS non-AP station
1403
Transmitting the trigger frame to the at least one OBSS non-AP station
1405
Receiving a power control report frame from the at least one OBSS non-AP station, wherein the power control report frame comprises power control information about the at least one OBSS non-AP station

Fig. 14

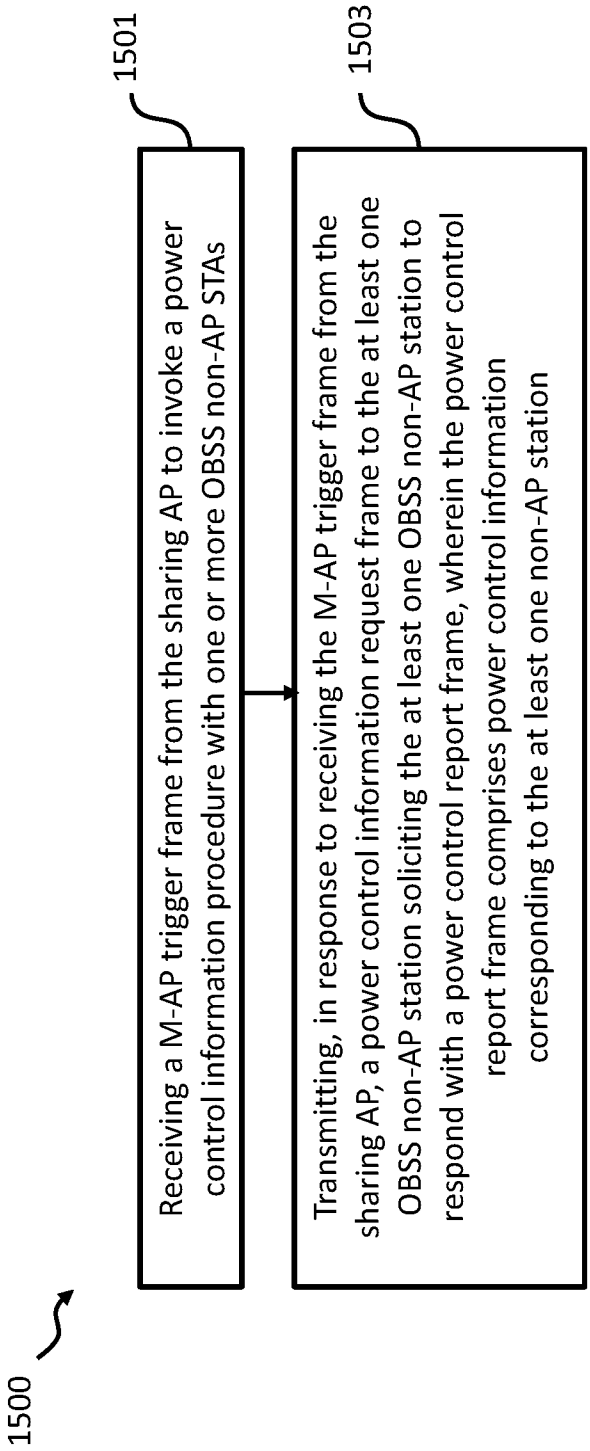
1500
1501
Receiving a M-AP trigger frame from the sharing AP to invoke a power control information procedure with one or more OBSS non-AP STAs
1503
Transmitting, in response to receiving the M-AP trigger frame from the sharing AP, a power control information request frame to the at least one OBSS non-AP station soliciting the at least one OBSS non-AP station to respond with a power control report frame, wherein the power control report frame comprises power control information corresponding to the at least one non-AP station

Fig. 15

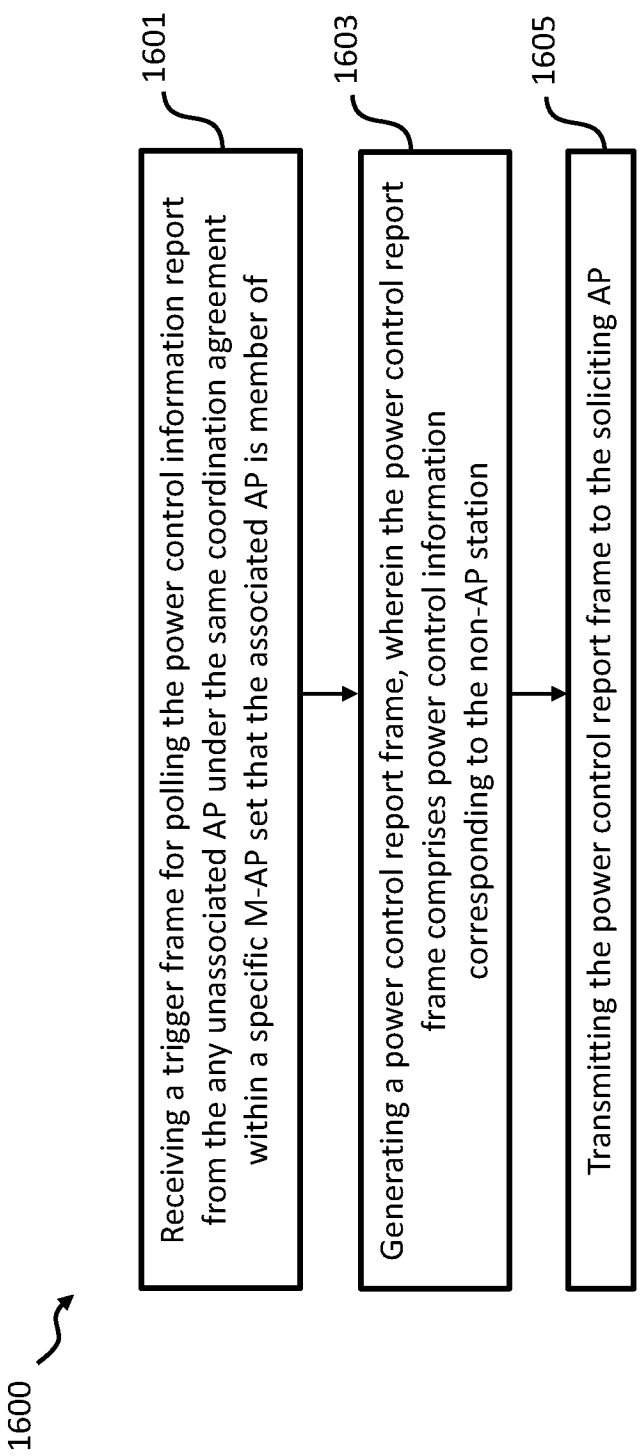
1600
1601
Receiving a trigger frame for polling the power control information report from the any unassociated AP under the same coordination agreement within a specific M-AP set that the associated AP is member of
1603
Generating a power control report frame, wherein the power control report frame comprises power control information corresponding to the non-AP station
1605
Transmitting the power control report frame to the soliciting AP

Fig. 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/063209

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W52/42 H04B7/024 H04B7/0452 H04W84/12
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2021/172727 A1 (LG ELECTRONICS INC [KR]) 2 September 2021 (2021-09-02) paragraphs [0296] - [0316], [0319] - [0332], [0343] - [0357], [0369] - [0372], [0378] - [0385]	1-49

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 December 2022	20/12/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lustrini, Donato

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2022/063209

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2021172727 A1	02-09-2021	NONE	