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FIG. 2

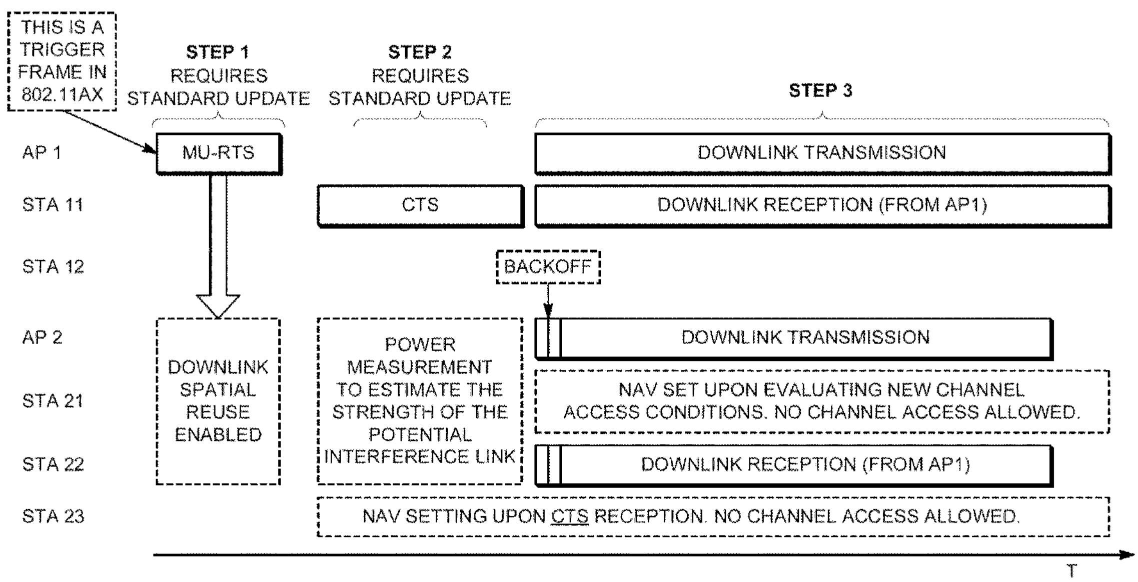

Figure 2: Illustration of the proposed procedure to enable a controlled spatial reuse during downlink based on the scenario considered in Figure 1.

(57) Abstract: Example embodiments improve spatial reuse by wireless devices in an overlapped Basic Service Set. An apparatus of a first wireless network receives from a device of a second wireless network, a request to reserve the wireless medium with a second device of the second wireless network, wherein the request indicates spatial reuse opportunity, a duration field, and a spatial reuse level field indicating a spatial reuse parameter. The apparatus determines a transmission threshold based at least in part on the spatial reuse parameter and a reception power level of an acknowledgement frame from the second device of the second wireless network. If transmission power of the apparatus is less than the transmission threshold, the apparatus transmits an overlapping frame simultaneously with the transmission of a subsequent frame from the device of the second wireless network.

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[Continued on next page]

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TITLE: CONTROLLING DOWNLINK SPATIAL REUSE IN WLAN THROUGH RTS/CTS

FIELD:

[001] The field of the invention relates to wireless communication and more particularly relates to improving spatial reuse in case of overlapping networks.

BACKGROUND:

[002] In IEEE 802.11 WLAN, a transmission may begin with a Request-to-send (RTS) frame and the receiver may respond with a Clear-to-send (CTS) frame. The channel may be cleared by these two messages, since all other wireless stations (STAs) that hear at least one of the CTS frames will respond by suppressing their own start of a transmission. The Request-to-send (RTS) frame sent by the sender and the Clear-to-send (CTS) frame sent in reply by the intended receiver, may alert all other devices within range of the sender or the receiver, to refrain from transmitting for a duration specified by either or both of the RTS and the CTS frames.

[003] However, in the case of overlapped Basic Service Sets (OBSS), where the coverage of two or more adjacent BSSs is overlapped, the conventional operation of the RTS and CTS prevents STAs in the other, overlapped BSS from transmitting during the transmission opportunity (TXOP) interval. This prevents spatial reuse of the wireless medium in the other, overlapped BSS, by preventing the AP and STAs in the other, overlapped BSS from accessing the channel. Allowing spatial reuse opportunities for the other, overlapped BSS may improve the overall network's performance.

[004] There may be other similar network concepts having overlapping networks and requirements for higher spatial reuse.

SUMMARY:

[005] Method, apparatus, and computer program product example embodiments improve spatial reuse by wireless devices in an overlapped Basic Service Set (OBSS).

[006] According to an example embodiment of the invention, a method comprises at least some of the following features:

[007] receiving via a wireless medium, by an apparatus of a first wireless network from a first device of a second wireless network, a request to reserve the wireless medium for further frame exchange between the first device of the second wireless network and at least one second device of the second wireless network,

[008] wherein the request indicates spatial reuse opportunity,

[009] wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the first device of the second wireless network, and

[0010] wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter;

[0011] receiving, by the apparatus from at least one of the at least one second device of the second wireless network, an acknowledgement message to the request and determining a reception power level of the acknowledgement message;

[0012] determining, by the apparatus, a transmission threshold based at least in part on the spatial reuse parameter and the reception power level; and

[0013] if a transmission power of the apparatus is less than the transmission threshold, transmitting, by the apparatus, an overlapping frame to another apparatus of the first wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with the transmission of the subsequent frame from the first device of the second wireless network.

[0014] According to another example embodiment of the invention, the above method comprises the spatial reuse parameter is a function of a maximum transmission power of acknowledgement messages transmitted by the at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network may tolerate.

[0015] According to another example embodiment of the invention, the above method comprises the transmission threshold is a maximum transmission power that the apparatus may use in sending the overlapping frame to the another apparatus without exceeding a maximum tolerable interference level of the at least one of the at least one second device of the second wireless network.

[0016] According to another example embodiment of the invention, the above method comprises the request to reserve the wireless medium is a MU-RTS frame and the acknowledgement message is a CTS frame.

[0017] According to another example embodiment of the invention, the above method comprises the determining the transmission threshold is based on performing the determination separately for each acknowledgement message received from different second devices of the at least one second device and then selecting the lowest of these transmission thresholds.

[0018] According to another example embodiment of the invention, the above method comprises the first device of the second wireless network is an access point and the second device of the second wireless network is a terminal.

[0019] According to another example embodiment of the invention, the above method comprises the apparatus of the first wireless network does not immediately change its medium condition and update its NAV upon reception of the request to reserve the wireless medium, but instead commences the determining the transmission threshold.

[0020] According to an example embodiment of the invention, a method comprises at least some of the following features:

[0021] transmitting, by an access node in a second wireless network, via a wireless medium, a request to reserve the wireless medium for further frame exchange between the access node of the second wireless network and at least one second device of the second wireless network,

[0022] wherein the request indicates spatial reuse opportunity for wireless devices in a first wireless network that is at least partially overlapped with the second wireless network,

[0023] wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the access node of the second wireless network, and

[0024] wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter that is a function of a maximum transmission power of acknowledgement messages transmitted by at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network may tolerate; and

[0025] transmitting, by the access node in the second wireless network, an overlapping frame to the at least one second device of the second wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with a transmission of a frame from the at least one device of the wireless devices of the second wireless network.

[0026] According to another example embodiment of the invention, the above method comprises the request to reserve the wireless medium is a MU-RTS frame and the acknowledgement message is a CTS frame.

[0027] According to another example embodiment of the invention, the above method comprises the access node is an access point and the at least one second device of the second wireless network is a terminal.

[0028] According to an example embodiment of the invention, an apparatus comprises at least some of the following features:

[0029] at least one processor;

[0030] at least one memory including computer program code;

[0031] the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to:

[0032] receive via a wireless medium, by the apparatus of a first wireless network from a first device of a second wireless network, a request to reserve the wireless medium for further frame exchange between the first device of the second wireless network and at least one second device of the second wireless network,

[0033] wherein the request indicates spatial reuse opportunity,

[0034] wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the first device of the second wireless network, and

[0035] wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter;

[0036] receive, by the apparatus from at least one of the at least one second device of the second wireless network, an acknowledgement message to the request and determining a reception power level of the acknowledgement message;

[0037] determine a transmission threshold based at least in part on the spatial reuse parameter and the reception power level; and

[0038] if a transmission power of the apparatus is less than the transmission threshold, transmit an overlapping frame to another apparatus of the first wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with the transmission of the subsequent frame from the first device of the second wireless network.

[0039] According to an example embodiment of the invention, an apparatus comprises at least some of the following features:

[0040] at least one processor;

[0041] at least one memory including computer program code;

[0042] the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to:

[0043] transmit, by the apparatus in a second wireless network, via a wireless medium, a request to reserve the wireless medium for further frame exchange between the apparatus of the second wireless network and at least one second device of the second wireless network,

[0044] wherein the request indicates spatial reuse opportunity for wireless devices in a first wireless network that is at least partially overlapped with the second wireless network,

[0045] wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the apparatus of the second wireless network, and

[0046] wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter that is a function of a maximum transmission power of acknowledgement messages transmitted by at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network may tolerate; and

[0047] transmit, by the apparatus in the second wireless network, an overlapping frame to the at least one second device of the second wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with a transmission of a frame from the at least one device of the wireless devices of the second wireless network.

[0048] According to an example embodiment of the invention, a computer program product comprises at least some of the following features:

[0049] code for receiving via a wireless medium, by an apparatus of a first wireless network from a first device of a second wireless network, a request to reserve the wireless medium for further frame exchange between the first device of the second wireless network and at least one second device of the second wireless network,

[0050] wherein the request indicates spatial reuse opportunity,

[0051] wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the first device of the second wireless network, and

[0052] wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter;

[0053] code for receiving, by the apparatus from at least one of the at least one second device of the second wireless network, an acknowledgement message to the request and determining a reception power level of the acknowledgement message;

[0054] code for determining, by the apparatus, a transmission threshold based at least in part on the spatial reuse parameter and the reception power level; and

[0055] if a transmission power of the apparatus is less than the transmission threshold, code for transmitting, by the apparatus, an overlapping frame to another apparatus of the first wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with the transmission of the subsequent frame from the first device of the second wireless network.

[0056] According to an example embodiment of the invention, a computer program product comprises at least some of the following features:

[0057] code for transmitting, by an access node in a second wireless network, via a wireless medium, a request to reserve the wireless medium for further frame exchange between the access node of the second wireless network and at least one second device of the second wireless network,

[0058] wherein the request indicates spatial reuse opportunity for wireless devices in a first wireless network that is at least partially overlapped with the second wireless network,

[0059] wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the access node of the second wireless network, and

[0060] wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter that is a function of a maximum transmission power of acknowledgement messages transmitted by at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network may tolerate; and

[0061] code for transmitting, by the access node in the second wireless network, an overlapping frame to the at least one second device of the second wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with a transmission of a frame from the at least one device of the wireless devices of the second wireless network.

DESCRIPTION OF THE FIGURES:

[0062] Figure 1 illustrates an example network diagram of two networks with overlapping coverage regions.

[0063] Figure 2 illustrates an example procedure to enable a controlled spatial reuse during downlink based on the network diagram of Figure 1, in accordance with at least one embodiment of the present invention.

[0064] Figure 3 illustrates an example wireless network showing a functional block diagram of the access point AP1 in BSS1 attempting to perform downlink data transmission to wireless station STA11 in its own BSS1 and to control spatial reuse by non-associated wireless device STA21 in the overlapped BSS2, by sending a new type request to send MU-RTS frame with new capabilities, which is received by non-associated wireless device STA21 in the overlapped BSS2. The figure also shows the wireless station STA11 in its own BSS1 sending a clear to send CTS frame that is received by non-associated wireless device STA21 in the overlapped BSS2.

[0065] Figure 4 illustrates the example wireless network of Figure 3, showing transmission of a data frame from access point AP1 to wireless station STA11 in its own BSS1 and a simultaneous transmission of a data frame from wireless device STA21 in the overlapped BSS2 to wireless station STA22.

[0066] Figure 5A illustrates an example flow diagram of operational steps in the non-associated wireless device STA21 in the overlapped BSS2 receiving the new type request to send MU-RTS frame and determining a transmission threshold based at least in part on the maximum interference level stated in the new type request to send MU-RTS frame and the reception power level of the received CTS frame.

[0067] Figure 5B illustrates an example flow diagram of operational steps in the access point AP1 in BSS1 attempting to perform downlink data transmission to wireless station STA11 in its own BSS1 and to control spatial reuse by non-associated wireless device STA21 in the overlapped BSS2 frame by transmitting the new type request to send MU-RTS frame.

[0068] Figure 6 illustrates an example embodiment of the invention, wherein examples of removable storage media are shown, for storing data and/or computer program code as an example computer program product, in accordance with an example embodiment of the invention.

DISCUSSION OF EXAMPLE EMBODIMENTS OF THE INVENTION:

[0069] Method, apparatus, and computer program product example embodiments improve spatial reuse by wireless devices in an overlapped Basic Service Set (OBSS). Figure 1 illustrates an example network diagram of two BSSs with overlapping coverage regions, wherein BSS1 is comprised of AP1, STA11, and STA12 and BSS2 is comprised of AP2, STA21, STA22, and STA23. In an example embodiment, a first wireless device, for example an access point (AP1) in a BSS (BSS1) as shown in Figure 1, attempts to perform downlink data transmission to second wireless station, for example (STA11) in its own BSS (BSS1) and to control spatial reuse by non-associated wireless devices, for example (AP2 and STA21) in an overlapped BSS (BSS2), by sending a new type request to send (RTS) frame with new capabilities.

[0070] The new type request to send (RTS) frame with new capabilities announces to the non-associated wireless devices (AP2 and STA21) in the overlapped BSS (BSS2) that: 1) the subsequent transmission will be a downlink transmission, and 2) the spatial reuse is enabled during that downlink transmission as long as the non-associated wireless devices (AP2 and STA21) in the overlapped BSS (BSS2) comply with the set of conditions listed below.

[0071] As AP1 conducts ongoing exchanges of information with the STA11 and STA12 stations in its BSS1, it monitors and characterizes the transmission power of these stations, and in particular the maximum transmission power of CTS frames transmitted by these stations when they respond to requests to transmit (RTS) frames from AP1. In some embodiments, AP1 may directly indicate in the MU-RTS frame, the transmission power that STA11 and STA12 have to use in their CTS response. AP1 also characterizes the actual maximum tolerable interference level that the STA11 and STA12 stations may tolerate based, for example, on one or more parameters, including the modulation-coding scheme being used for wireless transmission, channel quality or contention situation of the channel, priority, quality of service (QoS), etc.

[0072] The new type request to send (RTS) frame with new capabilities provides a spatial reuse level field indicating a spatial reuse parameter (SRP) that is computed as a function of (a) the maximum transmission power of CTS frames transmitted by these stations and (b) the actual maximum tolerable interference level that the STA11 station may tolerate, which the AP1 has previously determined for the stations in its BSS1.

[0073] The STAs in BSS1 addressed by the new type request to send (RTS) frame, will reply with CTS, provided that their medium condition is not busy.

[0074] The non-associated wireless devices (AP2 and STA21) in the overlapped BSS (BSS2) should not immediately change their medium condition and update the NAV upon reception of the new type request to send (RTS) frame, but instead should apply the following procedure for identifying channel access opportunities. A downlink channel access opportunity is identified when all the following conditions are met:

[0075] At least one CTS frame to the previous new type request to send (RTS) frame, is received,

[0076] The current medium condition is not indicated as busy, and

[0077] The non-associated wireless device (AP2 and/or STA21) is capable of generating an interference to the data-receiving STAs that is below the actual maximum tolerable interference level specified by a spatial reuse parameter that the AP sent in the new type request to send (RTS) frame. In order to measure an upper bound on the potential interference generated by the non-associated wireless device (AP2 and/or STA21) identifying a channel access opportunity, the non-associated wireless device (AP2 and/or

STA21) will measure the aggregate received power level (RPL) during the received CTS frames.

[0078] The non-associated wireless device (AP2 and/or STA21) determines a transmission threshold based at least in part on the spatial reuse parameter and the reception power level of the received CTS frames.

[0079] If the transmission power of the non-associated wireless device (AP2 and/or STA21) is below the transmission threshold, the non-associated wireless devices (AP2 and STA21) transmit an overlapping frame to another device, such as STA22 of the overlapped BSS2 network. The overlapping frame may be transmitted at least in part simultaneously with the transmission of the subsequent frame from the AP1 of the BSS1 network.

[0080] The spatial reuse parameter is a function of a maximum transmission power of acknowledgement messages transmitted by the STA11 and STA12 stations and an actual maximum tolerable interference level that the STA11 and STA12 stations may tolerate. The transmission threshold takes into account the distance between the non-associated wireless device (AP2 or STA21) and STA11 in the BSS1 network, which is related to the received power level (RPL) during the received CTS frame from STA11.

[0081] As a result, the access point AP1, in the BSS1 that sent the new type request to send (RTS) frame, performs a successful downlink transmission. The non-associated wireless device (AP2 and/or STA21) in the overlapped BSS (BSS2), which identified a channel access opportunity, continues the countdown of an existing backoff procedure. The device (AP2 and/or STA21) that gains channel access first may perform a transmission, as long as it does not exceed the maximum tolerable interference level of the STA11 station.

[0082] <u>**DETAILED DESCRIPTION OF THE EMBODIMENTS**</u>

[0083] As illustrated in Figure 2, which is based on the scenario considered in Figure 1, in this embodiment we propose a method to efficiently control spatial reuse during downlink transmissions protected with multi-user request-to-send (MU-RTS) Trigger frame and CTS frame exchange procedure introduced in the IEEE 802.11ax, to enhance spatial reuse. We consider the scenario shown in Figure 1, where two basic service sets (BSSs), BSS1 and BSS2, have overlapping coverage regions, and use the same frequency channel. The MU-RTS/CTS process may be summarized as follows:

[0084] __Step 1:__ Prior to initiating a data transmission, AP1 may transmit an MU-RTS trigger frame (TF), requesting a simultaneous CTS response from the addressed stations (STAs) (STA 11 and STA12 in Figure 1). The MU-RTS indicates a duration during which a subsequent data transmission may be performed.

[0085] __Step 2:__ Upon reception of the MU-RTS frame, the STA 11 and STA12 may respond with simultaneous CTS message, if their medium condition is not indicated as busy. The simultaneous CTS messages may be identical. Other non-addressed devices that receive the MU-RTS message (AP2, STA21, and STA22 in Figure 1) may update their network vector allocation (NAV).

[0086] __Step 3:__ AP1 may proceed with the downlink transmission, as long as one CTS response is correctly decoded. Since the CTS message may also include the duration of the subsequent downlink data transmission, other devices that did not receive the first MU-RTS frame (STA23 in Figure 1) may also update their NAV based on this information.

[0087] The MU-RTS/CTS process is generally performed to guarantee an efficient NAV distribution, and prevent hidden terminal issues. Indeed, in the situation of Figure 1, the MU-RTS/CTS exchange may prevent STA23, which is outside the coverage region of AP1, from accessing the channel and generating harmful interference to STA11's data reception.

[0088] However, in the setup illustrated in Figure 1, there is no spatial reuse: AP1's downlink transmission towards STA11 and/or STA12 prevents AP2 from accessing the channel simultaneously, since the listen-before-talk (LBT) procedure prevents spatial reuse. However, allowing AP2 to access the channel may be positive for the overall network's performance, since AP2 is physically far from STA11 and STA12, and would generate a reduced amount of interference. The existing MU-RTS/CTS procedure is designed in such a way that prevents spatial reuse.

[0089] In a system without MU-RTS/CTS there is uncontrolled spatial reuse. AP1 places spatial radiation nulls towards those BSS2 devices in coverage (AP2, STA21, and STA22) when accessing the channel, STA21, STA22, or STA23, which may deem the channel as not busy, resulting in performing a transmission that would severely hurt STA11 or STA12's data reception.

[0090] In accordance with example embodiments of the invention, we propose the following options, one or more of which may be performed according to some embodiments:

[0091] **<u>For Step 1 in Figure 2</u>**, introduce new capabilities to the MU-RTS frame for devices that want to avail from controlled spatial reuse opportunities during their subsequent downlink transmissions.

[0092] We define new field/s with the purpose of communicating inter-BSS devices of an upcoming downlink spatial reuse opportunity and the actual maximum tolerable interference level towards the data-receiving STA/s addressed by the MU-RTS.

[0093] **<u>For Step 2 of Figure 2</u>**, introduce new rules for inter-BSS devices to be applied upon receiving a MU-RTS Trigger frame with the new capabilities followed by one or more CTS frames.

[0094] Upon reception of the enhanced MU-RTS frame, announcing a potential downlink spatial reuse opportunity, inter-BSS devices will not immediately update their NAV. Instead, they identify channel access opportunities and adjust their transmission power based on a) the actual maximum tolerable interference level specified by the MU-RTS frame, and b) the aggregate received power level (RPL) measured during the CTS response/s. These RPL measurements acquired during the CTS response/s allow inter-BSS devices to obtain up-to-date estimates of the potential interference generated towards downlink data-recipient STAs.

[0095] **<u>An Example Embodiment of the Invention:</u>**

[0096] In this example embodiment, we detail the new functionalities required in the 802.11 standard to implement the proposed method. We also illustrate the benefits of the proposed method in the situation considered in Figure 1 and Figure 2.

[0097] **<u>Step 1 in Figure 2.</u>** MU-RTS for controlling downlink spatial reuse.

[0098] The Extreme High Throughput (EHT) AP attempting to perform downlink data transmission and controlling spatial reuse (AP1 in Figure 1) sends a MU-RTS with new capabilities. Through the addition of a new field in the MU-RTS frame, e.g., in the Common Info field of the Trigger frame (TF), the MU-RTS TF announces non-associated APs/STAs that 1) the subsequent transmission will be a downlink transmission, and 2) that spatial reuse is enabled during that downlink transmission as long as the AP/STAs comply with the set of conditions specified in the following Step 2.

[0099] In this MU-RTS TF, the AP (AP1 in Figure 1) also indicates the actual maximum tolerable interference level that the STA11 and STA12 stations may tolerate, which may be identical for all addressed STAs in the BSS1 network. The actual maximum tolerable interference level that the STA11 and STA12 stations may tolerate may also be referred to as the max. level of interference perceived by the STAs addressed by MU-RTS [dBm]

[00100] This information may be potentially provided through the existing spatial reuse parameter (SRP) value conveyed in the Spatial Reuse subfield of the Common Info field of the MU-RTS TF. The Spatial Reuse subfield of the Common Info field is also referred to herein as the spatial reuse level field. Some embodiments will define the SRP value as:

[00101] Spatial reuse parameter (SRP) = (maximum transmission power of CTS frames transmitted by these stations when they respond to requests to transmit (RTS) frames from AP1) + (actual maximum tolerable interference level that the STA11 and STA12 stations may tolerate). Stated otherwise, the Spatial reuse parameter (SRP) may be expressed as:

[00102] SRP = max. TX power of STAs addressed by MU-RTS [dBm] + max. level of interference perceived by the STAs addressed by MU-RTS [dBm]*

(Eq. 1)

[00103] *While the addition of dBm does not have physical meaning, the effectiveness of this procedure is independent of that circumstance. Indeed, an identical situation may occur when defining the SRP value in an uplink SRP framework.

[00104] In the example of Figure 1 and Figure 2, assuming that the maximum power of the STAs STA11 and STA12 addressed by the MU-RTS is 18 dBm and the actual maximum tolerable interference level that the STA11 and STA12 stations may tolerate is -72 dBm, the SRP would adopt the value:

[00105] $\text{SRP} = 18\,[\text{dBm}] - 72\,[\text{dBm}] = -54$

[00106] Throughout this embodiment, only for illustrative purposes and as shown in Figure 2, we will consider that AP1 addresses the MU-RTS to both STA11 and STA12, but only STA11 responds to the MU-RTS message sent by AP1.

[00107] **<u>Step 2 in Figure 2.</u>** New rules for inter-BSS devices AP2, STA21, and STA22 receiving the MU-RTS Trigger frame and one or more CTS frames from the STAs STA11 and STA12 addressed by the MU-RTS.

[00108] As in the current version of the standard, STAs STA11 and STA12 addressed by the MU-RTS will reply with CTS provided that their medium condition is not busy.

[00109] Instead, a new functionality is required for inter-BSS Extreme High Throughput (EHT) APs/STAs AP2, STA21, and STA22 in Figure 1, which 1) decode a MU-RTS TF, announcing a subsequent downlink transmission allowing spatial reuse, and 2) have physical layer protocol data units (PPDU)s to transmit. These inter-BSS devices should not immediately change their medium condition and update the inter-BSS NAV upon reception of the MU-RTS, as in the current version of the standard, but instead should apply the following procedure for identifying SRP-based channel access opportunities. A downlink SRP-based channel access opportunity is identified by AP2, STA21, and/or STA22 when all the following conditions are met:

> **[00110]** At least one CTS frame to the previous MU-RTS is received,
>
> **[00111]** The current medium condition is not indicated as busy, and
>
> **[00112]** The node AP2, STA21, and/or STA22 will generate less interference to the data-receiving STAs STA11 and/or STA12 than the actual maximum tolerable interference level specified by the AP that sent in the MU-RTS. In order to measure an upper bound on the potential interference generated by the devices identifying an SRP-based channel

access opportunity, inter-BSS nodes AP2, STA21, and/or STA22 will measure the aggregate RPL during the received CTS frames.

[00113] The transmission threshold is the maximum transmission power "TX power" that the inter-BSS node AP2, STA21, or STA22 may use without exceeding the maximum tolerable interference level of the data-receiving STAs STA11 and/or STA12.

[00114] The transmission threshold = (max. TX power of STAs addressed by MU-RTS [dBm] + actual maximum tolerable interference level) – RPL [dBm].

[00115] In some embodiments, the transmission threshold of the node AP2, STA21, and/or STA22 would be then given by:

[00116] TX power [dBm]* ≤ SRP – RPL [dBm]. (Eq. 2)

[00117] For illustrative purposes, in this embodiment we consider that

[00118] a) AP2, STA21, and STA22 receive both the MU-RTS from AP1 and the CTS frame from STA11,

[00119] b) AP2, STA21, and STA22 medium's condition was not busy prior to the reception of the MU-RTS, and

[00120] c) the received power level measured by AP2 during the CTS reception phase is RPL = −70 dBm. As a result, following (Eq. 1) and (Eq. 2), AP2 would compute its transmission power (TX power AP2) that must be less that the transmission threshold, as:

[00121] TX power AP2 [dBm] ≤ (max. TX power of STAs addressed by MU-RTS [dBm] + max. level of interference perceived by the STAs addressed by MU-RTS [dBm]) – RPL [dBm]

[00122] = (max. TX power of STAs addressed by MU-RTS + max. level of interference perceived by the STAs addressed by MU-RTS) − (STA11 power [dBm] + channel gain [dB])

[00123] = max. level of interference perceived by the STAs addressed by MU-RTS − channel gain

[00124] $= -72 \text{ dBm} + 88 \text{ dB} = 16 \text{ dBm}.$

[00125] Following a similar procedure, for the transmission threshold of STA22, we also assume that TX power STA22 [dBm] ≤ 18 dBm, since STA22 is located farther than AP2 from the CTS transmitter (STA11). Instead, for the transmission threshold of STA21, we assume that TX power STA21 [dBm] ≤ -10 dBm, since STA21 is located very close to the CTS transmitter (STA11). This effectively prevents STA21 from accessing the channel, and disrupting STA11's subsequent data reception.

[00126] **<u>Step 3 in Figure 2.</u>** Simultaneous data transmission. As a result of implementing the above features, the proposed procedure enables a safe downlink spatial reuse and, simultaneously:

[00127] The AP that sent the MU-RTS (AP1 in Figure 1) performs a successful downlink transmission, since the actual maximum tolerable interference level is controlled.

[00128] The inter-BSS APs/STAs that identified an SRP opportunity (AP2 and STA22 in Figure 2) continue the countdown of an existing backoff procedure, and the one that gains channel access first (AP2 in Figure 2) may perform a transmission as long as it satisfies the power constraint computed in Step 2, wherein the transmit power is less than the transmission threshold.

[00129] Additional note 1: When more than one device replies with a CTS frame to the MU-RTS frame sent by AP1, the RPL will be an aggregate of multiple devices. In this circumstance, since the SRP level defined (Eq. 1) considers the maximum transmission power of all MU-RTS-addressed STAs, (Eq. 2) still guarantees that the transmission power used by any of the inter-BSS devices satisfies the actual maximum tolerable interference level to any of the AP1's downlink-scheduled STAs. This may be inferred by noticing that, when multiple devices reply with a CTS frame, the RPL value will be larger than that received from the worst link, making the transmission power in (Eq. 2) a conservative estimate.

[00130] In some embodiments, the determining of the transmission threshold may be based on performing the determination separately for each CTS acknowledgement message received from different MU-RTS-addressed STAs and then selecting the lowest of these transmission thresholds.

[00131] **<u>Example Methods for AP1 to Generate an Actual Maximum Tolerable Interference Level for the Wireless Station (STA11) in its own BSS (BSS1)</u>**

[00132] AP1 may generate an actual maximum tolerable interference level that STA11 station may tolerate, which the AP1 has previously determined for the stations in its BSS1, which is included in the MU-RTS frame sent by AP1. AP1 may monitor wireless transmissions from STA11 for an indication as to its tolerance to interference. This indication may be based, for example, on one or more parameters, including the modulation-coding scheme being used for wireless transmission, channel quality or contention situation of the channel as experienced by the transmitting device, priority (e.g. target block error rate) of the wireless transmission, quality of service (QoS), etc. The indicators may be in any form, such as a data bit or combination of data bits that are encoded to provide specific information about the wireless transmission or information about the wireless network from which it was transmitted. The indicators may include, for example, a robustness indication, a transmission priority indication, or any combination thereof. The frame may include a header (or preamble) (e.g., a PHY header of the BSS) in which the indicators are located. In some variations, the indicators are implicit, for example, by using different synchronization sequences in a preamble that correspond to different indicators or different indicator values.

[00133] Figure 3 illustrates an example wireless network showing a functional block diagram of the access point AP1 in BSS1 attempting to perform downlink data transmission to wireless station STA11 in its own BSS1 and to control spatial reuse by non-associated wireless device STA21 in the overlapped BSS2, by sending a new type request to send MU-RTS frame with new capabilities, which is received by non-associated wireless device STA21 in the overlapped BSS2. The figure also shows the wireless station STA11 in its own BSS1 sending a clear to send CTS frame that is received by non-associated wireless device STA21 in the overlapped BSS2.

[00134] Both the access node AP1 and the STAs may include a processor 122 that may include at least one of the following: a dual or multi-core central processing unit CPU 124 and 125, a RAM memory 126, a ROM memory 127, an interface for a keypad, display, and other input/output devices, and a protocol stack 107 for communication over the network. The device includes a transceiver 118 and an application program 114.

[00135] Figure 4 illustrates the example wireless network of Figure 3, showing transmission of a data frame from access point AP1 to wireless station STA11 in its own BSS1 and a simultaneous transmission of a data frame from wireless device STA21 in the overlapped BSS2 to wireless station STA22.

[00136] Figure 5A illustrates an example flow diagram 400 of operational steps in the non-associated wireless device (STA21), in accordance with at least one embodiment of the present invention. The steps of the flow diagram represent computer code instructions stored in the device's RAM and/or ROM memory, which when executed by the device's central processing units, carry out the functions of the example embodiments of the invention. The steps may be carried out in another order than shown and individual steps may be combined or separated into component steps. In some embodiments, one or more steps may be optional. The flow diagram has the following steps:

[00137] Step 402: receiving via a wireless medium, by an apparatus of a first wireless network from a first device of a second wireless network, a request to reserve the wireless medium for further frame exchange between the first device of the second wireless network and at least one second device of the second wireless network,

[00138] wherein the request indicates spatial reuse opportunity,

[00139] wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the first device of the second wireless network, and

[00140] wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter;

[00141] Step 404: receiving, by the apparatus from at least one of the at least one second device of the second wireless network, an acknowledgement message to the request and determining a reception power level of the acknowledgement message;

[00142] Step 406: determining, by the apparatus, a transmission threshold based at least in part on the spatial reuse parameter and the reception power level; and

[00143] Step 408: if a transmission power of the apparatus is less than the transmission threshold, transmitting, by the apparatus, an overlapping frame to another apparatus of the first wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with the transmission of the subsequent frame from the first device of the second wireless network.

[00144] Figure 5B illustrates an example flow diagram 450 of operational steps in the access point AP1 in BSS1 attempting to perform downlink data transmission to wireless station STA11 in its own BSS1 and to control spatial reuse by non-associated wireless device STA21 in the overlapped BSS2 by transmitting the new type request to send MU-RTS frame), in accordance with at least one embodiment of the present invention. The steps of the flow diagram represent computer code instructions stored in the device's RAM and/or ROM memory, which when executed by the device's central processing units, carry out the functions of the example embodiments of the invention. The steps may be carried out in another order than shown and individual steps may be combined or separated into component steps. In some embodiments, one or more steps may be optional. The flow diagram has the following steps:

[00145] Step 452: transmitting, by an access node in a second wireless network, via a wireless medium, a request to reserve the wireless medium for further frame exchange between the access node of the second wireless network and at least one second device of the second wireless network,

[00146] wherein the request indicates spatial reuse opportunity for wireless devices in a first wireless network that is at least partially overlapped with the second wireless network,

[00147] wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the access node of the second wireless network, and

[00148] wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter that is a function of a maximum

transmission power of acknowledgement messages transmitted by at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network may tolerate; and

[00149] Step 454: transmitting, by the access node in the second wireless network, an overlapping frame to the at least one second device of the second wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with a transmission of a frame from at least one device of the wireless devices of the first wireless network.

[00150] Figure 6 illustrates an example embodiment of the invention, wherein examples of removable storage media 126 are shown, based on magnetic, electronic and/or optical technologies, such as magnetic disks, optical disks, semiconductor memory circuit devices and micro-SD memory cards (SD refers to the Secure Digital standard) for storing data and/or computer program code as an example computer program product, in accordance with an example embodiment of the invention.

[00151] **<u>Additional Embodiments:</u>**

[00152] **<u>Embodiment 2:</u>**

[00153] In other embodiments, APs attempting to perform a downlink transmission with spatial reuse may also request inter-BSS devices to guarantee a maximum uplink tolerable interference threshold through the MU-RTS frame. This may be useful in circumstances where APs want to perform uplink transmissions within the same transmission opportunity (TXOP). In these cases,

[00154] **<u>Step 1 in Figure 2</u>** should be modified so that the MU-RTS includes both downlink and uplink SRP values.

[00155] **<u>Step 2 in Figure 2</u>** should be modified so that the inter-BSS devices receiving the MU-RTS/CTS exchange account for both uplink and downlink maximum tolerable interference constraints. Specifically, in addition to the steps described in the main embodiment to compute a power constraint, P_{max}^{DL}, based on the downlink interference criterion, inter-BSS devices should, similarly to the existing uplink SRP framework of 802.11ax in [Sec. 27.9.3 of 4], compute another maximum power constraint based on the uplink interference criterion, P_{max}^{UL}. The maximum transmission power constraint would be then computed as $\min(P_{max}^{DL}, P_{max}^{UL})$.

[00156] **Step 3 in Figure 2** would not be modified.

[00157] **Embodiment 3:**

[00158] In other embodiments, APs attempting to perform a downlink transmission with spatial reuse in bandwidths wider than 20 MHz may schedule different STAs in distinct blocks of 20 MHz. In this case, APs will transmit an MU-RTS in a non-HT duplicate PPDU, across the entire transmission bandwidth and specifying the channel/s assigned for the subsequent reception per STA, and each STA will subsequently reply with CTS in those channels specified by the MU-RTS. For example, the AP transmits MU-RTS over the primary 40 MHz and a) a first STA1 replies on the primary 20 MHz channel, and b) a second STA2 replies on the primary 40 MHz channel.

[00159] **Step 1 in Figure 2** may be modified so that the MU-RTS specifies the maximum tolerable interference threshold per 20 MHz channel. This would allow indicating the tolerated interference in a more accurate manner, e.g., by defining the interference threshold based on the specific STAs that reply with CTS per channel. The maximum tolerable interference threshold per 20 MHz channel may be specified by providing one SRP value per channel, e.g., by including a Trigger Dependent Common Info subfield to the Common Info field of the MU-RTS frame.

[00160] **Step 2 in Figure 2** may be modified so that inter-BSS EHT APs/STAs attempting to find a downlink spatial reuse opportunity in specific channel/s compute their maximum transmission power based on the SRP value per channel indicated on the MU-RTS.

[00161] **Step 3 in Figure 2** would not be modified.

[00162] **List of abbreviations**

[00163] ACK – Acknowledgment

[00164] AP – Access point

[00165] AR – Augmented reality

[00166] BSS – Basic service set

[00167] CTS – Clear-to-send

[00168] EHT – Extreme High Throughput

[00169] HE – High Efficiency

[00170] LBT – Listen before talk

[00171] MU-RTS – Multi-user request-to-send

[00172] NAV – Network allocation vector

[00173] OBSS – Overlapping basic service set

[00174] PPDU – Physical layer protocol data unit

[00175] RPL – Received power level

[00176] RTS – Request-to-send

[00177] SRP – Spatial reuse parameter

[00178] STA – Station

[00179] TF – Trigger frame

[00180] TXOP – Transmission opportunity

[00181] Although specific example embodiments have been disclosed, a person skilled in the art will understand that changes may be made to the specific example embodiments without departing from the invention.

CLAIMS

What is claimed is:

1. A method for wireless communication, comprising:

receiving via a wireless medium, by an apparatus of a first wireless network from a first device of a second wireless network, a request to reserve the wireless medium for further frame exchange between the first device of the second wireless network and at least one second device of the second wireless network,

wherein the request indicates spatial reuse opportunity,

wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the first device of the second wireless network, and

wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter;

receiving, by the apparatus from at least one of the at least one second device of the second wireless network, an acknowledgement message to the request and determining a reception power level of the acknowledgement message;

determining, by the apparatus, a transmission threshold based at least in part on the spatial reuse parameter and the reception power level; and

if a transmission power of the apparatus is less than the transmission threshold, transmitting, by the apparatus, an overlapping frame to another apparatus of the first wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with the transmission of the subsequent frame from the first device of the second wireless network.

2. The method for wireless communication of claim 1, wherein the spatial reuse parameter is a function of a maximum transmission power of acknowledgement messages transmitted by the at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network can tolerate.

3. The method for wireless communication of claim 1, wherein the transmission threshold is a maximum transmission power that the apparatus can use in sending the overlapping frame to the another apparatus without exceeding a maximum tolerable interference level of the at least one of the at least one second device of the second wireless network.

4. The method for wireless communication of claim 1, wherein the request to reserve the wireless medium is a MU-RTS frame and the acknowledgement message is a CTS frame.

5. The method for wireless communication of claim 1, wherein the determining the transmission threshold is based on performing the determination separately for each acknowledgement message received from different second devices of the at least one second device and then selecting the lowest of these transmission thresholds.

6. The method for wireless communication of claim 1, wherein the first device of the second wireless network is an access point and the second device of the second wireless network is a terminal.

7. The method for wireless communication of claim 1, wherein the apparatus of the first wireless network does not immediately change its medium condition and update its NAV upon reception of the request to reserve the wireless medium, but instead commences the determining the transmission threshold.

8. A method for wireless communication, comprising:

transmitting, by an access node in a second wireless network, via a wireless medium, a request to reserve the wireless medium for further frame exchange between the access node of the second wireless network and at least one second device of the second wireless network, wherein the request indicates spatial reuse opportunity for wireless devices in a first wireless network that is at least partially overlapped with the second wireless network,

wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the access node of the second wireless network, and

wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter that is a function of a maximum transmission power of acknowledgement messages transmitted by at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network can tolerate; and

transmitting, by the access node in the second wireless network, an overlapping frame to the at least one second device of the second wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with a transmission of a frame from at least one device of the wireless devices of the first wireless network.

9. The method for wireless communication of claim 8, wherein the request to reserve the wireless medium is a MU-RTS frame and the acknowledgement message is a CTS frame.

10. The method for wireless communication of claim 8, wherein the access node is an access point and the at least one second device of the second wireless network is a terminal.

11. An apparatus, comprising:

at least one processor;

at least one memory including computer program code;

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to:

receive via a wireless medium, by the apparatus of a first wireless network from a first device of a second wireless network, a request to reserve the wireless medium for further frame exchange between the first device of the second wireless network and at least one second device of the second wireless network,

wherein the request indicates spatial reuse opportunity,

wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the first device of the second wireless network, and

wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter;

receive, by the apparatus from at least one of the at least one second device of the second wireless network, an acknowledgement message to the request and determining a reception power level of the acknowledgement message;

determine a transmission threshold based at least in part on the spatial reuse parameter and the reception power level; and

if a transmission power of the apparatus is less than the transmission threshold, transmit an overlapping frame to another apparatus of the first wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with the transmission of the subsequent frame from the first device of the second wireless network.

12. The method for wireless communication of claim 11, wherein the spatial reuse parameter is a function of a maximum transmission power of acknowledgement messages transmitted by the at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network can tolerate.

13. The method for wireless communication of claim 11, wherein the transmission threshold is a maximum transmission power that the apparatus can use in sending the overlapping frame to the another apparatus without exceeding a maximum tolerable

interference level of the at least one of the at least one second device of the second wireless network.

14. The apparatus of claim 11, wherein the request to reserve the wireless medium is a MU-RTS frame and the acknowledgement message is a CTS frame.

15. The apparatus of claim 11, wherein the determining the transmission threshold is based on performing the determination separately for each acknowledgement message received from different second devices of the at least one second device and then selecting the lowest of these transmission thresholds.

16. The apparatus of claim 11, wherein the first device of the second wireless network is an access point and the second device of the second wireless network is a terminal.

17. The apparatus of claim 11, wherein the apparatus of the first wireless network does not immediately change its medium condition and update its NAV upon reception of the request to reserve the wireless medium, but instead commences the determining the transmission threshold.

18. An apparatus, comprising:

at least one processor;

at least one memory including computer program code;

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to:

transmit, by the apparatus in a second wireless network, via a wireless medium, a request to reserve the wireless medium for further frame exchange between the apparatus of the second wireless network and at least one second device of the second wireless network, wherein the request indicates spatial reuse opportunity for wireless devices in a first wireless network that is at least partially overlapped with the second wireless network,

wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the apparatus of the second wireless network, and

wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter that is a function of a maximum transmission power of acknowledgement messages transmitted by at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network can tolerate; and

transmit, by the apparatus in the second wireless network, an overlapping frame to the at least one second device of the second wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with a transmission of a frame from the at least one device of the wireless devices of the second wireless network.

19. The apparatus of claim 18, wherein the request to reserve the wireless medium is a MU-RTS frame and the acknowledgement message is a CTS frame.

20. The apparatus of claim 18, wherein the access node is an access point and the at least one second device of the second wireless network is a terminal.

21. An apparatus, comprising:

means for receiving via a wireless medium, by an apparatus of a first wireless network from a first device of a second wireless network, a request to reserve the wireless medium for further frame exchange between the first device of the second wireless network and at least one second device of the second wireless network,

wherein the request indicates spatial reuse opportunity, wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the first device of the second wireless network, and

wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter;

means for receiving, by the apparatus from at least one of the at least one second device of the second wireless network, an acknowledgement message to the request and determining a reception power level of the acknowledgement message;

means for determining, by the apparatus, a transmission threshold based at least in part on the spatial reuse parameter and the reception power level; and

if a transmission power of the apparatus is less than the transmission threshold, means for transmitting, by the apparatus, an overlapping frame to another apparatus of the first wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with the transmission of the subsequent frame from the first device of the second wireless network.

22. An apparatus, comprising:

means for transmitting, by an access node in a second wireless network, via a wireless medium, a request to reserve the wireless medium for further frame exchange between the access node of the second wireless network and at least one second device of the second wireless network,

wherein the request indicates spatial reuse opportunity for wireless devices in a first wireless network that is at least partially overlapped with the second wireless network,

wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the access node of the second wireless network, and

wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter that is a function of a maximum transmission power of acknowledgement messages transmitted by at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network can tolerate; and

means for transmitting, by the access node in the second wireless network, an overlapping frame to the at least one second device of the second wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with a transmission of a frame from the at least one device of the wireless devices of the second wireless network.

23. A computer program product comprising computer executable program code recorded on a computer readable non-transitory storage medium, the computer executable program code comprising:

code for receiving via a wireless medium, by an apparatus of a first wireless network from a first device of a second wireless network, a request to reserve the wireless medium for further frame exchange between the first device of the second wireless network and at least one second device of the second wireless network,

wherein the request indicates spatial reuse opportunity,

wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the first device of the second wireless network, and

wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter;

code for receiving, by the apparatus from at least one of the at least one second device of the second wireless network, an acknowledgement message to the request and determining a reception power level of the acknowledgement message;

code for determining, by the apparatus, a transmission threshold based at least in part on the spatial reuse parameter and the reception power level; and

if a transmission power of the apparatus is less than the transmission threshold, code for transmitting, by the apparatus, an overlapping frame to another apparatus of the first wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with the transmission of the subsequent frame from the first device of the second wireless network.

24. A computer program product comprising computer executable program code recorded on a computer readable non-transitory storage medium, the computer executable program code comprising:

code for transmitting, by an access node in a second wireless network, via a wireless medium, a request to reserve the wireless medium for further frame exchange between the access node of the second wireless network and at least one second device of the second wireless network,

wherein the request indicates spatial reuse opportunity for wireless devices in a first wireless network that is at least partially overlapped with the second wireless network,

wherein the request comprises a duration field indicating a duration during which a subsequent frame is expected to be transmitted from the access node of the second wireless network, and

wherein the request comprises a spatial reuse level field indicating a spatial reuse parameter that is a function of a maximum transmission power of acknowledgement messages transmitted by at least one of the at least one second device of the second wireless network and an actual maximum tolerable interference level that the at least one of the at least one second device of the second wireless network can tolerate; and

code for transmitting, by the access node in the second wireless network, an overlapping frame to the at least one second device of the second wireless network, wherein the overlapping frame is transmitted at least in part simultaneously with a transmission of a frame from the at least one device of the wireless devices of the second wireless network.

25. A computer program product comprising computer executable program code recorded on a computer readable non-transitory storage medium, the computer executable

program code, when executed on a computer processor, performing the method of claims 1 to 7.

26. A computer program product comprising computer executable program code recorded on a computer readable non-transitory storage medium, the computer executable program code, when executed on a computer processor, performing the method of claims 8 to 10.

27. A computer program comprising computer executable program code, when executed on a computer processor, performing the method of claims 1 to 7.

28. A computer program comprising computer executable program code, when executed on a computer processor, performing the method of claims 8 to 10.

FIG. 1

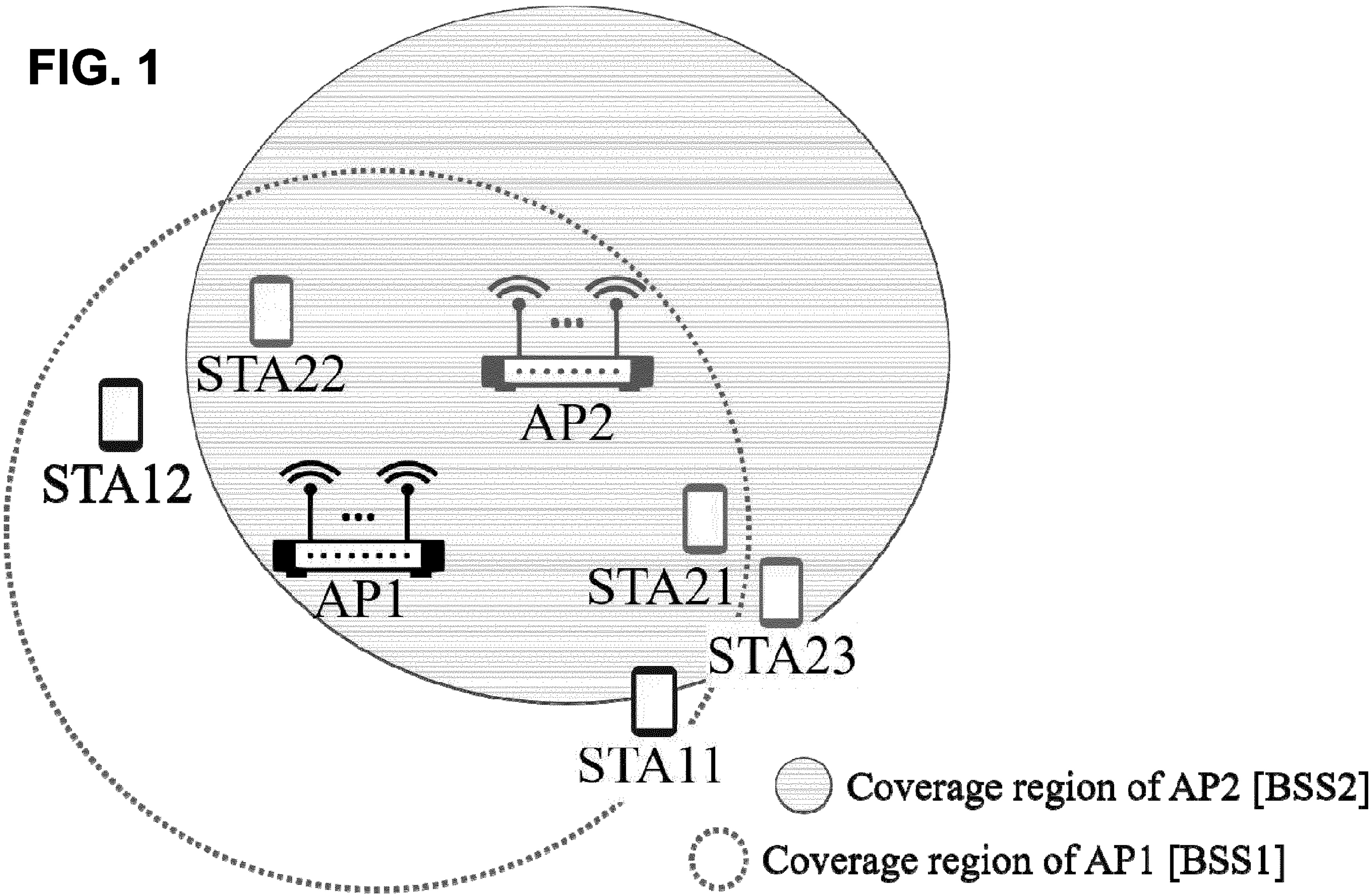

Figure 1. Two BSSs with overlapping coverage regions. BSS1 is comprised of AP1, STA11, and STA12. BSS2 is comprised of AP2, STA21, STA22, and STA23.

2/7

FIG. 2

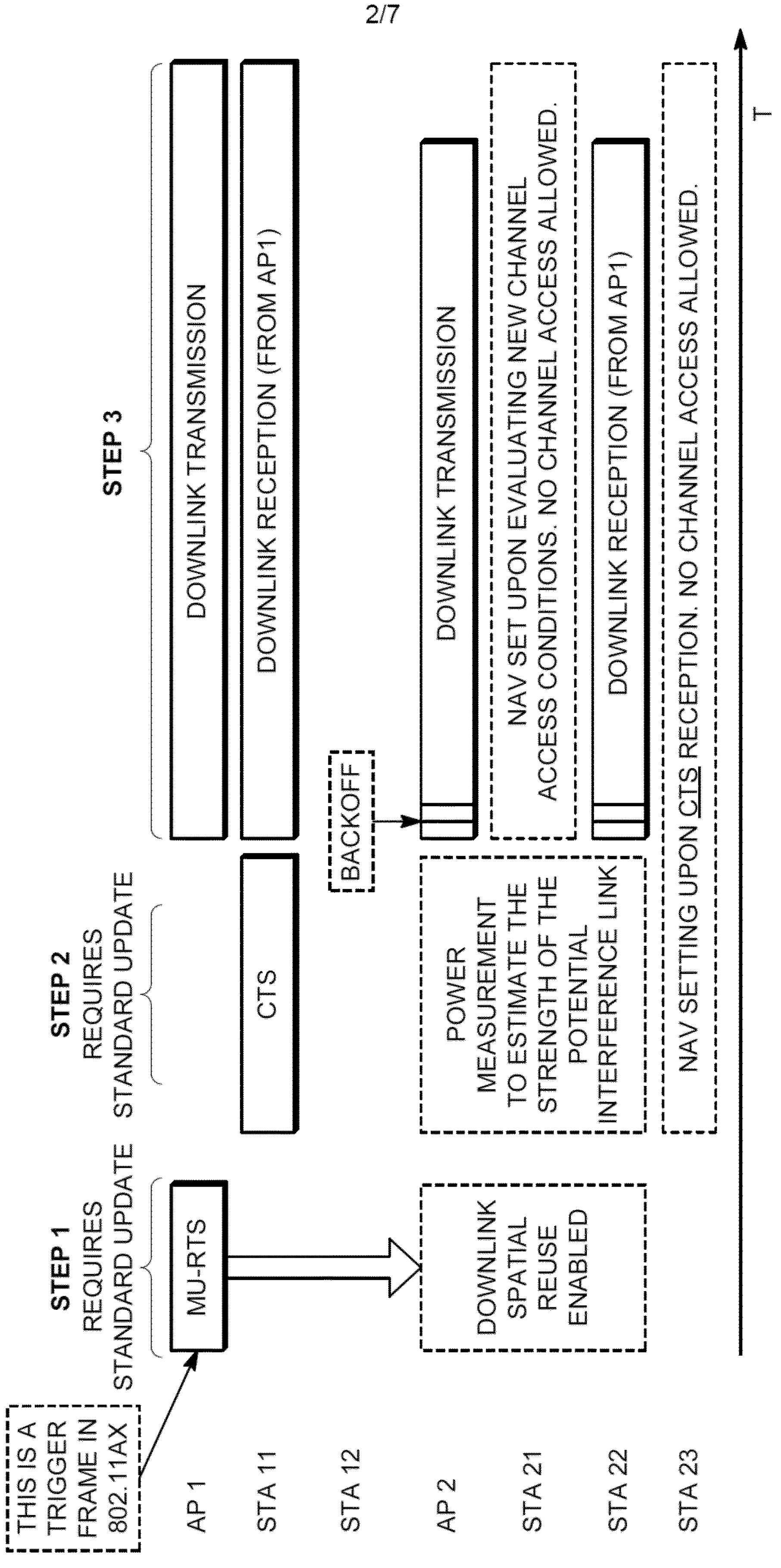

Figure 2: Illustration of the proposed procedure to enable a controlled spatial reuse during downlink based on the scenario considered in Figure 1.

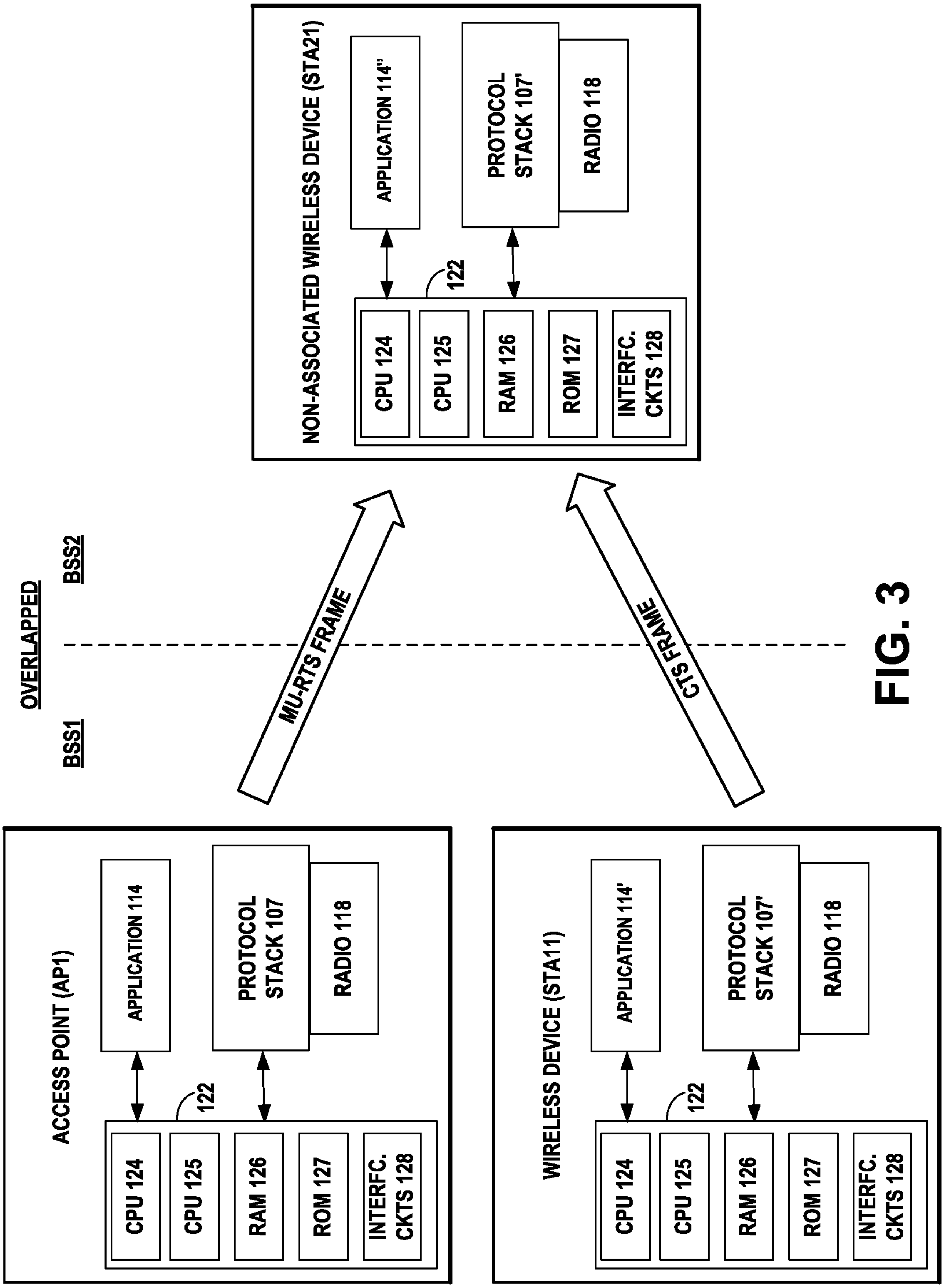
ACCESS POINT (AP1)
APPLICATION 114
PROTOCOL STACK 107
RADIO 118
122
CPU 124
CPU 125
RAM 126
ROM 127
INTERFC. CKTS 128
WIRELESS DEVICE (STA11)
APPLICATION 114'
PROTOCOL STACK 107'
RADIO 118
122
CPU 124
CPU 125
RAM 126
ROM 127
INTERFC. CKTS 128
BSS1
OVERLAPPED
BSS2
MU-RTS FRAME
CTS FRAME
NON-ASSOCIATED WIRELESS DEVICE (STA21)
APPLICATION 114"
PROTOCOL STACK 107'
RADIO 118
122
CPU 124
CPU 125
RAM 126
ROM 127
INTERFC. CKTS 128

FIG. 3

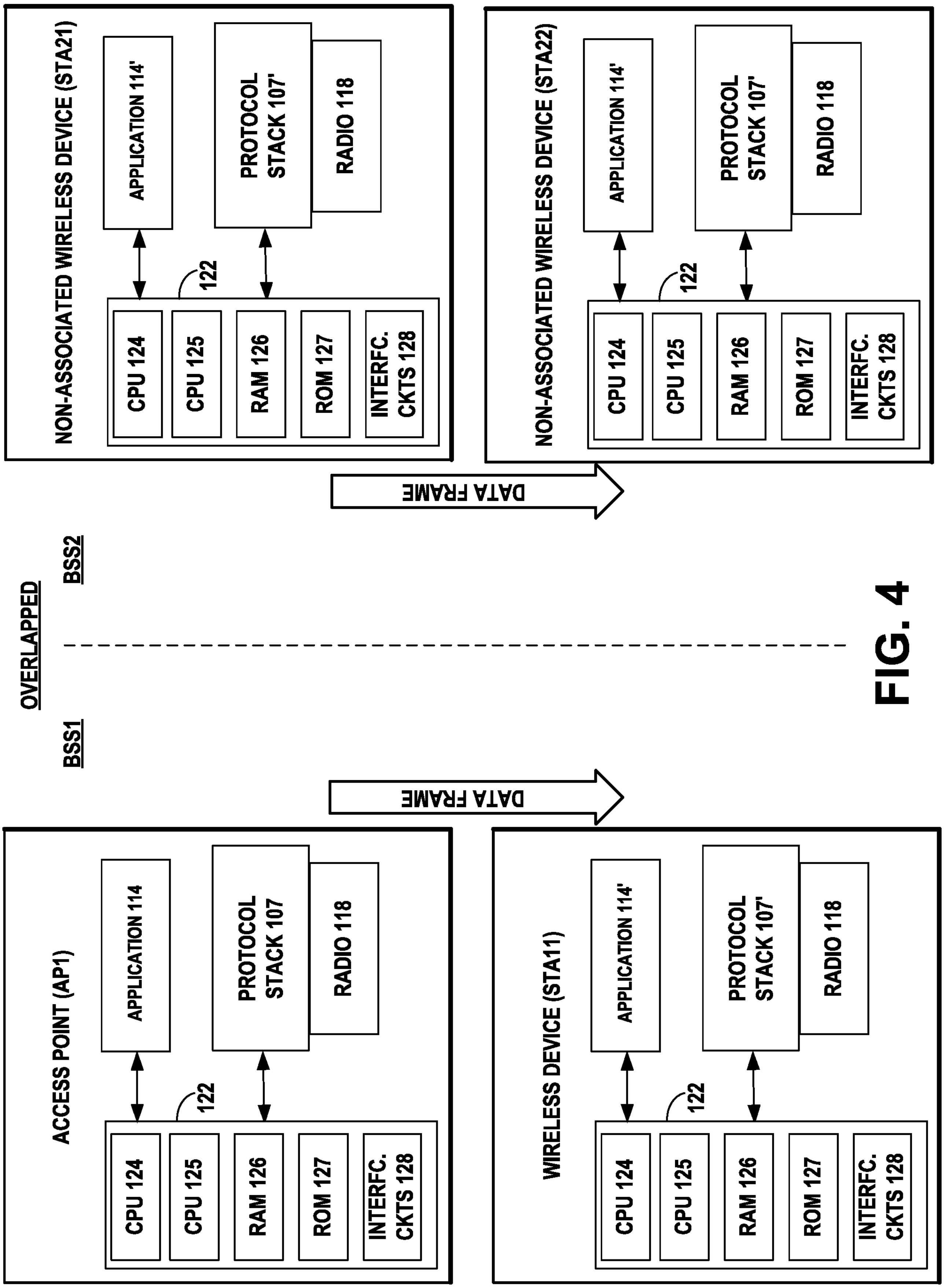
ACCESS POINT (AP1)
APPLICATION 114
PROTOCOL STACK 107
RADIO 118
122
CPU 124
CPU 125
RAM 126
ROM 127
INTERFC. CKTS 128
WIRELESS DEVICE (STA11)
APPLICATION 114'
PROTOCOL STACK 107'
RADIO 118
122
CPU 124
CPU 125
RAM 126
ROM 127
INTERFC. CKTS 128
DATA FRAME
BSS1
OVERLAPPED
BSS2
DATA FRAME
NON-ASSOCIATED WIRELESS DEVICE (STA21)
APPLICATION 114'
PROTOCOL STACK 107'
RADIO 118
122
CPU 124
CPU 125
RAM 126
ROM 127
INTERFC. CKTS 128
NON-ASSOCIATED WIRELESS DEVICE (STA22)
APPLICATION 114'
PROTOCOL STACK 107'
RADIO 118
122
CPU 124
CPU 125
RAM 126
ROM 127
INTERFC. CKTS 128

FIG. 4

FIG. 5A

OPERATIONAL STEPS IN THE NON-ASSOCIATED WIRELESS DEVICE (STA21)

400

STEP 402: RECEIVING VIA A WIRELESS MEDIUM, BY AN APPARATUS OF A FIRST WIRELESS NETWORK FROM A FIRST DEVICE OF A SECOND WIRELESS NETWORK, A REQUEST TO RESERVE THE WIRELESS MEDIUM FOR FURTHER FRAME EXCHANGE BETWEEN THE FIRST DEVICE OF THE SECOND WIRELESS NETWORK AND AT LEAST ONE SECOND DEVICE OF THE SECOND WIRELESS NETWORK,
WHEREIN THE REQUEST INDICATES SPATIAL REUSE OPPORTUNITY,
WHEREIN THE REQUEST COMPRISES A DURATION FIELD INDICATING A DURATION DURING WHICH A SUBSEQUENT FRAME IS EXPECTED TO BE TRANSMITTED FROM THE FIRST DEVICE OF THE SECOND WIRELESS NETWORK, AND
WHEREIN THE REQUEST COMPRISES A SPATIAL REUSE LEVEL FIELD INDICATING A SPATIAL REUSE PARAMETER;

STEP 404: RECEIVING, BY THE APPARATUS FROM AT LEAST ONE OF THE AT LEAST ONE SECOND DEVICE OF THE SECOND WIRELESS NETWORK, AN ACKNOWLEDGEMENT MESSAGE TO THE REQUEST AND DETERMINING A RECEPTION POWER LEVEL OF THE ACKNOWLEDGEMENT MESSAGE;

STEP 406: DETERMINING, BY THE APPARATUS, A TRANSMISSION THRESHOLD BASED AT LEAST IN PART ON THE SPATIAL REUSE PARAMETER AND THE RECEPTION POWER LEVEL; AND

STEP 408: IF A TRANSMISSION POWER OF THE APPARATUS IS LESS THAN THE TRANSMISSION THRESHOLD, TRANSMITTING, BY THE APPARATUS, AN OVERLAPPING FRAME TO ANOTHER APPARATUS OF THE FIRST WIRELESS NETWORK, WHEREIN THE OVERLAPPING FRAME IS TRANSMITTED AT LEAST IN PART SIMULTANEOUSLY WITH THE TRANSMISSION OF THE SUBSEQUENT FRAME FROM THE FIRST DEVICE OF THE SECOND WIRELESS NETWORK.

FIG. 5B

450

OPERATIONAL STEPS IN THE ACCESS POINT AP1 IN BSS1 ATTEMPTING TO PERFORM DOWNLINK DATA TRANSMISSION TO WIRELESS STATION STA11 IN ITS OWN BSS1 AND TO CONTROL SPATIAL REUSE BY NON-ASSOCIATED WIRELESS DEVICE STA21 IN THE OVERLAPPED BSS2

STEP 452: TRANSMITTING, BY AN ACCESS NODE IN A SECOND WIRELESS NETWORK, VIA A WIRELESS MEDIUM, A REQUEST TO RESERVE THE WIRELESS MEDIUM FOR FURTHER FRAME EXCHANGE BETWEEN THE ACCESS NODE OF THE SECOND WIRELESS NETWORK AND AT LEAST ONE SECOND DEVICE OF THE SECOND WIRELESS NETWORK,

WHEREIN THE REQUEST INDICATES SPATIAL REUSE OPPORTUNITY FOR WIRELESS DEVICES IN A FIRST WIRELESS NETWORK THAT IS AT LEAST PARTIALLY OVERLAPPED WITH THE SECOND WIRELESS NETWORK,

WHEREIN THE REQUEST COMPRISES A DURATION FIELD INDICATING A DURATION DURING WHICH A SUBSEQUENT FRAME IS EXPECTED TO BE TRANSMITTED FROM THE ACCESS NODE OF THE SECOND WIRELESS NETWORK, AND

WHEREIN THE REQUEST COMPRISES A SPATIAL REUSE LEVEL FIELD INDICATING A SPATIAL REUSE PARAMETER THAT IS A FUNCTION OF A MAXIMUM TRANSMISSION POWER OF ACKNOWLEDGEMENT MESSAGES TRANSMITTED BY AT LEAST ONE OF THE AT LEAST ONE SECOND DEVICE OF THE SECOND WIRELESS NETWORK AND AN ACTUAL MAXIMUM TOLERABLE INTERFERENCE LEVEL THAT THE AT LEAST ONE OF THE AT LEAST ONE SECOND DEVICE OF THE SECOND WIRELESS NETWORK CAN TOLERATE; AND

STEP 454: TRANSMITTING, BY THE ACCESS NODE IN THE SECOND WIRELESS NETWORK, AN OVERLAPPING FRAME TO THE AT LEAST ONE SECOND DEVICE OF THE SECOND WIRELESS NETWORK, WHEREIN THE OVERLAPPING FRAME IS TRANSMITTED AT LEAST IN PART SIMULTANEOUSLY WITH A TRANSMISSION OF A FRAME FROM AT LEAST ONE DEVICE OF THE WIRELESS DEVICES OF THE FIRST WIRELESS NETWORK.

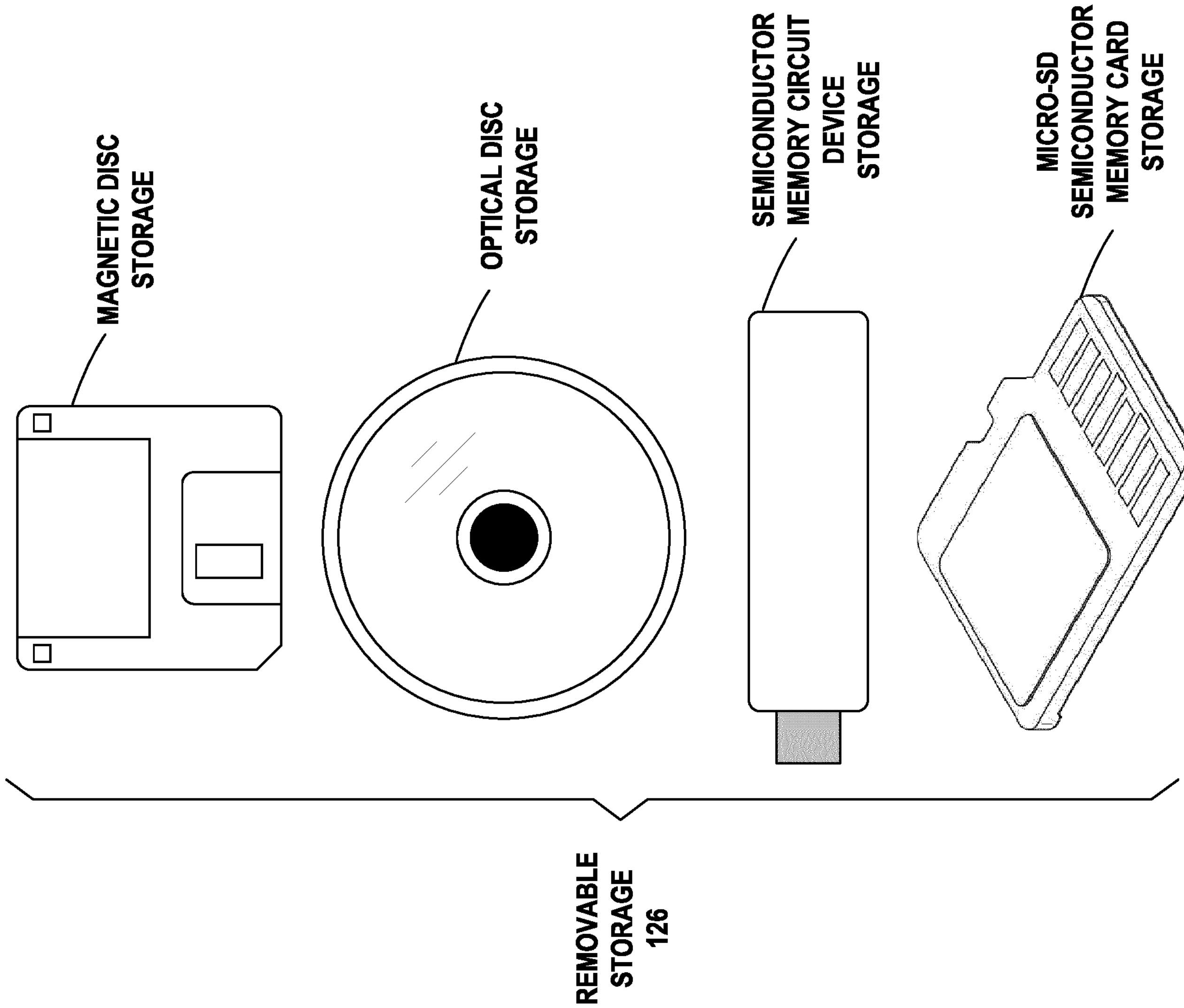
MAGNETIC DISC STORAGE
OPTICAL DISC STORAGE
SEMICONDUCTOR MEMORY CIRCUIT DEVICE STORAGE
MICRO-SD SEMICONDUCTOR MEMORY CARD STORAGE
REMOVABLE STORAGE 126

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/055606

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W74/00 H04B7/0452
ADD. H04W84/12 H04W16/14

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	MATTHEW FISCHER (BROADCOM LIMITED): "SRP-based SR Summary and Update", IEEE DRAFT; 11-17-0075-08-00AX-SRP-BASED-SR-SUMMARY-AND-UPDATE, IEEE-SA MENTOR, PISCATAWAY, NJ USA , vol. 802.11ax, no. 8 15 March 2017 (2017-03-15), pages 1-23, XP068115173, Retrieved from the Internet: URL:https://mentor.ieee.org/802.11/dcn/17/11-17-0075-08-00ax-srp-based-sr-summary-and-update.pptx [retrieved on 2017-03-15]	1-3,5-8, 10-13, 15-18, 20-28
Y	page 3 page 5 - page 6 page 8 - page 12 page 15 - page 16	4,7,9, 14,17,19

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[X] 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

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"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
8 May 2020	18/05/2020

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	page 18	
Y	MATTHEW FISCHER (BROADCOM LTD): "CR-SRG-and-SRP", IEEE DRAFT; 11-18-0026-10-00AX-CR-SRG-AND-SRP, IEEE-SA MENTOR, PISCATAWAY, NJ USA , vol. 802.11ax, no. 10 10 May 2018 (2018-05-10), pages 1-60, XP068125143, Retrieved from the Internet: URL:https://mentor.ieee.org/802.11/dcn/18/11-18-0026-10-00ax-cr-srg-and-srp.docx [retrieved on 2018-05-10] first row; page 21	4,9,14, 19
Y	ROSSI JUN LUO(HUAWEI): "OBSS NAV and PD Threshold Rule for Spatial Reuse ; 11-15-1109-01-00ax-obss-nav-and-pd-threshold-rule-for-spatial-reuse", IEEE DRAFT; 11-15-1109-01-00AX-OBSS-NAV-AND-PD-THRESHOLD-RULE-FOR-SPATIAL-REUSE, IEEE-SA MENTOR, PISCATAWAY, NJ USA, vol. 802.11ax, no. 1, 15 September 2015 (2015-09-15), pages 1-20, XP068098352, [retrieved on 2015-09-15] page 10 - page 12	7,17

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