DEVICE AND METHOD FOR NON-CONTIGUOUS MULTIPLE RESOURCE UNIT IN A WIRELESS NETWORK

TECHNICAL FIELD

The present disclosure relates to the communications field, and in particular, to a method and a wireless network device related to non-contiguous resource units (RUs) for the 802.11be standard. In particular, the disclosure provides a wireless network device for resource allocation. The wireless network device is configured to define a non-contiguous multiple resource unit (MRU), and to allocate the MRU to a wireless station. The wireless network device may be compatible with the 802.11ax standard or 802.11be standard, i.e., it may be referred to as a Wi-Fi device.

BACKGROUND

In the current 802.11ax standard, RUs with several sizes are defined, wherein each RU consists of contiguous frequency tones (except for rare cases regarding the middle small RU).

In particular, in the current 802.11ax standard there are 6 different sizes of RUs. In a resource allocation process, a scheduler, e.g. an Access Point (AP), can allocate only a single RU to a given wireless station (STA) for a PPDU transmitted to more than one user (MU-PPDU) transmission. That is, each non-AP STA is limited to being allocated a single RU. This means that the AP may allocate only a single RU to each of potentially multiple associated STAs, even if there exist available and non-occupied RUs. This limitation makes the resource allocation process inefficient, especially when channel puncturing is to be applied, and/or when the channel is relatively selective (i.e., the best RUs of a given STA are not necessarily close in the frequency domain).

Further, when a transmission is done for a single STA using a single-user PPDU (i.e., for a SU-PPDU transmission), then in the 802.11ax standard it is mandatory that the signal occupies the entire bandwidth (BW) of the channel, more specifically, the entire available BW. This means that for SU-PPDU there is no relevancy to RU.

A particular disadvantage in the case of MU-PPDU transmission is, consequently, that in case a selective channel exists, where there may be multiple and non-contiguous portions of the channel that experience a relatively high Signal-to-Noise Ratio (SNR), only one of these portions may be used. For example, as is depicted in FIG. 1, the highest SNR for a given non-AP STA may be achieved in RU#1, RU#3 and RU#8, however, the AP can transmit to this STA on only one of these RUs.

A particular disadvantage in the case of SU-PPDU transmission is, consequently, that if a portion of the channel is busy (e.g., the portion is used by an Overlapping Base Station Service (OBSS)), then the transmission is reduced to a smaller BW. For example, as is shown in FIG. 2, a portion of the channel (surrounded by the box) may be taken by an OBSS, thus, it is not available for the SU-PPDU transmission. In this case, a transmission of the SU-PPDU is limited to the two left free channels. Although the right channel is also free, it cannot be used.

SUMMARY

Embodiments of the invention are further based on the following considerations.

In the current 802.11ax standard, Orthogonal Frequency-Division Multiplexing Access (OFDMA) modulation was first introduced. The standard limits each non-AP STA to use a single RU comprised of contiguous frequency tones (e.g., comprised of contiguous sub-carriers). Although there are various different RU sizes defined in the current standard (26, 52, 106, 242, 484, 996 frequency tones, respectively), restricting the allocation to a single RU makes the dealing with the selective channel non-efficient.

In particular, for a channel BW smaller than 20MHz, there are defined RUs with 26 tones, 52 tones, and 102 tones. For a channel BW equal to or larger than 20MHz, there are defined RUs with 242 tones (20MHz), 484 tones (40MHz), 996 tones (80MHz), or 2X996 tones (160MHz). Further, also RUs with size bigger than 2X996, e.g. 2X1992 tones (for 320MHZ), are envisaged for Extreme High Throughput (EHT). Combinations of those RUs, in particular, combinations of RUs having different sizes (numbers of frequency tones), is not possible or envisaged in the current standard.

In view of the above-mentioned disadvantages and considerations, embodiments of the present invention aim to improve resource allocation in a wireless network. An objective is to allow

non-contiguous MRUs to be defined in the BW of a channel. Consequently, a goal is to improve the utilization of the channel. However, another aim is to avoid too many changes to the current 802.11ax standard.

The objective is achieved by the embodiments of the invention as described in the enclosed independent claims. Advantageous implementations of the embodiments of the invention are further defined in the dependent claims.

In particular, embodiments of the invention allow allocation of an MRU to the same STA, while the RUs (RU structure(s)) of the current standard may be kept.

A first aspect of the present disclosure provides a wireless network device, in particular a Wi-Fi device, for resource allocation, the wireless network device being configured to: define a non-contiguous multiple resource unit, MRU, in the bandwidth of a channel; wherein the channel comprises a plurality of resource units, RUs, and wherein the MRU is defined based on non-punctured RUs after puncturing one or more of the RUs of the channel and/or is defined by aggregating two or more non-adjacent RUs of the channel; and allocate the MRU to a wireless station.

The wireless network device of the first aspect allows defining the MRU based on multiple RUs. These RUs may each be as defined in the current 802.11ax standard, i.e., each RU may comprise a number of frequency tones or sub-carriers. The MRU definition also supports channel puncturing, in that a punctured “larger RU” (e.g., the entire channel or a channel segment, comprising multiple RUs) can be used as the MRU. Further, the MRU can be allocated to the wireless station (STA), i.e., STAs are not limited anymore to being allocated a single RU as in the 802.11ax standard.

The wireless network device may in addition be configured to define and allocate also a contiguous MRU to the STA, wherein the contiguous MRU comprises a plurality of differently sized RUs (e.g., at least two RUs of the MRU comprise a different number of frequency tones). The wireless network device may in addition be configured to further also allocate a single RU to the STA. That is, the wireless network device may be compatible with the current 802.11ax standard.

In an implementation form of the first aspect, the RUs are sub-channels.

For instance, the channel may be an 80MHz, 160MHz, 240MHz, or 320MHz channel, and the sub-channels may have a bandwidth of 20MHz and/or 40MHz.

In an implementation form of the first aspect, the channel comprises one, two, three or four 80MHz segments, and each 80MHz segment comprises four 20Mhz sub-channels.

That is, generally, the channel may be divided into a plurality of channel segments.

In other implementations, the channel may also comprise one 80MHz segment and one 160MHz segment or, respectively, may comprise two 160MHz segments. This is similar to three or four 80MHz segments, but not identical, because the standard may define that there cannot be three or four standalone 80MHz segments. Thus, if the BW is 240MHz, then it may be mandatory that one segment is a contiguous 160MHz segment. If the BW is 320MHz, then it may be mandatory to use two segments, wherein each is 160MHz (contiguous).

In an implementation form of the first aspect, the RUs each comprise a plurality of contiguous frequency tones.

In an implementation form of the first aspect, the frequency tones each have a 78.125 kHz bandwidth.

In an implementation form of the first aspect, each RU comprises 26, 52, 106, or 242 frequency tones.

Thus, the RUs may be RUs as defined in the 802.11ax standard.

In an implementation form of the first aspect, the wireless network device is further configured to aggregate two or more RUs, which comprise a different numbers of frequency tones.

The RUs may thereby be adjacent or non-adjacent in the channel BW, in particular, in a channel segment. Aggregating differently sized RUs is enabled, and is not possible in the 802.11ax standard.

In an implementation form of the first aspect, the MRU comprises at least two contiguous and/or non-contiguous parts, the parts having different bandwidths.

An MRU, as defined and allocated to the STA by the wireless network device may, in contrast to e.g. the 802.11ax standard, be non-contiguous. However, the wireless network device may

also define and allocate a contiguous MRU to the STA. Generally, an MRU may thus comprise more than one RU. Each RU may thereby be defined by its number of frequency tones, as described above, e.g., 26, 52, 106, 242, and so on. Thus, for example, an MRU may be defined by two RUs with 106 tones and 26 tones, respectively, i.e. in total 132 frequency tones. There is no definition the current 802.11ax standard for a RU with 132 frequency tones. The only way to have a RU with 132 tones (generally an MRU can also be considered a RU comprising multiple sub-RUs) is to combine such two RUs. In the given example, the RU with 106 frequency tones and the RU with 26 frequency tones may be either contiguous or non-contiguous.

In an implementation form of the first aspect, the wireless network device is further configured to transmit a packet to the wireless station utilizing the determined MRU.

In an implementation form of the first aspect, a preamble of the packet comprises information indicating, for transmitting the packet to the wireless station utilizing the determined MRU, the RUs that are used and/or the non-punctured RUs and/or the punctured RUs.

Thus, the STA is aware of the used RUs, i.e., also the definition and allocation of the MRU.

In an implementation form of the first aspect, the packet is a physical layer conformance procedure (PLCP) protocol data unit (PPDU), and the information is included in a Universal Signaling (U-SIG) or EHT Signaling (EHT-SIG) field of the preamble of the PPDU.

The PPDU may be a MU-PPDU or a SU-PPDU.

In an implementation form of the first aspect, the packet is a MU-PPDU; and the EHT-SIG field of the MU-PPDU comprises a sub-field for each of one or more wireless stations, and the information is included in the sub-field associated with the wireless station to which the packet is transmitted utilizing the determined MRU.

In an implementation form of the first aspect, the packet is a SU-PPDU or MU-PPDU; and the information is included as a bitmap in the U-SIG field of the SU-PPDU or MU-PPDU.

In an implementation form of the first aspect, the wireless network device is an access point of a Wi-Fi network.

That is, the wireless network device is configured according to a Wi-Fi standard, in particular, according to the 802.11ax or 802.11be standard.

A second aspect of the present disclosure provides a method for resource allocation, the method comprising: defining a non-contiguous multiple resource unit, MRU, in the bandwidth of a channel; wherein the channel comprises a plurality of resource units, RUs, and wherein the MRU is defined based on non-punctured RUs after puncturing one or more of the RUs of the channel and/or is defined by aggregating two or more non-adjacent RUs of the channel; and allocating the MRU to a wireless station.

In an implementation form of the second aspect, the RUs are sub-channels.

In an implementation form of the second aspect, the channel comprises one, two, three or four 80MHz segments, and each 80MHz segment comprises four 20Mhz sub-channels.

In an implementation form of the second aspect, the RUs each comprise a plurality of contiguous frequency tones.

In an implementation form of the second aspect, the frequency tones each have a 78.125 kHz bandwidth.

In an implementation form of the second aspect, each RU comprises 26, 52, 106, or 242 frequency tones.

In an implementation form of the second aspect, the method further comprises aggregating two or more RUs, which comprise a different numbers of frequency tones.

In an implementation form of the second aspect, the MRU comprises at least two contiguous and/or non-contiguous parts, the parts having different bandwidths.

In an implementation form of the second aspect, the method further comprises transmitting a packet to the wireless station utilizing the determined MRU.

In an implementation form of the second aspect, a preamble of the packet comprises information indicating, for transmitting the packet to the wireless station utilizing the determined MRU, the RUs that are used and/or the non-punctured RUs and/or the punctured RUs.

In an implementation form of the second aspect, the packet is a physical layer conformance procedure, PLCP, protocol data unit, PPDU, and the information is included in a Universal Signaling, U-SIG, or Extremely High Throughput Signaling, EHT-SIG, field of the preamble of the PPDU.

In an implementation form of the second aspect, the packet is a multi-user PPDU; and the EHT-SIG field of the multi-user PPDU comprises a sub-field for each of one or more wireless stations, and the information is included in the sub-field associated with the wireless station to which the packet is transmitted utilizing the determined MRU.

In an implementation form of the second aspect, the packet is a single-user PPDU or multi-user PPDU; and the information is included as a bitmap in the U-SIG field of the single-user PPDU or multi-user PPDU.

In an implementation form of the second aspect, the method is performed by a wireless network device, in particular, an access point of a Wi-Fi network.

The method of the second aspect and its implementation forms achieve all advantages and effects of the wireless network device according to the first aspect and its respective implementation forms.

A third aspect of the present disclosure provides a computer program comprising a program code for performing, when running on a computer, the method according to the second aspect or any implementation form thereof.

A fourth aspect of the present disclosure provides a non-transitory storage medium storing executable program code which, when executed by a processor, causes the method according to the second aspect or any of its implementation forms to be performed.

A fifth aspect of the present disclosure provides a method comprising, particularly in 802.11be: defining a non-contiguous resource unit, which is an aggregation of multiple single resource units, wherein each of the single resource units comprises a group of contiguous sub-carriers, e.g. the RUs defined in 802.11ax, which may be not-contiguous in the frequency domain.

In an implementation form of the fifth aspect, the multiple non-contiguous RUs may be of different sizes.

A sixth aspect of the present disclosure provides a second method comprising: defining a non-contiguous RU by using a single punctured RU, wherein its non-punctured portions may be seen as multiple separated (non-contiguous) RUs.

A seventh aspect of the present disclosure provides a transmission of a signal, wherein the transmission utilizes the methods of the second aspect or any of its implementation forms, the fifth aspect or its implementation form, or the sixth aspect, respectively, using non-contiguous RUs at the same time.

It has to be noted that all devices, elements, units and means described in the present application could be implemented in the software or hardware elements or any kind of combination thereof. All steps which are performed by the various entities described in the present application as well as the functionalities described to be performed by the various entities are intended to mean that the respective entity is adapted to or configured to perform the respective steps and functionalities. Even if, in the following description of specific embodiments, a specific functionality or step to be performed by external entities is not reflected in the description of a specific detailed element of that entity which performs that specific step or functionality, it should be clear for a skilled person that these methods and functionalities can be implemented in respective software or hardware.

BRIEF DESCRIPTION OF DRAWINGS

The above described aspects and implementation forms will be explained in the following description of specific embodiments in relation to the enclosed drawings, in which

FIG. 1 shows a selective channel with non-contiguous high Signal-to-Noise-Ratio (SNR) portions.

FIG. 2 shows a SU-PPDU when a portion of the channel is busy.

FIG. 3 shows a wireless network device according to an embodiment of the invention.

FIG. 4 shows an MRU defined by the wireless network device of FIG. 3.

FIG. 5 shows a first alternative for defining a non-contiguous MRU, which may be performed by a wireless network device according to an embodiment of the invention.

FIG. 6 shows a second alternative for defining a non-contiguous MRU, which may be performed by a wireless network device according to an embodiment of the invention.

FIG. 7 shows an example of a RU allocation subfield included in a preamble of a packet.

FIG. 8 shows an example of signaling a non-contiguous MRU.

FIG. 9 shows an example of signaling and using a non-contiguous MRU for SU-PPDU.

FIG. 10 shows a first example of aggregation for defining a non-contiguous MRU, and allocating it to the same STA.

FIG. 11 shows a second example of aggregation for defining a non-contiguous MRU, and allocating it to the same STA.

FIG. 12 shows the second example of aggregation for defining a non-contiguous MRU, and allocating it to the same STA.

FIG. 13 shows an example of using both alternatives for defining a non-contiguous MRU separately at the same time.

FIG. 14 shows an example of using both alternatives for defining a non-contiguous MRU in a mixed format.

FIG. 15 shows a method according to an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 3 shows a wireless network device 300 according to an embodiment of the invention. The wireless network device 300 is suitable for resource allocation, e.g. to a STA 303, in a wireless network. The wireless network device 300 may be a Wi-Fi device, e.g. according to the 802.11ax standard or the 802.11be standard. In particular, the wireless network device 300 may be an AP of the wireless network.

The wireless network device 300 may comprise a processor or processing circuitry (not shown) configured to perform, conduct or initiate the various operations of the wireless network device 300 described herein. The processing circuitry may comprise hardware and/or the processing circuitry may be controlled by software. The hardware may comprise analog circuitry or digital circuitry, or both analog and digital circuitry. The digital circuitry may comprise components such as application-specific integrated circuits (ASICs), field-programmable arrays (FPGAs), digital signal processors (DSPs), or multi-purpose processors.

The wireless network device 300 may further comprise memory circuitry, which stores one or more instruction(s) that can be executed by the processor or by the processing circuitry, in particular under control of the software. For instance, the memory circuitry may comprise a non-transitory storage medium storing executable software code which, when executed by the processor or the processing circuitry, causes the various operations of the wireless network device 300 to be performed.

In one embodiment, the processing circuitry comprises one or more processors and a non-transitory memory connected to the one or more processors. The non-transitory memory may carry executable program code which, when executed by the one or more processors, causes the wireless network device 300 to perform, conduct or initiate the operations or methods described herein.

The wireless network device 300 is configured to define a non-contiguous MRU 400 in the bandwidth of a channel 301, and to further allocate the MRU 400 to the STA 303. FIG. 4 shows an example of such an MRU 400 as defined by the wireless network device 300 of FIG. 3. The channel 301 comprises a plurality of RUs 401, e.g. sub-channels. Each RU 401 may comprise frequency tones. Different RUs may comprise the same or a different number of frequency tones.

The wireless network device 300 may define the MRU 400 either based on non-punctured RUs 401 of the channel 310 – after puncturing one or more of the RUs 401 of the channel 301, i.e. obtaining one or more punctured RUs 401p – and/or by aggregating two or more non-adjacent RUs 401 of the channel 301 (in this case, the RUs 401p are not-aggregated/left-out RUs when defining the MRU 400).

The wireless network device 300 may further be configured to transmit a packet 302 to the STA 303 over the channel. This transmission may utilize the MRU 400. The MRU 400 definition may be indicated to the STA 303 by the packet 302, e.g., in a preamble of the packet 302.

Notably, in the present disclosure the notation “MRU” (the aggregated RUs 401 or a punctured set of RUs 401, e.g., in the channel 301 or in a channel segment), and “RU” (e.g., the smallest frequency resource that can be allocated in the channel) are used. However, other notations may be used. For instance, the “MRU” may be referred to as a “larger RU” and the “RUs” as “smaller RUs”. For example, the MRU 400 defined “based on non-punctured RUs 401 after puncturing one or more of the RUs” may also be referred to as a “large RU with some unavailable

channels/tones", wherein the "channels/tones" are the RUs 401. Further, the MRU defined by "aggregating two or more non-adjacent RUs 401" may also be referred to as "an aggregation of two channels", wherein a "channel" is an RU 401. All notations result the same technical result. Thus, embodiments of the invention should not be limited by the used notation.

Further, the present disclosure also uses the notation "channel" (overall BW), and sometimes refers to "channel segment" (e.g., a logical separation of the channel BW), and sometimes refers to "sub-channel" (e.g., the smallest frequency resource in the channel, i.e. the RU 401). However, other notations may be used. For instance, the "sub-channels" may also be referred to as "channels" that are included in a certain BW. Thus, embodiments of the invention should also not be limited by these used notation.

In an example, the channel 301 may be an 80MHz channel, and may comprise four 20MHz sub-channels 401. For defining the MRU 400, a punctured 20MHz portion of the channel 301 may be defined, i.e., one sub-channel 401 of the channel 301 may be a punctured/left-out sub-channel 401p.

The remaining 60MHz (three non-punctured RUs/sub-channels 401) of the MRU 400 in the channel 301 may be regarded as either as one "larger RU" (MRU 400) with some unavailable/punctured sub-channels/channels/tones (alternative 1), or as an aggregation of two RUs/sub-channels/channels (e.g. 20MHz + 40MHz) to form a "larger RU" (MRU 400) (alternative 2). Both alternatives 1 and 2 are not supported in the current 80211ax standard. For allocating the MRU 400 in the channel 301 to a single user (e.g., either as part of a MU-PPDU that is transmitted over a larger BW, or as an 80MHz SU-PPDU), both of the above alternatives 1 and 2 may be considered.

In the following, alternative 1 is described in more detail, i.e., an embodiment of the wireless network device 300 is described, wherein the wireless network device 300 may at least use the alternative 1 to define the MRU 400 in the BW of the channel 301.

The MRU 400 is enabled to be a punctured "larger RU" as shown in FIG. 5. In particular, FIG. 5 shows a case for MU-PPDU, wherein the MRU400 may be defined by multiple RUs 401 in the BW of the channel 301, wherein some RUs 401p in the BW of the channel 301 are punctured. The channel 301 may notably comprises more than one channel segment 500. Further, different MRUs 400 for different STAs (STA 1 and STA 2 in FIG. 5) may be defined in the channel BW, e.g., in different channel segments 500. For example, in FIG. 5, a STA 1 gets the whole

punctured first channel segment 500, wherein a STA 2 cannot use any of the RUs 401 in the first channel segment 500 (left side). Further, the STA 2 gets the whole punctured second channel segment 500, wherein the STA 1 cannot use any of the RUs 401 in the second channel segment 500 (right side). The RUs 401 may exemplarily all comprise the same number, e.g. 242, frequency tones.

Defining the MRU 400 is this way may mean that a single user-field per STA (here for STA 1 and 2) in the SIG-B field or U-SIG field (of a preamble of the transmitted packet 302, e.g., MU-PPDU) may be required, similarly to the 802.11ax standard. However, the RU granularity may be limited, i.e., multiple STAs 303 may not be able to coexist in the same MRU 400 in a non-MU-MIMO (Multiple Input Multiple Output) allocation.

Alternative 1 may also be used for SU-PPDU and supports puncturing, as shown in FIG. 6. Here, the alternative 1 yields significant improvement in channel utilization. Notably, SU-PPDU with puncturing is not supported in the current 802.11ax standard, but is assumed to be added in the 802.11be standard.

In order to enable this type of non-contiguous MRU 400 as part of the 802.11be standard, the RU allocation subfield of SIG-B or U-SIG should be modified/designed to support:

1. 1992-RU and 3984-RU (i.e. MRUs 400).
2. 16 SS for any RU>=106 (i.e. MRUs 400)
3. Empty 242-RU as part of a larger RU (i.e., MRU 400).

In the 802.11ax standard, in the RU Allocation subfield in the preamble of a packet 302, there is not enough room to support (1) and (2) above, but in the 802.11be standard, it may be modified/designed to address this issue. In this disclosure (3) above is dealt with.

New entries may be added in the RU Allocation subfield (SIG-B or U-SIG) to indicate a punctured 242-MRU that is a portion of a channel 301 or channel segment 500 (may be referred to as a “larger RU” or “wider RU”). For instance, the field content 011101x1x0 may be used to indicate an empty 242-tone MRU that is a part of a 996/1992/3984 RU as shown in FIG. 7. For instance:

a. 01110100 - empty 242-tone RU as part of 996-RU
b. 01110101 - empty 242-tone RU as part of 1992-RU

c. 01110110 - empty 242-tone RU as part of 3984-RU

d. 01110111 - reserve

FIG. 8 shows an example of signaling a non-contiguous MRU 400, in particular, a non-contiguous MRU 400 of size 160MHz (1992-RU) using the above procedure.

In MU-PPDU, the content of B7-B0 of the RU allocation subfield (SIG-B or U-SIG) for each content channel together with the STA-ID field (identification of the STA 303) in the user-specific field determine the punctured 1992 MRU structure and the STA 303 that got it. In SU-PPDU, the non-contiguous MRU 400 structure may be enabled by leveraging the puncturing method that will be defined in the 802.11be standard.

For example, as shown in FIG. 9, the puncturing method may employ a bitmap B0…B5 that determines which portions of the channel 301 are actually used in the SU-PPDU, according to the availability of the various RU-242's. This puncturing method is just an example.

In the following, alternative 2 is described in more detail, i.e., an embodiment of the wireless network device 300 is described, wherein the wireless network device 300 may at least use the alternative 2 to define the MRU 400 in the BW of the channel 301.

In this alternative 2, it is allowed to allocate multiple RUs 401 to the same STA 303, contrary to the current 802.11ax standard, which limits the number of RUs per STA 303 to one. Allowing multiple RUs 401 per STA 303 means that the limitation is increased to more than one, i.e. a specific limitation may be defined. Defining more than one RU 401 to the same STA 303 means that the allocation process is more flexible, and it also increases the frequency diversity and by that it solves the problem illustrated in FIG. 1.

An example, for how to aggregate multiple RUs 401 to an MRU 400, in particular, multiple MRUs 400 to multiple STAs 303 is given in FIG. 10. In particular, alternative 2 allows aggregating RUs 401 of any size, i.e., of any number of frequency tones, as illustrated in FIG. 11. In this example, and MRU 400 for one STA 303 is an aggregation of a RU 401 with 106 frequency tones (the left-most RU 401 in the figure) and a RU 401 with 26 frequency tones (the right-most RU 401 in the figure).

In order to enable such RU 401 aggregation of any size, the following parameters may be defined in the 802.11ax standard:

$$N_{CBPS,u} = \sum_{n=1}^{N_{RU,u}} N_{CBPS,u,n}$$

$$N_{CBPSS,u} = \sum_{n=1}^{N_{RU,u}} N_{CBPSS,u,n}$$

$$N_{DBPS,u} = \sum_{n=1}^{N_{RU,u}} N_{DBPS,u,n}$$

$$N_{SD,u} = \sum_{n=1}^{N_{RU,u}} N_{SD,u,n}$$

$$N_{SP,u} = \sum_{n=1}^{N_{RU,u}} N_{SP,u,n}$$

$$N_{ST,u} = \sum_{n=1}^{N_{RU,u}} N_{ST,u,n}$$

$N_{RU,u}$ is the number of RUs 401 allocated to a user (STA) denoted u).

A tone mapping distance parameter (DTM) may be maintained for each RU 401, separately. For example, consider the left-most and the right-most RUs 401 in FIG. 12, which are allocated to the same STA 303 (e.g., u=1, $N_{RU,u}$=2, MCS3). In this, for example:

$$N_{SD,1} = N_{SD,u,1} + N_{SD,u,2} = 102 + 24 = 126$$
$$N_{CBPS,1} = N_{CBPS,u,1} + N_{CBPS,u,2} = 408 + 96 = 504$$
$$N_{DBPS,1} = N_{DBPS,u,1} + N_{DBPS,u,2} = 204 + 48 = 252$$

It is also possible that the two alternatives 1 and 2 coexist, i.e., a wireless network device 300 according to an embodiment of the invention may be configured to define a MRU 400 according to both alternatives (at the same time). In particular, the two alternatives 1 and 2 may coexist (i.e. may be used at the same time) either separately or mixed. “Separately” means that a given STA uses a non-contiguous MRU 400 defined by employing one alternative of the above in a first portion of the channel 301, while a second STA uses a non-contiguous MRU 400 defined by the other alternative 2 in a second, separate portion of the channel 301. This is illustrated in

FIG. 13. “Mixed” means that a given STA may have an allocation of a MRU 400 defined by using both alternatives 1 and 2 at the same time, as illustrated in FIG. 14. In this example, a same STA may use (i.e., is allocated) a MRU 400 defined by (mixed) alternatives 1 and 2, while all other STAs use, e.g., alternative 2.

FIG. 15 shows a method 1500 according to an embodiment of the invention. The method 1500 is for resource allocation, and may be performed by the wireless network device 300. The method 1500 comprises a step 1501 of defining a non-contiguous MRU 400 in the bandwidth of a channel 301. The channel 301comprises a plurality of RUs 401. Further, the MRU 400 is defined based on non-punctured RUs 401 after puncturing one or more of the RUs, i.e. by obtaining one or more punctured RUs 401p of the channel 301 and/or is defined by aggregating two or more non-adjacent RUs 401 of the channel 301. Further, the method 1500 comprises a step 1502 of allocating the MRU 400 to a wireless station 303 (STA).

In summary, it is suggested to expand and improve the method of utilizing the channel resources in the 802.11be standard, by allowing the use of multiple and non-contiguous portions (RUs 401) of the channel 301 to define a MRU 400. Supporting an MRU 400 and non-contiguous RUs 401 to be allocated to the same STA 303 improves the channel utilization by making it more efficient, due to enhancing the capability of leveraging the channel selectivity. Improving the usage of the channel 301 may increase the overall system throughput and performance.

In particular, the 802.11ax RU definition is far from being optimal. In particular, the inability to aggregate MRUs for the same STA makes the channel utilization sub-optimal especially in two common cases: when channel puncturing exists; and when the channel is selective.

The present disclosure presents two alternatives 1 and 2 to apply an MRU 400 per STA without adding overhead to MU-PPDU, and by adding only a small amount of overhead to SU-PPDU. By allowing puncturing in SU-PPDU, and by allowing the use of non-contiguous RUs, the channel utilization for SU-PPDU can be significantly improved.

The present invention has been described in conjunction with various embodiments as examples as well as implementations. However, other variations can be understood and effected by those persons skilled in the art and practicing the claimed invention, from the studies of the drawings, this disclosure and the independent claims. In the claims as well as in the description the word “comprising” does not exclude other elements or steps and the indefinite article “a” or “an” does not exclude a plurality. A single element or other unit may fulfill the functions of several

entities or items recited in the claims. The mere fact that certain measures are recited in the mutual different dependent claims does not indicate that a combination of these measures cannot be used in an advantageous implementation.

CLAIMS

1. A method (1500) for resource allocation, the method (1500) comprising:

defining (1501) a non-contiguous multiple resource unit, MRU, (400) in the bandwidth of a channel (301);

wherein the channel (301) comprises a plurality of resource units, RUs, (401, 401p) and

wherein the MRU (400) is defined based on non-punctured RUs (401) after puncturing one or more of the RUs (401p) of the channel (301) and/or is defined by aggregating two or more non-adjacent RUs (401) of the channel (301); and

allocating (1502) the MRU (400) to a wireless station (303).

2. The method (1500) according to claim 1, wherein:

the RUs (401) are sub-channels.

3. The method (1500) according to claim 2, wherein:

the channel (301) comprises one, two, three or four 80MHz segments (500), and each 80MHz segment (500) comprises four 20Mhz sub-channels (401).

4. The method (1500) according to claim 1, wherein:

the RUs (401) each comprise a plurality of contiguous frequency tones.

5. The method (1500) according to claim 4, wherein:

the frequency tones each have a 78.125 kHz bandwidth.

6. The method (1500) according to any one of the claims 1 to 5, wherein:

the MRU (400) comprises one 26-tone RU and one 52-tone RU;

the MRU (400) comprises one 26-tone RU and one 106-tone RU; or

the MRU (400) comprises one 242-tone RU and one 484-tone RU.

7. The method (1500) according to any one of the claims 1 to 6, wherein:

the MRU (400) comprises at least two contiguous and/or non-contiguous parts.

8. The method (1500) according to any one of the claims 1 to 7, comprising:

transmit a packet (302) to the wireless station (303) utilizing the determined MRU (400).

9. The method (1500) according to claim 8, wherein:

a preamble of the packet (302) comprises information indicating, for transmitting the packet (302) to the wireless station (303) utilizing the determined MRU (400), the RUs (401) that are used and/or the non-punctured RUs (401) and/or the punctured RUs (401p).

10. The method (1500) according to claim 9, wherein:

the packet (302) is a physical layer conformance procedure, PLCP, protocol data unit, PPDU, and the information is included in a Universal Signaling, U-SIG, or Extremely High Throughput Signaling, EHT-SIG, field of the preamble of the PPDU.

11. The method (1500) according to claim 10 wherein:

the packet (302) is a multi-user PPDU; and

the EHT-SIG field of the multi-user PPDU comprises a sub-field for each of one or more wireless stations (303), and the information is included in the sub-field associated with the wireless station (303) to which the packet is transmitted utilizing the determined MRU (400).

12. The method (1500) according to claim 10, wherein:

the packet (302) is a single-user PPDU or multi-user PPDU; and

the information is included as a bitmap in the U-SIG field of the single-user PPDU or multi-user PPDU.

13. The method (1500) according to any one of the claims 1 to 12, wherein:

the method (1500) is executed in an access point of a Wi-Fi network.

14. A wireless network device (300), in particular a Wi-Fi device, for resource allocation, the wireless network device (300) being configured to implement the method according to any one of claims 1 to 13.

15. A computer program comprising a program code for performing, when running on a computer, the method (1500) according to any one of claims 1 to 13.

16. A non-transitory storage medium storing executable program code which, when executed by a processor, causes the method according to any one of claims 1 to 13 to be performed.