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(54) APPLICATION OF ALLOCATING WIRELESS LINKS OF ACCESS POINT MULTI-LINK DEVICE FOR WIRELESS STATIONS

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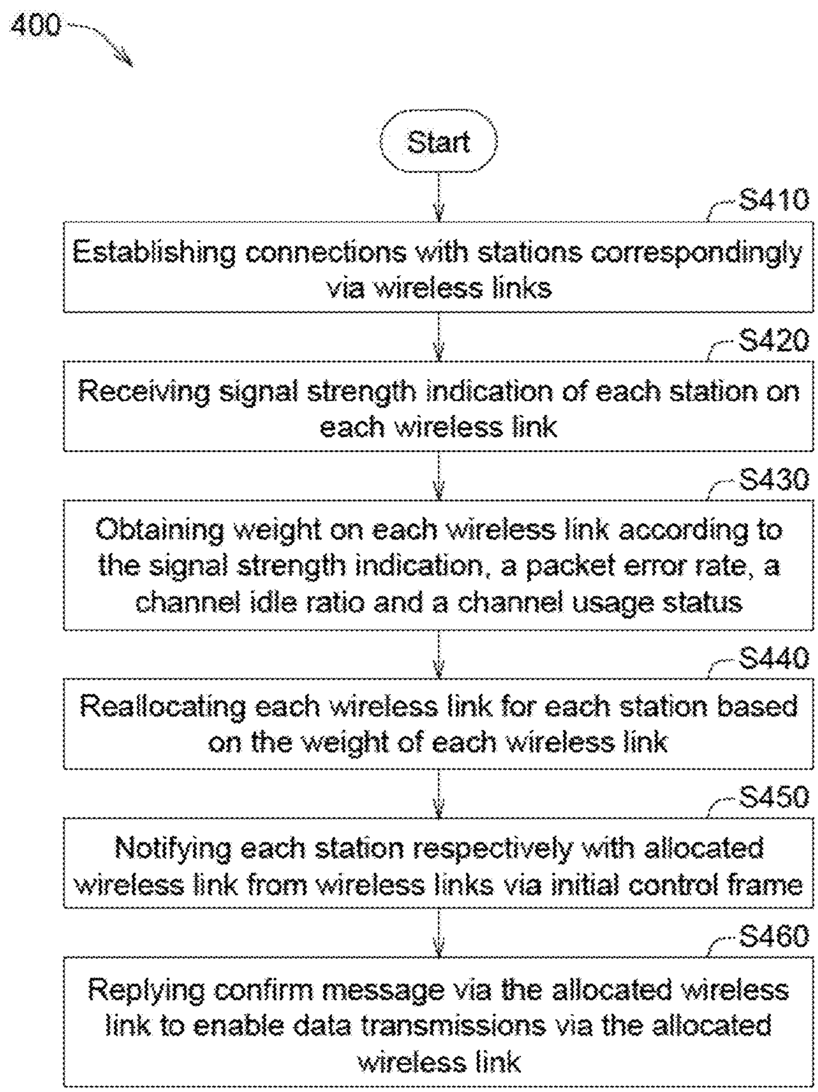
(57) **ABSTRACT**

In an aspect of the disclosure, a method for allocating wireless links of an access point (AP) multi-link device (MLD) is provided. The method comprises: establishing connections with stations correspondingly via wireless links; receiving a signal strength indication of each station on each wireless link; obtaining a weight on each wireless link according to the signal strength indication, a packet error rate, a channel idle ratio and a channel usage status; allocating each wireless link for each station based on the weight of each wireless link; and notifying each station respectively with an allocated wireless link from wireless links via an initial control frame.



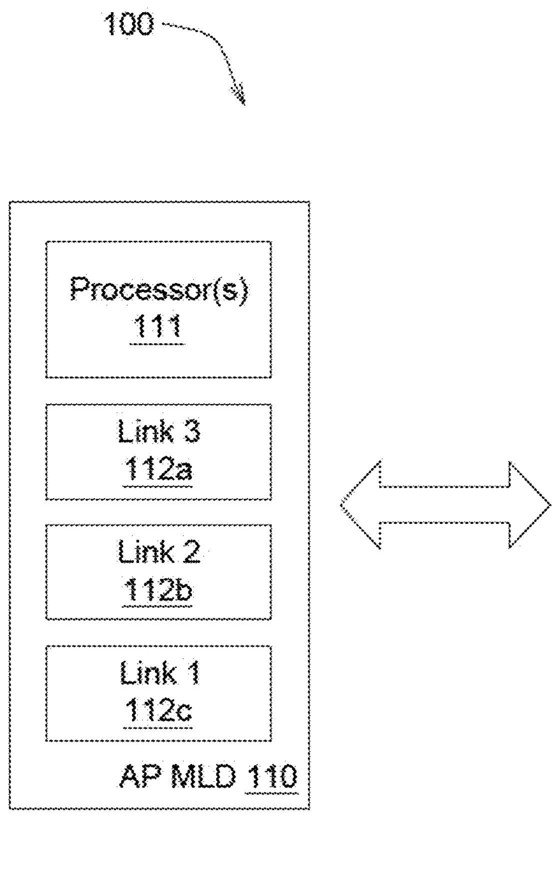

100
Processor(s)
111
Link 3
112a
Link 2
112b
Link 1
112c
AP MLD 110
STA 3 122a
STA 2 122b
STA 1 122c
Non-AP MLD 1 120
STA 3 132a
STA 2 132b
STA 1 132c
Non-AP MLD 2 130
Legacy STA 140

FIG. 1A

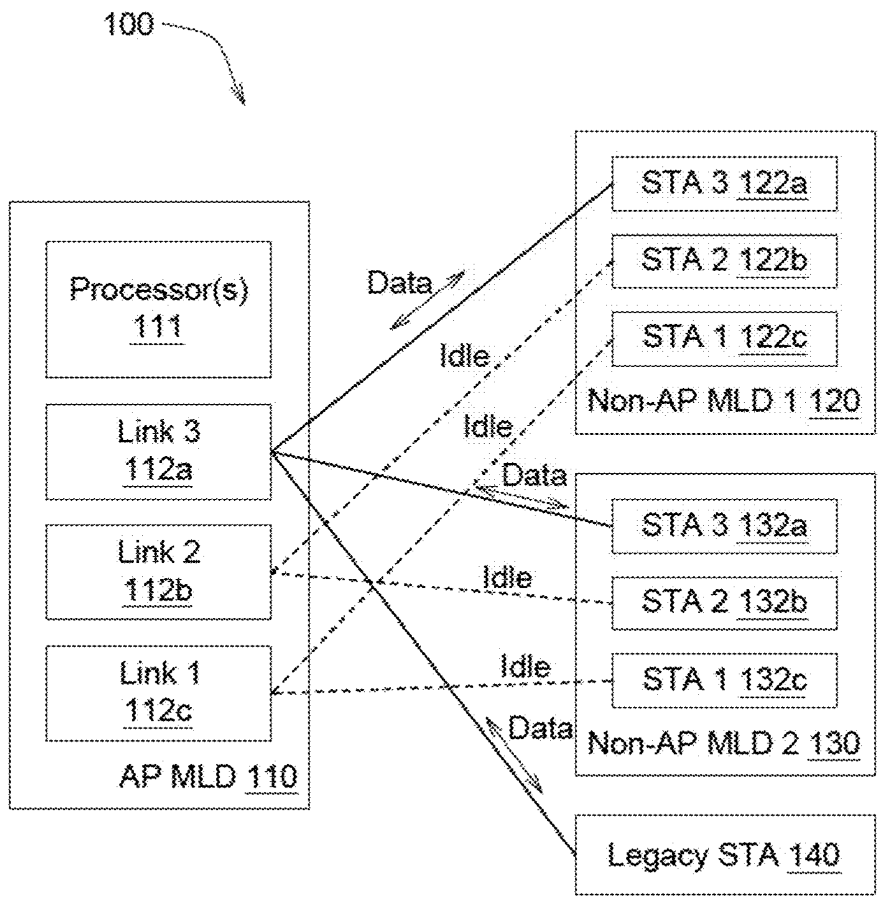

100
Processor(s) 111
Link 3 112a
Link 2 112b
Link 1 112c
AP MLD 110
Data
Idle
Idle
Data
Idle
Idle
Data
STA 3 122a
STA 2 122b
STA 1 122c
Non-AP MLD 1 120
STA 3 132a
STA 2 132b
STA 1 132c
Non-AP MLD 2 130
Legacy STA 140

FIG. 1B

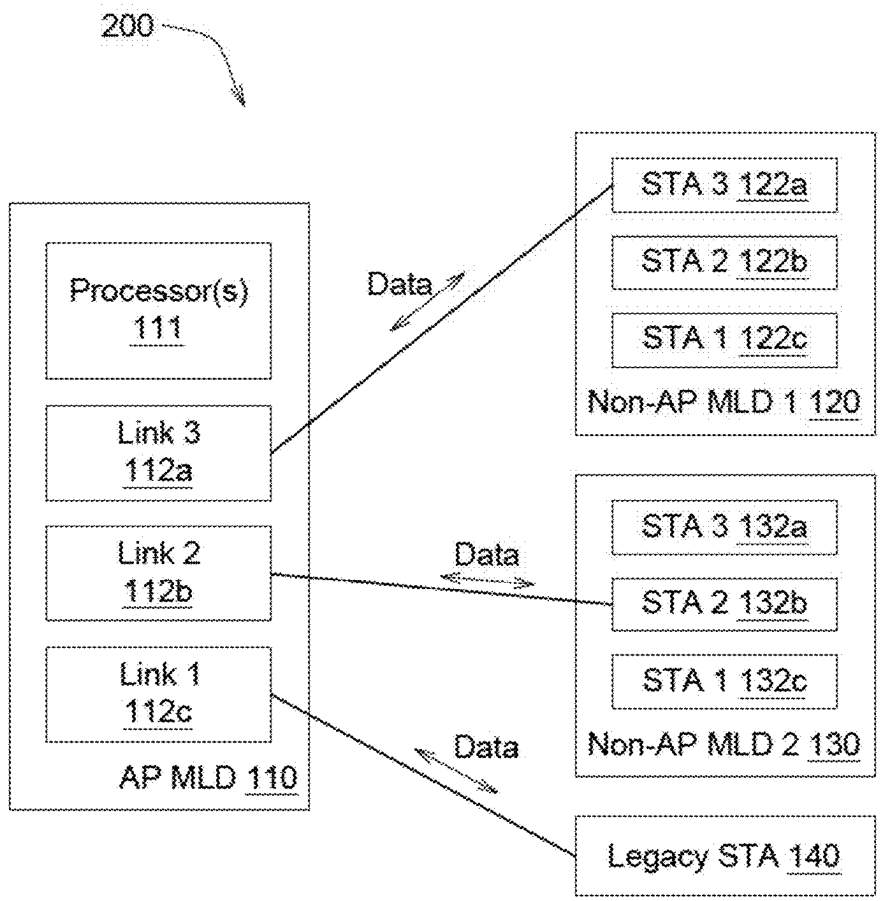

200
Processor(s) 111
Link 3 112a
Link 2 112b
Link 1 112c
AP MLD 110
Data
STA 3 122a
STA 2 122b
STA 1 122c
Non-AP MLD 1 120
Data
STA 3 132a
STA 2 132b
STA 1 132c
Non-AP MLD 2 130
Data
Legacy STA 140

FIG. 1C

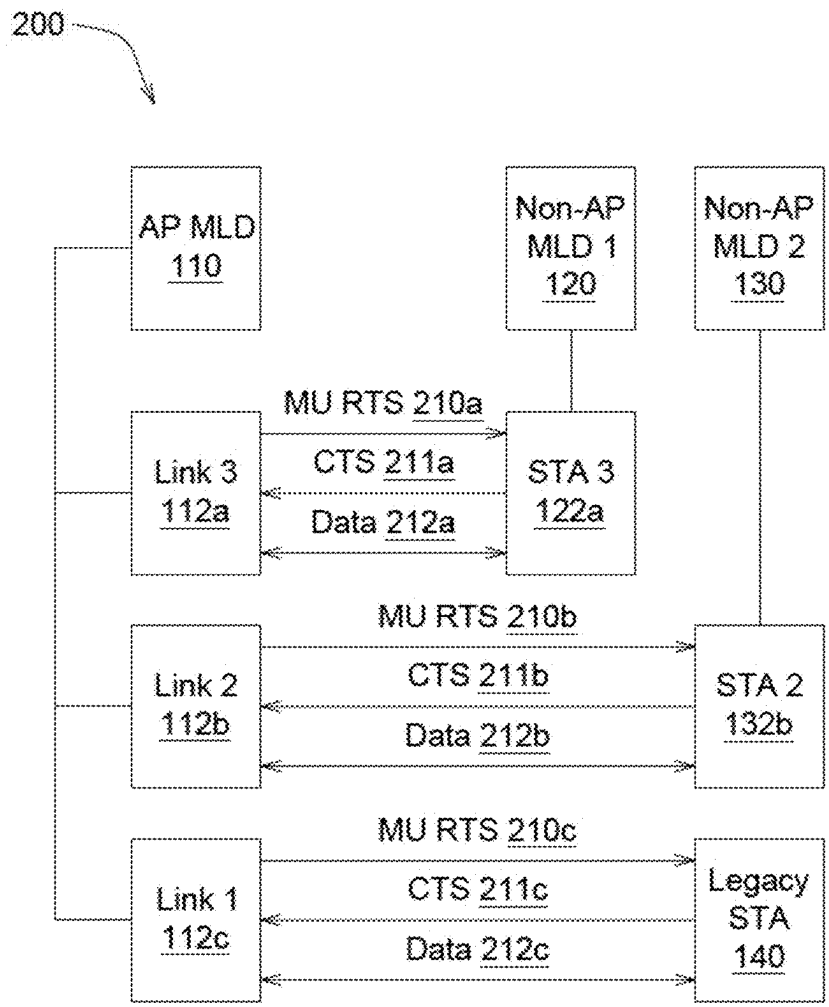

200
AP MLD
110
Non-AP
MLD 1
120
Non-AP
MLD 2
130
MU RTS 210a
CTS 211a
Data 212a
Link 3
112a
STA 3
122a
MU RTS 210b
CTS 211b
Data 212b
Link 2
112b
STA 2
132b
MU RTS 210c
CTS 211c
Data 212c
Link 1
112c
Legacy
STA
140

FIG. 2

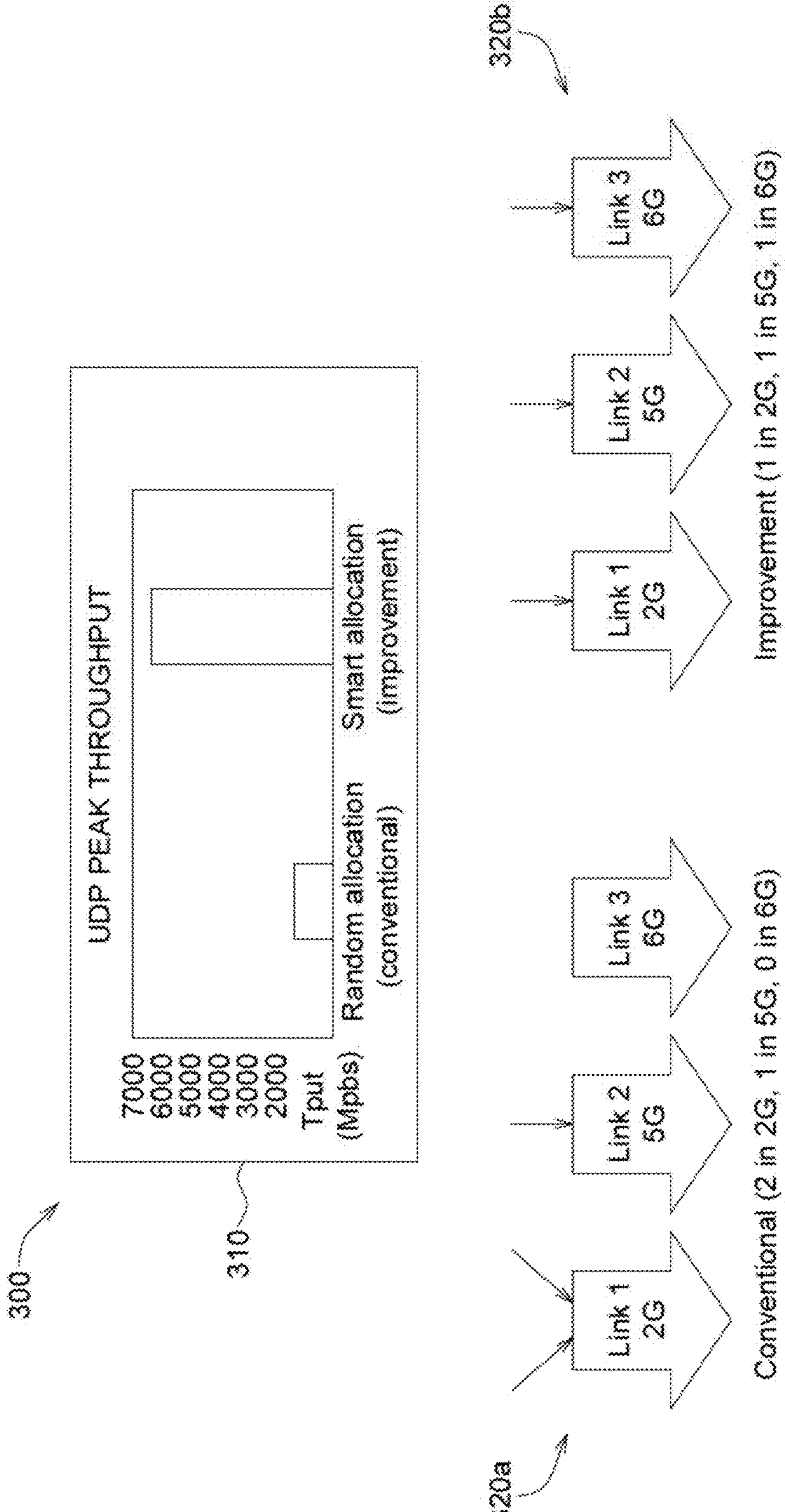

300
310
UDP PEAK THROUGHPUT
7000
6000
5000
4000
3000
2000
Tput (Mpbs)
Random allocation (conventional)
Smart allocation (improvement)
Link 1 2G
Link 2 5G
Link 3 6G
Conventional (2 in 2G, 1 in 5G, 0 in 6G)
Link 1 2G
Link 2 5G
Link 3 6G
Improvement (1 in 2G, 1 in 5G, 1 in 6G)
320a
320b

FIG. 3

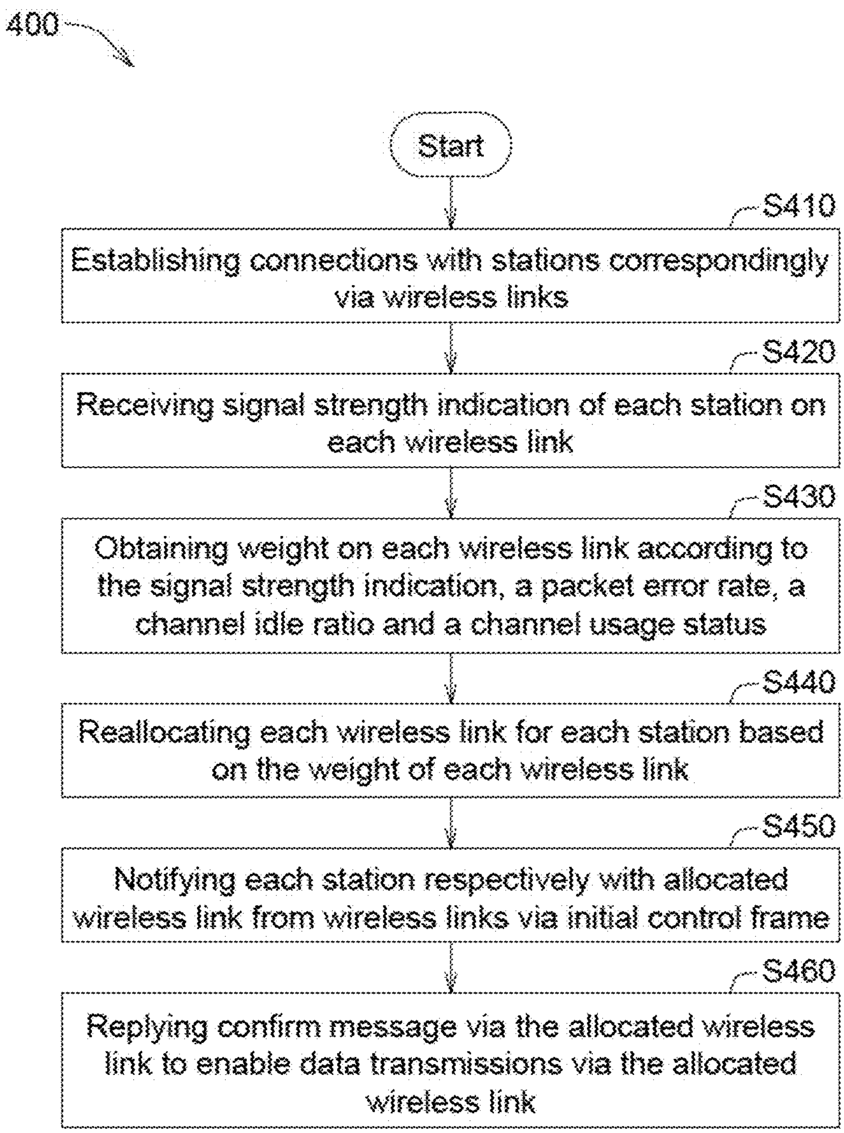

400
Start
S410
Establishing connections with stations correspondingly via wireless links
S420
Receiving signal strength indication of each station on each wireless link
S430
Obtaining weight on each wireless link according to the signal strength indication, a packet error rate, a channel idle ratio and a channel usage status
S440
Reallocating each wireless link for each station based on the weight of each wireless link
S450
Notifying each station respectively with allocated wireless link from wireless links via initial control frame
S460
Replying confirm message via the allocated wireless link to enable data transmissions via the allocated wireless link

FIG. 4

APPLICATION OF ALLOCATING WIRELESS LINKS OF ACCESS POINT MULTI-LINK DEVICE FOR WIRELESS STATIONS

[0001] This application claims the benefit of U.S. provisional application Ser. No. 63/555,923, filed Feb. 21, 2024, the subject matter of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The disclosure relates in general to wireless communication devices, and more particularly, to techniques of methods and apparatuses about schemes to have an application of allocating wireless links of access point (AP) multi-link device (MLD) for wireless stations.

BACKGROUND

[0003] Access point (AP) or non-access point (non-AP) multi-link device (MLD) can support multi-links with different bands (e.g., 2G, 5G or 6G), such as Wi-Fi 7 (802.11be) Multi-link operation (MLO) performed on a Wi-Fi 7 MLD. However, when more than one MLO devices (each including at least two stations (STAs)) is/are connected, CSMA/CA (Carrier-sense multiple access with collision avoidance) must be performed for contending and only one set of data transmission can occur at a time unless OFDMA (Orthogonal Frequency-Division Multiple Access) or Spatial reuse (SR) is available. Also, in the case of the AP device performing MLO with legacy device(s) (only available for connecting to MLD via single radio link), when legacy device(s)/station(s) (STAs) and STAs of non-AP MLO EMLSR (enhanced Multi-Link-Single-Radio) device(s) connect to the same MLO AP or AP MLD, the non-AP MLO EMLSR device(s) are also arranged on the same link of the AP MLD, due to the legacy device(s)/STAs only stay on a fixed link of the AP MLD. In the meantime, other links of the AP MLD are idle, and legacy device(s)/STAs and STAs of non-AP MLO EMLSR device(s) are competing on the same link, which causes network congestion. Thus, there are needs for allocating wireless links of AP MLD for wireless device(s)/STAs including legacy device(s)/STAs and non-AP MLO EMLSR device(s).

SUMMARY

[0004] The present disclosure describes techniques for allocating wireless links of AP MLD for wireless stations.

[0005] The first aspect of the present disclosure features a method for allocating one or more wireless links of an access point (AP) multi-link device (MLD). The method comprises establishing, by the AP MLD, one or more connections with one or more stations correspondingly via the one or more wireless links. The method also comprises receiving, by the AP MLD, a signal strength indication of each of the one or more stations on each of the one or more wireless links. The method also comprises obtaining, by the AP MLD, a weight on each of the one or more wireless links according to the signal strength indication, a packet error rate, a channel idle ratio and a channel usage status. The method also comprises allocating, by the AP MLD, each of the one or more wireless links for each of the one or more stations, based on the weight of each of the one or more wireless links. The method also comprises notifying, by the AP MLD, each of the one or more stations respectively with an allocated wireless link from the one or more wireless links via an initial control frame.

[0006] The second aspect of the present disclosure features an apparatus for wireless communication. The apparatus is an AP MLD. The apparatus comprises at least one processor and a plurality of wireless links. The at least one processor of the AP MLD is configured to perform operations. The operations comprise establishing one or more connections with one or more stations correspondingly via one or more wireless links of the plurality of wireless links. The operations also comprise receiving a signal strength indication of each of the one or more stations on each of the one or more wireless links. The operations also comprise obtaining a weight on each of the one or more wireless links according to the signal strength indication, a packet error rate, a channel idle ratio and a channel usage status. The operations also comprise allocating, by the AP MLD, each of the one or more wireless links for each of the one or more stations, based on the weight of each of the one or more wireless links. The operations also comprise notifying each of the one or more stations respectively with an allocated wireless link from the one or more wireless links via an initial control frame.

[0007] The details of one or more disclosed implementations are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages will become apparent from the description, the drawings and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1**A is a block diagram illustrating an example wireless communication system, according to some implementations of the present application.

[0009] FIG. **1**B is a diagram illustrating random allocation of wireless links of the AP MLD for Non-AP MLDs and a legacy station, according to some implementations of the present application.

[0010] FIG. **1**C is a diagram illustrating smart allocation of wireless links of the AP MLD for Non-AP MLDs and the legacy station, according to some implementations of the present application.

[0011] FIG. **2** is a diagram illustrating an example procedure for allocating wireless links between the AP MLD, and non-AP MLDs and the legacy station, according to some implementations of the present application.

[0012] FIG. **3** is a diagram illustrating a comparison between conventional mean and improvement mean for allocating wireless links of AP MLD, according to some implementations of the present application.

[0013] FIG. **4** is a flowchart of a method (process) for allocating wireless links of AP MLD, according to some implementations of the present application.

[0014] In the following detailed description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced without these specific details. In other instances, well-known structures and devices are schematically shown in order to simplify the drawing.

DETAILED DESCRIPTION

[0015] The following disclosure provides many different embodiments, or examples, for implementing different features of the provided subject matter. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. For example, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

[0016] The terms "comprise," "comprising," "include," "including," "has," "having," etc. used in this specification are open-ended and mean "comprises but not limited." The terms used in this specification generally have their ordinary meanings in the art and in the specific context where each term is used. The use of examples in this specification, including examples of any terms discussed herein, is illustrative only, and in no way limits the scope and meaning of the disclosure or of any exemplified term. Likewise, the present disclosure is not limited to various embodiments given in this specification.

[0017] These illustrative examples are given to introduce the reader to the general subject matter discussed here and are not intended to limit the scope of the disclosed concepts. The following sections describe various additional features and examples with reference to the drawings in which like numerals indicate like elements, and directional descriptions are used to describe the illustrative embodiments but, like the illustrative embodiments, should not be used to limit the present disclosure. The elements included in the illustrations herein may not be drawn to scale.

[0018] FIG. **1**A is a block diagram illustrating an example wireless communication system **100**, according to some implementations of the present application. A device enabling to perform MLO can be referred as an AP MLD **110**, as shown in FIG. **1**, which the AP MLD **110** may include at least one processor **111** and multiple links, link 3 **112***a*, link 2 **112***b* and link 1 **112***c*. The number of the links of the AP MLD **110** can be varied based on the specification of the AP MLD **110**. In this example, the 3 links of the AP MLD **110** represent different channel to access different access point wirelessly with different radio frequency. For example, the link 3 **112***a* supports a 6G AP channel with 320 MHz bandwidth (BW), the link 2 **112***b* supports a 5G AP channel with 160 MHz BW, and the link 1 **112***c* supports a 2G AP channel with 20 MHz BW.

[0019] The example wireless communication system **100** can also comprise multiple non-AP devices for wirelessly connecting to the AP MLD **110** to enable data transmission between the AP MLD **110** and the non-AP devices. As the example of FIG. **1**, the non-AP devices include non-AP MLD 1 **120**, non-AP MLD 2 **130** and legacy station (STA) **140**.

[0020] In some implementations, the non-AP MLD 1 **120** includes STA 3 **112***a*, STA 2 **112***b* and STA 1 **112***c*. In this example, the 3 STAs of the non-AP MLD 1 **120** represent different channel to wirelessly access different links of the AP MLD **110** with different radio frequency. For example, the STA 3 **122***a* supports the 6G AP channel with 320 MHz bandwidth (BW), the STA 2 **122***b* supports the 5G AP channel with 160 MHz BW, and the STA 3 **122***c* supports the 2G AP channel with 20 MHz BW. The non-AP MLD 2 **130**.

[0021] Similarly, the non-AP MLD 2 **130** includes STA 3 **132***a*, STA 2 **132***b* and STA 1 **132***c*. In this example, the 3 STAs of the non-AP MLD 2 **130** represent different channel to wirelessly access different links of the AP MLD **110** with different radio frequency. For example, the STA 3 **132***a* supports the 6G AP channel with 320 MHz bandwidth (BW), the STA 2 **132***b* supports the 5G AP channel with 160 MHz BW, and the STA 3 **132***c* supports the 2G AP channel with 20 MHz BW.

[0022] The legacy STA **140** is also referred with a wireless communication device which is only available for connecting to MLD via single radio channel, which may supports the 6G AP channel with 320 MHz bandwidth (BW), the 5G AP channel with 160 MHz BW or the 2G AP channel with 20 MHz BW, respectively corresponding to the link 3 **112***a*, link 2 **112***b* and link 1 **112***c* of the AP MLD **110**. The initial connecting status between the AP MLD **110** and the non-AP MLD 1 **120**, the non-AP MLD 2 **130** and the legacy STA **140** will be described referring to FIG. **1**B as following.

[0023] FIG. **1**B is a diagram illustrating random allocation (or initial connecting status) of wireless links of the AP MLD **110** for the non-AP MLD 1 **120**, the non-AP MLD 2 **130** and the legacy STA **140**, according to some implementations of the present application. As shown in FIG. **1**B, in the initial connecting status, the legacy STA **140** and EMLSR Stations, non-AP MLD 1 **120** and the non-AP MLD 2 **130**, are on the same channel, link 3 **112***a* of the AP MLD **110**, and, in the meantime, other links, link 2 **112***b* and link 1 **112***c* are idle while the data transmission on link 3 **112***a* is busy.

[0024] In this case, as when using Hybrid MLO devices (e.g., EMLSR, such as STAs of non-AP MLD 1 **120** and non-AP MLD 2 **130**) and legacy devices (such as the legacy STA **140**) connecting to MLO AP (such as links of AP MLD **110**), the AP MLD **110** will allocate wireless links, link 3 **112***a*, link 2 **112***b* and link 1 **112***c*, for wireless STAs, STAs of non-AP MLD 1 **120** and non-AP MLD 2 **130** and the legacy STA **140**. When the AP MLD **110** determines that more than one non-AP devices, non-AP MLD 1 **120**, non-AP MLD 2 **130** and the legacy STA **140**, are connected, the AP MLD **110** may obtain information of each connected device. The information may include the type of each connected device, and which links each connected device supports. For example, the AP MLD **110** may obtain the information of each connected device for identifying the connected devices including the legacy station **140** and the STAS of non-AP MLD 1 **120** and non-AP MLD 2 **130**, and identifying links that the STAs supports, such as the 2G, 5G or 6G AP channels as discussed above.

[0025] In some implementations, the information also includes RSSI (received Signal Strength Indicator) of the connected devices. The processor **111** of the AP MLD **110** may firstly obtain weight (WT) on each link, such as the link 3 **112***a*, the link 2 **112***b* and the link 1 **112***c*, based on RSSI of the connected device, for allocating each link for the connected devices, such as the legacy station **140** and the STAS of non-AP MLD 1 **120** and non-AP MLD 2 **130**. For example, if the absolute value of RSSI (|RSSI|) of the connected devices (corresponding to each supported STAs of each devices) via a specified link, such as link 3 **112***a* which may connected to the STA 3 **122***a* of the non-AP MLD 1 **120**, the STA 3 **132***a* of the non-AP MLD 2 **120** and the legacy STA **140**, is smaller than the absolute value of link range (can be also referred as the maximum linkage ability) RSSI (|Link Rang RSSI|), the weight can be set as zero (WT=0), which means the specified STA of connected device is not available for the specified link of the AP MLD **110**. If the absolute value of the RSSI is not smaller than absolute value of the link range RSSI, the WT may set as 100−25*(|RSSI|/70).

[0026] In some implementations, the information also includes packet error rate (PER) of the connected devices. The processor **111** of the AP MLD **110** may secondly obtain weight (WT) on each link, such as the link 3 **112***a,* the link 2 **112***b* and the link 1 **112***c,* based on PER between each link and STAs of the connected devices, for allocating each link for the connected devices, such as the legacy station **140** and the STAS of non-AP MLD 1 **120** and non-AP MLD 2 **130**. For example, if the weight is not set as zero due to the RSSI information, the weight may be then minus PER*25 (WT−PER*25, if WT is not 0).

[0027] In some implementations, the information also includes channel (Ch) idle ratio on each link of the AP MLD **110**. The processor **111** of the AP MLD **110** may thirdly obtain weight (WT) on each link, such as the link 3 **112***a,* the link 2 **112***b* and the link 1 **112***c,* based on the Ch idle ration on each link of the AP MLD **110**, for allocating each link for the connected devices, such as the legacy station **140** and the STAS of non-AP MLD 1 **120** and non-AP MLD 2 **130**. For example, if the weight is not set as zero due to the former information, RSSI and PER, the weight may be then minus 25 and add Ch idle ratio*25 (WT−25+Ch idle ratio*25, if WT is not 0).

[0028] In some implementations, the information also includes the ratio between the number of connected STAs on each link of the AP MLD **110** and the number of max support devices of the same link of the AP MLD **110**. The processor **111** of the AP MLD **110** may fourthly obtain weight (WT) on each link, such as the link 3 **112***a,* the link 2 **112***b* and the link 1 **112***c,* based on the ratio of each link of the AP MLD **110**, for allocating each link for the connected devices, such as the legacy station **140** and the STAS of non-AP MLD 1 **120** and non-AP MLD 2 **130**. For example, if the weight is not set as zero due to the former information, RSSI, PER and Ch idle ratio, the weight may be then set as 25 multiplexing the ratio (WT=25*(the number of connected STAs on this link/the number of max support devices on the same link), if WT is not 0). Consequently, the obtained weight of each link of the AP MLD **110** corresponding to STAs of the connected device, can be used for allocating (or reallocating) STAs of connected devices, and then the AP MLD **110** may notify the STAs of the connected device respectively with the allocated wireless link, such as link 3 **112***a,* link 2 **112***b* or link 1 **112***c,* via an initial control frame. The connecting status after reallocating (or smart allocating) between the AP MLD **110** and the non-AP MLD 1 **120**, the non-AP MLD 2 **130** and the legacy STA **140** will be described referring to FIG. **1**C as following.

[0029] FIG. **1**C is a diagram illustrating smart allocation of wireless links of the AP MLD for non-AP MLDs and the legacy station, according to some implementations of the present application. As shown in FIG. **1**C, after the relocating, the data transmission between the AP MLD **110** and non-AP MLD **120** is allocated on link 3 **112***a* of the AP MLD **110** and STA 3 **122***a* of the non-AP MLD **120**, based on the weight on link 3 **112***a* of the AP MLD **110** corresponding to STA 3 **122***a* of non-AP MLD 1 **120**, STA 3 **132***a* of non-AP MLD 2 **130** or the legacy STA **140** (if support). In this case, the weight on link 3 **112***a* of the AP MLD **110** corresponding to STA 3 **122***a* of non-AP MLD 1 **120** is greater than the weight corresponding to STA 3 **132***a* of non-AP MLD 2 **130** or the legacy STA **140**, thus link 3 **112***a* of the AP MLD **110** is allocated for STA 3 **122***a* of the non-AP MLD 1 **120**. Similarly, the weight on link 2 **112***b* of the AP MLD **110** corresponding to STA 2 **132***b* of non-AP MLD 2 **130** is greater than the weight corresponding to the legacy STA **140**, thus link 2 **112***b* of the AP MLD **110** is allocated for STA 2 **132***a* of the non-AP MLD 2 **130**, and link 3 **112***c* of the AP MLD **110** is allocated for the legacy STA **140**.

[0030] In some implementations, upon the process **111** of the AP MLD **110** determining that the connected device or STAs including legacy station (only available for connecting to MLD via single radio link, such as the legacy STA **140**), an individual wireless link, which is not used or connected by other stations for data transmission, may be allocated, by for the legacy station, such as the link 3 **112***c* of the AP MLD **110** is allocated for the legacy STA **140**, as shown by the example of FIG. **1**C. By this means, the competition between legacy stations and MLO devices on the same link of AP MLD can be avoid.

[0031] In some implementations, wherein upon the process **111** of the AP MLD **110** determining that the connected device or STAs including the non-AP MLD, one or two wireless links of the one or more wireless links are allocated, by the AP MLD, for the non-AP MLD including 3 channels (or stations), such as only one link (link 3 **112***a* or link 2 **112***b*) of the AP MLD **110** is respectively allocated for STA 3 **122***a* of the non-AP MLD 1 and STA 2 **132***b* of the non-AP MLD 2, which both non-AP MLD 1 and non-AP MLD 2 have 3 support stations (channels), as shown by the example of FIG. **1**C. By this means, power saving mode of the non-AP MLD(s) can be enabled for saving power consumption, since only 1 or 2 channels (or stations) of non-AP MLD is waked but not waking all channels (or stations) up.

[0032] FIG. **2** is a diagram illustrating an example procedure for allocating wireless links (link 3 **112***a,* link 2 **112***b* and link 1 **112***c*) between the AP MLD **110**, and non-AP MLDs (non-AP MLD 1 **120** and non-AP MLD 2 **130**) and the legacy STA **140**, according to some implementations of the present application. After the smart allocation (or reallocation) discussed above, the AP MLD **110** notifies each STA of connected device respectively with an allocated wireless link via an initial control frame. For the example of FIG. **2**, the initial control frame is implemented as a MU-RTS (Multi User Request to Send) **210***a,* **210***b* or **210***c,* which is respectively used for notifying STA 3 **122***a* of the non-AP MLD 1 **120** via the allocated link 3 **112***a,* notifying STA 2 **132***b* of the non-AP MLD 2 **130** via the allocated link 2 **112***b* and notifying legacy STA **140** via the allocated link 1 **112***c,* as shown. To response the MU-RTS on the allocated link, each non-AP MLD devices and legacy stations replies a control frame via the allocated wireless link. In this case, the control frame is implemented as CTS (Clear to Send) **211***a,* **211***b* or **211***c*. Then, the AP MLD **110** can enable data transmission (transmit and receive packets, such as data **212***a,* **212***b* or **212***c*) with each connected device (non-AP

MLD 1 **120**, non-AP MLD 2 **130** or legacy STA **140**) via the allocated wireless link (link 3 **112***a* for STA 3 **122***a* of non-AP MLD 1 **120**, link 2 **112***b* for STA 2 **132***b* of non-AP MLD 2 **130** and link 1 **112***c* for legacy STA **140**). It should be noticed that, after allocating the specified wires link for the individual STA, the MLD AP **110** does not send the initial control frames (e.g. MU-RTS or BSRP (Buffer Status Report)) on all support link of the connected devices or STAs, the initial control frame is only sent on each specified wireless link to arrange each non-AP MLD to work on the specified wireless link at the same time.

[0033] In some implementations, the wireless link used for data transmission between the AP MLD and the connected devices or STAs is reallocated due to different situation, such as the PER on the specified link increases or any device is disconnected. For example, when the PER on one link of the AP MLD increases, weight on each link of the AP MLD can be updated by the means for obtaining weight as discussed above, and each link can be than reallocated for the connected devices or STAs according to the updated weight of each link of the AP MLD corresponding to different STAs. For another example, when one or more devices or STAs is/are disconnected, weight on each link of the AP MLD can also be updated by the means for obtaining weight as discussed above, and each link can be than reallocated for the connected devices or STAs according to the updated weight of each link of the AP MLD corresponding to different STAs.

[0034] FIG. **3** is a diagram illustrating a comparison **300** between conventional mean **320***a* and improvement mean **320***b* for allocating wireless links of AP MLD, according to some implementations of the present application. As shown in graph **310** of FIG. **3**, after the reallocation (smart allocation, improvement mean **320***b*), comparing to conventional random allocation (conventional mean **320***a*), all non-AP MLD EMLSR devices could work on different links at the same time (as shown by improvement mean **320***b*, 1 in 2G, 1 in 5G and 1 in 6G), it will decrease ⅔ the latency and increase almost 5-times performance (such as UDP Peak Throughput in graph **310**).

[0035] FIG. **4** is a flowchart of a method (process **400**) for allocating wireless links of AP MLD, according to some implementations of the present application. In step S**410**, connections with stations are established correspondingly via wireless links, such as connections with non-AP MLD 1 **120**, non-AP MLD 2 **130** and legacy STA **140** are established correspondingly via wireless link 3 **112***a*, link 2, **112***b* and link 1 **112***c* of the AP MLD **110** as shown in FIG. **1**B. In step S**420**, the AP MLD receives a signal strength indication (such as RSSI) of each of the one or more stations on each of the one or more wireless links. In step S**430**, the APMLD obtains a weight (WT) on each wireless link according to the signal strength indication, a packet error rate (PER), a channel idle ratio and a channel usage status. In step S**440**, the AP MLD allocates each wireless link for each station, based on the weight of each wireless link, such as the AP MLD **110** allocates wireless link 3 **112***a*, link 2, **112***b* and link 1 **112***c* respectively for the STA 3 **122***a* of non-AP MLD 1 **120**, STA 2 **132***b* of non-AP MLD 2 **130** and legacy STA **140** as shown in FIG. **1**C. In step S**450**, the AP MLD notifies each station respectively with allocated wireless link from wireless links via initial control frame, such as the AP MLD **110** notifies the STA 3 **122***a* of non-AP MLD 1 **120**, STA 2 **132***b* of non-AP MLD 2 **130** and legacy STA **140** with allocated wireless link 3 **112***a*, link 2, **112***b* and link 1 **112***c* via initial control frames, MU RTS **210***a*, **210***b*, and **210***c*, respectively, as shown in FIG. **2**. In step S**460**, the connected devices/STAs which received the initial control frame, reply control frame via the allocated wireless link to enable data transmissions via the allocated wireless link, such as non-AP MLD 1 **120**, non-AP MLD 2 **130** and legacy STA **140** reply control frames, CTS **211***a*, **211***b* and **211***c*, via allocated link 3 **112***a*, link 2, **112***b* and link 1 **112***c* of the AP MLD **110** respectively, to enable data transmissions, data **212***a*, **212***b* and **212***c*, via allocated link 3 **112***a*, link 2, **112***b* and link 1 **112***c* of the AP MLD **110**, as shown in FIG. **2**.

[0036] In certain configurations, at least one processor of the AP MLD establishing the one or more connections with one or more stations comprises identifying the one or more stations including a legacy station or a non-access point (non-AP) multi-link device (MLD).

[0037] In certain configurations, upon the at least one processor of the AP MLD determining that the one or more stations including the legacy station, an individual wireless link of the one or more wireless links is allocated for the legacy station, which the individual wireless link is not connected by other stations.

[0038] In certain configurations, upon the at least one processor of the AP MLD determining that the one or more stations including the non-AP MLD, one or two wireless links of the one or more wireless links are allocated for the non-AP MLD including 3 channels, to enable a power saving mode of the non-AP MLD.

[0039] In certain configurations, upon the at least one processor of the AP MLD determining that the packet error rate on one of the one or more links increases, the weight on each of the one or more wireless links is updated and each of the one or more wireless links is reallocated for each of the one or more stations according to a updated weight of each of the one or more wireless links.

[0040] In certain configurations, upon the at least one processor of the AP MLD determining that one of the one or more stations is disconnected, the weight on each of the one or more wireless links is updated and each of the one or more wireless links is reallocated for connected stations according to a updated weight of each of the one or more wireless links.

[0041] A system may encompass all apparatus, devices, and machines for processing data, including by way of example a programmable processor, a computer, or multiple processors or computers. A system can include, in addition to hardware, code that creates an execution environment for the computer program in question, e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, or a combination of one or more of them.

[0042] A computer program (also known as a program, software, software application, script, or code) can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a standalone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program does not necessarily correspond to a file in a file system. A program can be stored in a portion of a file that holds other programs or data (e.g., one or more scripts stored in a markup language document), in a single file dedicated to the program in question, or in multiple coordinated files (e.g., files that store one or more modules, sub programs, or portions of code). A computer program can be deployed for execution on one computer or on multiple computers that are located at one site or distributed across multiple sites and interconnected by a communications network.

[0043] The processes and logic flows described in this document can be performed by one or more programmable processors executing one or more computer programs to perform the functions described herein. The processes and logic flows can also be performed by, and apparatus can also be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit).

[0044] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read only memory or a random access memory or both. The essential elements of a computer can include a processor for performing instructions and one or more memory devices for storing instructions and data. Generally, a computer can also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto optical disks, or optical disks. However, a computer need not have such devices. Computer readable media suitable for storing computer program instructions and data can include all forms of nonvolatile memory, media and memory devices, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks. The processor and the memory can be supplemented by, or incorporated in, special purpose logic circuitry.

[0045] While this document may describe many specifics, these should not be construed as limitations on the scope of an invention that is claimed or of what may be claimed, but rather as descriptions of features specific to particular embodiments. Certain features that are described in this document in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination in some cases can be excised from the combination, and the claimed combination may be directed to sub-combination or a variation of a sub-combination. Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results.

[0046] Only a few examples and implementations are disclosed. Variations, modifications, and enhancements to the described examples and implementations and other implementations can be made based on what is disclosed.

What is claimed is:

1. A method for allocating one or more wireless links of an access point (AP) multi-link device (MLD), comprising:

establishing, by the AP MLD, one or more connections with one or more stations correspondingly via the one or more wireless links;

receiving, by the AP MLD, a signal strength indication of each of the one or more stations on each of the one or more wireless links;

obtaining, by the AP MLD, a weight on each of the one or more wireless links according to the signal strength indication, a packet error rate, a channel idle ratio and a channel usage status;

allocating, by the AP MLD, each of the one or more wireless links for each of the one or more stations, based on the weight of each of the one or more wireless links; and

notifying, by the AP MLD, each of the one or more stations respectively with an allocated wireless link from the one or more wireless links via an initial control frame.

2. The method of claim **1**, wherein establishing the one or more connections with one or more stations comprises identifying the one or more stations including a legacy station or a non-access point (non-AP) multi-link device (MLD).

3. The method of claim **2**, wherein upon determining that the one or more stations including the legacy station, an individual wireless link of the one or more wireless links is allocated, by the AP MLD, for the legacy station, wherein the individual wireless link is not connected by other stations.

4. The method of claim **2**, wherein upon determining that the one or more stations including the non-AP MLD, one or two wireless links of the one or more wireless links are allocated, by the AP MLD, for the non-AP MLD including **3** channels, to enable a power saving mode of the non-AP MLD.

5. The method of claim **1**, further comprising replying, by each of the one or more stations, a control frame via the allocated wireless link, to enable data transmissions between the AP MLD and each of the one or more stations via the allocated wireless link,

wherein the initial control frame is a Multi User Request to Send (MU-RTS), and the control frame is a Clear to Send (CTS).

6. The method of claim **1**, wherein upon determining that the packet error rate on one of the one or more links increases, the weight on each of the one or more wireless links is updated and each of the one or more wireless links is reallocated for each of the one or more stations according to a updated weight of each of the one or more wireless links.

7. The method of claim **1**, wherein upon determining that one of the one or more stations is disconnected, the weight on each of the one or more wireless links is updated and each of the one or more wireless links is reallocated for connected stations according to a updated weight of each of the one or more wireless links.

8. An apparatus for wireless communication, the apparatus being an AP MLD, comprising:

at least one processor; and

a plurality of wireless links,

wherein the at least one processor of the AP MLD is configured to perform operations comprising:

establishing one or more connections with one or more stations correspondingly via one or more wireless links of the plurality of wireless links;

receiving a signal strength indication of each of the one or more stations on each of the one or more wireless links;

obtaining a weight on each of the one or more wireless links according to the signal strength indication, a packet error rate, a channel idle ratio and a channel usage status;

allocating, by the AP MLD, each of the one or more wireless links for each of the one or more stations, based on the weight of each of the one or more wireless links; and

notifying each of the one or more stations respectively with an allocated wireless link from the one or more wireless links via an initial control frame.

9. The apparatus of claim **8**, wherein the at least one processor of the AP MLD establishing the one or more connections with one or more stations comprises identifying the one or more stations including a legacy station or a non-access point (non-AP) multi-link device (MLD).

10. The apparatus of claim **9**, wherein upon the at least one processor of the AP MLD determining that the one or more stations including the legacy station, an individual wireless link of the one or more wireless links is allocated for the legacy station, wherein the individual wireless link is not connected by other stations.

11. The apparatus of claim **9**, wherein upon the at least one processor of the AP MLD determining that the one or more stations including the non-AP MLD, one or two wireless links of the one or more wireless links are allocated for the non-AP MLD including 3 channels, to enable a power saving mode of the non-AP MLD.

12. The apparatus of claim **8**, the at least one processor of the AP MLD is further configured to receiving a control frame from each of the one or more stations via the allocated wireless link, to enable data transmissions between the AP MLD and each of the one or more stations via the allocated wireless link,

wherein the initial control frame is a Multi User Request to Send (MU-RTS), and the control frame is a Clear to Send (CTS)

13. The apparatus of claim **8**, wherein upon the at least one processor of the AP MLD determining that the packet error rate on one of the one or more links increases, the weight on each of the one or more wireless links is updated and each of the one or more wireless links is reallocated for each of the one or more stations according to a updated weight of each of the one or more wireless links.

14. The apparatus of claim **8**, wherein upon the at least one processor of the AP MLD determining that one of the one or more stations is disconnected, the weight on each of the one or more wireless links is updated and each of the one or more wireless links is reallocated for connected stations according to a updated weight of each of the one or more wireless links.

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