

## DEVICES AND METHODS FOR ENERGY EFFICIENT MULTI-LINK COMMUNICATION IN A WIRELESS NETWORK

### TECHNICAL FIELD

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The present invention relates to wireless communications. More specifically, the present invention relates to devices and methods for energy efficient wireless communication in an IEEE-802.11-based wireless communication network.

### 10 BACKGROUND

IEEE-802.11-based WLANs have become popular at an unprecedented rate. WLANs support a variety of data transfer modes including (but not only) file transfer, emails, web browsing and real-time applications such as audio and video applications. For efficiently supporting high throughputs, a new feature referred to as "Multi-Link" has been introduced for IEEE-802.11be. "Multi-Link" is based on the idea to setup and use more than one link between a wireless access point (AP) and one or more non-AP stations for frame exchange.

20 However, increasing the number of links between the multi-link wireless AP and the one or more non-AP stations, results in an increased power consumption, in particular of the multi-link wireless AP, which may operate links with several multi-link wireless non-AP stations. One reason for the increased power consumption is that the multi-link wireless AP will require, for instance, an increased number of power amplifiers for supporting the communication via the larger number of links.

Power saving is an important issue for wireless devices in the consumer electronics market as well as in the enterprise market. In the consumer electronics market, a "Power Consumption level" certification may become de-facto a must for every product. For instance, as of the year 2022 an AP power save function will be mandatory in all products in the European market. Any new equipment sold in EU that must comply with a specific total power consumption regulation when the equipment is not in use.

In the enterprise market, an AP often uses POE (Power over Ethernet) which limits the power consumption of the AP between 15W and 75W (depending on the cable and POE

type). This limit strongly constrains the hardware of the enterprise AP, such as the number of power amplifiers per AP, number of radios, modems and antenna ports per radio.

#### SUMMARY

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It is an objective of the present disclosure to provide devices and methods for a more energy efficient wireless communication in an IEEE-802.11-based wireless communication network.

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

- According to a first aspect a multi-link wireless access point, AP, is configured to  
15 exchange a plurality of frames, including management frames, control frames and data frames, via a plurality of setup links with a plurality of multi-link wireless non-AP stations in a wireless communication network.

- The multi-link wireless AP comprises a communication interface configured to send a link  
20 disable notification management frame to at least one of the plurality of multi-link wireless non-AP stations operating on a first, i.e. the same setup link of the plurality of setup links. The link disable notification management frame comprises information, e.g. one or more information elements and fields, for the at least one of the plurality of multi-link wireless non-AP stations for identifying at least the first setup link of the plurality of setup links to  
25 be temporarily disabled by the multi-link wireless AP.

- Moreover, the multi-link wireless AP comprises a processing circuitry configured to, in response to sending the link disable notification management frame, temporarily disable at least the first setup link, i.e. block exchange of further frames via at least the first setup  
30 link for reducing a power required to operate at least the first setup link. The multi-link wireless non-AP station may be kept associated with the multi-link wireless AP using a second setup link of the plurality of setup links between the multi-link wireless AP and the multi-link wireless non-AP station, while the first setup link is disabled.

- 35 Thus, advantageously a more energy efficient multi-link wireless AP is provided due to its capability to suspend the entire traffic activity on any of its enabled links (i.e. on both DL

and UL directions), while keeping its operation with the associated multi-link wireless non-AP station(s) on other enabled links. This disabling link operation may not be limited to a fixed predefined time interval, but usually for a limited time interval.

- 5 In a further possible implementation form of the first aspect, the plurality of setup links comprises at least one disabled setup link and wherein the communication interface is further configured to send a further management frame (referred herein to as "link enable notification management frame") to at least one of the plurality of multi-link wireless non-AP stations. The further, i.e. the link enable notification management frame comprises
- 10 information, e.g. one or more information elements and fields, for the at least one of the plurality of multi-link wireless non-AP stations for identifying the at least one disabled link to be enabled by the multi-link wireless AP. The processing circuitry of the multi-link wireless AP is further configured, in response to sending the further management frame, to (re)allow the frame exchange on the at least one enabled link.
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- In a further possible implementation form of the first aspect, the communication interface of the multi-link wireless AP is configured to send the link disable notification management frame to the at least one of the plurality of multi-link wireless non-AP stations operating on the first setup link via the first setup link to be disabled by the multi-link wireless AP.
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- In a further possible implementation form of the first aspect, the link disable notification management frame and/or the link enable notification management frame is a unicast management frame sent to one multi-link wireless non-AP station of the plurality of multi-link wireless non-AP stations. The communication interface of the multi-link wireless AP is
- 25 configured to receive an acknowledgment frame, e.g. an ACK frame or Block ACK frame, from the one multi-link wireless non-AP station, in response to sending the link disable notification management frame and/or the link enable notification management frame to the one multi-link wireless non-AP station.
- 30
- In a further possible implementation form of the first aspect, the processing circuitry is configured to temporarily disable at least the first setup link, i.e. block exchange of further frames via at least the first setup link for reducing the power required to operate the first setup link, in response to sending the link disable notification management frame to the one multi-link wireless non-AP station and receiving the acknowledgement frame, e.g. the
- 35 ACK frame or Block ACK frame, from the multi-link wireless non-AP station.

In a further possible implementation form of the first aspect, the link disable notification management frame is a broadcast management frame, wherein the processing circuitry is configured to temporarily disable, i.e. block exchange of further frames via at least the first setup link for reducing the power required to operate the first setup link, in response to  
5 sending the link disable notification management frame to all multi-link wireless non-AP stations operating on the first setup link.

In a further possible implementation form of the first aspect, the link enable notification management frame is a broadcast management frame, wherein the processing circuitry is  
10 configured to temporarily enable the at least one disabled setup link, i.e. allow exchange of further frames via the at least one disabled setup link, in response to sending the link enable notification management frame to all multi-link wireless non-AP stations to operate on the at least one disabled setup link.

15 In a further possible implementation form of the first aspect, the plurality of frames comprises a plurality of data frames, wherein each data frame comprises a respective transmission identifier, TID, (from a plurality of possible TIDs, up to 8 TIDs) and wherein the processing circuitry is configured to map individually each TID of the respective data frame to one or more of the plurality of setup links for each of the one or more multi-link  
20 wireless non-AP stations.

In a further possible implementation form of the first aspect, the communication interface is configured to send each data frame, depending on the TID corresponding to the data frame, via the setup link to which the TID is mapped. The data frame may comprise one or  
25 more MSDUs.

In a further possible implementation form of the first aspect, the link disable notification management frame comprises for one or more of the plurality of TIDs a respective bitmap defining the one or more of the plurality of setup links to which each TID is mapped to  
30 (also referred to as: TID-to-link mapping) for the at least one of the plurality of multi-link wireless non-AP stations.

In a further possible implementation form of the first aspect, the bitmaps defining the one or more of the plurality of setup links to which each TID is mapped to (i.e. the TID-to-link  
35 mapping(s)) are valid until the communication interface sends a further link disable or

enable notification management frame to the at least one of the one or more multi-link wireless non-AP stations, which may define a different TID-to-link mapping.

5 In a further possible implementation form of the first aspect, for at least the first setup link to be disabled by the multi-link wireless AP, each respective bitmap defines that no TID is mapped to at least the first setup link to be disabled by the multi-link wireless AP. For instance, if a specific bit of all bitmaps is zero then the station may infer that the corresponding link is about to be disabled.

10 In a further possible implementation form of the first aspect, the plurality of TIDs comprises 8 TIDs, wherein the bitmap for each TID comprises 2 octets.

In a further possible implementation form of the first aspect, the further management frame, i.e. the link enable notification management frame comprises a default mapping  
15 indication for informing the at least one of the plurality of multi-link wireless non-AP stations about a default TID-to-link mapping of the plurality of TIDs to the plurality of setup links, wherein, if the default mapping indication is set, the default mapping defines that all of the plurality of TIDs are mapped to all of the plurality of setup links, i.e. that all setup links are enabled.

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In a further possible implementation form of the first aspect, the link disable notification management frame further comprises information, e.g. a direction field, for defining whether the TID-to-link mapping defined by the one or more bitmaps is for a downlink, DL, communication direction or an uplink, UL, communication direction between the multi-link  
25 wireless AP and the plurality of multi-link wireless non-AP stations.

In a further possible implementation form of the first aspect, the link disable notification management frame further comprises information, e.g. a TID presence indicator field, for identifying one or more of the plurality of TIDs for which the one or more bitmaps  
30 contained within the management frame define the TID-to-link mapping of the respective TID to one or more of the plurality of setup links.

In a further possible implementation form of the first aspect, the plurality of bitmaps define for one or more of the plurality of TIDs and for at least two of the plurality of multi-link  
35 wireless non-AP stations the one or more of the plurality of setup links to which the TID is mapped to for the respective multi-link wireless non-AP station. The plurality of bitmaps

contained within the management frame may comprise for each of the at least two of the plurality of multi-link wireless non-AP stations one or more bitmaps and information, in particular an association identifier (AID), for associating the one or more bitmaps with each of the at least two of the plurality of multi-link wireless non-AP stations, wherein each  
5 bitmap defines the one or more of the plurality of setup links to which the respective TID is mapped to. Each AID may be associated, for instance, with up to eight link bitmaps (each of the link bitmaps is for a specific TID of the respective multi-link wireless non-AP station).

10 In a further possible implementation form of the first aspect, the plurality of bitmaps contained within the management frame comprise for each of the one or more of the plurality of TIDs a single bitmap defining for all of the plurality of multi-link wireless non-AP stations the one or more of the plurality of setup links to which the respective TID is mapped to.

15 According to a second aspect, a method of operating a multi-link wireless access point, AP, is provided, wherein the multi-link wireless AP is configured to exchange a plurality of frames, including management frames, control frames and data frames, via a plurality of setup links with a plurality of multi-link wireless non-AP stations in a wireless  
20 communication network. The method comprises the steps of:

sending a link disable notification management frame to at least one of the plurality of multi-link wireless non-AP stations operating on a first setup link, i.e. the same setup link of the plurality of setup links, wherein the link disable notification management frame  
25 comprises information, e.g. one or more information elements, for the at least one of the plurality of multi-link wireless non-AP stations for identifying at least the first setup link of the plurality of setup links to be temporarily disabled by the multi-link wireless AP; and

in response to sending the link disable notification management frame, temporarily  
30 disabling at least the first setup link, i.e. blocking exchange of further frames via at least the first setup link for reducing a power required to operate at least the first setup link, wherein the at least one multi-link wireless non-AP station is kept associated using a second setup link of the plurality of setup links while at least the first setup link is disabled.

35 In a further possible implementation form of the second aspect, the link disable notification management frame is a broadcast frame and the step of disabling at least the first setup

link comprises immediately disabling at least the first setup link, in response to sending the broadcast management frame.

5 In a further possible implementation form of the second aspect, the link disable notification management frame is a unicast frame and the method further comprises receiving an acknowledgement frame, wherein the step of disabling at least the first setup link comprises disabling at least the first setup link, in response to sending the unicast management frame and receiving the acknowledgement frame.

10 In a further possible implementation form of the second aspect, the plurality of setup links comprises at least one disabled setup link, wherein the method further comprises sending a further management frame (herein referred to as link enable notification management frame) to at least one of the plurality of multi-link wireless non-AP stations. The further management frame, i.e. the link enable notification management frame comprises  
15 information, e.g. one or more information elements, for the at least one of the plurality of multi-link wireless non-AP stations for identifying the at least one disabled setup link to be enabled by the multi-link wireless AP and enabling the at least one disabled setup link, in response to sending the further management frame.

20 In a further possible implementation form of the second aspect, the link enable notification management frame is a broadcast management frame, wherein the step of enabling the at least one disabled setup link comprises immediately enabling the at least one disabled setup link, in response to sending the link enable notification management frame.

25 In a further possible implementation form of the second aspect, the link enable notification management frame is a unicast management frame, wherein the method further comprises a step of receiving a further acknowledgement frame, wherein the step of enabling the at least one disabled setup link comprises enabling the at least one disabled setup link, in response to sending the link enable notification management frame and  
30 receiving the further acknowledgement frame.

The method according to the second aspect of the present disclosure can be performed by the multi-link wireless AP according to the first aspect of the present disclosure. Thus, further features of the method, according to the second aspect of the present disclosure,  
35 result directly from the functionality of the multi-link wireless AP according to the first

aspect of the present disclosure as well as its different implementation forms described above and below.

According to a third aspect, a multi-link wireless non-access point, non-AP, station is provided that is configured to exchange a plurality of frames, including management frames, control frames and data frames, via a plurality of enabled setup links with a multi-link wireless AP in a wireless communication network. The multi-link wireless non-AP station comprises a communication interface to receive a link disable notification management frame from the multi-link wireless AP. Furthermore, the multi-link wireless non-AP station comprises a processing circuitry configured to extract, i.e. parse information, e.g. one or more information elements, from the link disable notification management frame for identifying at least a first setup link of the plurality of setup links to be temporarily disabled by the multi-link wireless AP. The processing circuitry is further configured to disable at least the first setup link, i.e. block exchange of further frames via at least the first setup link identified by the information extracted from the link disable notification management frame.

In a further possible implementation form of the third aspect, the link disable management frame is a unicast frame and the communication interface is further configured to send, in response to receiving the individually addressed link disable notification management frame from the multi-link wireless AP, an acknowledgment frame, e.g. an ACK frame or Block ACK frame, to the multi-link wireless AP.

In a further possible implementation form of the third aspect, the plurality of setup links comprises at least one disabled setup link and wherein the communication interface is configured to receive a further management frame (herein referred to as link enable notification management frame) from the multi-link wireless AP. The processing circuitry is configured to extract, i.e. parse further information, e.g. one or more further information elements from the further management frame, i.e. the link enable notification management frame for identifying the at least one disabled setup link to be enabled by the multi-link wireless AP. The processing circuitry is further configured to enable the at least one disabled setup link, i.e. allow exchange of further frames via the at least one disabled setup link identified by the further information extracted from the link enable notification management frame.

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In a further possible implementation form of the third aspect, the link enable notification management frame is a unicast management frame and the communication interface is further configured to send, in response to receiving the individually addressed link enable notification management frame from the multi-link wireless AP, a further acknowledgment  
5 frame, e.g. a further ACK frame or Block ACK frame, to the multi-link wireless AP.

In a further possible implementation form of the third aspect, the plurality of frames comprises a plurality of data frames and each data frame comprises a corresponding transmission identifier, TID, of a plurality of TIDs, wherein the processing circuitry is  
10 configured to map each TID to one or more of the plurality of setup links.

In a further possible implementation form of the third aspect, the communication interface is configured to send each data frame, depending on the TID of the data frame, via the one or more setup links the TID is mapped to.  
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In a further possible implementation form of the third aspect, the information of the management frame comprises for one or more of the plurality of TIDs a bitmap defining the one or more of the plurality of setup links to which each TID is mapped to.

20 In a further possible implementation form of the third aspect, the processing circuitry is configured to identify at least the first setup link based on the plurality of bitmaps by determining that for at least the first setup link to be disabled by the multi-link wireless AP each bitmap defines that none of the plurality of TIDs is mapped to at least the first setup link to be disabled by the multi-link wireless AP.

25 In a further possible implementation form of the third aspect, the processing circuitry is configured to identify the at least one disabled setup link based on the plurality of bitmaps by determining that for the at least one disabled setup link to be enabled by the multi-link wireless AP at least one bitmap of the plurality of bitmaps defines that at least one of the  
30 plurality of TIDs is mapped to the at least one disabled setup link to be enabled by the multi-link wireless.

In a further possible implementation form of the third aspect, the management frame is a broadcast management frame and the processing circuitry is further configured to extract  
35 an association identifier of the multi-link wireless non-AP station from the broadcast management frame for identifying a subset of the plurality of bitmaps for the multi-link

wireless non-AP station, wherein the subset of the plurality of bitmaps defines for one or more of the plurality of TIDs the one or more of the plurality of setup links to which the TID is mapped.

- 5 In a further possible implementation form of the third aspect, the processing circuitry is configured to extract the subset of the plurality of bitmaps from the management frame for identifying at least the first setup link of the plurality of setup links to be disabled, if the broadcast management frame comprises the association identifier of the multi-link wireless non-AP station.

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In a further embodiment of the third aspect, the multi-link wireless non-AP station further comprises a memory configured to maintain the plurality of bitmaps defining the one or more of the plurality of setup links to which each TID is mapped (i.e. the TID-to-link mappings), wherein the processing circuitry is configured to update the plurality of bitmaps

- 15 stored within the memory based on the new bitmaps contained within the link disable management frame and/or the link enable management frame and to identify, based on the plurality of bitmaps stored within the memory and the currently received link disable management frame and/or the link enable management frame, at least the first setup link of the plurality of setup links to be temporarily disabled by the multi-link wireless AP and/or  
20 the at least one disabled setup link to be enabled by the multi-link wireless AP.

- According to a fourth aspect, a method of operating a multi-link wireless non-access point, non-AP, station is provided that is configured to exchange a plurality of frames, including management frames, control frames and data frames, via a plurality of enabled setup links  
25 with a multi-link wireless AP in a wireless communication network. The method according to the fourth aspect comprises the steps of:

receiving a link disable notification management frame from the multi-link wireless AP;

- 30 extracting, i.e. parsing information, e.g. one or more information elements, from the link disable notification management frame for identifying at least a first setup link of the plurality of setup links to be temporarily disabled by the multi-link wireless AP; and

- disabling at least the first setup link, i.e. blocking exchange of further frames via at least  
35 the first setup link identified by the information extracted from the link disable notification management frame.

5 In a further possible implementation form of the fourth aspect, the management frame is a broadcast management frame and the step of disabling at least the first setup link comprises disabling at least the first setup link, in response to receiving the broadcast management frame.

10 In a further possible implementation form of the fourth aspect, the management frame is a unicast management frame and the method further comprises a step of sending an acknowledgement frame to the multi-link wireless AP, wherein the step of disabling at least the first setup link comprises disabling at least the first setup link, in response to receiving the unicast management frame and sending the acknowledgement frame to the multi-link wireless AP.

15 In a further possible implementation form of the fourth aspect, the plurality of setup links comprises at least one disabled setup link and wherein the method further comprises the steps of:

20 receiving a further management frame (herein referred to as link enable notification management frame) from the multi-link wireless AP;

extracting, i.e. parsing further information, e.g. one or more further information elements, from the further management frame, i.e. the link enable notification management frame for identifying the at least one disabled setup link to be enabled by the multi-link wireless AP; and

25 enabling at least one disabled setup link, i.e. allowing exchange of further frames via the at least one disabled setup link identified by the further information extracted from the further management frame, i.e. the link enable notification management frame.

30 In a further possible implementation form of the fourth aspect, the further management frame is a broadcast management frame and the step of enabling the at least one disabled setup link comprises the step of enabling the at least one disabled setup link, in response to receiving the broadcast management frame.

35 In a further possible implementation form of the fourth aspect, the further management frame is a unicast management frame and the method further comprises sending a further

acknowledgement frame to the multi-link wireless AP, wherein the step of enabling the at least one disabled setup link comprises the step of enabling the at least one disabled setup link, in response to receiving the further management frame and sending the further acknowledgement frame to the multi-link wireless AP.

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The method according to the fourth aspect of the present disclosure can be performed by the multi-link wireless non-AP station according to the third aspect of the present disclosure. Thus, further features of the method according to the fourth aspect of the present disclosure result directly from the functionality of the multi-link wireless non-AP station according to the third aspect of the present disclosure as well as its different implementation forms described above and below.

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According to a fifth aspect a computer program product is provided, comprising program code which causes a computer or a processor to perform the method according to the second aspect or the method according to the fourth aspect, when the program code is executed by the computer or the processor.

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

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#### BRIEF DESCRIPTION OF THE DRAWINGS

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

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Fig. 1 shows a wireless communication system including a multi-link wireless AP according to an embodiment and a plurality of multi-link wireless non-AP stations according to an embodiment;

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Fig. 2 shows a multi-link wireless AP according to an embodiment in communication with a multi-link wireless non-AP station according to an embodiment;

Fig. 3 shows a flow diagram illustrating steps of a method of operating a multi-link wireless AP according to an embodiment; and

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Fig. 4 shows a flow diagram illustrating steps of a method of operating a multi-link wireless non-AP station according to an embodiment.

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

#### DETAILED DESCRIPTION OF THE EMBODIMENTS

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

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

In the following different embodiments of wireless devices, in particular wireless devices in  
accordance with the family of IEEE 802.11 WLAN standards will be described making use  
35 of one or more of the following abbreviations:

|    |       |                                                                                                                                                         |
|----|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
|    | DL    | Downlink                                                                                                                                                |
|    | UL    | Uplink                                                                                                                                                  |
|    | BSS   | Basic Serving Set                                                                                                                                       |
|    | AP    | Access Point                                                                                                                                            |
| 5  | CSA   | Channel Switch Announcement                                                                                                                             |
|    | DFS   | Dynamic Frequency Selection                                                                                                                             |
|    | PHY   | Physical Layer                                                                                                                                          |
|    | MAC   | Medium Access Control                                                                                                                                   |
|    | ML    | Multi Link                                                                                                                                              |
| 10 | MLD   | Multi Link Device                                                                                                                                       |
|    | MSDU  | MAC Service Data Unit                                                                                                                                   |
|    | MPDU  | MAC Protocol Data Unit                                                                                                                                  |
|    | PPDU  | PHY Protocol Data Unit                                                                                                                                  |
|    | POE   | Power Over Ethernet                                                                                                                                     |
| 15 | STA   | Station (in general, can be either an AP STA or a non-AP STA)                                                                                           |
|    | OFDMA | Orthogonal Frequency Division Multiple Access                                                                                                           |
|    | TDMA  | Time Division Multiple Access                                                                                                                           |
|    | TID   | Traffic Identifier; Any of the identifiers usable by higher layer entities to distinguish medium access control (MAC) service data units (MSDUs) to     |
| 20 |       | MAC entities that support quality of service (QoS) within the MAC data service                                                                          |
|    | TXOP  | Transmit Opportunity                                                                                                                                    |
|    | BA    | Block-ACK – in 802.11, typically a receiver is expected to respond to a data transmission by responding with an ACK; if multiple frames are transmitted |
| 25 |       | within a single PPDU, each has to be acknowledged                                                                                                       |

Figure 1 shows a wireless communication system 100 including a multi-link wireless AP 110 according to an embodiment and a plurality of multi-link wireless non-AP stations 120 according to an embodiment. As will be described in more detail in the following, the multi-link wireless AP 110 is configured to exchange a plurality of frames, including management frames, control frames and data frames, via a plurality of setup links with the plurality of multi-link wireless non-AP stations 120 in the wireless communication network 100. In an embodiment, the multi-link wireless AP 110 and the plurality of multi-link wireless non-AP stations 120 comply with one or more of the requirements defined by the family of IEEE 802.11 WLAN standards. The plurality of setup links between the multi-link

wireless AP 110 and the plurality of multi-link wireless non-AP stations 120 may have been setup by means of a preceding setup procedure.

As illustrated in figure 1, the multi-link wireless AP 110 comprises a processing circuitry 111 for processing data and a communication interface 113 for transmitting and receiving frames via the plurality of setup links. As will be appreciated, the communication interface 113 may comprise, for instance, one or more antennas for wireless communication. The processing circuitry 111 may be implemented in hardware and/or software. The hardware may comprise digital circuitry, or both analog and digital circuitry. Digital circuitry may comprise components such as application-specific integrated circuits (ASICs), field-programmable arrays (FPGAs), digital signal processors (DSPs), or general-purpose processors. The multi-link wireless AP 110 may further comprise a non-volatile memory 115, e.g. a Flash memory 115, configured to store data and executable program code which, when executed by the processing circuitry 111, causes the multi-link wireless AP 110 to perform the functions and operations described herein.

Likewise, the multi-link wireless non-AP station 120 comprises a processing circuitry 121 for processing data and a communication interface 123 for receiving and transmitting frames via the one or more setup links from the multi-link wireless AP 110. In an embodiment, the communication interface 123 may comprise one or more antennas for wireless communication. The processing entity 121 may be implemented in hardware and/or software. The hardware may comprise digital circuitry, or both analog and digital circuitry. Digital circuitry may comprise components such as application-specific integrated circuits (ASICs), field-programmable arrays (FPGAs), digital signal processors (DSPs), or general-purpose processors. The multi-link wireless non-AP station 120 may further comprise a non-volatile memory 125, e.g. a Flash memory 125, configured to store data and executable program code which, when executed by the processing circuitry 121, causes the multi-link wireless non-AP station 120 to perform the functions and operations described herein.

The communication interface 113 of the multi-link wireless AP 110 is configured to send a management frame (herein referred to as link disable notification management frame) to one or more of the multi-link wireless non-AP stations 120 that operate on the same link of the plurality of setup links (which herein is also referred to as the "first setup link" of the plurality of setup links in order to distinguish this setup link from the other setup links). As will be described in more detail in the following, the link disable notification management

frame sent to the one or more multi-link wireless non-AP stations 120 comprises information, e.g. one or more information elements or information fields, for identifying the first setup link (as well as possibly other setup links) to be temporarily disabled by the multi-link wireless AP 110. In other words, the processing circuitry 121 of each multi-link  
5 wireless non-AP station 120 receiving the link disable notification management frame from the multi-link wireless AP 110 (that is an intended recipient of the frame) is configured to extract, i.e. parse this information from the link disable notification management frame for identifying the first setup link (as well as possibly other setup links) to be temporarily disabled by the multi-link wireless AP 110.

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The processing circuitry 111 of the multi-link wireless AP 110 is further configured to, in response to sending the link disable notification management frame to the one or more multi-link wireless non-AP stations 120, temporarily disable the first setup link (as well as possibly other setup links identified by the link disable notification management frame) by  
15 blocking the exchange of any further frames via the first setup link (as well as possibly other setup links identified by the link disable notification management frame). Likewise, the processing circuitry 121 of each multi-link wireless non-AP station 120 receiving the link disable notification management frame from the multi-link wireless AP 110 is configured to disable, i.e. block exchange of any further frames via the first setup link (as  
20 well as possibly other setup links identified by the information extracted from the link disable notification management frame).

However, the one or more multi-link wireless non-AP stations 120 will be kept associated with the multi-link wireless AP 110 using a further, i.e. second enabled setup link of the  
25 plurality of setup links while the first setup link is disabled. In other words, while the first setup link is in the disabled state, the multi-link wireless AP 110 may still exchange frames with the one or more multi-link wireless non-AP stations 120 using the still enabled at least second setup link. As will be appreciated, operating the first setup link (as well as possibly other setup links identified by the link disable notification management frame) in the  
30 disabled state will result in a reduced power consumption of the multi-link wireless AP 110 as well as the one or more multi-link wireless non-AP stations 120.

Figure 2 shows the multi-link wireless AP 110 according to an embodiment in communication with the multi-link wireless non-AP station 120 according to an  
35 embodiment. In the embodiment shown in figure 2, the multi-link wireless AP 110 includes three "APs" that are affiliated therewith (referred to as AP1, AP2, AP3 in figure 2). By way

of example, the multi-link wireless non-AP station 120 includes three "STAs" that are affiliated therewith (referred to as STA1, STA2, STA3 in figure 2). The exemplary embodiment shown in figure 2 shows the connection between the multi-link wireless AP 110 (also referred to as "AP MLD") and the multi-link wireless non-AP station 120 (also referred to as "non-AP MLD") via three setup links (referred to as Link1, Link 2, Link 3 in figure 2). By way of example, Link 1 operates on the 2.4 GHz band, Link 2 operates on the 5 GHz band and Link 3 operates on the 6 GHz band.

In an embodiment, the communication interface 113 of the multi-link wireless AP 110 is configured to send the link disable notification management frame to the one or more multi-link wireless non-AP stations 120 operating on the first setup link via the first setup link itself to be disabled by the multi-link wireless AP 110. In a further embodiment, one or more further enabled setup links may be used for sending the link disable notification management frame to the one or more multi-link wireless non-AP stations 120 (provided the one or more multi-link wireless non-AP stations 120 are also operating on these one or more further enabled setup links).

In an embodiment, the link disable notification management frame may be a unicast management frame that is sent to a single individually addressed multi-link wireless non-AP station 120 that is operating on this link or a broadcast management frame that is sent to a group or all of the multi-link wireless non-AP stations 120 that are operating on this link.

In case the disable notification management frame is a unicast management frame, the communication interface 123 of the multi-link wireless non-AP station 120 is further configured to send, in response to receiving the individually addressed link disable notification management frame from the multi-link wireless AP 110, an acknowledgment frame, e.g. an ACK frame or a Block ACK frame, to the multi-link wireless AP 110. In this embodiment, the processing circuitry 111 of the multi-link wireless AP 110 may be configured to temporarily disable the first setup link, i.e. block exchange of further frames via the first setup link (as well as possibly other setup links identified by the link disable notification management frame), in response to sending the unicast link disable notification management frame to the individually addressed multi-link wireless non-AP station 120 and receiving the acknowledgement frame from the multi-link wireless non-AP station 120.

In case the disable notification management frame is a broadcast management frame, the processing circuitry 111 of the multi-link wireless AP 110 is configured to temporarily disable the first setup link (as well as possibly other setup links identified by the link disable notification management frame), in response to sending the broadcast link disable notification management frame to all of the plurality of multi-link wireless non-AP stations 120 operating on the first setup link.

In the following further embodiments of the multi-link wireless AP 110 and the multi-link wireless non-AP station(s) 120 will be described in more detail that make advantageous use of a mechanism for mapping transmission identifiers (TIDs) corresponding to data frames to one or more of the plurality of setup links. More specifically, in an embodiment, each data frame comprises a respective TID to which it corresponds and the processing circuitry 111 of the multi-link wireless AP 110 is configured to map individually each TID to one or more of the plurality of setup links for each of the plurality of multi-link wireless non-AP stations 120. In other words, the multi-link wireless AP 110 may implement a different TID-to-link mapping for each of the plurality of multi-link wireless non-AP stations 120. Based on the TID-to-link mapping defined for each of the plurality of multi-link wireless non-AP stations 120, the communication interface 113 of the multi-link wireless AP 110 is configured to send a respective data frame, in particular MSDU, depending on the TID of the data frame, via the one or more setup links the TID is mapped to.

In an embodiment, the link disable notification management frame comprises for one or more of the plurality of TIDs a respective bitmap defining the one or more of the plurality of setup links to which each TID is mapped to (for the at least one of the plurality of multi-link wireless non-AP stations 120). In an embodiment, the bitmaps defining the one or more of the plurality of setup links to which each TID is mapped to are valid until the communication interface 113 of the multi-link wireless AP 110 sends a further link disable notification management frame (or a further link enable notification management frame) to the one or more multi-link wireless non-AP stations 120.

In an embodiment, the plurality of bitmaps included in the link disable notification management frame may define for the first setup link (as well as possibly other setup links of the plurality of links) to be disabled by the multi-link wireless AP 110 that none of the plurality of TIDs is mapped to the first setup link (as well as possibly other setup links of the plurality of links) to be disabled by the multi-link wireless AP 110. In an embodiment, the plurality of TIDs may comprise up to 8 TIDs, wherein the bitmap for each TID

- comprises 2 octets, which allows mapping the up to 8 TIDs to up to 16 setup links. In an embodiment, for disabling a link, all of the bitmaps pertaining to a specific non-AP multi-link station contain a zero bit at a position corresponding to the setup link to be disabled.
- 5 In an embodiment, the link disable notification management frame may further comprise a direction field for defining whether the TID-to-link mapping defined by the one or more bitmaps is for a downlink, DL, communication direction or an uplink, UL, communication direction between the multi-link wireless AP 110 and the plurality of multi-link wireless non-AP stations 120. In an embodiment, the link disable notification management frame
- 10 may further comprise a TID presence indicator field for identifying those TIDs for which the one or more bitmaps define the mapping of the respective TID to one or more of the plurality of setup links.
- In an embodiment, the link disable notification management frame may comprise a
- 15 plurality of bitmaps for each of the multi-link wireless non-AP stations 120, wherein for each of the multi-link wireless non-AP stations 120 the plurality bitmaps define for one or more of the plurality of TIDs the one or more of the plurality of setup links to which the TID is mapped to for the respective multi-link wireless non-AP station 120. For instance, in an embodiment, the link disable notification management frame may comprise tuples or
- 20 groups consistent of a respective plurality of bitmaps (defining the TID-to-link mapping) and an identifier, such as an AID, of the respective multi-link wireless non-AP station 120. In a further embodiment, the link disable notification management frame may comprise only a single set of bitmaps defining the TID-to-link mapping for all of the plurality of multi-link wireless non-AP stations 120 that are operating on the same set of setup links.
- 25
- Thus, as will be appreciated, embodiments disclosed herein make "indirect" advantageous use of a TID-to-link mapping mechanism by mapping a specific setup link to none of the TIDs and thereby essentially disabling the link for reducing the power consumption in particular of the multi-link wireless AP 110.
- 30
- In an embodiment, the plurality of setup links comprises at least one disabled setup link, such as a previously enabled setup link that has been disabled by the multi-link wireless AP 110 as described above. For such an embodiment, the communication interface 113 of the multi-link wireless AP 110 is configured to send a further management frame
- 35 (herein referred to as link enable notification) management frame to one or more of the plurality of multi-link wireless non-AP stations 120. The link enable notification

management frame comprises information, e.g. one or more information elements or information fields, for the one or more multi-link wireless non-AP stations 120 for identifying the at least one disabled setup link to be immediately enabled by the multi-link wireless AP. The processing circuitry 121 of the one or more multi-link wireless non-AP stations 120 is configured to extract, i.e. parse this information from the link enable notification management frame and to identify the at least one disabled setup link to be enabled by the multi-link wireless AP 110 on the basis thereof. In response to sending the link enable notification management frame to the one or more multi-link wireless non-AP stations 120, the processing circuitry 111 of the multi-link wireless AP 110 is further configured to enable the at least one disabled setup link.

In an embodiment, the link enable notification management frame may have the same format and structure as the link disable notification management frame. Moreover, the link enable notification management frame may comprise one or more of the information elements of the link disable notification management frame described above, for instance, the plurality of bitmaps for defining the TID-to-link mapping(s). In an embodiment, the link enable notification management frame may comprise a default mapping indication for informing the one or more multi-link wireless non-AP stations 120 about a default mapping of the plurality of TIDs to the plurality of setup links, wherein, if the default mapping indication is set, the default mapping defines that all of the plurality of TIDs are mapped to all of the plurality of setup links, i.e. that all setup links are enabled.

In an embodiment, the processing circuitry 121 of the multi-link wireless non-AP station 120 is configured to identify the first setup link (as well as possibly other setup links) to be temporarily disabled by the multi-link wireless AP 110 and/or the at least one disabled setup link to be enabled by the multi-link wireless AP 110 on the basis of a most recent link disable/enable management frame and one or more previously received link disable/enable management frames. In an embodiment, the multi-link wireless non-AP station 120 may maintain the TID-to-link mappings for all TIDs in its memory 125 and update these TID-to-link mappings based on the most recent received link disable/enable management frame. For instance, the most recent received link disable/enable management frame may contain TID-to-link mappings for only two out of eight TIDs, e.g., for TID 1 and TID 3 (as also indicated in the TID presence indicator field already mentioned above). In that case the processing circuitry 121 of the multi-link wireless non-AP station 120 may update the TID-to-link mappings for TID 1 and TID 3 in the memory 125 and maintain the TID-to-link mappings for the other TIDs (based on one or more

previously received link disable/enable management frames). In case the multi-link wireless non-AP station 120 has not received any information about the TID-to-link mappings for one or more TIDs it shall apply the default TID-to-link mapping for these TIDs.

5

The embodiments described above for enabling a disabled setup link can be advantageously used for improving dynamic frequency selection (DFS). As will be appreciated, DFS is mainly used in the 802.11 specifications for radar detection on 5 GHz (UNII-2 band) channels. It is currently prohibited to use channels on 5 GHz if radar is detected on these channels. The current standardized approach is to switch a channel (only solution in single link case). The radar detection on a specific channel, initiates the evacuation of this channel (using CSA procedure) in the BSS, where this procedure is relatively long (3 to 10 beacon periods).

10

15 However, embodiments disclosed herein may provide for a very short recovery after radar detection on 5 GHz channels by setting up several links on "DFS channels" while using only a subset of these setup links. The other non-used links are disabled and used only as "backup links" for the case that radar is detected on any of the operating enabled links. This will assist the fast transition of the one or more multi-link wireless non-AP stations 20 120 to the "clean" backup links while the "DFS channels" become disabled during the time that radar is being detected.

Figure 3 shows a flow diagram illustrating steps of a method 300 of operating the multi-link wireless AP 110 according to an embodiment.

25

The method 300 comprises a first step 301 of sending a link disable notification management frame to one or more of the plurality of multi-link wireless non-AP stations 120 operating on the first setup link of the plurality of setup links, wherein the link disable notification management frame comprises information, e.g. one or more information 30 elements and fields, for the one or more multi-link wireless non-AP stations 120 for identifying the first setup link (and possibly other setup links of the plurality of setup links) to be temporarily disabled by the multi-link wireless AP 110.

35

Furthermore, in response to sending the link disable notification management frame, the method 300 comprises a further step 303 of temporarily disabling the first setup link, i.e. blocking exchange of further frames via the first setup link (and possibly other setup links

identified by the link disable notification management frame), wherein the one or more multi-link wireless non-AP stations 120 are kept associated using one or more second setup links of the plurality of setup links while the first setup link is disabled.

- 5 In an embodiment, the link disable notification management frame is a broadcast management frame and the step 303 of disabling at least the first setup link comprises immediately disabling at least the first setup link, in response to sending the broadcast management frame to the one or more multi-link wireless non-AP stations 120 operating on the first setup link.

10

- In a further embodiment the link disable notification management frame may be a unicast management frame, wherein the method 300 further comprises the step of receiving an acknowledgement frame from the multi-link wireless non-AP station 120 individually addressed by the unicast management frame. In this case the step 303 of disabling at  
15 least the first setup link comprises disabling at least the first setup link, in response to sending the unicast management frame and receiving the acknowledgement frame from the multi-link wireless non-AP station 120 individually addressed by the unicast management frame.

- 20 In an embodiment, where the plurality of setup links comprises at least one disabled setup link, the method 300 further comprises a step of sending a further management frame (referred to as link enable notification management frame) to one or more of the plurality of multi-link wireless non-AP stations 120, wherein the link enable notification management frame comprises information, e.g. one or more information elements or  
25 fields, for the one or more multi-link wireless non-AP stations 120 for identifying the at least one disabled setup link to be immediately enabled by the multi-link wireless AP 110.

- In an embodiment, the link enable notification management frame is a broadcast management frame and the step of enabling the at least one disabled setup link  
30 comprises immediately enabling the at least one disabled setup link, in response to sending the link enable notification management frame.

- In a further embodiment, the management frame may be a unicast management frame and the method 300 further comprises a step of receiving a further acknowledgement  
35 frame from the multi-link wireless non-AP station 120 individually addressed by the unicast management frame. In this case the step of enabling the at least one disabled

setup link comprises the step of enabling the at least one disabled setup link, in response to sending the unicast management frame and receiving the further acknowledgement frame from the multi-link wireless non-AP station 120 individually addressed by the unicast management frame.

5

As the method 300 can be implemented by the multi-link wireless AP 110, further features of the method 300 result directly from the functionality of the multi-link wireless AP 110 and its different embodiments described above and below.

- 10 Figure 4 shows a flow diagram illustrating steps of a method 400 of operating the multi-link wireless non-AP station 120 according to an embodiment.

The method 400 comprises a first step 401 of receiving a link disable notification management frame from the multi-link wireless AP 110. Moreover, the method 400  
15 comprises a step 403 of extracting, i.e. parsing information, e.g. one or more information elements or fields, from the link disable notification management frame for identifying a first setup link (and possibly further setup links) of the plurality of setup links to be temporarily disabled by the multi-link wireless AP 110. The method 400 further comprises a step 405 of disabling, i.e. blocking exchange of further frames via the first setup link  
20 (and possibly other setup links identified by the link disable notification management frame).

In an embodiment, the link disable notification management frame is a broadcast management frame and the step 405 of disabling at least the first setup link comprises  
25 disabling at least the first setup link, in response to receiving the link disable notification management frame.

In a further embodiment, the link disable notification management frame is a unicast management frame and the method 400 further comprises a step of sending an  
30 acknowledgement frame to the multi-link wireless AP 110. In this case the step 405 of disabling at least the first setup link comprises disabling at least the first setup link, in response to receiving the individually addressed link disable notification management frame and sending the acknowledgement frame to the multi-link wireless AP 110.

35 In an embodiment, where the plurality of setup links comprises at least one disabled setup link, the method 400 further comprises a step of receiving a link enable notification

management frame from the multi-link wireless AP 110 and a step of extracting, i.e. parsing further information, e.g. one or more further information elements or fields, from the link enable notification management frame for identifying the at least one disabled setup link to be enabled by the multi-link wireless AP 110. Moreover, the method 400  
5 comprises enabling, i.e. allowing exchange of further frames via the at least one disabled setup link identified by the further information extracted from the link enable notification management frame.

10 In an embodiment, the link enable notification management frame is a broadcast management frame and the step of enabling the at least one disabled setup link comprises enabling the at least one disabled setup link, in response to receiving the link enable notification management frame.

15 In a further embodiment, the link enable notification management frame is a unicast management frame and the method 400 further comprises sending a further acknowledgement frame to the multi-link wireless AP 110. In this case the step of enabling the at least one disabled setup link comprises enabling the at least one disabled setup link, in response to receiving the individually addressed link enable notification management frame and sending the further acknowledgement frame to the multi-link  
20 wireless AP 110.

As the method 400 can be implemented by the multi-link wireless non-AP station 120, further features of the method 400 result directly from the functionality of the multi-link wireless non-AP station 120 and its different embodiments described above and below.

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

In the several embodiments provided in the present application, it should be understood that the disclosed system, apparatus, and method may be implemented in other manners. For example, the described embodiment of an apparatus is merely exemplary. For  
35 example, the unit division is merely logical function division and may be another division in an actual implementation. For example, a plurality of units or components may be

combined or integrated into another system, or some features may be ignored or not performed. In addition, the displayed or discussed mutual couplings or direct couplings or communication connections may be implemented by using some interfaces. The indirect couplings or communication connections between the apparatuses or units may be  
5 implemented in electronic, mechanical, or other forms.

The units described as separate parts may or may not be physically separate, and parts displayed as units may or may not be physical units, may be located in one position, or may be distributed on a plurality of network units. Some or all of the units may be selected  
10 according to actual needs to achieve the objectives of the solutions of the embodiments.

In addition, functional units in the embodiments of the invention may be integrated into one processing unit, or each of the units may exist alone physically, or two or more units are integrated into one unit.  
15

CLAIMS

1. A multi-link wireless access point, AP, (110) configured to exchange a plurality of  
5 frames via a plurality of setup links with a plurality of multi-link wireless non-AP stations  
(120) in a wireless communication network (100), wherein the multi-link wireless AP (110)  
comprises:

a communication interface (113) configured to send a management frame to at least one  
10 of the plurality of multi-link wireless non-AP stations (120) operating on a first setup link of  
the plurality of setup links, wherein the management frame comprises information for the  
at least one of the plurality of multi-link wireless non-AP stations (120) for identifying at  
least the first setup link of the plurality of setup links to be disabled; and

15 a processing circuitry (111) configured to, in response to sending the management frame,  
disable at least the first setup link.

2. The multi-link wireless AP (110) of claim 1, wherein the plurality of setup links  
comprises at least one disabled setup link and wherein the communication interface (113)  
20 is further configured to send a further management frame to at least one of the plurality of  
multi-link wireless non-AP stations (120), wherein the further management frame  
comprises information for the at least one of the plurality of multi-link wireless non-AP  
stations (120) for identifying the at least one disabled setup link to be enabled, and  
wherein the processing circuitry (111) is further configured, in response to sending the  
25 further management frame, to enable the at least one disabled setup link.

3. The multi-link wireless AP (110) of claim 1 or 2, wherein the communication  
interface (113) is configured to send the management frame to the at least one of the  
plurality of multi-link wireless non-AP stations (120) operating on the first setup link via the  
30 first setup link to be disabled by the multi-link wireless AP (110).

4. The multi-link wireless AP (110) of any one of the preceding claims, wherein the  
management frame is a unicast management frame sent to one of the plurality of multi-  
link wireless non-AP stations (120) and wherein the communication interface (113) is  
35 configured to receive an acknowledgment frame from the one multi-link wireless non-AP

station (120), in response to sending the management frame to the one multi-link wireless non-AP station (120).

5. The multi-link wireless AP (110) of claim 4, wherein the processing circuitry (111) is configured to disable at least the first setup link, in response to sending the management frame to the one multi-link wireless non-AP station (120) and receiving the acknowledgement frame.
6. The multi-link wireless AP (110) of any one of claims 1 to 3, wherein the management frame is a broadcast management frame and wherein the processing circuitry (111) is configured to disable at least the first setup link, in response to sending the management frame to all of the plurality of multi-link wireless non-AP stations (120) operating on the first setup link.
7. The multi-link wireless AP (110) of any one of the preceding claims, wherein the plurality of frames comprises a plurality of data frames and wherein each data frame comprises a corresponding transmission identifier, TID, to which it corresponds of a plurality of TIDs and wherein the processing circuitry (111) is configured to map each TID to one or more of the plurality of setup links.
8. The multi-link wireless AP (110) of claim 7, wherein the communication interface (113) is configured to send each data frame, depending on the TID of the data frame, via the one or more setup links the TID is mapped to.
9. The multi-link wireless AP (110) of claim 7 or 8, wherein the information of the management frame comprises for one or more of the plurality of TIDs a bitmap defining the one or more of the plurality of setup links to which each TID is mapped to.
10. The multi-link wireless AP (110) of claim 9, wherein the bitmaps defining the one or more of the plurality of setup links to which each TID is mapped are valid until the communication interface (113) sends a further management frame which includes the bitmaps defining the one or more of the plurality of setup links to which each TID is mapped, to the at least one of the plurality of multi-link wireless non-AP stations (120).
11. The multi-link wireless AP (110) of claim 9 or 10, wherein for at least the first setup link to be disabled by the multi-link wireless AP (110) each bitmap defines that none of the

plurality of TIDs is mapped to at least the first setup link to be disabled by the multi-link wireless AP (110).

12. The multi-link wireless AP (110) of any one of claims 9 to 11, wherein the plurality  
5 of TIDs comprises up to 8 TIDs and wherein the bitmap for each TID comprises 2 octets.

13. The multi-link wireless AP (110) of any one of claims 7 to 11, wherein the plurality  
of setup links comprises at least one disabled setup link and wherein the communication  
interface (113) is further configured to send a further management frame to at least one of  
10 the plurality of multi-link wireless non-AP stations (120), wherein the further management  
frame comprises a default mapping indication for informing the at least one of the plurality  
of multi-link wireless non-AP stations (120) about a default mapping of the plurality of TIDs  
to the plurality of setup links, wherein the default mapping defines that all of the plurality of  
TIDs are mapped to all of the plurality of setup links.

14. The multi-link wireless AP (110) of any one of claims 7 to 13, wherein the  
management frame further comprises information for defining whether the mapping  
defined by the one or more bitmaps is for a downlink, DL, communication direction or an  
uplink, UL, communication direction between the multi-link wireless AP (110) and the  
20 plurality of multi-link wireless non-AP stations (120).

15. The multi-link wireless AP (110) of any one of claims 7 to 14, wherein the  
management frame further comprises information for identifying one or more of the  
plurality of TIDs for which the one or more bitmaps define the mapping of the respective  
25 TID to one or more of the plurality of setup links.

16. The multi-link wireless AP (110) of claim 6, wherein the information of the  
management frame comprises a plurality of bitmaps, wherein the plurality of bitmaps  
define for one or more of the plurality of TIDs and for at least two of the plurality of multi-  
30 link wireless non-AP stations (120) the one or more of the plurality of setup links to which  
the TID is mapped and wherein the management frame further comprises information for  
associating the one or more bitmaps with each of the at least two of the plurality of multi-  
link wireless non-AP stations (120), wherein each bitmap defines the one or more of the  
plurality of setup links to which the respective TID is mapped.

35

17. The multi-link wireless AP (110) of claim 16, wherein the plurality of bitmaps comprise for each of the one or more of the plurality of TIDs a single bitmap defining for the plurality of multi-link wireless non-AP stations (120) the one or more of the plurality of setup links to which the TID is mapped to.
- 5
18. A method (300) of operating a multi-link wireless access point, AP, (110) configured to exchange a plurality of frames via a plurality of setup links with a plurality of multi-link wireless non-AP stations (120) in a wireless communication network (100), wherein the method (300) comprises:
- 10
- sending (301) a management frame to at least one of the plurality of multi-link wireless non-AP stations (120) operating on a first setup link of the plurality of setup links, wherein the management frame comprises information for the at least one of the plurality of multi-link wireless non-AP stations (120) for identifying at least the first setup link of the plurality
- 15
- of setup links to be disabled; and
- in response to sending the management frame, disabling (303) at least the first setup link.
19. The method (300) of claim 18, wherein the management frame is a broadcast management frame and wherein disabling (303) at least the first setup link comprises immediately disabling at least the first setup link, in response to sending the broadcast management frame.
20. The method (300) of claim 18, wherein the management frame is a unicast management frame and wherein the method (300) further comprises receiving an acknowledgement frame, wherein disabling (303) at least the first setup link comprises disabling at least the first setup link, in response to sending the unicast management frame and receiving the acknowledgement frame.
- 25
21. The method (300) of any one of claims 18 to 20, wherein the plurality of setup links comprises at least one disabled setup link and wherein the method (300) further comprises sending a further management frame to at least one of the plurality of multi-link wireless non-AP stations (120), wherein the further management frame comprises information for the at least one of the plurality of multi-link wireless non-AP stations (120)
- 30
- for identifying the at least one disabled setup link to be enabled, and enabling the at least one disabled setup link, in response to sending the further management frame.
- 35

22. The method (300) of claim 21, wherein the further management frame is a further broadcast management frame and wherein enabling the at least one disabled setup link comprises immediately enabling the at least one disabled setup link, in response to  
5 sending the broadcast management frame.

23. The method (300) of claim 21, wherein the management frame is a unicast management frame and wherein the method (300) further comprises receiving a further acknowledgement frame, wherein enabling the at least one disabled setup link comprises  
10 enabling the at least one disabled setup link, in response to sending the unicast management frame and receiving the further acknowledgement frame.

24. A multi-link wireless non-access point, non-AP, station (120) configured to exchange a plurality of frames via a plurality of setup links with a multi-link wireless AP (110) in a wireless communication network (100), wherein the multi-link wireless non-AP  
15 station (120) comprises:

a communication interface (123) to receive a management frame from the multi-link wireless AP (110); and  
20

a processing circuitry (121) configured to extract information from the management frame for identifying at least a first setup link of the plurality of setup links to be disabled;

wherein the processing circuitry (121) is further configured to disable at least the first  
25 setup link.

25. The multi-link wireless non-AP station (120) of claim 24, wherein the management frame is a unicast frame and wherein the communication interface (123) is further configured to send, in response to receiving the individually addressed unicast  
30 management frame from the multi-link wireless AP (110), an acknowledgment frame to the multi-link wireless AP (110).

26. The multi-link wireless non-AP station (120) of claim 24 or 25, wherein the plurality of setup links comprises at least one disabled setup link and wherein the communication  
35 interface (123) is configured to receive a further management frame from the multi-link wireless AP (110), wherein the processing circuitry (121) is configured to extract further

information from the further management frame for identifying the at least one disabled setup link to be enabled, wherein the processing circuitry (121) is further configured to enable the at least one disabled setup link.

- 5 27. The multi-link wireless non-AP station (120) of claim 26, wherein the further management frame is a unicast management frame and wherein the communication interface (123) is further configured to send, in response to receiving the individually addressed further management frame from the multi-link wireless AP (110), a further acknowledgment frame to the multi-link wireless AP (110).

10

28. The multi-link wireless non-AP station (120) of any one of claims 22 to 27, wherein the plurality of frames comprises a plurality of data frames and wherein each data frame comprises a corresponding transmission identifier, TID, of a plurality of TIDs and wherein the processing circuitry (121) is configured to map each TID to one or more of the plurality  
15 of setup links.

29. The multi-link wireless non-AP station (120) of claim 28, wherein the communication interface (123) is configured to send each data frame, depending on the TID of the data frame, via the one or more setup links the TID is mapped to.

20

30. The multi-link wireless non-AP station (120) of claim 28 or 29, wherein the information of the management frame comprises for one or more of the plurality of TIDs a bitmap defining the one or more of the plurality of setup links to which each TID is mapped to.

25

31. The multi-link wireless non-AP station (120) of claim 30, wherein the processing circuitry (121) is configured to identify at least the first setup link based on the plurality of bitmaps by determining that for at least the first setup link to be disabled by the multi-link wireless AP (110) each bitmap defines that none of the plurality of TIDs is mapped to at  
30 least the first setup link to be disabled by the multi-link wireless AP (110).

32. The multi-link wireless non-AP station (120) of claim 30 or 31, wherein the processing circuitry (121) is configured to identify at least one disabled setup link based on the plurality of bitmaps by determining that for the at least one disabled setup link to be  
35 enabled by the multi-link wireless AP (110) at least one bitmap of the plurality of bitmaps

defines that at least one of the plurality of TIDs is mapped to the at least one disabled setup link to be enabled by the multi-link wireless AP (110).

33. The multi-link wireless non-AP station (120) of claim 32, further comprising a  
5 memory (125) configured to maintain the plurality of bitmaps defining the one or more of the plurality of setup links to which each TID is mapped, wherein the processing circuitry (121) is configured to update the plurality of bitmaps stored within the memory based on the bitmaps contained within the link disable management frame and/or the link enable management frame and to identify, based on the plurality of bitmaps stored within the  
10 memory (125), at least the first setup link of the plurality of setup links to be temporarily disabled by the multi-link wireless AP (110) and/or the at least one disabled setup link to be enabled by the multi-link wireless AP (110).

34. The multi-link wireless non-AP station (120) of any one of claims 30 to 33, wherein  
15 the management frame is a broadcast management frame and wherein the processing circuitry (121) is further configured to extract an association identifier of the multi-link wireless non-AP station (120) from the broadcast management frame for identifying a subset of the plurality of bitmaps for the multi-link wireless non-AP station (120), wherein the subset of the plurality of bitmaps defines for one or more of the plurality of TIDs the  
20 one or more of the plurality of setup links to which the TID is mapped.

35. The multi-link wireless non-AP station (120) of claim 34, wherein the processing circuitry (121) is configured to extract the subset of the plurality of bitmaps from the management frame for identifying at least the first setup link of the plurality of setup links  
25 to be disabled, if the broadcast management frame comprises the association identifier of the multi-link wireless non-AP station (120).

36. A method (400) of operating a multi-link wireless non-access point, non-AP, station (120) configured to exchange a plurality of frames via a plurality of setup links with a multi-  
30 link wireless AP (110) in a wireless communication network (100), wherein the method (400) comprises:

receiving (401) a management frame from the multi-link wireless AP (110);

35 extracting (403) information from the management frame for identifying at least a first setup link of the plurality of setup links to be disabled; and

disabling (405) at least the first setup link.

37. The method (400) of claim 36, wherein the management frame is a broadcast  
5 management frame and wherein disabling (405) at least the first setup link comprises  
disabling at least the first setup link, in response to receiving the broadcast management  
frame.

38. The method (400) of claim 36, wherein the management frame is a unicast  
10 management frame and wherein the method (400) further comprises sending an  
acknowledgement frame to the multi-link wireless AP (110), wherein the step of disabling  
(405) at least the first setup link comprises disabling at least the first setup link, in  
response to receiving the unicast management frame and sending the acknowledgement  
frame to the multi-link wireless AP (110).

15 39. The method (400) of any one of claims 36 to 38, wherein the plurality of setup links  
comprises at least one disabled setup link and wherein the method (400) further  
comprises:

20 receiving a further management frame from the multi-link wireless AP (110);

extracting further information from the further management frame for identifying the at  
least one disabled setup link to be enabled; and

25 enabling the at least one disabled setup link.

40. The method (400) of claim 39, wherein the further management frame is a  
broadcast management frame and wherein enabling the at least one disabled setup link  
comprises enabling the at least one disabled setup link, in response to receiving the  
30 broadcast management frame.

41. The method (400) of claim 39, wherein the further management frame is a unicast  
management frame and wherein the method (400) further comprises sending a further  
acknowledgement frame to the multi-link wireless AP (110), wherein the step of enabling  
35 the at least one disabled setup link comprises enabling the at least one disabled setup

link, in response to receiving the further management frame and sending the further acknowledgement frame to the multi-link wireless AP (110).

42. A computer program product comprising a computer-readable storage medium for  
5 storing program code which causes a computer or a processor to perform the method (300) of any one of claims 18 to 23 or the method (400) of any one of claims 36 to 41, when the program code is executed by the computer or the processor.