

**METHODS, MODULES, AND STORAGE MEDIA FOR CHANGING COMMUNICATION LINKS FOR
MULTI-LINK DEVICES ON MOBILE WIRELESS LOCAL AREA NETWORKS**

TECHNICAL FIELD

The present disclosure relates generally to multi-link devices on wireless networks, and in particular, to changing communication links for multi-link devices on wireless networks.

BACKGROUND

Multi-link devices (MLDs) are network elements that communicate with peer MLDs over multiple communication links. A MLD that provides access point (AP) functionality is commonly referred to as an AP MLD. A non-AP MLD uses affiliated stations (STAs) for communication over a wireless medium with an AP MLD that in turn uses affiliated APs.

A MLD can support multiple radios operating simultaneously, each radio operating within one or more frequency bands. MLDs can establish a connection with other MLDs across multiple radios with each connection referred to as a communication link.

Wireless local network (WLAN) standards, such as Institute of Electrical and Electronics Engineers (IEEE) 802.11, can be configured for MLDs to be used in a variety of modes of operation including where a non-AP MLD and AP MLD operate in a multi-link operation (MLO) mode wherein the devices communicate over multiple, independent radio connections or communication links as illustrated in **FIG. 1** and **FIG. 2**. Communications over a single communication link occurs between an affiliated STA of a non-AP MLD and an affiliated AP of an associated AP MLD.

Generally, when a non-AP MLD associates with an AP MLD, a set of communication links is negotiated, wherein each communication link maps an affiliated STA of a non-AP MLD to an affiliated AP of an AP MLD. The mapping of communication links between the non-AP MLD and the AP MLD is fixed while the non-AP MLD is associated to the AP MLD. If one of the communication links between the AP MLD and the non-AP MLD needs to be changed, the AP MLD and the non-AP MLD are disassociated, resulting in termination of all communication links and a momentary loss in network connectivity, followed by a re-association establishing the new communications links.

SUMMARY

The present disclosure relates to multi-link devices (MLDs) including access point (AP) MLDs and non-AP MLDs, and specifically modules, systems and methods for changing a first communication link between a first affiliated station (STA) of a non-AP MLD and a first affiliated AP of an AP MLD to a second communication link between the first affiliated STA of the non-AP MLD and a second affiliated AP of the non-AP MLD, while maintaining a third communication link between a second affiliated STA of the non-AP MLD and a third affiliated AP of the AP MLD. More specifically, the present disclosure provides modules, systems and methods for changing a communication link independent of other communication links allowing for continuous connectivity between a non-AP MLD and an AP MLD.

In a broad aspect of the present disclosure, a method comprises changing a first communication link between a first affiliated station of a first device and a first affiliated AP of a second device to a second communication link between the first affiliated station of the first device and a second affiliated AP of the second device, while maintaining a third communication link between a second affiliated station of the first device and a third affiliated AP of the second device.

In some embodiments, the method further comprises the step of activating one or more affiliated APs of the second device from a deactivated state to an activated state upon detection of a proximate first device.

5 In some embodiments, the method further comprises the step of the first device sending a communication link configuration request management frame to the second device to request changing the first communication link to the second communication link.

In some embodiments, the method further comprises the second device sending a communication link configuration response management frame to the first device to confirm changing the first communication link to the second communication link.

10 In some embodiments, the method further comprises the second device sending a communication link configuration query management frame to the first device to suggest changing the first communication link to the second communication link.

In some embodiments, the communication link configuration request management frame comprises the following fields: category, communication link configuration action, dialog token, current communication link information, and new communication link information.

15 In some embodiments, the communication link configuration response management frame comprises the following fields: category, communication link configuration action, dialog token and new communication link information.

In some embodiments, the communication link configuration query management frame comprises the following fields: category, communication link configuration action, dialog token, current communication link information, and new communication link information.

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In some embodiments, the communication link configuration response management frame further comprises group keys of the second affiliated AP for decrypting data of the second affiliated AP.

In some embodiments, the second device is an AP MLD and the first device is a non-AP MLD for a network using an IEEE 802.11 protocol configured for multi-link operation.

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In some embodiments, the IEEE 802.11 protocol is IEEE 802.11be.

In some embodiments, at least one of the one or more affiliated APs of the second device are for operating in a dedicated service mode.

In some embodiments, the dedicated service mode comprises one of six gigahertz (6 GHz), Emergency Preparedness Communications Service (EPSC), and Enhanced Broadcast Service (EBCS).

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In some embodiments, at least one of the one or more affiliated APs of the second device are for operating in at least one service mode.

In some embodiments, the at least one service mode comprises one or more of Millimeter Wave (mmWave), Directional Multi-Gigabit (DMG), China Directional Multi-Gigabit (CDMG), and Enhanced Directional Multi-Gigabit (EDMG).

In a broad aspect of the present disclosure, a module comprises a second device comprising a plurality of affiliated APs, each affiliated AP for establishing a communication link with an affiliated station of a first device, wherein the second device is configured to independently change each communication link between an affiliated AP and an affiliated station.

5 In some embodiments, the second device is configured to send a communication link configuration query management frame to a first device to suggest changing a communication link.

In some embodiments, the second device is configured to send the communication link configuration query management frame upon detection of increased packet errors, environmental conditions, or other events supporting changing the communication link.

10 In some embodiments, the second device is configured to send a communication link configuration response management frame to a first device to confirm changing a communication link.

In some embodiments, the communication link configuration response management frame comprises group keys of an affiliated AP for decrypting information of the affiliated AP.

15 In some embodiments, one or more of the affiliated APs is configured to activate upon detection of a proximate first device.

In some embodiments, the second device is an AP MLD for a network using an IEEE 802.11 protocol configured for multi-link operation.

In some embodiments, the IEEE 802.11 protocol is IEEE 802.11be.

20 In some embodiments, one or more of the plurality of affiliated APs is configured to operate in a dedicated service mode.

In some embodiments, the dedicated service mode comprises one of 6 GHz, EPSC, and EBCS.

In some embodiments, one or more of the plurality of affiliated APs is configured to operation in at least one service mode.

25 In some embodiments, at least one service mode comprises one or more of mmWave, DMG, CDMG, and EDMG.

In a broad aspect of the present disclosure, a module comprises a first device configured to provide a plurality of affiliated stations, each affiliated station for establishing a communication link with an affiliated AP of a second device, wherein the first device is configured to independently change each communication link between an affiliated station and an affiliated AP.

30 In some embodiments, the first device is configured to send a communication link configuration request management frame to a second device to request changing a communication link.

In some embodiments, the first device is configured to send the communication link configuration request management frame upon detection of increased packet errors, environmental conditions, or other events supporting changing the communication link, or newly available affiliated APs.

In some embodiments, the first device is a non-AP MLD for a network using an IEEE 802.11 protocol configured for multi-link operation.

In some embodiments, the IEEE 802.11 protocol is IEEE 802.11be.

5 In a broad aspect of the present disclosure, one or more non-transitory computer-readable storage media comprises computer-executable instructions for managing communication links for MLDs, wherein the instructions, when executed, cause a processing structure to perform actions comprising changing a first communication link between a first affiliated station of a first device and a first affiliated AP of a second device to a second communication link between the first affiliated station of the first device and a second affiliated AP of the second device, while maintaining a third communication link between a second affiliated station of the first device and a third affiliated AP of the second device.

10 In some embodiments, the one or more storage media is further for activating one or more affiliated APs of the second device from a deactivated state to an activated state upon detection of a proximate first device.

In some embodiments, the one or more storage media is further for the first device sending a communication link configuration request management frame to the second device to request changing the first communication link to the second communication link.

15 In some embodiments, the one or more storage media is further for the second device sending a communication link configuration response management frame to the first device to confirm changing the first communication link to the second communication link.

20 In some embodiments, the one or more storage media is further for the second device sending a communication link configuration query management frame to the first device to suggest changing the first communication link to the second communication link.

In some embodiments, the communication link configuration request management frame comprises the following fields: category, communication link configuration action, dialog token, current communication link information, and new communication link information.

25 In some embodiments, the communication link configuration response management frame comprises the following fields: category, communication link configuration action, dialog token and new communication link information.

In some embodiments, the communication link configuration query management frame comprises the following fields: category, communication link configuration action, dialog token, current communication link information, and new communication link information.

30 In some embodiments, the communication link configuration response management frame further comprises group keys of the second affiliated AP for decrypting data of the second affiliated AP.

In some embodiments, the second device is an AP MLD and the first device is a non-AP MLD for a network using an IEEE 802.11 protocol configured for multi-link operation.

In some embodiments, the IEEE 802.11 protocol is IEEE 802.11be.

35 In some embodiments, at least one of the one or more affiliated APs of the second device are for operating in a dedicated service mode.

In some embodiments, the dedicated service mode comprises one of 6 GHz, EPSC, and EBCS.

In some embodiments, at least one of the one or more affiliated APs of the second device are for operating in at least one service mode.

5 In some embodiments, at least one service mode comprises one or more of mmWave, DMG, CDMG, and EDMG.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the disclosure, reference is made to the following description and accompanying drawings, in which:

10 **FIG. 1** is a schematic of an embodiment of a prior art pair of multi-link devices (MLDs);

FIG. 2 is a schematic of an embodiment of a prior art pair of MLDs;

FIG. 3 is a schematic of an embodiment of a pair of MLDs comprising an access point (AP) MLD and an associated non-AP MLD;

FIG. 4 is a schematic of the pair of MLDs of **FIG. 3** wherein a communication link between the AP MLD and the non-AP MLD is changed;

15 **FIG. 5** is a schematic of the pair of MLDs of **FIG. 4** wherein a communication link between the AP MLD and the non-AP MLD is changed;

FIG. 6 is a flowchart of an embodiment of a method of changing a communication link between an AP MLD and a non-AP MLD;

FIG. 7 is an illustration of an embodiment of a link configuration response management frame;

20 **FIG. 8** is an illustration of an embodiment of a link configuration query management frame;

FIG. 9 is an illustration of an embodiment of a link configuration request management frame;

FIG. 10 is an exemplary schematic of communication flow between an AP MLD and a non-AP MLD for changing a communication link initiated by the non-AP MLD;

25 **FIG. 11** is an exemplary schematic of communication flow between an AP MLD and a non-AP MLD for changing a communication link initiated by the AP MLD;

FIG. 12 is a schematic of an embodiment of a pair of MLDs comprising an AP MLD and an associated non-AP MLD, wherein the AP MLD comprises two disabled affiliated APs;

FIG. 13 is a schematic of the pair of MLDs of **FIG. 12** wherein the two disabled affiliated APs are enabled; and

30 **FIG. 14** is a schematic of the pair of MLDs of **FIG. 13** wherein a communication link between the AP MLD and the non-AP MLD is changed.

DETAILED DESCRIPTION

Unless otherwise defined, all technical and scientific terms used herein generally have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure pertains. Exemplary terms are defined below for ease in understanding the subject matter of the present disclosure.

5 In embodiments disclosed herein, a network comprises two or more devices that are interconnected through a communication link (by a cable, a wireless connection and/or other means) for sharing resources, information, and/or the like. In embodiments disclosed herein, a multi-link device (MLD) is a device that connects to one or more devices through two or more communication links. In embodiments disclosed herein, a multi-link network is a network comprising one or more MLDs.

10 The Institute of Electrical and Electronics Engineers (IEEE) is a professional association for electronic and electrical engineering, and is a body responsible for setting communication standards. The IEEE 802.11 standards are a part of IEEE 802 local area network technical standards specifying media access control (MAC) and physical layer (PHY) protocols for implementing wireless local area networks (WLANs). IEEE 802.11be is an amendment to the IEEE 802.11 standard which may include a multi-link operation (MLO) feature wherein two MLDs communicate over one or more,
15 independent radio connections or communication links.

In embodiments disclosed herein, an access point (AP) or wireless AP is a device which acts a portal to other devices to connect to one or more other networks. In some embodiments, the AP provides an interconnection between wireless devices and other wireless/wired networks including the devices thereon. APs are commonly used for extending wireless coverage of an existing network and for increasing the number of users or devices that can connect to a WLAN.

20 In embodiments disclosed herein, a station (STA) is a device configured to connect to one or more APs. A STA may be fixed, mobile or portable. A STA may also referred to as a wireless client, a node, and/or a transmitter or receiver based on transmission characteristics. IEEE 802.11-2020 specifies that a STA is any device that contains an IEEE 802.11-conformant MAC and PHY interface for connecting to a wireless medium.

25 In embodiments disclosed herein, a MLD is a network element that communicates with a peer MLD through two or more communication links. A MLD that provides AP functionality is commonly referred to as an AP MLD. A non-AP MLD comprises affiliated STAs for communicating over a wireless medium with affiliated APs in an AP MLD. An MLD can support multiple radios operating simultaneously within multiple bands. MLDs can establish a connection across multiple radios, which connections are referred to as communication links.

30 “Affiliated” as used herein means a device, component, element and/or the like that is either physically connected to and/or integrated with, or logically connected to another device, component, element and/or the like. As used herein, an affiliated AP may be physically, logically or otherwise connected to or used by an AP MLD, and a reference to an affiliated AP would be equivalent to an AP being affiliated with an AP MLD. Similarly, as used herein, an affiliated STA may be physically, logically or otherwise connected to or used by a non-AP MLD, and a reference to an affiliated STA would be equivalent to a STA being affiliated with a non-AP MLD.

35 In embodiments disclosed herein, an AP MLD may also be referred to as a multi-link AP, a multi-link AP device, and/or an AP multi-link device. A non-AP MLD associated with a non-AP STA may be referred to as a multi-link STA, a multi-link STA device, or a STA multi-link device.

In embodiments disclosed herein, MLDs support multiple radios simultaneously operating within multiple bands. MLDs may establish connections across multiple radios, which are referred to as communication links. Communications over a single communication link can occur between a STA affiliated with a non-AP MLD and an AP affiliated with an AP MLD.

5 When a non-AP MLD associates with an AP MLD, a set of communication links are negotiated, where each communication link maps an affiliated STA in the non-AP MLD to an affiliated AP in the AP MLD. Generally, the mapping of communication links between a non-AP MLD and AP MLD are fixed while the non-AP MLD is associated with the AP MLD. Referring to **FIG. 1**, a prior art MLD pair **100**, which may form part of a wireless network, comprises an AP MLD **102** and an associated non-AP MLD **120**. The AP MLD **102** comprises a first affiliated AP (AP-1) **104** and a second affiliated AP (AP-2) **106** and the non-AP MLD **120** comprises a first affiliated STA (STA-1) **122** and a second affiliated STA (STA-2) **124**. The first affiliated AP **104** and the first affiliated STA **122** are configured to operate at 2.4 GHz, while the second affiliated AP **106** and the second affiliated STA **124** are configured to operate at 5 GHz. The first affiliated AP **104** and the first affiliated STA **122** form a first communication link **130** and the second affiliated AP **106** and the second affiliated STA **124** form a second communication link **132**. When the AP MLD **102** associates with the non-AP MLD **120**,
10 the first communication link **130** and the second connection link **132** are established.
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Embodiments disclosed herein relate to systems, methods, and MLD modules, including circuitry and software for executing processes, relating to MLDs. As will be described later in more detail, a “module” is a term of explanation referring to a hardware structure such as a circuitry implemented using technologies such as electrical and/or optical technologies (and with more specific examples of semiconductors) for performing defined operations or processings.
20 A “module” may alternatively refer to the combination of a hardware structure and a software structure, wherein the hardware structure may be implemented using technologies such as electrical and/or optical technologies (and with more specific examples of semiconductors) in a general manner for performing defined operations or processings according to the software structure in the form of a set of instructions stored in one or more non-transitory, computer-readable storage devices or media.

25 As will be described in more detail below, a MLD module may be a part of a device, an apparatus, a system, and/or the like, wherein the MLD module may be coupled to or integrated with other parts of the device, apparatus, or system such that the combination thereof forms the device, apparatus, or system. Alternatively, the MLD module may be implemented as a standalone encryption/decryption device or apparatus.

30 The MLD module executes processes including those for establishing and changing communication links. Herein, a process has a general meaning equivalent to that of a method, and does not necessarily correspond to the concept of computing process (which is the instance of a computer program being executed). More specifically, a process herein is a defined method implemented using hardware components for processing data (for example, transmitting and receiving management frames, and/or the like). A process may comprise or use one or more functions for processing data as designed. Herein, a function is a defined sub-process or sub-method for computing, calculating, or otherwise processing input data in a
35 defined manner and generating or otherwise producing output data.

As those skilled in the art will appreciate, the MLD processes disclosed herein may be implemented as one or more software and/or firmware programs having necessary computer-executable code or instructions and stored in one or more non-transitory computer-readable storage devices or media which may be any volatile and/or non-volatile, non-removable or removable storage devices such as RAM, ROM, EEPROM, solid-state memory devices, hard disks, CDs,
40 DVDs, flash memory devices, and/or the like. The MLD module may read the computer-executable code from the storage devices and execute the computer-executable code to perform the encryption and/or decryption processes.

Alternatively, the MLD processes disclosed herein may be implemented as one or more hardware structures having necessary electrical and/or optical components, circuits, logic gates, integrated circuit (IC) chips, and/or the like.

FIG. 2 illustrates an embodiment of a prior art MLD pair **100**, which may form part of a wireless network, comprising an AP MLD **102** and an associated non-AP MLD **120**. The AP MLD **102** comprises three affiliated APs, a first affiliated AP (AP1) **104** configured to operate at 2.4 GHz, a second affiliated AP (AP2) **106** configured to operate at 5 GHz, and a third affiliated AP (AP3) **108** configured to operate at 5 GHz. The non-AP MLD **120** comprises two affiliated STAs, a first affiliated STA (STA1) **122** configured to operate at 2.4 GHz and a second affiliated STA (STA2) **124** configured to operate at 5 GHz. As above, when a non-AP MLD associates with an AP MLD, one or more communication links are negotiated and established between affiliated APs of the AP MLD and affiliated STAs of the non-AP MLD. Referring to **FIG. 2**, a first communication link **130** is established between the first affiliated AP **104** and the first affiliated STA **122** and a second communication link **132** is established between the second affiliated AP **106** and the second affiliated STA **124**, while the third affiliated AP **108** is unconnected and available.

In some embodiments, an AP MLD, a non-AP MLD and/or another device may monitor network conditions to determine if modifying communication links would provide improved quality. For example, this can be a result of monitoring environmental factors such as data traffic flow, packet errors, available APs and STAs, and/or the like. Changes in conditions can also be a result of physical migration of devices, including a non-AP MLD, environmental changes, or other events.

In some embodiments, during operation of the MLD pair **100**, it is determined that the third affiliated AP **108** provides a better quality communication link with the second affiliated STA **124** than the second affiliated AP **106**. To change a communication link between AP MLD **102** and the associated non-AP MLD **120**, disassociation of the AP MLD **102** and the non-AP MLD **120** is first required. Following the disassociation, a re-association between the AP MLD **102** and the non-AP MLD **120** can occur with the new or re-mapped communication links. The disassociation and re-association, or re-negotiation, between the AP MLD **102** and the non-AP MLD **120** results in a temporary loss in network connectivity in both the first communication link **130** and the second communication link **132**.

Referring to **FIG. 2**, to change the second communication link **132** for the second affiliated STA **124** from the second affiliated AP **106** to the third affiliated AP **108**, the AP MLD **102** and the non-AP MLD **120** will first disassociate. As previously described, this means that network connectivity is temporarily suspended and the security association between the AP MLD **102** and the non-AP MLD **120** is lost. When the non-AP MLD **120** successfully completes re-association to the AP MLD **102**, the first communication link **130** remains between the first affiliated AP **104** and the first affiliated STA **122** and the second communication link **132** is re-mapped from between the second affiliated AP **106** and the second affiliated STA **124** to between the third affiliated AP **108** and the second affiliated STA **124**.

In some embodiments disclosed herein, affiliated APs use different group security keys to cryptographically encapsulate group addressed traffic. When the non-AP MLD **120** changes its link mapping with the AP MLD **102**, the non-AP MLD **120** needs to receive updated group keys based on the new communication link mapping. As a result of the re-mapping described above, a new security association is established between the AP MLD **102** and the non-AP MLD **120**.

Referring to **FIG. 3**, in embodiments of the present disclosure, an MLD pair **200**, which may form part of a wireless network, comprises an AP MLD **202** and a non-AP MLD **220**. The AP MLD comprises a first affiliated AP (AP1) **204** configured to operate at 2.4 GHz, a second affiliated AP (AP2) **206** configured to operate at 5 GHz, a third affiliated AP (AP3) **208** configured to operate at 2.4 GHz and a fourth affiliated AP (AP4) **210** configured to operate at 5 GHz. The non-AP MLD **220** comprises a first affiliated STA (STA1) **222** and a second affiliated STA (STA2) **224**. In embodiments

disclosed herein, the MLD pair **200** is connected to a local area network (LAN) **240**, which may be connected to one or more other devices including a wired gateway **250**.

While **FIG. 3** depicts one AP MLD **202**, a wireless network can comprise any number of additional AP MLDs and additional non-AP MLDs, each AP MLD comprising one or more affiliated APs wherein each AP is configured to operate at one or more operating frequencies and each non-AP MLD comprising one or more affiliated STAs wherein each affiliated STA is configured to operate at one or more operating frequencies.

In embodiments disclosed herein, the non-AP MLD **220** can change communication link mapping of the first affiliated STA **222** or the second affiliated STA **224** with affiliated APs of the AP MLD **202** using a message exchange that takes place while the non-AP MLD remains associated without a corresponding loss of network connectivity, wherein the message exchange occurs over the unchanged communication link.

By updating the mapping of communication links of affiliated STAs, the non-AP MLD **220** can optimize the usage of the multiple radio resources of the AP MLD **202**. In embodiments disclosed herein, group keys associated with new communication link mappings can also be updated using the message exchange. Further, the AP MLD **202** can also manage its radio resources more efficiently by suggesting to one or more associated non-AP MLDs to change their communication links dynamically to optimize performance, using the message exchange.

Referring to **FIG. 3**, in embodiments disclosed herein, the AP MLD **202** comprises two affiliated APs operating at 2.4 GHz, the first affiliated AP **204** and the third affiliated AP **208** and two affiliated APs operating at 5 GHz, the second affiliated AP **206** and the fourth affiliated AP **210**. In an embodiment, the first affiliated STA **222** of the non-AP MLD **220** is configured to operate at 2.4 GHz and the second affiliated STA **224** of the non-AP MLD **220** is configured to operate at 5 GHz. Referring to **FIG. 3**, in an embodiment, the AP MLD **202** and the non-AP MLD **220** are associated wherein a first communication link **230** is established between the first affiliated AP **204** and the first affiliated STA **222** and a second communication link **232** is established between the second affiliated AP **206** and the second affiliated STA **224**.

In embodiments disclosed herein, an AP MLD of a plurality of AP MLDs is distributed throughout a coverage area with the AP MLD comprising multiple affiliated APs. This may be an example of an AP MLD forming part of a WLAN within an enterprise or a large home. In embodiments, disclosed herein, a non-AP MLD (with fewer affiliated STAs than the number of affiliated APs in the AP MLD) associates to the AP MLD. The MLD pair **200** of **FIG. 3** comprises four available affiliated APs in the AP MLD **202**.

As the non-AP MLD **220** moves within a coverage zone of the AP MLD **202** or the wireless environment changes, the non-AP MLD **220** may change its communication link configuration to use other affiliated APs of the same AP MLD **220**, while maintaining its association with the AP MLD **202**, to optimize its communication link quality.

In an exemplary embodiment, referring to **FIG. 3**, after association between the AP MLD **202** and the non-AP MLD **220**, the first communication link **230** is established between the first affiliated AP **204** and the first affiliated STA **222** and the second communication link **232** is established between the second affiliated AP **206** and the second affiliated STA **224**. Of note, the third affiliated AP **208** and the fourth affiliated AP **210** are not mapped to affiliated STAs of the non-AP MLD **220**.

As a result of physical movement, environmental changes, or other events, the non-AP MLD **220** initiates a change of the second communication link **232**. Referring to **FIG. 4**, the second affiliated STA **224** is associated with the fourth affiliated AP **210** to establish a third communication link **234**. Notably, the first communication link **230** between the

first affiliated AP **204** and the first affiliated STA **222** is maintained during the transition from the second communication link **232** to the third communication link **234** such that communication between the AP MLD **202** and the non-AP MLD **220** is maintained including for message exchanges. After the transition from the second communication link **232** to the third communication link **234**, the second affiliated AP **206** is no longer mapped to an affiliated STA of the AP MLD **202**.

5 As a result of further physical movement, environmental changes, or other events, the non-AP MLD **220** initiates a change of the first communication link **230**. Referring to **FIG. 5**, the first affiliated STA **222** is associated with the third affiliated AP **208** to establish a fourth communication link **234**. Notably, the third communication link **234** between the fourth affiliated AP **210** and the second affiliated STA **224** is maintained during the transition from the first communication link **230** to the fourth communication link **236** such that communication between the AP MLD **202** and the non-AP MLD **220** is maintained including for message exchanges. After the transition from the first communication link **230** to the fourth communication link **236**, the first affiliated AP **204** is no longer mapped to an affiliated STA of the AP MLD **202**.

The methods disclosed herein may be applied to Directional Multi-Gigabit (DMG), China Directional Multi-Gigabit (CDMG) and Enhanced Directional Multi-Gigabit (EDMG) communication links, wherein coverage areas are often limited and the affiliated APs supporting the applicable frequency bands use highly directional antennas.

15 **FIG. 6** illustrates the steps of an embodiment of a method **600** of changing a communication link of an AP MLD **202** and a non-AP MLD **220**. The method **600** begins with changing a first communication link between a first affiliated station of a first device and a first affiliated AP of a second device to a second communication link between the first affiliated station of the first device and a second affiliated AP of the second device, while maintaining a third communication link between a second affiliated station of the first device and a third affiliated AP of the second device at step **602**. At step **604**, optionally, one or more affiliated APs of the second device are activated from a deactivated state to an activated state upon detection of a proximate first device. At step **606**, optionally, the first device sends a communication link configuration request management frame to the second device to request changing the first communication link to the second communication link. At step **608**, optionally, the second device sends a communication link configuration response management frame to the first device to confirm changing the first communication link to the second communication link. At step **610**, optionally, the second device sends a communication link configuration query management frame to the first device to suggest changing the first communication link to the second communication link.

When a non-AP MLD associates to an AP MLD, the association results in a mapping of affiliated AP to affiliated STA communication links. Link IDs are assigned by the AP MLD and map AP MAC addresses to STA MAC addresses.

30 The IEEE 802.11 standard generally uses three types of frames: management, control and data. Management frames are generally used to manage a basic service set, control frames control access to a medium, and data frames contain payloads of information. Managing of the basic service set includes probing, associating, roaming and disconnecting clients from the basic service set. In embodiments disclosed herein, message exchanges relating to changing communication links between the AP MLD **202** and the non-AP MLD **220** are in the form of management frames.

35 The re-mapping of communication links described above as illustrated in **FIG. 3** to **FIG. 5** requires updating of the communication link mapping. In embodiments disclosed herein, this is accomplished using three management frames: a link configuration request management frame, a link configuration response management frame, and a link configuration query management frame. The link configuration request management frame is transmitted by a non-AP MLD to an AP MLD to request a configuration change to one or more of its communication links. The link configuration response management frame is transmitted by an AP MLD to respond to a link configuration request management frame received

from a non-AP MLD to change its communication link configuration. The link configuration query management frame is transmitted by an AP MLD to suggest that a non-AP MLD change its communication link configuration to a recommended new communication link mapping. A non-AP MLD that receives a link configuration query management frame can send a link configuration request management frame to change a communication link configuration based on the recommendation.

FIG. 7 illustrates an exemplary frame format of a link configuration request management frame **700** comprising the following fields: category **702**, link configuration action **704**, dialog token **706**, current link info **708** and new link info **710**. The category field **702** is set to the link configuration value in table 9-79 of IEEE 802.11-2020. The link configuration action field **704** is set to 0 for the link configuration request frame **700**. The dialog token field **706** can be set to any integer between 0 and 255. The current link info field **708** comprises a basic variant of the multi-link element of IEEE 802.11be D1.5 which conveys the current mapping for each communication link. The new link info field **710** comprises a basic variant of the multi-link element which conveys the requested mapping for each communication link.

FIG. 8 illustrates an exemplary frame of a link configuration response management frame **800** comprising the following fields: category **802**, link configuration action **804**, dialog token **806**, status **808**, new link info **810** and key delivery **812**. The category field **802** is set to the link configuration value in table 9-79 of IEEE 802.11-2020. The link configuration action field **804** is set to 1. The dialog token field **806** can be set to any integer between 0 and 255. The status field **808** indicates the result of the request, which can be: success, denied, or a new mapping suggestion. The new link info field **810** is conditionally present when the result of the request is a new mapping suggestion and comprises a basic variant of multi-link element which conveys a suggested alternative mapping. Note that the suggested alternative would require a non-AP MLD to transmit a new link configuration request frame.

An AP MLD could optionally include an update to the cryptographic material such as keys of Group Temporal Key (GTK), Integrity Group Temporal Key (IGTK), Beacon Integrity Group Temporal Key (BIGTK) associated with that communication link. These keys can be included in the key delivery (KeyDelivery) field 812 in a Key Delivery Element (KDE) defined in the IEEE 802.11 standard in clause 9.4.2.185.

FIG. 9 illustrates an exemplary frame of a link configuration query frame **900** comprising the following fields: category **902**, link configuration action **904**, dialog token **906**, current link info **908**, and new link info **910**. The category field **902** is set to the link configuration value in table 9-79 of IEEE 802.11-2020. The link configuration action field **904** is set to 2 for the query frame. The dialog token field **906** can be set to any integer between 0 and 255. The current link info field **908** comprises a basic variant of the multi-link element conveying the current mapping for each communication link. The new link info field **910** comprises a basic variant of the multi-link element conveying the requested mapping for each communication link. Note that the suggested alternative would require a non-AP MLD to issue a new link configuration request frame to request changes to its link mapping.

FIG. 10 illustrates an exemplary method **1000** for reconfiguring communication links between a non-AP MLD **220** and an AP MLD **202** using management frames, wherein the communication link change is initiated by the non-AP MLD **220**. The method **1000** begins with the non-AP MLD **220** identifying a communication link change at step **1008**. At step **1010**, a link configuration request management frame is transmitted from the non-AP MLD **220** to the AP MLD **202**. At step **1012**, the AP MLD provides status and communicates group key information for the new communication link. At step **1014**, a link configuration response management frame is transmitted from the AP MLD **202** to the non-AP MLD **220**. At step **1016**, the non-AP MLD **220** updates the communication link.

In an exemplary embodiment, referring to **FIG. 10**, the AP MLD **202** may initiate a communication link re-configuration by sending a link configuration request management frame to the non-AP MLD **220**, which then sends a link

configuration response management frame. Group key updates could either be included in the link configuration request management frame from the AP MLD **202**, or in another message.

FIG. 11 illustrates an exemplary method **1100** for reconfiguring communication links between a non-AP MLD **220** and an AP MLD **202** using management frames, wherein the communication link change is initiated by the AP MLD **202**. The method **1100** begins with the AP MLD **202** identifying a communication link change at step **1102**. At step **1104**, a link configuration query management frame is transmitted from the AP MLD **202** to the non-AP MLD **220**. At step **1106**, the non-AP MLD **220** confirms the communication link change. At step **1108**, a link configuration request management frame is transmitted from the non-AP MLD **220** to the AP MLD **202**. At step **1110**, the AP MLD provides status and communicates group key information for the new communication link. At step **1112**, a link configuration response management frame is transmitted from the AP MLD **202** to the non-AP MLD **220**. At step **1114**, the non-AP MLD **220** updates the communication link.

In embodiments disclosed herein affiliated APs use different group keys to cryptographically encapsulate group addressed traffic. In embodiments disclosed herein, when a non-AP MLD changes its communication link mapping with an AP MLD, the non-AP MLD needs to receive updated group keys (with the remainder of the security association between the non-AP MLD and the AP MLD not changing) in order to successfully receive group addressed traffic on that communication link.

In embodiments, KDEs are included in the link configuration response management frame **800** to update cryptographic material (e.g. group keys) without requiring an additional protocol exchanges (e.g. Group Key handshakes) for cryptographic material associated with each new communication link.

In embodiments disclosed herein, two or more affiliated APs of an AP MLD can also be deployed in the same location, physically co-located or distributed with similar coverage. Affiliated APs of an AP MLD can be dynamically disabled/enabled depending on operating conditions. For example, some affiliated APs could be configured to have dedicated service modes (e.g. 6 GHz, Emergency Preparedness Communications Service (EPSC), or Enhanced Broadcast Services (EBCS) only). In another example, Millimetre Wave (mmWave) APs (e.g. DMG, EDMG, CDMG) could be dynamically enabled when a non-AP MLD is in their proximity.

In embodiments disclosed herein, a non-AP MLD establishes multiple communications links using affiliated STAs, with distributed, affiliated APs. Further, communication links can be re-mapped depending on service conditions.

In an exemplary embodiment, a non-AP MLD **220** may change a communication link from a 5 GHz UNII 1 band to a 5 GHz UNII 3 band, as illustrated in **FIG. 12** to **FIG. 14**, wherein in embodiments of the present disclosure, an MLD pair **200** comprises an AP MLD **202** and a non-AP MLD **220**. The AP MLD comprises a first affiliated AP (AP1) **204** configured to operate at 2.4 GHz, a second affiliated AP (AP2) **206** configured to operate in a 5 GHz UNII 1 band, a third affiliated AP (AP3) **208** configured to operate in a 5 GHz UNII 3 band, and a fourth affiliated AP (AP4) **210** configured to operate at 6 GHz. The non-AP MLD **220** comprises a first affiliated STA (STA1) **222** and a second affiliated STA (STA2) **224**. In embodiments disclosed herein, the MLD pair **200** is connected to a local area network (LAN) **240**, which may be connected to one or more other devices including a wired gateway **250**.

In **FIG. 12**, a first communication link **230** is established between the first affiliated AP **204** and the first affiliated STA **222**, a second communication link **232** is established between the second affiliated AP **206** and the second affiliated STA **224**, while the third affiliated AP **208** and the fourth affiliated AP **210** are disabled.

5 In FIG. 13, the AP MLD 202 enables the third affiliated AP 208 and the fourth affiliated AP 210, and the non-AP MLD 220 determines that the third affiliated AP 208 provides better service than the second affiliated AP 206. As a result, the non-AP MLD 220 transmits a link configuration request management frame 700 to the AP MLD 202 requesting a change in its communication link mapping. Where an AP MLD comprises affiliated APs that support mmWave technology (e.g. DMG, EDMG, or CDMG) and a non-AP MLD supports this technology, the non-AP MLD can use the above disclosed methods to initiate the non-AP MLD to update its configuration to establish connectivity over the mmWave capable affiliated AP.

10 Referring to FIG. 14, the second affiliated STA 224 associates with the third affiliated AP 208 to establish a third communication link 236. Notably, the first communication link 230 between the first affiliated AP 204 and the first affiliated STA 222 is maintained during the transition from the second communication link 232 to the third communication link 236 such that communication between the AP MLD 202 and the non-AP MLD 220 is maintained. After the transition from the second communication link 232 to the third communication link 236, the second affiliated AP 206 is no longer mapped to an affiliated STA of the AP MLD 202. Note that in this embodiment, the AP MLD 202 that deploys new resources by enabling the third affiliated AP 208 and the fourth affiliated AP 210.

15 Although embodiments have been described above with reference to the accompanying drawings, those of skill in the art will appreciate that variations and modifications may be made without departing from the scope thereof as defined by the appended claims.

CLAIMS

1. A method comprising:
changing a first communication link between a first affiliated station of a first device and a first affiliated access point (AP) of a second device to a second communication link between the first affiliated station of the first device and a second affiliated AP of the second device, while maintaining a third communication link between a second affiliated station of the first device and a third affiliated AP of the second device.
2. The method of claim 1 further comprising:
activating one or more affiliated APs of the second device from a deactivated state to an activated state upon detection of a proximate first device.
3. The method of claim 1 or 2 further comprising:
the first device sending a communication link configuration request management frame to the second device to request changing the first communication link to the second communication link.
4. The method of claim 3 further comprising:
the second device sending a communication link configuration response management frame to the first device to confirm changing the first communication link to the second communication link.
5. The method of claim 3 further comprising:
the second device sending a communication link configuration query management frame to the first device to suggest changing the first communication link to the second communication link.
6. The method of claim 3, wherein the communication link configuration request management frame comprises the following fields: category, communication link configuration action, dialog token, current communication link information, and new communication link information.
7. The method of claim 4, wherein the communication link configuration response management frame comprises the following fields: category, communication link configuration action, dialog token and new communication link information.
8. The method of claim 5, wherein the communication link configuration query management frame comprises the following fields: category, communication link configuration action, dialog token, current communication link information, and new communication link information.
9. The method of claim 7, wherein the communication link configuration response management frame further comprises group keys of the second affiliated AP for decrypting data of the second affiliated AP.
10. The method of any one of claims 1 to 9, wherein the second device is an AP multi-link device (MLD) and the first device is a non-AP MLD for a network using an IEEE 802.11 protocol configured for multi-link operation.
11. The method of claim 10, wherein the IEEE 802.11 protocol is IEEE 802.11be.
12. The method of any one of claims 1 to 11, wherein at least one of the one or more affiliated APs of the second device are for operating in a dedicated service mode.

13. The method of claim 12, wherein the dedicated service mode comprises one of six gigahertz (6 GHz), Emergency Preparedness Communications Service (EPSC), and Enhanced Broadcast Service (EBCS).
14. The method of any one of claims 1 to 13, wherein at least one of the one or more affiliated APs of the second device are for operating in at least one service mode.
15. The method of claim 14, wherein the at least one service mode comprises one or more of Millimeter Wave (mmWave), Directional Multi-Gigabit (DMG), China Directional Multi-Gigabit (CDMG), and Enhanced Directional Multi-Gigabit (EDMG).
16. A module comprising:
a second device comprising a plurality of affiliated APs, each affiliated AP for establishing a communication link with an affiliated station of a first device, wherein the second device is configured to independently change each communication link between an affiliated AP and an affiliated station.
17. The module of claim 16, wherein the second device is configured to send a communication link configuration query management frame to a first device to suggest changing a communication link.
18. The module of claim 17, wherein the second device is configured to send the communication link configuration query management frame upon detection of increased packet errors, environmental conditions, or other events supporting changing the communication link.
19. The module of claim 16, wherein the second device is configured to send a communication link configuration response management frame to a first device to confirm changing a communication link.
20. The module of claim 19, wherein the communication link configuration response management frame comprises group keys of an affiliated AP for decrypting information of the affiliated AP.
21. The module of any one of claims 16 to 20, wherein one or more of the affiliated APs is configured to activate upon detection of a proximate first device.
22. The module of any one of claims 16 to 21, wherein the second device is an AP MLD for a network using an IEEE 802.11 protocol configured for multi-link operation.
23. The module of claim 22, wherein the IEEE 802.11 protocol is IEEE 802.11be.
24. The module of any one of claims 16 to 23, wherein one or more of the plurality of affiliated APs is configured to operate in a dedicated service mode.
25. The module of claim 24, wherein the dedicated service mode comprises one of 6 GHz, EPSC, and EBCS.
26. The module of any one of claims 16 to 25, wherein one or more of the plurality of affiliated APs is configured to operation in at least one service mode.

27. The module of claim 26, wherein the at least one service mode comprises one or more of mmWave, DMG, CDMG, and EDMG.
28. A module comprising:
5 a first device configured to provide a plurality of affiliated stations, each affiliated station for establishing a communication link with an affiliated AP of a second device, wherein the first device is configured to independently change each communication link between an affiliated station and an affiliated AP.
29. The module of claim 28, wherein the first device is configured to send a communication link configuration request management frame to a second device to request changing a communication link.
10
30. The module of claim 29, wherein the first device is configured to send the communication link configuration request management frame upon detection of increased packet errors, environmental conditions, or other events supporting changing the communication link, or newly available affiliated APs.
15
31. The module of any one of claims 28 to 30, wherein the first device is a non-AP MLD for a network using an IEEE 802.11 protocol configured for multi-link operation.
32. The module of claim 31, wherein the IEEE 802.11 protocol is IEEE 802.11be.
20
33. One or more non-transitory computer-readable storage media comprising computer-executable instructions for managing communication links for MLDs, wherein the instructions, when executed, cause a processing structure to perform actions comprising:
25 changing a first communication link between a first affiliated station of a first device and a first affiliated AP of a second device to a second communication link between the first affiliated station of the first device and a second affiliated AP of the second device, while maintaining a third communication link between a second affiliated station of the first device and a third affiliated AP of the second device.
34. The one or more storage media of claim 33 further for:
30 activating one or more affiliated APs of the second device from a deactivated state to an activated state upon detection of a proximate first device.
35. The one or more storage media of claim 33 or 34 further for:
35 the first device sending a communication link configuration request management frame to the second device to request changing the first communication link to the second communication link.

36. The one or more storage media of claim 35 further for:
the second device sending a communication link configuration response management frame to the first device to confirm changing the first communication link to the second communication link.
- 5 37. The one or more storage media of claim 35 further for:
the second device sending a communication link configuration query management frame to the first device to suggest changing the first communication link to the second communication link.
- 10 38. The one or more storage media of claim 35, wherein the communication link configuration request management frame comprises the following fields: category, communication link configuration action, dialog token, current communication link information, and new communication link information.
- 15 39. The one or more storage media of claim 0, wherein the communication link configuration response management frame comprises the following fields: category, communication link configuration action, dialog token and new communication link information.
- 20 40. The one or more storage media of claim 37, wherein the communication link configuration query management frame comprises the following fields: category, communication link configuration action, dialog token, current communication link information, and new communication link information.
- 25 41. The one or more storage media of claim 39, wherein the communication link configuration response management frame further comprises group keys of the second affiliated AP for decrypting data of the second affiliated AP.
42. The one or more storage media of any one of claims 33 to 41, wherein the second device is an AP MLD and the first device is a non-AP MLD for a network using an IEEE 802.11 protocol configured for multi-link operation.
43. The one or more storage media of claim 42, wherein the IEEE 802.11 protocol is IEEE 802.11be.
- 30 44. The one or more storage media of any one of claims 33 to 43, wherein at least one of the one or more affiliated APs of the second device are for operating in a dedicated service mode.
45. The one or more storage media of claim 44, wherein the dedicated service mode comprises one of 6 GHz, EPSC, and EBCS.
- 35 46. The one or more storage media of any one of claims 33 to 45, wherein at least one of the one or more affiliated APs of the second device are for operating in at least one service mode.
- 40 47. The one or more storage media of claim 46, wherein the at least one service mode comprises one or more of mmWave, DMG, CDMG, and EDMG.