IEEE P802.11
Wireless LANs

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| Resolution for CIDs related to MLD Data Plane Architecture (CC34) |
| Date: June, 2021 |
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 Abstract

This submission proposes resolutions for CID 2239, 2720, 3410, and 3417 received for TGbe (CC34):

Revisions:

* Rev 0: Initial version of the document.
* Rev 1: Incorporated various editorial and technical comments from other members to improve the text.
* Rev 2: Incorporated various comments from discussion with the 802.11 ARC SC group
* Rev 3: Incorporated feedback from ARC meeting 6/7 and 6/17, comments from Jay Yang, Guogang Huang
* Rev 4: Incorporated editorial comments from Payam Torab, Li-Hsiang Sun, and Rubayet Shafin. Added TID-to-link mapping.

Interpretation of a Motion to Adopt

A motion to approve this submission means that the editing instructions and any changed or added material are actioned in the TGbe Draft. This introduction is not part of the adopted material.

***Editing instructions formatted like this are intended to be copied into the TGbe Draft (i.e. they are instructions to the 802.11 editor on how to merge the text with the baseline documents).***

***TGbe Editor: Editing instructions preceded by “TGbe Editor” are instructions to the TGaxbe editor to modify existing material in the TGbe draft. As a result of adopting the changes, the TGbe editor will execute the instructions rather than copy them to the TGbe Draft.***

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| --- | --- | --- | --- | --- | --- | --- |
| **CID** | **Commenter** | **Pg/Ln** | **Section** | **Comment** | **Proposed Change** | **Resolution** |
| 2075 | Joseph Levy | 87.1 | 11 | There are many feature/capabilities that are specified for an 802.11 non-AP STA that are essential for that STA to be able to operate in an ESS. Most if not all of these features/capabilities will need to be modified to include the non-AP MLD and AP MLD to allow these new entities to operate in an ESS. (e.g. most of the sub-clauses in clause 11). The current draft only attempts to address sub-clauses 11.1, 11.2, 11.3, 11.13, 11.21, and 11.24. I do not believe the current approach of dealing with MLDs such that they are a combination of multiple STAs causes significant issues with these sub-clauses. In my opinion it would be much simpler to define an MLD as a STA and then most of these subclauses would be fine as they are now written. This also applies to clause 12. | Either redefine an MLD to be a STA or address all sub-clauses in clauses 11 and 12 critical to ESS operation so that MLO can be fully supported. The commentors preference is for redefining an MLD to be a STA. | **Refer to Mike’s contribution doc 21/562** |
| 2085 | Joseph Levy |  |  | This draft has many network, architecture, and security issues due to the introduction of MLO and the way it is being specified. 802.11 should try to align as best it can with 802 network architecture and concept. This current draft does not seem to even attempt to do so and in the process may break the base standard's ability to provide logical links in an 802 network. |  | **Refer to Mike’s contribution doc 21/562** |
| 2239 | Mark Hamilton | 7 | 50.1 | If my comment suggesting to simplify the concept of MLD to be a type/operational mode of STA/AP is not persued, then clause 7 will need updates to support the concept added in 4.5.3 that the DS is aware of "non-AP MLD to AP MLD" mappings. Also, clause 5 will need updates to explain how the DSAF function is accomplished in an AP MLD, and this likely ripples into the clause 4 discussion of the services (and entities that provide/use the services). | Either move in the direction that non-AP/AP MLD are just examples of non-AP STA/AP (respectively) per my other comment, or update clause 7 to add the concept of a non-AP MLD to MLD mapping in the DS, and the SAP support for managing this mapping. This includes explaining how the DSAF is archtecturally connected to the AP MLD structures in clause 7 and 5.1.5.3, and how the new structure maps to/provides the services in 4.5 (and probably other clause 4 subclauses). | **Revised**Since TGbe has decided on the non-AP MLD/AP MLD architecture, clause 7 has been updated to describe how an AP MLD is connected to the DS. Also, added two new subclause 5.1.5.10 and 5.1.5.11 to describe the non-AP MLD role and AP MLD role.**TGbe editor, please make changes that are marked as “#2239” in doc 11-21/0577r4** |
| 2720 | Ryuichi Hirata | 0 | - | MAC data plane architecture for MLD is not clear. | Define MAC data plane architecture for MLD | **Revised**Agree in principle with the comment. Proposed resolution is to explain the MLO architecture and the data plane architecture.**TGbe editor, please make changes as shown in doc 11-21/0577r4****Note to editor: Same resolution for CIDs 2720, 3410, 3417** |
| 3410 | Yonggang Fang | 0 | - | MLD introduces a new concept for 802.11 architecture. It needs to add a new clause to describe MLD architecture. | as suggested in comment. | **Revised**Agree in principle with the comment. Proposed resolution is to explain the MLO architecture and the data plane architecture.**TGbe editor, please make changes as shown in doc 11-21/0577r4****Note to editor: Same resolution for CIDs 2720, 3410, 3417** |
| 3417 | Yonggang Fang | 0 | - | MLD introduces a new concept for 802.11 architecture. It needs to add a new clause to describe MLD reference model. | as suggested in comment. | **Revised**Agree in principle with the comment. Proposed resolution is to explain the MLO architecture and the data plane architecture.**TGbe editor, please make changes as shown in doc 11-21/0577r4****Note to editor: Same resolution for CIDs 2720, 3410, 3417** |

***TGbe editor: Please add the following new section 4.9.5 to the spec:***

**4.9.5 Reference model for multi-link operation (MLO)**

MLO allows operation over multiple links. The reference model of a multi-link device (MLD) (see 35.3 (Multi-link operation)) is shown in Figure 4-29a (Reference model for an MLD).

NOTE—For simplicity, Figure 4-29a (Reference model for an MLD) depicts the reference model when there are two links, while in general, an MLD can support more than two links.



An MLD manages communication over multiple links. Communication across different frequency bands/channels can occur simultaneously or not depending on the capabilities of both the AP MLD and the non-AP MLD (see 35.3.13.2 (Simultaneous transmit and receive (STR) operation) and 35.3.13.3 (Nonsimultaneous transmit and receive (NSTR) operation)).

NOTE—The SME boundary top is left open in Figure 4-29a (Reference model for an MLD) to indicate that the SME can contain other functions that are not defined by this standard.

An MLD supports multiple MAC sublayers, coordinated by an SME.

The SME maintains the authentication and association states. The Authenticator and the MAC-SAP of the AP MLD are identified by the same AP MLD MAC address. The Supplicant and the MAC-SAP of the non-AP MLD are identified by the same non-AP MLD MAC address.

The MLO procedures (see 35.3 (Multi-link operation)) allow a pair of MLDs to discover, synchronize, (de)authenticate, (re)associate, disassociate, and manage resources with each other on any common bands or channels that are supported by both MLDs.

As described in 35.3.1 (General), each AP MLD has a single MAC-SAP and each non-AP MLD has a single MAC-SAP. Each AP affiliated with an AP MLD has a different MAC address within the MLD and each STA affiliated with a non-AP MLD has a different MAC address within the MLD.

The SME is responsible for coordinating each of the MLMEs of all affiliated STA to maintain a single RSNA key management entity, as well as a single IEEE 802.1X Authenticator or Supplicant for MLO.

An example of an AP MLD with two links (Link 1 and Link 2) is shown in Figure 4-29b (Example MLD and the affiliated STA communication system). An AP MLD with MLD MAC address *M* and two affiliated APs (AP1 with MAC address *w* and AP2 with MAC address *x*) associated with a non-AP MLD with MLD MAC address *P* and two affiliated STAs (STA1 with MAC address *y* and STA2 with MAC address z*).* Link 1 is established between AP1 and STA1 and link 2 is established between AP2 and STA2. In general, the MAC address of an MLD and the MAC addresses of the STAs affiliated with the MLD are all different (e.g., *M*, *P*, *w*, *x*, *y*, and *z* have different values).



Figure 4-29b – Example MLD and the affiliated STA communication system

The MAC Sublayer is further divided into an MLD Upper MAC sublayer and an MLD Lower MAC sublayer. The MLD Upper MAC sublayer (MLD) performs functionalities that are common across all links and the MLD Lower MAC sublayer (AP or STA affiliated with the MLD) performs functionalities that are local to each link. Some of the functionalities require joint processing of both the Upper and MLD Lower MAC sublayers.

The MLD Upper MAC sublayer functions include:

* Authentication, association and reassociation (between an AP MLD and a non-AP MLD)
* Security association (e.g., PMKSA, PTKSA) and distribution of GTK/IGTK/BIGTK
* SN/PN assignment for frames to be encrypted by PTK for unicast frames
* Encryption/decryption using PTK for unicast frames
* Selection of the MLD Lower MAC sublayer for transmission (TID-to-link mapping (see 35.3.6.1 (TID-to-link mapping)))
* Reordering of packets to ensure in-order delivery per each BA session
* Block Ack scoreboarding for individually addressed frames (in collaboration with the MLD Lower MAC sublayer). Optionally, the MLD Upper MAC sublayer delivers the BA record on one link to the MLD Lower MAC sublayer of other links)
* MLD-level management information exchange/indication via the MLD Lower MAC sublayer

The MLD Lower MAC sublayer functions include:

* Maintenance of Link-specific GTK/IGTK/BIGTK (between an AP affiliated with the AP MLD and a STA affiliated with the non-AP MLD)
* Link-specific encryption/decryption/integrity protection and PN assignment using GTK/IGTK/BIGTK (between an AP affiliated with the AP MLD and a STA affiliated with the non-AP MLD)
* Link-specific management info exchange/indication (e.g., Beacon)
* Link-specific control info exchange/indication (e.g., RTS/CTS, Acks, NDP, etc.)
* Power save state and mode
* MAC address filtering for frame reception
* Block Ack scoreboarding for individually addressed frames (in collaboration with the MLD Upper MAC sublayer). Optionally, the MLD Lower MAC sublayer receives from the the BA record on the other links from the MLD Upper MAC sublayer)

NOTE—The above functionality partitioning is meant for modelling the functionalities of each MAC Sublayer and is not meant for describing the MAC Sublayer for which the actual implementation of each function should reside.

NOTE – The Block Ack scoreboarding maintenance collaborated between the MLD Upper MAC sublayer and MLD Lower MAC sublayer is implementation dependent.

**5.1.5 MAC data service architecture**

**5.1.5.1 General**

***TGbe editor: Please modify this subclause as follows:***

The MAC data plane architecture (i.e., processes that involve transport of all or part of an MSDU) is shown in Figure 5-1 (MAC data plane architecture(11ak)(#2273)) when transparent FST is not being used and shown in Figure 5-2 (MAC data plane architecture (transparent FST)(11ak)(#2467)(#2273)) when transparent FST is being used.

The dotted line box labeled “Role-specific behaviors” is replaced by one of several options, depending on the role of the STA. See the following subclauses

(#4272)During transmission, an MSDU goes through the processes shown in the left-hand side of Figure 5-1 (MAC data plane architecture(11ak)(#2273)). When transparent FST is used, an MSDU first goes, as shown in Figure 5-2 (MAC data plane architecture (transparent FST)(11ak)(#2467)(#2273)), through an additional transparent FST entity that contains a demultiplexing process that forwards the MSDU down to the selected TX MSDU Rate Limiting process, and thence MAC data plane processing as described in the previous sentence. IEEE Std 802.1X-2010 may block the MSDU at the Controlled Port before the preceding processing occurs. Otherwise, at some point, the Data frames that contain all or part of the MSDU are queued per AC/TS.

(#4272)During reception, a received Data frame goes through the processes shown in the right-hand side of of Figure 5-1 (MAC data plane architecture(11ak)(#2273)). Then, one or more MSDUs are delivered to the MAC SAP or, via the DSAF, to either the DS or an IEEE 802.1Q bridge port.(11ak) When transparent FST is used, MSDUs originating from different PHY SAPs go, as shown in Figure 5-2 (MAC data plane architecture (transparent FST)(11ak)(#2467)(#2273)), through a final step of a transparent FST entity that contains a multiplexing process before delivering the MSDU. The IEEE 802.1X -Controlled/Uncontrolled Ports discard any received MSDUs if the Controlled Port is not enabled and if the MSDU does not represent an IEEE 802.1X frame.

(#4272)NOTE—Many of the processes shown in Figure 5-1 (MAC data plane architecture(11ak)(#2273)) also apply to MMPDU flows for the MAC control plane architecture, and the processes shown at the bottom also apply to Control and Extension frames.

When transparent FST is used, the same security keys, sequence counter, and PN counter are used by the MAC data plane to encrypt the MPDU prior to and following an FST, and the same security keys are used to check the integrity and perform the protection of MSDUs. When nontransparent FST is used, independent RSNAs, security keys, sequence counters, and PN counters have to be established for each MAC data plane to be used prior to and following an FST. When transparent FST is used, a single MAC SAP at each peer is presented to the higher layers of that peer for all of the frequency bands/channels that are identified by the same MAC address at that peer. When nontransparent FST is used, different MAC SAPs are presented to higher layers since different MAC addresses are used prior to and following an FST.

For Multi-link Operation (MLO), one or more links are used for communication between the AP MLD and non-AP MLD after MLD (re)setup as described in 35.3.5 (Multi-link (re)setup)). The MAC data plane architecture with *n* links (i.e., processes that involve transport of all or part of an MSDU) is shown in Figure 5-2a (MAC data plane architecture (MLO)).

During transmission, an MSDU from the MAC SAP goes through the processes shown in the left-hand side of Figure 5-2a (MAC data plane architecture (MLO)), then through the TID-to-link mapping process (see 35.3.6.1 (TID-to-link mapping)) that forwards the MPDUs down to one of the MLD Lower MAC sublayers and then to the corresponding PHY SAP.

Note – TID-to-link mapping negotiation is an optional feature.

During reception, MPDUs originating from different PHY SAPs first go through an MLD Lower MAC sublayer, followed by a merging process, and then go through the process in the right-hand side of Figure 5-2a (MAC data plane architecture (MLO)). Then, one or more MSDUs are delivered to the MAC SAP or, via the DSAF to the DS. The IEEE 802.1X Controlled/Uncontrolled Ports discard any received MSDUs if the Controlled Port is not enabled and if the MSDU does not represent an IEEE 802.1X frame.

NOTE—Many of the processes shown in Figure 5-2a (MAC data plane architecture (MLO)) also apply to MLD-level MMPDU flows for the MAC control plane architecture, and the processes shown at the MLD Lower MAC sublayer also apply to Control and Extension frames.

When MLO is being used, the same security association (PTKSA) is used to encrypt the unicast MPDUs and MMPDUs prior to transmission on the links. The same security association (PTKSA) is used to decrypt the unicast MPDUs and MMPDUs received on the links. The GTK of a link is used to encrypt the group addressed frames MPDUs and MMPDUs prior to transmission on the link. The GTK of a link is used to decrypt the group addressed frames MPDUs and MMPDUs received on the link.

When MLO is being used, the “Block Ack Scoreboarding” block in the MLD Upper MAC sublayer manages the BA status of the MPDUs (of this BA session) that are received on any setup link. The “Block Ack Scoreboarding” block in the MLD Lower MAC sublayer manages the BA status of the MPDUs (of this BA session) that are received on this link. It may convey BA status of the MPDUs received on another link if it obtained such info from the other link via the MLD Upper MAC sublayer.



Figure 5-2a - MAC data plane architecture (MLO) for unicast data frames**5.1.5.10 Non-AP MLD role**

***TGbe editor: Please add this new subclause to the spec (#2239)***

The MAC data plane architecture of a non-AP MLD as shown in Figure 5-2a (MAC data plane architecture (MLO) for unicast data frames) is completed by replacing the role-specific behavior block with that shown in Figure 5-11 (Role-specific behavior block for a non-AP MLD). The function of this block in a non-AP MLD is to perform destination address filtering as described in 10.2.7 (MAC data service).

NOTE—In implementations, the DA address filtering function may be done “lower in the stack.” It is shown in the role-specific behavior block location for simplicity, and any implementation choice needs to provide equivalent behavior.



Figure 5-11 – Role-specific behavior block for a non-AP MLD**5.1.5.11 AP MLD role**

***TGbe editor: Please add this new subclause to the spec (#2239)***

In an AP MLD, the MAC data plane architecture as shown in Figure 5-2a (MAC data plane architecture (MLO) for unicast data frames) includes Distribution System (DS) access in its role-specific behavior block, as shown in Figure 5-12 (Role-specific behavior block for an AP MLD). This block provides access to the DS for associated non-AP MLDs as described in 4.5.2.1 (Distribution).

NOTE—This behavior block indicates that there is no access through the controlled port to or from the local upper-layers (e.g., the LLC sublayer) at an AP MLD. Any such access is logically achieved in the architecture via transition of the DS and Portal to an integrated LAN. In actual implementations, this is likely to be optimized, and Data frames appear to be delivered directly to one or more local LLC sublayer entities on the same physical device as the AP MLD. Such optimization is effectively distributing the functions of the DS and Portal, and it is the responsibility of the implementation to ensure the logical behavior of these entities is maintained.



Figure 5-12 - Role-specific behavior block for an AP MLD**7.1 Introduction**

***TGbe editor: Please modify this subclause as follows:***

The DS SAP is the interface between the DS SAP service users and the DS SAP service provider. The DS SAP service users are the connected APs, mesh gates, the portal, and AP MLDs. The DS SAP service provider is the DS. Figure 7-1 (DS architecture(#2251)) shows the location of the DS in the IEEE 802.11 architecture. The DS SAP is indicated in this Figure by the lines connecting the DS to its service users. In Figure 7-1 (DS architecture(#2251)), the DS has four users, two APs, a mesh gate, a portal, and an AP MLD, so the DS is shown passing behind the MAC/PHYs of the STAs.



Figure 7-1 – DS architecture

The DS SAP interface specification describes the primitives required to get MAC service tuples in and out of the DS and

* update the DS’s mapping of STAs to APs or to mesh gates,
* update the DS’s mapping of non-AP MLDs to AP MLDs

Describing the DS itself or the functions thereof is out of scope of this standard.

The DS SAP actions are as follows:

1. Accept MSDUs (as part of MAC service tuples) from APs, mesh gates, the portal and AP MLDs.
2. Deliver MSDUs (as part of MAC service tuples) to APs, mesh gates, the portal, or the AP MLDs.
3. Accept STA-to-AP mapping updates from the APs.
4. Accept STA-to-mesh gate mapping updates from the mesh gates.
5. Accept non-AP-MLD-to-AP-MLD mapping updates from the AP MLDs.

NOTE – For MLDs, the source address or destination address parameters of the MAC service tuples (see 5.2.3.2 (Semantics of the service primitive)) are set to the MLD MAC address of the non-AP MLD, which is the identity of the non-AP MLD known by the DS.

When the DS delivers the MAC service tuples to an AP, the AP then determines when and how to deliver the MAC service tuples to the AP’s MAC (via the MAC SAP). When the DS delivers the MAC service tuples to a mesh gate, the mesh gate then determines when and how to deliver the MAC service tuples to the mesh gate’s MAC (via the MAC SAP). When the DS delivers the MAC service tuples to an AP MLD through DSAF, the AP MLD then determines when and how to deliver the MAC service tuples to the AP MLD’s MLD Upper MAC sublayer (via the MAC SAP).

**35. Extremely high throughput (EHT) MAC specification**

**35.1 Introduction**

***TGbe editor: Please modify this subclause as follows:***

An EHT STA shall set dot11EHTBaseLineFeaturesImplementedOnly to true.

An EHT STA supports the MAC and MLME functions defined in Clause 35 (Extremely high throughput (EHT) MAC specification) in addition to the MAC functions defined in Clause 26 (High efficiency (HE) MAC specification) and Clause 10 (MAC sublayer functional description), the MLME functions defined in Clause 11 (MLME), and the security functions defined in Clause 12 (Security) except when the functions in Clause 35 (Extremely High Throughput (EHT) MAC specification) supersede the functions in Clause 10 (MAC sublayer functional description), Clause 11 (MLME), Clause 12 (Security), or Clause 26 (High efficiency (HE) MAC specification).

A reference model for MLO is described in subclause 4.9.5 (Reference model for multi-link operation (MLO)).

Do you agree to the resolution provided in doc 11-21/0577r4 for CID 2239, 2720, 3410, and 3417?