

# MediaTek MLO Technology

## Smart Link-Dispatch

White Paper

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## Key Insights

**MediaTek's Smart Link-Dispatch has the following advantages:**

- Improves performance of Multi-Link Operation (MLO) in various scenarios
- Enhances throughput by 57% in clean environments
- Prevents throughput degradation by up to 32% in busy environments

## Overview and Objectives

Multi-Link Operation (MLO) is one of the key innovations of Wi-Fi 7 standard, achieving 80% throughput enhancement and 85% average latency reduction compared to a single link in a heavily loaded network. MLO enables Multi-Link Devices (MLD) to allow concurrent data transmission and reception in multiple channels across single or multiple frequency bands in 2.4GHz, 5GHz and 6GHz. By performing link aggregation and band-switching in the MAC layer across different PHY links according to traffic requirements, MLO allows Wi-Fi to support the growing number of use cases with strict latency and QoS requirements such as video calls, wireless VR/AR headsets, cloud gaming and IoT devices.

To enhance the performance of MLO operation, it is important to look at how the AP efficiently dispatches (i.e. schedules) data among available links. A previous white paper, "[Wi-Fi 7 Multi-Link Operation \(MLO\)](#)," reviewed various modes of MLO in comparison with different system architectures. This whitepaper builds on these findings by going deeper into the factors that impact throughput efficiency, including how to further improve results with a method called adaptive link-dispatching that utilizes MediaTek Smart Link-Dispatch technology.

### Recap of Channel Efficiency Design in IEEE 802.11 Standards

First, let us recap the evolution of channel efficiency in IEEE 802.11 standards. Block Ack (BA) was initially defined in IEEE 802.11e (for QoS) as an optional scheme to improve MAC efficiency by aggregating several Acks for MAC Protocol Data Units (MPDUs) into a single BA frame. IEEE 802.11n, a.k.a. HT, amendment enhanced this mechanism and made it mandatory. In this amendment, two types of BA policies were defined:

1. **HT-Immediate BA**, which is suitable for high-throughput, low-latency traffic.
2. **HT-Delayed BA**, which is suitable for applications that tolerate medium latency.

Since we are shooting for applications that require high throughput and low latency, we will focus on the HT-Immediate BA policy.

### Defining HT-Immediate BA for High-Throughput, Low-Latency Traffic

In the HT-Immediate BA, the originator contains two entities:

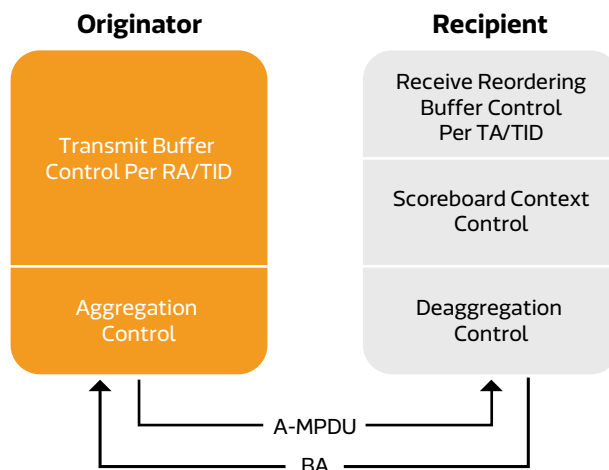
1. **Transmit Buffer Control per Recipient Address (RA)/Traffic Identifier (TID)**: Uses the starting Sequence Number (SN) of the transmission window and negotiates the transmission window size in the BA agreement to submit MPDUs for transmission, releasing transmit buffers upon receiving BA frames from the recipient.
2. **Aggregation Control**: Creates Aggregate MAC Protocol Data Units (A-MPDUs) by aggregating all data frames to simplify BA use and reduce recipient resource requirements.

On the other hand, the recipient contains three entities:

1. **Receive Reordering Buffer Control per Transmission Address (TA)/TID**: Reorders MAC Service Data Units (MSDUs) or Aggregate MAC Service Data Units (A-MSDUs) and passes them up to the MAC process in the order of the received SN.
2. **Scoreboard Context Control**: Provides bitmap and value of the Starting Sequence Number subfields to be sent in BA frame responses to the originator.
3. **Deaggregation Control**: Separates frames contained in an A-MPDU.

The HT-Immediate BA architecture is shown in Figure 1

Figure 1. HT-Immediate BA Architecture.



## BA Procedures in MLO

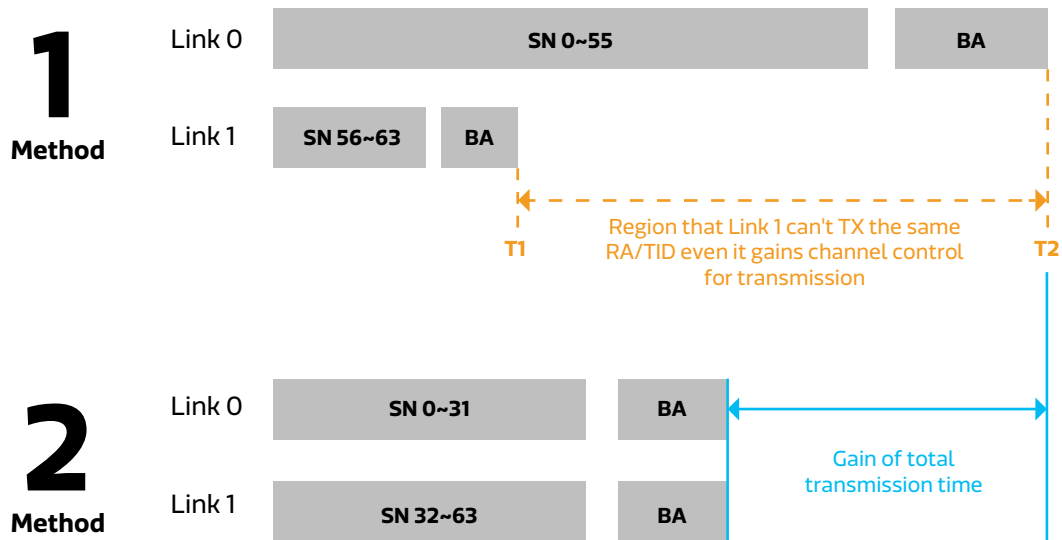
With MLO, TIDs are mapped to all setup links for both downlink and uplink by default, and only one BA agreement is applied to all MLD links (i.e., there are no independent BA agreements for each TID on a per-link basis). Furthermore, the originator MLD only maintains a single transmit buffer for corresponding TID across links, which means the frames of the same RA/TID fields may be transmitted on all links and share the same SN space and aggregation window size. As the originator, MLD will not release the Transmit Buffer associated with the MPDU until it has received the BA frame containing the reception status for that MPDU from the recipient MLD; so the sliding window cannot move further.

## Method for Optimizing Efficiency for MLO Links

To demonstrate how different methods for dispatching MPDUs over two links can affect transmission time and efficiency, Figure 2 compares the operation of two overlapping MLD links with TX PPDU of Link 0/Link 1 and a size 64 aggregation window in the negotiated BA agreement.

1. **Method 1** shows that the sliding window cannot move forward. SN 0 through SN 55 are aggregated to Link 0, and SN 56 through SN 63 are aggregated to Link 1. Link 1 receives BA for SN 56 through 63 at T1. During T1 to T2 period, it cannot transmit the same RA/TID even if it gains channel control for transmission; this is because the BA for SN 0 through SN 55 in Link 0 is not received.
2. **Method 2** mitigates the sliding window problem, with a better way to dispatch MPDUs between the two links: adaptive dispatching.

Figure 2. Examples of Methods for Dispatching MPDUs over Two Links



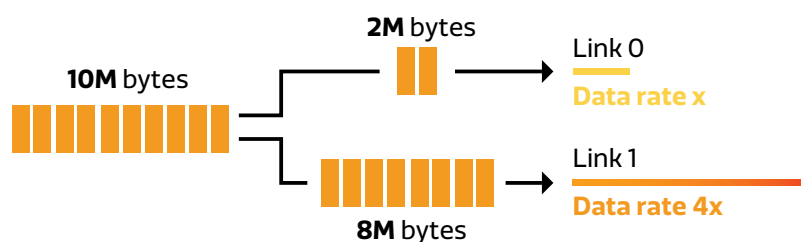
We can see that the total transmission time of Method 2 is less than Method 1 for the same data traffic. Therefore, we can improve efficiency for MLO links by intelligently dispatching links based on different use scenarios and fulfilling the requirements of the IEEE TGbe standard.

## Factors Affecting Throughput Efficiency

Channel efficiency is related to the percentage of the theoretical physical layer (PHY) transmission rate that the actual maximum throughput can be achieved. The throughput is primarily impacted by real-world environmental conditions such as: modulation rate, channel width, signal degradation with distance, adjacent channel interference (ACI), co-channel interference (CCI), packet loss, retransmission attempts, transmit opportunity (TXOP) limit, number of concurrent users, etc.

There are many ways to improve channel efficiency. However, our main intention is to dispatch MPDUs dynamically according to channel efficiencies of the links, to achieve higher total throughput when PPDUs overlap over multiple links. Figure 3 shows an example of transmitting 10M bytes of data over two MLD links, the dispatch algorithm estimates the data rate on each link first. If the data rate of Link 1 is about four times of Link 0, then four-fifths of the data will be dispatched to Link 1, and one-fifth of the data will go to Link 0 for transmission (assume no PER on both links).

Figure 2. Examples of Methods for Dispatching MPDUs over Two Links



## Packet Error Rate (PER)

PER is the ratio of incorrectly received packets to the total number of received packets. A PER test is one of the methods of measuring the performance of a Wi-Fi device; an acceptable PER depends on the type of application traffic. PER can affect transmission quality significantly.

Higher PER results in a smaller number of packages per aggregation, which increases the overhead for the backoff and response time of ACK packets. Since the effect of PER on aggregation numbers is non-linear, PER can be an important factor in improving efficiency.

## Minimum MPDU Start Spacing (MMSS) Overhead

MMSS is a subfield of the A-MPDU parameter fields declared by the receiver. It defines the minimum time between the start of two consecutive MPDUs within an A-MPDU that the STA can receive, measured at the PHY Service Access Point (SAP). When the spacing is shorter than the MMSS, paddings are added between MPDUs to meet the requirement. The formula defines the number of bytes to be inserted between MPDUs according to the timing requirement is given by:

$$t_{MMSS} \times \frac{r}{8}$$

wherein

- $t_{MMSS}$ : time in microseconds as present in MMSS
- $r$ : PHY data rate

The timing constraint allows the receiver to decrypt the MPDUs in an A-MPDU without being over-whelmed. Thus,  $r$ , the MMSS overhead ratio of the PHY data rate is one of the factors to examine in terms of throughput improvement.

## MediaTek Simulation Results

The following test scenarios demonstrate how the adaptive dispatch mechanism from MediaTek improves efficiency.

### Scenarios

- **Scenario 1: Link with clean channels**

- o **Network Topology**

Figure 4 illustrates the network topology of a traffic environment with clean channels. The network elements include an AP MLD and an STA MLD. Both MLDs support two links.

Figure 4. Network Topology of Links with Clean Channels



- o **Link Configuration**

- Link 0: DBW=80MHz, MCS13, 2NSS
- Link 1: DBW=160MHz, MCS11, 2NSS
- BA window size: 256
- PER ratio: 0% per link
- Traffic type: Downlink (DL) TCP traffic

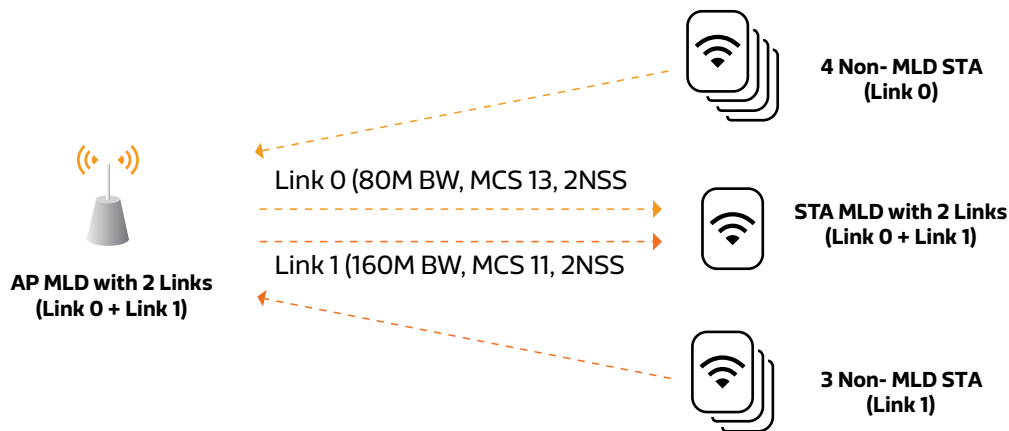
- **Scenario 2: Link with busy channels**

- o **Network Topology**

To ensure the algorithm is suitable for not only in clean environment but also in real world, seven Non-MLD STAs are added to the network. The network topology of a traffic environment with busy channels is given in Figure 5. The network elements include: one AP MLD that supports two links, one MLD STA that supports two links, four Non-MLD STAs for Link 0, and three Non-MLD STAs for Link 1.



Figure 5. Network Topology of Link with Busy Channels



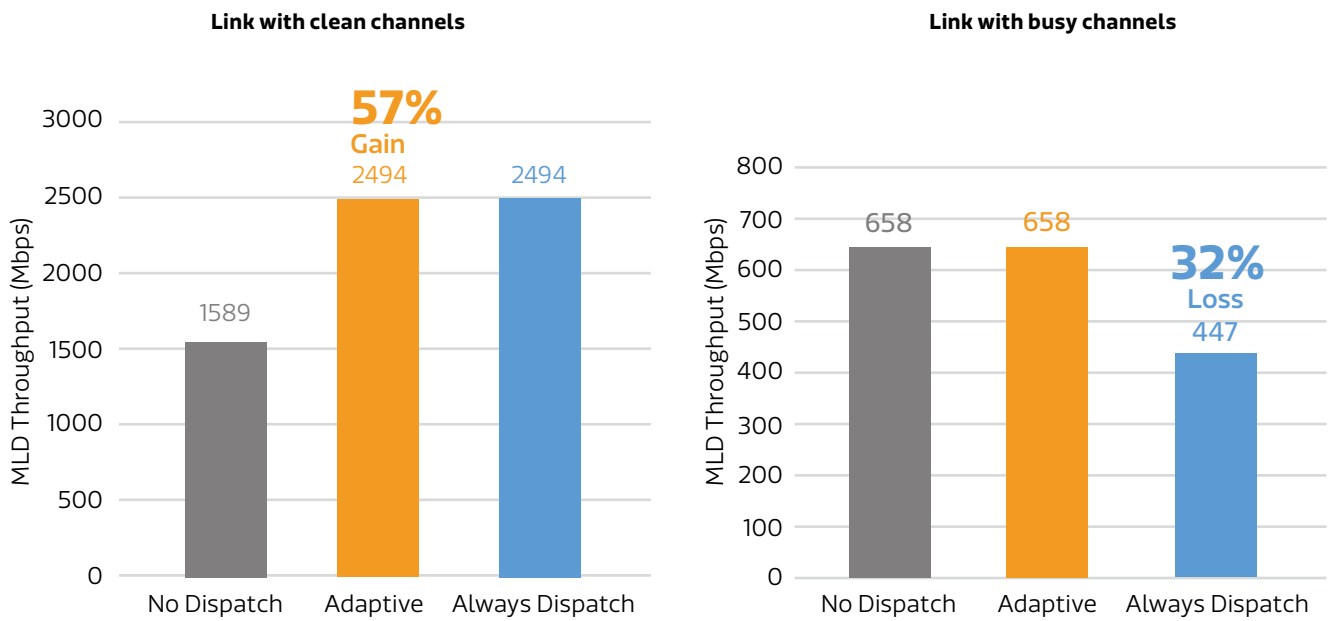
#### o Link Configuration

- Link 0: DBW=80MHz, MCS13, 2NSS
- Link 1: DBW=160MHz, MCS11, 2NSS
- BA window size: 256
- PER ratio: 0% per link
- Traffic type: DL UDP traffic for MLD STA and UL UDP traffic for Non-MLD STA

## Results & Analysis

The throughput results for both scenarios are given in Figure 6 below. When MediaTek Smart Link-Dispatch mechanism is applied, the peak throughput has 57% gain and 0% lost in scenario 1 and scenario 2, respectively. Without the adaptive approach, the throughput may degrade by 32%, as shown in the right side of Figure 6. The enhanced throughput is a result of MediaTek's Smart Link-Dispatch mechanism that dynamically dispatches MPDUs to the link with higher channel efficiency by estimating the data rate on each link and then aggregating data to different links for transmission.

Figure 6. Comparisons of Throughput Efficiency



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## Conclusions

MLO is one of the most significant features in Wi-Fi 7, enabling Wi-Fi to support latency-sensitive use cases like video calls, wireless VR/AR headsets, cloud gaming and IoT. This white paper examines how an adaptive link-dispatching technology, called MediaTek Smart Link-Dispatch, can improve the efficiency for MLO links in real-world environments. With adaptive link-dispatching in place, MLO can enhance throughput by 57% in clean channels and prevent throughput degradation by up to 32%, compared to always-dispatch mode in busy channels.

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## MediaTek in the Wi-Fi Industry

MediaTek is the world's largest supplier of Wi-Fi solutions, including standalone networking products such as routers, repeaters and mesh access points, as well as devices with embedded Wi-Fi connectivity such as smartphones, tablets, TVs, IoT, smart home devices, PCs and laptops, games consoles, and others.

Besides delivering high performance and low power integrated solutions to these platforms, MediaTek has been actively participating in IEEE and Wi-Fi Alliance certification development to ensure the utmost performance and industry interoperability. Some recent examples include selection of MediaTek's Filogic platforms as Wi-Fi 6E and Wi-Fi 6 R2 test bed devices. For Wi-Fi 7, MediaTek has and will continue to contribute its technical know-how and knowledge of different market segment requirements to improve Wi-Fi performance for everyday use.