Single-MAC MLO Architecture for Wi-Fi 7 Routers

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Table of Contents

List of Figures

Key Insights

- MediaTek has opted to implement a single-MAC Multi-Link Operation (MLO) architecture.
- Experiments confirm the superiority of the single-MAC MLO architecture over the multi-MAC MLO.
- MediaTek's single-MAC MLO architecture achieves 50% higher throughput compared to multiple-MAC MLO in Flagship BE19000 Wi-Fi 7 Tri-band Routers.

Introduction

Wi-Fi 7 MLO (Multi-Link Operation) is a cutting-edge technology that unlocks the full potential of Wi-Fi connectivity. By enabling multiple simultaneous links between a single station (STA) and an access point (AP), Wi-Fi 7 MLO revolutionizes the way devices communicate and exchange data. Devices can establish multiple parallel connections with a single AP, leveraging different frequency bands, channels, or spatial streams. This innovative technology aggregates the bandwidth of these multiple links, resulting in unprecedented throughput and reliability.

The benefits of Wi-Fi 7 MLO are tangible and far-reaching. Users can enjoy faster data transfer rates, reduced latency, and improved overall network performance. Critical applications such as online gaming, 4K video streaming, and virtual reality are greatly enhanced, providing a seamless and immersive experience. Furthermore, Wi-Fi 7 MLO enables advanced network functionality, including link aggregation, load balancing, and fault tolerance. This means that even in the event of link failure, the remaining links can continue to operate, ensuring uninterrupted connectivity and minimal downtime.

MLO architecture is typically categorized into single-MAC MLO or multiple-MAC MLO. This whitepaper will review why MediaTek prioritizes single-MAC MLO over multiple-MAC MLO to optimize throughput and latency and ensure the best user experience.

Considerations for System Design in MAC architecture

MLO operates as a MAC-layer carrier aggregation solution, dividing the MAC sub-layer into upper MAC (UMAC) and lower MAC (LMAC). This two-tier MAC structure facilitates concurrent frame transmission across multiple links. UMAC acts as a central component which is shared among all interfaces, managing link operations, buffering traffic from the host, and assigning it to specific interfaces for transmission. It also buffers interface traffic before forwarding it to the host in a sequentially manner. UMAC ensures seamless link transitions to minimize access latency and optimize load balancing. On the other hand, LMAC functions as an independent component for each interface, executing link-specific tasks with its unique channel access method and parameters.

In our prior white paper on Wi-Fi 7 Multi-Link Operation (MLO), we examined various MLO modes in comparison to different system architectures. The MLO architecture can be partitioned in several ways, as shown in Figure 1, typically categorized into single-MAC MLO (Arch#1) and multiple-MAC MLO (Arch#2, Arch#3, and Arch#4). Below, we detail the implementations, highlight key variances, and outline their advantages.

Types of MLO Architectures

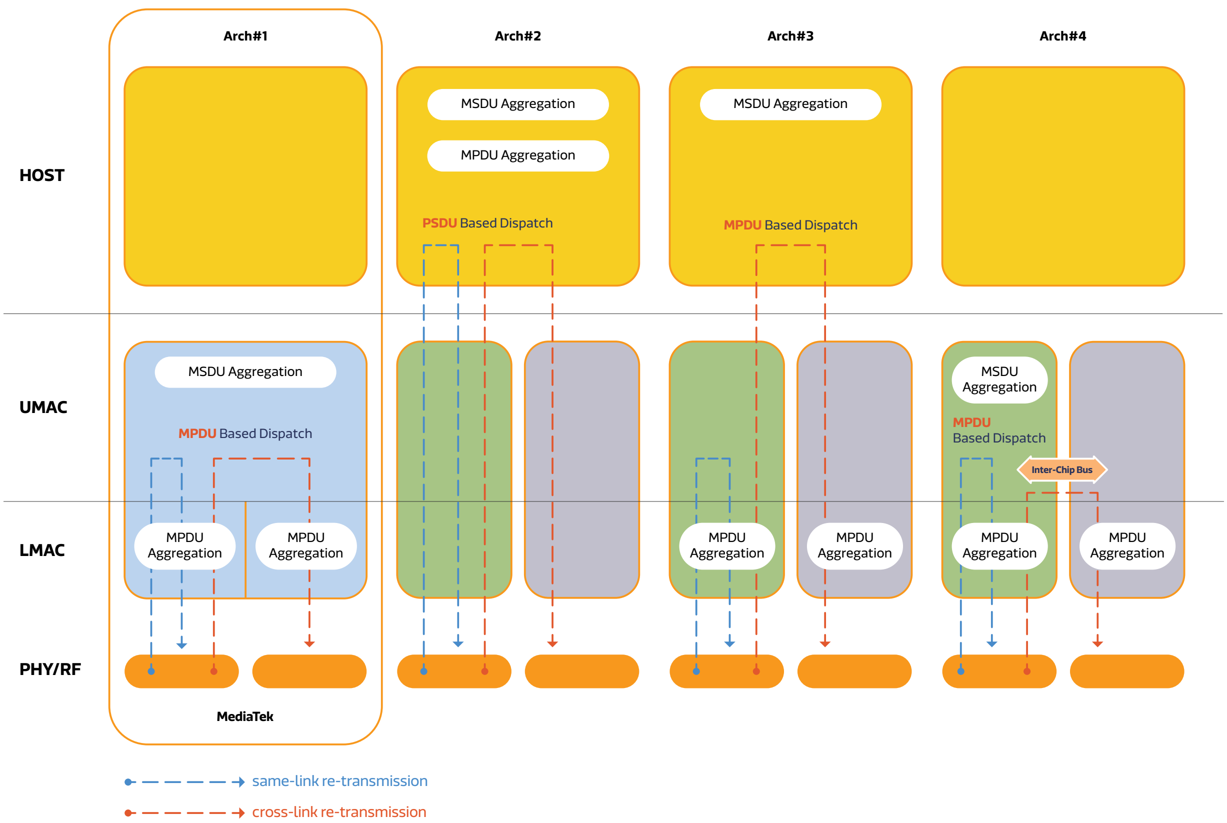

Figure 1. Implementation of Different MLO Architectures

- **Arch#1** implements an MLD with a single MAC. Each affiliated device within the MLD comprises PHY and LMAC elements. At the MLD top level, a sole UMAC unit aggregates these devices and provides an LLC layer in the HOST with a single HOST interface. UMAC manages MAC functions like MSDU aggregation/de-aggregation and MPDU dispatch across multiple links, while LMAC handles specific operations such as MPDU aggregation/de-aggregation.

- **Arch#2** introduces multiple MAC HOST interfaces to upper layers, where the HOST layer oversees MSDU aggregation/de-aggregation, MPDU aggregation/de-aggregation, and orchestrates session transfer for traffic balancing across diverse bands/channels using PSDU information.
- **Arch#3** similarly incorporates multiple HOST interfaces. The primary difference between Arch#3 and Arch#2 is the management of MSDU aggregation/de-aggregation and MPDU dispatch at the HOST layer, while MPDU aggregation/de-aggregation takes place in LMAC.
- **Arch#4** operates as a distributed solution, offering a single MAC to the HOST layer via the HOST interface, maintaining upper layers unaware of session transfer across bands or channels. In this MAC setup, UMAC handles MSDU aggregation/de-aggregation and MPDU dispatch across links. Due to potential link switches between MACs, an inter-chip bus is required which may limit the performance to the bus speed capability.

Advantages and Disadvantages of MLO Architectures

To maximize data throughput, real-time link information is essential for determining the allocation range of the Block Ack (BA) window. To achieve low latency, it is crucial to consider the computation time for resending at the sender, processing of reordered packets at the receiver, and the time delay for retransmitting packets across links at the sender.

If Arch#2 or Arch#3 architecture is implemented, the host will predict and allocate the number of MPDUs for transmission on each link. However, this approach may not fully reflect the current radio status, potentially leading to overestimation or underestimation and suboptimal throughput.

If Arch#4 architecture is utilized, a significant issue arises concerning the necessity for physical transmission interfaces (e.g., PCIe, GPIO, etc.) across chips. The data exchanged between them influences the precision of MPDU counts; higher accuracy demands additional pins from the transmission interface. Given the potential need for the transmitter to resend MPDUs and the synchronization requirements for BA Ack information across diverse links, any delay in synchronization could impact the effectiveness of MPDUs retransmission, resulting in increased latency and reduced capacity for transmitting MPDUs.

When utilizing Arch#1, a single UMAC aggregates all MLD devices, resulting in better estimation of the number of MPDUs for transmission and lower internal synchronization cost.

Due to these advantages MediaTek prioritizes Single-MAC MLO (Arch#1) over multiple-MAC MLO (Arch#2, Arch#3, and Arch#4) as its preferred choice to optimize throughput and latency and ensure the best user experience.

Testing Results

This section outlines the experimental throughput test results for two BE19000 Wi-Fi 7 Tri-band Routers. The first Device Under Test (DUT), the MediaTek Filogic 880 Tri-band Router, employs a Single-MAC MLO architecture. In contrast, the second DUT, another BE19000 Wi-Fi 7 Tri-band Router, utilizes a Multiple-MAC MLO architecture and does not incorporate MediaTek's chipset.

The routers' TCP Throughput performance is showcased in the following results, highlighting the distinct characteristics of each configuration. The data indicates that the Single-MAC MLO architecture consistently outperforms the Multiple-MAC MLO architecture across all traffic directions. Specifically, the Single-MAC MLO architecture achieves approximately 50% better performance.

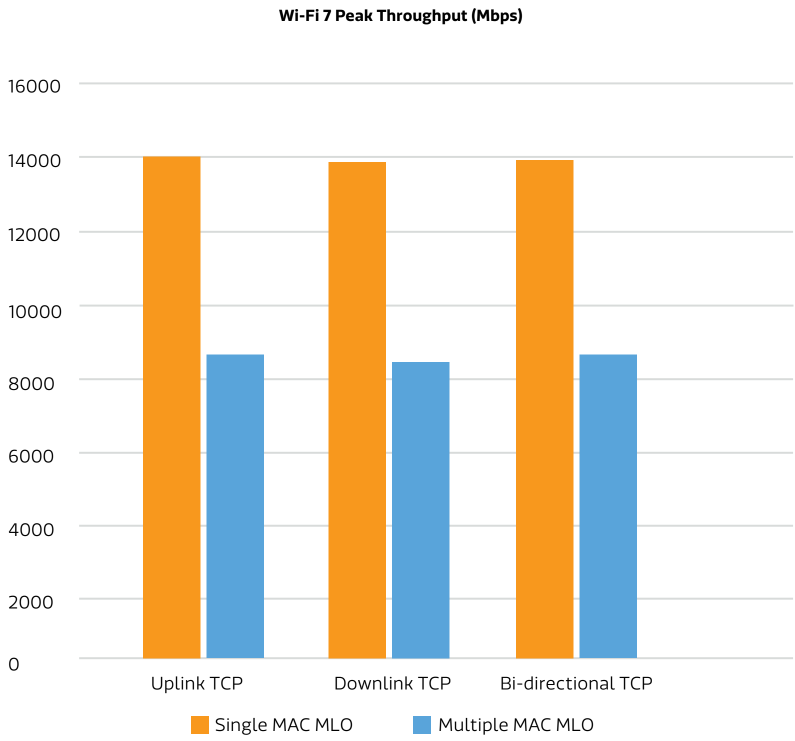

Figure 2. Throughput Test Results

Throughput Test Results as shown in Figure 2.

- Uplink TCP Throughput: The Single-MAC MLO architecture demonstrates superior performance compared to the Multiple-MAC MLO architecture.
- Downlink TCP Throughput: Similar trends are observed, with the Single-MAC MLO architecture outperforming the Multiple-MAC MLO architecture.
- Bi-directional TCP Throughput: The Single-MAC MLO architecture maintains its performance advantage, delivering higher throughput in bi-directional traffic scenarios.

These results underscore the effectiveness of MediaTek's Single-MAC MLO architecture in optimizing throughput and enhancing overall network performance for Wi-Fi 7 routers.

Conclusions

Multi-Link Operation (MLO) represents a significant advancement in Wi-Fi 7 technology, markedly enhancing the system's ability to handle latency-sensitive applications such as video calls, wireless VR/AR headsets, and cloud gaming. This enhancement is a substantial improvement over previous Wi-Fi standards. MediaTek has strategically opted for the single-MAC MLO architecture in its Wi-Fi 7 routers, aiming to provide an optimal user experience. The empirical data gathered during testing validates the theoretical advantages of MLO, clearly showing that the single-MAC MLO architecture outperforms its multiple-MAC counterparts in Wi-Fi 7 routers.

This evidence underscores the effectiveness of MediaTek's approach in leveraging cutting-edge technology to elevate connectivity and user satisfaction.

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 expertise and knowledge of different market segment requirements to improve Wi-Fi performance for everyday use.

Get ready for Wi-Fi 7 with the latest in MLO innovation from MediaTek

MediaTek's innovations and product platforms are ready to support next-generation MLO reliability using our just-announced Filogic 880 and Filogic 380 high performance, power-efficient and reliable Wi-Fi solutions.

Discover Filogic

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