LANCOM White Paper
MU-MIMO with IEEE 802.11ac

The introduction of the Wi-Fi standard IEEE 802.11n launched the technology known as MIMO (multiple input and multiple output). MIMO describes the capability to simultaneously transmit data to wireless devices via multiple streams. This significantly increases the connection speed between the transmitter and receiver—but only for one receiver at a time.

Following the performance improvements that came with the release of the IEEE 802.11ac standard, the subsequent arrival of IEEE 802.11ac Wave 2 MU-MIMO (multi-user multiple input and multiple output) brought even further improvements to the utilization of the available bandwidth.

This white paper describes how MU-MIMO makes the enormous benefits from MIMO available to multiple clients at the same time, while also raising the overall performance of Wi-Fi networks to a new level.

MIMO

MIMO uses different transmitters and receivers to implement multiple parallel data links, which are known as spatial streams. The differences in the signal paths between the various transmitters and receivers, which arise from reflections and the differential distances between the antennas, mean that these signals can be separately identified. As a result, the separate data streams can be used to carry additional data.

A signal sent by transmitter A and received by receiver 1 follows a different path to a signal from transmitter B to receiver 2. Due to the different reflections and changes in polarization that both signals experience along their paths, each of these paths takes on its own characteristics (Fig. 1).

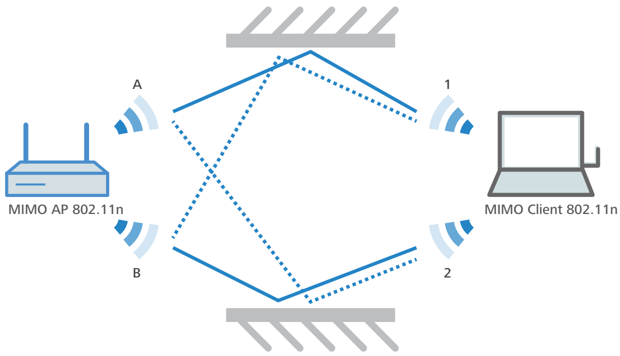

Fig. 1: 2x2 MIMO

For example, the access point splits the data into two groups, which are then sent in parallel to the Wi-Fi client via separate antennas. Data throughput can theoretically be doubled using two transmitting and receiving antennas. The notation "transmitter x receiver" indicates the number of the transmitting and receiving antennas. 3x3 MIMO describes three transmitting and three receiving antennas.

The biggest limitation on the use of MIMO is that an IEEE 802.11n access point can only communicate with one client at a time, which is why this technology is frequently referred to as Single-User MIMO (SU-MIMO). Consequently, data transfer can only occur with one of the connected clients at a time, and in many cases not all of the available spatial streams can be used. If a 4x4 access point transmits via SU-MIMO data to a 1x1 client (e.g. a smartphone or tablet), communication with

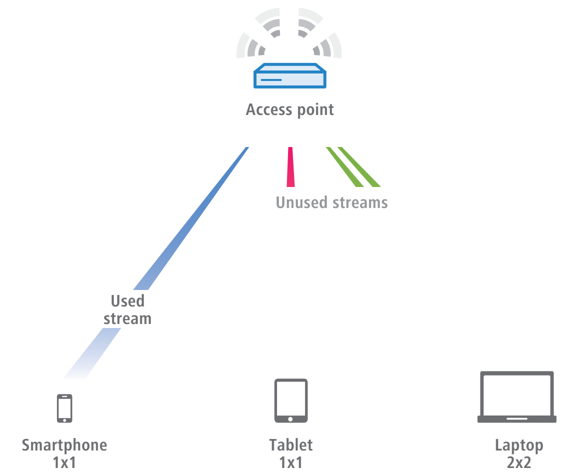

Fig. 2: Single-User MIMO

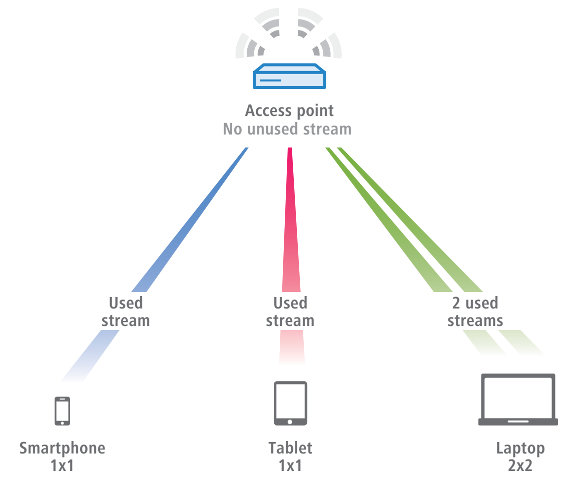

Fig. 3: Multi-User MIMO

other connected clients is impossible throughout this transmission, even though only one of the potential four streams is actually being used (Fig. 2).
These restrictions have been lifted by MU-MIMO, a component of IEEE 802.11ac Wave 2. A prerequisite for this is that the clients and the access points must support this standard.

MU-MIMO

Multi-User MIMO (MU-MIMO for short) is a part of the IEEE 802.11ac Wave 2 standard that works only in the 5-GHz frequency band and allows the different spatial streams of an access point to be split between different clients. This supplies several clients with data at the same time and all of the available spatial streams are used to maximum effect. The result is an increase in the overall bandwidth, and this is used to transfer data in parallel. For example, MU-MIMO enables an access point with 4x4 MIMO to divide its four spatial streams in parallel between a 2x2 client (e.g. a laptop) and two 1x1 clients (e.g. tablets or smartphones) (Fig. 3).
Additionally, the wireless network is able to serve a greater number of clients in the queue even faster. This means that data is transmitted more efficiently, even though the speed of the individual clients is not actually any higher. The result is a better Wi-Fi experience for all of the clients. This effect is most noticeable in scenarios with many users, such as with public Wi-Fi hotspots. This technology even benefits wireless clients that do not directly support MU-MIMO. Because the MU-MIMO-capable clients can be provided with data more quickly, the access point has more time available for communicating with the other clients.

Beamforming

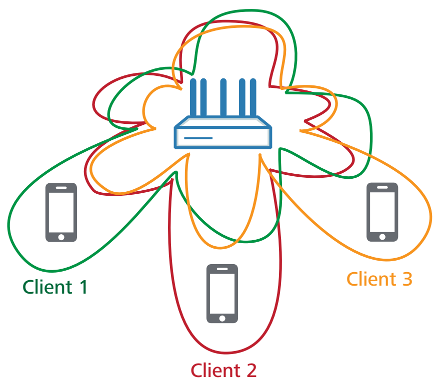

Fig. 4: Beamforming

Beamforming is essential for the functionality of MU-MIMO. Beamforming enables an access point to control the strength of the signal in relation to the direction. For example, certain clients can be offered a particularly good connection while the other clients not using the signals are subjected to less interference. In combination with MU-MIMO, the various clients receive dedicated spatial streams with a minimum of interference, which has a positive influence on the available gross data rates for all of the clients (Fig. 4). Although beamforming was an option with IEEE 802.11n, it was not precisely specified. This resulted in proprietary implementations, which only operate with specific hardware. With IEEE 802.11ac, beamforming is specified within the standard, so compatibility is assured irrespective of the hardware.

Additional enhancements with IEEE 802.11ac Wave 2

In addition to MU-MIMO, the second generation of the IEEE 802.11ac standard brings two further improvements that aim to increase the bandwidth.

4x4 MIMO

4x4 MIMO with up to four spatial streams was already implemented in IEEE 802.1ac Wave 1, but it can only be effectively employed since the introduction of 802.11ac Wave 2. Even though the compatibility between the different technologies is guaranteed in both directions, the maximum attainable bandwidth is always dictated by the device with the least number of transmitters or receivers. The true strengths of a 4x4 MIMO access point really come into play in combination with MU-MIMO: The maximum available data rate of 1733 Mbps can be divided between multiple clients to exploit the radio field to the full.

MIMO	80 MHz	160 MHz
1x1	433	866
2x2	866	1733
3x3	1300	2600
4x4	1733	3466

The standard's maximum gross data rate in Mbps depending on MIMO and channel width

Support of channel widths up to 160 MHz

One of the biggest advantages in the 5-GHz frequency band is the number of overlap-free channels, each of which has a bandwidth of 20 MHz. A Wi-Fi access point is capable of aggregating the channels to increase the data amount that can be transferred. IEEE 802.11ac Wave 2 access points use this technology to create channel widths of 160 MHz. Compared to IEEE 802.11ac Wave 1 with its maximum channel width of 80 MHz, the increase in channel width to 160 MHz theoretically means that performance is doubled. However, the number of available channels is significantly reduced when operating link aggregation for 160 MHz. Another consideration is that certain channels are reserved for weather radar services and therefore are basically unavailable. In practice, these benefits play a relatively minor role (Fig. 6).

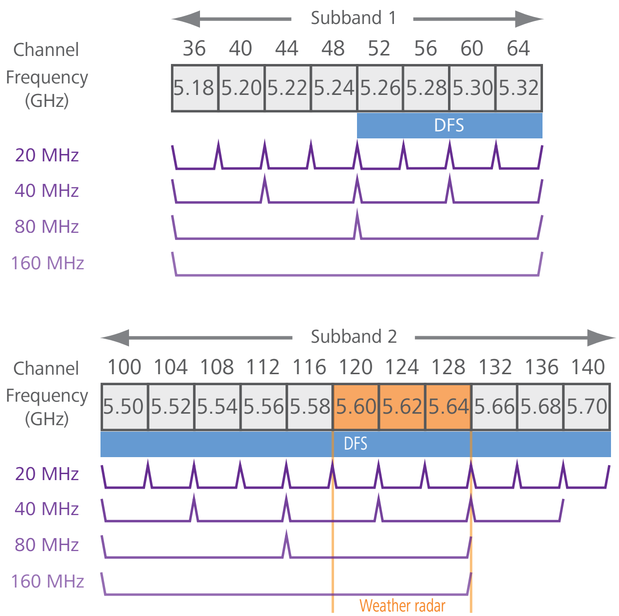

Fig. 6: Channels in the 5-GHz frequency band

LANCOM Systems

Infrastructure requirements

The infrastructure must meet a number of requirements to exploit the full speed of IEEE 802.11ac Wave 2:

- IEEE 802.11ac Wave 2 clients are required in order to take advantage of the new standard.
- Gigabit switches with at least 1-Gbps or better 10-Gbps uplink ports to exploit the high transmission rates.
- Support of the LACP protocol by switches and access points; aggregating multiple ports breaks the Gigabit barrier imposed by Ethernet cabling.
- For 3x3 MIMO and higher, dual-radio access points require full-power IEEE 802.3at (PoE+).
- Dual-radio access points supporting IEEE 802.11ac Wave 2 at 5 GHz for maximum performance and 2.4 GHz for Wi-Fi access by older clients.

Summary

The Wi-Fi standard IEEE 802.11ac Wave 2 offers a significant increase in performance and efficiency for wireless networks. Multi-User MIMO allows the simultaneous use of all available streams for multiple clients, as opposed to single-user MIMO, which can only serve one client at a time. The available bandwidth is used more efficiently and delays in the wireless network are substantially reduced.

Beamforming additionally improves signal strength for the clients while at the same time reducing the interference on the other clients. In combination with MU-MIMO, the clients receive dedicated spatial streams with a minimum of interference, which positively influences the data rates for all of the clients.

In comparison to the former SU-MIMO, MU-MIMO works in combination with the other enhancements to IEEE 802.11ac Wave 2 to provide a massively improved Wi-Fi experience.

www.lancom-systems.com

LANCOM Systems GmbH I Adenauerstr. 20/B2 I 52146 Wuerselen I Germany I E-mail info@lancom.de

LANCOM Systems