UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

INTELLECTUAL VENTURES I LLC and INTELLECTUAL VENTURES II LLC, Plaintiffs, v. TP-LINK CORPORATION LIMITED f/k/a TP-LINK INTERNATIONAL LTD., Defendant.	Civil Action No. 6:23-cv-308 **JURY TRIAL DEMANDED**

COMPLAINT FOR PATENT INFRINGEMENT

Plaintiffs, Intellectual Ventures I LLC ("Intellectual Ventures I") and Intellectual Ventures II LLC ("Intellectual Ventures II") (together, "IV"), for its complaint against Defendant TP-Link Corporation Limited f/k/a TP-Link International Ltd. ("TP-Link"), hereby allege:

THE PARTIES

1. Intellectual Ventures I is a Delaware limited liability company having its principal place of business located at 3150 139th Avenue SE, Bellevue, Washington 98005.

2. Intellectual Ventures II is a Delaware limited liability company having its principal place of business located at 3150 139th Avenue SE, Bellevue, Washington 98005.

3. Upon information and belief, TP-Link Corporation Limited is a private limited company organized under the laws of Hong Kong, with its principal place of business located at Suite 901, New East Ocean Centre, Tsim Sha Tsui, Hong Kong, China.

4. Upon information and belief, in 2020, TP-Link International Ltd. changed its name to TP-Link Corporation Limited.

5. According to its website, TP-Link was founded in 1996 and is ranked as "the No. 1 provider of Wi-Fi devices for a consecutive 11 years, supplying distribution to more than 170 countries."[1] TP-Link supplies a full range of products to consumers in the United States, and in this District.

6. Upon information and belief, TP-Link is the parent company of a multinational conglomerate that operates under the name "TP-Link." TP-Link and each conglomerate member are believed to be part of the same corporate structure and distribution chain and have acted in concert with respect to the facts alleged herein such that any act of one member is attributable to every other member and vice versa.

7. TP-Link may be served with process at its primary office location at Suite 901, New East Ocean Centre, Tsim Sha Tsui, Hong Kong.

8. Upon information and belief, if TP-Link cannot be served at its primary office location, TP-Link may alternatively be served at its registered office for service with Hong Kong Companies' Registry, to the extent it differs from its primary office location, which is listed as Room 901, 9/F, New East Ocean Centre, 9 Science Museum Road, Tsim Sha Tsui, KLN, Hong Kong.

NATURE OF THE ACTION, JURISDICTION, AND VENUE

9. IV brings this action for patent infringement pursuant to 35 U.S.C. § 271, *et seq.* This Court has subject matter jurisdiction under 28 U.S.C. §§ 1331 and 1338(a).

10. TP-Link is subject to this Court's specific and general personal jurisdiction pursuant to due process and/or the Texas Long-Arm Statute, due at least to its substantial business in Texas and this Judicial district, including: (i) its infringing activities alleged herein by which

[1] *See* https://www.tp-link.com/hk/about-us/corporate-profile/

TP-Link purposefully avails itself of the privilege of conducting its business activities in this state and district, therefore, submitting itself to the jurisdiction of this Court; and (ii) regularly doing or soliciting business, contracting with and engaging in other persistent conduct targeting residents of Texas and this district, or deriving substantial revenue from goods and services offered for sale, sold, and imported to and targeting residents of Texas and this district directly and through or in concert with intermediaries, agents, distributors, importers, customers, subsidiaries and/or consumers. *See* https://www.tp-link.com/us/where-to-buy/.

11. Furthermore, TP-Link conducts its business of marketing, distributing, deploying, and selling products and services in Texas and in this district through its agents, representatives, affiliates, related entities, partners, distributors, and retailers.

12. TP-Link also continuously and systematically solicits business and contracts with residents of Texas and this district. For example, requiring users and customers to enter into written contracts containing terms and conditions governing access and use of TP-Link products and technology, such as TP-Link's mobile applications.

13. TP-Link registers its products with the United States Federal Communications Commission (FCC).[2]

14. TP-Link represents that the TP-Link hardware products, technical support and services accessible through the TP-Link websites, and software downloaded to a user's smartphone or tablet in order to access services and subscriptions are provided by TP-Link located at Suite 901, New East Ocean Centre, Tsim Sha Tsui, Hong Kong, its affiliates and subsidiaries.[3]

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[2] *See, e.g.*, https://fccid.io/2AXJ4C200V2; https://fccid.io/2AXJ4C200V2; https://fccid.io/2AXJ4C200V2; https://fccid.io/2AXJ4C400.

[3] *See* https://www.tp-link.com/us/about-us/privacy/#sec_b.

15. TP-Link partners with retailers in Texas, such as Target, and specifically directs customers to purchase its products at its partner's locations.[4]

16. Venue is proper in this District under 28 U.S.C. § 1391(c) because TP-Link is a foreign corporation. In addition, TP-Link has committed acts of patent infringement in this District and IV has suffered harm in this District.

FACTUAL BACKGROUND

17. Intellectual Ventures Management, LLC ("Intellectual Ventures") was founded in 2000. Intellectual Ventures fosters inventions and facilitates the filing of patent applications for those inventions; collaborates with others to develop and patent inventions; and acquires and licenses patents from individual inventors, universities, corporations, and other institutions. A significant aspect of Intellectual Ventures' business is managing the plaintiffs in this case, Intellectual Ventures I and Intellectual Ventures II.

18. One founder of Intellectual Ventures is Nathan Myhrvold, who worked at Microsoft from 1986 until 2000 in a variety of executive positions, culminating in his appointment as the company's first Chief Technology Officer ("CTO") in 1996. While at Microsoft, Dr. Myhrvold founded Microsoft Research in 1991 and was one of the world's foremost software experts. Between 1986 and 2000, Microsoft became the world's largest technology company.

19. Under Dr. Myhrvold's leadership, Intellectual Ventures acquired thousands of patents covering many important inventions of the Internet era, including many pertaining to the networked computers that comprise the Internet. Many of these inventions coincided with Dr. Myhrvold's successful tenure at Microsoft.

Cyclic Diversity

[4] *See, e.g.*, https://www.tp-link.com/us/press/news/19198/; https://www.tp-link.com/us/press/news/19198/.

20. A particular area of importance in today's computing environments is that as wireless communications systems are widely deployed to provide various types of communications, demand for increased data rates has skyrocketed. This has led wireless system providers to develop new techniques for increasing data rates within the limited available radio frequency (RF) spectrum. One of these advancements has been the use of orthogonal frequency division multiplexing (OFDM) transmission. In OFDM transmissions, a radio channel is divided into a large number of closely spaced subchannels, an outgoing bitstream representing data to be transmitted is divided into multiple sub-bitstreams, and each sub-bitstream is transmitted over a subchannel in parallel with other sub-bitstreams that are each transmitted over their respective subchannels. Each such sub-bitstream is comprised of a series of symbols, that is, a waveform of the communication channel that persists for a fixed period of time, and from which data can be extracted by taking samples (i.e., measuring segments) of that waveform. Each of the symbols is separated by a guard interval (a gap in time between successive symbols that provides a buffer making transmission channels more resilient against the effects of a multipath propagation). The main advantages of OFDM is its ability to cope with severe channel conditions (e.g., signal fading, echoes, and interference).

21. As technology continued to advance, demand for increased speed and reduced interference resulted in the implementation of further improvements such as using multiple antennas in a single device, sometimes referred to as multiple input, multiple output (MIMO), which enables simultaneous or substantially simultaneous transmission of multiple bitstreams/sub-bitstreams in the same RF spectrum. When combined with OFDM, MIMO increases speed and improves reliability, however, it also introduces challenges, particularly when a multi-antenna MIMO enabled transmitter is communicating with a single antenna single input, single output

(SISO), receiver device. For example, signals transmitted from the MIMO transmitter may follow direct paths and multipaths to the SIS receiver, which can result in constructive interference (when multiple signals interact with one another to increase their amplitudes) or destructive interference (when multiple signals interact with one another to decrease their amplitudes), thus increasing packet error rates and causing other unwanted behavior that degraded the network quality.

22. One way that prior art systems addressed these inefficiencies was by implementing linear diversity schemes in which the transmission of one signal from a MIMO system is delayed relative to another signal from the MIMO system. Linear diversity schemes tend to reduce constructive and destructive interference by temporally decorrelating the transmissions of two signals, but they resulted in other problems such as one of the signals occupying the other's guard interval.

23. To address the inefficiencies set out above, cyclic diversity schemes were implemented (e.g., the cyclic-delay diversity scheme). In the cyclic-delay diversity scheme each of two or more transmitters send the same data in a respective stream of symbols, but cyclically offset one spatial stream vis-a-vis the other by a defined number of samples resulting in a circular shift of all the samples in a particular symbol (or part thereof). By introducing a relatively small cyclic delay to a first transmitted MIMO signal relative to a second transmitted MIMO signals, those of skill in the art were able to substantially reduce the problems set out above. But, by introducing a small cyclic delay between the first and second MIMO signals, upon receipt sometimes the receiver would be unable to determine whether the cyclic delay was intentional or caused by environmental or other factors. This inability in turn led to the receiver incorrectly assuming an attempt by the transmitter to beamform, which occurs when antennas are intentionally electronically steered to adjust the phase and amplitude of a transmitted signal at each antenna,

such that the signals combine constructively in the desired direction and destructively in other directions. That is, small cyclic delays were causing unintentional beamforming.

24. To address these and other problems in the art, Mark Webster and Michael Seals, at the time engineers for Conexant Systems, developed improved systems and methods of wireless communication, which include, but are not limited to, an improved signal transmitting system capable of manipulating OFDM data packets and data streams using a cyclic diversity scheme based on cyclic advancement rather than cyclic delay, thereby improving packet reception performance and reducing packet error rates, among other benefits.

25. Defendant makes, uses, and sells devices that include embedded wireless 802.11n, 802.11ac and 802.11ax compliant chipsets configured to use MIMO and OFDMA with a cyclic shift diversity feature compliant with the respective 802.11 standard, such as the EAP660 HD access points, part of the AX3600 family product line.

Access Point Overlapping Basic Service Set (BSS) Coloring in Device Dense Environments

26. An additional area of continued importance in wireless communication is the need for access points to balance the desire for increased coverage and overlapping services with the risk of causing interference in device dense environments potentially reducing the quality of such communications.

27. Autocell Laboratories, Inc. ("Autocell"), was a New Hampshire-based wireless communications company that developed innovative solutions that automatically reduced radio frequency interference, ensured robust wireless performance in business and wireless broadband deployments, and enhanced quality of life in digital homes and businesses. Autocell technology was featured in devices throughout the world, including but not limited to products sold by important companies such as Microsoft.

28. Defendant makes, uses, and sells devices that include Wi-Fi 6 (802.11ax) compliant chipsets configured to use BSS coloring, per the 802.11ax standard requirements, such as the EAP660 HD access points, part of the AX3600 family product line.

Wireless Mesh Networking

29. Access points in modern wireless networks must be able to efficiently and easily provide high quality coverage over ever-increasing distances. One traditional way to provide increased coverage while minimizing inherent limitations in transmit power, spectrum availability, etc., has been to implement "multi-hop" wireless link systems, which use relay stations that are not connected to fixed (e.g., cabled or wired) networks, in addition to wireless access points (sometimes referred to as "base stations") which are connected to fixed networks. Traditional multi-hop link networks however, struggled with providing the necessary combination of high data rates and wide area coverage.

30. Though multiple antennas can be used at the relay stations to increase range to the next hop, doing so limits the data rate that can be achieved due to the inherent limitations of wireless communication systems. One example of such a limitation is the tradeoff between cardinality of modulation which enables increased transmission rates, and the reliability of transmissions which enables increased range between hops. The contradicting requirements of high data rates and long range are especially difficult to optimally reconcile over a relay topology, in which the requirements of radio links between relays and users (i.e., where higher data rates may be more important) may differ from the requirements of radio links between relays and base stations (i.e., where longer range may be more important).

31. In furtherance of this goal Nokia Corporation leveraged its extensive expertise in wireless communication solutions to create a wireless multi-hop system whereby radio links

between relays and users are optimized separately from the links between relays and base stations in in which multiple simultaneous data streams between relays and base stations are created and maintained.

32. Defendant makes, uses, and sells devices that include 802.11 compliant access points, which use mesh networking technology, such as the Omada Mesh Technology in combination with OFDMA, to provide high data rate multi-hop wireless mesh networks, such as the EAP660 HD.

THE PATENTS-IN-SUIT

33. On November 24, 2009, the United States Patent and Trademark Office issued United States Patent No. 7,623,439 ("the '439 patent"), titled CYCLIC DIVERSITY SYSTEMS AND METHODS. The '439 patent is valid and enforceable.

34. Intellectual Ventures I LLC is the owner and assignee of all rights, title, and interest in the '439 patent, including the rights to grant licenses, to exclude others, and to recover past damages for infringement of that patent.

35. The '439 patent is directed to a system and method for transmitting OFDM signals from a multiple antenna transmitting device. The system is able to manipulate an OFDM signal using a cyclic advancement scheme whereby a portion of sampled symbol data from packets comprising the OFDM signal are shifted (advanced) into the guard interval of the packet relative to a first non-shifted version of the packet. The system and method then allow for the substantially simultaneous transmission of the respective packets from different antenna in the transmitting device, thereby allowing a receiver to more easily acquire and correlate the received data.

36. The inventions claimed in the '439 patent were conceived by Mark Webster and Michael Seals, both of whom were engineers at Conexant Systems, a well-known software

developer and fabless semiconductor company specializing in, among other things, developing technology for voice and audio processing. Mr. Webster is currently employed by L3Harris Technologies as a Senior Scientist, while Mr. Seals is a Principal Systems Engineer at Thales Group.

37. On January 14, 2014, the USPTO reissued United States Patent No. 7,773,944 as US RE44,706 ("the '706 patent"), titled RF DOMAINS. The '706 patent is valid and enforceable.

38. Intellectual Ventures II LLC is the owner and assignee of all rights, title, and interest in the '706 patent, including the rights to grant licenses, to exclude others, and to recover past damages for infringement of that patent.

39. The '706 patent is also directed to improved systems and methods of wireless communication. According to embodiments, a wireless device such as an AP may broadcast a unique identifier for a service set supported by that wireless device. The wireless device also listens to wireless messages broadcast by other wireless devices, e.g., other APs, for such identifiers. If the wireless device discovers another wireless device, e.g., another AP, that supports a same service set on the same frequency channel (i.e., an overlapping service set), the wireless device may reduce its transmission power so as not to interfere with transmissions emitted by the other wireless device that are associated with the overlapping service set. The transmit power of communications associated with non-overlapping service sets is not affected by the patented transmit power reduction method and apparatus. The performance of wireless networks is thereby improved by the technologies disclosed and claimed in the '706 patent.

40. The inventions claimed in the '706 patent were conceived by Thomas Gulick during his time at Autocell Laboratories, Inc.

41. On June 10, 2008, the USPTO issued United States Patent No. 7,386,036 (“the ’036 patent”), titled WIRELESS MULTI-HOP SYSTEM WITH MACROSCOPIC MULTIPLEXING. The ’036 patent is valid and enforceable.

42. Intellectual Ventures I LLC is the owner and assignee of all rights, title, and interest in the ’036 patent, including the rights to grant licenses, to exclude others, and to recover past damages for infringement of that patent.

43. The ’036 patent is directed to improved systems and methods of wireless communication in the context of high throughput multi-hop network implementations. According to embodiments, radio links between relays and users are optimized separately from the links between relays and base stations and multiple simultaneous data streams between relays and base stations are created. The system includes a base station that is connected to the core network with a link of wireline quality which is sufficient to reliably carry all communication between the base station and core network. It also implements two kinds of radio interface. A first relay station is connected to the base station and another relay station over a first radio interface, and to user equipment over a second radio interface. The first and second radio interfaces are separate from each other, and independently optimizable. The two interfaces may operate, at least in part, using the same frequency bandwidth. By maintaining separate and independently optimizable radio interfaces, the claimed systems and methods are able to achieve increased range, higher throughput and also be used to create transmissions with high directivity and reduced interference.

44. The inventions claimed in the ’036 patent were conceived by Pirjo Pasanen and Olav Tirkkonen at Nokia Corporation.

COUNT I
(Defendant’s Infringement of U.S. Patent No. 7,623,439)

45. The preceding paragraphs are reincorporated by reference as if fully set forth herein.

46. The '439 patent claims and teaches, *inter alia*, an improved signal transmitting system capable of manipulating OFDM data packets and data streams using improved cyclic diversity schemes, thereby improving packet reception performance when compared to conventional packet diversity mechanisms by reducing packet error rates, among other benefits.

47. The inventions improved upon then-existing cyclic diversity schemes in wireless communication by enabling a cyclic diversity scheme by which a portion of an OFDM packet's symbol data is cyclically advanced into the guard interval with respect to the original OFDM signal and then each signal is sent to a receiver device at substantially the same time from two respective antennas. This allowed for improved acquisition and correlation at the receiver while at the same time keeping intersymbol interference and unintentional beamforming to a minimum.

48. Unlike in prior art systems and methods, the cyclic diversity taught by the '439 patent uses cyclic advancement as opposed to delay. Doing so substantially reduces the probability of unintentional beamforming.

49. More specifically, one exemplary embodiment comprises an improved cyclic diversity system in which a logic circuit is configured to cyclically advance samples of a symbol data portion of an OFDM packet to be transmitted on a first antenna, relative to the samples of a symbol data portion of another OFDM packet to be transmitted on another antenna. The duration of the cyclic advance is less than the duration of a guard interval portion of the OFDM packet. By using a cyclic advance as described above, the symbol data portions of the two different transmitted signals are better decorrelated, thus reducing the probability of unintentional beamforming. The

performance of wireless networks is thereby improved by the technologies disclosed and claimed in the ’439 patent.

50. The system and methods covered by the asserted claims, therefore, differs markedly from prior art systems in use at the time of this invention, which lacked the claimed combination of cyclically advancing a first OFDM packet by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate a shifted version of the first OFDM packet in which at least a non-zero number of samples from the symbol data portion of the first OFDM packet are shifted into the guard interval portion of the shifted version, and a same non-zero number of samples from the guard interval portion of the first OFDM packet are shifted out of the guard interval portion of the shifted version. And, further where both versions are substantially simultaneously transmitted.

51. Defendant has directly infringed and continues to directly infringe at least claim 1 of the ’439 patent by making, using, selling, offering for sale, or importing products and/or services covered by the ’439 patent. Defendant’s products and/or services that infringe the ’439 patent include all wireless communication products that support IEEE 802.11n, 802.11ac and 802.11ax, including the transmission of multiple spatial streams, which requires a cyclic diversity shift when transmitting OFDM packets, that are made, used, sold, or offered for sale by or on behalf of Defendant and/or its subsidiaries or parent companies (cumulatively, “the ’439 Accused Products”), including but not limited to, the EAP660 HD family of access points.

52. Claim 1 of the ’439 patent is reproduced below:

1. A method for transmitting orthogonal frequency division multiplexing (OFDM) signals comprising:

generating a first OFDM packet for transmission including a guard interval portion and a symbol data portion each comprised of a plurality of samples;

> *cyclically advancing the first OFDM packet by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate a shifted version of the first OFDM packet for transmission in which at least a non-zero number of the samples from the symbol data portion of the first OFDM packet are shifted into the guard interval portion of the shifted version and a same non-zero number of samples from the guard interval portion of the first OFDM packet are shifted out of the guard interval portion of the shifted version; and*
>
> *substantially simultaneously transmitting the first OFDM packet and the shifted version of the OFDM packet.*

53. The '439 Accused Products are configured to perform a method for transmitting OFDM signals. As one example, the EAP660 HD supports the IEEE 802.11n standard, including the transmission of multiple spatial streams, which requires a forward shift diversity feature for transmitting OFDM signals:


EAP660 HD

AX3600 Wireless Dual Band Multi-Gigabit Ceiling Mount Access Point

- **Ultra-Fast Wi-Fi 6 Speeds**: Simultaneous 1148 Mbps on 2.4 GHz and 2402 Mbps on 5 GHz totals 3550 Mbps Wi-Fi speeds.†

WIRELESS FEATURES

Wireless Standards	IEEE 802.11ax/ac/n/g/b/a
Frequency	2.4 GHz and 5 GHz

Source: *https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap660-hd/#specifications*

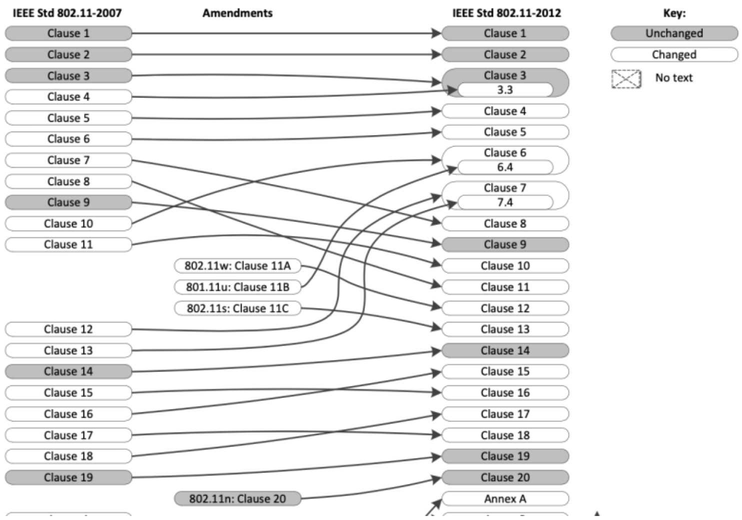
	TP-Link EAP660 HD
CPU	quad-core 2GHz Qualcomm IPQ8072A
RAM	512MB ESMT (2x M15T4G16256A)
Storage	128MB ESMT F59D1G81MB-AZM1P0H9N
5GHz Radio	Qualcomm Atheros IPQ8072A (QCN5054) 802.11a/n/ac/ax 4×4:4
2.4GHz Radio	Qualcomm Atheros IPQ8072A (QCN5024) 802.11b/g/n/ax 4×4:4

Source: *https://www.mbreviews.com/tp-link-eap660-hd-access-point-review/*

IPQ8074

CPU	Name: 4x ARM Cortex-A53 Number of Cores: 4 Clock Speed: Up to 2 GHz
Wi-Fi	Peak Speed: Up to 4.8 Gbps Generation: Wi-Fi 6

Source: *https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/product_brief_-_snapdragon_695_5g_mobile_platform.pdf*



Source: IEEE 802.11-2012.

20. High Throughput (HT) PHY specification

20.1 Introduction

20.1.1 Introduction to the HT PHY

Clause 20 specifies the PHY entity for a high throughput (HT) orthogonal frequency division multiplexing (OFDM) system.

In addition to the requirements found in Clause 20, an HT STA shall be capable of transmitting and receiving frames that are compliant with the mandatory PHY specifications defined as follows:

— In Clause 18 when the HT STA is operating in a 20 MHz channel width in the 5 GHz band
— In Clause 17 and Clause 19 when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band

The HT PHY is based on the OFDM PHY defined in Clause 18, with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth).

The HT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), or 64-QAM. Forward error correction (FEC) coding (convolutional coding) is used with a coding rate of 1/2, 2/3, 3/4, or 5/6. LDPC codes are added as an optional feature.

Source: IEEE Std 802.11-2012 pp. 1669.

20.1.2 Scope

The services provided to the MAC by the HT PHY consist of two protocol functions, defined as follows:

a) A PHY convergence function, which adapts the capabilities of the physical medium dependent (PMD) system to the PHY service. This function is supported by the physical layer convergence procedure (PLCP), which defines a method of mapping the PSDUs into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs using the associated PMD system.

Source: IEEE Std 802.11-2012 pp. 1669.

20.1.4 PPDU formats

The structure of the PPDU transmitted by an HT STA is determined by the TXVECTOR FORMAT, CH_BANDWIDTH, CH_OFFSET, and MCS parameters as defined in Table 20-1. The effect of the CH_BANDWIDTH, CH_OFFSET, and MCS parameters on PPDU format is described in 20.2.3.

The FORMAT parameter determines the overall structure of the PPDU as follows:

— *Non-HT format* **(NON_HT)**: Packets of this format are structured according to the Clause 18 (OFDM) or Clause 19 (ERP) specification. Support for non-HT format is mandatory.

— *HT-mixed format* **(HT_MF)**: Packets of this format contain a preamble compatible with Clause 18 and Clause 19 receivers. The non-HT-STF (L-STF), the non-HT-LTF (L-LTF), and the non-HT SIGNAL field (L-SIG) are defined so they can be decoded by non-HT Clause 18 and Clause 19 STAs. The rest of the packet cannot be decoded by Clause 18 or Clause 19 STAs. Support for HT-mixed format is mandatory.

— *HT-greenfield format* **(HT_GF)**: HT packets of this format do not contain a non-HT compatible part. Support for HT-greenfield format is optional. An HT STA that does not support the reception of an HT-greenfield format packet shall be able to detect that an HT-greenfield format packet is an HT transmission (as opposed to a non-HT transmission). In this case, the receiver shall decode the HT-SIG and determine whether the HT-SIG cyclic redundancy check (CRC) passes.

Source: IEEE Std. 802.11-2012, pp. 1669-70.

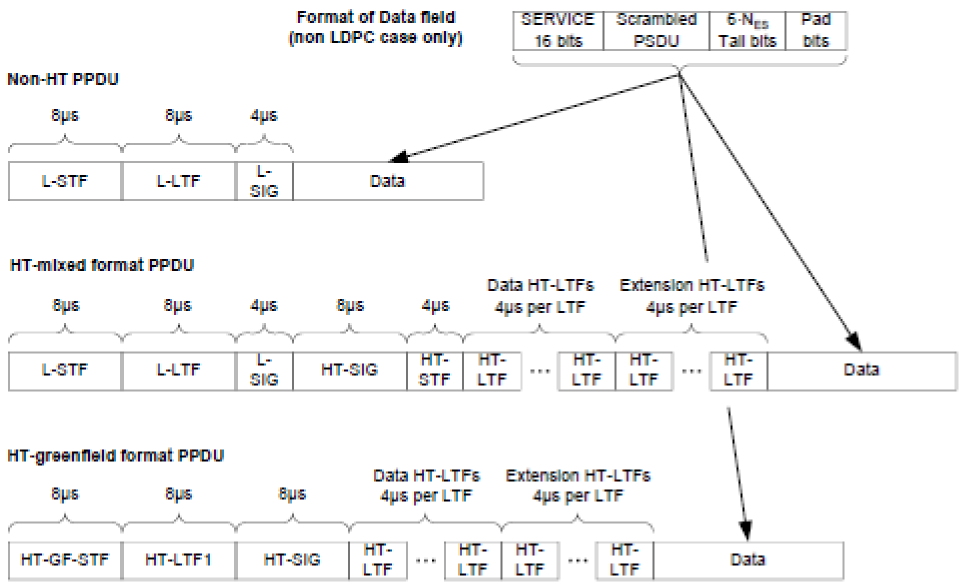


Figure 20-1—PPDU format

Source: IEEE Std. 802.11-2012, pp. 1682.

The HT portion of the HT-mixed format preamble enables estimation of the MIMO channel to support demodulation of the HT data by HT STAs. The HT portion of the HT-mixed format preamble also includes the HT-SIG field, which supports HT operation. The SERVICE field is prepended to the PSDU.

Source: IEEE Std. 802.11-2012, pp. 1682.

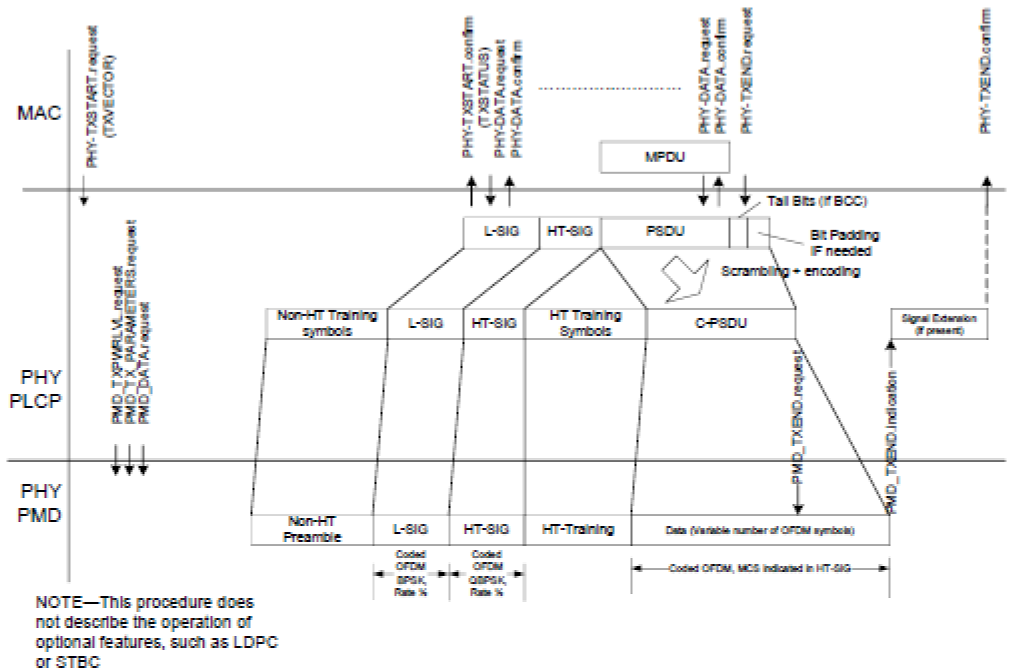


Figure 20-22—PLCP transmit procedure (HT-mixed format PPDU)

Source: IEEE Std. 802.11-2012, p. 1748.

54. The method practiced by the ’439 Accused Products includes generating a first OFDM packet for transmission including a guard interval portion and a symbol data portion each comprised of a plurality of samples. For instance, the 802.11 transmitter in the Accused Products creates an OFDM packet, known as an HT-SIG OFDM packet, which includes a symbol data portion comprised of a plurality of samples and a guard interval portion comprised of a plurality of samples, as seen below:

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- In Clause 17 and Clause 19 when the HT STA is operating in a 20 MHz channel width in the 2.4 GHz band

The HT PHY is based on the OFDM PHY defined in Clause 18, with extensibility up to four spatial streams, operating in 20 MHz bandwidth. Additionally, transmission using one to four spatial streams is defined for operation in 40 MHz bandwidth. These features are capable of supporting data rates up to 600 Mb/s (four spatial streams, 40 MHz bandwidth).

The HT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), or 64-QAM. Forward error correction (FEC) coding (convolutional coding) is used with a coding rate of 1/2, 2/3, 3/4, or 5/6. LDPC codes are added as an optional feature.

Source: IEEE Std 802.11-2012 pp. 1669.

20.1.2 Scope

The services provided to the MAC by the HT PHY consist of two protocol functions, defined as follows:

a) A PHY convergence function, which adapts the capabilities of the physical medium dependent (PMD) system to the PHY service. This function is supported by the physical layer convergence procedure (PLCP), which defines a method of mapping the PSDUs into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs using the associated PMD system.

Source: IEEE Std 802.11-2012 pp. 1669.

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The structure of the PPDU transmitted by an HT STA is determined by the TXVECTOR FORMAT, CH_BANDWIDTH, CH_OFFSET, and MCS parameters as defined in Table 20-1. The effect of the CH_BANDWIDTH, CH_OFFSET, and MCS parameters on PPDU format is described in 20.2.3.

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- *HT-greenfield format* (**HT_GF**): HT packets of this format do not contain a non-HT compatible part. Support for HT-greenfield format is optional. An HT STA that does not support the reception of an HT-greenfield format packet shall be able to detect that an HT-greenfield format packet is an HT transmission (as opposed to a non-HT transmission). In this case, the receiver shall decode the HT-SIG and determine whether the HT-SIG cyclic redundancy check (CRC) passes.

Source: IEEE Std. 802.11-2012, pp. 1669-70.

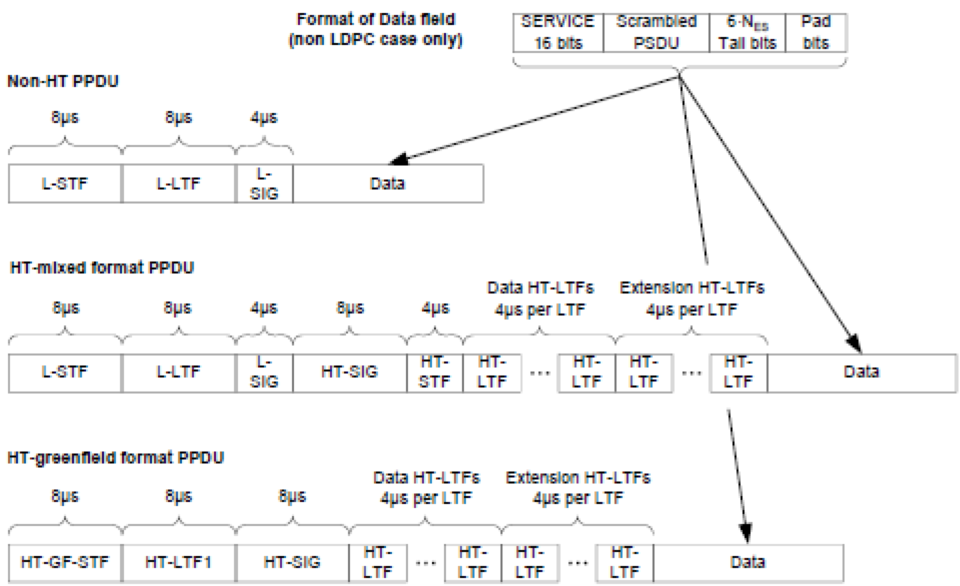


Figure 20-1—PPDU format

<u>Source</u>: IEEE Std. 802.11-2012, pp. 1682.

> The HT portion of the HT-mixed format preamble enables estimation of the MIMO channel to support demodulation of the HT data by HT STAs. The HT portion of the HT-mixed format preamble also includes the HT-SIG field, which supports HT operation. The SERVICE field is prepended to the PSDU.

<u>Source</u>: IEEE Std. 802.11-2012, pp. 1682.

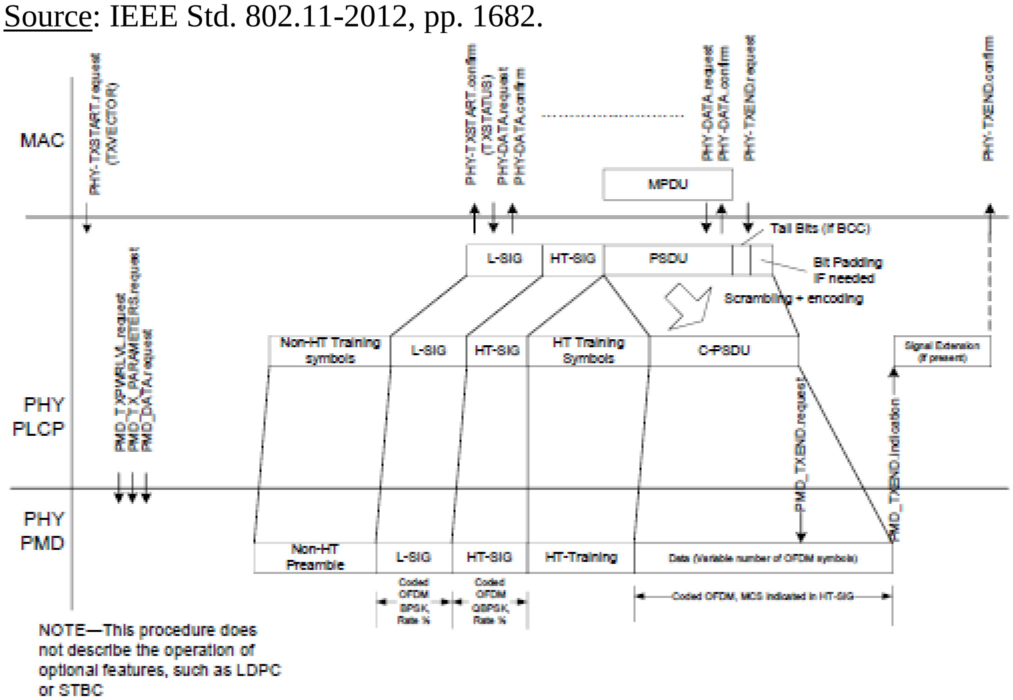


Figure 20-22—PLCP transmit procedure (HT-mixed format PPDU)

<u>Source</u>: IEEE Std. 802.11-2012, p. 1748.

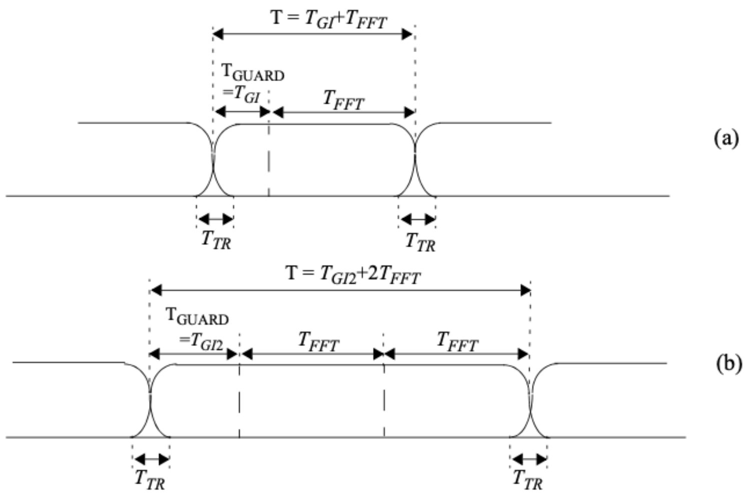


Figure 18-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period

Source: IEEE Std. 802.11-2012, p. 1592.

T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 µs ($1/\Delta_F$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 µs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 µs ($T_{FFT}/4$)

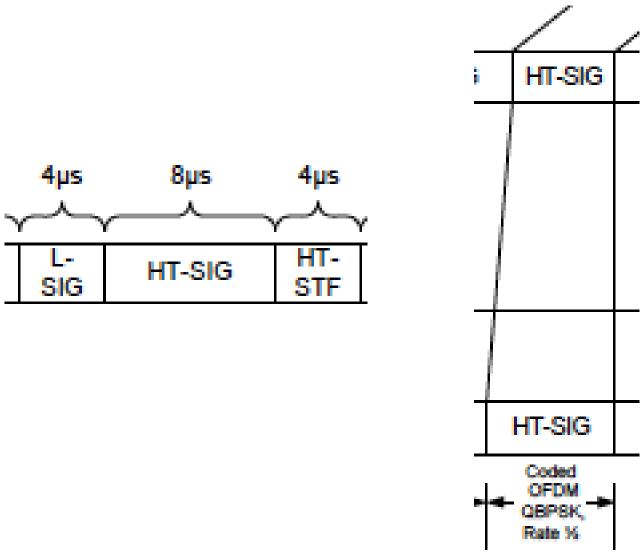
Source: IEEE Std. 802.11-2012, p. 1590-91.

20.3.9.4.3 HT-SIG definition

The HT-SIG is used to carry information required to interpret the HT packet formats. The fields of the HT-SIG are described in Table 20-11.

Table 20-11—HT-SIG fields

Field	Number of bits	Explanation and coding
Modulation and Coding Scheme	7	Index into the MCS table. See NOTE 1.
CBW 20/40	1	Set to 0 for 20 MHz or 40 MHz upper/lower. Set to 1 for 40 MHz.
HT Length	16	The number of octets of data in the PSDU in the range of 0 to 65 535.



Source: IEEE Std. 802.11-2012, p. 1682, 1748, 1699.

The HT-SIG is composed of two parts, $HT\text{-}SIG_1$ and $HT\text{-}SIG_2$, each containing 24 bits, as shown in Figure 20-6. All the fields in the HT-SIG are transmitted LSB first, and $HT\text{-}SIG_1$ is transmitted before $HT\text{-}SIG_2$.

The HT-SIG parts shall be encoded at R = 1/2, interleaved, and mapped to a BPSK constellation, and they have pilots inserted following the steps described in 18.3.5.6, 18.3.5.7, 18.3.5.8, and 18.3.5.9, respectively. The BPSK constellation is rotated by 90° relative to the L-SIG in order to accommodate detection of the start of the HT-SIG. The stream of 96 complex numbers generated by these steps is divided into two groups of 48 complex numbers: $d_{k,n}$, $0 \le k \le 47$, $n = 0, 1$. The time domain waveform for the HT-SIG in an HT-mixed format packet in a 20 MHz transmission shall be as shown in Equation (20-16).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} (jD_{k,n} + p_{n+1}P_k) \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) \quad (20\text{-}16)$$

Source: IEEE Std. 802.11-2012, p. 1700.

18.3.2.6 Discrete time implementation considerations

The following descriptions of the discrete time implementation are informational.

In a typical implementation, the windowing function is represented in discrete time. As an example, when a windowing function with parameters T = 4.0 μs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

$$w_T[n] = w_T(nT_S) = \begin{Bmatrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{Bmatrix} \quad (18\text{-}5)$$

Source: IEEE Std. 802.11-2012, p. 1593.

Figure 20-2 and Figure 20-3 show example transmitter block diagrams. In particular, Figure 20-2 shows the transmitter blocks used to generate the HT-SIG of the HT-mixed format PPDU. These transmitter blocks are

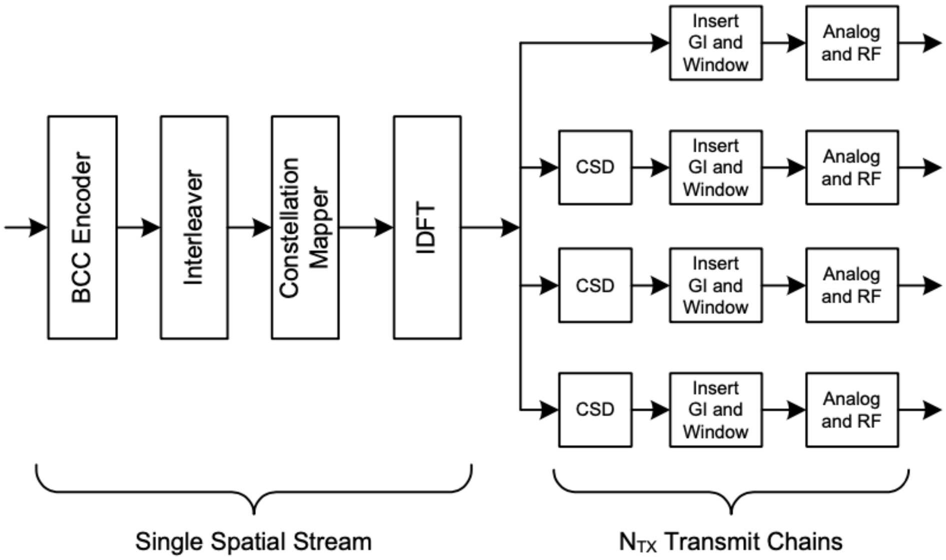


Figure 20-2—Transmitter block diagram 1

Source: IEEE Std. 802.11-2012, p. 1684-85.

20.3.3 Transmitter block diagram

HT-mixed format and HT-greenfield format transmissions can be generated using a transmitter consisting of the following blocks:

a) *Scrambler* scrambles the data to reduce the probability of long sequences of 0s or 1s; see 20.3.11.3.

b) *Encoder parser*, if BCC encoding is to be used, demultiplexes the scrambled bits among N_{ES} (number of BCC encoders for the Data field) BCC encoders, in a round robin manner.

c) *FEC encoders* encode the data to enable error correction. An FEC encoder may include a binary convolutional encoder followed by a puncturing device, or it may include an LDPC encoder.

d) *Stream parser* divides the outputs of the encoders into blocks that are sent to different interleaver and mapping devices. The sequence of the bits sent to an interleaver is called a *spatial stream*.

e) *Interleaver* interleaves the bits of each spatial stream (changes order of bits) to prevent long sequences of adjacent noisy bits from entering the BCC decoder. Interleaving is applied only when BCC encoding is used.

f) *Constellation mapper* maps the sequence of bits in each spatial stream to constellation points (complex numbers).

g) *STBC* encoder spreads constellation points from N_{SS} spatial streams into N_{STS} space-time streams using a space-time block code. STBC is used only when $N_{SS} < N_{STS}$; see 20.3.11.9.2.

h) *Spatial mapper* maps space-time streams to transmit chains. This may include one of the following:
   1) *Direct mapping*: Constellation points from each space-time stream are mapped directly onto the transmit chains (one-to-one mapping).
   2) *Spatial expansion*: Vectors of constellation points from all the space-time streams are expanded via matrix multiplication to produce the input to all the transmit chains.
   3) *Beamforming*: Similar to spatial expansion, each vector of constellation points from all the space-time streams is multiplied by a matrix of steering vectors to produce the input to the transmit chains.

i) *Inverse discrete Fourier transform (IDFT)* converts a block of constellation points to a time domain block.

Source: IEEE Std. 802.11-2012, p. 1683-84.

55. The method practiced by the '439 Accused Products includes cyclically advancing the first OFDM packet by shifting the samples in a first direction an amount less than a sample duration of the guard interval portion to generate a shifted version of the first OFDM packet for transmission. For example, the Accused Products cyclically shift the symbol data portion of the HT_SIG by -200 ns up to -50 ns, which is less than its guard interval's total length of 0.8 us, to generate a shifted version for transmission as seen below:

20.3.3 Transmitter block diagram

HT-mixed format and HT-greenfield format transmissions can be generated using a transmitter consisting of the following blocks:

a) *Scrambler* scrambles the data to reduce the probability of long sequences of 0s or 1s; see 20.3.11.3.
b) *Encoder parser*, if BCC encoding is to be used, demultiplexes the scrambled bits among N_{ES} (number of BCC encoders for the Data field) BCC encoders, in a round robin manner.
c) *FEC encoders* encode the data to enable error correction. An FEC encoder may include a binary convolutional encoder followed by a puncturing device, or it may include an LDPC encoder.
d) *Stream parser* divides the outputs of the encoders into blocks that are sent to different interleaver and mapping devices. The sequence of the bits sent to an interleaver is called a *spatial stream*.
e) *Interleaver* interleaves the bits of each spatial stream (changes order of bits) to prevent long sequences of adjacent noisy bits from entering the BCC decoder. Interleaving is applied only when BCC encoding is used.
f) *Constellation mapper* maps the sequence of bits in each spatial stream to constellation points (complex numbers).
g) *STBC* encoder spreads constellation points from N_{SS} spatial streams into N_{STS} space-time streams using a space-time block code. STBC is used only when $N_{SS} < N_{STS}$; see 20.3.11.9.2.

h) *Spatial mapper* maps space-time streams to transmit chains. This may include one of the following:

1) *Direct mapping*: Constellation points from each space-time stream are mapped directly onto the transmit chains (one-to-one mapping).
2) *Spatial expansion*: Vectors of constellation points from all the space-time streams are expanded via matrix multiplication to produce the input to all the transmit chains.
3) *Beamforming*: Similar to spatial expansion, each vector of constellation points from all the space-time streams is multiplied by a matrix of steering vectors to produce the input to the transmit chains.

i) *Inverse discrete Fourier transform (IDFT)* converts a block of constellation points to a time domain block.

Source: IEEE Std. 802.11-2012, p. 1683-84.

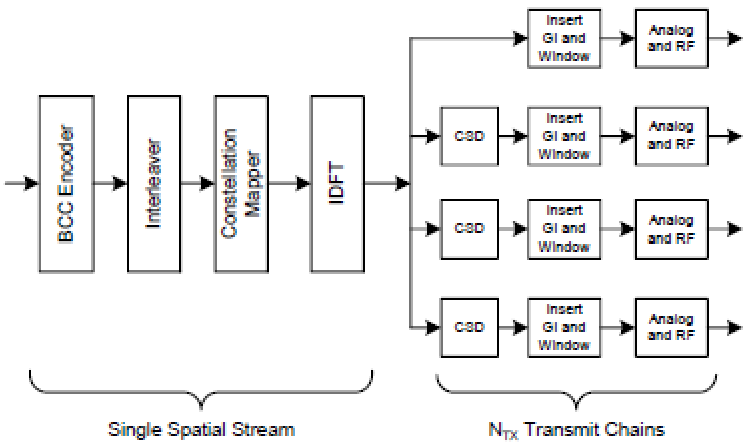


Figure 20-2—Transmitter block diagram 1

Source: IEEE Std. 802.11-2012, p. 1685.

20.3.9.3.2 Cyclic shift definition

The cyclic shift values defined in this subclause apply to the non-HT fields in the HT-mixed format preamble and the HT-SIG in the HT-mixed format preamble.

Cyclic shifts are used to prevent unintentional beamforming when the same signal or scalar multiples of one signal are transmitted through different spatial streams or transmit chains. A cyclic shift of duration T_{CS} on a signal $s(t)$ on interval $0 \le t \le T$ is defined as follows, where T is defined as T_{DFT} as referenced in Table 20-6.

With $T_{CS} \le 0$, replace $s(t)$ with $s(t - T_{CS})$ when $0 \le t < T + T_{CS}$ and with $s(t - T_{CS} - T)$ when $T + T_{CS} \le t \le T$. The cyclic-shifted signal is defined as shown in Equation (20-7).

$$s_{CS}(t;T_{CS})\big|_{T_{CS}<0} = \begin{cases} s(t - T_{CS}) & 0 \le t < T + T_{CS} \\ s(t - T_{CS} - T) & T + T_{CS} \le t \le T \end{cases} \quad (20\text{-}7)$$

The cyclic shift is applied to each OFDM symbol in the packet separately. Table 20-9 specifies the values for the cyclic shifts that are applied in the L-STF (in an HT-mixed format packet), the L-LTF, and L-SIG. It also applies to the HT-SIG in an HT-mixed format packet.

Source: IEEE Std. 802.11-2012, p. 1694-95.

Table 20-9—Cyclic shift for non-HT portion of packet

$T_{CS}^{i_{TX}}$ values for non-HT portion of packet				
Number of transmit chains	Cyclic shift for transmit chain 1 (ns)	Cyclic shift for transmit chain 2 (ns)	Cyclic shift for transmit chain 3 (ns)	Cyclic shift for transmit chain 4 (ns)
1	0	—	—	—
2	0	–200	—	—
3	0	–100	–200	—
4	0	–50	–100	–150

Source: IEEE Std. 802.11-2012, p. 1695.

Table 20-5—Timing-related constants *(continued)*

T_{DFT}: IDFT/DFT period	3.2 µs
T_{GI}: Guard interval duration	0.8 µs= T_{DFT}/4

Source: IEEE Std. 802.11n-2009, p. 266.

20.3.4 Overview of the PPDU encoding process

The encoding process is composed of the steps described below. The following overview is intended to facilitate an understanding of the details of the convergence procedure:

b) Construct the PLCP preamble SIGNAL fields from the appropriate fields of the TXVECTOR by adding tail bits, applying convolutional coding, formatting into one or more OFDM symbols, applying cyclic shifts, applying spatial processing, calculating an inverse Fourier transform for each OFDM symbol and transmit chain, and prepending a cyclic prefix or GI to each OFDM symbol in each transmit chain. The number and placement of the PLCP preamble SIGNAL fields depend on the frame format being used. Refer to 20.3.9.3.5, 20.3.9.4.3, and 20.3.9.5.4.

r) For each group of N_{ST} subcarriers and each of the N_{TX} transmit chains, convert the subcarriers to time domain using IDFT. Prepend to the Fourier-transformed waveform a circular extension of itself, thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Determine the length of the GI according to the GI_TYPE parameter of the TXVECTOR. Refer to 20.3.11.11 and 20.3.11.12 for details. When beamforming is not used, it is sometimes possible to implement the cyclic shifts in the time domain.

Source: IEEE Std. 802.11-2012, p. 1684, 1688.

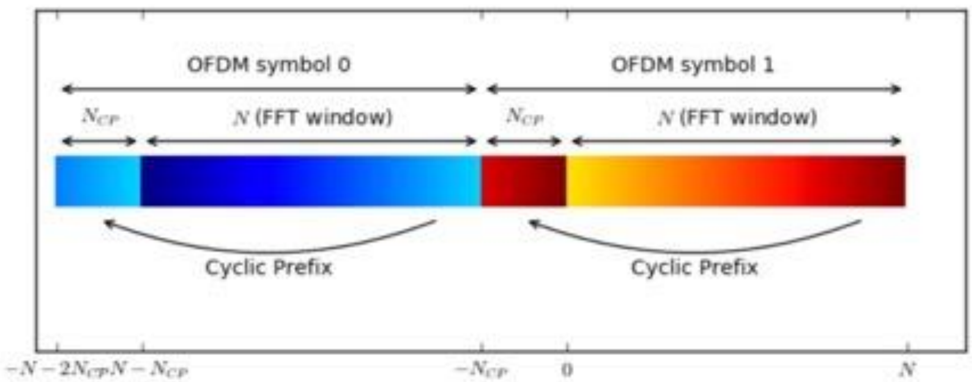
The Cyclic Prefix for OFDM

In a previous post, we have elaborated about the building blocks of OFDM.

There, we have stated two benefits of using a cyclic prefix between subsequent OFDM symbols:

- The CP isolates different OFDM blocks from each other when the wireless channel contains multiple paths, i.e. is frequency-selective.
- The CP turns the linear convolution with the channel into a circular convolution. Only with a circular convolution, we can use the single-tap equalization OFDM is so famous for.

As we see, the CP of an OFDM symbol is obtained by prepending a copy of the last N_{CP} samples from the end of the OFDM signal to its beginning. This way we obtain a circular signal structure, i.e. the first N_{CP} and last N_{CP} samples are equal in each OFDM symbol.



In the above figure, we see two subsequent OFDM symbols, each having a dedicated CP. The colors encode the signal value. The cyclic prefix at the beginning of each OFDM symbol shows a copy of the color of end of the OFDM symbol. When the signal is demodulated, the N-point FFT is taken at the position after the CP, which is indicated with *FFT window*.

Source: *https://dspillustrations.com/pages/posts/misc/the-cyclic-prefix-cp-in-ofdm.html*

The HT-SIG is composed of two parts, HT-SIG$_1$ and HT-SIG$_2$, each containing 24 bits, as shown in Figure 20-6. All the fields in the HT-SIG are transmitted LSB first, and HT-SIG$_1$ is transmitted before HT-SIG$_2$.

The HT-SIG parts shall be encoded at R = 1/2, interleaved, and mapped to a BPSK constellation, and they have pilots inserted following the steps described in 18.3.5.6, 18.3.5.7, 18.3.5.8, and 18.3.5.9, respectively. The BPSK constellation is rotated by 90° relative to the L-SIG in order to accommodate detection of the start of the HT-SIG. The stream of 96 complex numbers generated by these steps is divided into two groups of 48 complex numbers: $d_{k,n}$, $0 \le k \le 47$, $n = 0, 1$. The time domain waveform for the HT-SIG in an HT-mixed format packet in a 20 MHz transmission shall be as shown in Equation (20-16).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} (jD_{k,n} + p_{n+1}P_k)\exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) \quad (20\text{-}16)$$

where

$$D_{k,n} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M^r(k), n}, \text{ otherwise} \end{cases}$$

$M^r(k)$ is defined in 20.3.9.3

P_k and p_n are defined in 18.3.5.10

N^{Tone}_{HT-SIG} has the value given in Table 20-8

$T^{i_{TX}}_{CS}$ represents the cyclic shift for transmit chain i_{TX} and is defined by Table 20-9 for HT-mixed format PPDUs.

Source: IEEE Std. 802.11-2012, pp. 1700-1701.

T_{GI2}: Double guard interval	1.6 µs	1.6 µs	1.6 µs

Source: IEEE Std. 802.11-2012, p. 1689.

56. In the method practiced by the '439 Accused Products, a number of samples from the symbol data portion of the first OFDM packet are shifted into the guard interval portion of the shifted version of the first OFDM packet, and the same number of samples from the guard interval portion of the first OFDM packet are shifted out of the guard interval portion of the shifted version of the first OFDM packet. For example, the Accused Products cyclically advance the number of samples corresponding to the time duration of $|T_{CS}|$ out of the symbol portion of the shifted OFDM packet and into the guard interval portion of the packet, while the same number of samples corresponding to the time duration of $|T_{CS}|$ are shifted out of the guard interval portion of the shifted OFDM packet, as illustrated below:

20.3.3 Transmitter block diagram

HT-mixed format and HT-greenfield format transmissions can be generated using a transmitter consisting of the following blocks:

a) *Scrambler* scrambles the data to reduce the probability of long sequences of 0s or 1s; see 20.3.11.3.

b) *Encoder parser*, if BCC encoding is to be used, demultiplexes the scrambled bits among N_{ES} (number of BCC encoders for the Data field) BCC encoders, in a round robin manner.

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Source: IEEE Std. 802.11-2012, p. 1683-84.

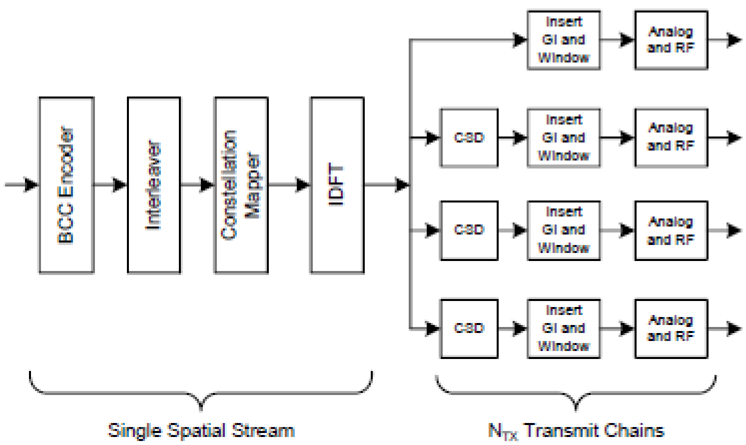

Figure 20-2—Transmitter block diagram 1

Source: IEEE Std. 802.11-2012, p. 1685.

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The cyclic shift values defined in this subclause apply to the non-HT fields in the HT-mixed format preamble and the HT-SIG in the HT-mixed format preamble.

Cyclic shifts are used to prevent unintentional beamforming when the same signal or scalar multiples of one signal are transmitted through different spatial streams or transmit chains. A cyclic shift of duration T_{CS} on a signal $s(t)$ on interval $0 \le t \le T$ is defined as follows, where T is defined as T_{DFT} as referenced in Table 20-6.

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$$s_{CS}(t;T_{CS})\Big|_{T_{CS}<0} = \begin{cases} s(t-T_{CS}) & 0 \le t < T + T_{CS} \\ s(t-T_{CS}-T) & T + T_{CS} \le t \le T \end{cases} \qquad (20\text{-}7)$$

The cyclic shift is applied to each OFDM symbol in the packet separately. Table 20-9 specifies the values for the cyclic shifts that are applied in the L-STF (in an HT-mixed format packet), the L-LTF, and L-SIG. It also applies to the HT-SIG in an HT-mixed format packet.

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4	0	–50	–100	–150

Source: IEEE Std. 802.11-2012, p. 1695.

Table 20-5—Timing-related constants *(continued)*

T_{DFT}: IDFT/DFT period	3.2 μs
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r) For each group of N_{ST} subcarriers and each of the N_{TX} transmit chains, convert the subcarriers to time domain using IDFT. Prepend to the Fourier-transformed waveform a circular extension of itself, thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Determine the length of the GI according to the GI_TYPE parameter of the TXVECTOR. Refer to 20.3.11.11 and 20.3.11.12 for details. When beamforming is not used, it is sometimes possible to implement the cyclic shifts in the time domain.

Source: IEEE Std. 802.11-2012, p. 1684, 1688.

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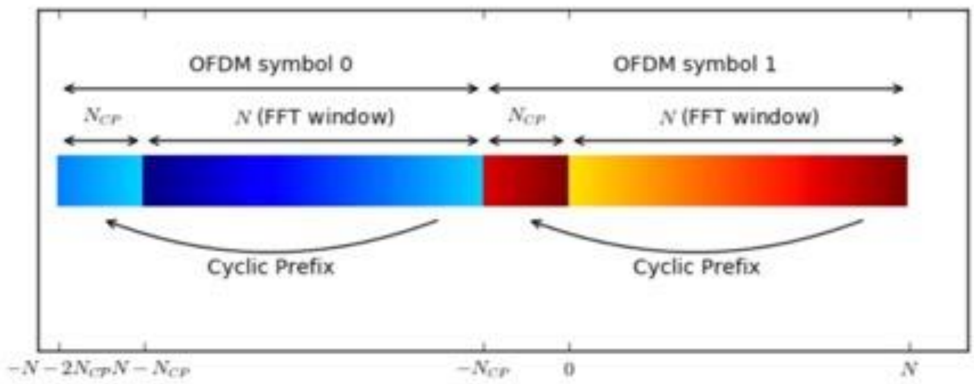
As we see, the CP of an OFDM symbol is obtained by prepending a copy of the last N_{CP} samples from the end of the OFDM signal to its beginning. This way we obtain a circular signal structure, i.e. the first N_{CP} and last N_{CP} samples are equal in each OFDM symbol.



In the above figure, we see two subsequent OFDM symbols, each having a dedicated CP. The colors encode the signal value. The cyclic prefix at the beginning of each OFDM symbol shows a copy of the color of end of the OFDM symbol. When the signal is demodulated, the N-point FFT is taken at the position after the CP, which is indicated with *FFT window*.

Source: *https://dspillustrations.com/pages/posts/misc/the-cyclic-prefix-cp-in-ofdm.html*

The HT-SIG is composed of two parts, $HT\text{-}SIG_1$ and $HT\text{-}SIG_2$, each containing 24 bits, as shown in Figure 20-6. All the fields in the HT-SIG are transmitted LSB first, and $HT\text{-}SIG_1$ is transmitted before $HT\text{-}SIG_2$.

The HT-SIG parts shall be encoded at R = 1/2, interleaved, and mapped to a BPSK constellation, and they have pilots inserted following the steps described in 18.3.5.6, 18.3.5.7, 18.3.5.8, and 18.3.5.9, respectively. The BPSK constellation is rotated by 90° relative to the L-SIG in order to accommodate detection of the start of the HT-SIG. The stream of 96 complex numbers generated by these steps is divided into two groups of 48 complex numbers: $d_{k,n}$, $0 \le k \le 47$, $n = 0, 1$. The time domain waveform for the HT-SIG in an HT-mixed format packet in a 20 MHz transmission shall be as shown in Equation (20-16).

$$r_{HT-SIG}^{i_{TX}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{HT-SIG}^{Tone}}} \sum_{n=0}^{1} w_{T_{SYM}}(t - nT_{SYM}) \cdot \sum_{k=-26}^{26} (jD_{k,n} + p_{n+1}P_k) \exp(j2\pi k\Delta_F(t - nT_{SYM} - T_{GI} - T_{CS}^{i_{TX}})) \qquad (20\text{-}16)$$

where

$$D_{k,n} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M^r(k),n}, \text{ otherwise} \end{cases}$$

$M^r(k)$ is defined in 20.3.9.3

P_k and p_n are defined in 18.3.5.10

N_{HT-SIG}^{Tone} has the value given in Table 20-8

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} and is defined by Table 20-9 for HT-mixed format PPDUs.

Source: IEEE Std. 802.11-2012, pp. 1700-1701.

T_{GI2}: Double guard interval	1.6 μs	1.6 μs	1.6 μs

Source: IEEE Std. 802.11-2012, p. 1689.

2.7.4 Mixed Mode Preamble

The mixed mode preamble is needed for compatibility with IEEE 802.11a/g. It starts with the 802.11a/g preamble. The 802.11n mixed mode preamble for two spatial streams is shown in Figure 2.34. The legacy short training field (L-STF) is identical to 802.11a/g except that different transmitters use different cyclic delays (CDs). This also applies to the legacy long training field (L-LTF). The STFs from different transmitters have low cross-correlation. For example, a CD of −400 ns (or a cyclic advance of 400 ns) minimizes correlation between two different transmitted short symbols. The L-STF uses a CD of only −200 ns for two transmitters, since legacy 802.11a/g receivers may not be able to cope with larger CD values.

Source: B. Bing, Broadband Wireless Multimedia Networks, Wiley, 2013, p. 120.

With $T_{CS} \leq 0$, replace $s(t)$ with $s(t - T_{CS})$ when $0 \leq t < T + T_{CS}$ and with $s(t - T_{CS} - T)$ when $T + T_{CS} \leq t \leq T$. The cyclic-shifted signal is defined as shown in Equation (20-7).

$$s_{CS}(t;T_{CS})\big|_{T_{CS}<0} = \begin{cases} s(t-T_{CS}) & 0 \leq t < T + T_{CS} \\ s(t - T_{CS} - T) & T + T_{CS} \leq t \leq T \end{cases} \quad (20\text{-}7)$$

Source: IEEE Std. 802.11-2012, pp. 1700-1701.

57. The method practiced by the '439 Accused Products includes substantially simultaneously transmitting the first OFDM packet and the shifted version of the OFDM packet. For example, the signals transmitted from different transmit chains are aligned and synchronized in the time domain, as seen below:

Figure 20-2 and Figure 20-3 show example transmitter block diagrams. In particular, Figure 20-2 shows the transmitter blocks used to generate the HT-SIG of the HT-mixed format PPDU.

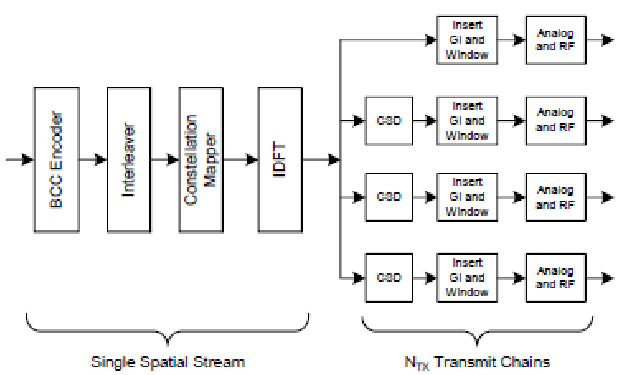


Figure 20-2—Transmitter block diagram 1

Source: IEEE Std. 802.11-2012, pp. 1684-85.

Radio Chains

Between the operating system and antenna, an 802.11 radio interface has to perform several tasks. When transmitting a frame, the main tasks are the inverse Fourier transform to turn the frequency-domain encoded signal into a time-domain signal, and amplification right before the signal hits the antenna so it has reasonable range. On the receive side, the process must be reversed. Immediately after entering the antenna, an amplifier boosts the faint signal received into something substantial enough to work with, and performs a Fourier transform to extract the subcarriers. In an 802.11 interface, these components are linked together and called a *radio chain*. Selecting the components to make up the radio chain is an important task for system designers, especially

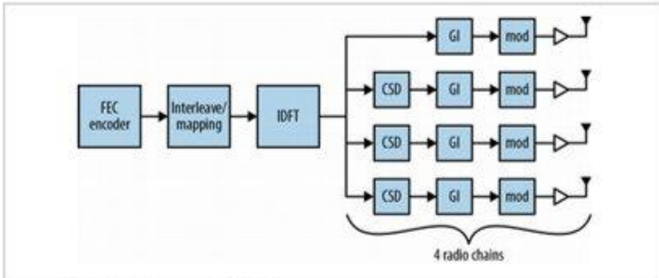


Figure 2-3. 4x4 802.11n interface block diagram

Source: Gast, Matthew, S., 802.11n A Survival Guide, O'Reilly, 2012, pp. 13-14.

58. Additionally, Defendant has been and currently is an active inducer of infringement of the '439 patent under 35 U.S.C. § 271(b) and a contributory infringer of the '439 patent under 35 U.S.C. § 271(c).

59. Defendant has actively induced, and continues to actively induce, infringement of the '439 patent by causing others to use, offer for sale, or sell in the United States, products or services covered by the '439 patent, including but not limited to the '439 Accused Products and any other products or services that include WiFi chipsets compliant with 802.11n, 802.11ac and/or 802.11ax, having the cyclic shift advance functionality described above. Defendant provides these products and services to others, such as customers, resellers, partners, and end-users, who, in turn, use, provision for use, offer for sale, or sell those products and services, which directly infringe the '439 patent as described above. Defendant's inducement includes requiring WiFi chipsets within the Accused Products to be compliant with the IEEE 802.11n, 802.11ac and 802.11ax standard, in which the cyclic advance diversity scheme described above is mandatory, and advertising and promoting such compliance to its customers, partners, re-sellers and the like, including the promotion, directions and instructions found at one or more of the following links, the provision of which has been on-going since the filing of the Complaint in case 6:23-cv-291 and much of the content of which is specifically illustrated above:

- https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap660-hd/

- *https://www.tp-link.com/us/omada-wifi6/*
- https://www.tp-link.com/us/business-networking/omada-sdn-access-point/
- https://www.tp-link.com/us/business-networking/omada-sdn-access-point/?filterby=5730
- https://www.wi-fi.org/product-finder-results?sort_by=certified&sort_order=desc&certifications=189&keywords=TP-Link
- https://www.wi-fi.org/product-finder-results?sort_by=certified&sort_order=desc&keywords=TP-Link
- https://www.wi-fi.org/product-finder-results?sort_by=certified&sort_order=desc&certifications=235&keywords=TP-Link
- https://www.wi-fi.org/product-finder-results?sort_by=certified&sort_order=desc&certifications=276&keywords=TP-Link
- https://www.tp-link.com/us/deco-mesh-wifi/product-family/deco-xe5300/
- https://www.tp-link.com/us/home-networking/wifi-router/archer-axe75/
- https://www.tp-link.com/us/deco-mesh-wifi/product-family/deco-x55/
- https://www.tp-link.com/us/home-networking/wifi-router/archer-ax5400-pro/
- https://www.tp-link.com/us/home-networking/wifi-router/archer-gx90/
- https://www.tp-link.com/us/deco-mesh-wifi/product-family/deco-x3600/

60. Defendant has contributed to, and continues to contribute to, the infringement of the ’439 patent by others by knowingly providing one or more components, for example the 802.11 WiFi chipset with cyclic shift (advance) functionality included in the Accused Products, a portion thereof, and/or the software/hardware modules responsible for the accused functionality described herein, that, when installed, configured, and used result in systems that, as intended by Defendant described above, directly infringe one or more claims of the ’439 patent.

61. Defendant knew of the ’439 patent, or should have known of the ’439 patent, but was willfully blind to its existence. Upon information and belief, Defendant had actual knowledge of the ’439 patent since at least as early as the filing of the Complaint in case 6:23-cv-291. Alternatively, upon information and belief, Defendant has had knowledge of the ‘439 patent since Defendant received a copy of this Complaint or at least as early as the service upon Defendant of the Complaint in this action.

62. By the time of trial, Defendant will or should have known and intended (since receiving such notice) that its continued actions would infringe and would actively induce and contribute to the infringement of the '439 patent.

63. Defendant has committed, and continues to commit, contributory infringement by selling products and services that directly infringe the '439 patent when used by a third party, such as the Accused '439 Products, and that are a material part of the invention, knowing them to be especially made or adapted for use in infringement of the '439 patent and not staple articles or commodities of commerce suitable for substantial non-infringing use.

64. As a result of Defendant's acts of infringement, IV has suffered and will continue to suffer damages in an amount to be determined at trial.

COUNT II

(Defendant's Infringement of U.S. Patent No. RE44,706).

65. The '706 patent claims and teaches improved AP devices capable of transmitting and receiving identifiers corresponding to a service. In preferred embodiments, these identifiers may be included in 802.11ax Beacon frames. If a first AP receives an identifier transmitted by a second AP that identifies a service that is also offered by the first AP on the same radio channel (i.e., overlapping support for the service is detected), then the power of transmissions associated with that identified service can be reduced at the first AP. A benefit of using APs of the invention is more efficient use of wireless channels in a wireless network by reducing interference (i.e., the degree of overlap) between APs supporting the same service.

66. Prior art APs operating in device-dense environments did not advertise services that they support so that services could be differentiated by other APs, which in turn would allow those other APs to identify situations where an overlap in service (i.e., on the same radio channel) was being provided by the two APs. Without this capability, service overlap situations were not

identified, which meant that the APs supporting the overlapping services could not reduce their transmit power so as not to interfere with one another. More specifically, claims of the ’706 patent recite an apparatus, e.g., an AP, for providing radio frequency access in support of at least one service to a client device. The apparatus may comprise a receiver operable to receive communications from the client device and to receive an RF identifier transmitted by another device, which may be another AP. The apparatus may include processing logic operable to determine whether the service associated with the received RF identifier is the same as a service supported by that AP, and to reduce the power of transmissions associated with that service (i.e., by the received RF identifier). The apparatus may further include a transmitter operable to transmit communications to the client device, the transmitter being further operable to support multiple services, and to transmit an RF domain identifier associated with each supported service.

67. TP-Link has directly infringed, and continues to directly infringe, at least claim 14 of the ’706 patent by making, using, selling, offering for sale, or importing products and services covered by claims of that patent. TP-Link’s products and services that infringe the ’706 patent include all APs that support mandatory provisions of the 802.11ax specification, such as the EAP6609 HD access points, and any access points and/or wireless devices operating in substantially the same manner as described herein, which are made, used, sold, or offered for sale by or on behalf of TP-Link (collectively, “the ’706 Accused Products”).

68. Claim 14 of the ’706 patent is reproduced below:

14. A wireless access point comprising:

a transmitter configured to transmit a signal containing an identification of at least one service offered by the wireless access point; and

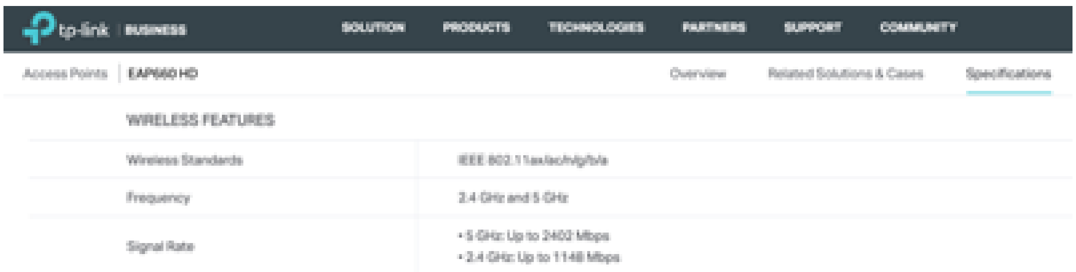
a receiver configured to receive from at least one other wireless access point at least one signal containing an identification of at least one service offered by the at least one other wireless access point;

wherein the wireless access point is configured:

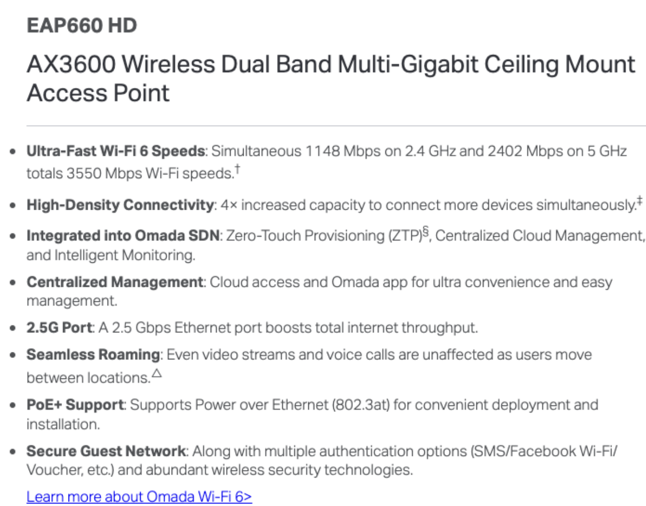
to determine whether a received identification of at least one service offered by the at least one other wireless access point identifies at least one service also offered by the wireless access point, and,

to reduce a power level to be used by the transmitter to transmit at least signals associated with the at least one service also offered by the wireless access point, in the case where it is determined that the received identification of at least one service offered by the at least one other wireless access point identifies at least one service also offered by the wireless access point.

69. The ’706 Accused Products include wireless access points, as illustrated below:



Source: *https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap660-hd/#specifications*



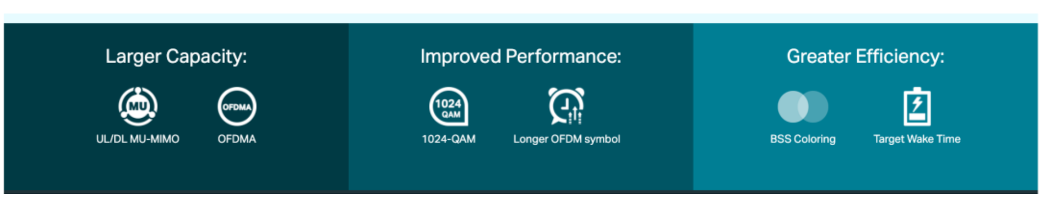
EAP660 HD

AX3600 Wireless Dual Band Multi-Gigabit Ceiling Mount Access Point

- **Ultra-Fast Wi-Fi 6 Speeds**: Simultaneous 1148 Mbps on 2.4 GHz and 2402 Mbps on 5 GHz totals 3550 Mbps Wi-Fi speeds.†
- **High-Density Connectivity**: 4× increased capacity to connect more devices simultaneously.‡
- **Integrated into Omada SDN**: Zero-Touch Provisioning (ZTP)§, Centralized Cloud Management, and Intelligent Monitoring.
- **Centralized Management**: Cloud access and Omada app for ultra convenience and easy management.
- **2.5G Port**: A 2.5 Gbps Ethernet port boosts total internet throughput.
- **Seamless Roaming**: Even video streams and voice calls are unaffected as users move between locations.△
- **PoE+ Support**: Supports Power over Ethernet (802.3at) for convenient deployment and installation.
- **Secure Guest Network**: Along with multiple authentication options (SMS/Facebook Wi-Fi/ Voucher, etc.) and abundant wireless security technologies.

Learn more about Omada Wi-Fi 6>

Source: *https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap660-hd/#specifications*



Source: *https://www.tp-link.com/us/omada-wifi6/*

70. The '706 Accused Products comprise a transmitter configured to transmit a signal containing an identification of at least one service offered by the wireless access point. For example, each '706 Accused Product (which is an AP) comprises radios that transmit Beacon frames containing an identification of a basic service set ("BSS") and a BSS Color, which collectively enable other APs to place that BSS inside or outside a subset of BSSs supported by the network, which in turn allows another AP to identify overlapping BSS ("OBSS") situations for that transmitted BSS. In an OBSS situation, the two APs are offering an overlapping BSS on the same channel, and as a result, it becomes desirable to take action to mitigate the interference and throughput effects of the OBSS situation.

access point (AP): An entity that contains one station (STA) and provides access to the distribution services, via the wireless medium (WM) for associated STAs. An AP comprises a STA and a distribution system access function (DSAF).

Source: 802.11ax – 2021 p. 5.

spatial reuse group (SRG): A group of basic service sets (BSSs) identified by their BSS colors or partial basic service set identifiers (BSSIDs) for overlapping basic service set packet detect (OBSS PD) based spatial reuse operation with SRG OBSS PD level.

Source: 802.11ax – 2021 p. 45.

basic service set (BSS) color: An identifier for a BSS or for a set of BSSs belonging to a multiple basic service set identifier (BSSID) set or a co-hosted BSSID set.

Source: 802.11ax – 2021 p. 41.

transmitted basic service set identifier (BSSID): The BSSID included in the MAC Header transmitter address field of a Beacon frame when the multiple BSSID capability is supported.

Source: 802.11-2012, p. 23.

An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.

Figure 4-2 adds the DS, DSM and AP components to the IEEE 802.11 architecture picture.

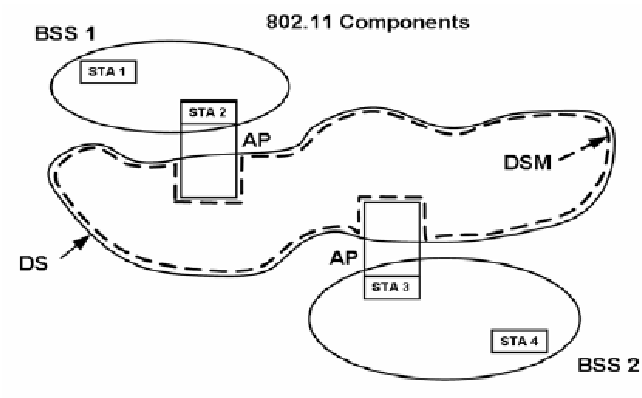


Figure 4-2—DSs and APs

Data move between a BSS and the DS via an AP. Note that all APs are also STAs; thus they are addressable entities. The addresses used by an AP for communication on the WM and on the DSM are not necessarily the same.

Source: 802.11-2012, p. 47.

	TP-Link EAP660 HD
CPU	quad-core 2GHz Qualcomm IPQ8072A
RAM	512MB ESMT (2x M15T4G16256A)
Storage	128MB ESMT F59D1G81MB-AZM1P0H9N
5GHz Radio	Qualcomm Atheros IPQ8072A (QCN5054) 802.11a/n/ac/ax 4×4:4
2.4GHz Radio	Qualcomm Atheros IPQ8072A (QCN5024) 802.11b/g/n/ax 4×4:4

Source: *https://www.mbreviews.com/tp-link-eap660-hd-access-point-review/*

Source: *https://www.tp-link.com/us/omada-wifi6/#AP*

BSS Coloring

The SR operation uses BSS color identifier to enable 802.11ax devices to distinguish between different BSSs when other devices transmit on same channel. The BSS color is a numerical identifier of the BSS having a value in the range [1, 63]. BSS color information is present in a 6-bit BSS color field in the HE SIG-A which is present in the preamble of 802.11ax physical layer (PHY) header. If the color of the frame matches with the color of the BSS, it is an intra-BSS transmission as the transmitting device belongs to the same BSS as the receiver. If the detected frame has a different BSS color from its own, the frame is an inter-BSS frame. An 802.11ax AP can change its BSS color if it detects an OBSS using the same color. This flowchart shows the BSS coloring procedure.

Source: *https://www.mathworks.com/help/wlan/ug/spatial-reuse-with-bss-coloring-in-802.11ax-residential-scenario.html*

3.2. Spatial Reuse Groups

To further enhance network efficiency, the 11ax amendment provides a mechanism for differentiating between two types of inter-BSS frames; that is to say, belonging or not to the same SRG. These groups can be formed by BSSs to achieve a more sophisticated SR operation. For instance, more aggressive channel access policies can be used for transmissions

3.1. BSS coloring

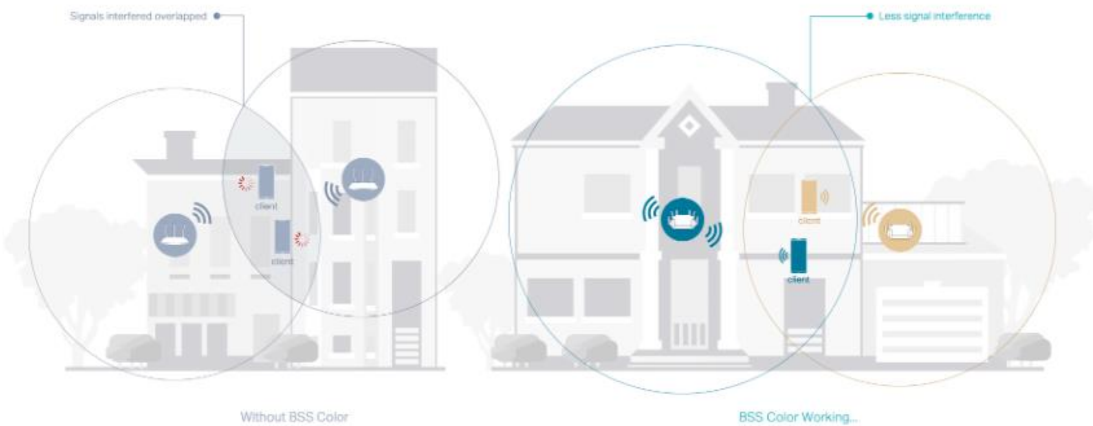
BSS coloring is a key enabler of the 11ax SR operation, whereby HE nodes can rapidly identify the source of a given detected transmission. When implementing BSS coloring, a given device can effectively determine whether the channel is occupied by another device belonging to the same BSS (intra-BSS transmission, same color) or from a different one (inter-BSS transmission, different color). The BSS color is determined by the AP (an integer between 1 and 63) and is included in the preambles of Wi-Fi frames.[4] It remains static until

Source: Spatial Reuse in IEEE 802.11ax WLANs, https://www.sciencedirect.com/science/article/abs/pii/S0140366421000499

What is BSS Coloring?

BSS Coloring is a mechanism to mark each BSS (Basic Service Set), consisting of an AP (Access Point) and its associated clients), with a "color" for differentiation.

BSS Color, as an identifier, can mark each frame and tell routers/APs/clients which data packets are coming from neighboring networks and ignore them. Only the right data is received. Co-channel interference is minimized between BSSs so they can transmit in sync. Clients in the same BSS share the same color, so they need to communicate in turn with the AP. BSS Coloring makes it possible for different BSSs to share the same channel, greatly boosting channel capacity.



BSS Coloring allows APs/clients to ignore packets from other BSSs. Yet if two BSSs are too close, the overlapping signals can still cause interference. Just like having group discussions in a classroom, voices from close neighboring groups can make it difficult to hear people in your own group clearly.

Source: *https://community.tp-link.com/en/home/forum/topic/167172*

26.2.3 SRG PPDU identification

Identification of SRG and non-SRG PPDUs is used during SRG OBSS PD spatial reuse operation as described in 26.10.

A non-AP HE STA that has received a Spatial Reuse Parameter Set element from its associated AP with a value of 1 in the SRG Information Present subfield shall use information provided in the Spatial Reuse Parameter Set element to identify BSSs that are members of the STA's SRG to determine if a received inter-BSS PPDU is an SRG PPDU. An HE AP may use an SRG that is different from the SRG that it transmits to other STAs in Spatial Reuse Parameter Set elements to determine whether a received inter-BSS PPDU is an SRG PPDU.

A received HE PPDU that is an inter-BSS PPDU is an SRG PPDU if the bit in the SRG BSS Color Bitmap field indexed by the value of the RXVECTOR parameter BSS_COLOR is 1 (see 9.4.2.252). A received VHT PPDU that is an inter-BSS PPDU is an SRG PPDU if the GROUP_ID parameter of the RXVECTOR has a value of 0 and the bit in the SRG Partial BSSID Bitmap field that corresponds to the numerical value of PARTIAL_AID[0:5] of the RXVECTOR is 1 (see 9.4.2.252).

A received PPDU that is an inter-BSS PPDU is an SRG PPDU if BSSID information from a frame carried in the PPDU is correctly received and the bit in the SRG Partial BSSID Bitmap field that corresponds to the numerical value of BSSID[39:44] is 1.

A VHT PPDU that is an inter-BSS PPDU and that is received with RXVECTOR parameter GROUP_ID equal to 0 is an SRG PPDU if the bit in the SRG Partial BSSID Bitmap field that corresponds to the numerical value of bits [39:44] of the RA field of any correctly received frame from the PPDU is 1.

A VHT PPDU that is an inter-BSS PPDU and that is received with RXVECTOR parameter GROUP_ID equal to 63 is an SRG PPDU if the bit in the SRG Partial BSSID Bitmap field that corresponds to the numerical value of bits [39:44] of the TA field of any correctly received frame from the PPDU is 1.

An HE SU PPDU, HE ER SU PPDU, or HE MU PPDU that is an inter-BSS PPDU and that is received with the RXVECTOR parameter UPLINK_FLAG equal to 1 is an SRG PPDU if the bit in the SRG Partial BSSID Bitmap field that corresponds to the numerical value of bits [39:44] of the RA field of any correctly received frame from the PPDU is 1.

Source: 802.11ax-2021, p. 313.

high-efficiency (HE) basic service set (BSS): A BSS in which the transmitted Beacon frame includes an HE Operation element.

high-efficiency (HE) beacon: A Beacon frame transmitted in a HE single-user (SU) physical layer (PHY) protocol data unit (PPDU).

Source: 802.11ax – 2021, p. 42.

Table 9-32—Beacon frame body *(continued)*

Order	Information	Notes
58	Transmit Power Envelope element	One Transmit Power Envelope element is present for each distinct combination of values of the ~~Local~~ Maximum Transmit Power ~~Unit~~ Interpretation subfield and Maximum Transmit Power Category subfield that is supported for the BSS if both of the following conditions are met: — Either dot11VHTOptionImplemented or dot11ExtendedSpectrumManagementImplemented is true. — Either dot11SpectrumManagementRequired ~~is true~~ or dot11RadioMeasurementActivated is true. Otherwise, this element is not present. NOTE—In a 6 GHz HE AP, both dot11VHTOptionImplemented (see 26.17.1) and dot11SpectrumManagementRequired (see 26.17.2.1) are true.
...		
63	Reduced Neighbor Report	~~The~~ One or more Reduced Neighbor Report elements are ~~is~~ optionally present if dot11TVHTOptionImplemented, ~~or~~ dot11FILSActivated, or dot11ColocatedRNRImplemented is true; otherwise, they are not present.
...		
76	Multiple BSSID Configuration	The Multiple BSSID Configuration element is optionally present if dot11MultiBSSIDImplemented is true.
77	HE Capabilities	The HE Capabilities element is present if dot11HEOptionImplemented is true; otherwise, it is not present.
78	HE Operation	The HE Operation element is present if dot11HEOptionImplemented is true; otherwise, it is not present.

Source: 802.11ax – 2021 p. 120-121.

9.4.2.249 HE Operation element

The operation of HE STAs in an HE BSS is controlled by the following:

— The HT Operation element and the HE Operation element if operating in the 2.4 GHz band.

— The HT Operation element, VHT Operation element (if present) and the HE Operation element if operating in the 5 GHz band.

— The HE Operation element if operating in the 6 GHz band.

The format of the HE Operation element is defined in Figure 9-788h.

	Element ID	Length	Element ID Extension	HE Operation Parameters	BSS Color Information	Basic HE-MCS And NSS Set	VHT Operation Information	Max Co-Hosted BSSID Indicator	6 GHz Operation Information
Octets:	1	1	1	3	1	2	0 or 3	0 or 1	0 or 5

Figure 9-788h—HE Operation element format

Source: 802.11ax – 2021 p. 197.

26.17.3 BSS color

26.17.3.1 General

BSS color identifies a BSS and assists a STA receiving a PPDU that carries BSS color in identifying the BSS from which the PPDU originates so that the STA can use the channel access rules in 26.10, reduce power consumption as described in 26.14.1, or update its NAV as described in 26.2.4.

All APs that are members of a multiple BSSID set or co-hosted BSSID set shall use the same BSS color.

26.17.3.2 Initial BSS color

An HE AP starting an infrastructure BSS or an HE STA starting an IBSS or MBSS shall set the BSS Color subfield of the first HE Operation element it transmits to a value in the range 1 to 63 and shall maintain that value in subsequent HE Operation elements it transmits for the lifetime of the BSS or until the BSS color is changed as described in 26.17.3.4 (Selecting and advertising a new BSS color). When selecting a BSS color,

Source: 802.11ax – 2021 p. 41.

	B0 B5	B6	B7
	BSS Color	Partial BSS Color	BSS Color Disabled
Bits:	6	1	1

Figure 9-788j—BSS Color Information field format

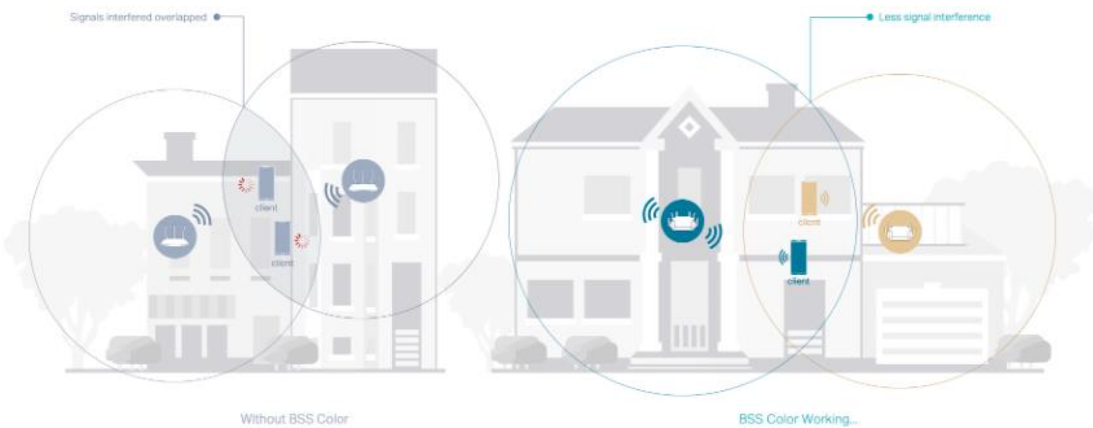
Source: 802.11ax – 2021, p. 198.

71. The ’706 Accused Products include a receiver configured to receive from at least one other wireless AP at least one signal containing an identification of at least one service offered by the other wireless AP. For example, ’706 Accused Products implementing 802.11ax include radios configured to receive Beacon frames from neighboring APs. Beacon frames comprise an identification of services offered by the APs, including the BSS and BSS color.

What is BSS Coloring?

BSS Coloring is a mechanism to mark each BSS (Basic Service Set), consisting of an AP (Access Point) and its associated clients), with a “color” for differentiation.

BSS Color, as an identifier, can mark each frame and tell routers/APs/clients which data packets are coming from neighboring networks and ignore them. Only the right data is received. Co-channel interference is minimized between BSSs so they can transmit in sync. Clients in the same BSS share the same color, so they need to communicate in turn with the AP. BSS Coloring makes it possible for different BSSs to share the same channel, greatly boosting channel capacity.



BSS Coloring allows APs/clients to ignore packets from other BSSs. Yet if two BSSs are too close, the overlapping signals can still cause interference. Just like having group discussions in a classroom, voices from close neighboring groups can make it difficult to hear people in your own group clearly.
Then what is the maximum value of BSS signal strength that decides communication in one BSS is not affected by another BSS?

Source: *https://community.tp-link.com/en/home/forum/topic/167172*

Intra-BSS frame VS Inter-BSS frame:

BSS colouring is not a new concept infect it has been used in 802.11ah already. 802.11ax specification bringing mix of good technologies together.

BSS colouring enables devices to identify their own BSS against OBSS (Overlap BSS) with the help of frame MAC header. BSS colour is not a colour such as blue or white colour but it's a 6 bits field which can have value range from 1 to 63.

Source: *https://www.wifi-professionals.com/2019/07/bss-colouring-or-spatial-reuse-802-11ax-aka-wifi6*

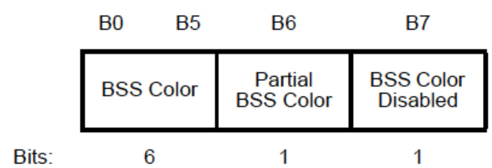


Figure 9-788j—BSS Color Information field format

Source: 802.11ax – 2021, p. 198.

Table 9-32—Beacon frame body *(continued)*

Order	Information	Notes
78	HE Operation	The HE Operation element is present if dot11HEOptionImplemented is true; otherwise, it is not present.

Source: 802.11ax – 2021, p. 120-121.

	Element ID	Length	Element ID Extension	HE Operation Parameters	BSS Color Information	Basic HE-MCS And NSS Set	VHT Operation Information	Max Co-Hosted BSSID Indicator	6 GHz Operation Information
Octets:	1	1	1	3	1	2	0 or 3	0 or 1	0 or 5

Figure 9-788h—HE Operation element format

Source: 802.11ax-2021, p. 197.

26.17.3 BSS color

26.17.3.1 General

BSS color identifies a BSS and assists a STA receiving a PPDU that carries BSS color in identifying the BSS from which the PPDU originates so that the STA can use the channel access rules in 26.10, reduce power consumption as described in 26.14.1, or update its NAV as described in 26.2.4.

Source: 802.11ax – 2021 p. 458.

During the time leading up to the BSS color change TBTT,

— An HE AP shall set the BSS Color Disabled subfield to 1 and shall continue to advertise the existing BSS color via the BSS Color subfield in the HE Operation element.
— An HE AP shall not change the value it advertises in the New BSS Color subfield of the BSS Color Change Announcement element.
— An HE AP shall set the TXVECTOR parameter BSS_COLOR of an HE PPDU to the existing BSS color.

Source: 802.11ax-2021, p. 459.

72. The ’706 Accused Products comprise a feature in which the wireless AP is configured to determine whether a received identification of a service offered by another wireless AP identifies a service also offered by the first wireless AP. For example, the Beacon frame may contain an identification of services offered by the other wireless AP, using BSS coloring, that may also be offered by the first wireless AP.

BSS Coloring

The SR operation uses BSS color identifier to enable 802.11ax devices to distinguish between different BSSs when other devices transmit on same channel. The BSS color is a numerical identifier of the BSS having a value in the range [1, 63]. BSS color information is present in a 6-bit BSS color field in the HE SIG-A which is present in the preamble of 802.11ax physical layer (PHY) header. If the color of the frame matches with the color of the BSS, it is an intra-BSS transmission as the transmitting device belongs to the same BSS as the receiver. If the detected frame has a different BSS color from its own, the frame is an inter-BSS frame. An 802.11ax AP can change its BSS color if it detects an OBSS using the same color. This flowchart shows the BSS coloring procedure.

Source: *https://www.mathworks.com/help/wlan/ug/spatial-reuse-with-bss-coloring-in-802.11ax-residential-scenario.html*

3.1. BSS coloring

BSS coloring is a key enabler of the 11ax SR operation, whereby HE nodes can rapidly identify the source of a given detected transmission. When implementing BSS coloring, a given device can effectively determine whether the channel is occupied by another device belonging to the same BSS (intra-BSS transmission, same color) or from a different one (inter-BSS transmission, different color). The BSS color is determined by the AP (an integer between 1 and 63) and is included in the preambles of Wi-Fi frames.[4] It remains static until

Source: Spatial Reuse in IEEE 802.11ax WLANs, https://www.sciencedirect.com/science/article/abs/pii/S0140366421000499

26.2.2 Intra-BSS and inter-BSS PPDU classification

A STA shall classify a received PPDU as an inter-BSS PPDU if at least one of the following conditions is true:

— The RXVECTOR parameter BSS_COLOR is not 0 and is not the BSS color of the BSS of which the STA is a member.

Source: 802.11ax – 2021, p. 312.

Intra-BSS frame VS Inter-BSS frame:

BSS colouring is not a new concept infect it has been used in 802.11ah already. 802.11ax specification bringing mix of good technologies together.

BSS colouring enables devices to identify their own BSS against OBSS (Overlap BSS) with the help of frame MAC header. BSS colour is not a colour such as blue or white colour but it's a 6 bits field which can have value range from 1 to 63.

Source: *https://www.wifi-professionals.com/2019/07/bss-colouring-or-spatial-reuse-802-11ax-aka-wifi6*

73. The '706 Accused Products are further configured to reduce a power level to be used by the transmitter to transmit signals associated with the service also offered by the other wireless AP, where it is determined that the received identification of the service offered by the

other wireless AP identifies a service also offered by the first wireless AP. For example, where two APs offer OBSSs, the transmitting AP will not be as reliant on the CSMA/CD protocol to share the wireless medium (i.e., by using a lower CCA power detect threshold, that if met causes an AP to delay its transmission until other APs operating on the same channel have completed their transmissions), and will instead reduce its transmit power level to better coexist (without excessive interference) with the other AP operating in an OBSS (i.e., as the power detect threshold is raised for the CSMA/CD protocol in place for these two APs supporting the OBSS).

3.1. BSS coloring

BSS coloring is a key enabler of the 11ax SR operation, whereby HE nodes can rapidly identify the source of a given detected transmission. When implementing BSS coloring, a given device can effectively determine whether the channel is occupied by another device belonging to the same BSS (intra-BSS transmission, same color) or from a different one (inter-BSS transmission, different color). The BSS color is determined by the AP (an integer between 1 and 63) and is included in the preambles of Wi-Fi frames.[4] It remains static until

In practice, once a frame is detected (the received power is above the receiver's sensitivity), a device locks onto it and starts decoding the fields of the different headers. If the preamble and PHY headers can be successfully decoded (the received signal of interest is above the CCA/CS), the frame is forwarded to the MAC layer for further processing (e.g., determining the transmission destination, or setting virtual carrier sensing). Otherwise, the packet is considered as interference. In particular, HE nodes applying SR use the default CCA/CS threshold (i.e., -82 dBm) upon detecting intra-BSS frames. On the contrary, when inter-BSS frames are detected, more aggressive PD thresholds can be applied to increase the number of parallel transmissions. Those PD thresholds are termed **non-SRG OBSS/PD** and **SRG OBSS/PD**. The SRG OBSS/PD is used when spatial reuse groups are allowed, which is discussed in detail in Section 3.2.

4.1. OBSS/PD-based Spatial Reuse

Upon PPDU reception, the MAC layer of a given device receives a notification from the PHY. At that moment, the node inspects the frame, and, among several operations, it determines whether the PPDU is an intra-BSS or an inter-BSS frame. The latter may be subdivided into SRG or non-SRG frames, provided that SRGs are enabled. By quickly identifying the source of an ongoing transmission, an HE STA can employ the appropriate OBSS/PD value to improve the probability of accessing the channel.

Source: Spatial Reuse in IEEE 802.11ax WLANs,
https://www.sciencedirect.com/science/article/abs/pii/S0140366421000499

Notice that the 11ax amendment does not provide any mechanism for setting the OBSS/PD threshold, thus remaining open (see, e.g., the proposal in [32]). Nevertheless, the standard defines a set of rules for limiting the OBSS/PD threshold,[9] which is upper bounded as follows (also illustrated in Figure 9):

$$\text{OBSS/PD} \leq \max\Big(\text{OBSS/PD}_{\text{min}},\ \min\left(\text{OBSS/PD}_{\text{max}}, \text{OBSS/PD}_{\text{min}} + (\text{TX\_PWR}_{\text{ref}} - \text{TX\_PWR})\right)\Big),$$

where $\text{OBSS/PD}_{\text{min}}$ and $\text{OBSS/PD}_{\text{max}}$ are set to −82 dBm and −62 dBm, respectively, the reference power $\text{TX\_PWR}_{\text{ref}}$ is set to 21 or 25 dBm, based on the capabilities of the device,[10] and TX_PWR refers to the transmission power at the antenna connector in dBm of the HE node identifying the SR-based TXOP. Besides the general rules for setting the OBSS/PD threshold, further constraints apply when considering SRGs (the details can be found in Appendix A.2.1).

Together with sensitivity adjustment, the SR operation includes a transmit power limitation for any transmission occurring as a result of a detected SR TXOP (i.e., after ignoring a

given inter-BSS frame through the OBSS/PD-based SR operation). The maximum allowed transmission power ($\text{TX\_PWR}_{\text{max}}$) is defined as:

$$\text{TX\_PWR}_{\text{max}} = \text{TX\_PWR}_{\text{ref}} - (\text{OBSS/PD} - \text{OBSS/PD}_{\text{min}}) \quad (1)$$

Source: Spatial Reuse in IEEE 802.11ax WLANs, https://www.sciencedirect.com/science/article/abs/pii/S0140366421000499

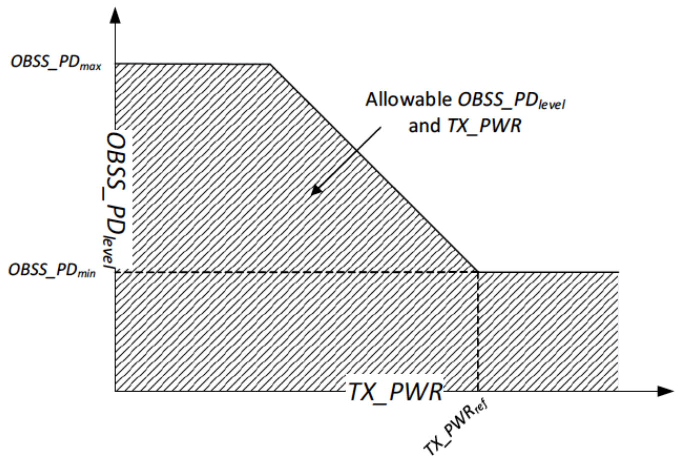
26.10.2.4 Adjustment of OBSS PD and transmit power

If using OBSS PD-based spatial reuse, an HE STA shall maintain an OBSS PD level and may adjust this OBSS PD level in conjunction with its transmit power and a value, *PPDU_BW*, derived from the received PPDU. The adjustment shall be made in accordance with Equation (26-5).

$$OBSS\_PD_{level} \leq max(OBSS\_PD_{min}, min(OBSS\_PD_{max}, OBSS\_PD_{min} + (TX\_PWR_{ref} - TX\_PWR))) + \log 10(PPDU\_BW / 20\text{ MHz}) \quad (26\text{-}5)$$

Source: 802.11ax – 2021, p. 417.

The adjustment rule is illustrated in Figure 26-11.



Source: 802.11ax – 2021 p. 418.

$$TX\_PWR_{max} = \begin{cases} \text{unconstrained, if } OBSS\_PD_{level} \le OBSS\_PD_{min} \\ TXPWR_{ref} - (OBSS\_PD_{level} - OBSS\_PD_{min}), \text{ if } OBSS\_PD_{max} \ge OBSS\_PD_{level} > OBSS\_PD_{min} \end{cases} \quad (26\text{-}6)$$

Source: 802.11ax – 2021, p. 420.

An AP transmitting a Spatial Reuse Parameter Set element shall respect the following constraints:

— –82 ≤ –82 + SRG OBSS PD Min Offset ≤ –62
— SRG OBSS PD Min Offset ≤ SRG OBSS PD Max Offset
— –82 + SRG OBSS PD Max Offset ≤ –62
— –82 + Non-SRG OBSS PD Max Offset ≤ –62

Source: 802.11ax-2021, p. 418.

74. Additionally, Defendant has been, and currently is, an active inducer of infringement of the ’706 patent under 35 U.S.C. § 271(b) and a contributory infringer of the ’706 patent under 35 U.S.C. § 271(c).

75. Defendant has actively induced, and continues to actively induce, infringement of the ’706 patent by causing others to use, offer for sale, or sell in the United States, products or services covered by the ’706 patent, including but not limited to the ’706 Accused Products and any other products or services that include 802.11ax compliant access points, or products and services with the same or substantially similar functionality to that described above. Defendant

provides these products and services to others, such as customers, resellers, partners, and end-users, who, in turn, use, provision for use, offer for sale, or sell those products and services, which directly infringe the ’706 patent as described above. Defendant’s inducement includes requiring the Accused Products to be compliant with the IEEE 802.11ax standard, in which the BSS Coloring/Spatial Reuse functionality described above is mandatory, and advertising and promoting such compliance to its customers, partners, re-sellers and the like, including the promotion, directions and instructions found at one or more of the following links, the provision of which has been on-going since the filing of the Complaint in case 6:23-cv-0068 and the content of which is specifically illustrated above:

- *https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap660-hd/#specifications*
- *https://www.tp-link.com/us/omada-wifi6/*
- *https://community.tp-link.com/en/home/forum/topic/167172*
- https://www.tp-link.com/us/business-networking/omada-sdn-access-point/
- https://www.tp-link.com/us/business-networking/omada-sdn-access-point/?filterby=5730
- https://www.wi-fi.org/product-finder-results?sort_by=certified&sort_order=desc&certifications=189&keywords=TP-Link
- https://www.wi-fi.org/product-finder-results?sort_by=certified&sort_order=desc&keywords=TP-Link
- https://www.tp-link.com/us/deco-mesh-wifi/product-family/deco-xe5300/
- https://www.tp-link.com/us/home-networking/wifi-router/archer-axe75/
- https://www.tp-link.com/us/deco-mesh-wifi/product-family/deco-x55/
- https://www.tp-link.com/us/home-networking/wifi-router/archer-ax5400-pro/
- https://www.tp-link.com/us/home-networking/wifi-router/archer-gx90/
- https://www.tp-link.com/us/deco-mesh-wifi/product-family/deco-x3600/

76. Defendant has contributed to, and continues to contribute to, the infringement of the ’706 patent by others by knowingly providing one or more components, for example the 802.11ax WiFi chipset with BSS Coloring/Spatial Reuse functionality included in the Accused Products, a portion thereof, and/or the software/hardware modules responsible for the accused functionality described herein, that, when installed, configured, and used result in systems that, as intended by Defendant described above, directly infringe one or more claims of the ’706 patent.

77. Defendant knew of the ’706 patent, or should have known of the ’706 patent, but was willfully blind to its existence. Upon information and belief, Defendant had actual knowledge of the ’706 patent at least as early as the filing of the Complaint in case 6:23-cv-291. Alternatively, Defendant has had knowledge of the ‘706 patent since Defendant received a copy of this Complaint or at least as early as the service upon Defendant of the Complaint in this action.

78. By the time of trial, Defendant will or should have known and intended (since receiving such notice) that its continued actions would infringe and would actively induce and contribute to the infringement of the ’706 patent.

79. Defendant has committed, and continues to commit, contributory infringement by selling products and services that directly infringe the ’706 patent when used by a third party, such as the Accused ’706 Products, and that are a material part of the invention, knowing them to be especially made or adapted for use in infringement of the ’706 patent and not staple articles or commodities of commerce suitable for substantial non-infringing use.

80. As a result of Defendant’s acts of infringement, IV has suffered and will continue to suffer damages in an amount to be determined at trial.

COUNT III
(Defendant’s Infringement of U.S. Patent No. 7,386,036)

81. The preceding paragraphs are reincorporated by reference as if fully set forth herein.

82. The ’036 patent claims and teaches, *inter alia*, an improved method, device and system for separately optimizing radio links between relays and users as well as radio links between relays and base stations, in which multiple simultaneous data streams between relays and base stations are created, thereby improving wireless network quality and range, among other benefits.

83. The inventions improved upon then-existing wireless radio technology (in what is referred to as wireless mesh networking deployments), by using radio links between relays and user equipment that can be optimized separately from the links between relays and base stations and multiple simultaneous data streams between relays and base stations are created. In certain embodiments a base station connected to a core network via a wireline or equivalently robust means, a relay station is connected to the base station via a first radio interface, and user equipment connected to the relay station via a second radio interface. The first and second radio interfaces being capable of operating, at least in part, using the same frequency bandwidth.

84. Unlike in prior art systems and methods the simultaneous and independently optimizable radio link scheme taught by the '036 patent uses independent transceivers and radio links in order to significantly increase the range and quality of wireless networks, particularly in diverse environments where existing mesh networks provided weak or non-existent coverage and quality. Doing so substantially improves the quality of each respective link, reduces the degradation of the network in disperse configurations and enables more efficient use of existing bandwidth.

85. More specifically, one exemplary embodiment comprises an improved wireless communication system having a base station and a relay station that communicate with user equipment, the system comprising a base station having a first radio transceiver and being connected to a core network as well as a first relay station having a second radio transceiver and being configured to simultaneously communicate with the base station and with a second relay station using a first radio interface. The first relay station also being configured to communicate with user equipment having a third radio transceiver using a second radio interface, wherein the operation of the first radio interface and the second radio interface are separate from each other.

86. The system and methods covered by the asserted claims, therefore, differs markedly from prior art systems in use at the time of this invention, which lacked the claimed combination of radio transceivers, base stations, relay stations, and radio interfaces capable of simultaneous and independent operation/optimization.

87. Defendant has directly infringed and continues to directly infringe at least claim 11 of the ’036 patent by making, using, selling, offering for sale, or importing products and/or services covered by the ’036 patent. Defendant’s products and/or services that infringe the ’036 patent include all wireless communication products that support multi-hop wireless networking, including the capability to relay wireless transmission to/from a core network to relay stations and user equipment using multiple interfaces, that are made, used, sold, or offered for sale by or on behalf of Defendant and/or its subsidiaries or parent companies (cumulatively, “the ’036 Accused Products”), including but not limited to, the TP-Link EAP 610 (AX1800) indoor/outdoor family of access points.

88. Claim 11 of the ’036 patent is reproduced below:

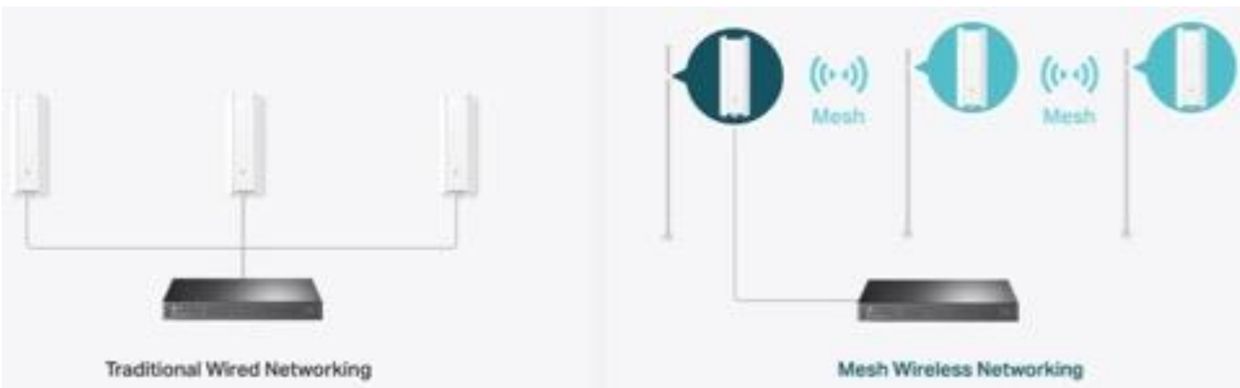
> *11. A wireless communication system having a base station and a relay station that communicate with user equipment, the system comprising:*
>
> *A base station having a first radio transceiver and being connected to a core network; and*
>
> *A first relay station having a second radio transceiver and being configured to simultaneously communicate with the base station and with a second relay station using a first radio interface and being configured to communicate with user equipment having a third radio transceiver using a second radio interface, wherein the operation of the first radio interface and the second radio interface are separate from each other.*

89. The ’036 Accused Products are a wireless communication system having a base station and a relay station that communicate with user equipment. For example, the ’036 Accused Products are wireless access points capable of multi-hop mesh configuration and simultaneous communication with user equipment, as illustrated below:

EAP610-Outdoor V1.20 New

AX1800 Indoor/Outdoor WiFi 6 Access Point

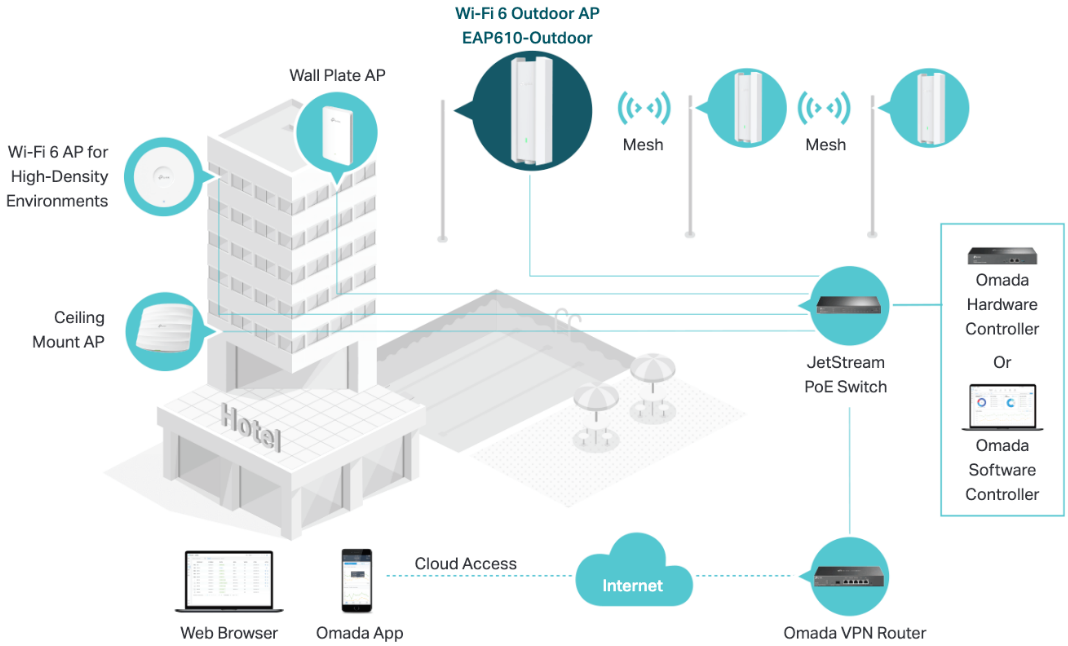
- **Superior WiFi 6 Speeds:** Delivers dual-band speeds of up to 1.8 Gbps powered by the latest WiFi 6 technology†
- **Higher Network Efficiency:** Enjoy faster speeds on more devices with less lag via OFDMA and MU-MIMO
- **Long-Range Coverage:** Dedicated high-power amplifier and professional antennas with IP67 weatherproof enclosure
- **Omada Mesh Technology:** Enables wireless connectivity between access points for extended range and flexible deployment**
- **Stay Smooth with Fast Roaming:** Users can enjoy seamless streaming across the property with their devices switching effortlessly between access points**
- **Centralized Cloud Management:** Integrates into Omada SDN for cloud access and remote management



Antenna	• 2.4 GHz: 2× 4 dBi • 5 GHz: 2× 5 dBi
Weatherproof Enclosure	IP67
Mounting	Pole/Wall Mounting (Kits included)

WIRELESS FEATURES

Wireless Standards	IEEE 802.11ax/ac/n/g/b/a
Frequency	2.4 GHz, 5 GHz



Source: https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap610-outdoor/

Wireless Functions	• MU-MIMO • Omada Mesh** • Seamless Roaming**

Source: https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap610-outdoor/#specifications

Network Topology

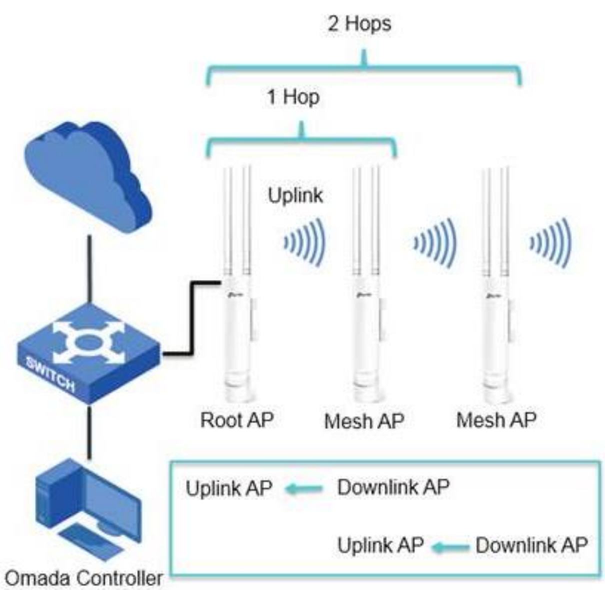
We are using EAP225, EAP245, and EAP225-Outdoor to build the Mesh network. The EAP225 connect with PoE Switch works as the Root AP. The EAP245 and EAP225-Outdoor connect with EAP225 (Root AP) wirelessly as the Mesh AP.

Source: https://www.tp-link.com/us/support/faq/2949/

90. The ’036 Accused Products include a base station having a first radio transceiver and being connected to a core network. For example, an EAP 610 access point can connect to an enterprise network, the internet, or other core network via a TP-Link switch, as seen below:

Basic Concepts	Explanation
Uplink	Data link between AP and its direct front-end EAP device.
Root AP	The wired AP in a Mesh network.
Mesh AP	AP with wireless uplink.
Uplink AP	The AP provide wireless uplink for Mesh AP will be called the Uplink AP for this Mesh AP.
Downlink AP	The Mesh AP connect to other AP wirelessly will be called as Downlink AP for the other AP.
Hop	The relative distance between Mesh AP and Root AP.

Here is a picture showing the relationships between these concepts:



Source: https://www.tp-link.com/us/support/faq/2949/

Interface	1× Gigabit Ethernet (RJ-45) Port (Support 802.3at PoE and Passive PoE)
Button	Reset
Power Supply	• 802.3at PoE • 48V/0.5A Passive PoE (PoE Adapter Included)
Power Consumption	• EU: 12.5W (802.3at PoE or Passive PoE) • US: 14.7W (802.3at PoE or Passive PoE)
Dimensions (W x D x H)	• 280.4×106.5×56.8 mm (without antenna & mounting kit)
Antenna	• 2.4 GHz: 2× 4 dBi • 5 GHz: 2× 5 dBi

Source: https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap610-outdoor/#specifications

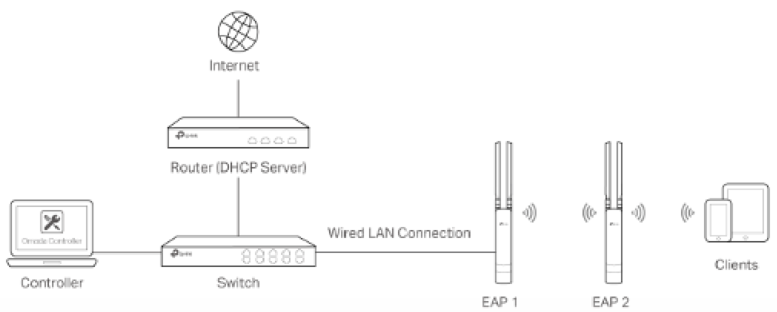
TP-Link EAP610-Outdoor Teardown.

Doing so will also reveal the metallic plate that comes in contact with the plastic case and with the PCB via thermal paste – I am very grateful that TP-Link didn't use that dreadful glue-paste-thing again (as it did on the TL-ER7206). As for the WiFi, the TP-Link EAP610-Outdoor uses the Qualcomm QCN5022 802.11b/g/n/ax chip along with 2x Skyworks SKY85340-11 front-end modules for the 2.4GHz radio band and the Qualcomm QCN5052 802.11a/b/g/n/ac/ax chip along with 2x Qorvo QPF4588 integrated front-end modules for the 5GHz radio band.

Source: *https://www.mbreviews.com/tp-link-eap610-outdoor-wifi-6-review/*

The topology below shows a basic mesh network with 2 EAPs managed by Omada Controller locally. The controller and EAPs are in the same subnets and get IP addresses from a router. EAP 1 is adopted by the switch with a wired connection, while EAP 2 supporting the Mesh function needs to expand a wired network through a wireless connection.

Figure 11 Basic Topology for the Mesh Network



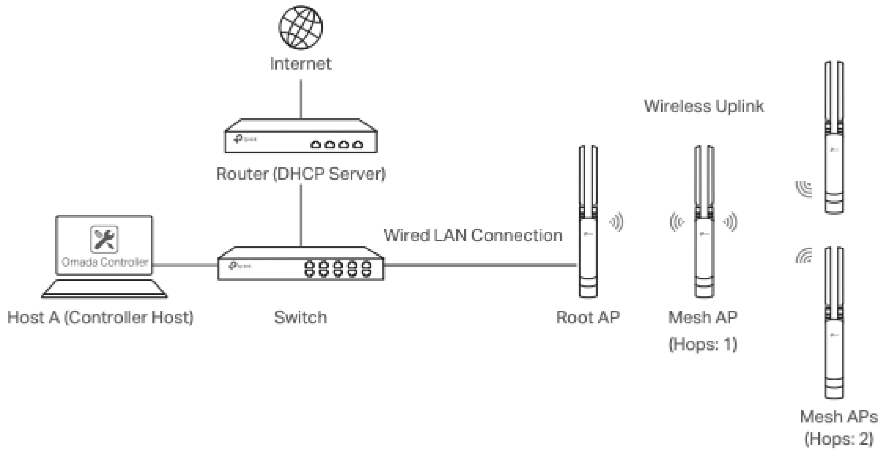
Source: *https://www.tp-link.com/us/support/faq/2580/*

91. The '036 Accused Products can be configured to include a first relay station having a second transceiver. For instance, an EAP 610 access point can be wirelessly connected to the root AP (base station), and has multiple radios on the 2.4 and 5 GHz frequencies, as seen below:

3.1.4 Configure Mesh

Mesh is used to establish a wireless network or expand a wired network through wireless connection on 5GHz radio band. In practical application, it can help users to conveniently deploy APs without requiring Ethernet cable. After mesh network establishes, the EAP devices can be configured and managed within Omada controller in the same way as wired EAPs. Meanwhile, because of the ability to self-organize and self-configure, mesh also can efficiently reduce the configuration overhead.

In a basic mesh network as shown below, there is a root AP that is connected by Ethernet cable, while other isolated APs have no wired data connection. Mesh allows the isolated APs to communicate with pre-configured root AP on the network. Once powered up, factory default or unadopted EAP devices can sense the EAP in range and make itself available for adoption within the Omada controller.



After all the EAPs are adopted, a mesh network is established. Then the EAPs connected to the network wirelessly also can broadcast SSIDs and relay network traffic to and from the network through the uplink AP.

- Wireless Uplink: The action that a Downlink AP connects to the uplink AP.
- Hops: In a deployment that uses a root AP and more than one level of wireless uplink with intermediate APs, the uplink tiers can be referred to by root, first hop, second hop and so on. The hops cannot be more than 3.

Source: https://static.tp-link.com/2018/201809/20180907/1910012447_Omada%20Controller%20Software%203.0.2_UG.pdf

Doing so will also reveal the metallic plate that comes in contact with the plastic case and with the PCB via thermal paste – I am very grateful that TP-Link didn't use that dreadful glue-paste-thing again (as it did on the TL-ER7206). As for the WiFi, the TP-Link EAP610-Outdoor uses the Qualcomm QCN5022 802.11b/g/n/ax chip along with 2x Skyworks SKY85340-11 front-end modules for the 2.4GHz radio band and the Qualcomm QCN5052 802.11a/b/g/n/ac/ax chip along with 2x Qorvo QPF4588 integrated front-end modules for the 5GHz radio band.

Source: https://www.mbreviews.com/tp-link-eap610-outdoor-wifi-6-review/.

TP-Link EAP610-Outdoor Teardown.

Source: https://www.mbreviews.com/tp-link-eap610-outdoor-wifi-6-review/ .

92. The ’036 Accused Products’ first relay station is configured to simultaneously communicate with the base station and with a second relay station using a first radio interface. For example, another EAP 610 access point can be added to the mesh network and wirelessly connect to the first relay station, which in turn is wirelessly connected to the base station, thereby allowing the first relay station to relay wireless communications from the second relay station to the base station as illustrated below:

Basic Concepts	Explanation
Uplink	Data link between AP and its direct front-end EAP device.
Root AP	The wired AP in a Mesh network.
Mesh AP	AP with wireless uplink.
Uplink AP	The AP provide wireless uplink for Mesh AP will be called the Uplink AP for this Mesh AP.
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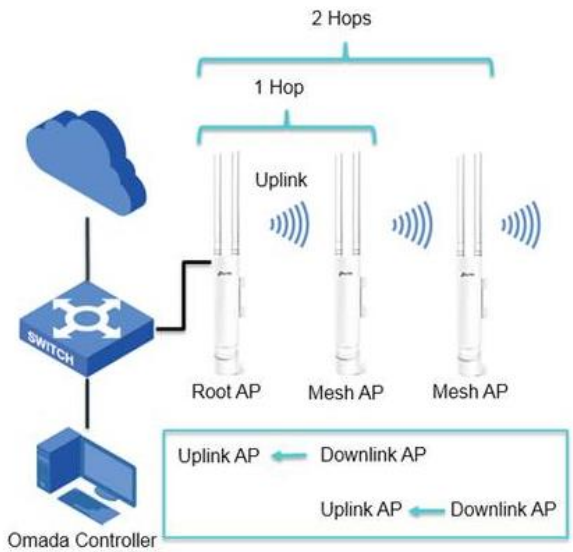
Hop	The relative distance between Mesh AP and Root AP.

Here is a picture showing the relationships between these concepts:



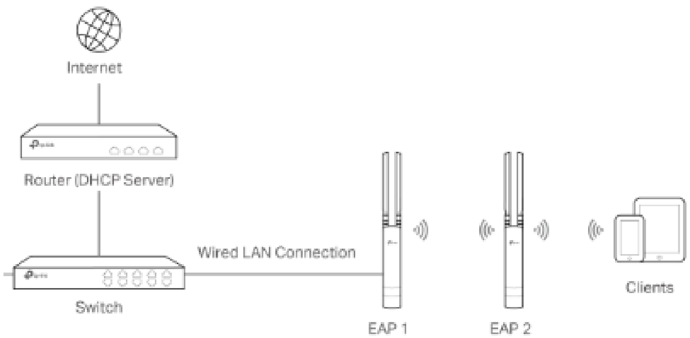
Mesh is used to establish a wireless network or expand a wired network through wireless connection on 5GHz radio band. In practical application, it can help users to conveniently deploy APs without requiring Ethernet cable. After mesh network establishes, the EAP devices can be configured and managed within Omada controller in the same way as wired EAPs. Meanwhile, because of the ability to self-organize and self-configure, mesh also can efficiently reduce the configuration overhead.

In a basic mesh network as shown below, there is a root AP that is connected by Ethernet cable, while other isolated APs have no wired data connection. Mesh allows the isolated APs to communicate with pre-configured root AP on the network. Once powered up, factory default or unadopted EAP devices can sense the EAP in range and make itself available for adoption within the Omada controller.

Source: https://static.tp-link.com/2018/201809/20180907/1910012447_Omada%20Controller%20Software%203.0.2_UG.pdf.

- Mesh AP: An isolated AP will be mesh AP after establishing a wireless connection to the AP with network access.
- Uplink AP/Downlink AP: Among mesh APs, the AP that offers the wireless connection for other APs is Uplink AP. A Root AP or an intermediate AP can be the Uplink AP. And the AP that connects to the Uplink AP is called Downlink AP. An uplink AP can offer direct wireless connection for 4 Downlink APs at most.

Source: https://static.tp-link.com/2018/201809/20180907/1910012447_Omada%20Controller%20Software%203.0.2_UG.pdf.



Source: https://www.tp-link.com/us/support/faq/2580/.

Wireless Functions	• MU-MIMO • Omada Mesh** • Seamless Roaming**

Source: https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap610-outdoor/#specifications

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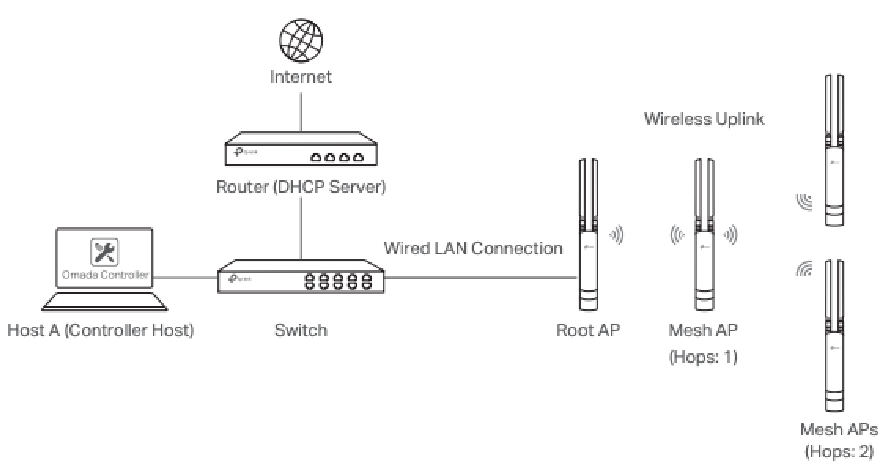
Source: https://www.mbreviews.com/tp-link-eap610-outdoor-wifi-6-review/



After all the EAPs are adopted, a mesh network is established. Then the EAPs connected to the network wirelessly also can broadcast SSIDs and relay network traffic to and from the network through the uplink AP.

Source: https://static.tp-link.com/2018/201809/20180907/1910012447_Omada%20Controller%20Software%203.0.2_UG.pdf

Features:

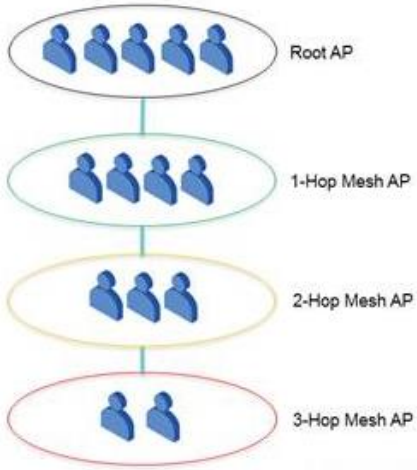
- **Ultra-Fast WiFi 6 Speeds**: Simultaneous 574 Mbps on 2.4 GHz and 1201 Mbps on 5 GHz totals 1775 Mbps Wi-Fi speeds.
- **High-Efficiency WiFi 6**: More connected devices can enjoy faster speeds.
- **Centralized Cloud Management**: Manage the whole network locally or from the cloud via web UI or Omada app.
- **Seamless Roaming**: Even video streams and voice calls are unaffected as users move between locations.
- **Omada Mesh**: Enables wireless connectivity between access points for extended range and flexible deployment.
- **PoE+ Powered**: Supports both Power over Ethernet (802.3at) and DC power supply for flexible installations.
- **Secure Guest Network**: Along with multiple authentication options (SMS/Facebook Wi-Fi/ Voucher, etc.) and abundant wireless security technologies.

Source: https://www.wifi-stock.com/details/tp-link-ax1800-wireless-dual-band-ceiling-mount-

93. The '036 Accused Products' first relay station is further configured to communicate with user equipment having a third radio transceiver using a second radio interface. For instance, the first EAP 610 access point, which is connected wirelessly to the EAP 610 access point operating as the root node, can simultaneously maintain a connection with another EAP 610 access point—operating as an uplink AP to the second EAP 610 and a downlink AP for the root node—and user equipment, sometimes referred to as clients, such as laptops, smart TVs, and other IoT devices like the TP Link Tapo line of wireless security cameras, as seen below:

Chain Topology

Source: https://static.tp-link.com/2018/201809/20180907/1910012447_Omada%20Controller%20Software%203.0.2_UG.pdf.



Most clients connect to root AP & 1-Hop Mesh AP(Recommended)

Source: https://www.tp-link.com/us/support/faq/2283.

cable). You can also connect to your network using the 2.4GHz Wi-Fi radio and position the antennas for the best signal.

Source: https://www.pcmag.com/reviews/tp-link-tapo-c320ws-outdoor-security-wi-fi-camera.

(2) Make sure that most of the wireless clients connect to Root AP or 1-Hop AP(s).

- Root AP and 1-Hop Mesh AP usually have better wireless performance than 2 or 3-Hop AP.
- So when choosing the site to deploy Root AP and 1-Hop AP, please choose the position that can cover most of the wireless clients.

(2) Make sure the Mesh AP locate in the coverage of Root AP or other Mesh AP.

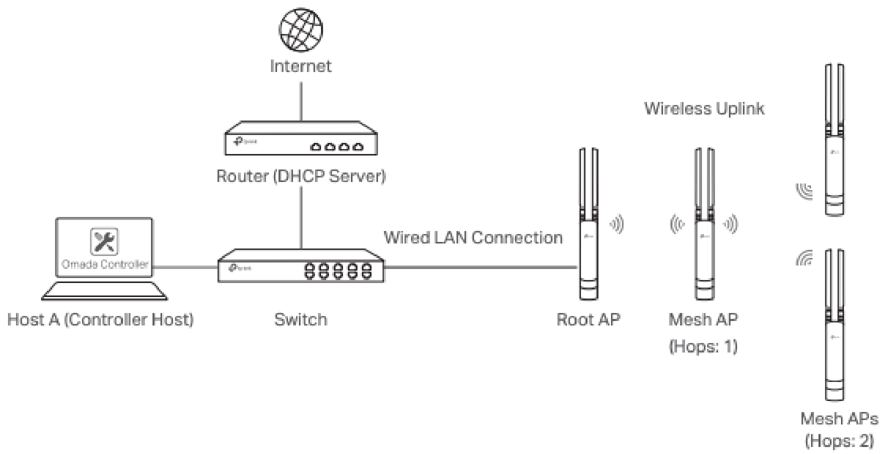
This can make sure that this Mesh AP can be found by the Mesh network and deliver wireless data flow normally. It is similar to the "router + range extender" system. The range extender need to be placed in the coverage of the main router to get the wireless data flow and relay it.

Source: https://www.tp-link.com/us/support/faq/2283/

Doing so will also reveal the metallic plate that comes in contact with the plastic case and with the PCB via thermal paste – I am very grateful that TP-Link didn't use that dreadful glue-paste-thing again (as it did on the TL-ER7206). As for the WiFi, the TP-Link EAP610-Outdoor uses the Qualcomm QCN5022 802.11b/g/n/ax chip along with 2x Skyworks SKY85340-11 front-end modules for the 2.4GHz radio band and the Qualcomm QCN5052 802.11a/b/g/n/ac/ax chip along with 2x Qorvo QPF4588 integrated front-end modules for the 5GHz radio band.

Source: https://www.mbreviews.com/tp-link-eap610-outdoor-wifi-6-review/

In a basic mesh network as shown below, there is a root AP that is connected by Ethernet cable, while other isolated APs have no wired data connection. Mesh allows the isolated APs to communicate with pre-configured root AP on the network. Once powered up, factory default or unadopted EAP devices can sense the EAP in range and make itself available for adoption within the Omada controller.



After all the EAPs are adopted, a mesh network is established. Then the EAPs connected to the network wirelessly also can broadcast SSIDs and relay network traffic to and from the network through the uplink AP.

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Source: https://www.wifi-stock.com/details/tp-link-ax1800-wireless-dual-band-ceiling-mount-

Wireless Functions	• MU-MIMO • Omada Mesh** • Seamless Roaming**

Source: https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap610-outdoor/#specifications

94. In the ’036 Accused Products the operation of the first radio interface and the second radio interface are separate from each other. For example, the EAP 610 access points include multiple radio interfaces and MU-MIMO functionality, as seen below:

Doing so will also reveal the metallic plate that comes in contact with the plastic case and with the PCB via thermal paste – I am very grateful that TP-Link didn’t use that dreadful glue-paste-thing again (as it did on the TL-ER7206). As for the WiFi, the TP-Link EAP610-Outdoor uses the Qualcomm QCN5022 802.11b/g/n/ax chip along with 2x Skyworks SKY85340-11 front-end modules for the 2.4GHz radio band and the Qualcomm QCN5052 802.11a/b/g/n/ac/ax chip along with 2x Qorvo QPF4588 integrated front-end modules for the 5GHz radio band.

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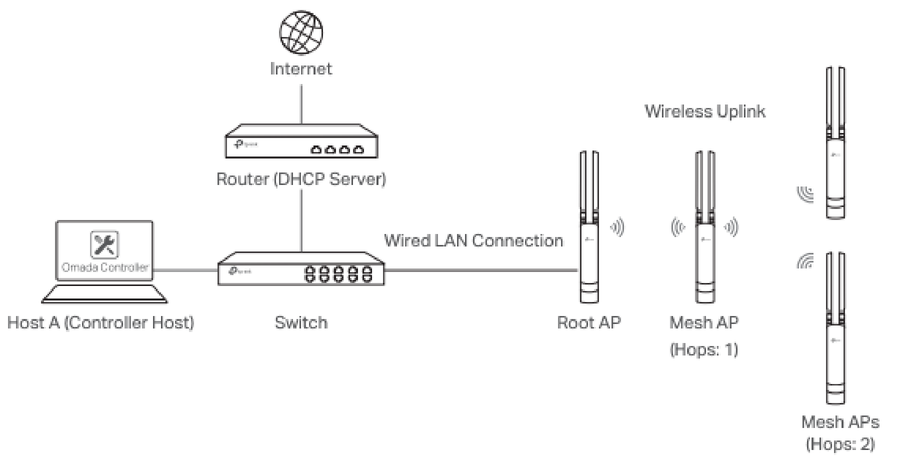

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95. Additionally, Defendant has been and currently is an active inducer of infringement of the ’036 patent under 35 U.S.C. § 271(b) and a contributory infringer of the ’036 patent under 35 U.S.C. § 271(c).

96. Defendant has actively induced, and continues to actively induce, infringement of the ’036 patent by causing others to use, offer for sale, or sell in the United States, products or services covered by the ’036 patent, including but not limited to the ’036 Accused Products and any other products or services that include wireless communication products that support multi-hop wireless networking, including the capability to relay wireless transmission to/from a core network to relay stations and user equipment using multiple interfaces as described above. Defendant provides these products and services to others, such as customers, resellers, partners, and end-users, who, in turn, use, provision for use, offer for sale, or sell those products and services, which directly infringe the ’036 patent as described above. Defendant’s inducement includes the promotion, directions and instructions found at one or more of the following links, the provision of which has been on-going since the filing of the Complaint in case 6:23-cv-291 and the content of which is specifically illustrated above:

- https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap610-outdoor/
- https://www.tp-link.com/us/business-networking/omada-sdn-access-point/eap610-outdoor/#specifications
- https://www.tp-link.com/us/support/faq/2949/
- *https://www.tp-link.com/us/support/faq/2580/*
- *https://static.tp-link.com/2018/201809/20180907/1910012447_Omada%20Controller%20Software%203.0.2_UG.pdf*
- *https://www.tp-link.com/us/support/faq/2283/*

97. Defendant has contributed to, and continues to contribute to, the infringement of the ’036 patent by others by knowingly providing one or more components, for example the multi-

hop wireless mesh modules with the above described functionality included in the Accused Products, a portion thereof, and/or the software/hardware responsible for the accused functionality described herein, that, when installed, configured, and used result in systems that, as intended by Defendant described above, directly infringe one or more claims of the ’036 patent.

98. Defendant knew of the ’036 patent, or should have known of the ’036 patent, but was willfully blind to its existence. Upon information and belief, Defendant had actual knowledge of the ’036 patent since at least as early as the filing of the Complaint in case 6:23-cv-291. Alternatively, Defendant has had knowledge of the ‘036 patent since Defendant received a copy of this Complaint or at least as early as service upon Defendant of the Complaint in this action.

99. By the time of trial, Defendant will or should have known and intended (since receiving such notice) that its continued actions would infringe and would actively induce and contribute to the infringement of the ’036 patent.

100. Defendant has committed, and continues to commit, contributory infringement by selling products and services that directly infringe the ’036 patent when used by a third party, such as the Accused ’036 Products, and that are a material part of the invention, knowing them to be especially made or adapted for use in infringement of the ’036 patent and not staple articles or commodities of commerce suitable for substantial non-infringing use.

101. As a result of Defendant’s acts of infringement, IV has suffered and will continue to suffer damages in an amount to be determined at trial.

PRAYER FOR RELIEF

IV requests that the Court enter judgment as follows:

(A) that Defendant has infringed the ’439 patent;

(B) that Defendant has infringed the ’706 patent;

(C) that Defendant has infringed the ’036 patent;

(D) awarding damages sufficient to compensate IV for Defendant’s infringement under 35 U.S.C. § 284;

(E) finding this case exceptional under 35 U.S.C. § 285 and awarding IV its reasonable attorneys’ fees;

(F) awarding IV its costs and expenses incurred in this action;

(G) awarding IV prejudgment and post-judgment interest; and

(H) granting IV such further relief as the Court deems just and appropriate.

DEMAND FOR JURY TRIAL

IV demands trial by jury of all claims so triable under Federal Rule of Civil Procedure 38.

Dated: April 26, 2023.

Respectfully submitted,

/s/Karl Rupp

Karl Rupp
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COUNSEL FOR PLAINTIFFS