UNIVERSITY OF PUERTO RICO
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COMPUTER SCIENCE AND ENGINEERING DEPARTMENT

Computer Networks

CIIC – 4070

Report 3:

Ethernet and Wi-Fi

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April 11, 2023

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Introduction

This Ethernet and Wi-Fi report will explore the fields of Internet transmission. Basic aspects such as the history of Ethernet and Wi-Fi will be explained. Standards of sophisticated ethernet models such as 10 Gigabit Ethernet, 100 Gigabit and one Terabit will then be explained. In addition to the IEEE standards, the physical model and the MAC Sub-Layers of the mentioned models will be shown. From this we will go to the Wi-Fi area. In this area will explain the most recent models of Wi-Fi such as Mesh Mode, 5 and 6. These Wi-Fi models will also be provided with information on IEEE standards, The Physical Layer, and the MAC Sub-Layer. After having demonstrated figures, schemes, and standards, it will be explained how to extend the Wi-Fi network using two routers and the Mode Mesh to cover a house completely.

Section 2: The Basics

The History of the Ethernet

- The Ethernet began as a project of the ALOHANET. This project was started on 1970, by the XPARC (Xerox Palo Alto Research Center) division. It all started when Robert Metcalfe created an initial version of a wired ethernet protocol. The tests were completed in 1976 when a scientific project was published by Metcalfe and David Boggs which spoke of local networks connected to linked personal computers. In 1979 after being patented in 1978 Metcalfe founded a company called 3com making a breakthrough to the development of computers and LAN networks in search of establishing Ethernet as a standard. In 1980 with the release of the Ethernet 1.0 model developed by the IEEE gave way to advances such as CSMA / CD (Carrier Sense Multiple Access / Collision Detection) then called IEEE 802.3. Companies such as Cheapernet, Ethernet on Broadband and StarLAN gave popularity to this mechanism and in 1990 began to use fiber optics and braided cable in high volume. Finally, standard protocols such as 100 Mbit/s for Ethernet IEEE 80.2.u and WLAN (802.11) were approved, giving way in 1995 to what we know as the birth of the modern internet.

Figure 2.1 First Ethernet Cable to Send an Internet Message

The history of Wi-Fi

- The history of Wi-Fi was also written by the United States since in 1971 ALOHANET connected to Hawaii using UHF wireless packet network. The ALOHA protocol was the early forerunner of Ethernet and then IEEE 802.11 respectively. Vic Hayes, known as the father of Wi-Fi, joined NCR Corporation in 1974, a semiconductor manufacturing company that boosted Wi-Fi. In 1985 the U.S. Federal Communications Commission released the ISM band for commercial or unlicensed use. These are the frequencies known as 2.4GHz band that are used in Wi-Fi and domestic equipment such as microwaves. With all these advances in 1991 the corporation in which Vic Hayes worked joined AT&T Corporation to invent the beginning of what is now 802.11 for use in cashier systems. The first products carried the name of WaveLAN and are the ones that took the credit of the Wi-Fi. The next steps of the 802.11 protocol were carried out in 1997 when the first versions sent 2 Mbit/s and then in 1999 it was increased to 11 Mbit/s with the 802.11b protocol.

Figure 2.2 WaveLan Device

Section 3: 10 Gigabit Ethernet

- Standard

  The 10 Gigabit Ethernet Standards established by 802.3ae-2002 are:

  1. 10GBase-CX4 (802.3ak) with approximately 15m distance.
  2. 10GBase-KR (802.3ap) with approximately 1m distance.
  3. 10GBase-T with approximately 100m distance.
  4. 10GBase-CU with approximately 15m distance.
  5. 10GBase-SR (802.3ae) with approximately 300m distance.
  6. 10GBASE-SW with approximately 300m distance.
  7. 10GBase-LR with approximately 10km distance.
  8. 10GBASE-LW with approximately 10km distance.
  9. 10GBase-LRM with approximately 220m distance.
  10. 10GBase-ER10GBASE-EW with approximately 40km distance.
  11. 10GBase-ZR10GBase-ZW with approximately 80km distance.
  12. 10GBase-LX4 with approximately 300m distance.
  13. 10GBase-PR with approximately 20km distance.

- The Physical Layer

  The Physical Layer of the 10 Gigabit Ethernet model can be transmitted in different ways such as copper or fiber optics. To understand this layer, we must first take into consideration the other sub-layers it contains. These include those listed below:

  XGMII (10 Gbps Media Independent Interface)

  ❖ This sublayer is responsible for transmitting and receiving the 10Gbps data paths.

PCS (Physical Coding Sublayer)

- ❖ This sublayer is responsible for encode, decode, and transmit the encoded data from XGMII to PMA sublayer.

PMA (Physical Medium Attachment)

- ❖ This sublayer is responsible for Mapping of transmit and receive data streams, Serialization of the transmission bits, optionally provides data loopback.

PMD (Physical Medium Dependent)

- ❖ This sublayer is responsible for ensuring the distance requirements and the transmission medium of the data.

MDI (Medium Dependent Interface)

- ❖ This sublayer is the cable connector between the signal transceivers and the link.

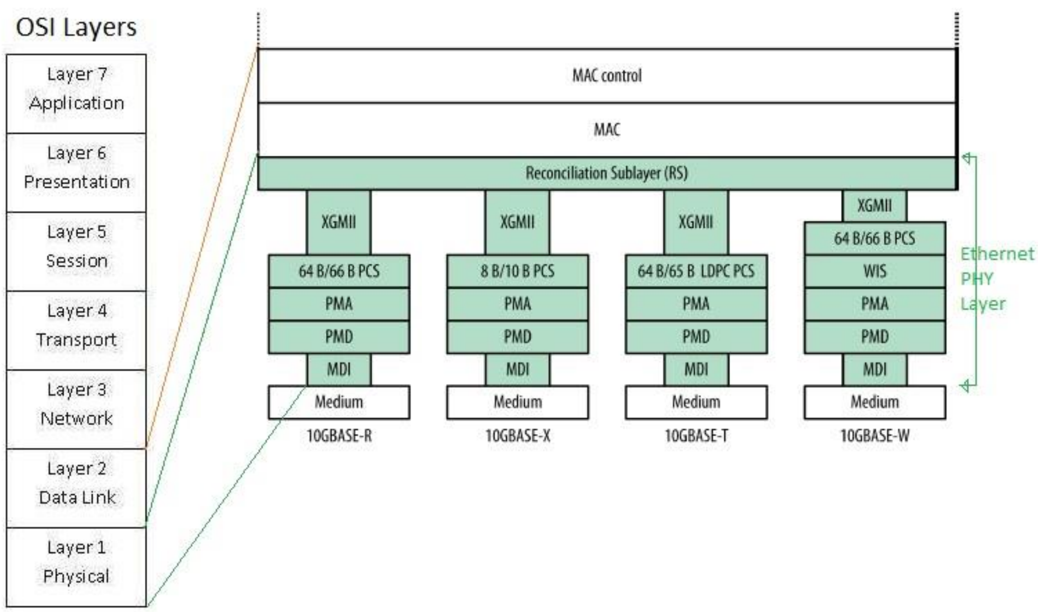

Figure 3.1 Example of Physical Layers of 10GBASE-R

- The MAC sub-layer

  The MAC (Media Access Control) is a part of Data Link Layer that is responsible for handling the data transmitted from the physical layer. In the 10 Gigabit model some of the characteristics change so that it is possible to transmit at this speed. According to the IEEE 802.3 standard, some of the main aspects are:

  - Frame Format: In this aspect that sends the destination and source of the MAC address remains the same as the other Ethernet models.
  - Frame Size: This size is used in the same way as other models (46 is minimum and 1500 bytes maximum).
  - Full Duplex operation: One of the different aspects to handle collisions is that it must operate in full duplex since it does not support other models such as CSMA/CD.
  - Flow control: Supports 802.3x standard (takes care of pausing the transmission when the receiver is full).
  - Addressing: Use 6-byte MAC addresses as other Ethernet Models.

Section 4: 100 Gigabit Ethernet

- Standard

The 100 Gigabit Ethernet Standards established by 802.3ba-2010 are:

1. 100GBASE-SR10 with approximately 100m distance.
2. 100GBASE-LR4 with approximately 10km distance.
3. 100GBASE-ER4 with approximately 40km distance.
4. 100GBASE-CR10 with approximately 7m distance.
5. 100GBASE-CR4 with approximately 3m distance.
6. 100GBASE-KP4, distance is extremely close.
7. 100GBASE-KR4, distance is extremely close.
8. 100GBASE-KS4, distance is extremely close.

- The Physical Layer

  The 100 Gigabit model also features several sublayers. The sublayers are described below:

  RS (Reconciliation Sublayer)

  - ❖ This mode is located between the Data Link and Physical Layer. It is responsible for adapting the MAC data rate and Physical data rate.

  CGMII (Converged Gigabit Media Independent Interface)

  - ❖ This model allows a single MAC to connect to multiple physical operators with different data rates.

PCS (Physical Coding Sublayer)

- This sublayer is responsible for encode, decode, and transmit the encoded data from XGMII to PMA sublayer.

FEC (Forward Error Correction)

- This model detects and correct errors during the data transmission.

PMA (Physical Medium Attachment)

- This sublayer is responsible for Mapping of transmit and receive data streams, Serialization of the transmission bits, optionally provides data loopback.

PMD (Physical Medium Dependent)

- This sublayer is responsible for ensuring the distance requirements and the transmission medium of the data.

AN (Auto-Negotiation)

- This model or protocol is used to configure and maintain the best possible communication between two devices. Try to do your best without manual intervention.

MDI (Medium Dependent Interface)

- This sublayer is the cable connector between the signal transceivers and the link.

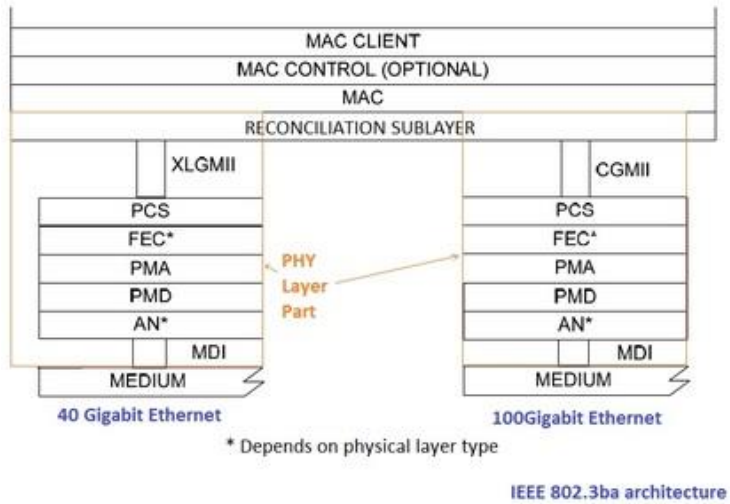

Figure 4.1 Example of Communication in 100 Gigabit Ethernet

- The MAC sub-layer

The MAC (Media Access Control) is a part of Data Link Layer that is responsible for handling the data transmitted from the physical layer. In the 100 Gigabit model some of the characteristics change so that it is possible to transmit at this speed. According to the IEEE 802.3ba-2010 standard, some of the main aspects are:

- ❖ Frame Format: In this aspect that sends the destination and source of the MAC address remains the same as the other Ethernet models.
- ❖ Frame Size: This size is used in the same way as other models (46 bytes is minimum and 1500 bytes maximum).
- ❖ Interframe Gap: The interframe gap must be smaller in this model since due to the higher speed rates has to be shortened. This is one of the biggest differences with the other models.
- ❖ Full Duplex operation: One of the different aspects to handle collisions is that it must operate in full duplex since it does not support other models such as CSMA/CD.

- ❖ Flow control: Supports 802.3x standard (takes care of pausing the transmission when the receiver is full).
- ❖ Addressing: Use 6-byte MAC addresses as other Ethernet Models.

Section 5: Terabit Ethernet

- Standard

The 100 Gigabit Ethernet Standards established by 802.3ab are:

1. 1000BASE-T with approximately 100m distance.
2. 1000BASE-TX with approximately 100m distance.
3. 1000BASE-CX with approximately 25m distance.
4. 1000BASE-SX with approximately 550m distance.
5. 1000BASE-LX/LH/LX10 with approximately 10km distance.
6. 1000BASE-ZX with approximately 100km distance (Not IEEE standard but supported).

- The Physical Layer

The 100 Gigabit model also features several sublayers. The sublayers are described below:

RS (Reconciliation Sublayer)

- ❖ This mode is located between the Data Link and Physical Layer. It is responsible for adapting the MAC data rate and Physical data rate. There have been changes from the other models in the complexity of bit alignment, lane distribution.

CGMII (Converged Gigabit Media Independent Interface)

- ❖ This model allows a single MAC to connect to multiple physical operators with different data rates.

PCS (Physical Coding Sublayer)

- ❖ This sublayer is responsible for encode, decode, and transmit the encoded data from XGMII to PMA sublayer.

FEC (Forward Error Correction)

- ❖ This model detects and correct errors during the data transmission.

PMA (Physical Medium Attachment)

- ❖ This sublayer is responsible for Mapping of transmit and receive data streams, Serialization of the transmission bits, optionally provides data loopback.

PMD (Physical Medium Dependent)

- ❖ This sublayer is responsible for ensuring the distance requirements and the transmission medium of the data.

AN (Auto-Negotiation)

- ❖ This model or protocol is used to configure and maintain the best possible communication between two devices. Try to do your best without manual intervention.

WDM (Wavelength Division Multiplexing)

- ❖ Increases data speed through fiber optics.

SDM (Spatial Division Multiplexing)

❖ It is responsible for increasing the speed and coupling at speeds of one terabit per second.

MDI (Medium Dependent Interface)

❖ This sublayer is the cable connector between the signal transceivers and the link. New cables and connectors are required compared to other models.

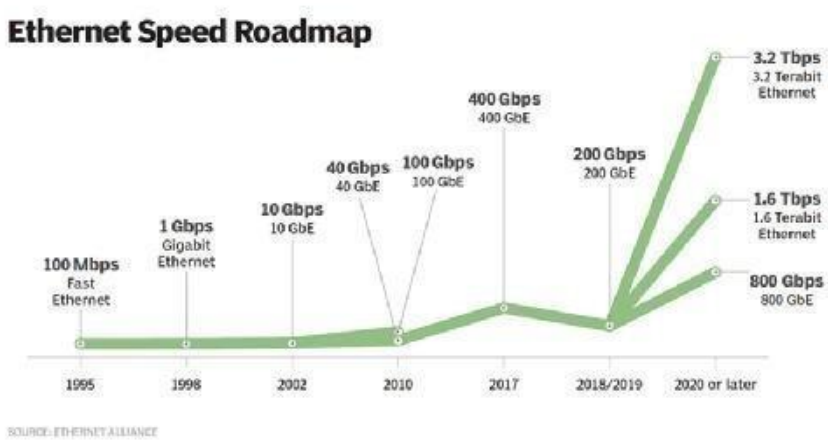

Figure 5.1 Roadmap of 1Tb Ethernet Speed

- The MAC sub-layer

The MAC (Media Access Control) is a part of Data Link Layer that is responsible for handling the data transmitted from the physical layer. In the 1 Terabit model some of the characteristics change so that it is possible to transmit at this speed. According to the IEEE 802.3ab standard, some of the main aspects are:

❖ Frame Format: In this aspect that sends the destination and source of the MAC address remains the same as the other Ethernet models.

❖ Frame Size: This size is used in the same way as other models (46 bytes is minimum and 1500 bytes maximum).

- ❖ Interframe Gap: The interframe gap must be smaller in this model compared to 100gb since due to the higher speed rates has to be shortened. This is one of the differences with the other models.
- ❖ Full Duplex operation: One of the different aspects to handle collisions is that it must operate in full duplex since it does not support other models such as CSMA/CD.
- ❖ Flow control: Supports 802.3x standard (takes care of pausing the transmission when the receiver is full).
- ❖ Addressing: Use 6-byte MAC addresses as other Ethernet Models.

Section 6: Wi-Fi 5

- Standard

The standard of Wi-Fi 5 established by the IEEE is 802.11ac (2013). Although it is the main standard, Wi-Fi 5 is backward compatible accepting standards such as 802.11n, 802.11g, 802.11b, and 802.11a.

- The Physical Layer

Some of the advancements and features that distinguish Wi-Fi 5 are shown below:

Frequency Band

- ❖ The Wi-Fi 5 is characterized by using the 5GHz frequency which allows less interference and better communication than its previous model with 2.4GHz.

Modulation

- ❖ The modulation used is 256-QAM which can achieve higher data rate.

Channel Bandwidth

❖ This standard uses different channels such as 20MHz, 40MHz, 80MHz and 160Mhz. This improves the connection to the network and ensures a stable connection.

MIMO (Multiple input Multiple Output)

❖ Allows many more devices to connect to the Wi-Fi network keeping the connection stable.

Guard Interval

❖ Offers more interval options which improves and maintains network integrity.

Modulation Techniques Used by the 802.11 Standards	
Legacy	DSSS - DBPSK (1M) DSSS - DQPSK (2M)
802.11b	HR/DSSS - CCK (5.5M, 11M) HR/DSSS - PBCC (5.5M, 11M) (obsolete)
802.11g	ERP - PBCC (22M, 33M) (obsolete) DSSS - OFDM (6-54M) (deprecated)
802.11a/g	OFDM (6-54M)
802.11n	HT20/40 (6.5 - 150M) (SISO 1x1:1) HT20/40 (13 - 600M) (MIMO, up to 4x4:4)
802.11ac	VHT20/40/80/160 (6.5 - 867M) (SISO 1x1:1) VHT80+80 (58.5 - 867M) (SISO 1x1:1) VHT20/40/80/160 (13 - 6933M) (MIMO, up to 8x8:8) VHT80+80 (117 - 6933M) (MIMO, up to 8x8:8)

Table 6.1 Modulation Techniques used in Wi-Fi.

- The MAC sub-layer

Communication between the Wi-Fi 5 standard and the MAC must be efficient so that messages can be transmitted quickly and reliably. Some of the main components are:

- Frame Format: It consists of having MAC header, Payload, FCS (Frame Check Sequence). This is control information to maintain good communication.
- EDCA (Enhanced Distributed Channel Access): Basically, it is established priority in the traffic of the data to improve the performance.
- BlockACK: Improves efficiency by accepting multiple data ACK (Acknowledgement) in a single frame.
- Multiuser MIMO: Multiple device connection.
- Check Sequence: Manage Errors in Frames.

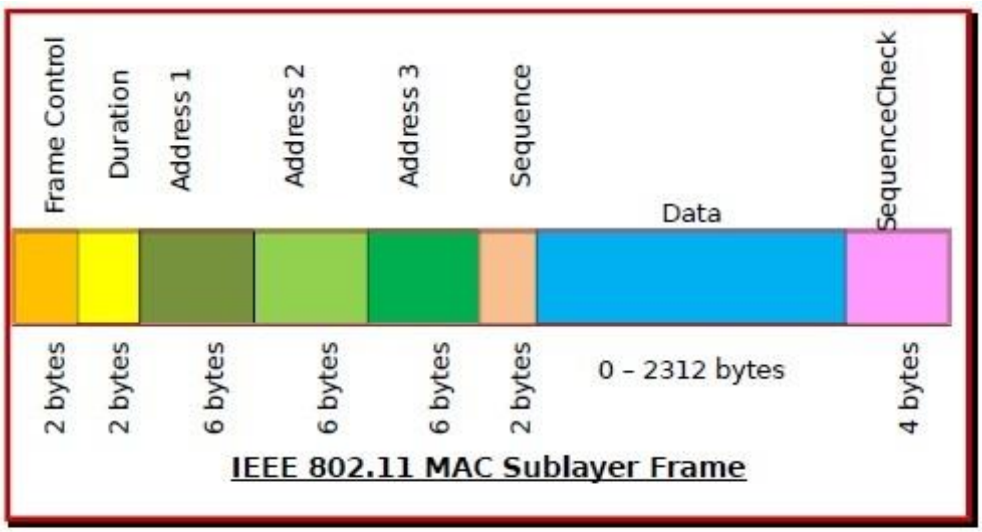

Figure 6.1 MAC Sublayer Process

Section 7: Wi-Fi 6

- Standard

  The standard of Wi-Fi 6 established by the IEEE is 802.11ax (2019). Although it is the main standard, Wi-Fi 6 is backward compatible accepting standards such 802.11a/b/g/n/ac.

- The Physical Layer

  Advancements and features that distinguish Wi-Fi 6 are shown below:

  Frequency Bands

  - ❖ Wi-Fi 6 uses multiple frequencies. The most common are 5GHz and 2.4GHz although there are models that reach up to 6Hz improving compatibility and avoiding channel overlapping.

  OFDMA (Orthogonal Frequency-Division Multiple Access)

  - ❖ This generation incorporated the OFDMA which divides a channel into subcarriers and allows multiple users to share a channel. This improves resource efficiency, increases capacity, and further reduces latency.

  MU-MIMO (Multiuser Input Multiple Output)

  - ❖ Wi-Fi 6 allows more spatial streams than its predecessors (8 simultaneous)

  Modulation

  - ❖ Modulation has been improved to 1024-QAM by adding more transmitted bits.

  Longer OFDM (Orthogonal Frequency Division Multiplexing)

- ❖ Brings significant improvements to interference and performance when the network is not stable.

BSS (Basic Service Set)

- ❖ Basically, through a technique called "Coloring" it identifies neighboring networks through colors and ignores them, reducing interference.

Guard Interval

- ❖ Wi-Fi 6 offers several methods to maintain data integrity on the device.

- The MAC sub-layer

Wi-Fi 6 communication must be more efficient and compatible than previous technologies. Some of the main layers are:

- ❖ Frame Format: It consists of having MAC header, Payload, FCS (Frame Check Sequence). This is control information to maintain good communication.
- ❖ EDCA (Enhanced Distributed Channel Access): Basically, it is established priority in the traffic of the data to improve the performance.
- ❖ BlockACK: Improves efficiency by accepting multiple data ACK (Acknowledgement) in a single frame.
- ❖ Multiuser MIMO: Multiple device connection.
- ❖ OFDMA (Orthogonal Frequency-Division Multiple Access): Allow users to use more channels reducing latency.
- ❖ Sequence Control: Identify and manage the transmission sequence.
- ❖ Duration: With a length of 4 bytes contains the time that the medium is running

❖ CRC (Cyclic Redundancy Check): Basically, it is an error detection method for the frames sent.

❖ Addresses: Contains MAC Addresses of 48 bits each indicating the different frames orders.

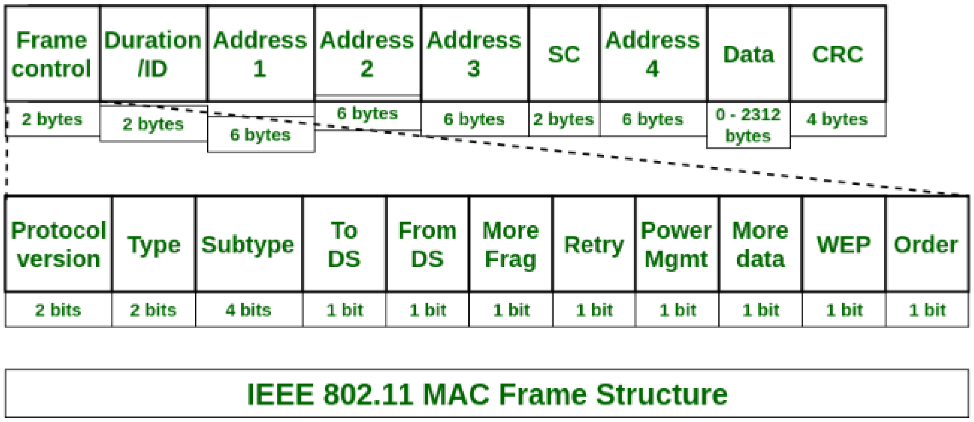

Figure 7.1 MAC Frame Structure

Section 8: Wi-Fi Mesh Mode

- Standard

  Wi-Fi Mesh mode does not have a standard set by the specific IEEE. Some of the models that fall into this mode have standards and are described below:

  1. Wi-Fi 4 standard is 802.11n.
  2. Wi-Fi 5 standard is 802.11ac.
  3. Wi-Fi 6 standard is 802.11ax.

- The Main MAC-based Networking Schemes

  The main or most important schemes of a Wi-Fi Mesh Mode are:

  CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)

- ❖ It is a common scheme in the different models of Wi-Fi. It is mainly used to avoid collisions and listen to the medium before.

DFC (Distributed Coordination Function)

- ❖ Used primarily to relay lost data. It also helps to avoid collisions.

EDCA (Enhanced Distributed Channel Access):

- ❖ Improves the performance of latency-sensitive applications, such as VoIP or video streaming.

MU-MIMO (Multi-User MIMO)

- ❖ Its function is to improve the capacity of a Wi-Fi network sent different types of streams to devices and thus be able to with as many devices as possible.

ACK (Acknowledgments)

- ❖ Confirm the successful transmission of frames. If there is an error in the frames send a request for retransmission.

- Explication of how to set up a Mesh mode to extend the Wi-Fi coverage in your home.

To facilitate the explanation, I will call the routers by numbers, router 1 and router.

1. Connect router 1 to the modem or ethernet cable with functional internet (You must have contracted an internet provider to have a stable connection).
2. Following the manuals of the routers do the initial configuration. They should be far enough away to cover the house but close enough so the signal can communicate.

3. On router 1 configure the network name (SSID) and password. This is usually configured by connecting to a standard page as https://192.168.0.1 following the steps of each router as they vary between each model.
4. Update the Firmware of router 1 and router 2 to the latest version available.
5. After this, a reset will be made to router 2 to ensure that there is no unwanted configuration. Access the management interface on router 2 (It is usually similar or the same as router 1 example https://192.168.0.1) and activate Mesh Mode. This mode is commonly found in Wireless > Advanced Settings > Network Settings.
6. Add additional settings such as router SSID 1 and password (Only on some models).
7. Go to the save area and reboot to router 2. It should have successfully extended and communicated to router 1.

With these steps you would have an extended Wi-Fi range using Mesh Mode.

Conclusion

After making the report of Ethernet and Wi-Fi I was able to learn the history of Ethernet and Wi-Fi. In addition to the story, I was able to understand the standards, the physical model, and the sub-layer of the MAC address of the different Ethernet protocols. Starting with the 10 Gigabits that although it transmits a lot of data per second there are much more sophisticated models such as 1 Terabit. In the same way, the models of Wi-Fi 5 and Wi-Fi 6 were studied, learning the speed differences, standards established by the IEEE, Physical Layer, and the sub-layers of the MAC address. In addition to learning how to expand our Wi-Fi network at home using only 2 routers and the Mesh Mode provided by the router configurations.

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