ASSIGNMENT 01

Comparison of IEEE 802.3 & IEEE802.11 MAC Protocol

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LOCAL AND METROPOLITAN AREA NETWORKS

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Comparison of IEEE 802.3 & IEEE802.11 MAC Protocol

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ABSTRACT

The IEEE 802.3 and 802.11 standards are used to define CSMA/CD (Carrier Sense Multiple Access with Collision Detection) based on the Ethernet LAN (Local Area Networks) and Wireless LAN (WLAN) protocol, respectively. This report deals with the comparison of IEEE 802.3 and IEEE802.11 MAC protocol in terms of the physical and medium access control (MAC) layer. CSMA/CD Ethernet-based protocol is the most widely used for LAN and wireless standard seems to be used for mobile LAN applications provides more flexible/mobile and less expensive than wired LANs, but generally has a lower transmission rate than Ethernet LANs. In terms of access techniques, the report describes the IEEE 802.3 CSMA/CD Ethernet-based LAN. Basically, CSMA/CD is the improvement of CSMA protocol by adding collision detection scheme and becomes popular scheme for controlling a LAN specifically on a bus system. On the other hand, the access technique used by the IEEE 802.11 Wireless LAN protocol is CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) since the use of CSMA/CD implementation is not possible due to the waste of the energy on mobiles.

I. INTRODUCTION OF IEEE 802.3, IEEE 802.11 AND IEEE 802 PROTOCOL MODEL

This chapter will introduce the short history of IEEE 802.3 and 802.11, the description of the IEEE 802 protocol layer compared to OSI 7 layer and the general function of layers, the PHYSICAL and DATA LINK layer in OSI protocol model. First of all, according to Keiser [7], IEEE 802.3 was developed in 1980, by a consortium of Digital Equipment Corporation, Intel Corporation and Xerox Corporation (DIX), which have invented the native Ethernet specifications intended for 10Mbps bus-based LAN using coaxial cable and then submitted to the IEEE in 1982. The IEEE 802.3 document for carrier sense multiple access with multiple collision (CSMA/CD) is for use in commercial and light industrial environments. Now, when people talk about Ethernet, it typically refers to IEEE 802.3 CSMA/CD. Over many years, this standard has significant developments in terms of transmission media types, even new concepts of operation. For instance, Fast Ethernet operates at 100Mbps, or called 100BaseT. Even more, there is a Gigabit Ethernet technology, which operates at 10Gbps. Figure 1 describes the family of the IEEE 802.3 standard [4].

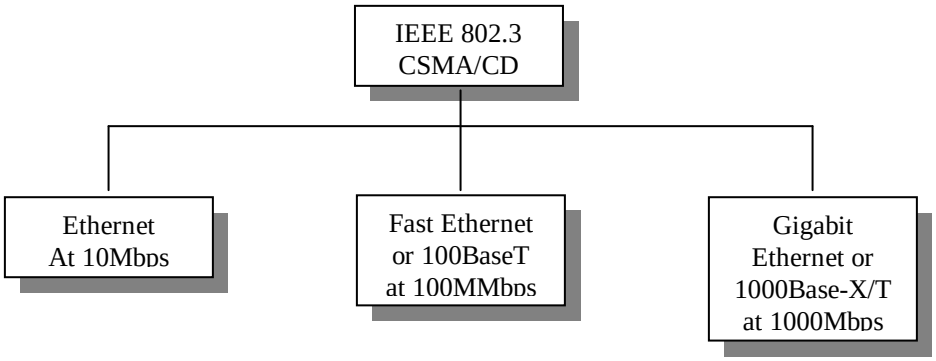


Figure 1. The IEEE 802.3 standard family [7]

The increase use of Internet emerge the new concepts and equipment needed to provide mobile communication services within localized area. Such LAN technology provides more flexible and mobile for the users, called wireless LAN (WLAN) standardized by IEEE 802.11 standard in 1997. Basically, WLAN is an alternative technology to solve the problem experienced on wired LAN, such as the high installation and maintenance costs. Unlike wired LAN terminals, which are static when working on the network, one of the advantages is freedom mobility. Generally, wireless LAN is a LAN, which employs the infrared or microwave radio rather than coaxial cable, twisted pair or fiber optic cable as used in IEEE 802.3 standard as the transmission medium. WLAN provides the advantage of mobility for the users. However, at the moment the lower transmission rate of WLAN must be considered. According to Stallings [10], wireless LAN has four application areas, such as LAN Extension, Cross Building interconnect, Nomadic access and Ad hoc network.

The main advantage of **Wireless LAN** network over the **CDMA/CD Ethernet** based **LAN** network is the freedom mobility and flexibility. Another advantage is WLAN can be applied when the installation and maintenance cost of wired LAN infrastructure rises significantly, to provide the need of LAN extension to other building. However, there are five issues that decrease the attractiveness of wireless LANs, such as the transmission medium degradation due to multipath fading which in turn leads to hidden terminal problem, the security of the transmission medium, which is open to anyone within the geographical range of transmitter, and leads to the need of the encryption, the lower transmission rate of around 1 to 10Mbps and the need of the licensed when applying wireless over radio technology. However, some countries, USA, European countries and Japan have stated that the use of ISM **not required the license** to operate at the ISM (industrial, scientific and medicine) frequency.

According to Stallings [10], in terms of OSI model, layers are divided to higher layer, layer 3 or 4 and above, and lower layer, layer 1 (physical layer) and layer 2 (data link layer). Higher layer protocols are regardless to the network architecture and able to implement to LANs, MANs and WANs. Hence, the mapping of IEEE 802 protocol model only compared to lower layer OSI model. The mapping of the IEEE 802 protocol is depicted on figure 2 and shows the relationship of LAN standard to OSI protocol model architecture. Basically, the function of the PHYSICAL layer of the OSI model has the following functions [10]:

- Data Encoding/Decoding, such as Manchester Coding
- Preamble generation/removal, which provides stations synchronization on the channel
- Bit transmission/reception
- Transmission medium specifications (defined in the IEEE 802 model, due to the importance of transmission medium selection)

Furthermore, the Data Link layer of OSI model provides the following functions:

- Provide interface to higher layer through one or more service access points (SAPs).
  The LLC (logical link control) layer of IEEE 802 protocol model performs the above function.
- Assemble data into frame with address and error detection on transmit side
- Disassemble data into frame with address and error detection on receive side
- Control the channel access to the LAN transmission medium, such as introducing the physical signals on to the channel, sensing a carrier on the channel and detecting a collision occurred on the channel.

Apparently, the second to last functions above are done by medium access control (MAC) layer on IEEE 802 protocol model.

<table>
<tr><td>Higher Layer</td><td colspan="7"></td><td>Higher Layer</td></tr>
<tr><td rowspan="3">Data Link Layer</td><td colspan="7">Logical Link Control / LLC (802.2)</td><td>LLC</td></tr>
<tr><td colspan="7">Medium Access Control / MAC Level Bridging (802.1d)</td><td rowspan="2">MAC</td></tr>
<tr><td>802.3 CSMA/CD</td><td>802.4 Token Bus</td><td>802.5 Token Ring</td><td>802.6 DQDB</td><td>802.9 Isochronous LAN</td><td>802.11 Wireless LAN</td><td>802.12 Demand Priority Access</td></tr>
<tr><td>Physical Layer</td><td>802.3 PHY</td><td>802.4 PHY</td><td>802.5 PHY</td><td>802.6 PHY</td><td>802.9 PHY</td><td>802.11 PHY</td><td>802.12 PHY</td><td>PHY</td></tr>
</table>

Figure 2. IEEE 802 LAN Standard Mapping [9]

II. PHYSICAL LAYER COMPARISON OF IEEE 802.3 AND 802.11

This section deals with the comparison between IEEE 802.3 CSMA/CD Ethernet based protocol and IEEE 802.11 Wireless protocol in terms of the PHYSICAL layer. The issues that will be discussed in the following paragraph are the transmission medium, network topology and data encoding.

IEEE 802.3 Standard: Transmission Medium, Network Topology and Encoding

The transmission mediums, that specified by the standard, such as **coaxial**, **twisted pair** and **optical fiber**, are the common medium used by wired LANs. Generally, 10Mbps-operating LANs use the coaxial and twisted pair. The selection of transmission medium will affect the performance of wired LANs and different cables have different characteristics, such as the maximum length allowed and the attenuation. Usually, the coaxial cable (50 Ohm) is used by **10Base5** and **10Base2**, which employ the **Bus** topology and the coaxial cable diameter used by two applications is different, 10mm (thick) and 5mm (thin), respectively. The maximum segment length allowed, used by 10Base5 and 10Base2, is 500m and 185m, respectively. 10Base5 and 10Base2 have the number of nodes per segment 100 and 300 nodes, respectively. The standard allows the segment length can be longer up to

2500m by using repeater devices. The thick coaxial cable tends to be more difficult to handle and install than the thin one. However, the thick coaxial is good for backbones and the thin coaxial is the cheapest system and easier to handle [11]. Furthermore, the digital encoding implemented on two applications is **Manchester Encoding** [10].

Twisted pair cable is another physical layer medium alternatives specified by IEEE 802.3 standard. Twisted pair cable is the oldest and general transmission medium for many applications an on-line connection is required [11], easy to maintenance and often found in office buildings as excess telephone cable. As indicated on the IEEE 802.3 standard, the twisted pair cable is used by Ethernet (10BaseT), Fast Ethernet (100BaseT) and Gigabit Ethernet (1000BaseT), which operates at 10Mbps, 100Mbps and 1,000Mbps, respectively. "T" means the technology uses Unshielded Twisted Pair (UTP). The implementation on 10BaseT uses UTP, usually employs the **Star** topology using the cable diameter 0.4 to 0.6mm with maximum segment length 100m. This star topology is a easy system that contents of a number of stations connected to a central point, known as Hub, via two twisted pairs. Hub will receives input on any one line and repeats it to all of the other lines. In addition to the encoding scheme, the **Manchester Encoding** is used by **10BaseT**. On the other hand, **MLT-3**, **8B6T** and **NRZ** are commonly used for **100BaseT** encoding scheme. Furthermore, 1000BaseT uses **4D-PAM5** encoding scheme [10].

The one of the transmission mediums specified by IEEE 802.3 standard is fiber optic cable. The fiber technology use seems to be secure from electromagnetic interference, high bandwidth; less attenuation and best for backbone link, but the cost is more expensive. As indicated on the standard fiber optic pair can be used for Ethernet (10BaseF), Fast Ethernet (100BaseFX) and Gigabit Ethernet (1000BaseLX or 1000BaseSX) with the star shape topology. The wavelength likely to be used is around **850nm** with cable diameter **62.5/125μm**, the maximum segment length of **500m** and the number of nodes **33 nodes** on the **10BaseF** and the encoding likely to be used is **Manchester/On-Off**. The **100BaseF** technology employs 2 optical fibers, which has the maximum segment length of **100m**, and the network span of **400m**. The encoding scheme used id **4B5B** or **NRZI**. Furthermore, **Gigabit Ethernet** uses **8B/10B** as its encoding scheme. Generally, the IEEE 802.3 transmission medium can be summarized as depicted in figure 3.

	10BASE5	10BASE2	10BASE-T	10BASE-FP
Transmission medium	Coaxial Cable (50Ω)	Coaxial Cable (50Ω)	Unshielded Twisted Pair	850-nm optical fiber pair
Signaling technique	Baseband (Manchester)	Baseband (Manchester)	Baseband (Manchester)	Manchester/on-off
Topology	Bus	Bus	Star	Star
Maximum segment length (m)	500	185	100	500
Nodes per segment	100	30	-	33
Cable diameter	10 nm	5 mm	0.4 to 0.6 mm	62.5/125 μm

Figure 3. IEEE 802.3 10Mbps Physical Layer Medium Alternatives [10]

IEEE 802.11 Standard: Transmission Medium, Network Topology and Encoding

Transmission medium employed by IEEE 802.11 Wireless LAN standard are **Infrared** and **radio microwave**. In a wired LANS network [8], such as in IEEE 802.3 standard, the transmission medium can be physically secured, and access to the network is easily managed. Unlike the wired network, wireless network seems **more difficult to be secure**, as the transmission medium is open to anyone within the geographical range of a transmitter. Data privacy is commonly accomplished over a radio medium using encryption. The figure 4 below is depicted to compare IEEE 802.11 standard to the two lower layer of the OSI.

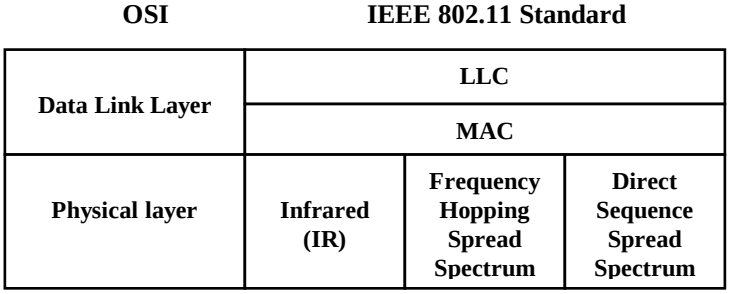


Figure. 4 IEEE 802.11 Standard Mapping to OSI Layer [6]

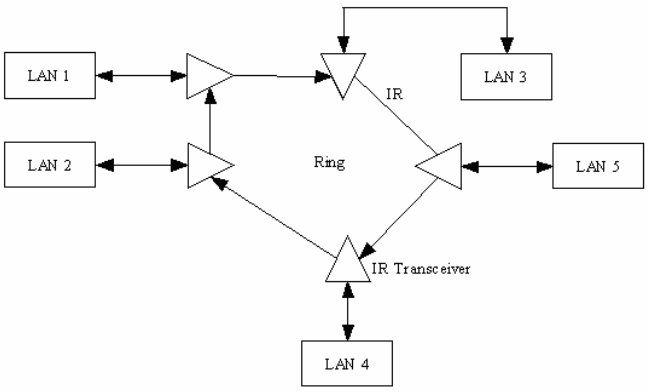
The attractive thing of wireless LAN is flexibility and mobility of the users. The IEEE 802.11 has specified the three different implementations of the physical layers implementations; **Frequency Hopping Spread Spectrum (FHSS)**, **Direct Sequence Spread Spectrum (DSSS)** and **Infrared** (**IR**). FHSS and DSSS are employed over a radio microwave technology, which operate at **2.4GHz ISM** (Industrial, Scientific and Medical) band from 2.4 to 2.4385GHz.

Under the frequency hopping, the signal is broadcast through a random series of radio frequency, at the fixed intervals hopping from frequency to frequency. According to [10], a receiver in frequency hopping hopes between frequencies in synchronization with the transmitter picks up the message. On the other hand, under direct sequence scheme, the original signal is spread over the channel by using a chipping code in direct proportion to the number of bits used. In contrast, the IR operates by using optical technology, which is commonly used in homes as remote control devices. The IR technology has the advantages over the frequency

hopping or direct sequence, such as IR can be easier to be secured against the eavesdropping, operated in every room in the building with no interference and relatively less expensive than other technologies.

FHSS utilizes the ISM 2.4 to 2.4385GHz with the basic rate of 1Mbps, which employs two-level **Gaussian Frequency Shift Keying** (**GFSK**) as the encoding. The enhanced of FHSS has the rate of 2Mbps, which operates 4-level GFSK. DSSS operates at similar frequency as FHSS, 2.4GHz, where that basic rate of 1Mbps encoded by using **Different Binary Phase Shift Keyin**g (**DBPSK**). The improvement of DSSS, which has the data rate of 2Mbps, uses **Differential Quadrature Phase Shift Keying** (**DQPSK**). The **range of mobility** FHSS and DSSS are **100-300m** and **100-800m**, respectively with the radiation power of less than 1W [9].
On the other hand, the **Infrared** (**IR**) specification identifies a wavelength range from 850 to 950nm. The IR band is designed for indoor use only and operates with non-directed transmissions. The IR designed to enable stations to receive line-of-sight (**Direct Beam**) and reflected transmissions (**Diffused**). The basic rate of the IR applications is 1Mbps, which uses the encoding scheme of 16-**pulse position modulation** (**PPM**). Basic concept of PPM is 4 data bits are mapped to 16 coded bits for transmission. The improvement using IR is 2Mbps data rate, which uses 4-PPM, where 2 data bits are mapped into 4 coded bits for transmission. However, according to [9], the Diffused IR has data rate of 1 to 4Mbps range, fixed or mobile applications and the range of operation of 50 to 200m. On the other hand, direct beam IR has data rate of 10Mbps, fixed and the range of operation of 80m.

The network topologies involved in the IEEE 802.11 are Ring, Nomadic, and Ad Hoc Network [Ian Palmer]. Ring network is applied if multiple wired-connected LANs (hubs) create a WLAN ring. The Nomadic network is likely happened when a single or many mobile users have ability to access to wired LAN. Furthermore, Ad Hoc network is defined when all of users are mobile. The picture of each of topologies is depicted in figure 5 [9].



(a)

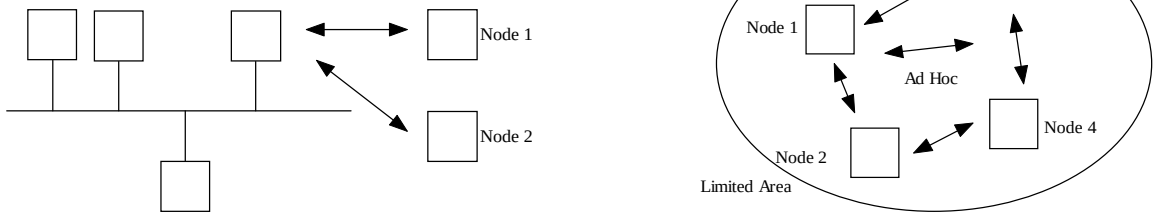


Figure 5. Wireless LAN topologies (a) Ring Network; (b) Nomadic; (c) Ad Hoc Network [9]

III. MEDIUM ACCESS CONTROL LAYER COMPARISON OF IEEE 802.3 AND 802.11

This section deals with the comparison between IEEE 802.3 CSMA/CD Ethernet based protocol and IEEE 802.11 Wireless protocol in terms of the MAC layer. The issue that will be discussed in the following paragraph is the media access technique of the stations in order to get access to the transmission medium. IEEE 802.3 protocol uses the CSMA/CD method to arrange the users in the network to gain the access to the medium in order to send the packet of transmission. On the other hand, IEEE 802.11 protocol makes the use of CSMA/CA to provide access to the transmission medium. IEEE 802.11 could not use CSMA/CD due to the dynamic range of signals involved in the transmission medium, is very large and this leads to the difficulty in distinguishing the weak incoming signal from the noise [7].

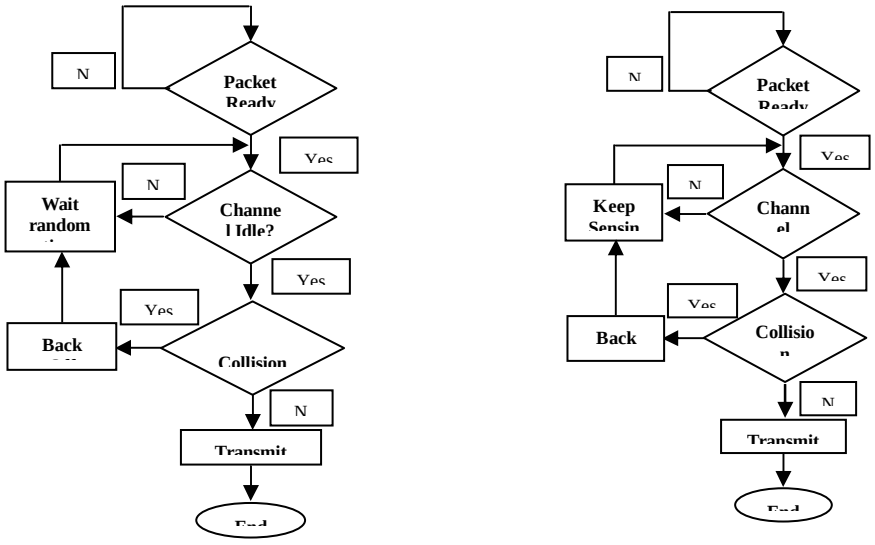
IEEE 802.3 Standard: CSMA/CD Protocol

The LANs use has been rising in popularity in recent years. CSMA/CD is popular as one of the most efficient protocols [1]. Initially, the IEEE 802.3 standard defined a 10Mbps LAN used for a bus topology, coaxial cable as transmission medium and broadcast fashioned transmission, using **CSMA/CD** as a **MAC Protocol**. The IEEE 802.3 standard intended for use in light industrial environment and commercial. The history of CSMA/CD started with the **ALOHA** access technique based on **Random Access** or **Contention** scheme. **Aloha** scheme allows the terminal to transmit the data/frame whenever the users need to send. Hence, no coordination among users and this leads to collisions and collide messages will be garbled. If this happened, the user must resend the data and with this particular scheme the achievable channel utilization only 18%. The next improvement was **Slotted Aloha.** Slotted Aloha has increased the channel utilization by 37%. Slotted Aloha employ the divided channel by time slots. Hence, the transmission only can be initiated in the beginning of the time slots. This eliminates the number of collisions but collisions still happened. The next improvement was **CSMA** (**Carrier Sense Multiple Access**). It just simply added the ability of users to sense the transmission medium. By sensing the transmission medium, the users will be aware to the status of the transmission medium, weather it is busy or

not, called **List Before Talk** (**LBT**). If the transmission medium detected being idle the user will send out the message. On the other hand, the user will delay the packet transmission if the transmission medium detected being busy. It successfully reduced the chance of the collisions. However, the collision still happened in CSMA [7][5].

The **CSMA/CD** protocol has been used to shorten the collision time duration. By adding the collision detection, the users in the network will keep sensing the transmission medium while sending out the packet, called **Listen While Talk** (**LWT**). While the user sending the packet and collision detected, the user will send the jamming signal to all users to indicate that collisions happened and then cease the transmission. After the jamming signal has been sent, the colliding users wait random amounts of time and then trying to send their packets. However, a random delay is used to avoid these stations have another collisions on the next transmission attempt. To ensure this mechanism, a method called as ***a Binary Exponential Back Off*** is used. This method a user keep trying to send when there are repeated collisions. These retries will keep going until either the transmission is successful or a particular number of attempts have been made unsuccessfully. Thereafter, the packet will be discarded and reported as an error. ***Binary Exponential Back Off*** mechanism is used to enable the stations or users to adapt the heavy load situation [7]. The **throughput** of CSMA/CD can be necessarily increased as a result of the binary back off algorithm in the system. Hammond argues that, 'the fact that CSMA/CD protocols maintain a throughput relatively high and close to the maximum over a large range of offered load suggest that CSMA/CD is probably more stable than other random access protocols" (Hammond, 1986) [5].

According to [9], there are two basics operation of CSMA/CD, **Non Persistent** and **Persistent.** The diagrams of their operation are given as follows in figure 6.



(a) (b)

Figure 6. CSMA/CD Protocol (a) Non Persistent and (b) Persistent [9]

The difference between them is Non Persistent does not keep sensing the medium while collision detected. According to [1] and [3], the development of CSMA/CD protocols was derived from the combination of the random access and reservation protocols, called **Two-Channel Reservation Network** (**TCRN**) and **Multiple Packet Multiple Channel** CSMA/CD protocol for broadcasting based LANs. As we know, the reservation protocol exhibits better throughput delay performance at medium loading.

IEEE 802.11 Standard: CSMA/CA Protocol

The CSMA/CD protocol is not used in a wireless environment due to the user has no capability to sense/listen to the channel for collision while sending the packet [12]. For IEEE 802.11 protocols, the MAC sublayer uses one of the methods to gain access to the network. The first method is Distributed Coordination Function (DCF). The second method is Point Coordination Function (PCF), which supports contention free frame transfer service by using the centralized operation to govern the access. The MAC layer on IEEE 802.11 protocol is depicted in figure 7.

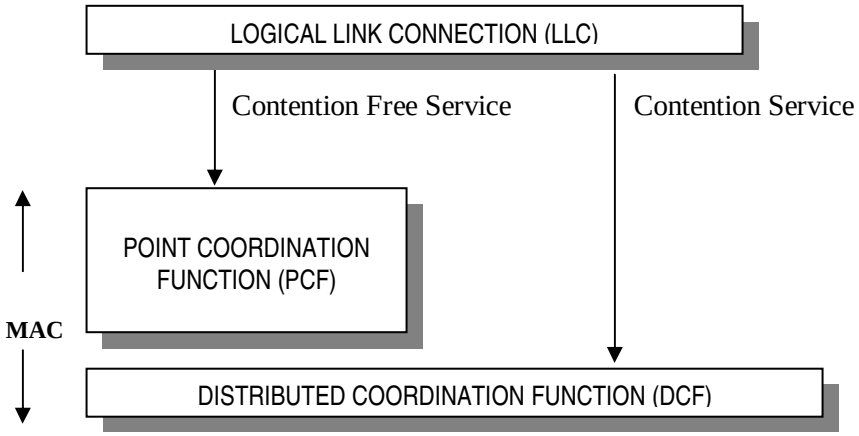


Figure 7. IEEE 802.11 MAC Layer [7]

The DCF is the basic access method used to provide asynchronous data transfer on a basis effort [7] [8]. All stations must support the DCF, basically used in the ad hoc network. As indicated in figure 7, DCF supports the contention service, which imply that each station must contend for access to the channel. Contention service supports the fair access of all stations to the transmission medium, which is the advantage of this scheme. Fairness means all stations have equal probability of gaining access to the channel. DCF is based on the **CSMA/CA (collision avoidance)** protocol. CSMA/CA is another variation of CSMA scheme. As described before, due to the large dynamic range of the signals in the medium, CSMA/CD cannot be used in Wireless environment. Therefore, a user has to wait for the channel to be really idle before transmitting, otherwise collision happened. When the channel is not occupied, this protocol needs a random set of delays to allow a user to send the packet. Without this mechanism, all waiting user will be involved in collision and waste the

transmission time. Consider Figure 8 depicted to describe the CSMA/CA protocol operation. After the channel becomes idle, all stations are required to keep silent for a certain minimum period, known as interframe space (IFS).

According to [7], if the medium is idle for longer than DIFS, the user can send the packet immediately. If the medium is busy and one or more stations have packet to send under the DCP protocol, the station will calculate a random backoff period by using binary exponential backoff scheme to arrange the access to the medium. The time period used by the user to indicate the need of an access is called contention window and it is divide to time slots. It is just the same scheme used by Ethernet to provide the fair access for all stations to access the medium.

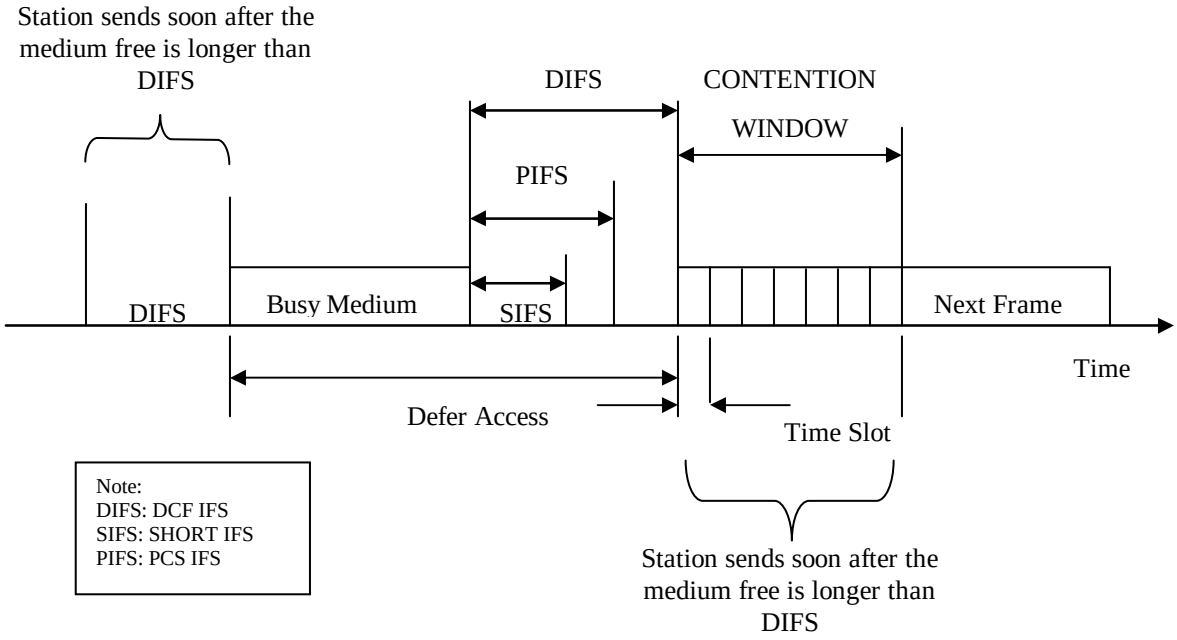


Figure 8. The basic concept of CSMA/CA [7]

Unlike DCF, PCF is an optional capability that provides contention free frame transfer. For instance, it may be used to support time sensitive data transfer like video or voice. The disadvantage of using the PCF is greater overhead and the network due to the need of sending polling frames that will permit the users to access the medium to send a packet to the destination. By using the PCF scheme the users not required to contend the medium to send the packet. The new development of CSMA/CA employed the **Adaptive Contention Window** as the throughput performance of CSMA/CA original becomes critical when the number of mobile users increases [2].

IV. CONCLUSION

To sum up, the differences between the IEEE 802.3 protocol and IEEE 802.11 in term of PHYSICAL layer are the type of transmission medium, the data-encoding scheme, and the network topology. Furthermore, in term of

MAC layer the differences are that IEEE 802.3 protocol makes the use of CDMA/CD protocol to solve the problem on the gain access of the users to the medium and IEEE 802.11 protocol seems to use CDMA/CA protocol, since the use of CDMA/CD is not possible due to the waste of energy.

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