International Journal of Contemporary Research in Computer Science and Technology (IJCRCST) e-ISSN: 2395-5325
Volume1, Issue 9 (December '2015)

STUDY ON IEEE 802.11 MAC PROTOCOL ARCHITECTURE

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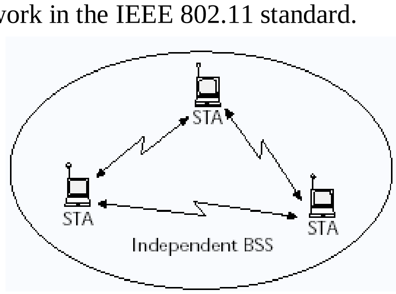
Abstract: Over the past few years, a range of new Media Access Control (MAC) protocols have been proposed for use in wireless networks. Medium access control (MAC) protocols provide a means to nodes to access the wireless medium efficiently and collision free to the best of their ability. MAC layer protocols allow a group of users to share a communication medium in a fair, stable, and efficient way. MAC protocols set defined rules to force distributed users/nodes to access the wireless medium in an orderly and efficient manner. MAC layer is sub layer of Data Link Layer involves the functions and procedures necessary to transfer data between two or more nodes of the network. It is responsible for error correction of anomalies occurring in the physical layer, framing, physical addressing, and resolving conflicts occurring in number of nodes to access the channel.

Keywords: Medium access control, Collision Avoidance, Carrier Sense Multiple Access

I. INTRODUCTION

WLAN cards with the IEEE 802.11 P2P (Peer-To-Peer) capability are used for wireless communication between Pocket PCs. IEEE 802.11 technology, particularly in terms of its architecture, physical layer and MAC sublayer, and basic access method to the medium, known as Distributed Coordination Function (DCF), based on a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) for wireless transmission. The basic service set (BSS) is the primary building block of the IEEE 802.11 architecture [1]. A BSS refers to a group of stations that are directly controlled by a single coordination function, such as Distributed Coordination Function (DCF) or Point Coordination Function (PCF), which will be explained below. The geographical area composed of the BSS is called as the basic service area (BSA), which is similar to a cell in a cellular communication network. Theoretically, all stations in a BSS can have communications directly with all other stations in a BSS. However, since transmission medium degradation may be caused by multipath fading or interference from adjacent BSSs reutilizing the same physical-layer characteristics, such as frequency and spreading code or hoping pattern, it can produce some stations to appear "hidden" from other stations [1].

An ad hoc network is an intentional grouping of stations into a single BSS for the goals of internetworked communications with no help of any infrastructure network. Figure 1 illustrates an independent BSS (IBSS), which is the formal name of an ad hoc network in the IEEE 802.11 standard.



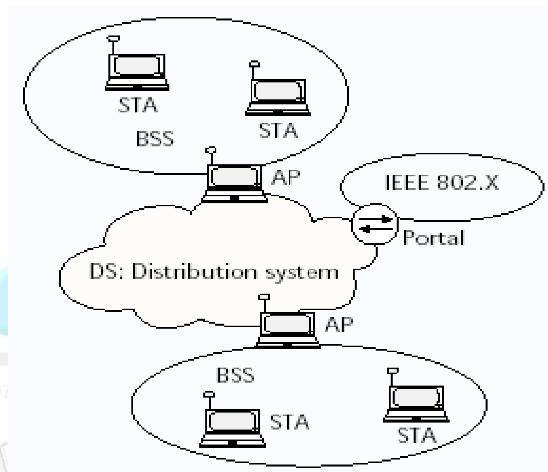


Figure 1: Sketch of an Ad Hoc Network.

Figure 2: Sketch of an Infrastructure Network.

In the BSS, any station can communicate with any other station without requiring a centralized access point (AP) to channel all traffics through it [1].

Different from the ad hoc network, infrastructure networks are utilized to provide wireless users for specific services and range extension. In the context of the IEEE 802.11, infrastructure networks are constructed using APs. The AP is similar to the base station in a cellular communications network. The AP provides range extension by supporting the integration points needed for network connectivity between multiple BSSs, therefore forming an extended service set (ESS) [1].

The BSS appears one large BSS to the logical link control (LLC). The ESS is made up of multiple BSSs that are integrated together by a common distribution system (DS). The DS can be regarded as a backbone network that is in charge of MAC layer transport of MAC service data units

(MSDUs). Based on the specifications of the IEEE 802.11, the DS is implementation independent. Thus, the DS could be a wired IEEE 802.3 Ethernet LAN, IEEE 802.4 token bus LAN, IEEE 802.5 token ring LAN, fiber distributed data interface (FDDI) metropolitan area network (MAN), or another IEEE 802.11 wireless medium. Even though the DS could physically be the same transmission medium as the BSS, they are logically not same because the DS is exclusively used as a transport backbone to transfer packets between different BSSs in the ESS [1].

II. IEEE 802.11 LAYERS DESCRIPTION

As any other 802.x protocol, the IEEE 802.11 protocol covers the physical layer and the Medium Access Control (MAC) layer [2, 1]. Figure 3 summarizes a brief description of the IEEE 802.11 layers [1].

802.2			Data Link Layer
802.11 MAC			
FH	DS	IR	PHY Layer

Figure 3: IEEE 802.11 Layers Description

A) Physical Layer

The IEEE 802.11 draft specification requires three different physical-layer implementations, which are Frequency Hopping Spread Spectrum (FHSS), Direct Sequence Spread Spectrum (DSSS), and Infrared (IR) light [2].

The FHSS uses the 2.4 GHz Industrial, Scientific, and Medical (ISM) band, for instance between 2.4000 and 2.4835 GHz. In the U.S., a maximum of 79 channels are stated in the hopping set. The first channel has a center frequency of 2.402 GHz, and all succeeding channels are spaced 1 MHz apart. The 1 MHz separation is required by the Federal Communications Commission (FCC) for the 2.4 GHz ISM band. The channel separation matches to 1 Mb/s of instantaneous bandwidth. Three different hoping sequence sets are formed with 26 hopping sequences per set. Different hopping sequences make multiple BSSs possible to coexist in the same geographical area, which may become crucial to reduce congestion and maximize the total throughput in a single BSS. Having three different sets is in order to avoid extended collision periods between different hopping sequences in a set. The minimum hop rate allowed is 2.5 hops/s [1].

The DSSS also uses the 2.4 GHz ISM frequency band, where the 1 Mb/s basic rate is encoded by differential binary phase shift keying (DBPSK), and a 2 Mb/s enhanced rate uses differential quadrature phase shift keying (DQPSK). The spreading is achieved by dividing the available bandwidth into 11 sub-channels, each 11 MHz wide, and using an 11-chip Barker sequence to spread each data symbol [1].

The IR (Infrared) specification recognizes a wavelength range from 850 nm to 950 nm. The IR band is devised for indoor use only and works with non-directed transmissions. The IR specification is created to enable stations to receive line-of-site and reflected transmissions [1].

B) MAC Sublayer

The Medium Access Control (MAC) sublayer has responsibilities for the channel allocation procedures, protocol data unit (PDU) addressing, frame formatting, error checking, and fragmentation and reassembly [1]. The transmission medium can solely operate in the contention mode. The operation of the transmission medium in the contention mode requires all stations to contend for access to the channel when each packet is transmitted. The medium can also alternate between the contention mode and non-contention mode, known as the contention period (CP) and a contention-free period (CFP) respectively [1]. While the medium is in the CFP, the medium usage is mediated by the AP, thus removing the need for stations to content for channel access. The IEEE 802.11 provides three different types of frames, which are management, control, and data. The management frames are utilized for station association and disassociation with the AP, timing and synchronization, and authentication and de-authentication [1]. Control frames are used for handshaking during the CP, for positive acknowledgements during the CP, and to end the CFP. Data fames are used for the transmission of data during the CP and CFP, and can be combined with polling and acknowledgements during the CFP [1].

Figure 4 illustrates the standard IEEE 802.11 frame format [1]. Note that if the optional Wired Equivalent Privacy (WEP) protocol is used, the frame body (MSDU) is variable-length field consisting of the data payload and 7 octets for encryption and decryption.

The IEEE Standard 48-bit MAC addressing is for identifying a station [1].

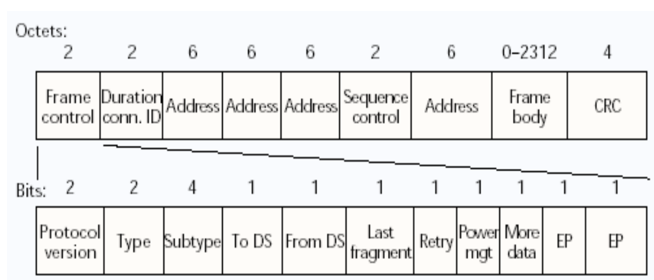


Figure 4: Standard IEEE 802.11 Frame Format

The 2 duration octets present the time (in microseconds) the channel will be allotted for successful transmission of a MAC protocol data unit (MPDU). The type bits indicate the frame as control, management, or data. The subtype bits also show the type of frame such as Clear to Send control frame, etc. Error detection is checked by a 32-bit cyclic redundancy check (CRC) [1].

III. BASIC ACCESS METHOD: CSMA/CA

The Distributed Coordination Function (DCF) is a basic channel access protocol for asynchronous data transmission in the contention period based on a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism [2, Sheu2002, Issariyakul2003]. As defined in the standard, all stations must support the DCF [1]. The DCF operates exclusively in the ad hoc network, and either works solely or works with the PCF in an infrastructure network. The MAC architecture is described in Figure 5 that shows the DCF sitting directly on top of the physical layer and supporting contention services [1].

Contention services imply that each station with an MSDU queued for transmission must contend for access to the channel. If the MSDU is transmitted, the station must contend again for access to the channel for all following frames. Contention services support fair access to the channel for all stations [1].

A CSMA protocol works in the following way. A station wishing to transmit senses a medium. If the medium is busy (e.g. some other station is transmitting), then the station will defer its transmission to a later time. If the medium is sensed free, then the station is permitted to transmit [2].

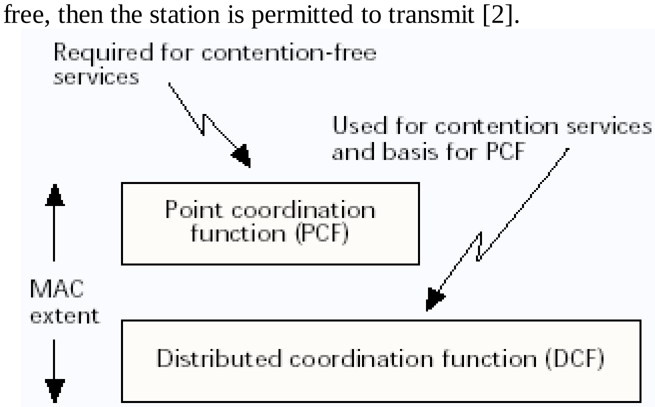


Figure 5: MAC Architecture

These kinds of protocols are very effective when network loads are not heavy because it allows stations to transmit with minimum latency. However, there is always a chance of occurrence of collision when more than one station transmits simultaneously, because stations sense the medium free and decide to transmit at one. These collision situations must be identified so that the MAC layer can retransmit the packet by itself and not by upper layers, which may cause significant delays [2].

In the Ethernet case, this collision is identified by the transmitting stations, which enter a retransmission stage based on an exponential random backoff algorithm [2]. Even though the Collision Detection is a good mechanism on a wired LAN, they cannot be applied to a Wireless LAN environment, due to the following two reasons [2]:

- Implementation of a Collision Detection Mechanism would require the implementation of a Full Duplex radio, enabling transmitting and receiving at once, which is an approach increasing the price significantly.
- Different from the wired LAN environment using the Collision Detection mechanism, the assumption that all stations hear each other is not true on a wireless environment. That is, the fact that a station wishes to transmit and senses the medium free does not necessarily mean that the medium is free around the receiver area.

In order to solve these problems, the IEEE 802.11 provides a Collision Avoidance mechanism combined with a positive acknowledgement scheme, as follows [2]:

A station is willing to transmit and senses the medium. If the medium is busy, then the station defers the transmission. If the medium is free from the specified time (called DIFS, Distributed Inter Frame Space, in the standard), then the station is allowed to transmit. The receiver will check the CRC of the received packet and transmit an acknowledgement packet (ACK). The receipt of the acknowledgement means to the sender no collision occurred. If the sender does not receive ACK, it will resend the same fragment until it receives the ACK or throw away after a certain number of retransmission [2].

In IEEE 802.11 [1], carrier sensing is done in terms of two layers, which are physical carrier sensing at the air interface and virtual carrier sensing at the MAC sublayer. Physical carrier sensing recognizes the existence of other IEEE 802.11 WLAN users by analyzing all detected packets, and also identifies activity in the channel through relative signal strength from other source [1].

A source station performs virtual carrier sensing by transmitting Request To Send (RTS), Clear To Send (CTS), and data frames containing MPDU duration information in their headers. An MPDU, a complete data unit being passed from the MAC sublayer to the physical layer, contains header information, payload, and a 32-bit CRC. The duration information indicates the amount of time (microseconds) after the end of the current frame that the channel will be used to complete the successful transmission of the data or management frame [1]. Stations in the BSS utilize the duration information to modify their network allocation vectors (NAVs), indicating the amount of time that has to elapse until the present transmission session is done and the channel can be checked out again if it is idle or not. The channel is indicated as busy if either the physical or virtual carrier sensing mechanisms say the channel is busy. The wireless medium is accessed based on priority controlled through the utilization of Inter Frame Space (IFS) time intervals between the transmissions of frames. The IFS intervals are required periods of idle time on the transmission medium. There are three IFS intervals specified in the standard as follows [2, 1]:

- Short Inter Frame Space (SIFS): This interval is the smallest IFS, which is followed by PIFS and DIFS respectively. When a station is only required to wait a SIFS, it has priority access over those stations that are required to wait a PIFS or DIFS before transmitting. Therefore, SIFS has the highest-priority for accessing to the communications medium.

- Point Coordination Function IFS (PIFS): This interval is used by the Access Point (AP) to obtain access to the medium before any other station. This interval value is a SIFS plus slot time, for example 78 microseconds.

- DCF-IFS (DIFS): This interval is IFS used for a station wishing to start a new transmission, which is calculated as PIFS plus one slot time, for instance 128 microseconds.

For the basic access mechanism, when a station senses the idleness of the channel, the station waits for a DIFS period and samples the channel again. If the channel is still idle, the station sends an MPDU. The receiver calculates the checksum and decides the correctness of the received packet. If the received packet is correct, the receiver waits a SIFS interval and transmits a positive acknowledgement frame (ACK) back to the sender station for the successful transmission [1]. Figure 6 illustrates a timing diagram explaining the successful transmission of a data frame [1].

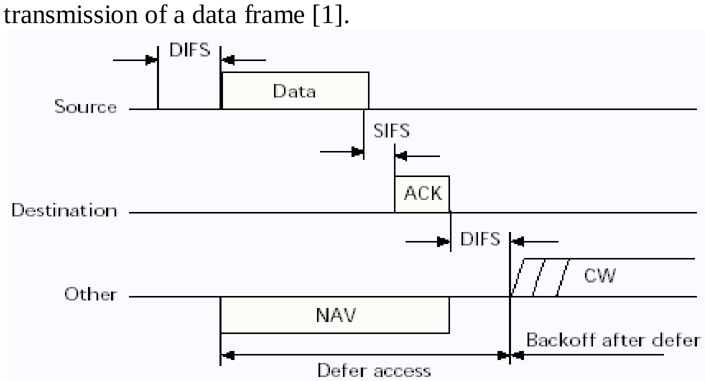


Figure 6: Transmission of an MPDU without RTS/CTS.

When the data frame is transmitted, the duration information of the frame is utilized to inform all stations in the BSS how long the medium will be busy. All stations hearing the transmission of the data frame adjust their NAVs according to the duration field value containing the SIFS interval and the ACK of the data frame. When a collision occurs, a source station continues transmitting the complete MPDU because the source station in a BSS cannot hear its own transmissions. If the MPDU is larger, for example 2300 octets, a lot of channel bandwidth is wasted because of a corrupt MPDU. The station can use RTS and CTS control frames in order to reserve channel bandwidth before it transmits an MPDU so that the amount of bandwidth wasted is minimized when a collision occurs [1]. RTS and CTS control frames are relatively small like 20 octets for RTS and 14 octets for CTS compared to the maximum size of MPDU such as 2346 octets. After successfully contending for the channel, the source station transmits the RTS control frame first with a data or management frame queued for transmission to an indicated destination station. All stations in the BSS hearing the RTS packet read the duration field and adjust their NAVs based on the duration information contained in the RTS.

CONCLUSION

Medium Access Control (MAC) involving design of resource reservation schemes, priority scheduling algorithms, and routing and multicasting mechanisms that take into account peculiar characteristics of multimedia traffic and unique characteristics of Ad hoc wireless networks. In this paper, we discuss MAC protocols architecture and layer discussions.

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