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Survey of IEEE 802.11 Standards

Engineering

KEYWORDS: Carrier sense multiple access/collision avoidance(CSMA/CA), medium access controller, physical layer, Quality of Service (Qos), wireless LAN(WLAN)

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ABSTRACT

This paper specifies technical corrections and clarifications to IEEE Std 802.11 for wireless local area networks (WLANS) sounds as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions. It also incorporates Amendments 1 through 8 including a corrigendum.

1. INTRODUCTION

IEEE 802.11 is a set of standards for implementing wireless local area network (WLAN) computer communication in the 2.4, 3.6 and 5 GHz frequency bands. These standards provide the basis for wireless network products using the Wi-Fi brand. 802.11 was the first wireless networking standard. The original version of the standard IEEE 802.11 was released in 1997 and clarified in 1999. The 802.11 standards are a group of evolving specifications defined by the Institute of Electrical and Electronic Engineers (IEEE). Commonly referred to as Wi-Fi the 802.11 standards define a through-the-air interface between a wireless Clint and a base station access point or between two or more wireless clients. There are many other standards by the IEEE, such as the 802.3 Ethernet standards. In June 1997, the IEEE finalized the initial standard for WLANs: IEEE 802.11. Each amendment has been published with a letter in addition to the 802.11. Example: IEEE 802.11a defined operations in the 5-GHz band. The radio interface operating at 5 GHz is therefore called the "A radio." In 2007, the IEEE consolidated all amendments into a new 802.11 standard.

2. IEEE802.11 Standard Overview:

802.11: A family of IEEE standards that extend the common wired Ethernet local network standard into the wireless domain. 802.11 standards are widely known as "Wi-Fi" because the Wi-Fi Alliance provides certification for 802.11 products. There have been four major 802.11 standards designated with letter suffixes (a, b, g and n); the latest and fastest being 802.11n (the slowest is 802.11b, and the two medium speed are 802.11a and 802.11g). For more about Wi-Fi networks, see wireless LAN and Wi-Fi. Following are the 802.11 specifications, from slowest to fastest.

FHSS Definition: - Frequency Hopping Spread Spectrum (FHSS) when using FHSS, the frequency spectrum is divided into channels. Data packets are split up and transmitted on these channels in a random pattern known only to the transmitter and receiver. Because collocated networks follow different random patterns, or hop code tables, multiple networks can operate in close proximity without interfering.

DSSS Definition: - Direct Sequence Spread Spectrum (DSSS) The DSSS encoder spreads the data across a broad range of frequencies using a mathematical key. The receiver uses the same key to decode the data. While narrowband and DSSS transmissions use the same total power to send data, DSSS uses a lower power density (power/frequency), making it harder to detect. DSSS also sends redundant copies of the encoded data to ensure reception.

802.11a:- This standard defines orthogonal frequency-division multiplexing (OFDM) 802.11a transmits up to 54 Mbps. It uses the 5 GHz band and is not backward compatible with the slower 11b. The 802.11a amendment to the original standard was ratified in 1999. The 802.11a standard uses the same core protocol as the original standard, operates in 5 GHz band, and uses a 52-subcarrier OFDM with a maximum raw data rate of 54 Mbit/s, which yields realistic net achievable throughput in the mid-20 Mbit/s. The data rate is reduced to 48, 36, 24, 18, 12, 9 then 6 Mbit/s if required. 802.11a originally had 12/13 non-overlapping channels, 12 that can be used indoor and 4/5 of the 12 that can be used in outdoor point to point configurations.

802.11b:- Using the Direct Sequence Spread Spectrum (DSSS) and the 2.4 GHz band, 802.11b boosted speed to 11 Mbps while retaining the slower DSSS modes to accommodate weak signals. It was the first major wireless local network standard, and many laptops were retrofitted with 11b network adapters. Later, 11b was built into the laptop motherboard. 802.11b is a Wi-Fi (Wireless LAN) standard. It is used for wireless internet purposes, mainly to connect to the internet or a network wirelessly.

Physical Layer: -

The IEEE 802.11 Working Group has developed an entire family of IEEE 802.11 protocols, the standards define both the Physical Layer and the Data Link Layer operation for IEEE 802.11 protocols. The first version of the IEEE 802.11 standard supported a data rate of 1 Mbps, using a physical layer transmission technique called Frequency Hopping Spread Spectrum (FHSS). Later improvements doubled the data rate to 2 Mbps, while still maintaining backward compatibility with the 1 Mbps versions. These standards were developed for both FHSS and DSSS (Direct-Sequence Spread Spectrum) transmission at the physical layer.

Channel Access Protocols: -

The IEEE 802.11b standard defines three channel access protocols that can be used at the Medium Access Control (MAC) sub layer. These protocols are called Distributed Coordination Function (DCF), Request-To-Send/Clear-To Send (RTS/CTS), and Point Coordination Function (PCF).

Distributed Coordination Function (DCF):-

The IEEE 802.11b DCF protocol solves this problem with a combination of mechanisms acknowledgements, timeouts, and retransmissions. Upon the successful arrival of a frame at the intended recipient, the receiver sends back a control frame with a positive acknowledgement to the sender. This acknowledgement tells the sender that its frame transmission was successful. In the absence of the acknowledgement, the sender will retransmit another copy of the same frame after a randomly chosen short timeout interval (e.g., up to 1 millisecond). This mechanism handles collision-related losses just the same as corruption-related losses due to wireless channel errors. It also recovers from the loss of either the data frame or its acknowledgement. In both cases, a frame retransmission is required.

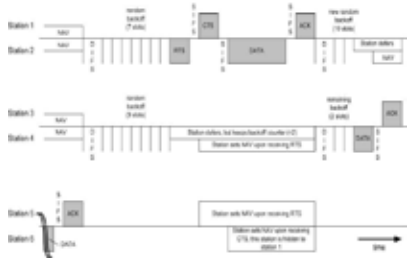

Figure 1:- Distributed Coordination Function Operation

802.11c:- Defines bridging operations for 802.11. 802.11c has been included as a chapter in the 802.1D standard concerning wireless bridging.

- Recommendations about bridge operation procedures.
- Used by AP manufactures.
- Interoperability of APs.
- Approved in 1998.

802.11d:- International roaming extensions. Add a country field in beacons and other frames. Adds countries not defined by the original standard.

The AX411 Access Point supports the IEEE 802.11d (world mode) standard by default. This standard causes the access point to broadcast the country it is operating in as part of its beacons and probe responses. This standard allows client stations to operate in any country without reconfiguration.

IEEE 802.11d was developed out of necessity, as initially, IEEE 802.11 was limited to only a few geographical domains. IEEE 802.11d was approved to provide recommendations for wireless communications, whereby geographical information is added to transmitted frames. This specification was applied to the frame format of beacons, probes and probe requests.

IEEE 802.11d allows a device to self-configure and operate according to the regulations of its operating country and includes parameters like country name, channel quantity and maximum transmission level.

802.11e:-Quality of service (QoS) features. Wi-Fi Multimedia (WMM) is a subset of 802.11e.

Introducing QoS:-
The Quality of Service (QoS) identifier introduced into the system. In this way those applications should have a high quality of service is required can tag their transmissions and take priority over the transmissions carrying data that does not require immediate transmission and response. In this way the level of delay and jitter on data such as that used for VoIP and video may be reduced. To introduce the QoS identifier, it has been necessary to develop a new MAC layer and this has been undertaken under the standard IEEE 802.11e. In this the traffic is assigned a priority level prior to transmission. These are termed User Priority (UP) levels and there are eight in total. Having done this, the transmitter then priorities all the data it has to waiting to be sent by assigning it one of four Access categories (AC).

MAC Functionality:-

- Reliable data delivery
- Fairly control access to the shared wireless medium.
- Protect the data that it delivers.
  MAC Frame Exchange Protocol:-
- Noisy and unreliable medium
- rame exchange protocol
- adds overhead to IEEE 802.3
- Hidden node problem
- Requires participation of all stations.
- Every station reacts to every frame it receives.

EDCA:-
The Enhanced Distributed Channel Access (EDCA) provides a mechanism whereby traffic can be prioritized but it remains a contention based system and therefore it cannot guarantee a give QoS. In view of this it is still possible that transmitters with data of a lower importance could still pre-empt data from another transmitter with data of a higher importance.

When using EDCA, a new class of interframe space called an Arbitration Inter Frame Space (AIFS) has been introduced. This is chosen such that the higher the priority the message, the shorter the AIFS and associated with this there is also a shorter contention window. The transmitter then gains access to the channel in the normal way, but in view of the shorter AIFS and shorter contention window, this means that the higher the chance of it gaining access to the channel.

802.11F:- Set of recommendations (optional) defining the Inter-Access Point Protocol (IAPP) for exchanging client security context between access points (AP).

Communication between 802.11 APs on the "distribution system"

- Exchange of information about a mobile station between APs.
- Maintenance of bridge forwarding tables.
- Securing the communications between the APs.

802.11g:- 802.11g is a Wi-Fi standard developed by the IEEE for transmitting data over a wireless network. It operates on a 2.4 GHz bandwidth and supports data transfer rates up to 54 Mbps. 802.11g is backward compatible with 802.11b hardware, but if there are any 802.11b-based computers on the network, the entire network will have to run at 11 Mbps (the max speed that 802.11b supports). However, you can configure your 802.11g wireless router to only accept 802.11g devices, which will ensure your network runs at its top speed.

New Features of the IEEE 802.11g Standard:-
The new features of the IEEE 802.11g standard are

- The provision of four different physical layers.
- The mandatory support of the short preamble type.
- The ERP network attributes.
- Newly defined protection mechanisms that deal with interoperability aspects.
- The CTS-to-self mechanism. In the next subsections, each of the above features is explained extensively.

802.11h:- Amendment for spectrum and transmit power management. It adds Dynamic Frequency Selection (DFS) to avoid radar in the 5-GHZ band as well as Transmit Power Control (TPC) to the 802.11a specification. 5.25-5.35 GHz and 5.47-5.725 GHz Note Code (ND) use is optional for both master and client devices. 802.11h spacification for spectrum and transmit power management. These are two new mechanisms the 802.11h defines on top of the 802.11 MAC and the 802.11a PHY, namely, DFS (Dynamic Frequency Selection) and TPC (Transmit Power Control), and then describe an example DFS algorithm and an intelligent TPC mechanism as sample applications of the 802.11h.

802.11i:- Wi-Fi Protected Access (WPA) was an early subset of 802.11i, whereas Wi-Fi Protected Access 2 (WPA2) is the full 802.11i implementation. It defines Robust Security Network's (RSN), Advanced Encryption Standard (AES), and Temporal Key Integrity Protocol (TKIP) encryptions. The 802.11i specification consists of three main pieces organized into two layers.

802.11i Goals:

- Security for Infrastructure.
- Relies on 802.1X EAP for authentication, authorization and key management.
- Adopts AES based encapsulation CCMP.
- Requires authentication servers for Central authentication/ authorization.

8**02.11j:**- Amendment specific for regulation in Japan allowing use in the 4.9-GHz band. IEEE 802.11j is an IEEE 802.11 amendment that extends wireless communication and signaling for 4.9 GHz and 5 GHz band operations in Japan. IEEE 802.11j facilitates communications for outdoor, indoor and mobile applications that comply with wireless local area network (WLAN) regulations.

802.11k:- The amendment that defines radio management. It will facilitate roaming in an Extended Service Set (ESS) by helping to choose the best access point available (load balancing).IEEE 802.11k and 802.11r are the key industry standards now in development that will enable seamless Basic Service Set (BSS) transitions in the WLAN environment. The 802.11k standard provides information to discover the best available access point.

802.11k is intended to improve the way traffic is distributed

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within a network. In a wireless LAN, each device normally connects to the access point (AP) that provides the strongest signal.

802.11L:- Reserved and will not be used.

802.11m:- An ongoing task group charged with the maintenance of the standard. It periodically produces the revisions as well as clarifications and modifications. IEEE 802.11m is an ongoing initiative that provides a unified view of the 802.11 base standards through continuous monitoring, management and maintenance. IEEE 802.11m is based on two documented initiatives, IEEE 802.11ma and IEEE 802.11mb. IEEE 802.11ma is comprised of the eight amendments (a, b, d, e, g, h, i, j) editorially applied through 2003. IEEE 802.11mb is the current maintenance draft version.

802.11n:- Amendment unleashing high speeds, Multiple Input Multiple Output (MIMO), 40-MHz channels, and many other features.

802.11o:- Reserved and will not be used.

802.11p:- Defines WAVE (Wireless Access for Vehicular Environment) for ambulances and other high-speed vehicles and a roadside infrastructure in the licensed band of 5.9 GHz. As part of a dedicated short range communications (DSRC) system, 802.11p operates in the 5.9 GHz band and deals with roaming from cell to cell in a fast-moving vehicle.

802.11q:- Not used, to avoid confusion with 802.1q VLAN trucking.

802.11r:- This amendment is charged with ensuring fast roaming, even for vehicles in motion. It is supposed to reduce the roaming delay between two basic service sets (BSS) to less than 50 ms. IEEE 802.11r was published in 2008 and enables wireless connectivity with secure and fast handoffs between base stations. The standard also refines the mobile client transition process between access points by redefining the security key negotiation protocol, which permits negotiations and requests for wireless resources. IEEE 802.11r key strength is IEEE 802.1X security support, which facilitates the deployment of portable phones with Session Initiation Protocol-based Voice over Wi-Fi.

802.11s:- An IEEE working group that is defining a Wi-Fi mesh network that can route around failures. Each device becomes a mesh station (mesh STA) that must support the Hybrid Wireless Mesh Protocol (HWMP), although other protocols can be used.

802.11t:- This amendment regroups recommended practices to test and measure performance in wireless networks. Also called WPP (Wireless Performance Prediction).

802.11u:- The amendment to improve internetworking with external non-802.11 networks. The idea is to be able to specify services provided by a BSS, to allow access to the BSS depending on previous authentication with other networks, and to restrict access to the BSS.

802.11v:- This amendment will enable configuring clients while they are connected to the network.

802.11w:- This amendment will bring protected management frames. It is supposed to be an add-on to 802.11i covering management frame security.

802.11 x: - Not used to avoid confusion with 802.1x.

802.11y:- Allows operation in the 3650- to 3700-MHz band (licensed), allowing higher power and thus longer ranges.

IEEE 802.11y adds three new concepts

Contention based protocol (CBP):- Enhancements have been made to the carrier sensing and energy detection mechanisms of 802.11 in order to meet the FCC's definition of a contention based protocol.

Extended channel switch announcement (ECSA):- provides a mechanism for an access point to notify stations of its intention to change channel frequency or bandwidth. This mechanism will allow for the WLAN to continuously choose the channel that is the least noisy and the least likely to cause interference. ECSA is also used in 802.11n, making it possible to switch between the 3.65GHz, 2.4GHz and 5GHz bands.

Dependent station enablement (DSE):- is the mechanism by which an operator extends and retracts permission to license exempt devices (referred to as dependent STAs in .11y) to use licensed radio spectrum.

Applications:-

- Back haul for Municipal Wi-Fi networks.
- Industrial automation and controls.
- QoS links for video delivery.
- Campus and enterprise networking.
- Last Mile Wireless Broadband Access.
- Fixed Point to point links.
- Fixed point to mobile links.
- Public safety and security networks.

802.11z:- Direct Link Setup (DLS) allows two stations to communicate directly with each other. Client devices are usually connected to an Access Point (AP) in what is known as a star topology. Data moving from one of the clients to another is transferred though the AP.

3. 802.12:- In 1990 it seemed that FODI would be the only standard 100m/s shared-medium LAN technology. However, the IEEE 802 project has since developed two new 100Mb/s standards - 802.12 and 100BaseTwhich offer equivalent data rates at much lower cost. In addition, packet switching has emerged as a third Technology that is driving the evolution of LANs. Maintaining compatibility between 10Base-T and the new low cost 100 Mb/s LAN was not an easy goal to achieve, however. The easy part was deciding on supporting the same frame format and the same basic star-wiring architecture as 10Base-T. However, the ten-fold increase in speed meant that the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) algorithm could only be retained at the cost of reducing the maximum topology by a factor of 10.

3.1 Multiplexin: - Instead of following the Fast Ethernet standard for twisted pair cabling by using only 2 pairs of wires, 100VG-AnyLAN used all four pairs in either Category 3 or Category 5 twisted pair cable. The design goals were to avoid the radio frequency radiation emitted at the higher frequencies required by Fast Ethernet and to leverage existing wiring installations of Category 3 cabling that most organizations had recently installed to support 10 megabit twisted-pair Ethernet.

3.2 Deterministic: - When Ethernet became Fast Ethernet, it continued to use the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) mechanism to manage traffic on the network cable.

4. 802.14:- In the mid-1990s the IEEE 802 committee formed a subcommittee (802.14) to develop a standard for cable modem systems. IEEE 802.14 developed a draft standard, which was ATM-based. However, the 802.14 working group was disbanded when North American multi system operators (MSOs) instead backed the then-fledgling DOCSIS 1.0 specification, which generally used best efforts service and was IP-based (with extension code points to support ATM for QoS in the future).

4.1 DOCSIS (Data Over Cable Service Interface Specification): - In the late 1990s, a consortium of US cable operators, known as "MCNS" formed to quickly develop an open and interoperable cable modem specification. The group essentially combined technologies from the two dominant proprietary systems at the time, taking the physical layer from the Motorola CDLP system and the MAC layer from the LAN city system.

5. 802.15:- IEEE 802.15 is a working group of the IEEE 802 standards committee which specifies Wireless Personal Area Network (WPAN) standards. It includes seven groups.

1: WPAN / Bluetooth: - Task group one is based on Bluetooth technology. It defines physical layer (PHY) and Media Access Control (MAC) specification for wireless connectivity with fixed, portable and moving devices within or entering personal operating space. Standards were issued in 2002 and 2005.

2: Coexistence: - Task group two addresses the coexistence of wireless personal area networks (WPAN) with other wireless devices operating in unlicensed frequency bands such as wireless local area networks (WLAN). The IEEE 802.15.2 standard was published in 2003 and task group two went into "hibernation".

3: High Rate WPAN: - IEEE 802.15.3 is a MAC and PHY standard for high-rate (11 to 55 Mbit/s) WPANs. IEEE 802.15.3a was an attempt to provide a higher speed UWB PHY enhancement amendment to IEEE 802.15.3 for applications which involve imaging and multimedia.

IEEE 802.15.3b amendment was released on May 5, 2006. It enhanced 802.15.3 to improve implementation and interoperability of the MAC. This will include minor optimizations while preserving backward compatibility. In addition, this amendment corrected errors, clarified ambiguities, and added editorial clarifications.

4: Low Rate WPAN: - IEEE 802.15.4 (Low Rate WPAN) deals with low data rate but very long battery life (months or even years) and very low complexity. The standard defines both the physical (Layer 1) and data-link (Layer 2) layers of the OSI model. The first edition of the 802.15.4 standard was released in May 2003. Several standardized and proprietary networks (or mesh) layer protocols run over 802.15.4-based networks.

5: mesh networking: - IEEE 802.15.5 provides the architectural framework enabling WPAN devices to promote interoperable, stable, and scalable wireless mesh networking. This standard is composed of two parts: low-rate WPAN mesh and high-rate WPAN mesh networks. The low-rate mesh is built on IEEE 802.15.4-2006 MAC, while the high rate mesh utilizes IEEE 802.15.3/3b MAC. The common features of both meshes include network initialization, addressing, and multihop unicasting. In addition, the low-rate mesh supports multicasting, reliable broadcasting, portability support, trace route and energy saving function, and the high rate mesh supports multihop time-guaranteed service.

6: Body Area Networks: - As of December 2011, the IEEE 802.15.6 task group has approved a draft of a standard for Body Area Network (BAN) technologies. The draft was approved on July 22, 2011 by Letter Ballot to start the Sponsor Ballot process

7: visible light communication: - The IEEE 802.15.7 Visible Light Communication Task Group has completed draft 5c of a PHY and MAC standard for Visible Light Communications (VLC). The inaugural meeting for Task Group 7 was held during January 2009, where it was chartered to write standards for free-space optical communication using visible light.

5.1 Wireless Next Generation Standing Committee: - The IEEE 802.15 Wireless Next Generation Standing Committee (SCwng) is chartered to facilitate and stimulate presentations and discussions on new Wireless related Technologies that may be subject for new 802.15 standardization projects or to address the whole 802.15 work group with issues or concerns with current techniques or technologies.

5.2 IEEE 802.15.4:- IEEE 802.15.4 is a standard which specifies the physical layer and media access control for low-rate wireless personal area networks (LR-WPANs). It is maintained by the IEEE 802.15 working group. It is the basis for the Zig Bee, ISA100.11a, Wireless HART, and Mi-Wi specifications, each of which further extends the standard by developing the upper layers which are not defined in IEEE 802.15.4.

6. IEEE 802.16:- IEEE 802.16 is a series of Wireless Broadband standards authored by the Institute of Electrical and Electronics Engineers (IEEE). The IEEE Standards Board established a working group in 1999 to develop standards for broadband for Wireless Metropolitan Area Networks. The Workgroup is a unit of the IEEE 802 local area network and metropolitan area network standards committee. Although the 802.16 family of standards is officially called Wireless MAN in IEEE, it has been commercialized under the name "WiMAX" (from "Worldwide Interoperability for Microwave Access") by the WiMAX Forum industry alliance. The Forum promotes and certifies compatibility and interoperability of products based on the IEEE 802.16 standards.

6.1 Introduction to IEEE Standard 802.16:-

The IEEE Standard 802.16 is still very much a new standard when compared to existing standards such as the more mature IEEE Standard 802.11, the standard used for Wi-Fi networking commonly seen in home and business. However, while the 802.11 standard is primarily used for small local area networks, the 802.16 standard is designed to be used as a means of allowing wireless broadband access as an alternative to cable and DSL connections.

The 802.16 standard is more commonly known referred to as Wireless MAN due to the fact that its goal is to implement a set of broadband wireless access standards for wireless metropolitan area networks. To this end, much of the work on the standard has been focused on the "last mile" that would allow fixed and mobile wireless substations to connect to the fixed wireless base stations, thus allowing the delivery of high-speed internet connections to customers. The 802.16 standard corresponds to the physical and data link layers of the OSI reference model, The 802.16 standard follows other standards within the 802 family in that it defines multiple physical layer (PHY) specifications that can be used, but all of them are supported by the same medium access control (MAC) layer. This flexibility is important as it allows for a common MAC implementation to be used by manufacturers, providing support for each of the possible PHY specifications without having to redevelop the MAC.

6.2 Frequency Bands:-

The 802.16 standard defines a number of air interfaces that make use of a frequency band that can be divided into one of three categories 10-66 GHz licensed bands, licensed bands below 11 GHz, and unlicensed bands below 11 GHz. Table 1 summarizes the air interface designations and their applicable category of frequency bands.

Conclusion:- The various IEEE Standards have been studied in detail to improve Quality of Service in Wireless LANs.

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