IEEE 802.11
Wireless Access Method and Physical Layer Specifications

An Improved Reference Model for IEEE 802.11

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Abstract

The current 802.11 reference model is not well suited to describing a LAN in which a single MAC protocol is used with a plurality of widely diverse PHYs. This submission proposes an improved reference model that remedies these shortcomings. The basic problem with the current reference model is that the layer which "normalizes" the physical media characteristics is a medium independent layer within PHY, and there is no provision for a medium dependent layer within MAC. This problem appears to have originated due to several semantic issues, the most significant of which is that the characteristics of frequency hopping PHYs have (implicitly) extended the conventional concept of "medium" beyond what is present in other 802 PHYs. This extension of "medium" involves time–variant medium usage rules that are visible to, and may be controlled by, MAC, but are independent of, and may by non–synchronous with, other MAC functions. The suggested solution to the limitations of the current reference model involves relocation of the medium "normalization" from the Medium Independent layer within PHY to a Physical Medium Adaptation (PMA) layer within MAC and moving the optional exposed DTE/DCE interface to the MAC/PHY boundary. A medium–independent Convergence layer remains within PHY to permit description of common functions below the MAC/PHY boundary in a uniform manner.

Issues Addressed

1.5, 3.1, 12.1, 12.1(a), 12.2(a), 12.3, 12.4, 12.8, 12.9, 15.4, 24.3

Specific comments on these issues appear in section 6.

1. Introduction

The primary purpose of a reference model is to provide "a common vehicle for understanding and communicating the various components and interrelationships of the standards." (This text is quoted from IEEE Std 802–1990, Overview and Architecture, p.15.) The reference model currently in use by 802.11, which appears in P802.11–93/20a3, lacks several elements needed to describe the functions and interactions needed for a single MAC protocol to be used in conjunction with any one of a plurality of diverse PHYs. Since the use of a single MAC protocol with all of the wireless PHYs is required by 802.11's PAR, the 802.11 reference model should be updated to provide the necessary descriptive framework. Continuing to define the MAC and PHY functions and interactions under the current reference model will result in higher complexity and lower clarity of the resulting descriptions.

The shortcomings of the current reference model are most visible when "looking downward" from the MAC layer toward the plurality of PHY alternatives that must be supported. The closer the MAC group gets to defining the 802.11 MAC protocol, the more critical it becomes to have a clear descriptive framework for the mechanisms and interfaces that permit this MAC protocol to be used with the various PHYs. Many submissions, including most of the concrete proposals for MAC protocols and for PHY transceiver interfaces, have avoided directly confronting these problems by restricting themselves to single boxes on the existing reference model. During the past year, numerous submissions concerning aspects of the MAC/PHY interface have explicitly or implicitly attempted to circumvent some of the problems with the existing reference model. A non–exhaustive list of such submissions includes:

- P802.11–92/85: Accommodating a Range of Intelligence in the Physical Layer (Schuessler);
- P802.11–93/13: MAC Interaction with a Frequency Hopping PHY (Belanger);
- P802.11–93/25: Radio PHY Layer for use with Medium Independent MAC (Rypinski);
- P802.11–93/73: An Unintelligent Radio Interface (Cooper);
- P802.11–93/75: A Compromise MAC Protocol Concept (Schuessler); and
- P802.11–93/82: Comments on Document P802.11–92/127r1 (Stevens).

At the P802.11 Interim meeting in September, 1993, two submissions directly addressed the reference model and proposed modifications thereto:

- P802.11–93/115: Protocol Layering Alternatives for Practical Implementation (Fischer); and
- P802.11–93/140: MAC/PHY Functional Partitioning (Belanger, Ennis and Diepstraten).

These submissions generated considerable discord between proponents of the current reference model and advocates of the modifications. As is often the case when people on opposite sides of the same interface cannot agree on how to describe the problem, there are underlying semantic issues that have not, to date, been adequately identified.

This submission

- identifies semantic issues that may be at the root of the disagreement over the reference model,
- summarizes problems with the current reference model as a descriptive basis for the 802.11 MAC;
- proposes an improved reference model, and
- lists some issues addressed by this proposal.

2. Semantic Problems

2.1 The Meaning of "Medium"

Most of the problems with the layer subdivisions of the current 802.11 reference model appear to originate with an extension that 802.11 has introduced to the concept of "medium" (as applied to LANs).

- The conventional concept of "medium" includes the path over which the electromagnetic signals are conducted, the method used to represent the information being transferred using those signals, the modulation technique used convey the information–bearing signals over the path, and the electrical and mechanical aspects of attaching stations to the path. A particular PHY layer is responsible for the conveyance of MPDUs between stations through the exchange of PhPDUs among peer PHY entities over a medium with particular characteristics. This concept of "medium" is adequate to describe physical layer alternatives on wired LANs. Using 802.3 as an example, these differences include cable type (10base2, 10base5, 10baseT, etc.), modulation technique (10broad36), frequency band (10baseF), and/or data rate (1base5).
- **802.11 has extended the concept of "medium" to include time–variant medium usage rules that are independent of (and possibly not synchronized with) the medium access control functionality of the associated MAC layer, but which are visible to, and may require active involvement by, MAC–layer functions**. Among the current 802.11 PHY proposals, this MAC–visible, time–variant medium usage is peculiar to the frequency hopping PHYs. The variations among the other PHY types fall within the conventional concept of "medium." IR can be considered to be a (very) different frequency band and direct sequence spread spectrum can be considered to be a different modulation technique. However, the MAC–visible, time–variant medium usage is not unique to the current FH PHY. The differences in the MAC–visible, time–variant characteristics of a "slow" frequency hopper and a "fast" frequency hopper are likely to be as significant to the MAC layer as the differences between a frequency hopping PHY and a wired PHY.

2.2 Medium Independent Layer in PHY vs. Medium Dependent Layer in MAC

The need to support a plurality of PHYs under a single MAC requires subdivisions within the reference model that separate medium–dependent functions from medium–independent functions and interpose a mechanism to normalize the different characteristics of the various media types as seen by the core MAC services. This normalization can be accomplished within MAC, within PHY, or partially within each. The primary problems with the current reference model stem from locating **all** of the medium–dependent portions, as well as the normalization mechanism, fully within PHY. Because of 802.11's extended concept of "medium," this approach is incorrect. The proper location for the medium–dependent normalization mechanism is as a subdivision at the bottom of the MAC layer.

- Placing a medium–dependent subdivision with MAC is not a violation of protocol layering because the MAC layer is inherently PHY–dependent. Each of the 802 LANs is a combined MAC and PHY standard, with the lowest 802 layer that is fully medium–independent being the LLC layer. The original reason that IEEE 802 separated the OSI Data Link layer into LLC and MAC was to accommodate the fact that, for LANs, a portion of the Data Link layer functionality was PHY–dependent, and needed to be specified in a matched pair with a particular Physical Layer. If you doubt the existence of such dependencies, contemplate using the 802.5 MAC over any of the 802.3 PHY media alternatives!
- Other 802 LANs, such as 802.3 and 802.5, support several media types using an undivided MAC and a subdivided PHY. However, these LANs use the conventional concept of "medium," and utilize media alternatives that have been deliberately specified in manners that restrict PHY variations to non–MAC–visible characteristics such as cable type, modulation technique, frequency band, data rate, and connector type.

When the LAN "medium" includes MAC–visible variations, attempting to provide medium normalization fully within PHY also results in semantic problems:

- The upper subdivision of PHY in the current reference model is a "physical medium independent" subset of the "physical layer." Based on normal usage of the English language, such a subset should be null.
- The central subdivision of PHY is a "convergence layer" that lies below the optional exposed DTE/DCE interface. "Convergence" implies a many–to–one mapping, but the lack of an exposed interface between the Convergence Layer and the Medium Dependent Layer limits to one the quantity of interfaces across which "convergence" could occur.

2.3 Interpretation of the PAR

The problems with layer subdivisions in the 802.11 reference model appear to have occurred due to a lack of understanding of the extension of the concept of "medium" and the side effects thereof. However, there was also potential for confusion in the semantics of the governing documents. In particular, there are two plausible interpretations of the statement in the PAR that "... the MAC shall support PHYs using electromagnetic waves through the air ...".

- A literal interpretation of this statement would lead one to believe that the entire MAC layer must be PHY–independent, and all differences between the various portions of the electromagnetic spectrum and the associated usage strategies must be abstracted below the MAC/PHY boundary. This interpretation leads to subdivision of the PHY layer, with the PHY differences normalized by the uppermost subdivision. This interpretation is based on a fallacy regarding layer–independence, as discussed in the previous section.
- A practical interpretation of this statement is to utilize a common media access mechanism and uniform MAC frame formats across the various PHYs, rather than to exclude PHY–dependent aspects within the MAC layer. This interpretation appears to have been the original intent of the working group, based on the discussion notes and voting results recorded in the minutes of the P802.4L Task Group session on September 10, 1990 that initiated the revision of the 802.4L PAR into the 802.11 PAR (see document P802.11/90–10, especially pages 4 and 22).

3. The Descriptive Problems

The general descriptive problem is that some of the PHY variations require explicit PHY–dependent operations within the MAC layer, but the current reference model provides no medium–dependent subdivisions within MAC. The differences between several of the known 802.11 PHY alternatives include characteristics that affect the operation of MAC functions (under any of the MAC protocol proposals under serious consideration). The PAR allows for additional PHYs, rendering the future scope of such inter–PHY distinctions unbounded. Specific areas that suffer due to an inadequate descriptive basis are discussed below.

3.1 Normalization of time–variant PHY characteristics

For uniform MAC functionality, the most troublesome PHY distinctions relate to time. The fundamental activities of a MAC layer are to permit orderly sharing of a common LAN medium. This is done, at least in part, by controlling the intervals when the LAN transmitters at each station are enabled. In other 802 LANs that support multiple media types, the different media types may posses different static time–related characteristics (data rate, propagation delay, signal detection delay, etc.), but none of these media exhibit the autonomous, dynamic time–variant medium usage characteristics of a frequency hopping RF PHY. The most direct manner of describing the abstractions needed to normalize this MAC–visible, time–variant behavior is to have a medium–dependent subdivision of MAC. Any other approach will involve substantially greater descriptive complexity and may impose some unnecessary restrictions on MAC efficiency when operating with PHYs other than frequency hoppers. Of special relevance is the timing, synchronization, ad control of a frequency hopper's hop sequence. These functions are primarily, if not solely, in the MAC domain, but require continuous access to a timebase that is separate from, and probably not synchronized with, either the PHY–layer transmit and receive clocks or the host system's clock.

3.2 Handling MPDU–level error recovery

The error recovery techniques appropriate for use with PHYs that occupy sequentially a changing, narrow subset of their frequency band (e.g. FH) are different than those for use with PHYs that simultaneously occupy a broad subset of their frequency band (e.g. DS and IR). In the absence of a medium dependent function within MAC, there must be additional interchange across the MAC–PHY boundary, to determine and control the appropriate retry mechanisms.

3.3 Generation and interpretation of PHY–dependent information in MPDU headers

Most of the MAC protocol proposals either require or allow inclusion of PHY–dependent information in MPDU headers (or elsewhere in MAC frames). This information needs to be transferred within the MPDU so that (at least) FCS protection, and possibly address validation, can be performed prior to usage of this information at the recipient station. Since (by definition) a PHY layer must not modify the contents of an outgoing MPDU provided by MAC for transmission, nor interpret the contents of an incoming MPDU being provided to MAC upon reception, the simplest means for handling this PHY–dependent information uses a PHY–dependent function within MAC.

3.4 Determining compliance with the PAR

The only location between the LSAP at the top of MAC and the wireless medium entity at the bottom of PHY at which it is possible to test an implementation of MAC or PHY for conformance with the 802.11 standard is at the (optional) exposed DTE/DCE Interface. In the current reference model this interface is located between the Medium Independent Layer of PHY and the Convergence Layer of PHY. Because this interface is not located at the MAC/PHY boundary, it is not possible (in a literal sense) to determine if a common MAC is being used with the various PHYs — the best that can be done is to determine that the combination of MAC and the Medium Independent Layer within a given PHY operate as specified.

4. An Improved Reference Model

It appears to be possible to specify the Wireless Access Method and Physical Layer(s) using the current reference model. However, it is undesirable to do so because the resulting specification will require a substantial amount of added complexity due to the need to transfer additional control, status, and parameter information across the MAC/PHY. The conclusion that this complexity is avoidable comes, in part, from the observation that much of this information is transferred across the MAC/PHY boundary twice (once in each direction) in order to effect the transfer of a single MPDU. The need to perform these extra transfers exists solely because a medium independent function in PHY cannot insert or extract information from MPDUs , and a strictly "medium independent" MAC (see section 2.1) cannot perform the medium dependent processing that a particular physical medium may require.

Figure 1 depicts the changes in the reference model. Figure 1(A) shows the current reference model, while Figure 1(B) shows the improved reference model. As the side–by–side presentation attempts to make clear, the differences are primarily in labeling and placement of certain boxes relative to the MAC/PHY boundary.

- The "MAC" box is labeled as medium independent in Figure 1(B) for clarity, the media access control functions in this box, and its position between LLC and the DSAP, are unchanged.
- The functions and relative position of "MAC Management" s unchanged.
- The Medium Independent Layer at the top of PHY is replaced by a Physical Medium Adaptation (PMA) layer at the bottom of MAC. This is the fundamental change needed to provide and adequate descriptive basis for the 802.11 MAC layer.
- The (optionally exposed) DTE/DCE interface is moved from to the MAC/PHY boundary to maintain its relative position between the layer that provides medium adaptation for MAC (now the PMA layer) and the PHY Convergence layer.
- The Convergence layer is labeled as medium independent in Figure 1(B) to indicate that any PHY functions that are common across the range of PHYs are located in this box. It remains unclear to this author that "Convergence" is the best name for this layer, given that a single 802.11 MAC entity is not attempting to support multiple PHYs simultaneously.
- The Medium Dependent layer at the bottom of PHY is unchanged.
- The Station Management box is shown on opposite sides of Figures 1(A) and 1(B) to permit the areas affected by this change to be placed closer together on the drawing. This change in horizontal position implies nothing regarding changes to the station management functions nor interfaces. Maintaining equivalence of paths between the current and improved reference models would have the vertical extent of Station Management ending at the PMA layer of Figure 1(B), so that the DTE/DCE interface is the sole connection to the Convergence layer. However, if station management functions that require direct access to the upper subdivision of PHY are identified, the dotted extension of Station Management is Figure 1(B) maintains this upper–PHY connectivity from the current reference model.

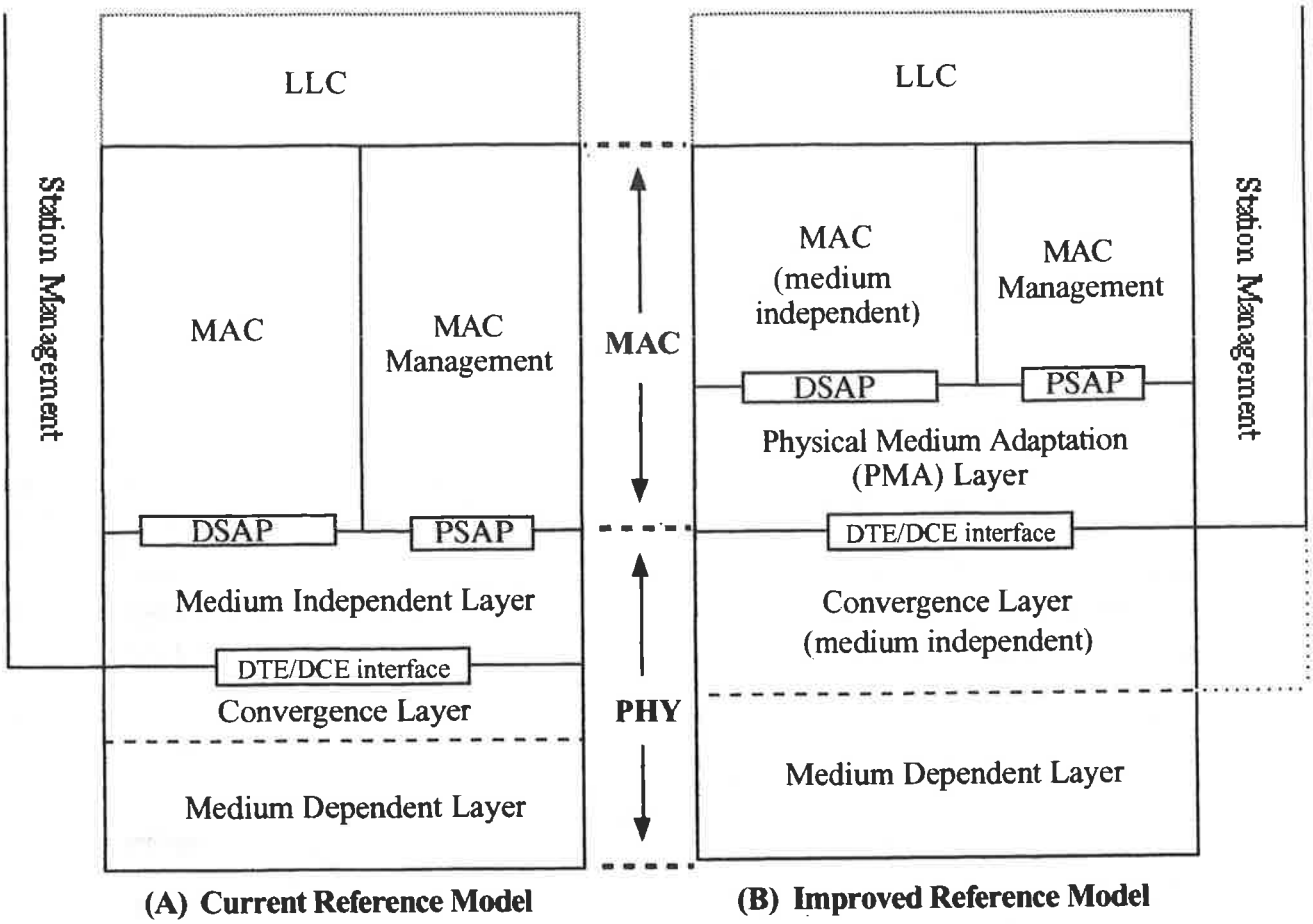

Figure 1. Reference Model Alternatives

5. Assignment of Functions to Layers

A detailed discussion of functional partitioning and assignment of functions and services among the layers of this improved reference model appears in a related submission:

- P802.11–93/205: Protocol Layers, Exposed Interfaces and LAN Services.

6. Comments On Relevant Issues

1.5 Should the protocol model generated during the July 1992 meeting be adopted by 802.11?

NO. A reference model with improved features for describing the 802.11 MAC/PHY relationship is proposed in this document.

3.1 What is the impact of the MAC implementation complexity in regard to "time–to–market"?

An increase in complexity cannot help, and can hurt, "time–to–market." In a similar manner, an increase in complexity of the specification of the mechanisms needed to support a variety of diverse PHYs under a single MAC protocol cannot help, and can hurt, implementation complexity. While the standard does not define implementation, the simpler the descriptive model and the simpler the resulting specifications, the greater the potential for simplified implementation.

12.1 What is the MAC/PHY interface?

The MAC/PHY interface is the (optionally exposed) DTE/DCE interface that is located between the Physical Medium Adaptation layer of MAC and the Convergence layer of PHY. This interface provides data and parameter transfer facilities that are functionally (and electrically and mechanically, if exposed) medium–independent. However, the information transferred over this interface may be medium–dependent, subject to the functions performed in the Physical Medium Adaptation layer.

12.1(A) What is the MAC Management/PHY interface?

The MAC Management/PHY interface takes place through the Physical Medium Adaptation layer, which accepts MAC Management information presented at the PSAP in a medium–dependent manner for transfer across the DTE/DCE interface to PHY.

12.2(A) What interfaces are exposed between MAC and PHY?

The MAC/PHY interface is optionally exposed. If exposed it must conform to the interface specified in the standard.

12.3 What is the intelligence level of the MAC/PHY interface?

The MAC/PHY interface is an "unintelligent" interface, permitting the common MAC, adapted through the Physical Medium Adaptation layer to encompass the intelligence, facilitating simple attachment of a wide variety of different PHY types.

12.4 Is the layer that provides PHY independence the same as the MAC/PHY interface?

NO. This independence is implemented in a Physical Medium Adaptation layer within MAC. There is also a provision for medium–independent interface functions in the Convergence layer within PHY to facilitate a common representation of items that are common to a plurality of PHYs. This partitioning permits generation of PHY–specific MPDUs for transmission and the processing of PHY–specific information from received MPDUs above the address recognition and FCS validation level without requiring the passing of information from MAC to PHY and back to MAC to achieve the necessary PHY–specific processing.

12.8 Does a PHY independence layer need to specified in the MAC?

YES.

12.9 Should data and control information be passed simultaneously across the MAC/PHY logical interface?

YES. Two, separate SAPs are available for this purpose, a DSAP for data and a PSAP for parameters and management information.

15.4 What are the services or functions unique to wireless networks?

In addition to the items already listed for this issue, the existence of MAC–visible, time–variant medium usage as a characteristic of a PHY is unique to wireless networking (and unique to frequency hopping PHYs among those currently under consideration).

24.3 How will multiple PHY support for the MAC be specified?

The Physical Medium Adaptation layer within MAC processes PHY–specific information, and inserts and extracts such information to/from MPDUs being exchanged over the wireless media. The MAC and MAC management functions are PHY–independent, while Physical Medium Adaptation layers are specific to a particular PHY.