IEEE 802.11
Wireless Access Method and Physical Specification

Title: **The need for MAC Data delimiters in the PHY.**

Presented by:

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Abstract: This paper discusses the MAC/ PHY function distribution. In particular it addresses the requirements for a delimiter, and discusses the reason for putting this function in the PHY. The concept of PHY signalling is introduced, which can among others provide for a mixed bitrate solution that allows receivers to adapt automatically to the speed of the received signal.

Issue's addressed:

12.1 What is the MAC/PHY interface?
12.3 Intelligence level of the MAC/PHY interface.
18.3 Will the standard support PHY's: with variable rates?
20.2 Can MAC handle different preamble length from PHY's?

Introduction:

An interface will need to be specified between the MAC and the PHY, that allows for sufficient flexibility to allow developments of future PHY's in the ISM or other bands.

Some of the functional requirements have been discussed in [1], where the concept of dynamic management, or the requirements for a per packet management function of the PHY by the MAC has been introduced.
A crude model is used to explain the basic interaction between the MAC and the PHY. A key issue is how the MAC data is being delimited, such that it meets the basic 802 hamming distance requirements.
Then following cover some aspects of the flexibility that is considered to be needed, which will in turn determine where the delimiter generation and detection functions are located.

MAC/PHY function distribution:

One aspect that needs to be decided is what the function distribution between the MAC and PHY would be. The most crude model would be as follows:

- The MAC transmits and receives MSDU's over a serial interface, with all clock signals being generated by the PHY.
- The PHY should upon a MAC command, start transmission of a preamble that is designed such that the remote station can train different functions needed to properly recover the MAC receive data and the receive clock.
- After the preamble the PHY should indicate to the MAC transmitter that DATA can be send, until the MAC turns its transmit command off.
- In the receiver the PHY should provide a Carrier Sense signal (CS) to the MAC indicating that the medium is sensed busy, and that Data reception may be in progress.
- After the receiver is fully synchronize it should deliver the received data and a clock signal to the MAC receiver.
- The receiver should also supply an indication to the MAC that provides frame delimiting information to the MAC .

The frame delimiting function needs some further discussion.

Delimiter function requirements:

In general the MAC does need a means to identify the start and the end of the MAC data field. These frame delimiting functions need to comply with the general requirements of 802. There it is stated that a hamming distance of 4 needs to be maintained, to assure that the undetected error probability is zero for up to 3 detection errors.
The 802 FCS is designed to provide for this hamming distance requirement as long as no errors occur in the MAC data delimiters. When due to errors delimiters are being misinterpreted, then the length over which the FCS is calculated will change. This can lead to a complete different FCS interpretation. So when due to up to 3 detection errors a delimiter fails, then there is a chance that this can cause an FCS match, even though the frame is in error, so an undetected error.
So the start and end delimiter detection functions need to have a hamming distance of 4, to prevent undetected errors under marginal signal conditions.

An example of a possible implementation of frame delimiters is provided in [2], where specific delimiters are included in the DS PHY modulation scheme.

An alternative method could be by coding unique patterns in the decoded bitstream, in such a way that those patterns do normally not occur in the MAC data field. An example of this is HDLC, which uses a unique flag to delimit the frame, and which prevents this code in the MAC data field by a bit stuffing/deletion algorithm.

However this type of method can never meet the hamming distance requirements, because a single detection error, can cause a false delimiter detection, that can lead to undetected errors. This is especially true for the end delimiter detection.

The use of a counter after the start delimiter to indicate where the end of the MAC data field is located has the same disadvantages. A single detection error in this field would cause an unacceptable undetected error rate.
It should also be noted that generally scramblers will be used in the PHY to assure that no fixed patterns occur in the output signal, that may cause regulatory problems, and undesirable pattern sensitivity in the receivers. Although the descramblers are self synchronizing, the result of this is that detection errors will be multiplied, so that a burst of multiple errors can occur.
The Start Delimiter:
An error in the start delimiter would also lead to truncated packets that could generate the same FCS. However the likelihood that a false (bit stream) start delimiter detection leads to an undetected error is in practice much lower, because there is also a destination address (plus other fields) match needed, before a frame is accepted by the MAC. The 802.3 standard is a good example. although the SFD (Start Frame Delimiter) is only 2 bits, another 48 bits need to match before the packet can ever be accepted. This means that the probability of an undetected error due to a false start delimiter is 2^50 times lower then the probability of a undetected error due to a false end delimiter.

Of course this probability is a function of the width of the destination address field, so it should be evaluated whether the undetected error probability due to a false start delimiter is acceptable when the width of these fields are determined.
In practice other fields like NID (Net ID) and APID (Access Point ID) need to match as well, so that it is likely that the net undetected error rate will be acceptable even with shorter address fields.

Delimiter conclusion.

The conclusion here is that a bitstream delimiter as a start delimiter can be acceptable, depending on the width of the destination address filtering function in the actual Data carrying frame (it was accepted in 802.3).
The end delimiter however can never be coded in the bitstream, and should therefore be derived from other signal characteristics in the PHY. For instance, like in 802.3, the PHY can signal the end of the frame to the MAC by monitoring for "end of energy" or "end of modulation". Alternative end delimiter methodologies are demonstrated in [2].
The accuracy requirements of the end delimiter needs to be evaluated. In 802.3 the FCS boundary is octet based, which means that the CRS end signal indication should drop within approx. one Byte following the last FCS byte. It may be required to increase the tolerance on this end delimiter signalling, so that the FCS boundary should be at even octet boundaries, so within 16 bits following the last FCS byte. This would result in a tolerance of 8-16 symbols in the DS and FH standards we work on today. This could also provide enough margin for higher bitrate systems up to 4 bits/symbol, which would then have to work with a tolerance of 4 symbols.
The start delimiter can be a short code in the bitstream, which could be detected in the MAC or the PHY. Where this function is located depends on possible other requirements that are evaluated in the next section.

Advantage of start delimiter detection in the PHY.

An advantage of having this function in the PHY is that PHY-to-PHY signalling functions can be implemented, which are important to provide the necessary flexibility in the standard.
Examples of features (either standardized or not) that can be provided with such a signalling capability are the following:

- Automatic bitrate detection, allowing mixed bitrate systems to interoperate.
- Use of optional short pre-amble in an Ack frame for systems with antenna diversity.

Mixed bitrate capability in the PHY

There are multiple reasons to allow a system to operate with mixed bitrates.

- One of the reasons is that a station may need to fallback to a lower bitrate to improve its performance. The reason can be the environmental noise and interference, but also the shape of the environment which will have effect on the delay spread.
- An other reason would be to allow for future migration towards higher speed implementations in the same band. It will then become important that products can be build that can include backwards compatibility to any of the then existing standards.
- New PHY standards will be developed for other bands that are visioned to come available in the future.

In this concept, it is important that a receiver can dynamically recognize the speed at which a packet is received. It will be able to receive the packet and retrieve the correct clock to send it to the MAC. In addition an indication of the bitrate with which this packet was received needs to be reported to the MAC. This indication will be needed by the MAC to build a database of the bitrate selection needed per destination station.

Use of short pre-amble in an Ack frame.

As described in doc IEEE P802.11-92/78, a shorter pre-amble might be specified for the Ack that is immediately returned after a successful received frame. This can be applicable for PHY's that use antenna diversity. The antenna selection part of the normal preamble can be omitted for the Ack signal, when the same antenna pair is used with which the original packet was exchanged. The ability to receive a short preamble can be signalled to the remote receiver, which can use this to determine which preamble to use for the return Ack.

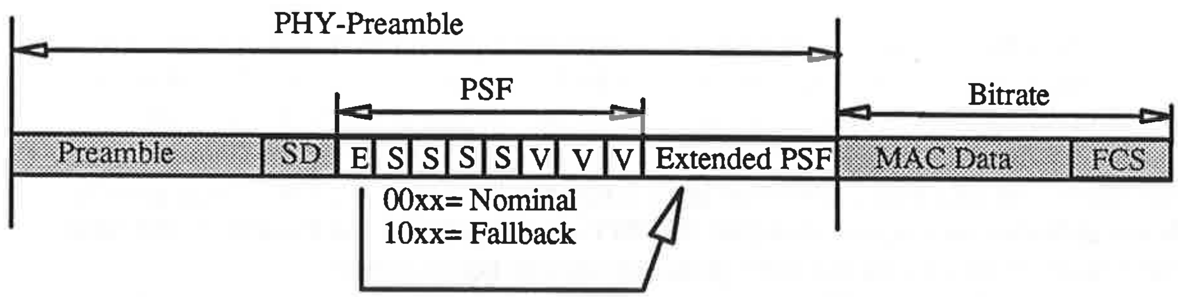
Use of a PHY signalling field:

When the start delimiter detect function is located in the PHY, then a subsequent small signalling field can be specified just before the MAC data field to contain the PHY signalling information.
The format of this field should be such that it allows for the basic requirements that need to be standardized, but should also allow vendor specific bits which would allow vendors to implement proprietary functions, while maintaining standard compatibility.
It is further important that a basic structure is adopted that allows for future expansions, in a way that allows backward compatibility.
This is provided by the following PSF (Phy Signalling Field) format:

PSF has a length of n*8 bits.

- 1-E bit: The First in Time (FIT) bit is an extension bit, that indicates whether or not an additional PSF octet is following.
- 4-S bits: for 802.11 standerdized functions (2 bits for speed, others may be reserved)
- 3-V bits: for vendor specific functions.

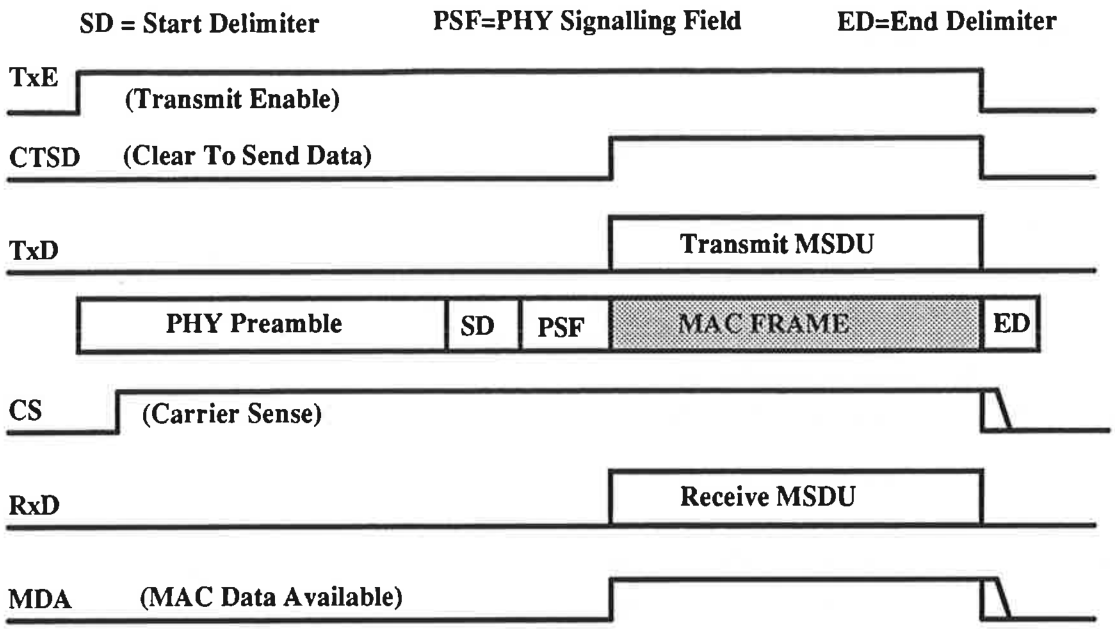
Subsequent PSF extension octets could have an identical format. A receiver would need to examine the E bit to determine where the "end of signalling" or "start of MAC Data" is located. Receivers that can not understand the content of any of the bits, would not react on them, but it knows the way to skip over them.



Typically the SD (start Delimiter) and the PSF field would be coded at the symbol rate, to allow proper detection at all speeds. The PHY will need to generate the actual bitrate clock and associated date at the start of the MAC Data field to the MAC.

The length of the Start Delimiter should be determined by the PHY. Its length should be selected such that it can provide for some filtering, against false detection on noise or some types of interference.

The following is an example of a MAC/PHY interface and associated framing of the PHY signal, which would include a signalling field immediately after the Start delimiter.



TX and RX CONTROL INTERFACE

The Delimiter detect functions are located in the PHY, and the PHY needs to signal the framing information to the MAC via the MAC/PHY interface. In the above example this is done by means of the MDA (MAC Data Available) signal.

Variable PHY preamble length and content.

The above scheme also allows for a variable length PHY preamble, which is required to allow the support of different types of PHY's, which may each need very different means for training the receiver functions properly, before reliable data reception is possible. Examples are the DS and FH PHY's, but also future higher speed PHY's that may require equalization. The preamble pattern can be different per PHY, and the PHY's may specify different delimiter means, and therefore the PHY should generate the Preamble. The MAC should not be involved with the PHY preamble content nor its length.
Therefor the interface should be such that the PHY indicates the end of the preamble to the MAC, so that the MAC can delay its MSDU frame until the PHY has completed the preamble and is ready to accept data from the MAC.

Issue's addressed:

The following issue's are addressed in this document.

12.1 What is the MAC/PHY interface?

This may not be the proper location for the MAC/PHY function distribution issue's that have been addressed in this paper. A sub issue should be specified that focus on the function distribution.

Should the MAC or the PHY be responsible for MAC Data delimiter generation and detection?

Alternatives:

1- MAC No
2- PHY Yes

Arguments:

1- Con:
The MAC can only do bitstream delimiting detection. This is acceptable for a start delimiter, but not for an end delimiter, because it violates the hamming distance requirements of 802.

2- Pro:
- Only the PHY can implement proper means for end delimiter detection. It can do start delimiter detection in various ways, including bitstream detection.
- Start delimiter detection on the PHY allows for the implementation of a PHY-to-PHY signalling field. This is desirable for migration flexibility to future standards. It is further needed to allow mixed bitrate implementations where the PHY is to adapt automatically to the proper speed.

12.3 Intelligence level of the MAC/PHY interface.

The function distribution between MAC and PHY should be such that :

- The PHY should generate the preamble upon a MAC command.
- The PHY should generate and detect the start and end delimiters, and should indicate this to the MAC.
- The PHY should be able to detect the proper bitrate of an incoming signal, when it is supporting multiple bitrates.
- A signalling field in the PHY preamble will allow future enhancements and proprietary functionality in the PHY.

18.3 Will the standard support PHY's with variable rates?

Yes. It is important that the MAC can support this in view of the migration requirements towards future higher speed PHY's, within the same band. This should allow for mixed operation where higher speed products can be build that are backward compatible with a currently developed standard.
This functionality would further be applicable in environments that can take advantage of dynamic speed switching.

20.2 Can MAC handle different preamble length from PHY's?

Yes. The PHY should be responsible for generating the preamble, upon a MAC command. The PHY should indicate the end of the preamble to the MAC, so that the MAC can start generating the MSDU data.

Conclusion:

Requirements for the MAC Data delimiters have been evaluated. The conclusion is that a bitstream delimiter can be defined to indicate the start, but a bitstream end delimiter coding technique is unacceptable, because it does not meet the hamming distance requirement of 802.
Features like automatic bitrate detection functionality and future migratability require that the delimiter generation and detection functions are located on the PHY. This allows for the implementation of a PHY-to-PHY signalling field, with a format that allows for future extension and vendor specific functionality.
Finally an example is given of the basic interface functions between MAC and PHY that allows for the desired flexibility, also to support multiple PHY's.

References:

[1] Wim Diepstraten, NCR: "Functional MAC/PHY interface Requirements". Doc P802.11-92/78.
[2] Jan Boer, NCR: "Proposal for a 2 Mbit/s DSSS PHY". Doc P802.11-93/37.
[3] Wim Diepstraten, NCR: "The Potential of Dynamic Power Control". Doc P802.11-92/76.
[4] Wim Diepstraten, NCR "A Distributed Access Protocol Proposal, supporting Time Bounded Services". Doc IEEE P802.11-93/70.