IEEE 802.11
Wireless Access Method and Physical Layer Specification

Title: **Proposed Revision of the Infrared Baseband Frame Format**

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Summary

A new frame format for the IR baseband is proposed. Its performance and implementation complexity is compared to the frame format proposed in documents 94/95 and 94/96. The terminology used to describe the frame format is also revised.

A system implementing the proposed specification is being developed by the University of Aveiro as part of the ESPRIT.6892 POWER (Portable Workstation for Education in Europe) project commissioned by the European Community.

1.0. Motivation for changing the frame format

In documents 94/95 and 94/96 a frame format for the IR baseband PHY have been proposed and its performance, meaning the Frame Error Rate (FER) and the influence of each field on the FER, was discussed in document 94/97. This frame format was designed and optimised in order to minimise the FER and to introduce a small overhead. Nevertheless, this frame format must be changed to take into account the following aspects:

a) the SFD proposed in doc. 94/95, while optimised for FER performance, does not conform with the 802 Functional Requirements [1] since the minimum Hamming distance of 4 is not verified. In the proposed case the SFD may be detect before its correct position (imitated during the preamble) if 2 or more errors occur, and the resulting misalignment not detected. The Functional Requirements requires that a minimum of 4 errors have to occur for an undetected error to occur.

b) in order to increase the probability of detection of frame misalignments resulting from wrong detection of the SFD, one of the following solutions may be adopted:
   • the use of a longer SFD (9 slots long to provide a Hamming distance of 4) or
   • the inclusion of a LENGTH field, protected by a CRC, a solution similar to those adopted by the FHSS and DSSS PHY groups. In case of a wrong detection of the SFD, the misalignment is detected by the CRC with very high probability. This is the proposed solution.

c) assuming the existence of a LENGTH field as proposed in b), the EFD is no longer required since the end of the frame is known a-priori. The use of a LENGTH field to locate the end of

the frame also contributes to a FER improvement since it reduces the probability of error in the end of frame detection: the probability of a wrong length to be undetected by the CRC is much lower than the error probability in the EFD detection. These reasons leads us to propose the exclusion of the EFD.

2.0. Proposed Frame Format

The proposed frame format is shown in figure 1.

PLCP Preamble		PLCP Header				MPDU
Sync 57-73 slots	SFD 4 slots	DR 3 slots	DC LA 32 slots	Length 16 bits	CRC 16 bits	Variable number of octets

Figure 1. Proposed frame format

The new frame format contains three main sections: the Physical Layer Convergence Procedure (PLCP) Preamble, the PLCP Header and the MPDU. Each of this sections consists in a different number of fields as follows:

2.1. PLCP Preamble

2.1.1. Synchronisation field (not changed)

The synchronisation field consists of a sequence of alternated presence and absence of a pulse in consecutive slots. This is a 2 MHz clock signal with 50% duty-cycle.

The transmitted preamble should last for a minimum of 57 slots and a maximum of 73 slots and terminate with an empty slot (absence of a pulse).

2.1.2. Start-of-Frame Delimiter

The same SFD is adopted in this proposal since this is the solution leading to the lower error probability of correct detection. The SFD length is 4 slots and consists of the sequence `1001`.

In order to conform to the 802 Functional Requirements, the correct alignment of the SFD is verified in the PLCP Header: a misalignment of the SFD is detected by the CRC field that protects the LENGTH field. The probability of a misalignment not being detected is very low. This method provides a higher protection against misalignment of the SFD than the use of a longer SFD (a minimum of 9 slots would be required for a Hamming distance of 4).

2.2. PLCP Header

2.2.1. Data Rate field (DR) (not changed)

The same DR field is adopted in this proposal. Its length is 3 slots and the already assigned words are:

- 1 Mbps: `000`
- 2 Mbps: `001`
- other data rates: TBD

For the 1 and 2 Mbps baseband PHY, an error condition should be signalled to the MAC if none of the known data rate words (000 or 001) is detected.

2.2.2. DC Level Adjustment field (DC LA) (not changed)

The same DC LA field is adopted in this proposal. Its format is as follows:

- 2 × symbol '8' for 1 Mbps (16-PPM);
- 8 × symbol '2' for 2 Mbps (4-PPM)

2.2.3. Length field (LENGTH) (new)

A new field indicating the MPDU length is introduced. The use of a length field discards the need for an EFD and provides an a-priori knowledge of the CRC (of the MPDU) location. The prior knowledge of the CRC location improves its ability to detect errors in the MPDU and reduces the time required to signal the MAC that the channel is already available, thus helping with Clear Channel Assessment (CCA).

In order to reduce the error probability in the LENGTH field detection, this field is sent to the medium in PPM format. This is the reason for its position after the DC LA field.

The LENGTH field is 16 bits long and represent the number of octets in the MPDU including the MPDU CRC.

2.2.4. Cyclic Redundancy Check field (CRC) (new)

The LENGTH field is protected by a CRC (16 bits long) that is sent after the LENGTH field. This field is also sent in PPM format. The CRC should follow the CCITT CRC16 FCS and is the ones compliment of the remainder generated by the modulo 2 division of the LENGTH field by the polynomial:

$$x^{16} + x^{12} + x^5 + 1$$

If an error condition is detected by the CRC, one of the following situations may have occurred:

- the SFD was detected in a wrong position and the frame is misaligned
- an error occurred in the DR field and the PHY is operating at a wrong data rate
- an error occurred in the LENGTH field
- an error occurred in the CRC field itself

If an error is detected by the CRC, an error condition should be signalled to the MAC.

2.3. MPDU

This field consists of a variable number of octets followed by a CRC.

3.0. Performance Evaluation of the New Frame Format

The frame format proposed in this document was modelled and its performance evaluated, similarly to what have been done in document 94/97. The Frame Error Rate (FER) was calculated and the contribution of each of the frame fields to the FER was estimated.

Figure 2 shows the FER versus irradiance for the proposed frame format when a MAP detector and a threshold detector are used. These results are also compared with those of the old frame format.

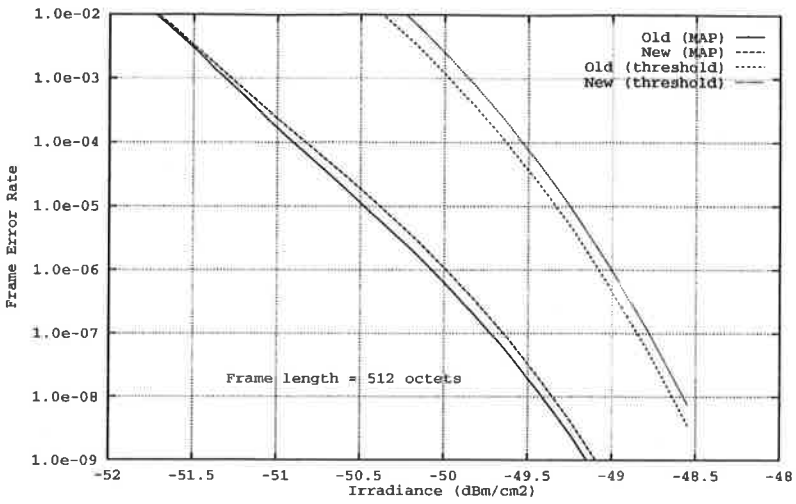

Figure 2. FER vs. irradiance

As shown in figure 2, there is a small penalty associated with the new frame format (about 0.1 dB) and this results from the error probability associated with the LENGTH and CRC fields detection.

For a target FER of 4.0×10^{-5}, the receiver sensitivity (using a MAP detector) was estimated and the contribution of each field to the total FER was calculated. The results are presented in table 1.

	1 Mbps	2 Mbps
Total Frame Error Rate (Target):	4.0×10^{-5}	4.0×10^{-5}
Receiver sensitivity	-50.65 dBm/cm^2	-44.64 dBm/cm^2
Probability of error in the SFD detection:	2.1×10^{-5}	2.2×10^{-5}
Probability of error in the DR detection:	1.6×10^{-5}	1.6×10^{-5}
Probability of error in the LENGTH detection:	1.4×10^{-8}	6.0×10^{-9}
Probability of error in the CRC detection:	1.4×10^{-8}	6.0×10^{-9}
Probability of error in the payload detection:	3.5×10^{-6}	1.5×10^{-6}

Table 1. Total Frame Error Rate and height of each field.

As for the old frame format, the FER is dominated by the error probability in the SFD detection. This is in favour of a small SFD instead of a longer SFD for conformance with the Hamming distance of 4. A longer SFD would degrade the FER even more.

Since the FER degradation is very small, compared to the old frame format, there is no need to review the sensitivity specification (doc. 94/96).

4.0. Implementation Complexity

In terms of implementation complexity, there exist a balance between the old and the proposed frame format. From one side, there is the necessity to implement the CRC generator and a counter to locate the frame end from the LENGTH field. From the other side, the EFD detection circuitry is no longer required. Since most of the electronics is to be implemented in VLSI, the differences in complexity should be meaningless.

References

[1] "Functional Requirements", IEEE Project 802, Draft 6.10, Revised: Nov 12, 1992