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Wireless Access Methods and Physical Layer Specifications

TITLE: Sorting Out PLCP Header Error Check CRC

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Introduction

This paper looks at the properties of the various CRCs proposed for the 16 bit Header Error Check field in the Frequency Hopping Spectrum PHY.

1.0 Introduction

The PLCP header as proposed in document 68 and later in document 103, contains three fields, a PLCP signaling field, a PLCP length field and a Header Error Check field. Document 103 which was tabled due to lack of time and knowledge regarding CRC, describes these fields in detail and propose text to document 68 for the PLCP Header. This paper addresses the issues surrounding the CRC for the 16 bit HEC field. (1)(2)

2.0 CRC Polynomials

There have been several generator CRC polynomials proposed by Apple and Symbol for the PLCP HEC field as well as other commonly use 16 bit CRC polynomials. This paper considers the following 16 bit CRC generator polynomials:

1). $x^{16} + x^{15} + x^{11} + x^{10} + x^8 + x^6 + x^2 + x + 1$ (Apple's CRC)
2). $x^{16} + x^{14} + x^{13} + x^{11} + x^{10} + x^9 + x^8 + x^6 + x^5 + x + 1$ (239,255 BCH)(4)
3). $x^{16} + x^{15} + x^2 + 1$ (CRC-16)(3)
4). $x^{16} + x^{12} + x^5 + 1$ (CCITT CRC16)(3)

The first polynomial was developed for Apple by a consultant for use in our wireless LAN protocol. The second one is a standard BCH style polynomial. The third polynomial is the standard CRC-16 polynomial used in many networking applications. The fourth is the CCITT approved 16 bit CRC generator polynomial also used in many networking applications.(3)

3.0 Detection and Correction Properties

The best way to chose the CRC to be used as the generator polynomial for the HEC field is to evaluate each one's properties against how the HEC is used. Two properties which can be used to evaluate CRCs are error detection and error correction capabilities. Lets first examine each of the CRCs error detection capabilities.

3.1 Error Detection Properties. The PLCP field is a fixed 32 bit field. It is desirable that the HEC portion of these 32 bits be able to detect all combinations of errors in the PLCP field. Unfortunately this is not possible because generally 16 bit CRCs are only guaranteed to detect burst errors up to 16 bits and the probability of not detecting burst errors beyond that usually approaches 1 in 2^{16}-1. Since the field is 32 bits, burst errors can exist up to 32 bits. Since all the proposed generator polynomials are of the order x^{16}, then each has this same property. The next property to evaluate then might be the ability of the generating polynomial to detect multiple burst errors. The Apple CRC was developed to detect all double burst errors of length less than or equal to 7. At Apple Carlos Puig compared via simulation the 3 other CRC generator polynomials against this property. The results are as follows

Polynomial	Undetected error patterns
Apple CRC	0
BCH	2
CRC-16	17
CCITT CRC16	2

In addition, the Apple CRC can detect all 6 bit random errors in the 32 bit field. We did not have the time to test the other 3 against this property.

3.2 Error Correction Properties. Another desirable property of a CRC generating polynomial might be its ability to correct in addition to detect errors. The following lists the known error correcting capabilities of each of the polynomials.

Polynomial	# of bits
Apple CRC	1
BCH	2
CRC-16	unknown
CCITT-CRC16	unknown

3.3 Other Facts. CRC generating polynomials have varying properties as the field size they are applied over grows. For example, CRC-16 and CCITT CRC16 can detect:

- All 1-bit error patterns
- All 2-bit error patterns in data of 32767 bits or less
- All error patterns with an odd number of bits (i.e., all 3-bit, 5-bit, 7-bit, etc.)

But in this case, the field is a fixed 32 bits so these properties of CRC16 and CCITT CRC16 are not very useful in this particular application. In the converse, if the field does change and becomes bigger than 32 bits, say 48 or 64 bits, some of the earlier properties discussed may not apply anymore to the Apple's CRC or the BCH.

4.0 Conclusion.

The Apple CRC is the best choice for the HEC if the PLCP field will never change in size and it is desirable to do one bit error correction. This CRC provides the best error detection capabilities and provides single bit error correction at a minimum and possibly two bits maximum (requires more research). The BCH polynomial we propose in 103 (2) will probably perform acceptable for error detection and also provide two bit error correction if desired. The CRC16 is probably the poorest choice from the section 3.1. The CCITT CRC16 is comparable in error detection capabilities with the BCH code but its correction capabilities are not known.

In my estimation, I believe that error correction probably is not very important at this time in the standard process and thus the error detection capabilities are most important. Although the Apple CRC is probably the best choice for detecting errors, I believe that avoiding controversy is probably the best course for making decisions so I will propose the following motion.

Motion: That CCITT CRC16 be accepted as the generating polynomial for the FHSS PLCP HEC field.

1. IEEE Doc 802.11-94/068, "Physical Layer Draft Specification for 2.4 GHz Frequency Hopping Spread Spectrum Media", Ed Geiger, Tim Blaney, Dean Kawaguchi.

2. IEEE Doc 802.11-94/103, " Proposed Revision to 94/068 Section 3. FHSS PLCP Sublayer", Dean Kawaguchi, Ed Geiger

3. Boyd & Fraser Publishing Company, "Data Communications Software Design", Malcolm G. Lane, ISBN 0-87835-145-0

4. McGraw-Hill Communications Series, "Error Correcting Coding Theory", Man Young Rhee, ISBN 0-07-052061-5