IEEE P802.11
Wireless LANs

Communication of PHY Specific Information

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Abstract

This is a proposal for text to be included in the draft of 802.11d. The text supplied addresses the additions needed to the current standard to support a generalized approach to new regulatory domains and to support international mobility.

X. Communication of PHY Specific Information

X.1 Introduction

Because the PHY layer of a WLAN is subject to regulations that may vary significantly from one geopolitical area to another, it is desirable that a mechanism exist that allows a conforming implementation to be built that is able to meet many different sets of regulations. Such an implementation would allow a manufacturer to take advantage of the economies of scale by minimizing the number of different manufacturing configurations required to support all of the sets of regulations. This would also allow conforming equipment to be able to operate in more than one regulatory domain over time. However, to accomplish this feat, information about the required operational characteristics of the PHY must be communicated amongst the stations of the WLAN. This clause describes the mechanism required to implement a capability in 802.11 stations that supports operation in multiple regulatory domains and cross-domain mobility.

X.1.1 References

S.V. Maric and E.L. Titlebaum, "A Class of Frequency Hop Codes with Nearly Ideal Characteristics for Use in Multiple-Access Spread-Spectrum Communications and Radar and Sonar Systems", *IEEE Transactions on Communications*, Vol. 40, No. 9, September 1992, pp. 1442-1447

D. Engwer and J. Zweig, "Algorithmically Derived Hop Sequences", submission 99/195 to the IEEE P802.11 Working Group, September 1999

X.1.2 Acronyms

HCC Hyperbolic congruence codes
EHCC Extended hyperbolic congruence codes

X.2 Changes to the MAC

The 802.11 MAC must be changed in two areas in order to support the new approach to operating in multiple regulatory domains. First the MAC must acquire the information to allow the station to properly configure the PHY for operation in the regulatory domain in which the station is located. Second, the MAC must disseminate regulatory domain information to other stations.

X.2.1 Channel Allocation Information Element

The Channel Allocation information element contains the information required to allow a station to identify the regulatory domain in which the station is located and to configure its PHY for operation in that regulatory domain. The format of this information element shall be as shown in Figure 1.

Element ID	Length
Regulatory Identifier	
Lifetime	Number of Subelements
Channel Descriptor Subelement 1	
• • •	
Channel Descriptor Subelement n	

Figure 1, Channel Allocation Information Element

The element identifier for this information element shall be XX. The length of the information element is variable, as the element may contain more than one channel descriptor sub-element. The minimum length of the information element is 14 octets.

The Regulatory Identifier field of the element shall be 2 octets in length. It shall contain a positive integer value that is unique to the regulatory domain. This value shall be placed in the dot11CurrentRegDomain attribute upon reception of this element. The transmitter of this element shall place the value of the STA's dot11CurrentRegDomain attribute in this field.

The Lifetime field of the element shall be one octet in length. It shall contain a positive integer value that indicates the length of time, in seconds, that the information contained in the element shall remain valid.

The Number of Subelements field shall be one octet in length. It shall contain an integer value that indicates the number of subelements contained in the information element. This value shall be positive and greater than zero.

The Channel Descriptor subelement shall be 8 octets in length. Its format shall be as shown in Figure 2. There shall be at least one channel descriptor subelement in the channel allocation information element. There may be as many as 31 subelements contained in the channel allocation information element.

Channel Spacing	Occupied Bandwidth
First Channel Center	
Number of Channels	
Maximum Allowable Transmit Power	

Figure 2, Channel Descriptor Subelement

The Channel Spacing field of the subelement shall be one octet in length. It shall contain a positive integer value that indicates the spacing between channel centers, in megahertz.

The Occupied Bandwidth field of the subelement shall be one octet in length. It shall contain a positive integer value that indicates the bandwidth, in megahertz, occupied by a single channel.

The First Channel Center field of the subelement shall be 2 octets in length. It shall contain a positive integer value that indicates the lowest center frequency, in megahertz, in the band described in this subelement.

The Number of Channels field of the subelement shall be 2 octets in length. It shall contain a positive integer value that indicates the number of channels described in this subelement.

The Maximum Allowable Transmit Power field of the subelement shall be two octets in length. It shall indicate the maximum power, in milliwatts, allowed to be transmitted in the channels described in this subelement.

An example of the channels defined by a single channel descriptor subelement is shown in Figure 3.

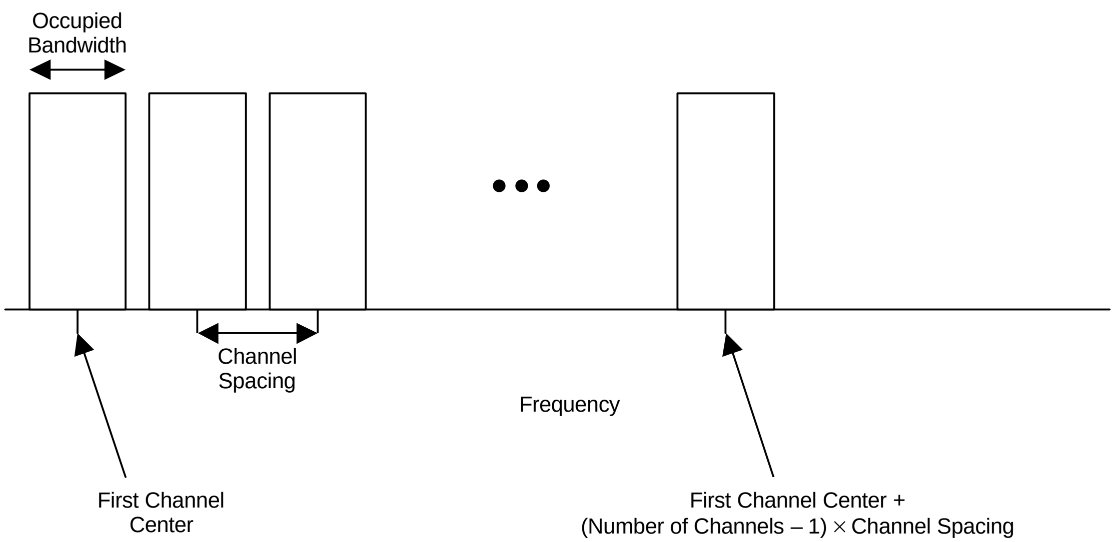

Figure 3, Channels Defined by the Channel Descriptor Subelement

X.2.2 Changes to the Beacon Frame

Implementations supporting operation in regulatory domains not defined in clauses 14, 15, 17, or 18 shall include a Channel Allocation element in the transmission of Beacon frames, such that a Beacon frame containing the element is transmitted at least once in a period defined by the lifetime field of the element. This element may be included in the Beacon frame while the implementation is operating in regulatory domains defined in clauses 14, 15, 17, and 18.

Frequency hopping implementations operating regulatory domains not defined in clause 14 shall include a Hopping Patterns Parameters information element in the transmission of Beacon frames, such that a Beacon frame containing the element is transmitted at least once in a period defined by the lifetime parameter of the Channel Allocation information element. This element shall not be included in Beacon frames while the implementation is operating in a regulatory domain defined in clause 14. If this element is present in the Beacon frame, it shall be included in the same Beacon frame as the Channel Allocation element.

X.2.3 Changes to the Probe Response Frame

Implementations supporting operation in regulatory domains not defined in clauses 14, 15, 17, or 18 shall include a Channel Allocation element in the transmission of every Probe Response frame. The value of the lifetime field of the element shall be equal to that of the Channel Allocation element lifetime field transmitted with the Beacon frame.

Frequency hopping implementations operating in regulatory domains not defined in clause 14 shall include a Hopping Pattern Parameters information element in the transmission of every Probe Response frame. This element shall not be included in Probe Response frames while the implementation is operating in a regulatory domain defined in clause 14.

X.3 Changes to MAC Management

X.3.1 Active Scanning

Implementations supporting operation in regulatory domains not defined in clauses 14, 15, 17, or 18 shall not transmit with transmit power exceeding 0 dBm until a valid Beacon or Probe Response frame containing a Channel Allocation element is received, or until the dot11CurrentRegDomain attribute value is set.

X.3.2 Starting a BSS

Implementations supporting operation in regulatory domains not defined in clauses 14, 15, 17, or 18 shall not start a BSS, either an infrastructure BSS or an IBSS, unless a properly formed Beacon frame including a Channel Allocation element can be constructed, or until the dot11CurrentRegDomain attribute has been set.

X.3.3 Joining a BSS

In addition to the procedures for joining a BSS that are currently required, an implementation receiving a Beacon or Probe Response frame containing a Channel Allocation element shall adopt the parameters included in that element when joining a BSS. If a Frequency Hopping Parameters element is present in the Beacon or Probe Response frame, an implementation shall adopt the parameters in the element and calculate the hopping patterns using the HCC or EHCC algorithm. Using the appropriate pattern, set, and index values from the FH Parameter Set element, the implementation shall adopt the values in use by the BSS when joining.

X.4 Changes to the MIB

X.5 Support for Frequency Hopping PHYs

X.5.1 Determination of Hopping Patterns

Hopping patterns shall be determined using hyperbolic congruence codes (HCC) or extended HCCs (EHCC). The HCC hopping sequences are derived from a simple formula that uses field operations on a group. For full details of the HCC placement operator function, please see the references. The placement operator function shall be as shown in equation 1.

$$y_{HCC}(k;a) = \frac{a}{k} \bmod N \qquad \text{for } k, a \in J'_N \qquad \text{(Equation 1)}$$

Where N is the prime radix, a is the family index, and k is in the group J'_N. J'_N is the group remaining when the element containing the value zero is removed from the field J_N. Therefore, k does not take the value zero. The value $1/k$ is the multiplicative inverse of k on the field J_N. The values computed for y_{HCC} are the channel numbers, a corresponds to the hopping pattern number, and k corresponds to the index into the hopping pattern. A code family is the set of N-1 hopping patterns generated for the prime radix N. There is no value equivalent to the hopping set of clause 14.

As an example, consider a code family that supports 10 channels. The prime radix for such a family is 11. The code family generated by the HCC algorithm is shown below in Table 1.

SEQ \ INDEX (k) ---->	1	2	3	4	5	6	7	8	9	10
1	1	6	4	3	9	2	8	7	5	10
2	2	1	8	6	7	4	5	3	10	9
3	3	7	1	9	5	6	2	10	4	8
4	4	2	5	1	3	8	10	6	9	7
5	5	8	9	4	1	10	7	2	3	6
6	6	3	2	7	10	1	4	9	8	5
7	7	9	6	10	8	3	1	5	2	4
8	8	4	10	2	6	5	9	1	7	3
9	9	10	3	5	4	7	6	8	1	2
10	10	5	7	8	2	9	3	4	6	1

Table 1: HCC Code Family – N=11; Family Indices (SEQ) 1 thru 10

The HCC method to calculate hopping sequences only generates sequences of a length that is one less than the prime radix. The EHCC algorithm extends the original HCC algorithm to support a larger number of possible hopping sequence lengths. The EHCC algorithm works through a process known as "deletion of the diagonals".

Using the same example in Table 1, a family of codes cannot be generated for code lengths of 9 or 8 by the HCC algorithm, since neither 9 or 8 is equal to a prime number minus one. However, the diagonals of the array in Table 1 represent the end points of the group. Thus, code families for code lengths 9 and 8 can be easily generated from the table simply by removing the diagonals. Table 2 shows such a code family with a code length of 9 (constructed by removing the diagonal of 10's).

SEQ \ INDEX (k) ---->	1	2	3	4	5	6	7	8	9
1	1	6	4	3	9	2	8	7	5
2	2	1	8	6	7	4	5	3	9
3	3	7	1	9	5	6	2	4	8
4	4	2	5	1	3	8	6	9	7
5	5	8	9	4	1	7	2	3	6
6	6	3	2	7	1	4	9	8	5
7	7	9	6	8	3	1	5	2	4
8	8	4	2	6	5	9	1	7	3
9	9	3	5	4	7	6	8	1	2

Table 2: HCC Code Family – Code Length=9, N=11; Family Indices (SEQ) 1 thru 9

Table 2 now contains a diagonal (upper left to lower right) consisting entirely of 1's. This is a necessary mathematical property of the result of removing the initial diagonal of (p-1)'s, and will be exhibited for any prime p.

Extending the process, Table 3 shows a code family with a code length of 8 (constructed from Table 2 by removing the opposite diagonal of 1's, and subtracting 1 from each value in the remaining array).

```
     INDEX (k) ---->
     1  2  3  4  5  6  7  8
SEQ------------------------
 1 | 5  3  2  8  1  7  6  4
 2 | 1  7  5  6  3  4  2  8
 3 | 2  6  8  4  5  1  3  7
 4 | 3  1  4  2  7  5  8  6
 5 | 4  7  8  3  6  1  2  5
 6 | 5  2  1  6  3  8  7  4
 7 | 6  8  5  7  2  4  1  3
 8 | 7  3  1  5  4  8  6  2
```

Table 3: HCC Code Family – Code Length=8, N=11; Family Indices (SEQ) 1 thru 8

To obtain a code family of length N-2, the code family of length N-1 calculated by the HCC algorithm shall be modified by deleting the diagonal of the code family with the value of N-1 and removing the row of the code family with the family coefficient of N-1. This results in a code family represented in a square (N-2) by (N-2) array.

To obtain a code family of length N-3, the code family of length N-1 calculated by the HCC algorithm shall be modified by deleting the diagonals of the code family with the values of 1 and N-1, removing the rows of the code family with the family coefficients of N-1 and N-2, and subtracting 1 from all remaining values in the code family array. This results in a code family represented in a square (N-3) by (N-3) array with array values of 1 through N-3.

When using hopping patterns calculated using the HCC or EHCC algorithms, the values in the FH parameter set element shall be set as follows:

a) the Hop Set field shall be zero,
b) the family index of the code being used shall be placed in the Hop Pattern field, and
c) the index shall be placed in the Hop Index field.

X.5.2 Hopping Pattern Parameters Information Element

The Hopping Pattern Parameters information element contains the information necessary to allow a station to calculate the code family using the HCC and EHCC algorithms. The format of this information element shall be as shown in Figure 4.

Element ID	Length
Prime Radix	Number of Channels

Figure 4, Hopping Pattern Parameters Information Element

The Element ID of this information element shall be XX. The length of this element is 4 octets.

The Prime Radix field of this element shall indicate the value to be used as the prime radix (N) in the HCC and EHCC algorithms. The value of this field shall be a positive integer. The size of this field is one octet.

The Number of Channels field of this element shall indicate the value to be used as the maximum for the family index (a) in the HCC and EHCC algorithms. The value of this field shall be a positive integer and shall not be less than the prime radix minus 3 (N-3). The size of this field is one octet.

X.6 Changes to the MAC State Machines