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Re:	
Abstract	The document present a technique to identify the RS in the network based on individual "signature" that is transmitted at prescribed interval of times and that can be detected by other RSs in the neighborhood area. This information is useful to determine the topology of the network, provide access to network to the RS, determine the level of interference, etc.
Purpose	Review and adopt.
Notice	
Release	
Patent Policy and Procedures	

Signature Identification for Multihop Relays

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Introduction

Part of the 802.16j PAR is the feature of having mobile RSs in the radio access network. Thus it is possible that two or more RSs get closer and interfere with each other. While using a GPS solution provides information with respect to the spatial proximity of the RSs, this option is not enough to estimate the real level of interference due to different propagation environments as well as different transmit powers used by RSs.

The document proposes that each RS should transmit at prescribed interval of times a unique “signature” that identifies the corresponding RS to other RSs in the radio access network.

Access station signature

The proposed signature spans over 1 or 2 OFDM symbols, with one of the OFDM symbols (preferable the first one) transmitting nothing, in order to be used for background interference level estimation.

In the case where 1 OFDM symbol is used, the background interference level estimation is carried out during other time intervals. In this case, the OFDM symbol can be used, for example, as a amble for the RS.

For simplicity of presentation, the following discussion is for the 2 OFDM symbol case.

The OFDM symbol that actually conveys the signature, transmits energy at prescribed carrier positions, while the other positions the energy transmitted is zero. This allows a very simple and fast energy detector on each transmitted carrier.

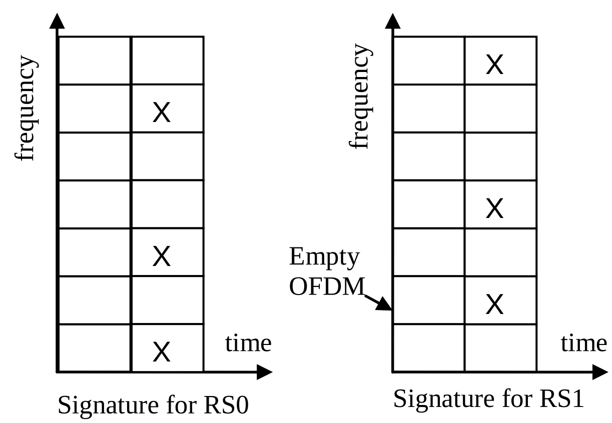

Figure 1. Example of signatures for two RSs. On the carriers marked with “X” energy is transmitted.

The idea is illustrated in Figure 1 where two signatures, for RS0 and RS1, are shown. On the positions marked by “X” energy is transmitted. It is noticeable that the positions on which energy is transmitted for RS0 do not collide with the positions on which the energy is transmitted for RS1, therefore, even if the signatures are transmitted simultaneously, they can be separated. Note that the detection can be performed non-coherently, i.e. there is not necessary to perform any channel estimation, therefore it is simple and fast.

The goal is to generate a large number of position-codes that map onto carrier positions which transmit energy, position-codes that have a small number of collisions.

We suggest that the position of the signature in the frame should be before the start of the preamble of the RS, if this is possible. The position of the signature is given by the access station and is relative to the beginning of the RS frame start.

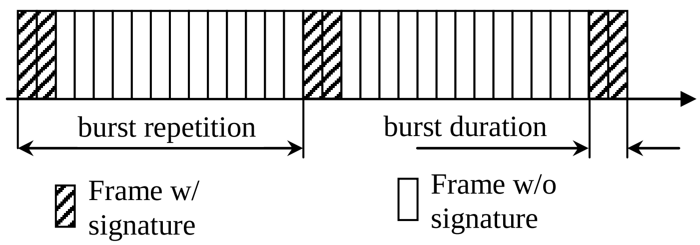

Figure 2. RS signature transmission

RS should transmit the signature periodically, say the RS_Signature_Repetition is every 200 frames, and the RS_Signature_Burst_Duration is 2 consecutive frames in order to allow averaging, as Figure 2 shows. The RS generates a random number between 1 and RS_Max_Signature_Detection, and at that burst index instead of transmitting, the RS does reception in order to sense the environment. A new number is generated after RS_Max_Signature_Detection burst repetitions. Note that RS can have assigned individual RS_Max_Signature_Detection values, function of fact that RS is fixed or mobile, for example.

If the signature is actually an amble, than the RS should have assigned times when it does not transmit the amble, but is in the receiving mode in order to sense the environment.

Generating the position-codewords

The position-codewords are formed from summation of an equally-spaced set and a Reed-Solomon (non-standard) code which has good distance properties.

Consider an (*N*,*K*) Reed-Solomon code of length *N* that encodes *K* symbols, each symbol being from an *M*-level alphabet, with the levels being normalized to the set {0, 1, … *M*-1}. To convey the signature, at least a number *N**M*P* of OFDM carriers is required (excluding the DC carrier), where *P* is a repetition factor. Thus, the position-codeword consists of transmitting energy on *N**P* carriers out of *N**M*P* carriers available for signature. To generate the positions where the energy is transmitted, the following algorithm is proposed:

- A signature is identified based on a given *K*-tuple $\mathbf{X} = [x_1, \cdots, x_K]$ (called RS_Signature_ID), which is used to generate one codeword $\mathbf{Y} = [y_1, \cdots, y_N]$, $\mathbf{Y} = \mathbf{X} * \mathbf{G}$ where $\mathbf{G}$ is the generator matrix and all operations are modulo M ;

- A repetition of **Y** of *P* times, is performed to obtain $\mathbf{R} = [\mathbf{Y}, \cdots, \mathbf{Y}]$.

- A fixed set having the cardinality *N**P*, of numbers is given $\mathbf{Z} = [z_1, \cdots, z_{NP}]$;

- The signature is generated by transmitting energy on the carriers given by the positions $\mathbf{C} = \mathbf{R} + \mathbf{Z}$, while in the rest of the carriers out of total *N*M*P* no energy being transmitted.

For an (*N*,*K*) Reed-Solomon code, a number of $M^K = (N+1)^K$ codewords are available, and the minimum distance between any two codewords is $N - K + 1$. If any two signatures are received simultaneously, the maximum number of carriers that may collide (where the energy is transmitted) is (*K*-1)**P*.

Note that because the detection is non-coherent, the values that are assigned to the carriers that transmit energy are not so important. However, there are provided values that have a good PAPR on average. The number of carriers that transmit energy are much less than the number of carriers that are used for the preamble (this will be see later). Therefore, the signatures can tolerate a larger PAPR.

Sets of no collision position-codewords

It can be shown that there is a *K*-tuple $\mathbf{X}_{\text{ones}}$ such that its codeword is all ones, i.e. $\mathbf{Y}_{\text{ones}} = [1, \cdots, 1]$. The Reed-Solomon codes are cyclic codes, which imply that the sum of any two codewords is also a codeword. Using this property, sets of no collision codewords can be generated. Consider an initial *K*-tuple $\mathbf{X}^{(q)}$, then the subset $\mathbf{S}^{(q)} = \{\mathbf{Y}_p \mid \mathbf{Y}_p \text{ codeword of } \mathbf{X}_p = \mathbf{X}_{p-1} + \mathbf{X}_{\text{ones}} \bmod N+1,\ p = 1, \cdots, N+1 \text{ and } \mathbf{X}_1 = \mathbf{X}^{(q)} \text{ given}\}$ is a set of *N*+1 codewords, codewords that are obtained, as relation shows, recursively using $\mathbf{X}_{\text{ones}}$ and the $\mathbf{X}_1$. There are a total of $M^{K-1} = (N+1)^{K-1}$ sets $\mathbf{S}^{(q)}$ of no collision codewords. From the set of codewords, the set of position-codewords is derived straightforward by adding $\mathbf{Z}$.

Example for 128-FFT OFDMA

The number of available carriers for preamble transmission for 128-FFT is 108 (excluding DC carrier). We chose *K*=2, *N*=6, i.e. the Reed-Solomon code is generated modulo *N*+1=7 and the maximum number of positions that can collide when any two codewords are used is *K*-1=1; there are a total of 7^2=49 codewords available. Also, the repetition factor *P*=2, thus the number of carriers that are required for transmission is *N**(*N*+1)**P*=84.

The fixed set is **Z**=[10, 17, 24, 31, 38, 45, 56, 63, 70, 77, 84, 91].

The generator polynomial vector is **g** = [1 6 3 2 4], the generator matrix is $\mathbf{G} = \begin{bmatrix} 1 & 6 & 3 & 2 & 4 & 0 \\ 0 & 1 & 6 & 3 & 2 & 4 \end{bmatrix}$, and $\mathbf{X}_{\text{ones}} = [1 \quad 2]$. There are 7 sets $\mathbf{S}^{(q)}$, each set having 7 codewords. The sets can be generated using as an initial $\mathbf{X}^{(q)} = [0 \quad q],\ q = 0, 1, \cdots, 6$.

Table 1 shows as an example the position-codewords for the no collision set $\mathbf{S}^{(3)}$. It is easy to observe that there are no collisions, even *all* the position-codewords are used *simultaneously* to identify the RSs, i.e. a receiver can distinguish them individually if it knows the set the codewords they pertain to. Note also, that given any codeword in a given set, it is easy to identify the set to which it belongs. However, the position-codewords from any two different sets collide, and thus whenever planning of assigning signatures is done, this has to be taken into account in order to minimize the potential collisions if two sets are used adjacently. Thus by partitioning the poll of signatures available into no collision sets can be a very powerful tool that can be used in planning the RS_Signature_ID assignment to different RSs that have to be easily identified in the system.

Table 1. Example of generating a set with no collisions with (6,2) Reed-Solomon code and P=2

Generating $S^{(3)}$ set			Position-codewords for the set (C=R+Z)	
X index	**[x_1 x_2] (mod 7)**	**Y index (mod 7)**	**Z**	**[10 17 24 31 38 45 56 63 70 77 84 91]**
X_{ones}	**[1 2]**	**[1 1 1 1 1 1]**	**C index**	
X_1 (initial)	[0 3]	[0 3 4 2 6 5]	C_1	[10 20 28 33 44 50 56 66 74 79 90 96]
X_2	[1 5]	[1 4 5 3 0 6]	C_2	[11 21 29 34 38 51 57 67 75 80 84 97]
X_3	[2 0]	[2 5 6 4 1 0]	C_3	[12 22 30 35 39 45 58 68 76 81 85 91]
X_4	[3 2]	[3 6 0 5 2 1]	C_4	[13 23 24 36 40 46 59 69 70 82 86 92]
X_5	[4 4]	[4 0 1 6 3 2]	C_5	[14 17 25 37 41 47 60 63 71 83 87 93]
X_6	[5 6]	[5 1 2 0 4 3]	C_6	[15 18 26 31 42 48 61 64 72 77 88 94]
X_7	[6 1]	[6 2 3 1 5 4]	C_7	[16 19 27 32 43 49 62 65 73 78 89 95]