Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Hit ratio problems with the PUSC permutation**
Date Submitted	**2005-03-13**
Source(s)	Ran Yaniv, Tal Kaitz, Danny Stopler **Alvarion Ltd.**

ran.yaniv@alvarion.com
tal.kaitz@alvarion.com
danny.stopler@alvarion.com

Re:	Call for comments, maintenance task group
Abstract	
Purpose	
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:chair@wirelessman.org> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

Hit Ratio Problems with PUSC Permutation

Ran Yaniv, Tal Kaitz, Danny Stopler
Alvarion Ltd.

1 Introduction

Subchannel permutations are important for averaging interference in an interference-rich environment. These permutations mitigate cross-interference between neighboring cells by minimizing the number of hits that any subchannel of one cell observes from any single subchannel of the neighbor cell. As a consequence, the MSS becomes sensitive to the average of the interference from multiple sources rather than to a single interference source. A well-designed permutation is characterized by:

- Maximal hit count (or 'hit ratio') between any two subchannels should be minimal.
- Standard deviation of hit count over all possible cell configurations should be minimal. This ensures that the permutation's effect is predictable across the deployment and is not sensitive to the specific subchannel indices and/or IDcell values used.
- Sufficient number of different permutation sequences.

The main findings are summarized in the next section, followed by a description of the simulation methodology. Results are then presented. An alternative that shares ideas with Samsung's contribution [1] is proposed in section 4.
.

2 Summary of main findings

- The hit ratio of PUSC in reuse 1/3 configuration (i.e. with orthogonal major groups created by without outer permutation) is such that a single subchannel in one cell may be hit by the same subchannel in the neighbor cell in as many as 38% of its tones.
- The standard deviation of the hit count on a subchannel is high and itself varies widely between different subchannels and IDcell pairs.
- The number of different permutation sequences is restricted to 8 due to the size of the odd major groups.

3 Discussion and Results

The PUSC permutation is comprised of an outer permutation and an inner permutation. The outer permutation divides the subcarriers of one OFDMA symbol into 6 groups of clusters (termed 'major groups') using a renumbering sequence that is IDcell dependent. Each major group comprises several subchannels (major groups vary in size - even major groups are larger than odd major groups). The inner permutation then operates separately on each major group, distributing subcarriers to subchannels within the group.

In PUSC 1/3 configuration, the outer permutation is constant throughout the deployment (IDcell for that permutation is set to constant 0). This mode is mandated for the first zone in the frame (in which maps are transmitted). The inner permutation is defined based on the FUSC permutation, with distinct parameters for the odd and even major groups.

A drawback of this mode is that the inner permutation of each major group is dependent only on (IDcell mod *Nsubchannels*), where *Nsubchannels* is the number of subchannels in the major group. Therefore, the number of different permutation sequences is restricted to 8 due to the size of the odd major groups.

Since the permutation in this configuration is confined to a single major group, the hit ratio was analyzed for each major group type (even/odd numbered) separately. The results are depicted in the figures below, followed by a summary in Table 1.

The results are summarized in Table 1.

Property	**Even major group**	**Odd major group**
Max(c1,c2)	17%	**25%…38%**
Minmax(c1,c2)	17%	**25%…38%**
Std(c1,c2)	3%…8%	**9%…13%**

Table 1 - Summary of hit ratio properties for PUSC 1/3

4 Proposed Solution

We propose an alternative PUSC permutation that addresses the problems raised. The proposal is comprised of both an outer and an inner permutation. Note that the two permutations (outer and inner) are controlled by separate PermBase constants, both signaled through the zone switch IE. This proposal uses the same building blocks of the optional FUSC (same pilot structure and inner permutation formula).

The frequency band is divided into $N_{clusters}$ consecutive physical clusters (enumerated in increasing frequency order [0… $N_{clusters}$-1]). The cluster is comprised of 18 consecutive subcarriers and has the structure depicted in Figure 1.

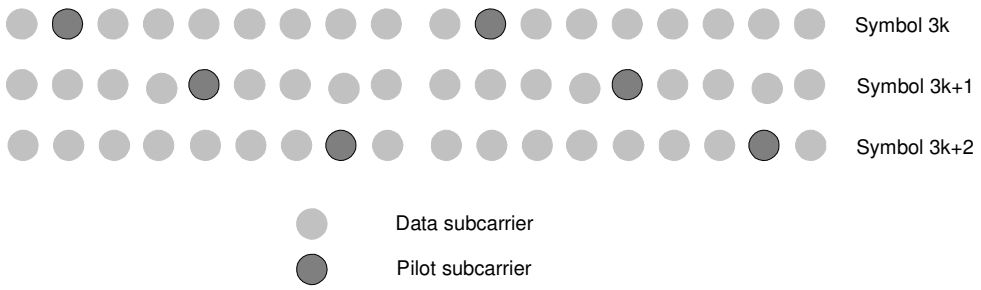

Figure 1 – Cluster structure over 3 OFDMA symbols

The clusters are grouped into 6 major groups through the following outer permutation:

$$cluster(k,n) = N_{groups} \cdot k + p_n[(k \cdot OuterPermBase) \bmod N_{groups}]$$

where

cluster(k,n) is the physical cluster index of cluster *k* in major group *n*,
N_{groups} is the total number of *non-empty* major groups
$p_n[j]$ is the series obtained by rotating the sequence [0:(N_{groups}-1)] cyclically to the left *n* times.
OuterPermBase is the outer permutation cell-specific value signaled through the STC_ZONE_SWITCH_IE(); it is equal to 0 for the first zone.

To form the inner permutation, each major group is comprised of N_s subchannels. To allocate the subchannels, the data subcarriers in a major group over 3 consecutive symbols are partitioned into 48 groups of data subcarriers. Each subchannel consists of one subcarrier from each of these groups. The exact permutation that partitions subcarriers into subchannels is according to the optional-FUSC permutation formula of section 8.4.6.1.2.3.1, with N_s, P_1, and P_2, determined by FFT size (see tables below), and IDcell determined by a separate field, *InnerPermBase*, signaled through the STC_ZONE_SWITCH_IE(). The enumeration of the data subcarriers starts from the major group's data subcarrier that is lowest in frequency in the first OFDMA symbol, and then ascends until the major group's subcarrier that is highest in frequency in the symbol. It then continues to the data subcarrier that is lowest in frequency in the next symbol and so on.

Parameters	Value	Comments
Number of DC Subcarriers	1	
Number of Guard Subcarriers, Left	160	
Number of Guard Subcarriers, Right	159	
Number of Used Subcarriers(N_{used}) (including all possible allocated pilots and the DC carrier)	1729	
Number of Pilot Subcarriers	192	
Pilot subcarrier index	9k+3m+1, for k=0,…, 191 and m=[symbol index]mod3	Symbol of index 0 is the first symbol of a frame
Number of Data Subcarriers	1536	Data subcarriers are reordered and indexed as 0 ~ 1535
Number of clusters	96	
Total number of subchannels	96	
Number of subcarriers per cluster	18	
Number of non-empty major groups (*Ngroups*)	6	
Number of subchannels per non-empty major group *(Ns)*	16	
Inner permutation sequence P1	1, 2, 4, 8, 3, 6, 12, 11, 5, 10, 7, 14, 15, 13, 9	
Inner permutation sequence P2	1, 4, 3, 12, 5, 7, 15 ,9, 2, 8, 6, 11, 10, 14, 13	

Table 2 - 2048 FFT downlink subcarrier allocation for alternative PUSC

The differences between this proposal and [1] should be noted:

1. In [1] no outer permutation is defined.
2. A cluster in [1] is comprised of 36 consecutive subcarriers in frequency, compared to 18 in this proposal. A narrower cluster provides more freedom for the outer permutation, at the cost of a small reduction in channel estimation performance.

5 Properties of the proposed solution

The outer permutation defined above guarantees that the maximal cluster hit ratio is at most 0.5 (it is usually less) between any two major groups in cells with different *OuterPermBase* values.

The new combined (outer+inner) permutation was examined both in a reuse 1/3 scenario (where the outer permutation is constant and merely ensures frequency diversity) and in a reuse 1/1 scenario (where we want to make sure that the new outer permutation does not degrade performance).

5.1 Reuse 1/3

Let us first consider the reuse 1/3 case in which *OuterPermBase*=0. Figure 1(a) depicts the hit ratio *max* and *minmax* for one major group of FFT-2048 for all possible combinations of *InnerPermBase* (combinations with identical *InnerPermBase* have been excluded). Figure 2(b) depicts its *std* for 2048. Interaction between the first 16 *InnerPermBase* values was examined.

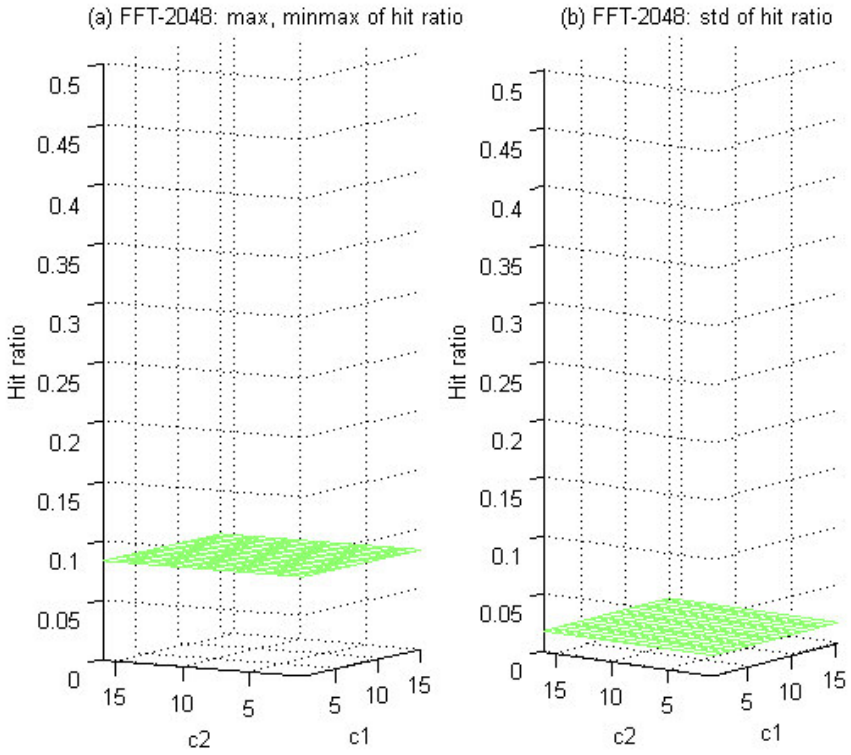

Figure 2 - Hit ratio properties for Alternative PUSC 1/3, FFT-2048 (InnerPermBase = [0…15])

The hit ratio properties of the alternative PUSC proposal for reuse 1/3 are summarized in the table below; for comparison, the properties of the mandatory PUSC are also shown.

Property	Mandatory PUSC: Even (Odd) major groups	Alternative PUSC
Max(c1,c2)	17% **(25%…38%)**	**8%**
Minmax(c1,c2)	17% **(25%…38%)**	**8%**
Std(c1,c2)	3%…8% **(9%…13%)**	**2%**

Table 3 - Summary of hit ratio properties for the two PUSC permutations in reuse 1/3 configuration (InnerPermBase = [0…7]).

5.2 Reuse 1/1

We now consider the case of reuse 1/1 in which *OuterPermBase* is independently signaled through the zone switch IE. Let us consider two scenarios:

1. Cells c1 and c2 are fully loaded.
2. Cells c1 and c2 are partially loaded, each using a set of subchannels ('active set') comprised of 2 consecutive major groups (thus utilizing 1/3 of the bandwidth).

For the full-load scenario, all possible combinations of *OuterPermBase* and *InnerPermBase* (combinations with identical *InnerPermBase* values have been excluded) were examined. Only *InnerPermBase* values in the range [0…7] were considered.

For the partial-load scenario, the hit ratio properties were computed per each (*InnerPermBase*, *OuterPermBase)* combination and the relevant property was computed over all subchannels in all combinations of active subchannel sets. Combinations with identical *InnerPermBase* values have been excluded. Note that the std has been computed for each IDcell combination as well as for each active subchannel set combination (over all subchannels participating in that combination). Per each IDcell combination, the std figure shows the maximum and minimum std value over all active set combinations.

The hit ratio properties of the alternative PUSC proposal for reuse 1/1 are summarized in the table below; for comparison, the properties of the mandatory PUSC are also shown.

Property	Fully loaded cells		Partially loaded cells (*)	
	Mandatory PUSC	Alternative PUSC	Mandatory PUSC	Alternative PUSC
Max(c1,c2)	13%…21%	4%…21%	13%…21%	4%…17%
Minmax(c1,c2)	4%…8%	4%…21%	0%…4%	0%…6%
Std(c1,c2)	3%	2%…3%	1%…4%	0%…3%

Table 4 - Summary of hit ratio properties for the two PUSC permutations in reuse 1/1 configuration (InnerPermBase = [0…7])

(*) Per each IDcell combination, std shows the maximum and minimum std value over all combinations of active sets.

6 References

[1] "Optional DL PUSC design". Jeong-Heon Kim, Panyuh Joo, Seung Joo Maeng, Jaeho Jeon, Soon YoungYoon, Samsung Electronics Co., Ltd. IEEE C802.16e-04/308.