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Types de permutations de sous-porteuses en IEEE 802.16e

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Dans ce rapport, on présente les différents schémas de permutations de sous-porteuses, distribués ou adjacents, prévus par la norme IEEE 802.16e. Les méthodes de permutations sont expliquées pour les voies descendante et montante à l'aide d'exemples appropriés. La diversité en fréquence offerte par les schémas distribués PUSC et FUSC est illustrée par figures et graphiques. On montre également la manière dont sont regroupées les sous-porteuses dans le mode AMC. Quelques caractéristiques d'AMC sont également décrites et discutées.

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List of Acronyms

WiMAX	Worldwide Interoperability for Microwave Access
PUSC	Partial Usage of Subchannels
FUSC	Full Usage of Subchannels
AMC	Adaptive Modulation and Coding
MCS	Modulation and Coding Scheme
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
DL	Downlink
UL	Uplink
FFT	Fast Fourier Transform
AAS	Adaptive Antenna System

1 Introduction

IEEE 802.16 standard pertains to wireless local and metropolitan area networks. Orthogonal Frequency Division Multiplex (**OFDM**) forms the basis of IEEE 802.16 PHY Layer. OFDM modulation technique offers good performance in frequency selective fading channels [1]. OFDM splits the radio signals into multiple smaller sub-signals (called subcarriers in [2] and [3]). The channel extends a flat fading response to these subcarriers. In this article, we are going to describe different subcarrier permutation types presented in IEEE 802.16-2004/2005. We split the subcarrier permutation types, given in [2] and [3], into distributed and adjacent subcarrier permutations.

The rest of the article is divided into two sections. Second section spans the distributed subcarrier permutation type. This type has further two subtypes, namely Partial Usage of Subchannels (**PUSC**) and Full Usage of Subchannels (**FUSC**). Both PUSC and FUSC have additional optional subtypes but only primary subtypes are described in this article. The process of subcarrier distribution is different for PUSC Downlink (**DL**), FUSC DL and PUSC Uplink (**UL**). The process for each case has been explained with the help of examples.

In section three, optional adjacent subcarrier permutation type for Adaptive Modulation and Coding (**AMC**) has been detailed. Adjacent subcarrier permutation specific definitions are given. The difference between band AMC and regular AMC is explained and finally mapping of data on subcarriers is illustrated. Finally, section four concludes this report.

2 Distributed Subcarrier Permutation

PUSC and **FUSC** are the two types to be discussed under this mode. **PUSC** can be employed to both DL and UL, while **FUSC** can be used in **DL** only [2] and [3]. For the purpose of explanation, 2048-FFT will be kept as a reference. In 2048-FFT, used bandwidth is 20 MHz. Total number of subcarriers is 2048 (numbered as 0-2047). We shall refer this 0-2047 scale as ‘absolute subcarrier index’ in the proceeding text.

Before we start with the description of PUSC and FUSC, it will be better

to establish definitions of few terms.

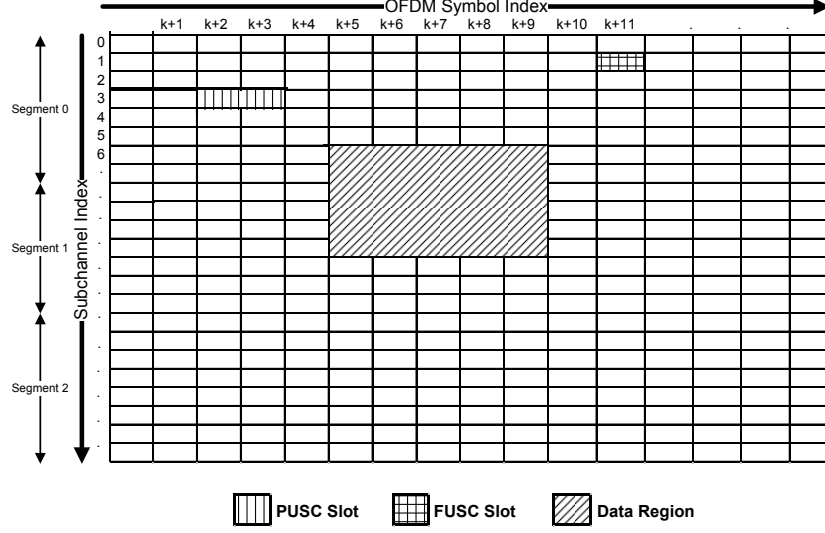


Fig. 1: OFDMA Downlink Frame.

Subcarrier: An **OFDM** symbol is made up of subcarriers. There are three subcarrier types: data subcarriers (for data transmission), pilot subcarriers (for channel estimation purposes) and null subcarriers (for no transmission, guard bands, non-active subcarriers and the DC-subcarrier). Subcarrier spacing is 10.9375 kHz [4].

Subchannel: It is a set of subcarriers. In distributed subcarrier permutation mode, subcarriers of a subchannel are not contiguous. Their distribution is determined by a permutation formula given in Eq.111 of [3]. In adjacent subcarrier mode, subchannels are constituted of bins.

Slot: It is the minimum possible data allocation unit. It spans both the time domain (**OFDM** symbol) and frequency domain (subchannel). It is expressed as number of subchannels per number of symbols (see Fig.1).

Data Region: It is a two-dimensional rectangular allocation of a group of subchannels in a group of **OFDMA** symbols (see Fig.1).

Segment: The set of available subchannels form a segment. There can be three segments in a frame (see Fig.1).

Group: It is the set of clusters (**PUSC DL**) or subcarriers (**FUSC DL**) or tiles (**PUSC UL**).

Permutation zone: It consists of **OFDMA** symbols that use the same permutation scheme (i.e., **PUSC**, **FUSC** or **AMC**). According to [2] and [3], first zone in the **DL** subframe is essentially **PUSC**. The maximum number of downlink zones in one downlink subframe is eight. The maximum number of bursts to decode in one downlink subframe is sixty four. An example of different permutation zones (in **DL** and **UL** subframes) is given in Fig.2 (Fig.219 copied from [3]).

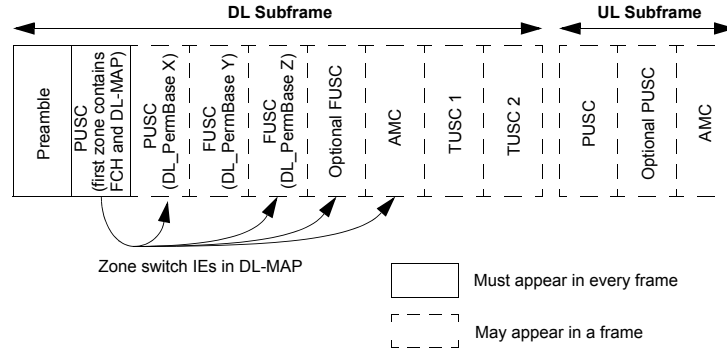


Fig. 2: Illustration of **OFDMA** frame with multiple zones [3].

DC Subcarrier: In an Orthogonal Frequency Division Multiplex (**OFDM**) or Orthogonal Frequency Division Multiple Access (**OFDMA**) signal, the subcarrier whose frequency would be equal to the RF center frequency of the station is called the DC subcarrier.

Perm_Base: It has been separately defined for DL and UL. In DL it is called DL.PermBase which is an integer ranging from 0 to 31, which identifies the particular BS segment and is specified by MAC layer. It is set to preamble IDCell in the first zone and determined by the DL-MAP for other zones. For UL, there is a different integer called UL.PermBase which ranges from 0 to 69 and is assigned by a management entity.

2.1 FUSC

In this type of subcarrier distribution, all of the subchannels are allocated to the transmitter. That is why it is called full usage of subchannel [2]. As already mentioned, it is used only in DL.

Introduction

One slot of FUSC DL is one OFDM symbols by one subchannel (Fig.1), while one FUSC DL subchannel comprises 48 data subcarriers. With 2048-FFT, there are 32 subchannels in total. Out of 2048, there are 173 left guard subcarriers, 172 right guard subcarriers, 1536 data subcarriers, 166 pilot subcarriers and one DC subcarrier. Out of 166, 24 Pilot subcarriers are fixed and their positions (w.r.t absolute subcarrier index) are specified in Table-311, page 531 of [3]. The rest 142 Pilot subcarriers are variable and they change from one FUSC symbol (starting from 0) to another. Their positions are given by the formula 110 [2]:

$$Pilot\ Locations = Variable\ Set\#x + 6.(FUSC\ Symbol\ Number\ mod\ 2)$$

Variable Sets 0 and 1 are given in Table-311, page 531 of [3].

FUSC group is a set of data subcarriers. Pilot subcarriers are not included in FUSC groups. With 2048 FFT, number of groups is equal to forty eight and number of subcarriers in a group is thirty two as shown in Fig. 3.

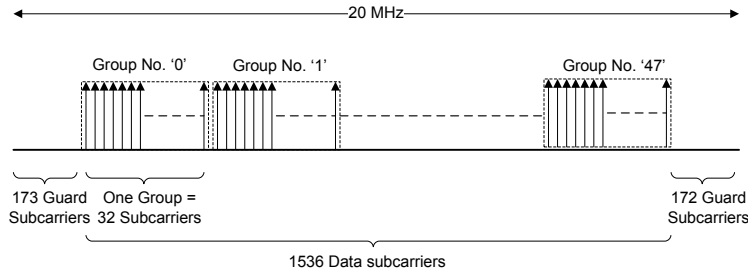


Fig. 3: Group structure in FUSC DL (2048-FFT).

Subchannel Formation (**FUSC** DL)

Before subcarriers are assigned to subchannels, both fixed and variable pilot subcarriers are first separated. The rest of subcarriers (data subcarriers) are combined in groups. Then permutation formula (Eq.111 of [2]) is used to assign subcarriers to subchannels. As already mentioned, number of data subcarriers in every subchannel is the same i.e., 48; however, number of subchannels is equal to number of subcarriers in a group. With 2048-FFT, there are 32 subchannels in total.

During subcarrier distribution process, one subcarrier is picked up using the permutation formula from every group and is being allocated to a subchannel. The process is shown in Fig.4.

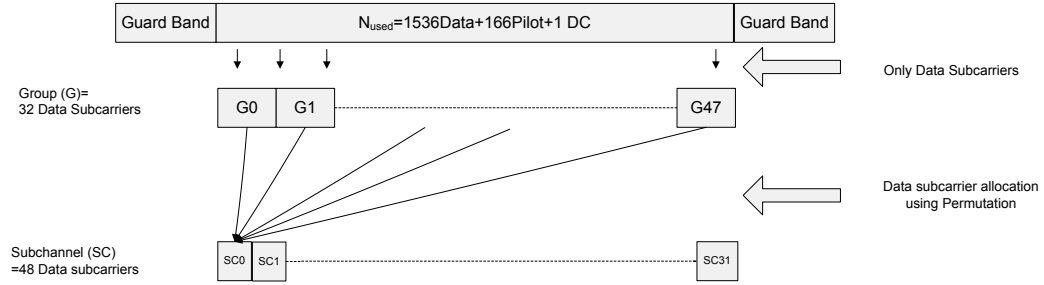


Fig. 4: Permutation process of **FUSC** DL (2048-FFT)

Here is Eq.111 of [2]:

$$subcarrier(k, s) = N_{subchannels} \cdot n_k + \{P_s[n_k \bmod N_{subchannels}] + DL_PermBase\} \bmod N_{subchannels}$$

where

$subcarrier(k, s)$ is the index of subcarrier k among all available data subcarriers. With 2048-FFT, index of subcarrier ranges from 0-1535.

s	is the index number of a subchannel in a group, from the set $[0...N_{subchannels}-1]$ i.e., with 2048-FFT, $N_{subchannels}$ ranges from 0-32.
n_k	$= (k + 13s) \bmod N_{subcarrier}$
k	is the subcarrier-in-subchannel index from the set $[0...N_{subcarrier} - 1]$. It ranges from 0 – 47.
$N_{subcarrier}$	is always 48 for FUSC .
$DL_PermBase$	is already defined (cf. section-1).
$P_s[.]$	is the series obtained by rotating basic permutation sequence cyclically to the left s times (Table-311 [3]). $P_s[.] = \{3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30\}$.

Following example explains the procedure:

Let $k = 46$, $s = 31$ and $DL_PermBase = 0$

$$n_k = (46 + 13 \times 31) \bmod 48 = 17$$

$$\begin{aligned}
Subcarrier(46, 31) &= 32 \times 17 + \{P_{31}[17 \bmod 32] + 0\} \bmod 32 \\
&= 544 + 29 \\
&= 573
\end{aligned}$$

[Fig.5](#) shows 48 subcarriers of subchannel ‘0’ of group zero plotted against absolute subcarrier index. It is clear from the figure that subcarriers of a subchannel are distributed through out the available band (excluding guard bands). But high density of figure does not allow us to appreciate how permutation formula picks up exactly one subcarrier from every group. For that purpose, [Fig.6](#) shows a magnified view of a subsection of [Fig.5](#).

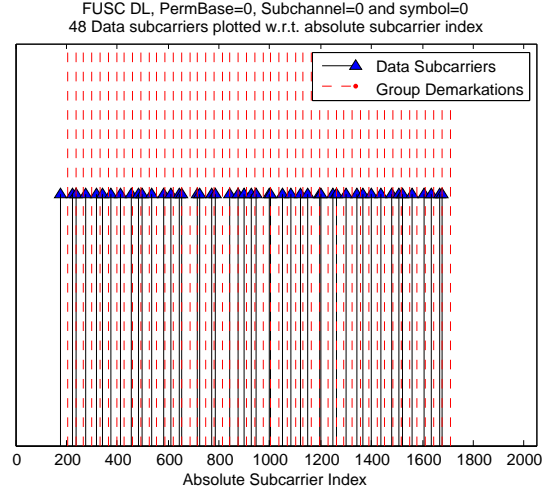


Fig. 5: Subcarriers of Subchannel '0' of FUSC DL (2048-FFT)

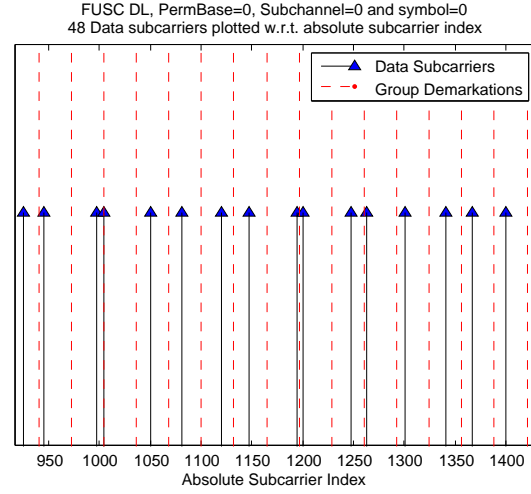


Fig. 6: Subcarriers of Subchannel '0' of FUSC DL (2048-FFT)

2.2 Partial Usage of Subchannels (PUSC)

In this type of subcarrier distribution, some of the subchannels are allocated to the transmitter. That is why it is called partial usage of subchannel [2]. The subchannels allocated to one transmitter form a segment. Remaining subchannels are attributed to different segments. Each segment is assigned to different sector. PUSC is used both in UL and DL.

2.2.1 PUSC DL

Definitions

One slot of PUSC DL is two OFDM symbols by one subchannel (see Fig.1), while one PUSC DL subchannel comprises 24 data subcarriers. Out of 2048, there are 184 left guard subcarriers, 183 right guard subcarriers, 1440 data subcarriers, 240 pilot subcarriers and one DC subcarrier. Few terms specific to PUSC DL are given hereafter.

Physical Cluster: It is a set of 14 adjacent subcarriers (12 data + 2 pilot). These clusters are contiguous in the frequency band (see Fig.8). There are total 120 physical clusters with 2048-FFT.

Logical Cluster: Physical Clustered are renumbered according to a renumbering sequence to form logical clusters. This renumbering sequence is given in [2]. The two adjacent logical clusters are not contiguous in frequency band.

Group: It is a set of logical clusters. Odd numbered groups contain half the number of logical clusters as compared to even numbered groups. These groups are commonly referred as major groups. There are six groups in total. With 2048-FFT, odd group consists of 24 logical clusters while even group comprises 16 logical clusters. For the purpose of inner permutation, the subcarriers of each group are indexed separately, i.e., every group will have subcarriers index starting from '0'. With 2048-FFT, even and odd groups will have subcarrier index 0-335 and 0-225 respectively. Using inner permutation (it is defined in the next paragraph), '12' and '8' subchannels will be formed from even and odd groups respectively. Before subchannel formation, pilot subcarriers are identified and rest of the subcarriers are re-indexed i.e., 0-287

and 0-194 for even and odd groups respectively. These re-indexed numbers will be referred as group subcarrier index in subsequent sections.

Inner Permutation: The process to form subchannels from the subcarrier of logical clusters of a group is called inner permutation. Permutation base can be set between (0-31) for the rest of **PUSC** zones. The effect of the value of permutation base will become clear when permutation method will be explained in detail.

Outer Permutation: It is the process by which physical clusters are renumbered to give rise to logical clusters. In case of outer permutation, *DL_PermBase* is set to IDCell in this first zone of all the cells/segments.

Subchannel Formation

The permutation process to form subchannels is shown in Fig.7. The process

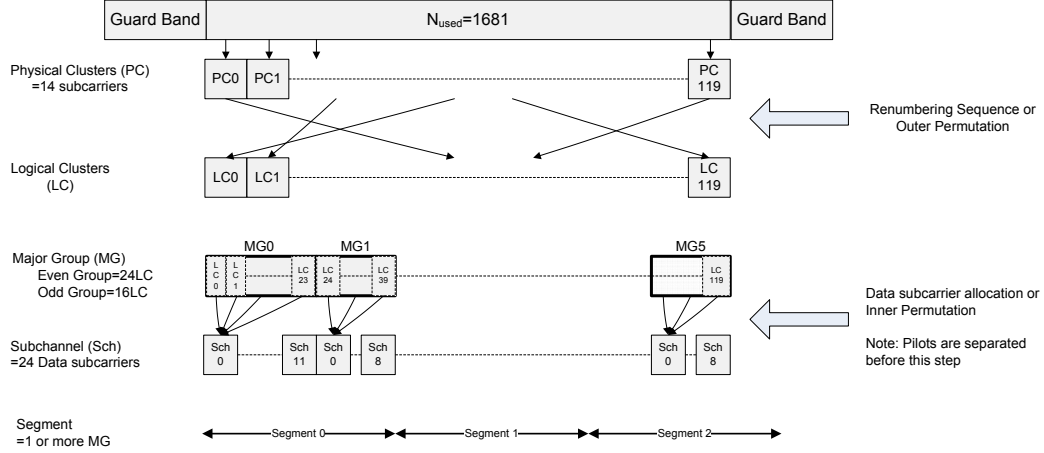


Fig. 7: Outer and inner permutations in **PUSC** DL.

is stepwise explained as follows:

Step 1: All available subcarriers are partitioned as right guard band, data, DC, pilot and left guard band subcarriers. Physical cluster is formed by grouping together 14 adjacent subcarriers. With 2048-FFT, there are total 120 physical clusters (numbered as 0-119). These clusters include all the data

and pilot subcarriers. Fig.8 explains this step.

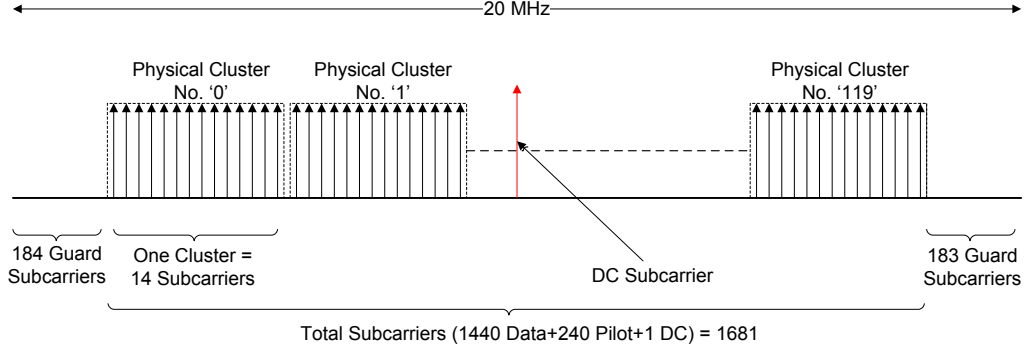


Fig. 8: PUSC Downlink (2048-FFT).

Step 2: Logical clusters are formed by renumbering the Physical clusters obtained in step 1 using equation given below [3]. This process is also called outer permutation.

$$\text{Logical Cluster} = \text{Renumbering Sequence}(\text{Physical Cluster}) + 13.DL_PermBase$$

The renumbering sequence as copied from [2] is given hereafter:

6, 108, 37, 81, 31, 100, 42, 116, 32, 107, 30, 93, 54, 78,
10, 75, 50, 111, 58, 106, 23, 105, 16, 117, 39, 95, 7,
115, 25, 119, 53, 71, 22, 98, 28, 79, 17, 63, 27, 72, 29,
86, 5, 101, 49, 104, 9, 68, 1, 73, 36, 74, 43, 62, 20, 84,
52, 64, 34, 60, 66, 48, 97, 21, 91, 40, 102, 56, 92, 47,
90, 33, 114, 18, 70, 15, 110, 51, 118, 46, 83, 45, 76, 57,
99, 35, 67, 55, 85, 59, 113, 11, 82, 38, 88, 19, 77, 3, 87,
12, 89, 26, 65, 41, 109, 44, 69, 8, 61, 13, 96, 14, 103, 2,
80, 24, 112, 4, 94, 0

Step 3: Logical clusters of step 2 are grouped together to form 6 major groups. These groups are numbered from 0 to 5. In case of 2048-FFT, even groups (0, 2 and 4) contain 24 logical clusters each, while odd groups (1,

3 and 5) have 16 logical clusters each. The formation of group is shown in Fig.9.

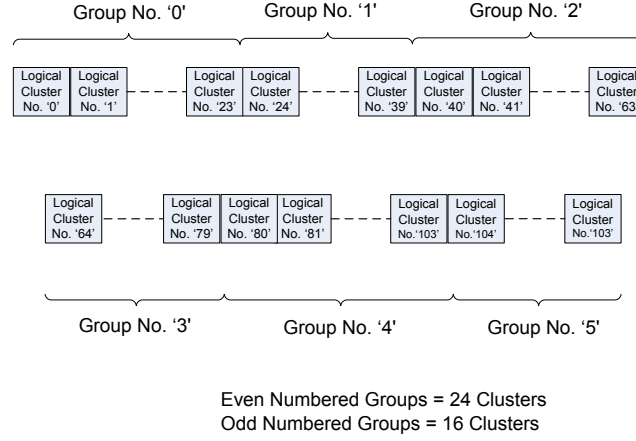


Fig. 9: Groups in PUSC DL (2048-FFT).

In order to appreciate how this outer permutation gives frequency diversity, plot in

Fig.10 shows distribution of logical clusters of group '0' with respect to 120 physical cluster positions.

Step 4: Pilot positions are marked separately for odd and even OFDM symbol. These subcarriers will be separated from the rest before inner permutation. For example, consider subcarriers of logical cluster '0' (With $Perm_Base = 0$, it is the 6th physical cluster). These subcarriers are numbered as 0-13 (Fig.11). Their positions w.r.t the absolute subcarrier index (0-2047) are 268-281. The pilot subcarriers for odd symbols will be '4' and '8' ('272' and '276' w.r.t absolute subcarrier index). For even OFDM symbols '0' and '12' ('268' and '280') will be pilot positions. The rest twelve subcarriers will be used as data subcarriers in the inner permutation.

Step 5: Subcarriers of a group are assigned to subchannels using permutation formula given in Eq.111 of [3]. It should be noted that this formula is explicitly applied to subcarriers of a group. While in FUSC DL it was applied to all available data subcarriers. Subcarrier index obtained from this formula is the group subcarrier index (defined under definition of PUSC

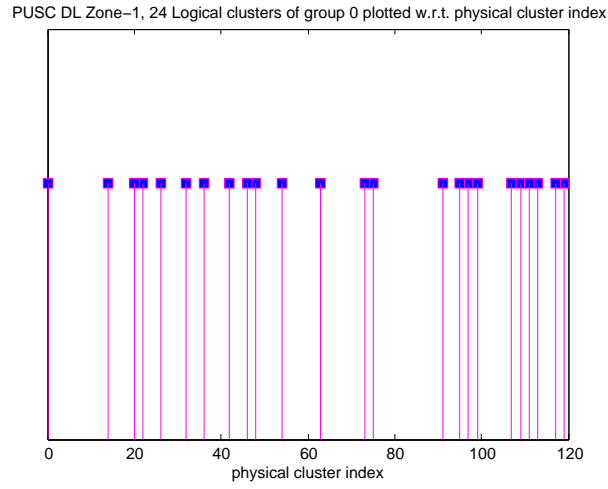


Fig. 10: Example of outer permutation ([PUSC DL](#), 2048-FFT).

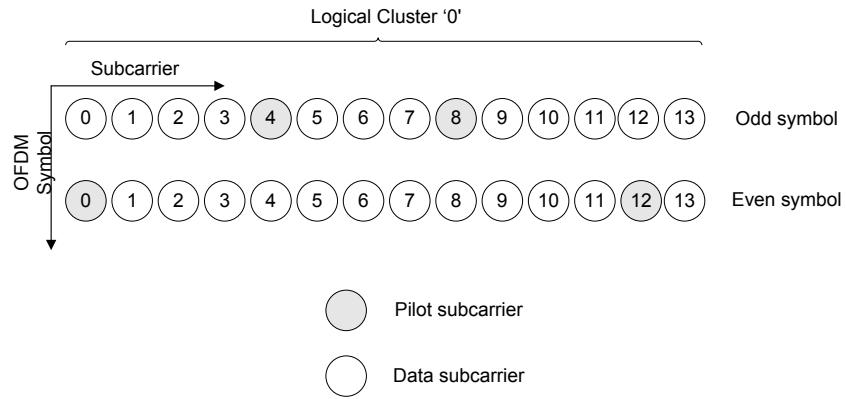


Fig. 11: PUSC DL Slot.

group). Here, Eq.111 of [3] has been rewritten for reference.

$$\text{subcarrier}(k, s) = N_{\text{subchannels}} \cdot n_k + \{P_s[n_k \bmod N_{\text{subchannels}}] + DL_PermBase\} \bmod N_{\text{subchannels}}$$

where

$\text{subcarrier}(k, s)$ is the index of subcarrier k within a group (i.e., with 2048-FFT, in group '0', it ranges from (0-287).

s is the index number of a subchannel in a group, from the set $[0 \dots N_{\text{subchannels}} - 1]$ (i.e., with 2048-FFT, $N_{\text{subchannels}}$ for even and odd groups are 12 and 8 respectively).

$$n_k = (k + 13s) \bmod N_{\text{subcarrier}}$$

k is the subcarrier-in-subchannel index from the set $[0 \dots N_{\text{subcarrier}} - 1]$.

$N_{\text{subcarrier}}$ is always equal to 24 for PUSC DL.

$DL_PermBase$ is already defined (cf. section-1).

$P_s[.]$ is the series obtained by rotating basic permutation sequence cyclically to the left s times (Table-310 [3]).
 $P_s[.] = \{6, 9, 4, 8, 10, 11, 5, 2, 7, 3, 1, 0\}$ and $\{7, 4, 0, 2, 1, 5, 3, 6\}$ for even and odd groups respectively.

The step 5 is explained with the help of following example:

Let $k = 11$, $s = 1$ and $DL_PermBase = 0$ and Group = 0

$$n_k = (11 + 13 \times 1) \bmod 24 = 0$$

$$\begin{aligned} \text{Subcarrier}(11, 1) &= 12 \times 0 + \{P_1[0 \bmod 12] + 0\} \bmod 12 \\ &= 0 + 9 \\ &= 9 \end{aligned}$$

For odd **OFDM** symbols, this will be 279^{th} subcarrier (w.r.t. the absolute subcarrier index) and for even **OFDM** symbols, this will be 278^{th} subcarrier (w.r.t. the absolute subcarrier index). In this way all subcarriers of a group are assigned to subchannels.

We have already seen the effect of outer permutation on frequency diversity. Now to see the effect of inner permutation, subcarriers of subchannel ‘0’ (of group ‘0’) are plotted w.r.t. the group subcarrier index (Fig.12). To see the effect of both the inner and outer permutation at the same time, subcarriers of subchannel ‘0’ (of group ‘0’) are also plotted against the absolute subcarrier index (Fig.13).

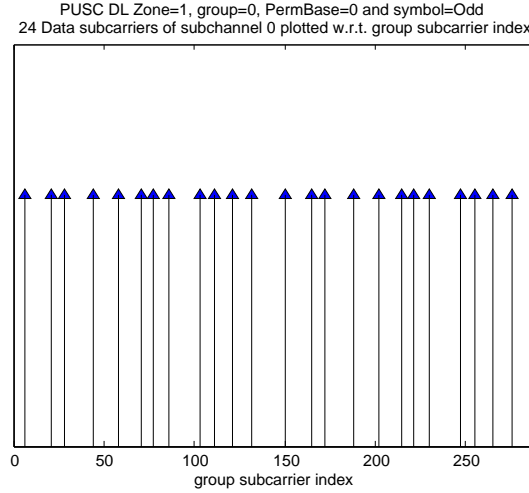


Fig. 12: Subcarriers of subchannel plotted against group subcarrier index.

2.2.2 **PUSC** UL

One slot of **PUSC** UL is three **OFDM** symbols by one subchannel. Out of 2048, there are 184 left guard subcarriers, 183 right guard subcarriers and one DC subcarrier. There are ‘840 data + 840 pilot’ subcarriers for even numbered **OFDM** symbols and ‘1680 data + 0 pilot’ for odd numbered **OFDM** symbols. Fig.14 explains how pilots are marked for even numbered **OFDM** symbols and also it points out the absence of pilot carriers during odd symbol.

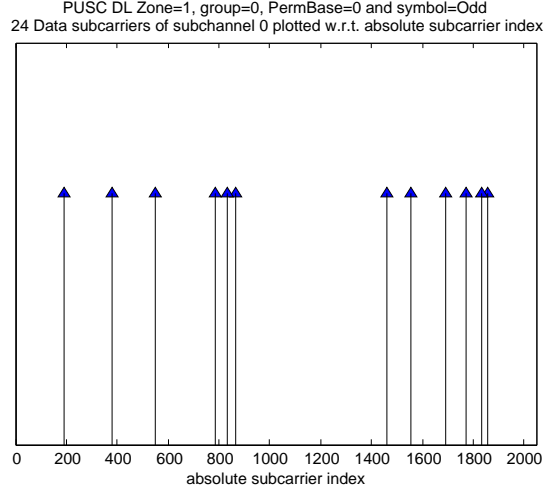


Fig. 13: Subcarriers of subchannel plotted against absolute subcarrier index.

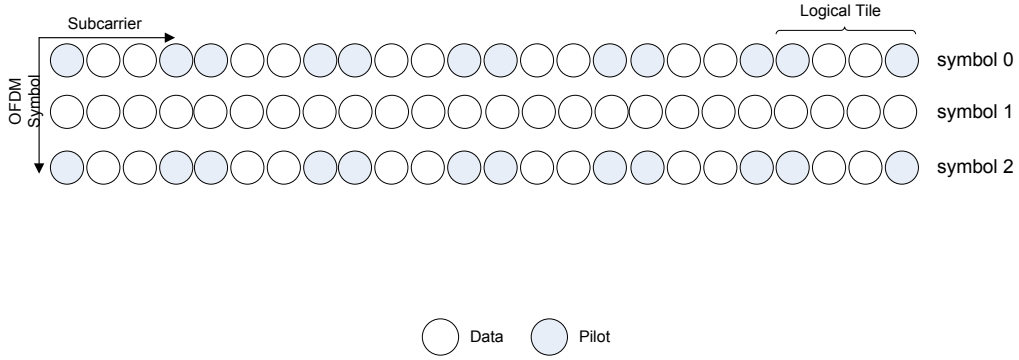


Fig. 14: One PUSC UL Slot.

Definitions

Tile: A tile is composed of four contiguous subcarriers. With 2048-FFT, there are 420 tiles in total. Tiles in PUSC UL can be compared to clusters in PUSC DL. Contiguous tiles in given frequency band are called physical tiles (Fig.15). Tiles are re-indexed using permutation formula (shall be explained later on) to form logical tiles. Logical tiles are not contiguous in given frequency band.

Subchannel PUSC UL: It is formed from six logical tiles.

Data Constellation Points: These are the data points produced after the modulation and coding process. These are transmitted on data subcarriers.

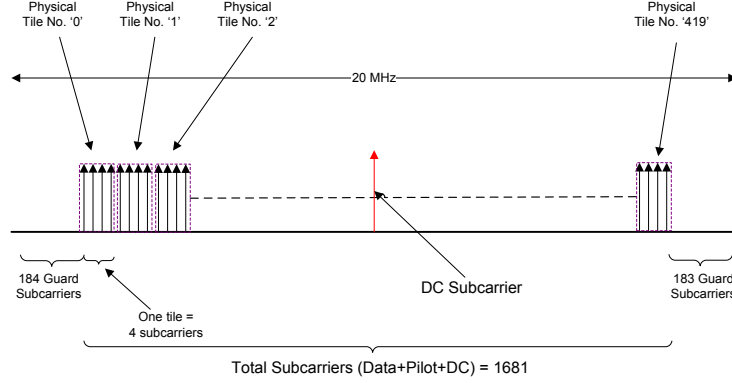


Fig. 15: PUSC UL (2048-FFT).

Data Points to Subcarrier Mapping (PUSC UL)

The permutation process to map data points on subcarriers of subchannels is shown in Fig.16. Here also we shall adopt the same technique of dividing the complete process into multiple steps.

Step 1: Physical tiles are renumbered as logical tiles using Eq.113 of [3].

$$Tile(s, n) = N_{subchannels} \cdot n + \{P_t[(s + n) \bmod N_{subchannels}] + UL_PermBase\} \bmod N_{subchannels}$$

where

$UL_PermBase$ is an integer value in the range [0....69], and is assigned by a management entity.

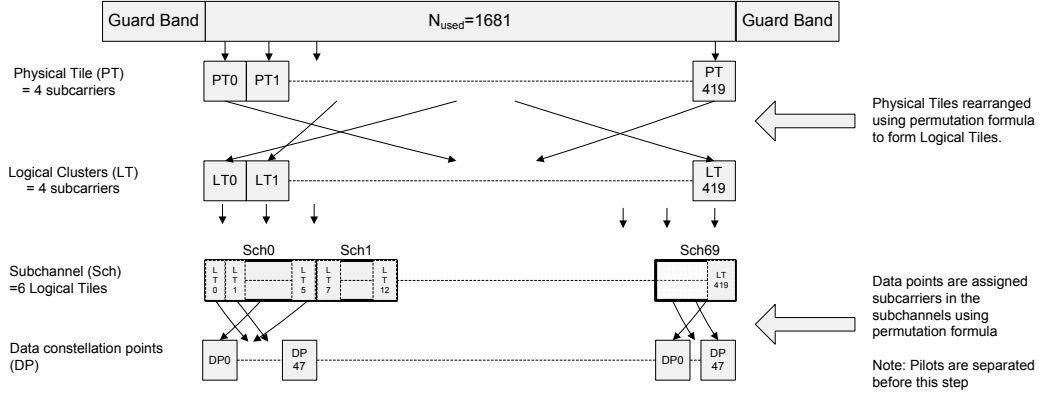


Fig. 16: Data allocation to subcarriers in PUSC UL (2048-FFT).

- $Tile(s, n)$ is the physical tile index [0....419].
- s is the channel number to which physical tile index is assigned [0....70].
- n is the index of the logical tile in subchannel s [0....5].
- $N_{subchannels}$ in our case it is 70 (i.e., for 2048-FFT).
- $P_t[.]$ is the tile permutation given in (Table-313, Page 569, of [3]). $P_t[.] = \{6, 48, 58, 57, 50, 1, 13, 26, 46, 44, 30, 3, 27, 53, 22, 18, 61, 7, 55, 36, 45, 37, 52, 15, 40, 2, 20, 4, 34, 31, 10, 5, 41, 9, 69, 63, 21, 11, 12, 19, 68, 56, 43, 23, 25, 39, 66, 42, 16, 47, 51, 8, 62, 14, 33, 24, 32, 17, 54, 29, 67, 49, 65, 35, 38, 59, 64, 28, 60, 0\}$.

The process of physical to logical tile mapping is explained using an example:

Let's calculate tiles for $s = 5$ and $UL_PermBase = 0$

Rotating the tile permutation 5 times we get: 1, 13, 26, 46, 44, 30, 3, 27, 53, 22, 18, 61, 7, 55, 36, 45, 37, 52, 15, 40, 2, 20, 4, 34, 31, 10, 5, 41, 9, 69, 63, 21, 11, 12, 19, 68, 56, 43, 23, 25, 39, 66, 42, 16, 47, 51, 8, 62, 14, 33, 24, 32,

17, 54, 29, 67, 49, 65, 35, 38, 59, 64, 28, 60, 0, 6, 48, 58, 57, 50

Taking the first six numbers from rotated tile permutation and adding $PermBase = 0$ we get: $\{1, 13, 26, 46, 44, 30\}$

Adding $70 \times n$ for each tile we get: $\{71, 83, 166, 256, 324, 380\}$ are the physical tile indexes of logical tiles in subchannel 5.

Step 2: Before assigning data constellation points to subcarriers, pilot carriers are allocated first. The mapping of data constellation points onto the data subcarrier is performed by Eq.114 of [3]:

$$Subcarrier(n, s) = (n + 13.s) \bmod N_{subcarrier}$$

where

- $Subcarrier(n, s)$ is the permuted subcarrier index for data constellation point n in subchannel s [0....47].
- n is the running index indicating data constellation point [0....47].
- s is the subchannel number.
- $N_{subcarrier}$ is the number of subcarriers in a slot (i.e., 48).

Here is an example of this mapping:

Let $s = 1$ and $n = 0$ then

$Subcarrier(0, 1) = 13$ and it is shown as a filled subcarrier in Fig.17

3 Adjacent Subcarrier Permutation

In this type of subcarrier permutation, subchannels are composed of contiguous subcarriers. It has better channel estimation capabilities and allows adaptive modulation and coding [5]. SS may switch from the “distributed

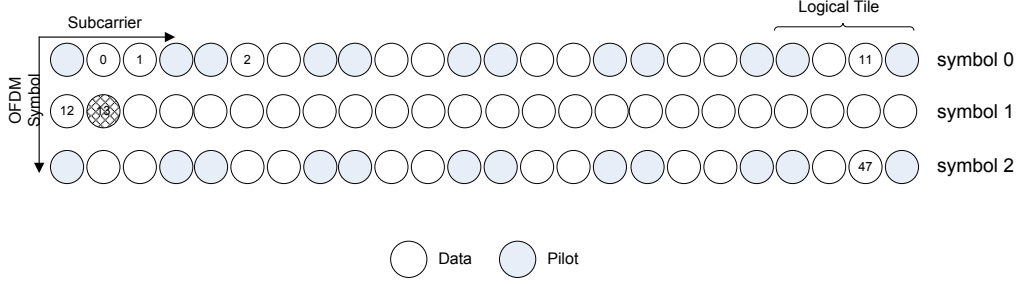


Fig. 17: Mapping of data constellation point.

subcarrier permutation” to the “adjacent subcarrier permutation”, when it changes from non-AAS to AAS-enabled traffic to support Adaptive Antenna System (AAS) adjacent subcarrier user traffic [3]. The permutation is same for UL and DL.

Once switched to the zone of adjacent subcarrier permutation mode in a frame, BS shall continue to transmit/receive data using the adjacent subcarrier permutation mode. The BS shall return to the distributed subcarrier permutation at the beginning of a new DL subframe [3]. Once again we start with some basic definitions.

Bin: It is the smallest unit in frequency domain for adjacent carrier permutation. It is composed of 9 contiguous subcarriers. Out of 9, eight are data tones and one is pilot tone as shown in Fig.18 (inspired from [3]).

Slot: There are four different slot structures types. In the first type (default type), a slot is six contiguous bins by one symbol. For the second type, it is two bins by three symbols. For the third type, it is three bins by two OFDMA symbols and for the fourth and last type, a slot is one bin by six symbols. If N is number of bins and M is number of symbols then product $N \times M$ is always equal to six.

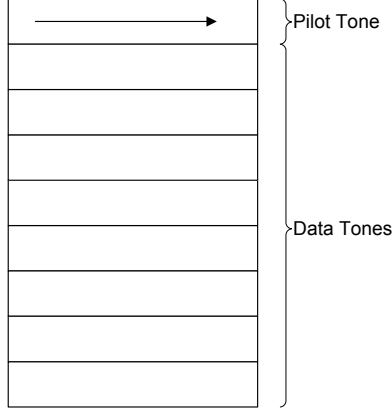


Fig. 18: Bin structure in adjacent subcarrier permutation [3].

FFT	2048	1024	512	128
Max. no. of logical bands	12	12	12	3
Total available physical bands	48	24	12	3
No. of physical bands in a logical band	4	2	1	1

Table 1: Number of PHY and logical bands for different FFT sizes.

Subchannel: The subchannel in adjacent subcarrier permutation is composed of bins. Number of bins depend upon slot structure. For example for default type, a subchannel comprises six bins. For rest of the three types, subchannel has two, three and six bins respectively.

PHY Band: A group of four rows of bins is called a physical band (see Fig.19).

Logical Band: A logical band is a group of physical bands (see Fig.19). For 2048/1024-FFT, number of physical bands per logical band is obtained by dividing maximum number of logical bands by total available physical bands. In case of 512/128-FFT, logical bands and physical bands are equal. Quantitative relationship between PHY and logical bands is shown in Tab.1.

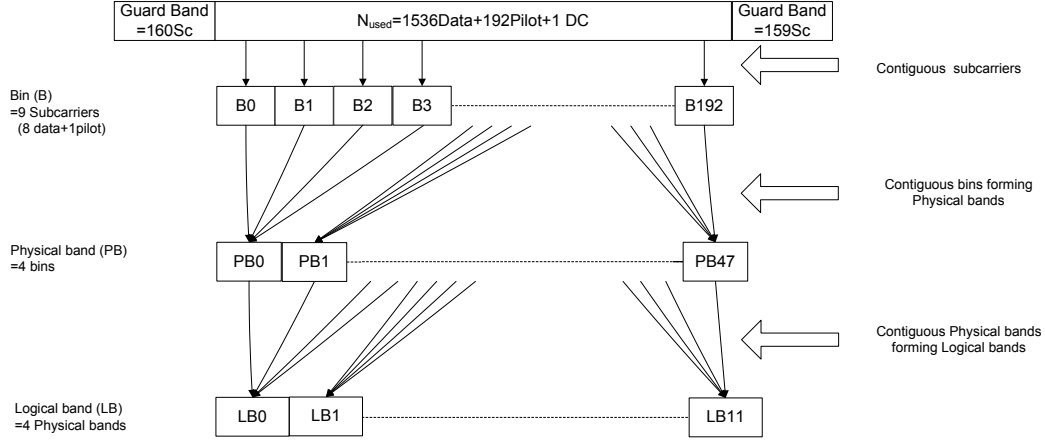


Fig. 19: PHY and Logical bands in adjacent subcarrier permutation.

Subcarrier Allocation

Pilots are allocated first and separated from the data subcarriers. The indexing of pilot tones is done using equation given below[3]:

$$Pilot\ Subcarrier\ Index = 9k + 3m + 1$$

with

$$m = [symbol\ index] \mod 3$$

where $k = 0, 1, 2, \dots, N_k$. Value of N_k depends upon FFT size and is given in Tab.310 of [3]. Symbol of index '0', in pilot subcarrier index (i.e., calculation of m), should be the first symbol of the current zone. m is incremented only for data symbols, excluding preambles, safety zones, sounding symbols, midambles, etc [3]. DC subcarrier is excluded when the pilot subcarrier index is calculated by the equation.

AMC allocations can be made by two mechanisms either by subchannel index reference in UL-MAP and DL-MAP or by subchannel allocation in a band using HARQ MAP. Both UL and DL zone may include allocations from HARQ and normal MAP. For regular and band AMC allocations with normal DL/UL MAP, a slot is always two bins by three symbols. Band-AMC allocation with DL/UL MAP or HARQ MAP is the same except CQI (channel quality indicator). Feedback mechanism is different for the two [6].

For AMC allocations using UL-MAP and DL-MAP, data mapping to subcarriers is done in a sequential way. For band AMC allocation through HARQ MAP, subcarrier permutation is used to identify AMC subchannel of a cell/sector [7]. Using this subcarrier permutation, the j^{th} symbol of the 48 data symbols (where a band AMC slot is allocated) is mapped onto the $(S_{off}^{per}(j) - 1)^{th}$ subcarrier of a slot. j is from $[0, \dots, 47]$ and

$$S_{off}^{per}(j) = \begin{cases} P_{per}(j) & P_{per}(j) + off \neq 0; \\ off & P_{per}(j) + off = 0. \end{cases}$$

where

$P_{per}(j)$ is the j^{th} element of the left cyclic shifted version of basic sequence P_0 by per .

P_0 is the basic sequence defined in $GF(7^2)$: {01, 22, 46, 52, 42, 41, 26, 50, 05, 33, 62, 43, 63, 65, 32, 40, 04, 11, 23, 61, 21, 24, 13, 60, 06, 55, 31, 25, 35, 36, 51, 20, 02, 44, 15, 34, 14, 12, 45, 30, 03, 66, 54, 16, 56, 53, 64, 10}.

$$per = PermBase \bmod 48$$

$$off = (|PermBase/48|) \bmod 49.$$

This field is an element of $GF(7^2)$.

The addition between two element in $GF(7^2)$ is component-wise addition modulo 7 of two representation. For example, $(56) + (34)$ in $GF(7^2) = (13)$

3.1 Conclusion

In this article distributed and adjacent subcarrier permutation types of IEEE 802.16e are presented. Permutation method for both the uplink and downlink are explained with the help of suitable examples. Frequency diversity offered by distributed subcarrier permutations, FUSC and PUSC, has been illustrated with the help of figures and plots. It is also shown that how subcarriers are grouped together in an AMC subchannel. Few characteristics of AMC mode are also discussed.

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