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Agenda Item: 9.2 New contributions: Multiplexing and channel coding

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Title: **Optimisation of extended TFCI encoding**

Document for: Discussion (Approval at WG1 #4)

1 Abstract

In this contribution we present an optimisation for the extended TFCI encoding. The basic encoding scheme i.e. the usage of two biorthogonal (16, 5) block codes is maintained, however the information is evenly distributed onto both block codes (both words) which provides an advantage in terms of required Eb/N0 over the asymmetrical distribution, which is the current working assumption. The introduction of this scheme will require only minor changes and will not affect decoding complexity but will achieve a performance gain of about 0.4 dB.

2 Introduction

Two schemes are specified in [1,2] to encode the Transport Format Combination Indicator (TFCI). If there are at most 6 bits of TFCI the channel encoding is done using one biorthogonal (32, 6) block code. Correspondingly, if the TFCI word is extended to 7-10 bits the channel encoding is done using two biorthogonal (16, 5) block codes. Only the latter case is addressed in this contribution. This scheme was first presented in [3], performance evaluations were presented in [3] and [4].

If 1024 different data rate combinations are to be encoded, which means that both words are fully loaded with information, the presently employed scheme is thought to be optimal.

If less rates (but still more than 64) are to be encoded i.e. 7 to 10 bits, the 5 least significant bits are placed in word 1, the remaining information is put in word 2. Then the second word carries less information than the first one. As a consequence, the FER for the second word will be lower, because during decoding a-priori information about a reduced range can be efficiently used. Unfortunately, the FER of the first word will not be improved. As the total TFCI will be in error if only one of the two words is decoded incorrectly, this coding scheme can not take full advantage of reduced TFCI sets, because the weaker performance of word 1 will limit the total performance.

A better performance can be obtained, if the data is distributed evenly on both words to enable both words to enjoy a similar performance gain over the fully loaded case. We present such distribution schemes, evaluate their merits and propose to include the best one in the specifications.

The paper is organised as follows:
In chapter 3 we cite from S1.12 the present distribution of the TFCI information on the two words.
In chapter 4 we present an improved distribution algorithm and evaluate its advantages. This algorithm is not the most general one, it is optimum only for special cases and is presented mainly to demonstrate the principle.
In chapter 5 we present and analyse an algorithm which achieves the best possible performance but has some disadvantages when changing the TFCI range dynamically as shown in chapter 6.
In chapter 7 we finally present the optimum algorithm, which combines all advantages.
In chapter 8 we estimate the performance gain for the new scheme and present simulation results comparing the optimum algorithm with the working assumption in chapter 9.
At last we will propose to incorporate this principle for the 3GPP specification.
We present a text proposal in the accompanyng contribution [5]

3 Presently employed extended TFCI coding scheme

The following text is a citation from S1.12, S1.22 contains the identical description:

7.3.1.2 Extended TFCI word

If the number of TFCI bits is 7-10 the TFCI information field is split into two words of length 5 bits as shown in the Figure 7-19. **Error! Bookmark not defined.**

Both of the words are encoded using biorthogonal (16, 5) block code. The code words of the biorthogonal (16, 5) code are from two mutually biorthogonal sets, $S_{C_{16}} = \{C_{16,1}, C_{16,2}, ..., C_{16,16}\}$ and its binary complement, $\bar{S}_{C_{16}} = \{\bar{C}_{16,1}, \bar{C}_{16,2}, ..., \bar{C}_{16,16}\}$. Words of set $S_{C_{16}}$ are from the level 16 of the code three of OVSF codes defined in document S1.13. The mapping of information bits to code words is shown in the Table 7-8. **Error! Bookmark not defined.**

4 Bit wise balanced distribution for TFCI encoding

Obviously the loading of the two words with information as depicted in the figure of the last paragraph is unbalanced in general. A better balancing can be obtained by moving one bit from the first to the second word as shown in Figure 1. The actual encoding is then done as usual i.e. using biorthogonal coding.

5 Optimally balanced distribution of TFCI information

In the above mentioned algorithm, a perfect balancing of the information can only be achieved for 256 RIs (8 bits). It would be desirable to obtain also a balance for the other cases i.e. distribute the information with a finer granularity than a single information bit. This can be done, because the biorthogonal decoder can not only use the a-priori information how many bits are encoded but more specific how many different code words are used. This property is exploited as shown in the following example:

Let us assume, that 81 different rates are to be encoded. Then 9 different code words should be used for the first word and 9 code words for the second word. Such a perfect balancing is possible for all square figures. In general the TFCI information field is split into two words as follows: The TFCI value is divided by the smallest integer being greater than or equal to the square root of the number of possible data rates. Word1 holds the integer division result and Word2 the remainder. Still the first word may have to carry one more code word, but this is the best possible balancing. This is a great improvement, as the algorithm presented in the last paragraph may almost allocate twice as many code words and the original algorithm even eight times as many!

6 Dynamic TFCI range adjustments

The above mentioned coding scheme has one disadvantage: If the number of possible data rates is extended during a call, the coding of all TFCI values changes, even for the subset which was already available. As a consequence, the change of the TFCI range has to be communicated well in advance. Otherwise a delay in the relevant higher layer signalling e.g. due to retransmissions could cause a complete service outage (possibly even the signalling would be lost causing a dead lock situation). This is not the case with the present working assumption, because the coding of the subset does not change.

7 Optimum coding scheme

We now propose an encoding scheme, which distributes the information as evenly as possible and is compatible with dynamic TFCI range adjustments at the same time.

The coding is as follows:

$n := \left\lfloor \sqrt{TFCI} \right\rfloor$; n is the largest integer being smaller than or equal to the square root of the transmitted TFCI value.

if $TFCI < n^2 + n$

then $Word1 := n$; $Word2 := TFCI - n^2$

else $Word2 := n$; $Word1 := n^2 + 2n - TFCI$

Using this definition, the sequence of encoded (word 1, word 2) pairs would start like this:
(0,0) (1,0) (1,1) (0,1) (2,0) (2,1) (2,2) (1,2) (0,2) (3,0) (3,1) (3,2) (3,3) (2,3) (1,3) (0,3) (4,0) (4,1) (4,2) (4,3) (4,4) (3,4) (2,4) (1,4) (0,4) (5,0) (5,1) ...
This encoding scheme avoids the above mentioned drawback because the number of possible data rates needs not be known. Still the knowledge about the TFCI range allows to calculate limits for the coding range of the two individual code words and thus allows to improve the performance of the biorthogonal decoder. The encoding scheme can be visualised by writing the encoded TFCI values into a word1/word2 diagram as shown in Fig. 2:

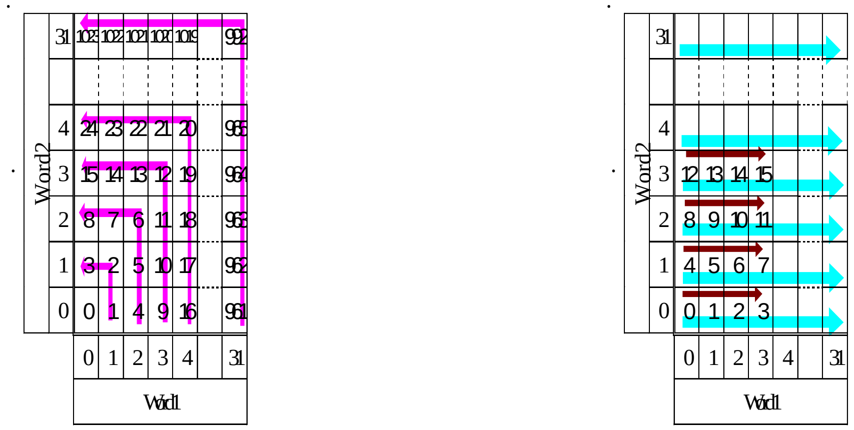

Fig. 2: Coding of TFCI values:
Left: proposal for optimum balancing and dynamic TFCI range adjustments.
Right: optimal coding, incompatible with dynamic TFCI range adjustments (short arrows, figures in the grid, valid for 10 to 16 rates only) and present working assumption (long arrows, no figures shown for this case).

The decoding can be implemented as follows:

$$n := \max(Word1, Word2)$$

$$TFCI = n^2 + n + Word2 - Word1$$

Note that for a real implementation lookup tables could be used as well. Lookup tables have to be implemented anyhow to point to the service combination which is associated with a given TFCI value. However, such implementational details are outside the scope of the standardisation.

8 Estimation of Performance Gain

The performance of the biorthogonal encoding for each of the two words in a given propagation environment obviously improves with increasing Eb/N_0. In practice, the energy per TFCI bit will be determined by the energy requirement of the data service which is time multiplexed on the same physical channel. The energy per TFCI payload bit or the Eb/N_0 depends further on how much information is encoded in the two words. This dependency is shown in the following figure. Eb/N_0 gain is the gain which is achieved by coding less than all 32 possible code words per word. There is a gain if less information has to be coded in one or both of the words. Because the weaker word will limit the performance, attention has to be given to the weaker Eb/N_0 value of the two words, which will be word1. Figure 3 shows the relative Eb/N_0 for the working assumption, the bit wise balancing and the optimum balancing. It also shows a theoretical curve for information distribution using fractional code words, which is of course not possible, but is shown here as a reference.
It can be seen from Figure 3, that the most substantial improvement can be realised, if the number of data rates is slightly higher than 64. These scenarios will probably be the most common ones whereas the extreme case approaching 1024 rates (here the advantage of the presented scheme becomes marginal), will be less common. The advantage is a gain in the Eb/No figure of up to 1,98 dB which can be realised by a simple redistribution of the information.

Note however that this simple comparison does not take the following two effects into account:

- For the working assumption word1 will limit the performance, while for the optimum scheme both word will equally contribute to Frame errors. Comparing only the word1 figures is therefore incomplete.
- The coding gain will improve the performance if more bits are being coded. This somewhat compensates the Eb/N_0 gain.

Due to both these effects the analysis in this chapter will be too optimistic as regards the expected gain by the new method. Therefore simulations have to be performed.

9 Simulation results

We have run simulations using an AWGN channel for the transmitted (coded) TFCI bits. The SNR gives the signal to noise ratio after despreading, so the results should be valid for a wide range of spreading factors. Note that this figure does not take any overhead (pilot bits, TPC bits) into account. This should give comparable results for a complete simulation chain, because power control will make the channel look similar to a AWGN channel. Of course due to imperfections of the power control and due to overhead transmission the absolute figures will be somewhat worse but the difference between the figures for the old and new coding scheme should be unaffected by this simplification.

It can be seen from Figure 4, that indeed there is an improvement of about 0.4dB over a wide range of the SNR.

10 Conclusion

We propose that the extended TFCI encoding scheme is changed as indicated in the text proposal. With only minimum changes and implementational complexity the performance of TFCI decoding can be increased by about 0.4 dB, particularly for number of data rates slightly above 64. This may avoid having to increase the entire DPCCH power (or even the entire downlink power) solely to meet TFCI decoding performance requirements.

References

[1] 3GPP (S1.12) V0.1.0 1999-02; 3GPP; FDD, multiplexing, channel coding and interleaving description;
[2] 3GPP (S1.22) V0.1.0 1999-02; 3GPP; TDD multiplexing, channel coding and interleaving description;
[3] Tdoc SMG2 UMTS L1 567/98; Nokia; Extended TFI field
[4] Tdoc SMG2 UMTS L1 568/98; Nokia; Downlink performance with TFI detection errors
[5] 3GPP TSG RAN WG1 99/201; Siemens; Text Proposal for Optimisation of extended TFCI encoding