nodes to act concurrently as producers of remote frames with the same identifier (for example to request the transmission of information stored remotely). If two or more nodes send remote frames characterized by the same identifier at the same time, no collision takes place because the bit streams which are written on the bus by the different nodes are exactly the same. This implies that in remote frames the M-zones are extended to the whole frame, and hence in general the overclocking technique cannot be used when sending remote frames.

Implementation issues: Implementation of the overclocking technique described above can be accomplished in a very straightforward manner, which also maintains an optimum degree of compatibility with existing CAN devices. In particular, the R0 bit can be used to distinguish between normal CAN frames and overclocked frames. The standard document [1], in fact, specifies for the R0 bit a dominant value, so that a recessive value can be used to denote an overclocked frame. In this case the R0 bit has the meaning of a bit rate overclocking (BRO) bit. Such a solution also ensures that the SOS bit delimiting the beginning of the S-zone be preceded by a one-arbitration-bit-wide period of inactivity on the bus, irrespective of the bit stuffing mechanism.

Conclusions: For physical reasons, in any communications network, increases in the throughput implies consequently reductions in the maximum bus length. In a CAN, because of the particular medium access technique adopted, this phenomenon is particularly evident and prevents the use of this network in high-performance applications when the controlled system is spread over a wide area. In this Letter we have shown that the throughput in a CAN-like network can be improved (without worsening either the responsiveness or the bus length) by increasing the bit rate for some selected portions of the frame where the access mechanism ensures that only one node has obtained bus control.

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Turbo TCM schemes for WCDMA systems

Zaichen Zhang and Guangguo Bi

Three novel turbo TCM schemes, 1/n TTCM, TTC-SPM and NP-TTC-SPM, are proposed. They are derived from the TTCM scheme but have better performance for use in WCDMA systems over fading channels. Simulation results are presented.

Introduction: Turbo codes have been adopted in many third generation mobile communication system proposals for one of the possible channel coding schemes. They are usually used in high rate data transmission schemes to achieve good error performance. In this Letter, combined turbo coding and TCM schemes are considered for use in WCDMA systems.

Based on the TTCM scheme [1], three new schemes are presented: 1/n TTCM, TTC-SPM, and NP-TTC-SPM. Using the criterion of equal throughput, we compared the scheme with the turbo code scheme used in NTT’s WCDMA proposal using a simulation for the WCDMA system and an indoor fading channel environment. The results show that 1/n TTCM, TTC-SPM and NP-TTC-SPM have increasingly better coding gains, and the latter two schemes have a higher performance than the turbo code scheme.

Scheme description: Although the TTCM scheme has good performance in non-spreading systems with an AWGN channel, it does not perform well for WCDMA systems and fading channel environments. It is well-known that in an interleaved Rayleigh fading channel, the length of the shortest error event path has a more important role than the maximum free distance in performance [2]. For this reason, better performance can be expected if rate 1/n component codes are used in TTCM schemes instead of rate n/(n + 1) component codes. This leads to the 1/n TTCM scheme. Also, for the same source data frame length N, the interleaving lengths of TTCM and 1/n TTCM are N/n and N, respectively. That is, the 1/n TTCM scheme also has the advantage of having a higher interleaving gain.

To further improve the performance, we introduce the concept of ‘TCM-SPM’ [3] to 1/n TTCM. The new scheme is called TTC-SPM (turbo TC-SPM). The block diagram of the encoder is shown in Fig. 1. In this scheme, each user has been assigned two spreading codes. The information bit is used to select a spreading code, and the parity bits alternatively coming from the two encoders select an output symbol from the signal constellation. The signal is then spread using the selected spreading code. By using the sequence and phase modulation, TTC-SPM has less sensitivity to phase error [3]. The TTC-SPM decoder is almost the same as that for TTCM except that the input has two signal sequences (y(0) and y(1)), which are the desired sequences of the two spreading codes, respectively (corresponding to information bits 0 and 1).

The probability function p(y_k|d_k = j, S_k = M, S_k+1 = M') of the MAP algorithm and the initial a priori information Pr(d_k = i) of the *th mode in the TTCM scheme [1] should be modified. Assuming selection combination is used in the Rake receiver and using the same notation as [1], the new formulations are given as follows:

p(y_k|d_k = i, S_k = M, S_k+1 = M') = p(y_k(0), y_k(1)|d_k = i, S_k = M, S_k+1 = M') = p(y_k(0)|d_k = i, S_k = M, S_k+1 = M') · p(y_k(1)|d_k = i) = C_1 e^{-|\alpha_0 y_k^{(0)} + \alpha_1 y_k^{(1)}|^2 / 2^\sigma} · e^{-|y_k^{(1)}|^2 / 2^\sigma} , i = 0, 1

where C_1 is a constant, y_k represents the side information of the fading channel, x_k is the signal sent when S_k = M, S_k+1 = M', and d_k = i, and \sigma is the variance of the additive noise:

Pr(d_k = i) ← Pr(d_k = i|y_k) = Pr(d_k = i|y_k^{(0)}, y_k^{(1)}) = C_1 p(y_k^{(0)}, y_k^{(1)}|d_k = i) = C_1 \left\{ \sum_{j=0}^{M-1} p(y_k^{(0)}, x_j|d_k = i) \right\} p(y_k^{(1)}|d_k = i) = C_1 \left\{ \sum_{j=0}^{M-1} p(y_k^{(0)}|x_j, d_k = i) \right\} p(y_k^{(1)}|d_k = i)
where $C_2$ and $C_5$ are constants, $x_j, j = 0, 1, ..., M - 1$, are possible output signals, $M$ is the size of the signal set, and $p(x_0) = 1/M$.

In TTCM, the output parity bits of the two encoders are punctured alternatively to avoid reusing the same information in iterative decoding and to save bandwidth. However, the puncturing method increases the decoding complexity and leads to the flattening of the BER curves. In the TTC-SPM scheme, by using information bits to select spreading codes, it is possible to separate the output information of the component decoders into three parts (priori, extrinsic and systematic) as in turbo code decoding, so that the puncturing of parity bits is not necessary and a common turbo code decoder structure can be used. Based on this consideration, a new scheme, NP-TTC-SPM (non-punctured TTC-SPM), is proposed, as shown in Fig. 2. To keep the same spreading gain as in TTC-SPM, multi-code transmission is used.

Assume that the output sequences of the two encoders are $\{y_k(0)\}$ and $\{y_k(1)\}$, and their available spreading codes are $\{C(0,0), C(0,1), C(1,0), C(1,1)\}$, respectively. When the information bits $d_k = i$, $C(0,0)$ and $C(1,1)$ are used, $i = 0, 1$. In the decoder, the despread signal by using $C^{(i,j)}$ is written as $y_k^{(i,j)}$, $1 \leq i, j \leq 0, 1$. The decoder is similar to a common turbo code decoder, but the probability function $p(y_k|d_k = i, S_k = M, S_{k-1} = M')$ used in the MAP algorithm should be modified. Take decoder 1 (corresponding to encoder 1) and its output $\{y^{(0)}_k\}$ for example:

$$
\begin{align*}
E_k = \prod_{i=0}^1 \prod_{j=0}^1 p\left(y_k^{\langle i,j\rangle}|d_k = i, S_k = M, S_{k-1} = M'\right) \\
= p\left(y_k^{(0)} | d_k = i\right) \times p\left(y_k^{(1-0)} | d_k = i\right) \\
= p\left(y_k^{(0)} | d_k = i\right) \times \sum_{j=0}^{i-1} p\left(y_k^{(j+1)} | y_k^{(j)} \right) \times \sum_{j=0}^{i-1} p\left(y_k^{(j+1)} | y_k^{(j)} \right)
\end{align*}
$$

where $C_2$ is a constant.

Table 1: Channel coding schemes

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Component codes $*$</th>
<th>SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbo code</td>
<td>G (7, 5)</td>
<td>16</td>
</tr>
<tr>
<td>TTCM</td>
<td>H (4, 2, 9)$_{16}$</td>
<td>128</td>
</tr>
<tr>
<td>1/n TTCM</td>
<td>G (11, 8, 2, 15)$_{16}$</td>
<td>64</td>
</tr>
<tr>
<td>TTC-SPM</td>
<td>G (11, 8, 2, 15)$_{16}$</td>
<td>64</td>
</tr>
<tr>
<td>NP-TTC-SPM</td>
<td>G (13, 7, 5, 12)$_{16}$</td>
<td>64</td>
</tr>
</tbody>
</table>

$*G$: generator polynomial, $H$: parity check polynomial.

Simulation results: To demonstrate the performance of the proposed schemes, simulations were carried out for a WCDMA system with an uncoded data rate of $R = 64$ kbits/s and chip rate $R_c = 4.096$ Mc/s. The sampling rate was made equal to the chip rate. A three-path indoor channel model was used. The delays of the paths were 0, 1, and 2 chip times, respectively, and their average powers 0, -9, and -33 dB. The Rake receiver used selection combination and picked up the first two paths of the channel. Ideal channel side information and ideal power control were assumed. The performance of turbo code, TTCM, 1/n TTCM $\alpha = 4$, TTC-SPM and NP-TTC-SPM schemes were compared. The component codes used and the corresponding spreading factors (SFs) are listed in Table 1.

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