Research of Encoding Algorithm Efficiency in 4G Communication

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Abstract: The efficient method how to calculate the physical layer communication rate matching in LTE communication system is proposed. The algorithm is based on the study of Turbo code transmission channel. The main process is that after treatments of multiple modules such as bits collection, selection, transmission, block interleaver and block cascade, the rates of streams are matched. The key algorithm efficiency is analyzed and its performance is better than other codings. The algorithm is proved to be efficient and reliable to achieve the desired objective of high-speed and stable transmission of data in physical layer.

Key words: LTE, bit collection, block interleaver, rate matching

INTRODUCTION

LTE (Long Term Evolution) is usually called the technology of 3.9 generation. Comparing with GSM, the second generation communication technology, LTE has advent-ages of shorter waiting time, higher user data rate, greater system capacity, lower operating costs caused by coverage improvement and many others. OFDM (Orthogonal Frequency Division Multiplexing)/FDMA (Frequency Division Multiple Access) is the key communication encode algorithm of LTE technology.

The physical layer technology is a key foundation of the wireless communication system. In the LTE system, the downlink of physical layer is using OFDMA (Orthogonal Frequency Division Multiple Access) and the uplink is using SC-FDMA (Signal Carrier Frequency Division Multiple Access) for data transmission (Wang et al., 2012). Different ways have different transmission rates, so the communication rate matching becomes the focus of the study.

This article describes a calculation method based on the physical layer of the communication rate matching in the LTE communication system.

RATE MATCHING

Needs analysis: In LTE hierarchical structure model, the physical layer technology is the key to improve the performance of the system. The physical layer parameters directly affect the merits of delay, the data transfer rate, the system capacity, the coverage and the operating costs. Physical layer process of the LTE system mainly includes a synchronization process in the physical layer, the power control process, a random access process, a related process for the physical downlink shared channel, a related process for the physical uplink shared channel and a physical shared control channel process.

Therefore, the essence of the communi-cation rate matching in the physical layer is to ensure that the amount of data of the transport channel and the physical channel can adapt each other. The basic principle of rate matching is that when the amount of data of the transport channel is more than that carried by the physical channel, the system performs a punch operation; on the contrary, it operates repeatedly.

Basic algorithm: If the rate of the transmission channel coded Turbo by is matched in units of blocks, the basic constructed algorithm process is as follows in Fig. 1. First, Interleave the three information bit streams (d_k (0), d_k (1) and d_k (2)). Then do the bit collection. At last, generate the circular buffer.

In the Fig. 1, e_k is the bit sequence used for transmission. The bit stream d_k (0) is interleaved according to the sub-block interleaver to get the output sequence v_k(0), v_k(0), v_k(0),..., v_k(0). The bit stream d_k (1) is interleaved according to the sub-block interleaver to get the output sequence v_k(1), v_k(1), v_k(1),..., v_k(1). The bit stream is interleaved according to the sub-block interleaver to get the output sequence v_k(2), v_k(2), v_k(2),..., v_k(2) (Elsayed H. A. S. and El-Saadawy, 2013).

MATCHING INSTANCES

Generating transmission data: If the transmission data in LTE physical layer is the bit sequence e_k, the method of calculating the rate matching sequence e_k is as follows:
In the foregoing codes, \( N_{\text{ch}} \) represents the bit length of the \( r \)-th code block cache. And its formula of calculation is:

\[
N_{\text{ch}} = \min \left( \frac{N_{\text{ch}}}{C}, K_{\text{ch}} \right)
\]

(1)

The Circular buffer with the length \( K_{\text{ch}} = 3K_{\text{ch}} \) corresponding to the \( r \)-th code block, is generated as follows:

\[
\begin{align*}
  w_k &= v_k(0) \quad \text{for} \quad k = 0, \ldots, K_{\text{ch}} - 1 \\
  w_{K_{\text{ch}} + 1} &= v_{K_{\text{ch}} + 1} \quad \text{for} \quad k = 0, \ldots, K_{\text{ch}} - 1
\end{align*}
\]

(2)

**Sub-block interleaver:** The bit stream of sub-block interleaver is \( d_k(i), d_l(I), d_l(I), \ldots, d_1(i) \). \( D \) is the number of the bits. The output bit sequence from the sub-block interleaver is got in the following steps:

- If the number of columns of the matrix \( C_{\text{adj}}^{\text{CC}} = 32 \), the columns of the matrix is sequentially numbered 0, 1, 2, ..., \( C_{\text{adj}}^{\text{CC}} - 1 \) from left to right.
- To determine the number of rows of the matrix, \( R_{\text{adj}}^{\text{CC}} \), which is the smallest integer satisfying the following formula:

\[
D \leq \left( R_{\text{adj}}^{\text{CC}} \times C_{\text{adj}}^{\text{CC}} \right)
\]

(3)

The numbers of the rows of the matrix from the top to bottom are 0, 1, 2, ..., \( C_{\text{adj}}^{\text{CC}} - 1 \).

- If \( \left( R_{\text{adj}}^{\text{CC}} \times C_{\text{adj}}^{\text{CC}} \right) > D \), add \( N_{\text{ch}} = (R_{\text{adj}}^{\text{CC}} \times C_{\text{adj}}^{\text{CC}} - D) \) visual bits in the head to make \( y_k \prec \text{NULL} \) \( (k = 0, 1, \ldots, ND - 1) \). Then \( y_{\text{ch}} = d_k(i) \) \( (k = 0, 1, \ldots, D - 1) \).

Write the bit sequence \( y_k \) into the matrix.

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**Table 1: Column displacement mode table of the sub-block interleaver**

<table>
<thead>
<tr>
<th>Column displacement mode</th>
<th>Column displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{\text{adj}}^{\text{CC}}$</td>
<td>$P(0)$, $P(1)$, ..., $P(C_{\text{adj}}^{\text{CC}} - 1)$</td>
</tr>
</tbody>
</table>

(4)

row by row from row 0 column 0, the final matrix is in the following formula:

\[
\begin{bmatrix}
  y_0 & \cdots & y_{C_{\text{adj}}^{\text{CC}} - 1}
  \\
  y_{C_{\text{adj}}^{\text{CC}} + P(1)} & \cdots & y_{C_{\text{adj}}^{\text{CC}} + P(C_{\text{adj}}^{\text{CC}} - 1)}
  \\
  \vdots & \ddots & \vdots
  \\
  y_{C_{\text{adj}}^{\text{CC}} + P(0)} & \cdots & y_{C_{\text{adj}}^{\text{CC}} + P(C_{\text{adj}}^{\text{CC}} - 1)}
\end{bmatrix}
\]

- To establish column displacement mode table of the sub-block interleaver (Scaglione et al., 2002)

The matrix column replacement is done with fixed mode in the above table. The replacement formula is:

\[
(P(j)_{\text{ch}}^{\text{CC}})_{\text{ch}}^{\text{CC}}
\]

in which the \( p(j) \) stands for the original position of the \( j \)-th changed column. \( (R_{\text{adj}}^{\text{CC}} \times C_{\text{adj}}^{\text{CC}}) \) dimensional matrix which has finished the column replacement is as follows.

\[
\begin{bmatrix}
  y_{R_{\text{ch}}^{\text{CC}} + P(1)} & \cdots & y_{R_{\text{ch}}^{\text{CC}} + P(C_{\text{adj}}^{\text{CC}} - 1)}
  \\
  y_{R_{\text{ch}}^{\text{CC}} + P(2)} & \cdots & y_{R_{\text{ch}}^{\text{CC}} + P(C_{\text{adj}}^{\text{CC}} - 1)}
  \\
  \vdots & \ddots & \vdots
  \\
  y_{R_{\text{ch}}^{\text{CC}} + P(0)} & \cdots & y_{R_{\text{ch}}^{\text{CC}} + P(C_{\text{adj}}^{\text{CC}} - 1)}
\end{bmatrix}
\]

(5)

Outputs of the sub-block interleaver are read from the changed \( (R_{\text{adj}}^{\text{CC}} \times C_{\text{adj}}^{\text{CC}}) \) dimensional matrix column by column. Thus, the output bit sequence is \( v_0(0), v_1(0), v_1(0), \ldots, v_{\text{ch}}(0) \) in which, \( v_0(i) \) is the \( y_0(i) \) in the matrix above, \( v_1(i) \) is \( y_{R_{\text{ch}}^{\text{CC}} + P(i)}(i) \) and:

\[
K_{\text{ch}} = (R_{\text{adj}}^{\text{CC}} \times C_{\text{adj}}^{\text{CC}})
\]

**Bit collection, selection and transmission:** The number of the blocks \( N_{\text{ch}} \) is calculated by the step 1 above in the formula below:

\[
N_{\text{ch}} = \left\lfloor \frac{N_{\text{ch}}}{K_{\text{ch}}} \right\rfloor \min \left( M_{\text{DL/HSRQ}}, M_{\text{HN}} \right)
\]

(6)

\( N_{\text{ch}} \) is the total number of the soft channel.
If the UE is configured in transmission mode 3, transmission mode 4 or transmission mode 8, $K_{SIMC}$ is the value of 2 when the PDSCH is accepted. In other cases, the value is taken as 1 (Abeta, 2010). $M_{CL, PDSCH}$ is the maximum number of processes in the downlink HARQ. $M_{init}$ is valued 8 constantly.

$E$ is the length of the output sequence from the rate matching in the $r$-th block. $r_{v, b}$ is the version number of the transmission ($r_{v, b} = 0, 1, 2, 3$). The output sequence of the rate matching is wrote as $e_{v, r, k}$ $k = 0, 1, ..., E-1$.

$G$ indicates the total available number of bits of a transport block.

In the formula $G' = G/(N_{c} \cdot Q_{e})$, $Q_{e}$ values ??2, 4, 6 respectively in the different modulation method QPSK, 16QAM, 64QAM.

When the transport block is mapped to a single-layer transfer layer, the value of $N_{c}$ is 1. But when it is mapped to tow or four layers transfer layer, the value of $N_{c}$ is 2 (Mohammad and Wafaa, 2012). In the formula $y$, $G' \ mod C$, $C$ is the number of block which is calculated by step 2. Thus the length $E$ is got from the following codes:

```
If \( r_{v, b} \leq 1 \)

\[
E = N_{c} \cdot Q_{e} \cdot \lfloor G' / C \rfloor
\]

else

\[
E = N_{c} \cdot Q_{e} \cdot \lfloor G' / C \rfloor
\]

End If
```

The symbol $k_{v}$ is defined as follows and $R_{SIMC}^{TC}$ is the row of the matrix:

$$k_{v} = R_{SIMC}^{TC} \cdot \left( 2 \cdot \frac{N_{eb}}{R_{SIMC}^{Eb, b}} \cdot r_{v, b} + 2 \right) \quad (7)$$

**SIMULATION AND ANALYSIS**

**Simulation result:** The bit sequence $e_{v}$ in the following section is the transmission data in the physical layer. The transmission unit is a block and the value of SNR is in the normal range from 8 to 10 dB. Enough results are got from the simulation of rate matching environment of the transmission channel coded by Turbo in Matlab 7.0.

**Result analyzing:** It is got from the Fig. 2 that in the normal SNR communication environment and using the matching algorithm in the following section, the system can complete the matching demand through punching adjustment when the data from the transmission channel is more than the data which the physical channel can load. But when it is less than that, the system completes the need by repeating adjustment.

![Simulations Results](image)

**CONCLUSION**

This study describes the rate matching algorithm of the LTE physical layer based on the needs analysis. The simulation result shows that the matching algorithm is effective and has certain guiding significance and application value for assessment of LTE standard.

**REFERENCES**


