3GPP TSG RAN WG1 #49 **R1-072542**
Kobe, Japan, May 7 – 11, 2007

Agenda Item: **7.5**

Source: **Broadcom**

Title: **Rate matching proposal based on 15 period 8 optimal puncturing patterns**

Document for: **Discussion/Decision**

1 Summary

In this document we propose a rate matching (RM) algorithm base on the 15 period 8 optimal puncturing patterns. As it is shown in a separate document [1] this new and simple rate matching algorithm out perform the other algorithms.

2 New rate matching algorithm

***Periodic Puncture*:**

Since the turbo mother code is rate 1/3. Given L information bits $x_{0,0}, x_{0,1}, \cdots x_{0,L-1}$, there will be two parity sequences of L bits, say $x_{1,0}, \cdots, x_{1,L-1}$, $x_{2,0}, \cdots, x_{2,L-1}$ respectively. Suppose the puncturing period is q. then a puncturing pattern is given by 3 binary vectors of size q, namely

$$P_i = (e_{i,0}, e_{i,1}, \cdots, e_{i,q-1}), e_{i,j} \in \{0,1\}, i = 0,\ldots,2, j = 0,\ldots,q-1 \qquad \text{(EQ-1)}$$

The periodic puncturing based on the above puncturing pattern can be defined as the 3 sequences $y_{i,0}, y_{i,1}, \cdots y_{i,L-1}, i = 0,\ldots,2$, such that

$$y_{i,j} = \begin{cases} x_{i,j} & \text{if } e_{i,j \bmod q} = 1 \\ \delta & \text{if } e_{i,j \bmod q} = 0 \end{cases}, i = 0,1,2, j = 0,\ldots,L-1 \qquad \text{(EQ-2)}$$

Then the final output sequences after puncturing are those $y_{i,j}$ such that $y_{i,j} \neq \delta$.

Single period 8 patterns for 15 rates:

Since the sizes of all 188 QPP interleaves adopted by 3GPP LTE are multiple of 8, this algorithm uses 8 as the only period for all interleaves. Consider the 15 rates $R_D = 8/D, \mathrm{D} = 9,10,11,\ldots,23$, i.e

$$\begin{aligned} &R_9 = 8/9,\ R_{10} = 8/10,\ R_{11} = 8/11,\ R_{12} = 8/12 = 2/3,\ R_{13} = 8/13, \\ &R_{14} = 8/14 = 4/7, R_{15} = 8/15,\ R_{16} = 8/16 = 1/2, R_{17} = 8/17,\ R_{18} = 8/18 = 4/9, \\ &R_{19} = 8/19,\ R_{20} = 8/20 = 2/5, R_{21} = 8/21,\ R_{22} = 8/22 = 4/11, R_{23} = 8/23. \end{aligned} \qquad \text{(EQ-3)}$$

An optimal design is to generate 15 period 8 patterns of these rates for all 188 QPP interleaves. A sub-optimal choice is to find 15 optimal patterns of certain interleave and then use them for all other interleaves. In [1] three such sub-optimal patterns are given by exhaustive searching, they are

R_{10}=8/10: $P_{10,0} = (11101111), P_{10,1} = (01010000), P_{10,2} = (00001000)$

R_{11}=8/11: $P_{11,0,} = (101111111), P_{11,1} = (01010001), P_{11,2} = (00000101)$

R_{12}=8/12: $P_{12,0} = (11110111), P_{12,1} = (10101000), P_{12,2} = (00001001)$

If the needed output code rate is one of the 15 rates in (EQ-3), then use its corresponded puncturing pattern to puncture.

Using combined patterns for all other rates:

To have puncturing pattern for the rate not among the 15 rates in (EQ-3), one can combine 2 patterns among the 15 patterns corresponded to the rates in (EQ-3). Before we give the detail, let us define two extreme rates, i.e. rate R_8=8/8=1 (all parity bits are punctured) and rate R_{24}=1/3=8/24 (no puncturing at all). Let r be any rate in the range (1,1/3) but not in the (EQ-3). Then there exist a number $u \in \{9,\ldots,23,24\}$ such that $R_{u-1} < r < R_u$. Compute

$$a = u - \frac{8}{r} \qquad \text{(EQ-4)}$$

We may find integers c, C such that $a = c/C$. Let "cont_P" be a counter on the number of periods and let P_{u-1} be optimal pattern for rate R_{u-1} and P_u be the optimal pattern for rate R_u. The puncturing method can then be described as follows

If $cont_p \bmod C < c$, use puncturing pattern P_{u-1}, otherwise use puncturing pattern P_u

In [1] as an example the solution a=4/7 is given for rate r=0.7 using rate R_{11} and R_{12} puncturing patterns.

On 12 tail bits:

Turbo encoder adopted by 3GPP LTE is with 12 bits extra tail bits added after coded bits. Therefore, to make the final output code rate as needed one need puncture additional 12 bits inside the code block. One way to do this is to evenly distribute 12 positions on the not-yet-punctured positions and puncture them before send out with 12 tail bits at the end.

3 Reference

[1] Broadcom, "Compare rate matching puncturing to optimal puncturing", 3GPP TSG RAN WG1 #49, R1-072406