Source:	**Ericsson**
Title:	**Considerations of CBRM and HARQ Operations**
Agenda Item:	**5.5 Channel Coding**
Document for:	**Discussion and Decision**

1. Introduction

It has been agreed in RAN1#49 Kobe to adopt a rate matching algorithm for LTE based on circular buffer designs [1—5]. To further improve the performance of the circular buffer rate matching (CBRM) algorithms, a new CBRM(σ=4,δ=4) design was proposed in [6] based on avoiding catastrophic puncturing patterns [7]. It has been verified that the improved CBRM algorithm can avoid catastrophic puncturing at high coding rates [6] and can achieve better performance by producing codewords of potentially higher Hamming weights in [8].

In Section 2, we first analyze the complexity and robustness concerns in a HARQ system where the initial transmissions need to switch between a redundancy version (RV) with systematic bit puncturing for high coding rate cases and another without such puncturing for low coding rate cases.

A third benefit of the CBRM(σ=4,δ=4) algorithm conjectured in [6] is that RV=0 could be optimal for all initial transmissions since the design has moved all critical parity bits to the front of the circular buffer. With availability of such an optimal RV for all code rates, the HARQ system can be operated more simply and robustly. We present extensive simulation results in Section 3 to verify.

Borrowing from the collective expertise gained in Enhanced Uplink (Rel6) and HSPA-MIMO (Rel7) works, we suggest adopting four redundancy versions as the working assumption for LTE HARQ operations.

2. Systematic Bit Puncturing and HARQ Operations

While the technique of systematic bit puncturing was proposed and has been shown to improve turbo coding performance at higher coding rates, there are two general concerns regarding its interaction with HARQ operations.

- First, it has been concerned that the same technique might be detrimental to the performance at lower rates. One straightforward solution is to choose RV=0 for initial transmissions with higher coding rates and RV=3 for lower coding rate cases. Since RV=3 starts at column 76 of the circular buffer, no systematic bits would be punctured if the code rate is lower than 32/(20+32) = 0.62. Hence, r=0.62 could perhaps serve as the threshold to switch between the two RVs.

- Secondly, because the incremental redundancy (IR) protocol lowers the effective code rates through retransmissions, the necessity to switch between code rate dependent RVs also means retransmissions should try to send the systematic bits that were punctured in earlier transmissions. Because the retransmissions should try to send the fixed number of systematic bits at the front of the circular buffer while avoiding repetition of bits already sent in previous transmissions, it then becomes desirable to choose an RV starting point based on the amount of bits to be transmitted such that the codeword would just contain the fixed number of systematic bits at the front of the circular buffer as illustrated in Figure 1. This makes the choice of RV for retransmissions code rate dependent, too.

Clearly, the two requirements are undesirable extraneous burdens on the complexity and robustness of HARQ operations. However, both can be spared if a single RV with systematic bit puncturing proves to be optimal (or almost so) for all code rates. That is, since it is optimal for all rates, there is no need to switch RVs for the initial transmissions. Simultaneously, the optimality of an RV with systematic bit puncturing at low rates means it is unnecessary to ensure punctured systematic bits be sent in IR retransmissions.

It is conjectured in [6] that RV=0 of CBRM(σ=4,δ=4) could be one such optimal candidate. This is based on the observation that the RV=0 codewords could achieve higher Hamming weights because all critical parity bits are located at the front (of the parity bit region) of the circular buffer. To verify this, we compare the performance of RV=0 and RV=3 in the next section.
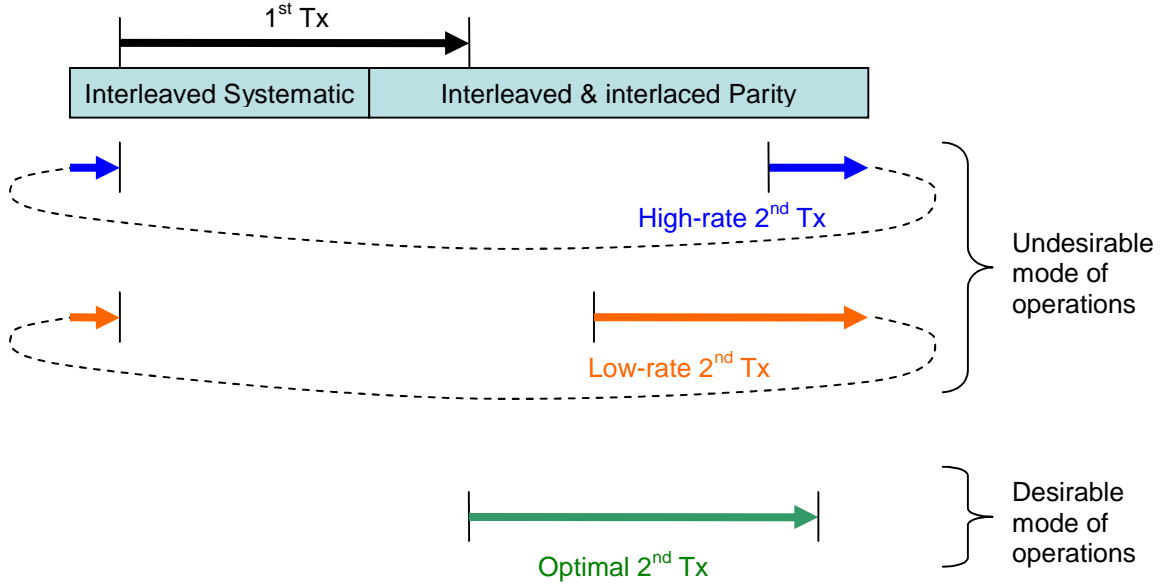
Figure 1 Illustration of HARQ operation concern 2.

3. Performance Analysis

We compare the performance of RV=0 and RV=3 based on the parameters listed in Table I. Three coding rates lower than the 0.62 threshold are tested. Since a resource block carries no more than 144 QPSK modulation symbols, the information block sizes K for a coding rate r are limited to those QPP interleaver sizes no smaller than $288 \times r$.

The required E_b/N_0 values for the two RVs at three different BLER targets are plotted in Figure 2, Figure 3 and Figure 4 for coding rates r=0.6, 0.5 and 0.4, respectively. For r=0.6 and 0.5 cases, RV=0 outperforms RV=3 clearly. For the r=0.4 case, performance of the two RVs is essentially identical.

Hence, it does not incur any performance loss if RV=0 is always used for the initial transmissions and retransmissions are freed from ensuring certain systematic bits be sent.

Table 1 Simulation Parameters

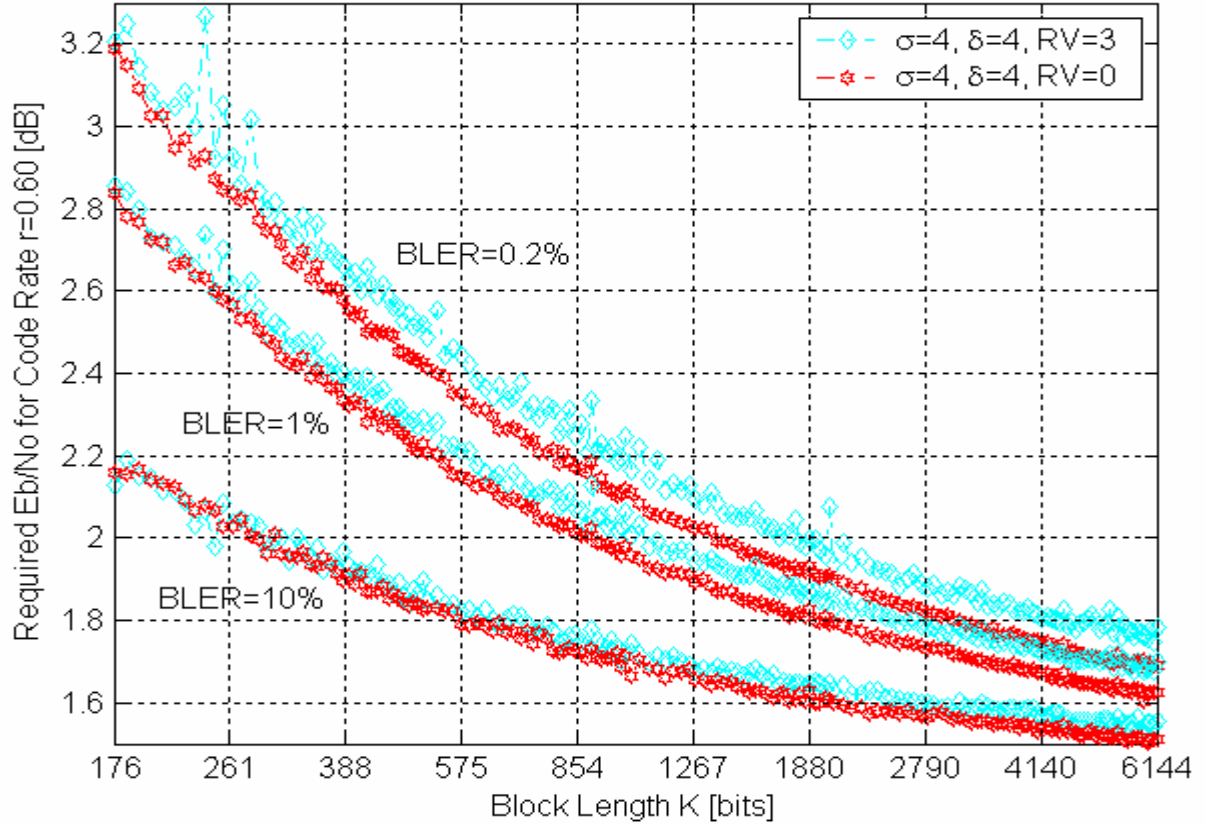|	
Common Code Structure	LTE Turbo Coding [9]
Rate Matching Algorithms	CBRM(σ=4,δ=4) as described in [6]
Coding Rates	r = 0.4, 0.5, 0.6
Test Block Lengths	For all QPP interleaver sizes $K \geq 288 \times r$
Redundancy Version	RV = 0 or 3 based on nRV=4
Decoding Algorithm	Improved Max-Log-MAP (i.e., 0.75 scaling on extrinsic information)
Iterations	8
Modulation	QPSK
Channel	Static AWGN

Figure 2 Required E_b/N_0 for the CBRM(σ=4,δ=4) algorithm at code rate r=0.6. For each of the two redundant versions, three curves corresponding to BLER targets of 10%, 1% and 0.2% are shown.
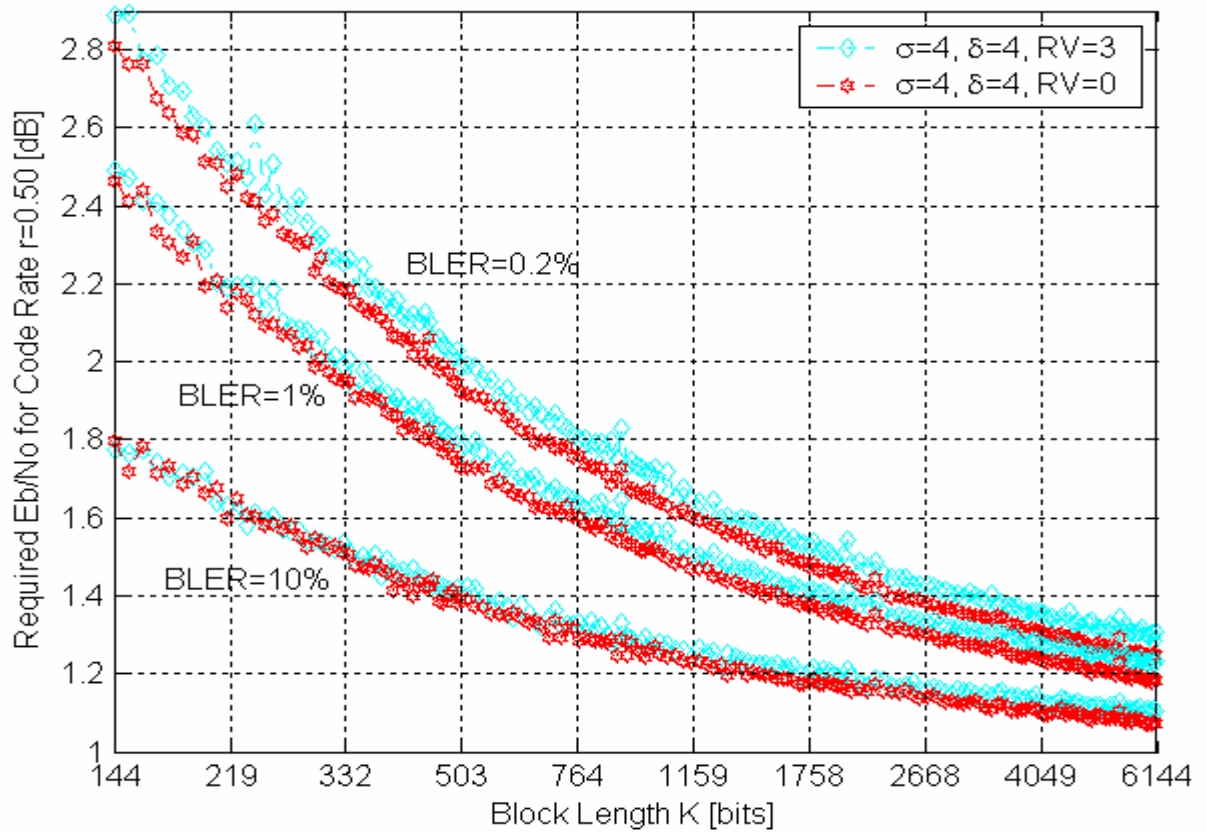

Figure 3 Required E_b/N_0 for the CBRM(σ=4,δ=4) algorithm at code rate r=0.5. For each of the two redundant versions, three curves corresponding to BLER targets of 10%, 1% and 0.2% are shown.

Figure 4 Required E_b/N_0 for the CBRM(σ=4,δ=4) algorithm at code rate r=0.4. For each of the two redundant versions, three curves corresponding to BLER targets of 10%, 1% and 0.2% are shown.
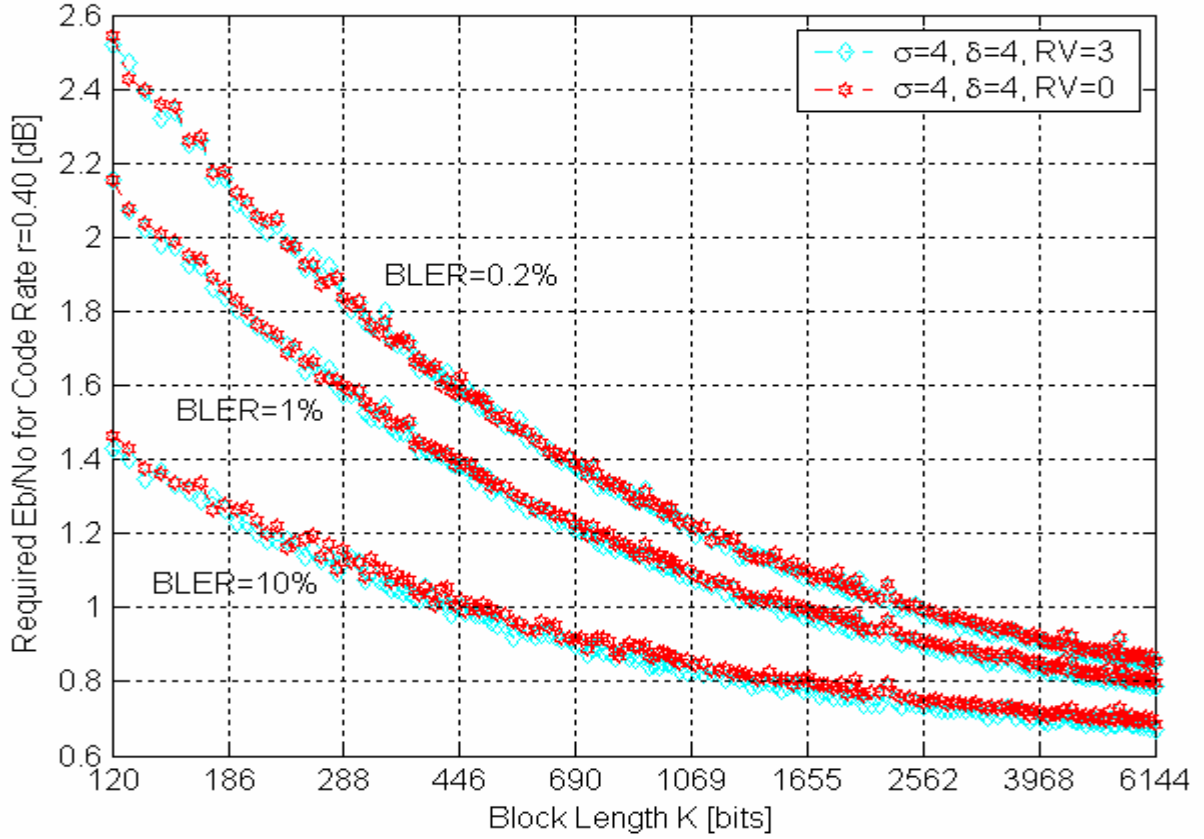
4.   Conclusion

We presented extensive simulation results to verify the operational benefits of the CBRM(σ=4,δ=4) algorithm proposed in [6]. It was concluded that there is no loss in performance if RV=0 is always used for the initial transmissions and retransmissions are freed from ensuring certain systematic bits be sent.

We also proposed to set the number of RVs to four for LTE HARQ operations.

5.   References

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