3GPP TSG RAN WG1 Meeting #64 **R1-110898**
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Agenda Item: **6.2.1**
Source: **Huawei, HiSilicon**
Title: **Soft buffer partitioning for Rel-10 downlink**
Document for: **Discussion/Decision**

1 Introduction

Currently the soft buffer size is identified as a topic that needs to be revisited for Rel-10. This is largely related to the Carrier Aggregation (CA) capability of the new UE categories that need to be defined for Rel-10. In defining the UE categories, factors including DL MIMO, UL MIMO, and CA Rel-10 enhancements were discussed in RAN1#62. In last meeting (RAN1#63bis), two principles were agreed in defining the soft buffer partitioning:

Agreed principles:

1. Single CC performance shall not be degraded compared to Rel-8;
2. Total number of soft channel bits for cats 1-5 does not depend on number of supported CCs

This contribution discusses the proposed methods in terms of their compliance to the two principles.

2 Analysis of Soft Buffer Partitioning Methods

2.1 Equal Partioning

The soft buffer size is equally divided among each of the configured CCs [3]. The soft buffer size for the transport block for n_c-th CC is written as:

$$N_{IR}(n_c) = \left\lfloor \frac{N_{soft} / N_{configuredCC}}{K_{\mathrm{MIMO}}(n_c) \cdot \min\left(M_{\mathrm{DL_HARQ}}, M_{\mathrm{limit}}\right)} \right\rfloor . \tag{1}$$

This is in contrast to the unequal soft buffer partitioning [4], where the soft buffer size for the n_c-th carrier, $N_{\mathrm{soft}}(n_c)$, is equal to:

$$N_{soft}(n_c) = \frac{N_{soft} \cdot L_{\max}(n_c) \cdot BW(n_c)}{\sum_{j=0}^{N_{carrier}-1} L_{\max}(j) \cdot BW(j)} \tag{2}$$

For the n_c-th carrier, the soft size for i-th TB is calculated as in Rel-8,

$$N_{IR}(n_c) = \left\lfloor \frac{N_{soft}(n_c)}{K_{\mathrm{MIMO}}(n_c) \cdot \min\left(M_{\mathrm{DL_HARQ}}, M_{\mathrm{limit}}\right)} \right\rfloor \tag{3}$$

In the following, the effective mother code rate R_{eff} of equal-partitioning and unequal partitioning are studied. The analysis shows that equal-partitioning does not satisfy the first principle since the effective mother code rate can be much higher than the Rel-8 target of 2/3.

In Figure 1 and 2, UE Categories 3 and 4 are studied in the following four cases of MIMO layer combinations, where each case is a point on the x-axis with the corresponding R_{eff} on the y-axis. Also

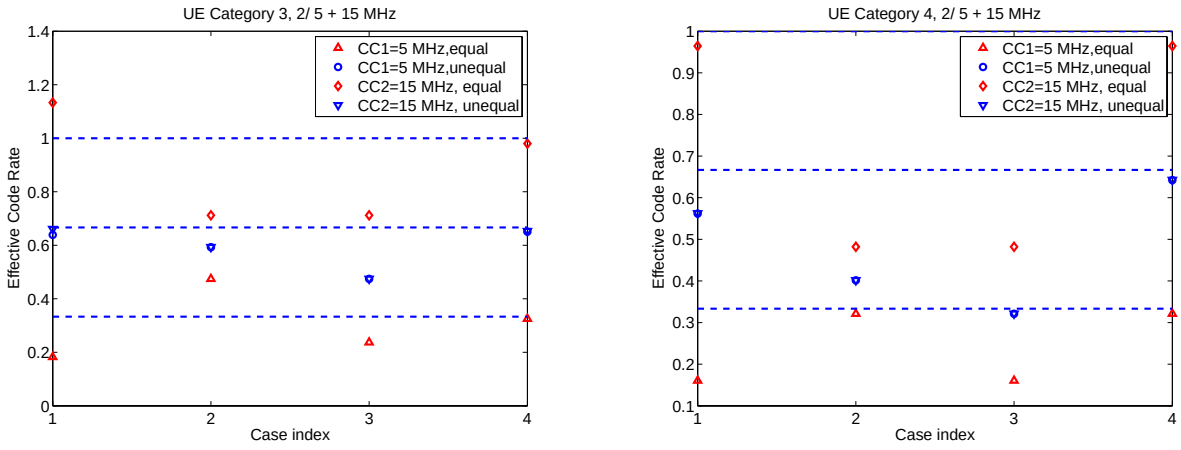
shown are blue dotted lines for R_{eff} = {1, 2/3, 1/3}, with code rate 1 being the upper limit, 2/3 being the target R_{eff} for most UE categories, and 1/3 being the natural turbo code rate. For the cases studied, the number of MIMO layers is assumed to be the maximum number of MIMO layers allowed by the UE capability. The component carrier combinations studied are 2/5+15 MHz and 2/10+10MHz. Maximum TB sizes are used while staying below the "Maximum number of DL-SCH transport block bits received within a TTI" parameter for each UE category.

Case 1. CC1 has 1 MIMO layer, CC2 has 2 MIMO layers;

Case 2. CC1 has 2 MIMO layer, CC2 has 1 MIMO layers;

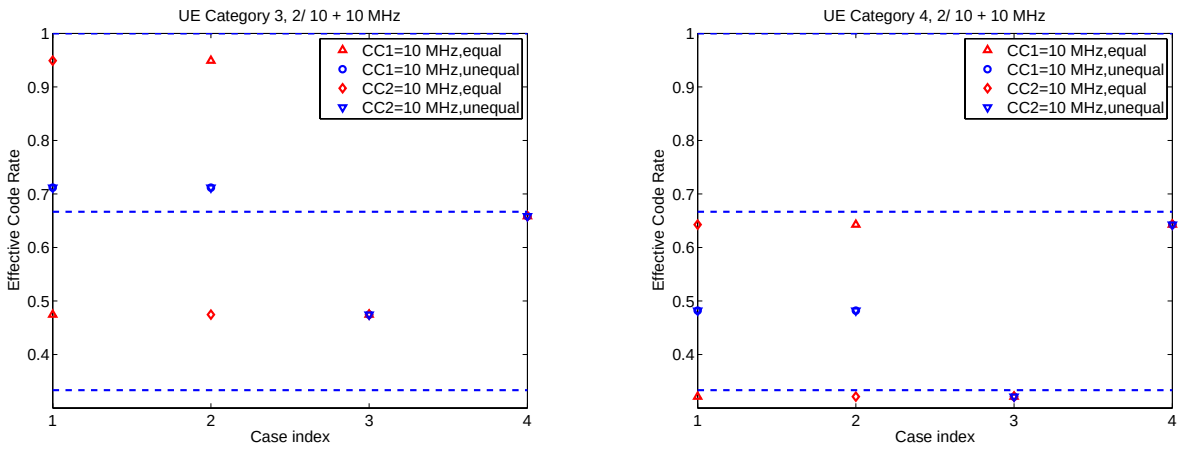
Case 3. CC1 has 1 MIMO layer, CC2 has 1 MIMO layers;

Case 4. CC1 has 2 MIMO layers, CC2 has 2 MIMO layers;



(a) (b)

Figure 1. Effective code rate of Category 3 and 4, respectively, for two carriers of 5 MHz and 15 MHz.



(a) (b)

Figure 2. Effective code rate of Category 3 and 4, respectively, for two carriers of 10 MHz.

In Figure 3, UE Categories 6, 7 are studied in the following four cases of MIMO layer combinations, where each case is a point on the x-axis with the corresponding R_{eff} on the y-axis. Also shown are blue dotted lines for R_{eff} = {1, 2/3, 1/3}, with code rate 1 being the upper limit, 2/3 being the target R_{eff} for most UE categories, and 1/3 being the natural turbo code rate. The two UE categories are not differentiated since their soft buffer related parameters for maximum of 4 MIMO layers are identical or nearly identical. Again

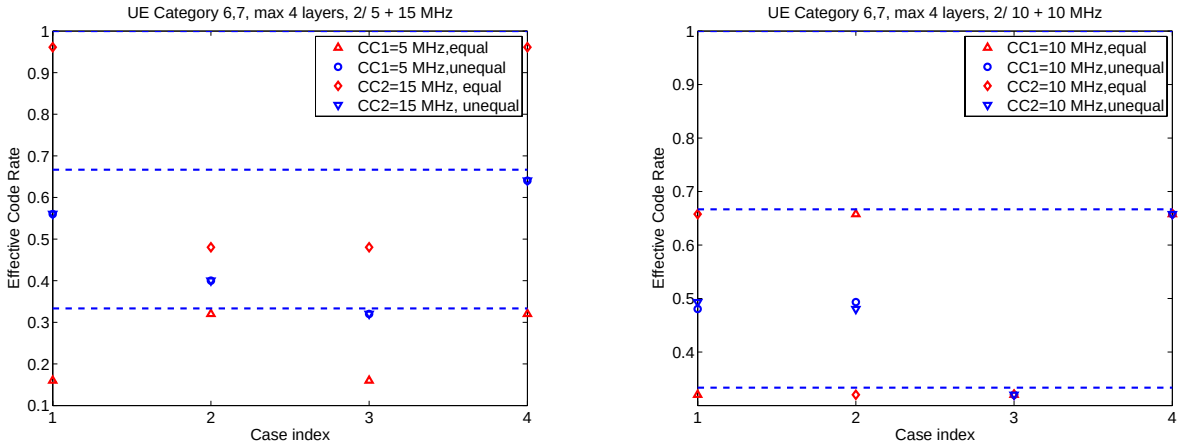
the component carrier combinations studied are 2/5+15 MHz and 2/10+10MHz. Maximum TB sizes are used while staying below the "Maximum number of DL-SCH transport block bits received within a TTI" parameter for each UE category.

Case 1. CC1 has 2 MIMO layer, CC2 has 4 MIMO layers;

Case 2. CC1 has 4 MIMO layer, CC2 has 2 MIMO layers;

Case 3. CC1 has 2 MIMO layer, CC2 has 2 MIMO layers;

Case 4. CC1 has 4 MIMO layers, CC2 has 4 MIMO layers;



(a) (b)

Figure 3. Effective code rate of Category 5, 6, 7, for two carriers of 5+15MHz and 10+10 MHz, respectively.

For Rel-8, the effective mother code rate R_{eff} for the largest TBs are designed to be 2/3. Figure 1-3 show that if equal partitioning is used, R_{eff} is often higher than 2/3, see Figure 1(a), 1(b), 2(a), 3(a). In particular, R_{eff} for 15 MHz is above 1.0 (Figure 1(a)), indicating that the higher TB sizes cannot be used in this scenario. Additionally, the figures show that whenever the component carriers have different capacity either due to bandwidth or MIMO layers allowed, R_{eff} for the individual component carriers can be far apart. For example, in Figure 3(a), equal soft buffer partitioning lead to R_{eff} = 0.96 for 15 MHz CC and R_{eff} = 0.16 for 5 MHz CC in case 1.

In contrast, unequal partitioning always makes sure that R_{eff} for each component carrier is (approximately) the same. Moreover, R_{eff} is always 2/3 or lower except in Figure 2(a), where the effective code rate is 0.71. Considering that 0.71 is fairly close to 0.667, and the effective code rate is calculated for the highest TBs, this is not expected cause noticeable performance degradation and is therefore in line with the first agreed principle that single CC performance shall not be degraded compared to Rel-8.

2.2 Interlace partitioning ("Overbooking")

In [6], interlace partitioning is proposed where HARQ processes of all carriers cooperatively share the soft buffer statistically. This proposal uses the overbooking argument used in the Rel-8 TDD soft buffer definition. Using the binomial modeling of [10], the blocking probability of FDD and TDD Configuration 4 and 5 is plotted in Figure 4-6. TDD Configuration 4 and 5 are studied since they have the highest number of possible HARQ processes, with Configuration 4 and 5 have a maximum of 12 and 15 HARQ processes, respectively. The packet error probability of a TB is assumed to be 0.3, as assumed in the study for Rel-8.

In the figures, the probability of more than B soft buffer blocks are occupied is plotted against B. When K_{MIMO}=1, the newly arriving TB will be blocked if more than 7 (i.e., 8 or more) soft buffer blocks are occupied. Thus the blocking probability is the probability of more than B=7 soft buffer blocks are occupied,

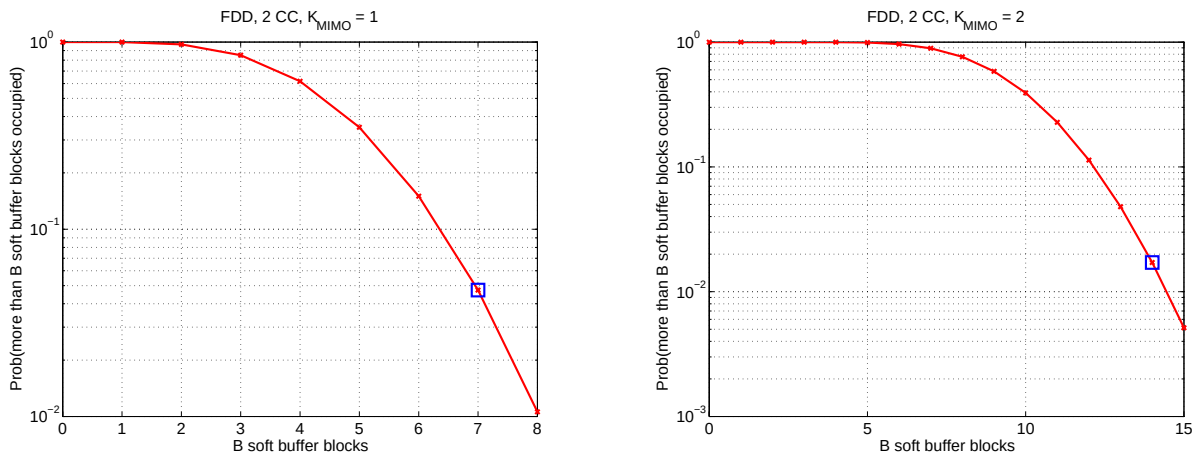
which is marked with a blue squre. Similarly, when K_{MIMO}=2, the newly arriving two TBs will be blocked if more than 14 (i.e., 15 or more) soft buffer blocks are occupied; and the probability of blocking is marked with a blue squre correponding to B=14.

Table 1. HARQ blocking probability assuming each TB has packet error probability of 0.3.

HARQ blocking probability	K_{MIMO}=1	K_{MIMO}=2
FDD	4.73%	1.71%
TDD, Configuration 4	42.9%	47.8%
TDD, Configuration 5	77.1%	89.3%

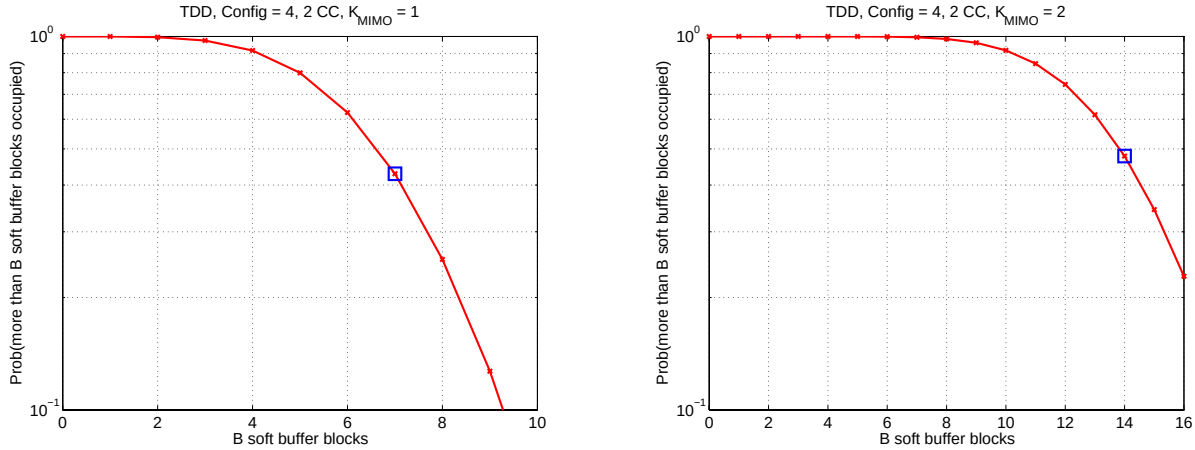
The figures show that while overbooking does not cause high probability of blocking for FDD, TDD configurations may have unacceptably high HARQ blocking probabilities. As shown, TDD Configuration 4 has blocking probability around 40%-50%, and TDD Configuration 5 has blocking probability of 70%-90%.

Thus interlace partitioning would require the eNB to increase the number of interlaces for each CC, or to make the number of interlaces configurable [6]. Alternatively the eNB can lower the operating point, which would cause an overall decrease in the system throughput.



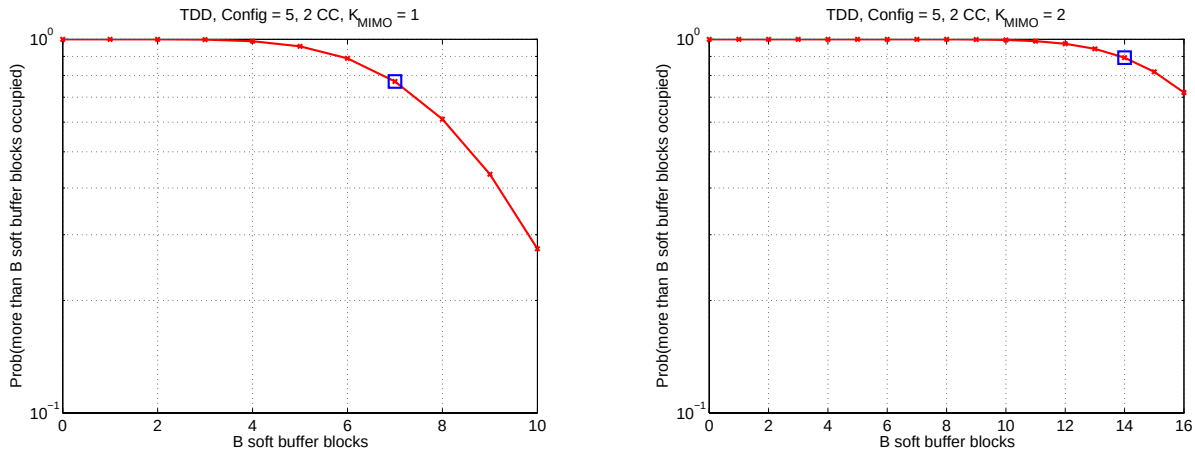
(a) (b)

Figure 4. Probability of blocking for FDD when K_{MIMO}=1 and 2, respectively. The packet error probability of a TB is set to 0.3.



(a) (b)

Figure 5. Probability of blocking for TDD configuration 4 when K_{MIMO}=1 and 2, respectively. The packet error probability of a TB is set to 0.3.



(a) (b)

Figure 6. Probability of blocking for TDD configuration 5 when K_{MIMO}=1 and 2, respectively. The packet error probability of a TB is set to 0.3.

2.3 RM-single CC

This method proposes to perform rate matching based on the soft buffer size of a single CC irrespective of the number of configured CCs [7]. It is debatable if this method satisfies either principle.

- For the first principle of not degrading performance, the performance of an initial transmission is not degraded the performance if the UE allocates dynamic buffer when needed, and discards the soft bits where necessary. However, for retransmissions, if any soft bits previously received have been discarded, this necessarily degrades the decoding performance at subsequent transmissions. Furthermore, since how the receiver processes the soft bits is left to UE implementation, the eNB would have difficulty estimating what kind of decoding performance a UE is able to achieve (e.g., effective mother code rate can be 1/3 or 2/3 depending on UE implementation), making it difficult for the eNB to efficiently schedule (re)transmissions. This is likely to result in system performance degradation as well.
- For the second principle of maintaining the soft buffer size regardless of number of CCs, this method effectively requires the UE to allocate the maximum buffer to allow mother code rate of 1/3 always, if the straightforward implementation is used. In this case, the second principle is violated in practice.

2.4 Configurable by Higher Layers

It has been proposed that certain parameters related to soft buffer partitioning can be configured semi-statically by higher layers [5][6]. While this provides high level of flexibility in soft buffer partitioning, and does not appear to violate either principle. Other concerns make this option undesirable.

- High signaling overhead. For example, the proposal in [6] calls for 5 bits (2 bits for $w(n_c)$ and 3 bits for $M(n_c)$) signaling overhead per CC. This amounts to 25 bits overhead if 5 CCs are configured.
- Large number of combinations to test. The high flexibility implies that the number of testing is very high and grows exponentially with the number of CCs. This is highly undesirable for implementation.

3 Conclusions

This contribution analyzes the attributes of proposed methods against the agreed principles. The analysis is summarized in Table 2 below.

Table 2. Proposed methods in light of the design principles.

	Equal Partioning	Unequal Partitioning	Interlace partitioning	RM-single CC	Configurable
Principle 1	No	Yes	No (TDD)	Practically No	Yes
Principle 2	Yes	Yes	Yes	Practically No	Yes

Among the options, unequal partitioning appears to satisfy both principles without incurring signaling overhead or overwhelming amount of testing. It is thus proposed that unequal partitioning be adopted for soft buffer partitioning.

References

[1] 3GPP TS 36.212 v10.0.0 (2010-12), Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding (Release 10).

[2] 3GPP TS 36.306 V10.0.0 (2010-12), Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities (Release 10).

[3] R1-110044, CATT, “Soft buffer partitioning in Rel-10”, 3GPP TSG RAN WG1 Meeting #63bis.

[4] R1-110008, Huawei, HiSilicon, “Soft buffer size allocation for Rel-10 downlink,” 3GPP TSG RAN WG1 Meeting #63bis.

[5] R1-110295, Motorola Mobility, “Soft Buffer Partitioning for Carrier Aggregation,” 3GPP TSG RAN WG1 Meeting #63bis.

[6] R1-110331, Qualcomm Incorporated, “Soft buffer partitioning for CA,” 3GPP TSG RAN WG1 Meeting #63bis.

[7] R1-110240, NTT DOCOMO, “Soft Buffer Partitioning and Rate Matching for Downlink CA,” 3GPP TSG RAN WG1 Meeting #63bis.

[8] R1-110203, Panasonic, “Soft buffer partitioning,” 3GPP TSG RAN WG1 Meeting #63bis.

[9] R1-110033, Ericsson, ST-Ericsson, “Views on soft buffer handling for Rel-10 UEs,” 3GPP TSG RAN WG1 Meeting #63bis.

[10] R1-082018, Ericsson, “On soft buffer usage for LTE TDD, ” 3GPP TSG-RAN WG1 #53.