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Agenda Item: **Plenary**

Source: **Panasonic, Mitsubishi Electric (Trium-RD)**

Title: **Limitation on the downlink rate matching repetition**

Document for: **Discussion**

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1. Introduction

This document looks at the impact of unlimited downlink rate matching repetition on UE capability memory dimensioning. Current specification has no limitation on the rate of the repetition in rate matching. This requires huge size of memory which will probably not be used. We propose to limit the maximum rate of the repetition in rate matching in the downlink.

2. UE capability and rate matching

There are two parameters which present UE memory requirement. These are the number of transport channel capability and physical channel capability. The exact name of transport channel capability is "Maximum sum of number of bits of all transport blocks being received at an arbitrary time instant". The exact name of physical channel capability is "Maximum number of physical channel bits received in any 10 ms interval (DPCH, PDSCH, S-CCPCH)". The exact name of transport channel capability is under the discussion [1]. The transport channel capability has a trade off between TTI length and bit rate: for same parameter, the highest the bit rate the shorter the implied TTI length.

For example, let's look at the memory requirement of 384kbps class and turbo decoding. Transport channel capability for turbo decoding is 6400 bit and physical channel capability is 19200bit in the 384kbps class. For simplify, let's consider the case of one transport block and one transport channel without CRC. Table 1 shows the number of bits which figure one pointed out.

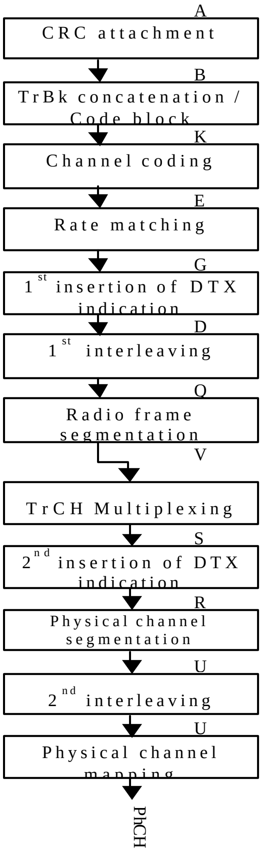

Figure 1

The number of bits at the point of G, the number of bits between "rate matching" and "1st insertion o DTX indication", cannot be decided according to the transport channel capability because there is no limitation on the ma ximum number of the repetition. The maximum value of G is decided by the number of physical channel capability. 80ms is the maximum TTI length. So, the number of G is 8 times of physical channel capability.

Table 1 Memory requirement of 384kbps class terminal

reference point	The value from "Maximum sum of number of bits of all transport blocks being received at an arbitrary time instant"		The value from "Maximum number of physical channel bits received in any 10 ms interval (DPCH, PDSCH, S-CCPCH)"	
	value	comment	value	comment
A	6400	TB size		
B	6400	TB+CRC size		
C	2	Number of code blocks		
K	3200	Code block size		
E	6400×3+2? 12= 19224	C? (3? K+12) size after channel encoding		
G	19224? ? =?	potential size after RM	19200×8 =153600	Worst case TTI is 8 frames.
P? U			19200	Maximum number of physical channel bits

In above discussion, note that those values are soft value from point E to point U in the receiver side of the UE. It means, in above discussion, the required memory size is multiplied.

The full usage of this memory is the case of 960ksps(SF=4) and 80kbps transmission with 80ms TTI. The rate of repetition is roughly 8 ? $\frac{19200\textit{bits} ? 8\,\textit{frames}}{6400\textit{bits} ? 3\textit{codingrate}}$ (denominator is an approximate value not considering tail bits and code block segmentation fillers). In the downlink, the bigger spreading factor can save code usage. So in the case of 80kbps with 80ms TTI, to reduce the rate of the repetition is desirable. 120ksps without repetition is the proper setting.

In the above discussion, we looked at the case of the 384kbps class and one TrCH as in the example. This discussion is not limited only to the case of the 384kbps class. No limitation in the rate of the repetition requires huge size of memory and it increases the complexity of the UE receiver.

Hence, we propose to limit the rate of repetition in downlink.

3. Discussion on the methods to limit the rate of the repetition

Let us take the 384k class example.

value for 384k class	acronym	name (not official, taken from CR25.926-015r1)
6400	MA_MAX	maximum sum of number of bit of all transport block that can be received from TTIs intersecting an arbitrary time instant
6400	TC_MA_MAX	maximum sum over all turbo encoded transport channels of number of bit of all transport block that can be received from TTIs intersecting an arbitrary time instant
640	CC_MA_MAX	maximum sum over all convolutionally encoded transport channels of number of bit of all transport block that can be

		received from TTIs intersecting an arbitrary time instant
32	M_MAX	maximum total number of transport blocks received from TTI's intersected by an arbitrary time instant
8	I_MAX	maximum number of transport channels

Now, we can find a worst case configuration in terms of memory requirement :

TrCH	coding scheme	I	M	A	$M \times A$	B =A+24	$M \times B$	Z	$C = \left\lceil \frac{M \times B}{Z} \right\rceil$	K	E
1	CC		25	20	500	44	1100	504	3	367	3375
2	CC		1	20	20	44	44	504	1	44	156
3	CC		1	20	20	44	44	504	1	44	156
4	CC		1	20	20	44	44	504	1	44	156
5	CC		1	20	20	44	44	504	1	44	156
6	CC		1	20	20	44	44	504	1	44	156
7	CC		1	40	40	64	64	504	1	64	216
8	TC		1	5760	5760	5784	5784	5114	2	2892	17376
total CC		7	31		640						4371
total TC		1	1		5760						17376
total		8	32		6400						**21747**

So we get that the maximum number of channel encoded bits for this very worst case configuration is **21747**. If we have a maximum number of repetition of 2, then the number of bits to store before de-1st-ILing is $2 \times 21747 = 43494$ instead of 8×19200 = **153600**, that is to say roughly **3.5** times as few. This is a substantial gain of memory, especially as we are talking about soft bits, and it is from the UE perspective, where resources are so scarce.

We considered three methods of the limitation.

Method 1) the limitation by each TrCH

Limitation for each TrCH means that :

$$\forall i, G_i \leq RF_{i,max} \cdot E_i$$

This method can limit the rate of each transport channel according to the coding scheme. For instance, the limitation $RF_{i,max}$ can be 2 for a CC 1/3 or TC encoded TrCH, 3 for CC 1/2, and 6 for no-coding.

In that case the maximum number of bits before de-1st-ILing is $\sum_{i=1}^{I} \left(RF_{i,max} \cdot E_i \right)$

Method 2) the limitation by sum of turbo capability, convolutional coding capability, sum of TrCH Capability

This method limits the average rate of the repetition over the sum of transport channels for one coding scheme.

In that case we have :

$$\begin{cases} \sum_{i \in CCS} G_i \leq RF_{CC,max} \cdot \left(\sum_{i \in CCS} E_i \right) \\ \sum_{i \in TCS} G_i \leq RF_{TC,max} \cdot \left(\sum_{i \in TCS} E_i \right) \\ \sum_{i \in NCS} G_i \leq RF_{NC,max} \cdot \left(\sum_{i \in NCS} E_i \right) \end{cases}$$

Where CCS, TCS, and NCS is the partition of the set of transport channels {1, 2, …, I} according to whether the coding scheme is CC, TC or no coding.

If CS(i) denotes the coding scheme CC, TC or NC for TrCH i, then the maximum number of bits before de-1st-ILing is with this method : $\sum_{i=1}^{i=I} (RF_{CS(i),\max} \times E_i)$, where $RF_{CS(i),\max}$ is for instance always 2. However, this method does not excludes that for some TrCH i_0 we could have :

$$G_{i_0} > RF_{\max} \times E_{i_0}$$

Method 3) the limitation by sum of all TrCH

This method limits the average rate of the repetition over the sum of all transport channels. In that case we have :

$$\sum_{i=1}^{i=I} G_i \leq RF_{\max} \times \left(\sum_{i=1}^{i=I} E_i \right)$$

So the maximum number of bits before de-1st-ILing is $RF_{\max} \times \left(\sum_{i=1}^{i=I} E_i \right)$, where $RF_{\max}$ is for instance 2.

However, this method does not excludes that for some TrCH i_0 we could have :

$$G_{i_0} > RF_{\max} \times E_{i_0}$$

Discussion

Basically, in method 1 and method 2, it does not make much sense to have different limits according to the coding scheme, one would use CC 1/2 rather than repeat twice no-coding. Similarly, one would use CC 1/3 or TC 1/3 rather than repeat 1.5 CC 1/2. So, if we have the same limitation for all the coding schemes, then the 3 methods lead to the same memory requirement.

Method 2 and 3 are more flexible, because they do not exclude repetition rate greater than 2 for one TrCH, the limitation is only over a sum of TrCH with same coding scheme used for method 2, and over the sum of all TrCH for method 3.
Method 1 is easy to understand but flexibility is limited. In section 2 of 384kbps class, we presented the example of one transport channel and saw the relation with downlink spreading factor. But usually more than one transport channels consist one CCTrCH. In this case, the repetition rate over two may happen to get appropriate QoS.

Method 3 has the drawback that it would prevent some UE implementations, as we should assume at some stage that the CC and the TC transport channels use the same memory and this would make parallel processing of TC and CC more complex.

So, we propose method 2, as it seems to be the good compromise between flexibility of CCTrCH configuration, and flexibility of UE implementation.

We calculated the repetition rate of ISG document ver 1.3. This result is attached in Annex.

4. Proposed change to the specification

We propose to add limitation for the repetition in TR 25.926. The actual CR will be proposed according to the outcome of this this discussion.

5. Conclusions

We looked the relation between UE capability and rate matching. No limitation in the rate of repetition requires huge size of memory (bigger by a factor 3.5 than with limitation) and full usage of this memory is not proper setting from code usage point of view. We compared three methods of the limitation and propose method 2, where the limitation is over over the sum of convolutional coding transport channel, the sum of turbo transport channel, and the sum of transport channel as R99.

Reference

[1] R1-00-1300 CR25.926, clarification on TTI simultaneousness in UE radio access capability

Annex. ISG document calculation between before rate match and after rate match

The following table represents the rate of rate match in ISG document. Each combinations of rate matching attribute by step of five were calculated and seek the maximum number at the point between rate match and 1st insertion of DTX indication. Then we calculated following formula.

The row of CC

$$\frac{\textit{Sum of every convolutional coding transport channel at after rate match}}{\textit{Sum of every convolutional coding transport channel at before rate match}}$$

The row of TC

$$\frac{\textit{Sum of every turbo coding transport channel at after rate match}}{\textit{Sum of every turbo coding transport channel at before rate match}}$$

The row of Total means

$$\frac{\textit{Sum of every transport channel at after rate match}}{\textit{Sum of every transport channel at before rate match}}$$

The section not described here are duplicational section from only downlink point of view and DL:2048 kbps / PS RAB service. No calculation is required because DL:2048 kbps/PS RAB is punctured.
We think the value of 2 for the limitation has a good margin for flexibility.

Section number of ISG document	CC	TC	Total
5.4.1.1.	0.93	0	0.93
5.4.1.2.	1.628	0	1.628
5.4.1.3	0.988	0	0.988
5.4.1.4.	0.977	0	0.977
5.4.1.5.	1.082	0	1.082
5.4.1.6.	1.235	0	1.235
5.4.1.7.	1.287	0	1.287
5.4.1.8.	1.359	0	1.359
5.4.1.9.	1.453	0	1.453
5.4.1.10.	0.64	0	0.64
5.4.1.11.	0.664	0	0.664
5.4.1.12.	0.907	0.908	0.882
5.4.1.13. _CS_20msTTI	1.093	1.011	1.004
5.4.1.13. _CS_40msTTI	1.101	1.013	1
5.4.1.14. _CS_20msTTI	0.806	0.829	0.804
5.4.1.14. _CS_40msTTI	0.814	0.831	0.806
5.4.1.15.	0.806	0.756	0.729
5.4.1.16.	1.054	0.895	0.882
5.4.1.17.	1.426	1.105	1.101
5.4.1.18.	1.271	0.981	0.978
5.4.1.20.	1.357	1.039	1.037
5.4.1.22.	1.116	0.745	0.745
5.4.1.23. _CC	1.203	0	1.203
5.4.1.23. _TC	1.388	1.258	1.212
5.4.1.26.	1.171	0.939	0.947
5.4.1.27.	1.349	0.992	1.001
5.4.1.29.	1.039	0.887	0.888
5.4.1.31. _PS_10msTTI	1.295	1.064	1.072
5.4.1.31. _PS_20msTTI	1.295	1.064	1.065

5.4.1.32. _PS_10msTTI	1.07	0.712	0.722
5.4.1.32. _PS_20msTTI	1.07	0.711	0.715
5.4.1.38.	1.255	1.15	1.14
5.4.1.39.	1.093	0.793	0.804
5.4.1.41.	1.401	0.901	0.918
5.4.1.42. _PS_10msTTI	1.455	1.016	1.048
5.4.1.42. _PS_20msTTI	1.455	1.016	1.019
5.4.1.43. _PS_10msTTI	1.21	0.686	0.718
5.4.1.43. _PS_20msTTI	1.21	0.686	0.694
5.4.1.45	1.27	0.903	0.909
5.4.1.46.	1.165	0.818	0.823
5.4.1.47.	1.407	0.942	0.945
5.4.1.48.	1.261	0.717	0.72
5.4.1.49. _CS_20msTTI	1.037	0.862	0.846
5.4.1.49. _CS_40msTTI	1.04	0.863	0.848
5.4.1.50. _CS_20msTTI+20msTTI	1.163	1.066	1.063
5.4.1.50. _CS_20msTTI+40msTTI	1.163	1.11	1.1
5.4.1.50. _CS_40msTTI+40msTTI	1.171	1.068	1.061
5.4.1.51. _CS_20msTTI	1.209	1.028	1.029
5.4.1.51. _CS_40msTTI	1.209	1.095	1.091
5.4.1.52. _CS_20msTTI	1.829	1.443	1.448
5.4.1.52. _CS_40msTTI	1.829	1.562	1.562
5.4.1.54.	1.93	1.504	1.51
5.4.1.55.	1.457	1.142	1.144
5.4.2.1. _CS_40msTTI	1.163	0	1.163
5.4.2.1. _PS_10msTTI	0	1.135	1.135
5.4.2.1. _PS_20msTTI	0	1.135	1.135
5.4.2.2. _CS_40msTTI	1.163	0	1.163
5.4.2.2. _PS_10msTTI	0	0.757	0.757
5.4.2.2. _PS_20msTTI	0	0.757	0.757
5.4.2.4. _CS	0.977	0	0.977
5.4.2.4. _PS_10msTTI	0	1.135	1.135
5.4.2.4. _PS_20msTTI	0	1.135	1.135
5.4.2.5. _CS	0.977	0	0.977
5.4.2.5. _PS_10msTTI	0	0.757	0.757
5.4.2.5. _PS_20msTTI	0	0.757	0.757
5.4.3.1. TrBk size is 240	1.136	0	1.136
5.4.3.1. TrBk size is 80	1.442	0	1.442
5.4.3.2.	1.436	0.947	1.436
5.4.3.3. TrBk size is 240	1.184	0.864	1.184
5.4.3.3. TrBk size is 80	1.436	0.947	1.436
Maximum value	1.93	1.562	1.628