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Agenda item: Ad Hoc 4

Source: Ericsson, Mitsubishi Electric, Siemens

Title: Text proposal for rate matching signalling

Document for: Decision

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1 Introduction

Rate matching signalling has been discussed in [1] - [4]. The general principle is the same in all these contributions but there are minor differences. After discussion, the sources of [1] - [4] propose that the text proposal in Section 2 of this contribution is inserted into the specification. The text proposal is based on [4] and the general principle is unchanged but some minor changes have been made. Revision marks are with respect to the current specification ([5] for FDD, [6] for TDD). Compared to [4], the following changes have been made:

- A separate section specific for TDD has been included
- Notation: RM_i is used instead of R_i, PL instead of P, N_{data} instead of N_{ch}.
- The calculation of DN_{ij} in FDD downlink is changed so that it is applicable also for the case when different TrCHs have different transmission time interval (TTI).
- For FDD the requirement that $RM_x=1$ is removed and in uplink normalization is instead done when the spreading factor (SF) and the number of codes is calculated. This enables RM_i to be integer numbers.
  In UL the SF and the number of codes are selected in order to satisfy the following criteria given by order of priority:
  i. The number of used DPDCH is minimised, or the SF is constrained to be greater than or equal to the minimum value supported by the UE
  ii. The puncturing is minimised, provided that constraint (i) still holds
  iii. The SF is maximised provided that constraints (i) and (ii) still hold.
- For TDD the requirement that $RM_x=1$ is removed and normalization is instead done when the physical channels are determined. This enables RM_i to be integer numbers.
  The physical channels are selected in order to satisfy the following criteria given by order of priority:
  i. The number of used physical channels is minimised
  ii. The puncturing is minimised provided that constraint (i) still holds

2 Text proposal for TS 25.212

4.2.6 Rate matching

Rate matching means that bits on a transport channel are repeated or punctured. Higher layers assign a rate-matching attribute for each transport channel. This attribute is semi-static and can only be changed through higher layer signalling. The rate-matching attribute is used when the number of bits to be repeated or punctured is calculated.

The number of bits on a transport channel can vary between different transmission time intervals. In the downlink the transmission is interrupted if the number of bits is lower than maximum. When the number of bits between different transmission time intervals in uplink is changed, bits are repeated or punctured to ensure that the total bit rate after second multiplexing is identical to the total channel bit rate of the allocated dedicated physical channels.

The rate matching applies repetition and puncturing of the different transport channels.

For each combination of rates of the different transport channels, a puncturing/repetition factor is assigned to each transport channel. The set of puncturing/repetition factors is determined based on following criteria:

- desired transmission quality requirements of each transport channel is fulfilled and not significantly exceeded. This means that required transmission power to meet quality requirements for all transport channels is as low as possible.
- on the uplink, the total bit rate after transport channel multiplexing is identical to the total channel bit rate of the dedicated physical channels allocated
- on uplink and downlink, the total allocated code resource should be minimised
- the puncturing factors should not exceed a certain maximum puncturing factor, specific for each transport channel.

Notation used in Section 4.2.6 and subsections:

N_{ij}: Number of bits in a radio frame before rate matching on transport channel *i* with transport format combination *j* .

N_{ij}^{TTI} : Number of bits in a transmission time interval before rate matching on transport channel *i* with transport format *j*.

ΔN_{ij} : If positive - number of bits that should be repeated in each radio frame on transport channel *i* with transport format combination *j*.
If negative - number of bits that should be punctured in each radio frame on transport channel *i* with transport format combination *j*.

ΔN_{ij}^{TTI} : If positive - number of bits to be repeated in each transmission time interval on transport channel *i* with transport format *j*.
If negative - number of bits to be punctured in each transmission time interval on transport channel *i* with transport format *j*.

RM_i: Semi-static rate matching attribute for transport channel *i*. Signalled from higher layers.

PL: Puncturing limit for uplink. This value limits the amount of puncturing that can be applied in order to avoid multicode or to enable the use of a higher spreading factor. Signalled from higher layers.

$N_{data,j}$: Total number of bits that are available for the CCTrCH in a radio frame with transport format combination j.

T: Number of transport channels in the CCTrCH.

Z_{mj}: Intermediate calculation variable.

F_i: Number of radio frames in the transmission time interval of transport channel *i*.

k: Radio frame number in the transmission time interval of transport channel *i* ($0 £ k < F_i$).

q: Average puncturing distance.

$I_F(k)$: The inverse interleaving function of the 1st interleaver (note that the inverse interleaving function is identical to the interleaving function itself for the 1st interleaver).

S(k): The shift of the puncturing pattern for radio frame k.

$TF_i(j)$: Transport format of transport channel i for the transport format combination j.

4.2.6.1Determination of Rate matching Parameters

The selection of the relative puncturing/repetition if several coded transport channels are multiplexed together is done in a way to ensure, that the relative SNR requirements to achieve the required QoS are balanced and that the maximum allowed puncturing is not exceeded.

<Editor’s note: There exist proposals for the exact determination of the puncturing rate for each individual coded transport channel, but the relevant text is still to be inserted. >

The following relations are used when calculating the rate matching pattern:

$$Z_{0,j} = 0$$

$$Z_{mj} = \left\lfloor \frac{\sum_{i=1}^{m} RM_i \cdot N_{ij}}{\sum_{i=1}^{T} RM_i \cdot N_{ij}} \cdot N_{data,j} \right\rfloor$$ for all m = 1 .. T, *where ë û means round downwards*

$$\Delta N_{ij} = Z_{ij} - Z_{i-1,j} - N_{ij}$$ for all i = 1 .. T

4.2.6.1 Determination of rate matching parameters in uplink

In uplink puncturing can be used to avoid multicode or to enable the use of a higher spreading factor. The maximum amount of puncturing that can be applied is signalled at connection setup from higher layers and denoted by *PL*. The number of available bits in the radio frames for all possible spreading factors is given in [2]. Denote these values by N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, and N_4, where the index refers to the spreading factor. The possible values of N_{data} then are { N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, $2N_4$, $3N_4$, $4N_4$, $5N_4$, $6N_4$}.Depending on the UE capabilities, the supported set of N_{data} , denoted SET0, can be a subset of { N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, $2N_4$, $3N_4$, $4N_4$, $5N_4$, $6N_4$}. $N_{data,j}$ for the transport format combination j is determined by executing the following algorithm:

SET1 = { N_{data} in SET0 such that $N_{data} - \sum_{i=1}^{T} \frac{RM_i}{\min_l \{RM_l\}} \cdot N_{ij}$ is non negative }

If the smallest element of SET1 requires just one DPDCH then

$N_{data,j}$ = min SET1

else

SET2 = { N_{data} in SET0 such that $N_{data} - PL \cdot \sum_{i=1}^{T} \frac{RM_i}{\min_l \{RM_l\}} \cdot N_{ij}$ is non negative }

Sort SET2 in ascending order

N_{data} = min SET2

While N_{data} is not the max of SET2 and the follower of N_{data} requires no additional DPDCH do

N_{data} = follower of N_{data} in SET2

End while

$N_{data,j} = N_{data}$

End if

4.2.6.2Parameters for Rate matching after first interleaving

The number of bits to be repeated or punctured, DN_{ij}, within one radio frame for each transport channel *i* is calculated with the relations given in Section 4.2.6 for all possible transport format combinations *j* and selected every radio frame. For each radio frame, the rate-matching pattern is calculated with the algorithm in Section 4.2.6.3, where $DN = DN_{ij}$ and $N = N_{ij}$.

Additionally, tThe following parameters are also needed:

Rate matching is performed for every radio frame.

~~Let's denote:~~

~~F: the number of radio frames corresponding to the transmission time interval.~~

~~k: the current radio frame in the transmission time interval (0 ≤ k < F)~~

~~$R_F(k)$ is the inverse interleaving function of the 1st MIL interleaver (note that the inverse interleaving function is identical to the interleaving function itself for the 1st MIL interleaver).~~

~~N_C number of data bits before rate matching for a particular coded transport channel for the radio frame k.~~

~~N_i number of data bits after rate matching for this particular coded transport channel for the radio frame k.~~

~~-- calculate average puncturing distance~~

q = ë*N*ij /(ô*DN*ij ô)û , where ë û means round downwards and ô ô means absolute value.

if q is even ~~-- avoid hitting the same column twice:~~

then $q' = q - gcd(q, F_i)/F_i$ -- where $gcd(q, F_i)$ means greatest common divisor of *q* and F_i

-- note that *q'* is ~~now~~ not an integer, but a multiple of 1/8

else

$q' = q$

endif

~~-- calculate S(k), representing the shift of the puncturing pattern for the radio frame k. S(k) is used when preloading e in the rate matching formula in section 4.2.4.4 below.~~

for *l* = 0 to F_i-1

$S(I_F$ (é*l**q'ù mod F_i)) = (é*l**q'ù div F_i) -- *where é ù means round upwards.*

end for

4.2.6.2 ~~4.2.6.3 Parameters for Rate matching before first interleaving~~ Determination of rate matching parameters in downlink

For downlink $N_{data,j}$ does not depend on the transport format combination *j*. $N_{data,j}$ is given by the channelization code(s) assigned by higher layers.

Radio frame segmentation is performed after 1st interleaving and N_{ij} is therefore calculated as:

$l = TF_i(j)$ and $N_{ij} = \left\lceil \frac{N_{i,l}^{TTI}}{F_i} \right\rceil$

The number of bits repeated or punctured, ΔN_{iL}, within one radio frame for each transport channel is calculated for the transport format combination *L* with highest bitrate with the relations given in Section 4.2.6.

If fix positions of the transport channels in the radio frame are used then the same ΔN_{ij} is used for all transport format combinations and the last part of the rate-matching pattern omitted. That is to say for all transport format combinations j we have:

$$\Delta N_{ij} = \Delta N_{iL}$$

When flexible positions of the transport channels are used, the number of bits ΔN_{ij} repeated or punctured for all transport format combinations *j* other than *L* is calculated as:

$$\Delta N_{ij} = \left\lfloor \frac{\Delta N_{iL}}{N_{iL}} \cdot N_{ij} \right\rfloor$$

For each transmission time interval, the rate-matching pattern is calculated with the algorithm in Section 4.2.6.3. The following parameters are used as input:

$l = TF_i(j)$ and $\Delta N = \Delta N_{il}^{TTI} = F_i \Delta N_{ij}$

$N = N_{il}^{TTI}$ Rate matching is performed for every transmission time interval.

Let's denote:

N_C number of data bits before rate matching for a particular coded transport channel for the transmission time interval.

N_i number of data bits after rate matching for this particular coded transport channel for the transmission time interval.

S is not used when preloading e in the rate matching formula in section 0 below but is set to

S=0.

4.2.6.34 Rate matching algorithm

Let's denote:

$S_0 = \{d_1, d_2, \ldots, d_{N_C}\}$ = set of N_C data bits

Denote the bits before rate matching by:

$c_1, c_2, c_3, \ldots c_N$

The rate matching rule is as follows:

if puncturing is to be performed

```
        y = -DNNC-Ni
        e = (2*S(k) * y +  NC) mod 2NC    -- initial error between current and desired puncturing ratio
        m = 1            -- index of current bit
        do while m <= NC
                e = e – 2 * y              -- update error
                if e <= 0 then             -- check if bit number m should be punctured
                        puncture bit cm from set S0
                        e = e + 2*NC       -- update error
                end if
                m = m + 1                  --  next bit
        end do
else
        y = DNNi-NC
        e = (2*S(k) * y +  NC) mod 2NC    -- initial error between current and desired puncturing ratio
        m = 1                -- index of current bit
        do while m <= NC
                e = e – 2 * y              -- update error
```

do while $e <= 0$ -- *check if bit number m should be repeated*

repeat bit c_m ~~from set S_0~~

$e = e + 2*N_C$ -- *update error*

enddo

$m = m + 1$ -- *next bit*

end do

end if

A repeated bit is placed directly after the original one.

3 Text proposal for TS 25.222

The following text shall replace the text in chapter 6.2.5 of TS 25.222:

6.2.5 Rate matching

Rate matching means that bits on a transport channel are repeated or punctured. Higher layers assign a rate-matching attribute for each transport channel. This attribute is semi-static and can only be changed through higher layer signalling. The rate-matching attribute is used when the number of bits to be repeated or punctured is calculated.

The number of bits on a transport channel can vary between different transmission time intervals. When the number of bits between different transmission time intervals is changed, bits are repeated to ensure that the total bit rate after second multiplexing is identical to the total channel bit rate of the allocated dedicated physical channels.

Notation used in Section 6.2.5 and subsections:

N_{ij}: Number of bits in a radio frame before rate matching on transport channel *i* with transport format combination *j* .

ΔN_{ij} : If positive - number of bits to be repeated in each radio frame on transport channel *i* with transport format combination *j*.
If negative - number of bits to be punctured in each radio frame on transport channel *i* with transport format combination *j*.

RM_i: Semi-static rate matching attribute for transport channel *i*. Signalled from higher layers.

PL: Puncturing limit for uplink. This value limits the amount of puncturing that can be applied in order to minimise the number of dedicated physical channels. Signalled from higher layers.

$N_{data,j}$: Total number of bits that are available for a CCTrCH in a radio frame with transport format combination j.

T: Number of transport channels in a CCTrCH.

Z_{mj}: Intermediate calculation variable.

F_i: Number of radio frames in the transmission time interval of transport channel *i*.

k: Radio frame number in the transmission time interval of transport channel *i* ($0 £ k < F_i$).

q: Average puncturing distance.

$I_F(k)$: The inverse interleaving function of the 1st interleaver (note that the inverse interleaving function is identical to the interleaving function itself for the 1st interleaver).

S(k): The shift of the puncturing pattern for radio frame k.

$TF_i(j)$: Transport format of transport channel i for the transport format combination j.

6.2.5.1 Determination of rate matching parameters

The following relations are used when calculating the rate matching pattern:

$$Z_{0,j} = 0$$

$$Z_{mj} = \left\lfloor \frac{\sum_{i=1}^{m} RM_i \cdot N_{ij}}{\sum_{i=1}^{T} RM_i \cdot N_{ij}} \cdot N_{data,j} \right\rfloor$$ for all m = 1 .. T, where ë û means round downwards

$$\Delta N_{ij} = Z_{ij} - Z_{i-1,j} - N_{ij}$$ for all i = 1 .. T

Puncturing can be used to minimise the number of required transmission capacity. The maximum amount of puncturing that can be applied is signalled at connection setup from higher layers and denoted by *PL*. The possible values for N_{data} are always multiples of the dedicated physical channel with the smallest capacity, reduced by the amount of bits which carry the TFCI. The supported set of N_{data} , denoted SET0, depends on the UE capabilities. $N_{data,j}$ for the transport format combination j is determined by executing the following algorithm:

SET1 = { N_{data} in SET0 such that $N_{data} - PL \cdot \sum_{i=1}^{T} \frac{RM_i}{\min_{l}\{RM_l\}} \cdot N_{ij}$ is non negative }

$N_{data,j}$ = min SET1

The number of bits to be repeated or punctured, DN_{ij}, within one radio frame for each transport channel *i* is calculated with the relations given at the beginning of this section for all possible transport format combinations *j* and selected every radio frame. For each radio frame, the rate-matching pattern is calculated with the algorithm in Section 4.2.6.3, where $DN = DN_{ij}$ and $N = N_{ij}$.

Additionally, the following parameters are needed:

q= ëN_{ij}/(ôDN_{ij}ô)û , where ë û means round downwards and ô ô means absolute value.

if q is even
then $q' = q - gcd(q, F_i)/F_i$ -- where $gcd(q, F_i)$ means greatest common divisor of q and F_i -- note that q' is not an integer, but a multiple of 1/8
else
$q' = q$

endif

for l = 0 to F_i-1
*S(I_F (él*q'ù mod F_i)) = (él*q'ù div F_i)* -- *where é ù means round upwards.*

end for

6.2.5.2 Rate matching algorithm

Denote the bits before rate matching by:

$c_1, c_2, c_3, \ldots c_N$

The rate matching rule is as follows:

if puncturing is to be performed

y = -DN
e = (2*S(k) * *y* + *N*) mod 2*N* -- *initial error between current and desired puncturing ratio*

m = 1 -- *index of current bit*

do while *m <= N*

*e = e – 2 * y* -- *update error*

if *e <= 0* then -- *check if bit number m should be punctured*

puncture bit c_m

*e = e + 2*N* -- *update error*

end if

m = m + 1 -- *next bit*

end do

else

y = DN

e = (2*S(k) * *y* + *N)* mod 2*N* -- *initial error between current and desired puncturing ratio*

m = 1 -- *index of current bit*

do while *m <= N*

*e = e – 2 * y* -- *update error*

do while *e <= 0* -- *check if bit number m should be repeated*

repeat bit c_m

*e = e + 2*N* -- *update error*

enddo

m = m + 1 -- *next bit*

end do

end if

A repeated bit is placed directly after the original one.

~~3~~4 References

[1] Mitsubishi Electric, "A rule to determine the rate matching ratio", TSGR1#5(99)538.

[2] Siemens, "Single-step Rate Matching for Service Multiplexing", TS R1#5(99)612.

[3] Mitsubishi Electric, Siemens "Determination of Rate Matching Parameters for Service Multiplexing", TSGR#5(99)710.

[4] Ericsson, "Rate matching signalling", TSGR1#6(99)849.

[5] TSG RAN WG1, "TS 25.212 Multiplexing and channel coding (FDD)"

[6] TSG RAN WG1, "TS 25.222 Multiplexing and channel coding (TDD)"