3GPP TSG-RAN4 Meeting #100e
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R4-2112133

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Motivation paper for R18 RRM enhancement

Background

- R17 leftover topics
  - In R17 discussion, only limited topics have been selected as R17 RRM enhancement, and therefore there are still many candidate leftover topics for study/work in R18 scope.
  - During the R17 RAN4 work, some other issues have been identified for further study, e.g.,
    - FR1+FR1 NR-DC scenario
    - New scenario for HO with PSCell
    - RRM requirement with NeedForGap
    - per-BC indication of per-FR measurement gap UE capabilities
- Newly raised topics for R18
  - There are also some other new valuable topics identified for R18 standardization work,
    - New Topics as discussed in the June RAN R18 workshop: e.g., Harmonized RLM/BM
    - Other new topics: e.g., *allowInterruption* for NR deactivated SCell measurements

Rel-18 new topics for eFeRRM

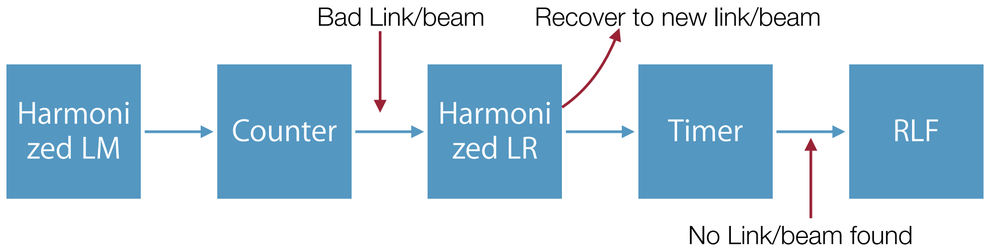
Candidate scope 1 | Harmonized RLM/BM

- Background
  - The existing BFD & CBD
    - BFD triggers BF and CBD/BFR to recover/find the candidate beam
      - BFD is SINR based evaluation with lower hypothetical PDCCH power than RLM OOS
      - CBD is L1-RSRP based and would be delivered to MAC layer
      - 10% target BLER for BFD and RSRP threshold for CBD
  - The existing RLM
    - OOS and counter/timer to trigger RLF, and during OOS/counter/timer IS could recover the link
      - OOS/INS is SINR based evaluation
      - The OOS/INS indication would be delivered to RRC layer
      - 2%/10% target BLER for IS/OOS based on same RS

- Commonality between RLM and BFD+CBD
  - Reflect the link quality, especially in FR2 (reflect the beam quality as well)
    - In FR2 the noise limited scenario is assumed rather than interference limited
    - Using L1-RSRP or SINR to recover the link is feasible (SINR evaluation in IS evaluation may not have obvious gain over the RSRP evaluation)
  - PHY measurement behavior is quite similar, and discrepancy between RLM and BFD is the sliding window size and L1 interval

- Benefit to harmonize RLM and BFD+CBD
  - Simplify the link evaluation procedure
    - e.g., using harmonized link monitoring procedure to trigger beam failure or bad link indication, when link quality is below certain threshold, using harmonized link recovery procedure for beam recovery and in case no candidate beam found, directly trigger RLF.
  - Reduced complexity on L1 sampling
    - In legacy case, UE monitors link by using RLM and monitors BF by using BFD, if even though the RS are same, the L1 sampling interval could be different, i.e., UE would maintain two parallel PHY evaluation window/timeline. However, harmonized RLM and BFD+CBD provide UE an unified evaluation procedure for different purpose
    - In legacy RLM, UE perform OOS and IS evaluation in parallel all the time (different evaluation window), however, harmonized link recovery would only be triggered after bad link was indicated
  - Delay reduction
    - FR2 is noise limited scenario, link quality could be equivalent to the beam quality. Using BFD+CBD like solution (harmonized BFD+CBD and RLM) would trigger RLF faster than legacy RLM.
      - The example for compression: periodical CSI-RS with 40ms periodicity, no DRX is used, counter N310=1 and timer T310=0

Note: P=1	RLM	Harmonized solution
Time to trigger RLF	Max(200, Ceil(M_{out}×P)×T_{CSI-RS}) = 800ms	Max(50, [M_{LM} (=10) × P × N × P_{BFD}] × T_{CSI-RS}) + Max(25, Ceil(M_{LR} (=3) × P × P_{CBD}) × T_{CSI-RS}) = 520ms



- ***Candidate scope 1:***
  - ***RAN4 to investigate and introduce a harmonized link monitoring/recovery mechanism to unify the RLM and BFD/CBD within single UE procedure***

Candidate scope 2 | RRM enhancement for large CC number

- Background
  - In Rel-15, Rel-16 and Rel-17, the serving CC number for RRM is specified as below, however in TS38.101-1/2/3 the allowed serving cell could be more than RRM requirement, e.g., 10 NR CCs in DC_1A-3A-5A-7A-7A_n78C-n257M.

3.6.2.1 Number of serving carriers for SA

Requirements for standalone NR with NR PCell are applicable for the UE configured with the following number of serving NR CCs:

- up to 8 NR DL CCs in total, with 1 UL (or 2 UL if SUL is configured) in PCell and up to 1 UL (or 2 UL if SUL is configured) in SCell.
- SUL may be configured together with one of the UL

  - With larger number of serving CC, it would result into huge long measurement/detection delay to degrade mobility performance based on CSSF factor without MG, as shown in following table.

Table 9.2.5.2-1: Measurement period for intra-frequency measurements without gaps(FR1)

DRX cycle	$T_{SSB_measurement_period_intra}$
No DRX	max(200ms, ceil(5 x K_p) x SMTC period)[Note 1] x $CSSF_{intra}$
DRX cycle ≤ 320ms	max(200ms, ceil(1.5x 5 x K_p) x max(SMTC period,DRX cycle)) x $CSSF_{intra}$
DRX cycle>320ms	ceil(5 x K_p) x DRX cycle x $CSSF_{intra}$
NOTE 1: If different SMTC periodicities are configured for different cells, the SMTC period in the requirement is the one used by the cell being identified	

For instance,
CSSF = 7 if 8 CCs are configured as CA (7 SCC share one searcher), and Scell measurement delay: 35 SMTC period (Kp=1 for simplicity)
CSSF = 9 if 10 CCs are configured as CA (9 SCC share one searcher), and Scell measurement delay: 45 SMTC period (Kp=1 for simplicity)

If beam sweeping is considered in FR2, then the delay would be even longer.

- ***Candidate scope 2:***
  - ***RAN4 to investigate and introduce a RRM enhancement mechanism for the measurement delay when large number of serving CCs are used.***

Candidate scope 3 | *allowInterruption* for deactivated SCell measurements

- Background
  - In current EN-DC, the interruption (caused by measurement of deactivated LTE SCC) on NR active serving CCs was specified as (in TS38.133)

8.2.1.2.5.2 Interruptions during measurements on deactivated E-UTRAN SCC

When one E-UTRA SCell in MCG is deactivated, the UE is allowed due to measurements on the E-UTRA SCC with the deactivated E-UTRA SCell:

- an interruption on PSCell or any activated SCell with up to 0.5% probability of missed ACK/NACK when any of the configured *measCycleSCell* [15] for the deactivated E-UTRA SCells is 640 ms or longer.
- an interruption on PSCell or any activated SCell with up to 0.5% probability of missed ACK/NACK regardless of the configured *measCycleSCell* [15] for the deactivated E-UTRA SCells if indicated by the network using IE *allowInterruptions* [15].

4.3.6.5 *benefitsFromInterruption-r11*

This field indicates whether the UE power consumption could benefit from being allowed to cause interruptions to serving cells when performing measurements of deactivated SCell carriers for *measCycleSCell* of less than 640ms, as specified in TS 36.133 [16].

  - In NR SA, the interruption (caused by measurement of deactivated NR SCC) on NR active serving CCs was specified as (in TS38.133)

8.2.2.2.3 Interruptions during measurements on deactivated SCC

Interruptions on PCell due to measurements when an SCell is deactivated are allowed with up to 0.5% probability of missed ACK/NACK when the configured *measCycleSCell* [2] is 640 ms or longer. The UE is only allowed to cause interruptions immediately before and immediately after an SMTC. Each interruption shall not exceed requirement in Table 8.2.2.2.2-1 if the PCell is not in the same band as the deactivated SCell. Each interruption shall not exceed requirement in Table 8.2.2.2.2-2 if the PCell is in the same band as the deactivated SCell.

The interruption requirement due to NR deactivated SCC measurement and interruption requirement due to LTE deactivated SCC measurement has essential difference on the supporting of *allowInterruptions*.

- ***Candidate scope 3:***
  - ***RAN4 to investigate and introduce allowInterruption mechanism for the NR deactivated SCell measurement to save UE power consumption when measCycleSCell<640ms.***

Candidate scope 4 | FR2 enhancement from RWS

- Justification
  - FR2 Coverage Enhancement and MPE requirements
    - At UE side, both Tx power (P-MPR) and UL duty cycle (maxUplinkDutyCycle-FR2) can be leveraged to comply with MPE requirements.
      - P-MPR can be flexibly decided and updated at UE side
      - maxUplinkDutyCycle-FR2 is static
    - In R17, FR2 UL gap is discussed to facilitate proximity sensing
      - When human body is not proximate, unnecessary power backoff (P-MPR) can be avoided
        - However, unnecessary UL duty cycle limitation still applies
      - When human body is proximate, P-MPR is the only degree of freedom to meeting MPE requirements.
        - UL duty cycle enhancement can help to reduce power backoff in case of power limited scenario.
    - Flexible tradeoff between power and UL duty cycle can enable better FR2 coverage and/or performance
      - Rel-16/17 status
      - Does not cover dynamic or semi-static signaling of changes at the UE side that impact P-MPR or uplink duty cycle.

- ***Candidate scope 4:***
  - ***RAN4 to investigate and introduce dynamic or semi-static signaling to enable the adaptation of maximum UL duty cycle or other MPE-complied means to enable better FR2 coverage and/or performance that are visible to the network.***

Rel-17 FeRRM leftover topics

Background - R17 leftover RRM topics

- RAN4 identified topics for RRM enhancement but some of them are not in the R17 FeRRM WI scope, e.g.,
  - CMTC for CSI-RS L3 measurement
  - TCI switching enhancement
  - Collision between SSB/CSI-RS based L1 and CSI-RS L3
  - CGI reading in NR-U
- In last RAN4 #99e meeting, some potential R17 topics have been identified, as summarized below,
  - (1) During discussion for HO with PSCell in R17 FeRRM, RAN4 identified the RRM requirement FR1+FR1 NR-DC scenario is missing in TS38.133 (observed in WF R4-2108344)
  - (2) During discussion for HO with PSCell in R17 FeRRM, RAN4 proposed to let RAN plenary to determine if the scenario for HO with PSCell could be extended to include:
    - from NR SA to NE-DC (newly added)
    - from NR SA to NR-DC (newly added)
    - from LTE SA to EN-DC (newly added)
  - (3) During discussion for NeedForGap in R16 TEI, the session chairman note was:
    - Session chair: There is no consensus to do the work in Rel-16 TEI due to potentially larger scope and late stage of Rel-16. The WF is agreeable to RAN4 and provides a set of candidate objectives. WF is noted as no work is planned. Further discussion in the plenary is recommended on whether and how to handle this.
  - (4) During discussion for per-BC indication of per-FR measurement gap UE capabilities, the agreement was:
    - Agreements:
      - Do not introduce per-BC indication of per-FR measurement gap UE capabilities in Rel-16.
      - RAN4 has a common understanding that further enhancements to the per-FR measurement gap UE capabilities to address UE implementation constraints can be further studied in future and the work is subject to RAN plenary approval and available time budget.

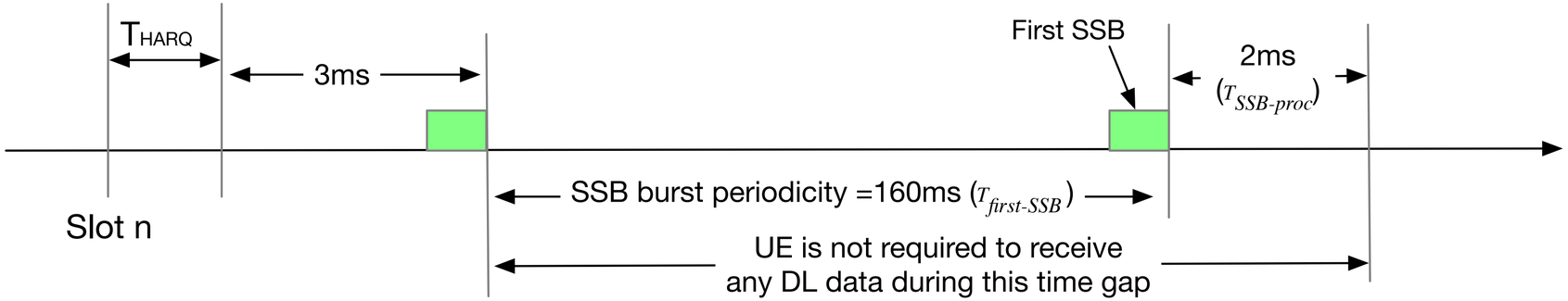
Candidate scope 5 | CMTC for CSI-RS L3 measurement

- Background
  - So far the timing limitation for CSI-RS L3 measurement is specified as a requirement applicability in RAN4, but it's not a real systematic solution for network and UE to configure and perform L3 CSI-RS measurement, respectively.
  - In our understanding, it's desirable to introduce clear timing window for L3 CSI-RS measurement, like SMTC for SSB based L3 measurement.

- ***Candidate scope 5: CMTC for CSI-RS L3 measurement***
  - ***CMTC for CSI-RS L3 measurement [RAN4, RAN2]***
    - ***RRM requirement based on CMTC for CSI-RS L3 measurement***
    - ***Signalling design for CMTC of CSI-RS L3 measurement***

Candidate scope 6 | TCI switching enhancement

- Background
  - In Rel-16 TCI switching requirement, there was a time gap from "*slot n+ T_{HARQ} +(3 ms) / NR slot length*" to "*slot n+ T_{HARQ} +(3 ms +TO_k*($T_{first\text{-}SSB}$ + $T_{SSB\text{-}proc}$)) / NR slot length*". Since UE is not required to receive DL data during this time gap, it will probably impact the throughput performance in case the first SSB arrives 160ms later (analyzed in R4-2006616). RAN4 to further discuss if UE behavior can be enhanced to receive DL data during the time gap of $T_{first\text{-}SSB}$ in Rel-18 or if any other reference signal could be used to speed up the switching delay.



- ***Candidate scope 6: TCI switching enhancement***
  - ***TCI switching enhancement in REL-18 [RAN4, RAN1]***
    - ***Work on the feasibility of enhancement to maintain the UE reception and transmission during the period (or part of period) of MAC CE based TCI switching***
    - ***Work on the feasibility of enhancement to maintain the UE reception and transmission during the period (or part of period) of RRC based TCI switching***

Candidate scope 7 | Collision between SSB/CSI-RS based L1 and CSI-RS L3

- Background
  - In RAN4 #97e meeting, one conclusion has been made on collision between SSB/CSI-RS based L1 and CSI-RS based L3 measurements in approved WF R4-2017223:
    - Do not define CSI-RS measurement requirements in Rel-16 for the collision between CSI-RS based L3 measurement of neighbor cell and serving cell measurement for SSB/CSI-RS based RLM/BFD or other SSB/CSI-RS based L1 measurements
  - The measurement requirement of CSI-RS based L3 measurement shall be clarified in R18 in case of collision between SSB/CSI-RS based L1 and CSI-RS based L3

- ***Candidate scope 7: add following working scope into R18 eFeRRM WI***
  - ***Measurement requirement for collision between SSB/CSI-RS based L1 and CSI-RS based L3 [RAN4]***
    - ***CSI-RS L3 measurement requirement in case of collision between SSB/CSI-RS based L1 and CSI-RS based L3 measurements***
    - ***SSB/CSI-RS based L1 measurement requirement in case of collision between SSB/CSI-RS based L1 and CSI-RS based L3 measurements***

Candidate scope 8 | CGI reading requirement for NR-U cell

- Background
  - In RAN4 #98e meeting, one conclusion has been made in approved WF R4-2103512:
    - Rel-16 CGI reading for Rel-16 NR-U
      - Do not include RRM requirements for the Rel-16 CGI reading feature in Rel-16 NR-U
  - However, the CGI reading feature is an important functionality especially on unlicensed carrier, and therefore it would be worthwhile to discuss the corresponding CGI reading requirement with CCA in REL-18.

- ***Candidate scope 8: CGI reading requirement for NR-U cell***
  - ***CGI reading requirement with CCA in REL-18 [RAN4]***
    - ***Specify delay requirement of CGI identification of an NR-U cell with autonomous gaps***
    - ***Specify requirement of interruption when identifying CGI of an NR cell with autonomous gaps***

Candidate scope 9 | FR1+FR1 NR-DC RRM

- Background
  - In RAN4 #99e meeting, during discussion for HO with PSCell in R17 FeRRM, RAN4 identified the RRM requirement FR1+FR1 NR-DC scenario is missing in TS38.133 (observed in WF R4-2108344)
    - Based on the discussion in RANP #92e meeting, the R17 FeRRM scope would not be expended for this FR1+FR1 NR-DC scenario, and therefore it's FFS if R18 eFeRRM could contain this work.

- ***Candidate scope 9: FR1+FR1 NR-DC RRM***
    - ***Full set of RRM requirements for FR1+FR1 NR-DC would be discussed in R18 FeRRM WI.***

Candidate scope 10 | New MR-DC Scenario for HO with PSCell in FeRRM

- Background
  - In RAN4 #99e meeting, during discussion for HO with PSCell in R17 FeRRM, RAN4 proposed to let RAN plenary to determine if the scenario for HO with PSCell could be extended to include:
    - from NR SA to NE-DC (newly added)
    - from NR SA to NR-DC (newly added)
    - from LTE SA to EN-DC (newly added)
  - However, in RANP #92e meeting, it's decided that the R17 FeRRM scope would not be expended for above new scenarios, and therefore it's FFS if R18 eFeRRM could contain this work
- **Candidate scope 10: New MR-DC scenario for HO with PSCell in FeRRM:**
  - ***Study and, if necessary, to specify the following new scenarios for HO with PSCell in R18 eFeRRM WI.***
    - ***from NR SA to NE-DC***
    - ***from NR SA to NR-DC***
    - ***from LTE SA to EN-DC***

Candidate scope 11 | RRM requirement with NeedForGap

- Background
  - In RAN4 #99e meeting, during discussion for NeedForGap in R16 TEI, the session chairman note was:
    - Session chair: There is no consensus to do the work in Rel-16 TEI due to potentially larger scope and late stage of Rel-16. The WF is agreeable to RAN4 and provides a set of candidate objectives. WF is noted as no work is planned. Further discussion in the plenary is recommended on whether and how to handle this.
  - However, in RANP #92e meeting, it's decided that the R17 FeRRM scope would not be expended for NeeForGap RRM, and therefore it's FFS if R18 eFeRRM could contain this work
- ***Candidate scope 11: RRM requirement with NeedForGap***
  - ***Specify and revise RRM requirements with NeedForGap in R18 [RAN4]***
    - ***Further define the interruption length, occasion and ratio, if the interruption is allowed***
    - ***Study the related requirements, such as CSSF, measurement period, scheduling restriction etc.***
    - ***RAN4 to further consider the relation with other UE capabilities, such as NCSG etc.***
    - ***Analyse other WG impact although impact is not expected.***

Candidate scope 12 | Per-BC indication of per-FR MG UE capabilities

- Background
  - In RAN4 #99e meeting, during discussion for per-BC indication of per-FR measurement gap UE capabilities, the agreement was:
    - Agreements:
      - Do not introduce per-BC indication of per-FR measurement gap UE capabilities in Rel-16.
      - RAN4 has a common understanding that further enhancements to the per-FR measurement gap UE capabilities to address UE implementation constraints can be further studied in future and the work is subject to RAN plenary approval and available time budget.

- ***Candidate scope 12:***
  - ***Study and, if necessary, to specify RRM enhancements with Per-BC indication of per-FR MG UE capabilities in R18.***

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