

97e-30-UE-Capabilities - Version 0.0.4
RAN

3GPP TSG-RAN Meeting # 97-e

Electronic Meeting, September 12-16, 2022

RP-222590

Agenda item: 9.11

Source: Moderator (Mediatek Inc)

Document for: Discussion

1 Per FR Gaps

1.1 Introduction

Two docs were submitted to TSG RAN 97e on this topic, RP-222276 [QC1] and RP-222366 [Nok]. This topic was discussed at last TSG RAN 96 (was left open), and has been discussed before in different settings.

1.2 Initial Round

The Issue

[QC1] and [Nok] makes the following observations:

[QC1] Observation 1. Due to increased complexity, it is becoming increasingly difficult for a UE to support the per-FR measurement gaps feature.

[QC1] Observation 2. Introducing a per band combination capability for the per-FR measurement gap feature will enable UEs to support this feature for many CA band combinations.

[QC1] Observation 5. If the proposal is not agreed and the updated capability is not introduced, the per-UE capability and the feature itself could become obsolete.

[Nok] Observation 1: The per-FR gaps are a consequence of different hardware required for FR1 and FR2 operation, which the UE either supports or doesn't support.

[Nok] Observation 2: The current UE capabilities for measurements gaps are per-UE or per-FR.

[Nok] Observation 3: The supporting arguments for per-BC capability of per-FR gaps are all centred on UE implementation difficulties.

[Nok] Observation 4: Before creating any per-BC indications, the root causes of why per-BC gaps are needed should be understood.

Moderator: Please input on the following: To what extent do you agree on specific observations related to the issue? Is there an issue that is important enough to warrant a solution? Feel free to provide explanations and justifications.

Feedback Form 1: Input on the Issue

1 – Apple (UK) Limited

Based on previous discussion, our understanding is the main motivation for a per-BC indication is due to possible constraint a UE may face when supporting high-order CA in an FR while measuring the other FR. And this is an issue of implementation choice, meaning some implementations may need per-BC indication to relax the per-UE requirement, while others do not. It is not an implementation challenge for all UE implementations. As such, per-BC indication for every BC is not justified. That's why we proposed a compromise solution in RP-221702.

Having said the above, we are open to further discussions on better understanding the root causes as requested in Nokia's contribution.

2 – HuaWei Technologies Co.

We understand this is somehow relevant to the hardware processing complexity for UEs, which may be dependent on UE implementations. We are open to hear views from companies to further clarify the exact issues.

3 – Beijing Xiaomi Mobile Software

We are also open to hear more views on this to understand the issue.

4 – CATT

In general we tend to agree with Nokia's statement that 'The supporting arguments for per-BC capability of per-FR gaps are all centred on UE implementation difficulties'. Our 1st preference is not to change this per FR gap capability.

5 – TELECOM ITALIA S.p.A.

Same view as CATT

6 – ZTE Corporation

We think supporting per-FR gap may require separate RF chains for FR1 and FR2, but we are unclear how difficult it is for different BCs because it relates to the detailed UE implementation.

We understand introducing per-BC capability may not have backward compatible issue to Uu interface, but we are afraid this may also impact X2/Xn interfaces, e.g. gap coordination procedure between MN and SN

in MR-DC. For example, when the SN changes SCG carriers, the per-FR gap capability may change and the original configured gap may not be suitable.

So if a solution is needed, it should be complete so that both Uu and INM impacts are considered.

7 – QUALCOMM JAPAN LLC.

We agree that this issue is due to implementation on the UE side, but this is valid for most capabilities. It is an implementation choice, of course, but to us it seems unlikely that a UE will be overprovisioned (for example it will be have an extra RF chain or additional baseband capabilities) just to support this feature. What will happen is that this feature will not be available for any of the UE supported CA combinations even though it could be supported on the vast majority of the combinations that the UE supports. As NRCA combinations become more and more complicated, it will be more unlikely that this feature will be supported. We believe the feature is very useful and attractive also from a network point of view because throughput/capacity will increase and also gap management for different UEs becomes simpler. This feature is very useful for the case in which the UE is active only in one FR(for example, UE configured with a FR1 only combo) and can perform gapless measurements in the other FR(UE active in FR1 performing periodic searches to find an FR2 cell).

As stated before, we are open to different solutions as long as we make this feature available for more UEs.

8 – LG Electronics France

We understand the motivation of per-BC measurement gap capability indication is to relax the implementation difficulties in supporting per-FR gap feature for every possible BCs. However, it seems good to better understand in which case such difficulties are actually arising. We are open to hear companies view.

9 – Ericsson LM

To change the capability from per-UE increases complexity so we should try to avoid it. We also had the same understanding as Nokia's Observation 1. It is not clear to us how "more complicated" BCs would change the Nokia-Observaion1.

10 – vivo Mobile Communication (S)

Firstly, the per-FR gap is a very useful feature considering the long measurement period for FR2. If the feature is not supported, FR1 mobility performance is also degraded when there are measurements on FR2 carrier frequencies being configured.

Secondly, we understand there could be implementation difficulties, which is UE impementation specific, when it comes to very high CA combos. A solution to solve the issue can be considered, either in Rel-17 or Rel-18.

Regarding the solution, per-BC indication is straightforward and simple. On the other hand, the signalling overhead is quite large. We are open to consider more efficient capability indication.

11 – Telia Company AB

Same views as CATT and Ericsson.

12 – Guangdong OPPO Mobile Telecom.

we think it is reasonable to introduce per BC UE capability considering the potential difficulty of UE implementation

13 – AT&T GNS Belgium SPRL

We would like to have a better understanding of the root causes as requested in Nokia's contribution. In addition, we would also like to understand the impact to UE capability signalling capacity to introduce per BC per UE.

14 – VODAFONE Group Plc

We tend to agree that 'The supporting arguments for per-BC capability of per-FR gaps are all centered on UE implementation difficulties'. We would like to understand the root causes before introducing solutions which increases complexity.

15 – QUALCOMM JAPAN LLC.

The root cause is that NR CA combinations are becoming more and more complex. If in previous releases the maximum number of CCs/bands for CA combinations was dictated by LTE, this will no longer be the case. Also, to make the UE implementation more efficient, there will be more reuse/sharing of hardware resources among different CCs/bands in CA implementation. Because of this, when the UE is operating in a high order CA combination it will not have additional hardware available to perform per FR gaps. For example, the UE could support a high order CA in FR1(e.g. 5 bands with many MIMO layers). In this CA combination, the UE would have to perform gapless measurements in FR2 if it supports per-FR gaps. If the UE does not have the additional hardware resources to do this(spare RF chain, baseband processing capability) then it cannot do this gapless measurements so it cannot support per-FR gaps. This UE can support per-FR gaps for all other CA combos which are lower order.

Because the UE cannot support this feature on a single or very few CA combos it cannot declare support because the capability is per UE, not per BC or with a finer granularity than per UE.

When this capability was introduced in Rel.15, the baseline assumption was that the UE hardware for FR1 and FR2 will be completely separate but this will no longer be the case as implementations become more integrated/optimized and there is more hardware sharing/reuse.

We would like to point out that this issue has been discussed in RAN4 for several meetings(also in Rel.16), it would have been good if all these questions would have been asked then, not after 2 years of discussion.

The solution(s)

Both [Nok] and [QC1] mentions backwards compatibility, which was also discussed at TSG RAN 96. The moderator assumes that Backwards compatibility need to be kept, i.e. the meaning of the existing signaling is not changed, and the new behavior is introduced by adding additional signaling, e.g. as indicated in [Nok] and in [QC1], if legacy signaling indicates per-UE-per-FR-gaps, then this is supported for/applicable to all BCs.

Last TSG RAN96, there was also another solution discussed, introducing a capability based on number of CCs. Moderator observes that this proposal is not resubmitted to current meeting and assumes that such solution is then off the table, and [QC1] Observation 6 doesn't need further discussion.

[QC1] proposes to have a solution For Rel-17, while [Nok] proposes to have a solution for Rel-18 if necessary.

[QC1] Observation 3. The proposed capability is backwards compatible (UEs can still signal the per UE capability if they support the feature for all CA combinations, legacy networks will still understand the per UE

capability).

[QC1] Observation 4. The specification(TS 38.133) impact is trivial (some editorial changes at most, no actual requirement changes) as summarized in [3].

[QC1] Proposal 1. Introduce the per band combination capability for the per-FR measurement gaps feature

[Nok] Proposal 1: Do not introduce general per-BC capabilities for per-FR gaps in Rel-17.

[Nok] Proposal 2: If any modifications to per-FR gaps is agreed, introduce them under Rel-18 MG enhancements WI as shown above (in the [Nok] paper)

Moderator: Please input on the following: Observations and proposals related to the solution, backwards compatibility aspects (if any), which release could be acceptable / preferred (and reasons why). Other important considerations. Can also ask proponents for clarifications. Note that if something seems agreeable, we will discuss more details in the next phase, so in this phase please focus on solution aspects that relate to whether it can be acceptable / not acceptable to move forward.

Feedback Form 2: Comments on Solution, Release etc.

1 – Apple (UK) Limited

First, we'd like to clarify that although we didn't resubmit RP-221702, our understanding is the proposal in it, i.e., UE indicates the maximum number of CCs per UE, based on which per-BC indication is allowed or not, is still on the table for the group to consider. At the last meeting, it was agreed to further discuss the possible solutions, and no solution was precluded.

Second, the proposal in RP-221702 is aimed to preserve the benefit of per-FR gap for most BCs while making exceptions for few really difficult BCs. And the maximum number of CCs per UE is reported by the UE, so the UE can report based on its own implementation, thereby allowing for different tiers of UEs, say high-end, mid-end, and low-end UEs, each of which may have different CA capabilities in terms of how many CCs it may support. In our view, this is a reasonable compromise for R17. However, we are also OK if the group decides not to introduce any per-BC capabilities in Rel-17 and to study it in Rel-18.

Third, we have some clarification questions on Nokia's proposal. On “- BCs are classified into “easy” and “difficult” BCs”, how a BC is easy or difficult is UE specific, depending on UE implementation and the UE tier, i.e., high-end/mid-end/low-end UE. Therefore, it may be difficult to make such classification. Furthermore, we'd like to understand how the bitmap capability signaling for difficult BC works.

2 – HuaWei Technologies Co.

If to decide solving this issue by introducing a finer granularity reporting, we think the per BC indication could be straight forward and backward compatible. To further identify difficult band combinations is not that realistic, as different UEs may have different implementations, which may bring a variety of difficult band combinations. For which release to potentially introduce this is up to feedback on Q1 whether we have common understanding on the issues.

3 – Beijing Xiaomi Mobile Software

If the identified issue are solid, we are open to introduce per BC MG. Not sure whether it is allowed only on part of the BC, or all of the BCs, or dependent on the number of CCs. And depending on the impact to the spec, either Rel-17 or Rel-18 can be considered.

4 – CATT

If RAN decides that a solution is anyway needed, we tend to think QC's proposal is better as it is clearer and simpler.

5 – SoftBank Corp.

We think that QC's proposal seems to be clear and simple. And we think that the solution should not impact the specification work for band combination. Its work is important from operator's perspective but the workload has already been high.

6 – ZTE Corporation

As we commented to previous question, besides Uu interface (i.e. UE capability), we also need to study the potential impact on inter-node messages. So in our view, it is more realistic to do it in Rel-18.

7 – QUALCOMM JAPAN LLC.

We are open to find any other solutions and we understand that per BC signaling could increase the overhead, especially if the UE has to now signal many fallback combos for which the feature is supported if the superset doesn't support it.

The Nokia proposal seems a bit difficult because categorization of combinations into easy/difficult will be complicated and depends on each UE's overall CA capability. It is not feasible to have an absolute categorization as an easy band for some UEs will be difficult for others. Also, it is not clear what happens in the future when we will have new band combinations that are categorized. Will the network have to be updated everytime we have a new type of CA combo which is categorized?

Instead of having a change in capability, it might be better/simpler to extend the use of the "needForGaps" framework to cover also this case. In our understanding, there would be a need for some RAN2 changes but these should be fairly small. With this framework, there would be no additional capability needed. The old bit would still be kept and the new procedure would be needed for UEs that set the bit to 0.

We would prefer to make the changes from Rel.17 or as early as possible, we do not see any good reason to wait for another release. The earlier a solution is available, the more UEs (and networks) could benefit from this change.

8 – LG Electronics France

If finer granularity reporting is needed, per-BC reporting is the most straightforward. Signaling overhead in indicating those for many fallback combinations may be an issue, but it cannot be avoided anyway if

that is the case. The dynamic signaling approach by extending needForGaps requires more discussion in RAN2, which do not prefer for now in particular for Rel-17.

9 – Ericsson LM

What was on the table going in to this plenary was per-UE (current spec) and per-BC. These two solutions have been discussed in the WGs and we know that they are at least technically feasible (spec-wise they can work). The question in plenary now is **if** indeed there is a motivation for changing from per-UE to per-BC.

We see now that there is a new proposal on the table, the needForGaps-approach. We don't think this has been properly discussed in the WGs (or even discussed at all?). We do not think that plenary can agree to proceed with the needForGaps-approach without having it properly discussed in the WGs (mainly RAN2), and we therefore suggest that this is pushed back to the WGs and the WGs can (if agreeable) provide CRs to the next plenary cycle. Of course, this would then take one more quarter, but we think that plenary anyway do not have everything in place to approve any CRs in this cycle anyway.

Regarding which release to provide this in: we don't think there is any technical difference of doing this in Rel-17 or Rel-18. The only difference it makes is **which suffix** the capability indications have and potentially **where** in the "UE capability signalling"-tree the capability indications would be placed, and in practice this does not make much difference.

10 – Samsung Electronics Co.

If update on the per FR gap needed, we prefer per BC basis.

11 – Guangdong OPPO Mobile Telecom.

we support to introduce per BC UE capability from Rel17 . For this solution additional restriction like number of CCs is not needed. In our understanding if only partial band combinations are supported, then the UE shall set the legacy per UE capability bit as 0. It means legacy gNB will intrepret the UE doesn't support such per-FR measurement gap while new gNB can further interpret the per BC UE capability. So technically it is backwards compatible.

12 – AT&T GNS Belgium SPRL

We prefer to focus on the possible solutions after we have a better understanding of the root causes and impact on UE capability signalling capacity.

13 – VODAFONE Group Plc

We agree with AT&T comment that we should have a better understanding of the root causes prior to discussing on possible solutions.

14 – Nokia Corporation

We thank Qualcomm for the additional proposal on how to handle this issue. We are open to consider that as one possibility but from the answers to question 1 it seems to us that most companies still need to have a better understanding of what is the core issue to be addressed, as that will have an impact on the solution to be selected in the end. Therefore, we would propose to focus on the characterization of the problem to be solved next in RAN Plenary, so that when this is eventually discussed by the WGs, that is done in an efficient manner.

15 – QUALCOMM JAPAN LLC.

We provided more details on the root cause in the previous section.

We understand that the new proposal that we brought up would require more discussion in the working groups, we would not expect to be agreed straight away. We are trying to find a solution that is relatively simple and efficient.

We are open to discussions and other proposals, our main goal is to make this feature easier to support. Keeping the per UE capability will likely lead to this feature becoming obsolete.

Moderator Conclusions Initial Round: The initial round was largely inconclusive. Propose to continue the discussion in the intermediate round, to consolidate potential conclusions, see below.

1.3 Intermediate Round

Root Cause: Please see the initial Round, e.g. QC provided an explanation in the initial round that a) the possibility to do gapless measurements is valuable, which is possible by using per-FR-gaps, b) the assumption behind per-FR-gaps that FR1 and FR2 has separate resources in the UE is no longer true, and is the main reason why per-FR gaps need more fine-granular capability, or why other solution like needforgap should be considered.

Moderator: Potentially the gapless measurement characteristic is valuable, and there were no specific comments in the other direction. This issue/rootcause discussion should be consolidated in the intermediate round.

Impact / Solution: There seems to be multiple possibilities.

1) More fine-grained capability for per-FR-gap.

1.1) The main proposal is to have 1bit per BC. According to comments this proposal seems to have the most support (preferred solution by a cpl of companies). It can work and can be backwards compatible and is straight-forward, but it is associated with some signaling overhead. Several companies indicated that Rel-17 could be ok with this solution. One company expressed that Inter-node signaling may be impacted (and there was no reply comments).

Further Signaling optimizations:

1.2) The proposal by Nokia to identify problematic combinations for which per-FR-gaps is not applicable received comments of being less feasible as UE implementation is indeed implementation specific. Moderator Observes that the Nokia proposal may not have been fully understood and no attempts were done at clarification.

1.3) The Apple proposal to identify problematic combinations by providing a limit to no of carriers in CA configuration received comments that the UE resources has more dependencies, and some companies expressed that this was not a preferred solution.

2) It was indicated (somewhat late in the discussion) that the same benefit could potentially be achieved by using NeedForGap signalling (with small modification). There was some interest for this approach, but also comments that this should be looked at by WGs (RAN2). Moderator understand that this avoids completely

the overhead for UE cap signalling.

Moderator: In the intermediate Round, we continue from the initial round. Please **consolidate the discussion around the root cause / the issue, importance etc.** Please also **elaborate acceptance/preference for the possible solutions/ways forward**, Whether Alt 1.1 can be acceptable as-is (or almost as-is, can comment on internode), whether signaling optimizations such as Alts 1.2, 1.3 should be considered, or whether Alt 2 needforgap should be considered / would be preferred / is acceptable. Acceptance/preference Rel-17, vs Rel-18.

Feedback Form 3: Intermediate Round

1 – QUALCOMM JAPAN LLC.

For the root cause, it is difficult to say more than what we explained in the 2nd round. It is because of optimized UE implementations for CA together with an increase in NR CA complexity. The issue we see for the future is that UEs implementing more complicated CA combinations(e.g. higher tier UEs with higher CA capability) will be the ones having the most difficulties in supporting this feature.

We agree that having gapless measurements when the UE is active in just one FR is a valuable feature to have when there are mixed FR1+FR2 deployments.

Regarding the solutions, it might be best if RAN2 can check if Alt.2 is feasible to implement and what would be the impact. We understand this cannot be decided in the plenary and has to go back to the working group, we would be perfectly fine to wait for another quarter. In our understanding, the per BC capability(basically a "fallback" option) can also be done in the next plenary and can still be made available from Rel.17 if Alt. 2 is not feasible or there are difficulties to support it.

Alt. 1.1 is the simplest, we see that the main overhead increase is not because of the 1 bit added per band combination but because this might cause the UE to have to signal the capabilities for more band combos(for example all the fallbacks) if the higher order combination cannot support this feature.

For alternatives 1.2 and 1.3, we are open to discuss ways to optimize the signaling, however, we would need something relatively simple and efficient. Alt. 1.3 or some variant would be fine for us(if UE can choose N) but infra vendors commented in the previous meeting that handling of the capability at the network side is difficult. Alt. 1.2 seems complicated because it will be difficult to categorize combinations relative the each UE's overall CA capability.

2 – Intel Corporation (UK) Ltd

If NeedforGap is considered a potential solution, it would be the most practical solution although we wonder what enhancement should be made further.

In Rel-16 NR, the detailed gap capability was proposed in TEI16 (RAN2 #107). However, detailed gap capability signaling was not introduced due to several reasons, e.g. BC, BWP, SUL, and impact on fallback BC (RAN2#108). Instead, RAN2 introduced NeedforGap reporting in RRC signaling (RRC reconfiguration complete/RRC resume complete) in Rel-16 (RAN2#109). The UE indicates the list of bands that requires a gap based on the current configuration. This dynamic approach would be more flexible and more detailed than UE capability based approach.

In summary, we support that companies can have more time to check and discuss further in RAN2 if any enhancement is needed in NeedforGap signaling.

3 – Apple (UK) Limited

As we commented in the first round, in our understanding the only possible implementation difficulty is when a UE supports high-order CA in an FR while measuring the other FR without gap. In this case, we believe Alt. 1.3 is the right solution. And it is flexible and accommodates all tiers of UE. And we don't quite understand why it is perceived as more complicated on the network side, because the network needs to check each band combination to understand the gap is per-UE or per-FR for both Alt. 1.1 and Alt. 1.3, while Alt. 1.1 incurs more signaling overhead.

Meanwhile, we are willing to learn if there are other implementation difficulties that would warrant a more relaxed approach, such as Alt. 1.1. In other words, we are willing to find out if there are more details about the root cause, knowing and appreciating what QC has explained.

For Alt. 1.2, we sought clarification in the first round in order to understand how it works in detail.

As for the NeedforGap approach, we share the view that more detailed discussion in RAN2 is needed.

4 – MediaTek Inc.

On the root cause: We do not have strong view but okay to have finer granularity capability to address different UE implementation.

On solution: Alt-1.1 (per-BC indicator as QC original proposal) is straightforward and companies know how it works. We do not think 1 bit per BC is a big problem in signaling overhead. Alt-1.2 and Alt-1.3 is not the common approach for capability signaling. We don't think RP should select this direction without WG discussion. Similar comment to Alt-2 (NeedForGap approach), it is not clear to us how this work. Discussion in WG is needed for solutions other than Alt-1.1.

On which release to go - Prefer Rel-18 but can accept Alt-1.1 in Rel-17. Other solutions request much more discussion/clarification and it is not so suitable after Rel-17 freeze.

5 – Guangdong OPPO Mobile Telecom.

for both alt1.2 and alt1.3 they have the points that per FR gap capability is related to the order of carrier aggregation, the more carriers the more likely UE can't support per FR gap. But for alt1.2 the difficult part is how to define which BCs are difficult and which are easy ones. if we want to mark it per band combination, then the signaling overhead is ready as high as per BC signaling i.e. alt1.1. For alt1.3 it is not clear whether the parameter N is the only criteria.

As for needforGap solution, we are also open to discuss it in RAN2. This direction may be able to address the signaling overhead issue pointed out by QC. So in short we are open to discuss the solution in coming RAN2 if alt1.1 can't be agreed in this plenary.

6 – Guangdong OPPO Mobile Telecom.

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part is how to define which BCs are difficult and which are easy ones. if we want to mark it per band combination, then the signaling overhead is ready as high as per BC signaling i.e. alt1.1. For alt1.3 it is not clear whether the parameter N is the only criteria.

As for needforGap solution, we are also open to discuss it in RAN2. This direction may be able to address the signaling overhead issue pointed out by QC. So in short we are open to discuss the solution in coming RAN2 if alt1.1 can't be agreed in this plenary.

7 – HuaWei Technologies Co.

We can understand there could be some UE implementation difficulties as the root cause, but we also see some new solutions submitted here, which have not yet been thoroughly discussed. It is difficult for the plenary to select the solution and a bit too late as Rel-17 is already frozen. So from our side Rel-18 is a better release to further discuss the solutions in this case.

8 – Ericsson LM

We don't think option 1.2 is feasible: 1.2 will create a lot of discussion/work in 3GPP to do the classification. This classification would need to be "hard-coded" in the spec and it would not be backwards compatible to change it, but likely there will be future proposals to change an "easy" BC to a "difficult" BC later.

Option 1.3 seems unnecessarily complex (perhaps not signalling-wise) but it is complex to decipher the capabilities.

We think plenary can task **RAN2** to handle this topic, meaning RAN2 should decide between "do-nothing" (= per-UE) vs. Option 1.1 vs. Option 2.

9 – vivo Mobile Communication (S)

As commented in the initial round, per-FR gap is a very useful feature considering the long measurement period for FR2. Mobility performance will be degraded highly when there are FR2 carrier frequencies to be measured if the feature is not supported.

Regarding the solutions, we are open for discussion.

Alt 1.1 is straightforward and simple. However, overhead is one issue and optimization would be possible for this option.

Alt 1.2 needs a lot of discussions and it could be very hard to identify problematic CA combos as this is UE implementation specific.

Alt 1.3 seems also simple. However, it is not crystal clear for now if the 'implementation difficulties' is only due to high order of CA combos or it is also related to other aspects, such as BW of carriers, MIMO layers etc. So it may lack of flexibility to some extent.

Alt 2 would be potential optimization of Alt 1.1 and could be further studied in WGs.

10 – ZTE Corporation

Alt 1.1 looks straightforward, but it may increase the signalling overhead if per-FR gap capabilities are different for different fallback BCs.

For Alt 1.2, it is currently unclear how it works, further clarification/explanation is needed.

It seems Alt 1.3 can avoid increased signalling overhead, so we are open to discuss this solution in WG, we understand Alt 1.3 may not match UE implementation perfectly (not flexible enough), but we prefer

to find a balance between signalling overhead and flexibility, especially if eventually per-FR gap can be supported only for few band combinations.

For Alt-2, NeedForGap does not work in MR-DC, so it is not a preferable/complete solution right now.

As we indicated in initial round, changing the capability granularity requires discussion on INM impacts. So we suggest to task RAN2 to discuss and decide the final solution.

11 – Nokia Corporation

Our main concern with Alt.1.1 is the signaling overhead it causes, especially as it is expected to be more often used for higher order CA cases, as explained by the proponent. In such cases there is indeed a high risk of overhead growing significantly due to the need to signal fallbacks in addition. Another concern is the lack of predictability from the network point of view, as the signaling would essentially allow UEs to cherry-pick which band combinations to support with or without gaps, without transparent criteria.

However, we understand the concerns on the difficulty to characterize specific band combinations as difficult (i.e. Alt.1.2), but we are open to approaches where UE can be assumed to do gapless measurements if configured up to a certain number of carriers, as proposed in Alt.1.3, and also mentioned by the proponent of Alt1.1.

As for Alt 2, it addresses the signaling overhead concerns on Alt.1.1, and we believe it should be further discussed in RAN2, including discussion on how to increase predictability to the network. Hence, **we believe the best course of action for now would be for RAN Plenary to task RAN2 to further investigate if the issue can be resolved by Alt. 2, and if anything needs to be done on top of existing framework to make it more adequate to handle this specific problem.**

12 – Beijing Xiaomi Mobile Software

Alt 1.1, alt 1.3 and alt 2 seems workable, but still need RAN2 to evaluate on these solutions and make the decision.

13 – AT&T GNS Belgium SPRL

We agree with the WF to task RAN2 to further investigate Alt. 2 and to provide an assessment of Alt. 1.1 vs. Alt. 2.

14 – VODAFONE Group Plc

As suggested by Ericsson, ZTE and Nokia, we think that plenary can ask **RAN2** to investigate this topic and decide on a solution.

1.4 Moderator conclusions after intermediate Round

Conclusion 1: The following Root Cause / Justification is applicable: a) the possibility to do gapless measurements is valuable, which is possible by using per-FR-gaps, b) the assumption behind per-FR-gaps that FR1 and FR2 has separate resources in the UE is no longer true, and is the main reason why per-FR gaps need more fine-granular capability, or why other solution like needforgap should be considered.

Conclusion 2: RAN2 should be tasked to progress this issue (also taking into account comments collected at TSG RAN), including solution Alt 1.1: More fine grained Cap for Per-FR-Gaps, 1 bit per BC, with the possibility for non-complex optimization such as Alt 1.3: more fine grained Cap for Per-FR-Gaps - limited by number of carriers, and including Alt 2: Use Need For Gap.

Conclusion 3: Moderator proposes that RAN2 is tasked to provide results after one Quarter, and leave final decision(s) to TSG RAN.

Explanation: In the current discussion there is support from multiple companies that the simplest solution 1.1 could be done for rel-17 (if it is acceptable in the end), while most companies seems to need time to consider 2 NeedForGap, which was not explicitly proposed into the meeting, and/or 1.3, e.g. it seems not clear to everyone whether these two are "simple" or not. Also the overhead of 1.1 may need to be further considered. One company states that whatever the solution, this should be for Rel-18.

1.5 Final Round

Moderator: Please input in the final round only if you think the conclusions and way forward after intermediate round are not acceptable or need modification (or to reply to other companies comment). No input = acceptance. If there are major comments we may need to CB online (hopefully not).

Feedback Form 4: Final Round - Conclusions consolidation

1 – QUALCOMM JAPAN LLC.

We agree with the moderator's conclusions. It would be good to make Conclusion 3 clear so that the RAN2 discussion is streamlined. Conclusion 3 could be reworded to: RAN2 to consider Alt. 1.1, 1.3 and 2, and discuss the signaling overhead and network processing requirements/complexity.

2 – AT&T GNS Belgium SPRL

We also agree with the moderator's conclusions and with Qualcomm's suggested rewording for Conclusion 3 but adding back some of the timeline suggested by the moderator as below.

RAN2 to consider Alt. 1.1, 1.3 and 2, and discuss the signaling overhead and network processing requirements/complexity. RAN2 is tasked to provide results after one Quarter, and leave final decision(s) to TSG RAN.

3 – vivo Mobile Communication (S)

The description of Alt 2 in coculsion 2 is not very accurate in our view. The revised wording is as follows.

Conclusion 2: RAN2 should be tasked to progress this issue (also taking into account comments collected at TSG RAN), including solution Alt 1.1: More fine grained Cap for Per-FR-Gaps, 1 bit per BC, with the possibility for non-complex optimization such as Alt 1.3: more fine grained Cap for Per-FR-Gaps - limited by number of carriers, and including **Alt 2: use similar framework/procedure as for "NeedForGap"**.

For conclusion 3, we agree with AT&T's rewording.

4 – Apple (UK) Limited

We would like to reword Conclusion 1 and Conclusion 2 as follows to better reflect the discussion status:

Conclusion 1: The following Root Cause / Justification is applicable: a) the possibility to do gapless measurements is valuable, which is possible by using per-FR-gaps, b) the assumption behind per-FR-gaps that FR1 and FR2 has separate resources in the UE is no longer true, and is the main reason why per-FR gaps need more fine-granular capability for some high-order CA band combinations.

Conclusion 2: RAN2 should be tasked to progress this issue (also taking into account comments collected at TSG RAN), including solutions Alt 1.1 (More fine grained capability for Per-FR-Gaps, 1 bit per BC), Alt 1.3 (more fine grained capability for Per-FR-Gaps - limited by number of carriers), and Alt 2 (Use Need For Gap).

We also agree with AT&T's reworded conclusion 3.

5 – HuaWei Technologies Co.

We are in general fine with the proposals. We understand if one solution is selected, from which release to accommodate the potential solution should also be decided at next RAN plenary.

6 – MediaTek Inc.

Moderator / R2 Chair:

Yes, if the task to R2 is agreeable, my intention is that indeed R2 should attempt to select solution as far as possible, and depending on the status/progress also develop tech endorsed CRs. TSG RAN would then decide if to approve for Rel-17, or do this or something similar for Rel-18 (i.e. if agreeable in the end).

7 – ZTE Corporation

Just clarification on Conclusion 3, so the main job in RAN2 is to discuss Alt-1.1, Alt-1.3 and Alt-2, and to **select one option** in Oct/Nov meetings, but **whether and which release** to apply the change can be discussed further in RANP?

8 – MediaTek Inc.

Moderator / R2 chair: The previous post is a reply to Huawei. Then for the other proposals, it seems most companies want to copy Conclusions 2 into Conclusion 3, which is ok (the AT&T clarification of conclusion 3). The vivo rewording for conclusion 2 is also ok, as at this stage Alt 2 is somewhat vague. I find that the Apple proposal to remove parts of conclusion 1 is not reasonable, so I suggest to not wordsmith further the conclusion 1. For conclusion 2, on Alt 1.3 I chose the wording to reflect that most companies think that 1.1. is a baseline proposal. Apple proposes to make the wording more neutral to indicate that both 1.1. and 1.3 would be considered none being the baseline .. this re-writing is from technical sense somewhat correct as 1.1. and 1.3 are different solutions .. so dep on other companies comments, I guess this can be considered,

9 – MediaTek Inc.

Moderator / R2 chair: The previous post is a reply to Huawei. Then for the other proposals, it seems most companies want to copy Conclusions 2 into Conclusion 3, which is ok (the AT&T clarification of conclusion 3). The vivo rewording for conclusion 2 is also ok, as at this stage Alt 2 is somewhat vague. I find that the Apple proposal to remove parts of conclusion 1 is not reasonable, so I suggest to not wordsmith further the conclusion 1. For conclusion 2, on Alt 1.3 I chose the wording to reflect that most companies think that 1.1. is a baseline proposal. Apple proposes to make the wording more neutral to indicate that both 1.1.

and 1.3 would be considered none being the baseline .. this re-writing is from technical sense somewhat correct as 1.1. and 1.3 are different solutions .. so dep on other companies comments, I guess this can be considered,

10 – MediaTek Inc.

Moderator / R2 Chair: Reply to ZTE, of course the release would also be discussed in R2, e.g. in order to prepare CRs .. e.g. if contrary to current discussion, it is agreed that the preferred solution is for Rel-18, possibly R2 would not even prepare CRs. BUT Yes, TSG RAN would decide to approve and for which release. I expect RAN2 to produce at most tech endorsed CRs, hopefully just one set.

11 – ZTE Corporation

Reply to Moderator/ R2 Chair, thanks for the clarification, this sounds a reasonable plan to us.

12 – ZTE Corporation

Reply to Moderator/ R2 Chair, thanks for the clarification, this sounds a reasonable plan to us.

Moderator report on the final Round: No objection comments were raised. There were agreeable proposals for rewording of conclusions 2 and 3. Conclusion 1 wording not changed. See final Conclusions below. There were also some discussion on how RAN2 would treat such task.

1.6 Final Conclusions

The following conclusions can be considered Final

Conclusion F1: The following Root Cause / Justification is applicable: a) the possibility to do gapless measurements is valuable, which is possible by using per-FR-gaps, b) the assumption behind per-FR-gaps that FR1 and FR2 has separate resources in the UE is no longer true, and is the main reason why per-FR gaps need more fine-granular capability, or why other solution like needforgap should be considered.

Conclusion F2: RAN2 to be tasked to progress this issue (also taking into account comments collected at TSG RAN), including solutions Alt 1.1 (More fine grained capability for Per-FR-Gaps, 1 bit per BC), Alt 1.3 (more fine grained capability for Per-FR-Gaps - limited by number of carriers), and Alt 2 (Use similar framework/procedure as for "NeedForGap").

Conclusion F3: RAN2 to consider Alt. 1.1, 1.3 and 2, and discuss the signaling overhead and network processing requirements/complexity. RAN2 is tasked to provide results after one Quarter, and leave final decision(s) to TSG RAN.

Comment by RAN2 chair: RAN2 would attempt to: select solution, make assumption for the Release and provide technically endorsed CRs to next TSG RAN, and leave remaining decision(s) if any, and final decision(s) to TSG RAN.

2 MBS capabilities for FDM TDM Unicast/xCast transmission

2.1 Introduction

Two discussion docs were submitted to TSG RAN 97e on this topic, RP-222068 [QC2] and RP-222473 [HW1], and also two related CRs RP-222552 [HW2] and RP-222553 [HW3].

2.2 Initial Round

[HW1] motivates to have this discussion in TSG RAN in the following way.

[HW1] two FGs regarding FDM between one unicast PDSCH and one group-common PDSCH for broadcast/multicast with reporting granularity FFS/pending for a long time without conclusion due to controversy in RAN1, which consequently is NOT implemented by RAN2. As a result, unicast scheduling FDM-ed with broadcast/multicast is not implementable so far.

[HW1] Therefore, comparing to other FGs regarding HARQ-ACK feedback for multicast and SPS scheduling for multicast in RRC_CONNECTED state, among all the UE features for NR MBS, FG33-1-2 and FG33-3-2 are expected to be in the first tier of features for early commercialization but not implementable so far because of no capability signaling implemented due to unsolved reporting granularity.

and on the details the following is proposed:

[HW1][QC2] Proposal: FG33-1-2 and FG33-3-2 are reported per FSPC with NA for “Need of FDD/TDD differentiation” and for “Need of FR1/FR2 differentiation”.

In addition [QC2] addresses TDM capability and proposes FG33-3-3 is reported per FSPC with NA for “Need of FDD/TDD differentiation” and for “Need of FR1/FR2 differentiation”.

Both provided papers provides similar motivation and e.g. [QC2] States: *For FG33-1-2, 33-3-2 and 33-3-3, we think the reporting type should be ‘per FSPC’, because the UE needs to consider the maximum data rate and the LLR buffering of 14 consecutive OFDM symbols to select a carrier of one band entry of a band combination based on supported DL BW, max MIMO layer number and maximum modulation order for unicast, broadcast and multicast, respectively. Note that the maximum number of layers and the maximum modulation order used for calculating the maximum data rate is reported per FSPC for unicast and for multicast, respectively.*

Moderator understands that the proposals has technical motivation and may represent the majority view.

Moderator: Please input on the following: Confirm that we (TSG RAN) now will attempt to address the issues in [HW1] and [QC2] on the reporting for FG33-1-2, 33-3-2 and 33-3-3. Please provide also initial feedback on the detailed proposals, and related justification in case you believe other direction is preferable.

Feedback Form 5: Initial Rnd: MBS FDM TDM Unicast/x-Cast Features

1 – Nokia Corporation

FG 33-3-2 is for multicast operation, and it has 33-2 (main multicast capability) as pre-requisite. FG 33-2 has been agreed as per FS, with the reasoning that UE will only support MBS services in a few bands, and not in all bands of a band combination. As communicated by RAN1 in LS R1-2208250, this means that whatever we agree for FG 33-3-2, it can only apply to the bands within the feature set where the UE sets FG 33-2 as supported. Hence, in practice FG 33-2 creates a "per FS mask" for its depend capabilities already.

In addition, we have agreed on specific capabilities for the number of MIMO layers for multicast PDSCH and supported maximum modulation order for maximum data rate calculation for multicast PDSCH, both per FSPC. The network must take these into account when scheduling multicast services already.

Hence, it is unclear to us what is the need for the UE to select in which carriers of the MBS band it can be multiplexed in FDM manner with multicast services, as this seems to be the only extra dimension to be taken into account by this signaling. For the network it is definitely making the feature more attractive for early implementation if it can be assumed as supported more broadly, instead of limited to specific carriers within specific MBS bands.

Similar reasoning applies to FG 33-1-2, with the caveat that there is no explicit signaling for the broadcast capability 33-1. Hence, we can accept per FS signaling for this one for more isonomic treatment corresponding to multicast transmissions.

Regarding FG 33-3-3, it can follow the same granularity as 33-1-2, as 33-3-3 applies for both multicast and broadcast.

2 – Qualcomm Incorporated

We support FSPC granularity as stated in our contribution.

The concern in general is that for any FDM transmission (will use FDM as example but equally applies also to intra-slot TDM) the amount of LLR bits can double. This is a somewhat subtle issue. For any concurrent transmission, if they are both initial transmissions, it is true that the sum rate is shared, i.e. adding more broadcast or unicast 'bits' will necessarily involve a corresponding reduction in unicast 'bits' and vice versa, so the peak data rate is not increased. However, this doesn't hold for retransmissions. Assume for example, that Slot #0 is unicast initial transmission at max data rate with no FDM. Then Slot #1 is multicast initial transmission at max data rate also with no FDM. And then slot #5 is an FDM'd retransmission of Slot #0 and Slot #1, with say, half the RBs allocated for each of ReTx of Slot #0 and ReTx of Slot #1. In this slot, the UE has to decode twice the data rate and load twice the LLRs compared to a regular (non-FDM'd) slot. Of course, 'twice' is somewhat reduced by any applicable multicast and broadcast limitations, but the point remains. We do not assume that existing relaxations would apply to the FDM/TDM cases in question.

Therefore it is expected that the UE can indicate support FDM/TDM operation only as a function of aggregate BW over which such FDM/TDM operation is to be supported, which necessitates FSPC granularity.

3 – Xiaomi Communications

We are supportive to have *FG33-1-2* and *FG33-3-2* reported per FSPC, as it allows earlier implementation and commercialization for different types of UEs.

4 – CATT

We support QC and HW proposals, and we agree with the reasoning mentioned by their contributions. As has been pointed out by Moderator, QC paper, compared with HW paper, additionally addresses the TDM capability. In our view the latter is not as urgent/critical as the FDM capabilities. We'd suggest to at least agree on the FDM ones in this plenary meeting if agreeing on all of them is not possible.

5 – vivo Mobile Communication Co.

Given the reason that FDM /intra-slot TDM transmissions of unicast and broadcast/multicast may have impact on LLR buffer size, we support the proposals that FG33-1-2, FG33-3-2, and FG33-3-3 are reported per FSPC to facilitate the early MBS commercialization.

6 – CBN

We share same view with CATT. As it involves the demands of commercial network deployment, FDM capabilities is more urgent, so we hope to address this issue as soon as possible.

7 – MediaTek Inc.

First, we would like to support the intention to address the issues in [HW1] and [QC2] in this RP at least for FDM capability FG 33-1-2 and FG 33-3-2.

As one of proponent in [HW1], we think the reasonable granularity for this capability is FSPC. The FDM capability is to define whether the UE could receive unicast PDSCH data together with MBS multicast/broadcast data within one slot. From UE implementation point of view, the capability may be impacted by number of active CC, the maximum modulation order, and the maximum MIMO layer as the baseband resource are all shared. We therefore think per CC granularity is needed.

For FG 33-3-3, it can follow the same granularity as 33-1-2 and 33-3-2. However, we also agree FDM case is more important and we are fine to postpone this one if no consensus.

8 – HUAWEI TECHNOLOGIES Co. Ltd.

The reporting granularity of FG 33-1-2, FG 33-3-2 and FG 33-3-3 have been staying in FFS/pending for a long time due to controversy in RAN1. As a consequence, it is NOT implemented by RAN2 and hence is delaying implementation. Co-sourcing companies of RP-222473, RP-222474, RP-222475 believe that it would be important that RAN can address and conclude this issue of reporting granularity, and approve the corresponding CRs to make sure these capabilities are included in the September version of specification.

We support FG 33-1-2, FG 33-3-2 and FG 33-3-3 to be with report granularity of FSPC. Apart from impacting factors pointed by Qualcomm, VIVO and MediaTek, other aspects like storage of parameters to detect unicast PDSCH, storage of parameters to detect multicast PDSCH, detection of unicast control channel and detection of multicast control channel, as well as the corresponding logic processing coordination for multicast and unicast, all can have impact on whether FDM or intra-slot TDM can be supported on a certain carrier or not. We understand from network perspective, it is always preferable to have UEs broadly support a feature. We also understand that some UEs may not be able to support FDM or intra-slot TDM on all carriers due to implementation consideration. If specification force UE to report a broader support, e.g. with a per UE or per FS granularity, a UE not supporting the feature on some of the carriers can only report not supporting this feature or not support the feature in the corresponding band, then the network cannot schedule FDMed or intra-slot TDMed unicast on top of multicast/broadcast for that UE or on that band.

<p>We believe FG 33-1-2, FG 33-3-2 and FG 33-3-3 with report granularity of FSPC provide good balance between network and UE, and can be a good way forward.</p>
<p>9 – Lenovo (Beijing) Ltd</p> <p>We share same view with Huawei and agree with other companies that having FG33-1-2, FG33-3-2, and FG33-3-3 reported per FSPC can enable earlier implementation and commercialization of different types of UEs.</p>
<p>10 – Spreadtrum Communications</p> <p>We also support FG33-1-2, FG33-3-2, and FG33-3-3 with report granularity as FSPC. FDMed operation would require more complex UE processing, as pointed out by Qualcomm/MTK/Huawei. In our mind, in one possible UE’s implementation, M-TRP PDSCH processing may be borrowed to support simultaneous multicast/broadcast and unicast reception and processing. Given M-TRP operation is per CC, we also think FDMed operation shall be per CC, which could provide more flexibility for UE’s implementation. For TDMed operation, we also prefer to keep the same granularity with FDMed operation.</p>
<p>11 – Guangdong OPPO Mobile Telecom.</p> <p>we support FG33-1-2, FG33-3-2 and FG33-3-3 reported per FSPC</p>
<p>12 – Apple Computer Trading Co. Ltd</p> <p>We support FG33-1-2, FG33-3-2 and FG33-3-3 reporting granularity is per FSPC. As the FDM/TDM reception is highly related to the modulation order, MIMO layer, dynamic scheduling for multicast for SCell. These features are reported per FSPC. Thus, it’s natural FG33-1-2, FG33-3-2 and FG33-3-3 reports per FSPC. The flexible reporting granularity could facilitate the feature implementation.</p>
<p>13 – China Mobile Com. Corporation</p> <p>We support Huawei and QC’s proposal that FG 33-1-2, FG 33-3-2 and FG 33-3-3 are reported per FSPC, we think this provides good balance between network and UE and can be a good way forward.</p>

Moderator Conclusion Initial Round: FG33-1-2 and FG33-3-2 are reported per FSPC.

Explanation: There is support from multiple UE/Chipset vendors and Operator support for FG33-1-2 and FG33-3-2 to be reported per FSPC, and that this will make earlier commercialization possible. Moderator understand that this weighs more than the general desire for wide support with less granular signaling, and this seems also visible in the support (12-1).

2.3 Intermediate Round

Moderator Conclusion Initial Round: FG33-1-2 and FG33-3-2 are reported per FSPC.

Moderator: Based on comments and support in the initial round it is proposed that also FG33-3-3 is reported per FSPC.

Moderator: Based on lack of comments in the initial round it is proposed that All of the above FGs has NA for “Need of FDD/TDD differentiation” and for “Need of FR1/FR2 differentiation”.

In the intermediate round, Consolidate conclusion of initial round (if needed), and Consolidate the proposals

above (no comments will be interpreted as acceptance).

Feedback Form 6: Intermediate Round - conclusions and proposals consolidation

1 – Qualcomm Incorporated

Unsure if comments in support of the proposal are required.... but just in case

We support the moderator’s proposal that FG33-1-2, FG33-3-2, FG33-3-3 are all reported per FSPC.

We support the moderator’s proposal that for FG33-1-2, FG33-3-2, FG33-3-3, “Need of FDD/TDD differentiation” is ”N/A” and “Need of FR1/FR2 differentiation” is ”N/A”.

Company Change Requests

Based on the significant support in the initial round, Moderator assumes that it is now agreeable to progress company CRs at TSG RAN.

The CRs in RP-222552 [HW2] and RP-222553 [HW3] does not include the FG33-3-3, which would need to be added, if agreeable (see above).

However it would be useful to collect one round of comments to understand whether there are high level issues. Please provide comments on the referenced company CRs.

Feedback Form 7: Intermediate Round - Company CRs

1 – Xiaomi Communications

We are fine to include FG33-3-3 as per FSPC.

2.4 Conclusions

The below conclusions are consolidated, i.e. received no objection comments in the intermediate round, and can be considered the final conclusions.

Conclusion 4: FG33-1-2 FG33-3-2 and FG33-3-3 are reported per FSPC, with NA for “Need of FDD/TDD differentiation” and for “Need of FR1/FR2 differentiation”

Conclusion 5: It is agreeable to approve Company CRs at current TSG RAN. The Company CRs (in RP-222552 and RP-222553) to be revised to include FG33-3-3.

2.5 Final Round

Final Round to finally review and approve the CRs will take place by email and by ftp-server (not by NWM).

Moderator report on the final Round: When reviewing the CRs an issue was found for FG33-3-3, and there

were diverging views whether it applies equally to broadcast and multicast. It seems FG33-3-3 either need to be excluded or requires more discussion. Moderator proposes this to be excluded, and further discussion on FG33-3-3 if needed can be done in RAN1 (without explicit task from TSG RAN). However there were no comments on the CRs regarding the FDM capabilities FG33-1-2 and FG33-3-2, and the CRs seems agreeable. This leads to the final Conclusions, see below.

2.6 Final Conclusions

Conclusion F4: FG33-1-2 and FG33-3-2 are reported per FSPC, with NA for “Need of FDD/TDD differentiation” and for “Need of FR1/FR2 differentiation”

Conclusion F5: The latest revision of the Company CRs are agreeable and can be approved (revision of RP-222552 and RP-222553, now not including FG33-3-3).

3 Conclusions

Final Conclusions from above two sections are copied here.

Per FR Gaps

Conclusion F1: The following Root Cause / Justification is applicable: a) the possibility to do gapless measurements is valuable, which is possible by using per-FR-gaps, b) the assumption behind per-FR-gaps that FR1 and FR2 has separate resources in the UE is no longer true, and is the main reason why per-FR gaps need more fine-granular capability, or why other solution like needforgap should be considered.

Conclusion F2: RAN2 to be tasked to progress this issue (also taking into account comments collected at TSG RAN), including solutions Alt 1.1 (More fine grained capability for Per-FR-Gaps, 1 bit per BC), Alt 1.3 (more fine grained capability for Per-FR-Gaps - limited by number of carriers), and Alt 2 (Use similar framework/procedure as for "NeedForGap").

Conclusion F3: RAN2 to consider Alt. 1.1, 1.3 and 2, and discuss the signaling overhead and network processing requirements/complexity. RAN2 is tasked to provide results after one Quarter, and leave final decision(s) to TSG RAN.

Comment by RAN2 chair: RAN2 would attempt to: select solution, make assumption for the Release and provide technically endorsed CRs to next TSG RAN, and leave remaining decision(s) if any, and final decision(s) to TSG RAN.

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Conclusion F4: FG33-1-2 and FG33-3-2 are reported per FSPC, with NA for “Need of FDD/TDD differentiation” and for “Need of FR1/FR2 differentiation”

Conclusion F5: The latest revision of the Company CRs are agreeable and can be approved (revision of RP-222552 and RP-222553, now not including FG33-3-3).