3GPP TSG-RAN WG2 #103bis Tdoc R2-18xxxxx

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Agenda Item: 10.x.x.x

Source: Ericsson

Title: Email discussion 103bis#23: Relation of feature sets and band combinations

Document for: Discussion, Decision

# 1 Introduction

At RAN2-103bis the Relation of feature sets and band combinations was discussed based on [1]. Companies seemed to agree that the current procedural text in 36.331 and 38.331 does not reveal how the network requests the three capability containers (all in one enquiry or separately), how the network includes the capability filters and how the UE includes the *featureSets* for EUTRA. Depending on how these open issues are resolved, ambiguities among the feature sets provided in and referred to from capability containers may occur.

This email discussion is meant to clarify the problem scope and to identify an agreeable solution direction. If possible, agreeable CRs are supposed to be provided to the next meeting.

# 2 Discussion

## 2.1 Problem Analysis

### 2.1.1 Relation of *featureSet* ID:s

The *UE-MRDC-Capabilities* contain the *supportedBandCombinationList* as well as a list of *featureSetCombinations*. The latter contains the IDs of EUTRA- and NR Feature Sets. The EUTRA feature sets are conveyed in the *UE-EUTRA-Capabilities* in the field *featureSetsEUTRA-r15*. The NR feature sets are carried in the *UE-NR-Capabilities* in the field *featureSets*. The reasoning behind that split is that the network node needs to know and comprehend only the feature set of its own RAT and in addition the compatible feature set ID for the other RAT.

1. The IDs in UE-MRDC-Capabilities->featureSetCombinations refer to the *featureSets* in UE-EUTRA-Capabilities and UE-NR-Capabilities

The feature sets do not contain their ID explicitly. It is derived from the position of the feature set in the *featureSets* list. The ID space for feature sets is limited to 1024 elements.

1. The feature sets do not contain their ID explicitly. It is derived from the position of the feature set in the *featureSets* list.

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| Company | Comment |
| Huawei | We have same understanding as the above. |
| Nokia | This is our understanding as well of the current specification. |
| NTT DOCOMO | Yes, it is our understanding as well. |
| Intel | Same understanding as well, with a minor correction made to observation 1. |
| Qualcomm Incorporated | Same understanding as well. |

### 2.1.2 When to include *featureSetsEUTRA-r15*

The current 36.331 does not indicate explicitly when the UE is supposed to include the *featureSets*EUTRA-r15. The fact that the field is on the top level of the UE-EUTRA-Capabilities may hint that a UE supporting ENDC shall always include this field when the NW enquires capabilities for *eutra*.

There is currently also no procedural text indicating how the UE shall fill the *featureSets*EUTRA-r15. This may hint that the UE shall always include all *featureSets* that it may refer to in any of its supported MRDC band combinations. In other words, the filtered requests (requestedFrequencyBands-r11, requestedMaxCCsDL-r13, ...) do not seem to limit the requested *featureSets*EUTRA-r15.

1. Absence of explicit procedural text seems to imply that the UE includes the full *featureSetsEUTRA-r15* upon UE capability enquiry for RAT type *eutra*.

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| Company | Comment |
| Ericsson | As discussed in the remainder of the document, it may be desirable to avoid including always the complete featureSetsEUTRA-r15.No matter which way RAN2 chooses, there is certainly a need to specify explicitly what the UE is meant to do. Currently, the procedure is at least ambiguous.  |
| Huawei | We agree that the procedural text should be clarified to avoid any confusion. |
| Nokia | For LTE SA operation, the feature sets need not be signalled as they are sent later as part of eutra-nr request (3 parts i.e. the common MR-DC capability container and the feature sets corresponding to LTE and NR parts). This should be clarified. Currently, the absence of any text may lead to misinterpretation.  |
| NTT DOCOMO | We agree to define the procedure text to clarify when fetureSetsEUTRA is included in UE-EUTRA-Capability. |
| Intel | Agree with the comments from Nokia. UE is to send the featureSetEUTRA-r15 only for MR-DC capabilities. The procedural text needs to be clarified. To further eloborate our understanding: the procedural text in 36.331 for handling EN-DC (in essence for MR-DC) is to be taken from 38.331. And so 36.331 simply refers to 38.331 whenever the requested containers include nr or eutra-nr. The procedural text in 38.331 is added first for handling eutra-nr and nr containers from EN-DC perspective and then later on NR SA handling is added. Ideally a seperate section of procedural text for handling EN-DC where the LTE capability enquiry handling of eutra-nr and nr compared to the procedural text for handling these containers in NR SA might have avoided the ambiguities. We agree there are some places where clarifications are needed.But the philosophy has been that UE provides containers in reponse to the NW request, and **that the NW requests the containers correctly depending on the capability it is interested in.** As mentioned by Ericsson in 2.1.1, the capabiilty of EN-DC (MR-DC) is split across eutra, eutra-nr and nr containers, NOT from functional decoposition where eutra reflects LTE, eutra-nr reflects MR-DC, nr reflects NR SA, rather the containers are defined from how the eNB-gNB view the these: MR-DC container has enough info for both eNB and gNB to see the common capabilities needed for MR-DC operation, while eutra and nr containers are to be seen from eNB and gNB respectively with the intention that other node does not have to know the content of the container meant for the current node.In effect, MR-DC functionality is now dispersed across all three containers!! Another important note is that when the UE provides the containers, the UE is expected to report it’s full capability related to that container. For eg: if the nr container is requested along with eutra-nr, the UE should not only provide the EN-DC specific NR capabilities in nr container, but also the NR SA specfic capabilities in the nr container. The CR from Qualcomm with eutra-nr-only, allows the UE to skip the NR SA BCs in the nr container in case the NW is interested in MR-DC only. So in essence, the UE always provides the complete capabilities of a container unless there are filtering requests by the NW.  |
| Qualcomm Incorporated | Agree to the issue being raised here.It is relatively easy to conclude that the UE shall include the featureSetsEUTRA when both E-UTRA and MR-DC UE capability is requested in a single UE capability enquiry procedure. We should also take into account the case where the UE is requested to report E-UTRA UE capability and MR-DC UE capability later, through multiple UE capability enquiry procedures. |

### 2.1.3 Combined or separate capability enquiry

Currently, 36.331 and 38.331 allow the eNB to request the three capability containers (EUTRA, MRDC, NR) in the same or in subsequent capability enquiry attempts. Being able to request them separately is desirable as it allows the total size to grow beyond 9 Kbyte.

1. The eNB may request the three capability containers (EUTRA, MRDC, NR) in the same or in subsequent capability enquiry attempts.
2. Requesting the containers separately allows the total size to grow beyond 8188 byte and 9000 byte in LTE and NR respectively.

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| Company | Comment |
| Ericsson | Already today, LTE UEs reach the 8188 byte limit with their UE-EUTRA-Capabilities. We consider it therefore important that the NW is able to request MRDC- and NR capabilities separately. |
| Huawei | The main constraint here is the reporting size for the UE capability and if the request from the network side can be decoupled with the way that UE reports, maybe it is not necessary to let network always separate different UE capabilities request. Please see our response on Proposal 2 below. |
| Nokia | In our understanding, the current procedure is expected to work as follows. Requesting MR-DC capabilities also requires the UE to send the LTE and NR feature sets corresponding to these MR-DC capabilities (so with a request of eutra-nr, the UE returns eutra-nr capability container and the LTE and NR specific containers containing the feature sets corresponding to the eutra-nr BC’s and the NR SA standalone capabilities that are outside the capability coordination). Of course, the size of the total response from the UE is a concern as was for LTE but the filtering from the network should trim the size to under what is allowed for LTE. |
| NTT DOCOMO | We agree on observation 4/5. Both mechanisms (same or subsequent enquiry) should be supported as today. |
| Intel | As mentioned in response to 2.1.2, even though the NW can request at the same time or one after the other, the expectation is that for EN-DC (or MR-DC) capability, the NW has to request eutra, eutra-nr and nr containers at the same time. Otherwise it is not clear for the UE to fill in the MR-DC container where the IDs from this container have to refer to eutra and nr containers!!! We understand that size issue from this, but we discussed the filtering solutions to handle the size problem. If the UE is requested just the MR-DC container, it is ambiguous for the UE on what to fill (with respect to ID references), and a procedural change is needed!The featureSet dependency as mentioned by Ericsson in later sections is also a factor when the NW requests the containers in subsequent messages.As mentioned earlier, the container segregation, when done at the time of EN\_DC was not meant to unction based on the feature functionality (EN-DC or NR SA etc..), but rather on how the eNB-gNB process the containers. In the respect, we are not sure in the NW requesting the container in subsequent messages, as it effects the UE unctionality in filling the containers.  |
| Qualcomm Incorporated | We also agree that both single UE capability enquiry and multiple UE capability enquires should be supported by the standard. |

### 2.1.3 When to include *featureSets* in UE-NR-Capabilities

In the subsequent analysis we assume that the NW requests NR- and MRDC capabilities in subsequent requests. According to 36.331 and 38.331 the UE includes the NR *featureSets* when the NW enquires capabilities for “*nr*”:

36.331, section 5.6.3.3

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| 2> if the *ue-CapabilityRequest* includes *nr* and if the UE supports NR:3> include the UE radio access capabilities for NR within a *ue-CapabilityRAT-Container*, with the *rat-Type* set to *nr* and in accordance with *requestedFreqBandsNR-MRDC* and as specified in TS 38.331 [82], clause 5.6.1. |

38.331, section 5.6.4

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| 1> if the requested *rat-Type* is *nr*:2> **include the *featureSets* for the *supportedBandCombinations* included above**;2> include the *featureSetCombinations* corresponding to the *supportedBandCombinations* and for the *featureSets* included above;1> if the requested *rat-Type* is *eutra-nr*:2> include the *featureSetCombinations* corresponding to the *supportedBandCombinations* included above and to the *featureSets* included in a corresponding capability request for *rat-Type* set to *nr*. |

Based on the excerpts from 36.331 and 38.331, the UE is required to return the *UE-NR-Capabilities* with the *supportedBandCombinationList* filtered in accordance with the *FreqBandList* provided by the NW (if any). It also includes the *featureSets* for the *supportedBandCombinationList* as well as the featureSetCombinations.

If the NW requests capabilities for “*nr*” only, it seems natural that the *FreqBandList* should also contain only NR band numbers. Even if the NW would also include LTE band numbers, only the *featureSets* for the NR-only band combinations are included by the text above (since “for the *supportedBandcombinations* included above” refers to the NR band combinations).

Subsequently, the NW may (or may not) perform another capability enquiry for “*eutra-nr*” and request band combinations for the required EUTRA- and NR band numbers. The UE will generate a *supportedBandCombinationList* as described in 38.331, 5.6.1.4 and the corresponding *featureSetCombinations*. The feature set IDs in the latter should refer to feature sets defined previously in the *featureSets* list in the *UE-NR-Capabilities*. However, when generating that one the UE did not know which MRDC band combinations it will later be required to include and hence it is likely that the previously defined *featureSets* do not suffice for the MR-DC band combinations.

1. Even if the NW requests NR- and EUTRA capabilities in one enquiry, the current procedural text suggests that the UE fills the *featureSets* in the UE-NR-Capability container only based on the NR-only band combinations. In particular the procedures for filtered requests don’t cover the EN-DC case correctly.

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| Company | Comment |
| Huawei | The text is ambiguous and needs to be clarified, but we are not sure whether the original intention is consistent with Observation 6. Anyway we need to find a way to solve the ambiguity. |
| Nokia | It is correct that the TS 38.331 procedural text that refers eutra-nr does not use the “*requestedFreqBandsNR-MRDC”* field but rather uses a NR only IE “*supportedBandCombinations”.* There should be some fixes made to connect this back to the request in TS 36.331. |
| NTT DOCOMO | Observation 6 seems correct although it is not the original intention. |
| Intel | We agree with observation 6 in that what band combinations that ‚supportedBandCombinations from above‘ needs to be clarified for 38.331. We think the text in 36.331 is ok. |
| Qualcomm Incorporated | Not sure if we understood the issue.The *FreqBandList* (“filter” as defined in 38.331, which also corresponds to *requestedFreqBandsNR-MRDC* defined in 36.331) contains both LTE and NR bands. And the current specification is based on the assumption that the network always requests “nr” when it requests “eutra-nr”. |

### 2.1.4 Capability enquiries with different filters

A general consequence of the split between band combinations and feature sets and the rule to include only the *featureSets* needed for the currently requested band combinations is that the NW cannot simply merge the band combinations acquired with different filters into a single list of supportedBandCombination. As discussed in the past, this would have been possible in LTE and it would have allowed to collect more band combinations that fit into the maximum PDU size (8188 byte in LTE).

1. Feature sets obtained from subsequent capability enquiries using different filters (e.g. different bands; NR-only vs. MRDC) are not compatible with each other, i.e., the *featureSetId*:s in two *featureSets* lists are likely not consistent.
2. A consequence of Observation 7 is that the NW cannot merge subsequently received *supportedBandCombinationLists* or *featureSets* lists into one (as it would have been possible in LTE).

This constraint means that all nodes in a NW have to enquire capabilities for all bands and number of carriers that are used anywhere in the current PLMN. If e.g. pico cells would request different capabilities than surrounding macro cells, the capabilities stored in the CN would often not match what the current serving cell needs. This would result in frequent capability enquiry procedures over Uu and hence in large connection establishment delays.

1. To avoid significant connection establishment delays due to re-requesting capabilities from UEs frequently, all eNBs and gNBs should request capabilities for all bands that are used anywhere in the PLMN (not only for their own).

This certainly increases the burden on OAM configuration and it may also increase the size of the capabilities requested at once.

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| Company | Comment |
| Ericsson | It should be possible to store capabilities efficiently in the CN and RAN2 should avoid solutions that require the NW to re-request the capabilities from the UEs frequently. |
| Huawei | The CN would not interpret the AS capabilities and therefore we don’t think CN would take any action to identify different filters. However we don’t think this problem would be a serious one as well. If the two eNB/gNBs have quite different filtering, this means the they might be deployed in a different area or might belong to different operators. So frequent re-request of the capabilities might not be the typical case. |
| Nokia | This makes sense that ideally all the UE capabilities must be available in the network and then the UE doesn’t have to be frequently queried. |
| NTT DOCOMO | Observation 9 would work unless the number of bands and their combinations used in the entire PLMN are quite huge. |
| Intel | As mentioned above, the filtering parameters from NW are to be used to reduce the UE capability size How the NW requests these for a particular PLMN would depend on the NW deployment and it’s implementation options. But in cases where a PLMN has large number of bands, we agree with Huawei’s view that not all of the bands of the PLMN might be deployed in one location itself. And NW (re)requesting the UE capability based on a different set of filtering parametes would be similar in terms of RRC signaling costs compared to requesting the entire UE capability in multiple capability enquiries (with diff containers in each request). For this we assume that the capabilities are stored in the NW based on the filters requested by the NW, so that they can be re-used (without asking the UE again) in places where the NW deployed configuration has the same configuration as the filtering parameters for which the capability already exists in core NW. |
| Qualcomm Incorporated | It is our understanding that a set of RAN nodes in a particular area has the same policy on what UE capability “filter” that thy are to use and hoping that it is not that frequent that the UE is re-requested to provide its capability.Such policy is reflected in the UE capability filter (*FreqBandList* in 38.331 and *requestedFreqBandsNR-MRDC* in 36.331) used by the network. The UE echoes it back in UE Capability Information message so that another RAN nodes can determine whether it should re-acquire the UE capability. |

## 2.2 Solution Directions

The following sub-sections depict possible solution directions how to address this issues outlined in the previous section.

### 2.2.1 Complete Feature Sets

One could change the procedures so that the UE must always include all *featureSets* and that the *featureSets* must not be modified across subsequent requests. While not written specifically, this seems to be what the current procedural text implies for the *featureSets*EUTRA-r15 (see Observation 3).

It is difficult to predict how much the overall size of the *UE-NR-Capability* and *UE-EUTRA-Capabilities* would be impacted by this solution direction. And it might lead to that the total number of *featureSets* (1024) becomes a limiting factor either in terms of RRC message size or in terms of distinguishable feature sets.

1. Requiring the UE to include all un-filtered feature sets in UE-NR- and UE-EUTRA-Capabilities may increase the total size of the transferred UE capabilities and may lead to shortage of feature sets.
2. Alternative 1: Require the UE to include all feature sets in the *featureSets* lists of the *UE-NR-Capabilities* and *UE-EUTRA-Capabilities*, i.e., even the ones that it does not refer to in the currently requested filtered subset of supported band combinations.

If Proposal 1 is adopted, the network could enquire EUTRA-, NR- and MRDC capabilities in any order and with any *FreqBandList* filter and be confident that the *featureSetId*:s used in the *FeatureSetCombinations* unambiguously identify the correct feature sets in the *UE-NR-* and *UE-EUTRA-Capabilities*.

If Proposal 1 is considered unacceptable to its impact on message size or number of *featureSets*, RAN2 should consider other solution directions in the subsequent sub-sections.

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| Company | Comment |
| Ericsson | Considering the number of parameters in the FeatureSets and FeatureSetsPerCC, we fear that including all possible feature sets (unfiltered) is not the best choice. |
| Huawei | We agree Proposal 1 might carry too many unnecessary UE feature sets. |
| Nokia | Unfiltered requests might result in very large containers and is undesirable. |
| NTT DOCOMO | Agree that this approach is not the best given that the size of feature sets is likely to grow in future releases. |
| Intel | Not the best choice ☺...! |
| Qualcomm Incorporated | Agree this solution is undesirable, |

### 2.2.2 Consistency within one UECapabilityEnquiry

[1] suggested considering an alternative in which the NW has to request *eutra*, *nr* and/or *eutra-nr* capabilities in a single UECapabilityEnquiry. In this way, the UE could ensure that the *featureSets* in the *UE-EUTRA-Capabilities* and in the *UE-NR-Capabilities* contain all feature set IDs that the *featureSetCombinations* in the *UE-NR-Capabilities* and in the *UE-MRDC-Capabilities* refer to.

1. When the NW requests *eutra*, *nr* and/or *eutra-nr* capabilities in one UECapabilityEnquiry, the UE can ensure that the *featureSets* in the UE-EUTRA-Capabilities and in the UE-NR-Capabilities contain all feature set IDs that the featureSetCombinations in the UE-NR-Capabilities and in the UE-MRDC-Capabilities refer to.

If the network issues subsequent UECapabilityEnquiries with different filters, consistency would not be ensured. Hence, the NW cannot merge and store results from subsequent requests with different filters.

1. Alternative 2: The NW requests *eutra*, *nr* and/or *eutra-nr* capabilities in one UECapabilityEnquiry and the UE ensures that the *featureSets* in the *UE-EUTRA-Capabilities* and in the *UE-NR-Capabilities* contain all feature set IDs that the *featureSetCombinations* in the *UE-NR-Capabilities* and in the *UE-MRDC-Capabilities* refer to.

Proposal 2a: another approach which can be derived from Proposal 2 is that the network still requests eutra, nr and/or eutra-nr capabilities in one UECapabilityEnquiry. The UE can either report all the capabilities into one message, or to use 3 messages to report eutra, NR, and EN-DC capabilities in sequence.

1. Alternative 2: If RAN2 agrees Proposal 2, the NW stores only UE capabilities enquired with the same filter setting. When storing UE capabilities for another filter setting in the CN (AMF or MME), these replace the previously stored capabilities.

As mentioned in the problem analysis, the current procedures in section 5.6.1 require the UE to “*include the featureSets for the supportedBandCombinations included above*” when the NW requests “*nr*”. The text should be extended so that the UE includes also the *featureSets* for a corresponding request for EN-DC if that was received in the same UE-CapabilityEnquiry.

1. Alternative 2: If RAN2 agrees Proposal 2, extend the procedural text in section 5.6.1.4 so that the UE includes also the *featureSets* for a corresponding request for EN-DC received in the same *UE-CapabilityEnquiry* (if any).

With this approach, there is actually no need to requests *eutra*, *nr* and *eutra-nr* explicitly: If the eNB is not interested in the capabilities for NR SA, it could enquire for rat-Type “eutra-nr” only. The UE would in response include the UE-MRDC-Capabilities and the UE-NR-Capabilities. It could however omit the *supportedBandCombinations* list in the UE-NR-Capabilities and it could omit the *featureSets* needed only for NR-only band combinations.

If the NW is interested in NR and EN-DC capabilities, it should requests “nr” and “eutra-nr” in the same enquiry. In this case, the UE should include also the NR *supportedBandCombinations* and the full *featureSets*.

As can be seen, the *eutra-nr-only* flag is not needed and since its behaviour is currently anyway not described in procedural text, the field could be dummified.

1. Alternative 2: If RAN2 agrees Proposal 2, remove the *eutra-nr-only* flag from the UECapabilityEnquiry in EUTRA and change the procedure so that the UE includes both the *UE-NR-Capabilities* and the corresponding *UE-MRDC-Capabilities* when the NW requests “*eutra-nr*”. If the network does not request “*nr*”, too, the UE omits the *supportedBandCombinations* list and the *featureSets* required only for NR SA in the *UE-NR-Capabilities*.

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| Company | Comment |
| Ericsson | Alternative 2 would require that all three capability containers fit into 8188 byte. We would prefer avoiding this restriction.  |
| Huawei | We think Proposal 2 can be enhanced as 2a listed above. If all the capabilities can be fit into one PDCP packet, this is same as Proposal 2.Otherwise, the UE would first report EUTRA UE capability in one RRC message, and then NR capability and MR-DC capability in subsequent two RRC messages. As in current EUTRA UE capability the UE will already report whether it supports EN-DC and NR, the network can use these two capability bits to understand whether there would be subsequent RRC messages for NR SA capability and MR-DC capability respectively. |
| Nokia | Agree that Alt 2 is not that optimal. |
| NTT DOCOMO | Agree with Ericsson and Nokia due to the restriction of maximum PDU size. On the alternative proposal (2a) from Huawei, we understand that the UE delivers the required UE capabilities via separate RRC messages with the same tranaction ID in response to a UECapabilityEnquiry message. It could be regarded as a sort of RRC segmentation discussed under the Rel-16 UE capability SI. We think that Proposal 2a should be discussed for that Rel-16 SI. |
| Intel | If we understand the proposals from this, it is on changing from the network asking for containers to tthe actual features, and that the UE selects the containers that it has to use to report the corresponding features? As mentioned earlier, our undestanding is that in LTE, the NW has to request eutra, eutra-nr and nr container for MR-DC capability, and when nr container is requested as part of this, the UE includes the NR SA capabilities in the nr container by default (unless eutra-nr-only is set). So proposal-2 is the actual intended behaviour. If the NW is interested in NR SA only, then the request of nr container would suffice. Similarly in NR SA, if the NW requests eutra container, LTE capabiity is provided, but if the NW is interested in NE-DC (MR-DC), then all three containers have to be requested (agree that procedural text needs to be clarified).Proposal-3 is also ok with us, in that we expect that capabilities saved in the core network are based on the filters that were requested by the NW.We do not need to remove eutra-nr-only (Proposal-5), as there might still be NWs which are NSA only and there is no need for the UE to include NR SA BCs in nr container, when the NW requests eutra, eutra-nr and nr containers as part of EN-DC capability.Agree with DCM that Huawei’s proposal can be viewd in rel-16. We have concern that expanding the procedure of RRC response to capability into three seperate PDCP SDUs might create race conditions (handover, or RLF in the middle of transfer of the three RRC messages etc..), while segmentation in rel-16 (if agreed) can solve this as one RRC transaction.  |
| Qualcomm Incorporated | Proposal 2 does not scale due to UE capability size issue, and is not sufficient solution.Proposal 2a requires changes to the existing UE enquiry procedure, which is not desirable at this late stage of release-15.Proposal 3 seems reasonable.The current 38.331 and 36.331 only have a single form of UE capability filter (*FreqBandList* in 38.331 and *requestedFreqBandsNR-MRDC* in 36.331), which can contain both LTE and NR bands. The UE can already know from the filter that the network is intending to request MR-DC capability, and possibly make sure the content of feature sets is consistent across the UE capability containers. We can also consider changing the UE behavior when the UE is requested “eutra” capability only (not “eutra-nr”), but with *requestedFreqBandsNR-MRDC* so that the UE includes necessary E-UTRA feature sets according to the filter.Note that Qualcomm’s original proposal in RAN2#103 was the same as the proposal 5, which was not agreed in the last meeting. The current 38.331 assumes the network always request “nr” when it requests “eutra-nr” and the single UE capability filter is included in the UE Capability Enquiry message. See also our input in section 2.1.3. |

### 2.2.3 Consistency among requests with same filter

When the eNB requests UE capabilities from the UE, each UECapabilityEnquiry may include only one *requestedFreqBandsNR-MRDC-r15*, i.e., only one filter. When requesting NR- and EN-DC band combinations, the NW would be expected to include NR- and EUTRA band numbers in that filter.

If the network is also allowed to include both types of band numbers when requesting only the NR capabilities, RAN2 could modify the procedural text in 38.331, 5.6.1.4 so that the UE includes the NR *featureSets* for EN-DC band combinations that it would include in *supportedBandCombinationsList* if the request would be for *eutra-nr*.

If RAN2 chooses this solution direction, the EN-DC procedures should also be changed so that the UE applies the FreqBandList (filter) also to the *featureSets*EUTRA-r12 (which currently seems to be the full list).

1. If the network is allowed to include both EUTRA- and NR- band numbers even when requesting capabilities for only one RAT-type (“nr” or “eutra”), the UE could determine and include the *featureSets* for all possible band combinations for “nr”, “eutra”, and “eutra-nr”.
2. Alternative 3: The network is allowed to include both NR- and EUTRA band numbers even when requesting capabilities for only one RAT-type.
The UE includes *featureSets* based on the provided filter (*FreqBandList*) and not based on the included *supportedBandCombinations*.

This would require corresponding changes to the procedural text but anyway only ensure consistency among capability enquiries using the same filter, i.e., the same *requestedFreqBandsNR-MRDC-r15*.

1. Alternative 3 ensures consistency of *featureSets* and feature set IDs among all capability enquiries with the same filter (*FreqBandList*).

As mentioned before, the procedural text for the *eutra-nr-only* flag is currently missing. In this solution direction, it may serve a purpose: If the eNB includes the *eutra-nr-only* flag in a UE capability enquiry for “*nr*” the UE knows that it is not supposed to include NR-only band combinations. Hence, it could also omit *featureSets* which it would only refer to from NR-only band combinations. To achieve this, the NW should include the *eutra-nr-only* flag not only in the capability enquiry for “*nr*” but already when requesting “*eutra*” (if it plans to requests *nr* and *eutra-nr* later).

1. Alternative 3: If the eNB includes the *eutra-nr-only* flag, the UE omits *featureSets* which it would only refer to from NR-only band combinations. The eNB may include in UECapabilityEnquiry:s for “*eutra*” and/or “*nr*”.

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| Company | Comment |
| Ericsson | This may be a viable approach if it is considered feasible to convey all band combinations needed anywhere in the current PLMN at once, i.e., at least in three subsequent capability enquiries for “eutra”, “nr” and “etura-nr”. |
| Huawei | This solution seems also feasible. The only limitation is how to set this FreqBandList, but this can be up to implementation.  |
| Nokia | This is feasible but has larger impact on current specification. |
| NTT DOCOMO | We also think that this solution looks feasible, as long as the band filtering rule is consistent across separate enquiries.  |
| Intel | We agree that currently there is no mechanism for the NW to provide the NR bands for filtering of NR SA BCs while the request is made in LTE. We only have the list of LTE and NR bands meant for filtering EN-DC BCs. However, we are not sure if these are needed based on our comments on earlier items. We need to discuss this online.  |
| Qualcomm Incorporated | This looks like a nice way to resolve the entire issue. We kind of discussed a similar solution in our input to section 2.2.3. |

### 2.2.4 UE-MRDC-Capabilities with own featureSets

Instead of requesting *eutra*, *nr* and *eutra-nr* capabilities with consistent sets of filters, RAN2 could consider removing the coupling of the featureSets among the three capability containers.

The *UE-NR-Capabilities* would only contain the *featureSets* for NR-only band combinations.

The *UE-MRDC-BandCombinations* would contain the EUTRA- and NR- features sets needed for MRDC. To avoid that one RAT has to decode the other RAT’s *featureSets*, they could be included as transparent containers. If RAN2 follows this approach, the requests for eutra-nr, nr and eutra would become fairly self-contained and independent from each other.

The *UE-EUTRA-Capabilities* would not need to contain any featureSets unless RAN2 agrees to use the them also for EUTRA standalone operation.

1. Alternative 4: Remove the dependencies between UE-MRDC-Capabilities and UE-NR/EUTRA-Capabilities by including the *featureSets*NR and *featureSets*EUTRA as OCTET STRINGs into the UE-MRDC-Capabilities. The UE only includes featureSets in accordance with the *supportedBandCombinations* in the same UE capability IE.

This approach would probably require the least changes to procedural text as shown below:

38.331, section 5.6.4: Changes for Alternative 4

|  |
| --- |
| 1> if the requested *rat-Type* is *nr*:2> include the *featureSets* for the *supportedBandCombinations* included above;2> include the *featureSetCombinations* corresponding to the *supportedBandCombinations* and for the *featureSets* included above;1. if the requested *rat-Type* is *eutra-nr*:

2> include the *featureSetsNR* and *featureSetsEUTRA* for the *supportedBandCombinations* included above;2> include the *featureSetCombinations* corresponding to the *supportedBandCombinations* included above and to the *featureSetsNR and featureSetsEUTRA* ~~included in a corresponding capability request for~~ *~~rat-Type~~* ~~set to~~ *~~nr~~*. |

The new featureSetsNR and featureSetsEUTRA could be added as backwards compatible non-critical extensions. Of course, the change is anyway not fully backwards compatible. But considering that the current procedures are incomplete/erroneous corrections are required anyway.

Like Alternative 2 and 3, also this solution direction suffers from the problem that subsequent capability requests with different filters are not combinable. Hence, the network must request band combinations for all possible bands and band combinations used anywhere in the PLMN to avoid frequent capability enquiry towards the UE.

|  |  |
| --- | --- |
| Company | Comment |
| Ericsson | We are also open for this solution direction. It requires a change in signalling but it might ultimately simplify the handling of capabilities as it removes dependencies among capability containers.  |
| Huawei | If at least one solution from 2.2.3 is workable, maybe this solution is not that essential. We agree that this solution is more straight forward and simple, but this solution also potentially duplicates the featuresets which are common for NR SA and MR-DC. This might add more signalling overhead in the end.  |
| Nokia | Our understanding of how Alt 4 is supposed to work:1. eNB requests UE capability with RAT-type set to eutra-nr and with the filter *requestedFreqBandsNR-MRDC*
2. UE includes MR-DC band combinations with respect to *requestedFreqBandsNR-MRDC*
3. UE includes feature sets corresponding to E-UTRA and NR corresponding to the band combinations from b)
4. UE includes the standalone NR capabilities that are not under the capability coordination in a separate container (i.e. RAT-type nr)
5. eNB receives 2 containers eutra-nr, and nr type

If this ist he common understanding, then from all the alternatives described above this might just be the simplest thing to specify. The impact on the specification is lower and this works well also for the other architecture options. |
| NTT DOCOMO | We also think that this approach is cleaner than any other options to remove the depencency. On the other hand, as discussed in the last meeting and Nokia spotted in their comment, the network needs to acquire 1) per-UE and 2) per band outside BC NR capabilities. To do this, the network request UE-NR-Capability together with UE-MRDC-Capability or via separate enquiry. To address the concern raised by Huawei, i.e. duplicated reporting of featuresets, one approach is that the eutra-nr-only frag is extended to omit the feature sets from UE-NR-Capability, as well as NR band combinations. |
| Intel | Well, for one this, the UE may have to include the same featuresets across nr and eutra-nr containers, increaseing the size.This also requires a lot of change in UE implementation. And we think the size concerns raised can be addressed without this change. We would like to understand if this is really needed ( also considering that in rel-16 we are evaluating segmentation/compression and the usage of ID to replace the large capability msg of mostly all three containers)  |
| Qualcomm Incorporated | We do not prefer signaling change at this stage. |

### 2.2.x [MORE?]

## 2.3 Other issues to be resolved

### 2.3.1 Need to store UE capabilities for different filters

As discussed in [1], the alternative 4 would in principle allow requesting and storing several instances of UE-NR- and UE-MRDC-Capabilities with different filters. It should however be discussed whether the additional complexity is justified or whether each NW could request the band combinations needed anywhere in its PLMN.

1. Discuss whether the NW should be able to store and use capabilities for more than one filter.

|  |  |
| --- | --- |
| Company | Comment |
| Ericsson | It would be good to avoid the additional complexity that this brings. If required, we should at least avoid impact to the CN.  |
| Huawei | We also think this should not impact the CN and could be left to the network implementation. |
| Nokia | Agree with the intention (especially for the EPC) |
| NTT DOCOMO | We agree that the CN impact shoudl be avoided. |
| Intel | While this is NW implementation, we feel that this is the way to go. |
| Qualcomm Incorporated | We do not prefer the alternative 4. |

### 2.3.2 Relation between UE-MRDC-Capabilities and UE-NR-Capabilities

At RAN2-103bis one company thought that the content of the UE-NR-Capabilities may be different depending on whether the NW requests them only for EN-DC or also for NR-SA. Other companies argued that all parameters that depend on the band combination (standalone or with LTE) were included in the band combinations or in the feature sets. The other parameters are meant to be independent of whether or not NR is used alone or with EUTRA.

1. Discuss the consistency and dependency of UE-MRDC-Capabilities and UE-NR-Capabilities.

|  |  |
| --- | --- |
| Company | Comment |
| Ericsson | Except for the featureSets all other parameters in the UE-NR-Capabilities shall **not** dependent on whether or not the NW also requested the UE-MRDC-Capabilities. RAN2 discussed and agreed that all parameters that may be set differently for NR-SA and EN-DC are inside the band combinations and feature sets. A NW enquiring both *eutra-nr* and *nr* capabilities can anyway handle just once instance of UE-NR-Capabilities which must be applicable for both modes of operation.  |
| Huawei | The thing we are not sure is which parameters might have such problem? In our understanding if MR-DC and NR SA have different capabilities, they can link to different featureset combination. If this refers to other per band parameters, better companies can provide detailed parameters. In our investigation, we think per band parameters can always use the same value. |
| Nokia | If we understood your question correctly, in our understanding of Alt 4 above, the NR standalone part that is generated for eutra-nr is compliant with that particular request (our earlier RAN2 agreement specifically says that the capabilities that are not under capability coordination are invariant across MR-DC and NR SA and the SgNB still needs them for generating a SCG configuration). If the LTE eNB later on requests NR SA specific capabilities that request is independent of the others and must be treated as a separate one. |
| NTT DOCOMO | We’re also of opinion that 1) per-UE capabilities and 2) per-band outside BC capabilities should not be affected by supported band combinations. If affected, such the capabilities should have been included in the feature sets... |
| Intel | That one company (assuming it’s us) is also ok with the proposal 10 ☺..! The container bit-string (other than params which are BC specific) should be the same for a container irresprective of whether is provided as part of MR-DC or NR SA. |
| Qualcomm Incorporated | This should be discussed with specific examples.We cannot think of a single example where “UE-NR-Capabilities may be different depending on whether the NW requests them only for EN-DC or also for NR-SA”. |

### 2.3.x [MORE?]

# Conclusion

**TO BE REPLACED by the actual outcome and conclusion of this email discussion!**

In the previous sections we made the following observations:

[Observation 1 The IDs in UE-MRDC-Capabilities->featureGroupCombinations refer to the *featureSets* in UE-EUTRA-Capabilities and UE-NR-Capabilities](#_Toc527725265)

[Observation 2 The feature sets do not contain their ID explicitly. It is derived from the position of the feature set in the *featureSets* list.](#_Toc527725266)

[Observation 3 Absence of explicit procedural text seems to imply that the UE includes the full *featureSetsEUTRA-r15* upon UE capability enquiry for RAT type *eutra*.](#_Toc527725267)

[Observation 4 The eNB may request the three capability containers (EUTRA, MRDC, NR) in the same or in subsequent capability enquiry attempts.](#_Toc527725268)

[Observation 5 Requesting the containers separately allows the total size to grow beyond 8188 byte and 9000 byte in LTE and NR respectively.](#_Toc527725269)

[Observation 6 Even if the NW requests NR- and EUTRA capabilities in one enquiry, the current procedural text suggests that the UE fills the *featureSets* in the UE-NR-Capability container only based on the NR-only band combinations. In particular the procedures for filtered requests don’t cover the EN-DC case correctly.](#_Toc527725270)

[Observation 7 Feature sets obtained from subsequent capability enquiries using different filters (e.g. different bands; NR-only vs. MRDC) are not compatible with each other, i.e., the *featureSetId*:s in two *featureSets* lists are likely not consistent.](#_Toc527725271)

[Observation 8 A consequence of Observation 7 is that the NW cannot merge subsequently received *supportedBandCombinationLists* or *featureSets* lists into one (as it would have been possible in LTE).](#_Toc527725272)

[Observation 9 To avoid significant connection establishment delays due to re-requesting capabilities from UEs frequently, all eNBs and gNBs should request capabilities for all bands that are used anywhere in the PLMN (not only for their own).](#_Toc527725273)

[Observation 10 Requiring the UE to include all un-filtered feature sets in UE-NR- and UE-EUTRA-Capabilities may increase the total size of the transferred UE capabilities and may lead to shortage of feature sets.](#_Toc527725274)

[Observation 11 When the NW requests *eutra*, *nr* and/or *eutra-nr* capabilities in one UECapabilityEnquiry, the UE can ensure that the *featureSets* in the UE-EUTRA-Capabilities and in the UE-NR-Capabilities contain all feature set IDs that the featureSetCombinations in the UE-NR-Capabilities and in the UE-MRDC-Capabilities refer to.](#_Toc527725275)

[Observation 12 If the network is allowed to include both EUTRA- and NR- band numbers even when requesting capabilities for only one RAT-type (“nr” or “eutra”), the UE could determine and include the *featureSets* for all possible band combinations for “nr”, “eutra”, and “eutra-nr”.](#_Toc527725276)

[Observation 13 Alternative 3 ensures consistency of *featureSets* and feature set IDs among all capability enquiries with the same filter (*FreqBandList*).](#_Toc527725277)

Based on the discussion in the previous sections we propose the following:

[Proposal 1 Alternative 1: Require the UE to include all feature sets in the *featureSets* lists of the *UE-NR-Capabilities* and *UE-EUTRA-Capabilities*, i.e., even the ones that it does not refer to in the currently requested filtered subset of supported band combinations.](#_Toc527725278)

[Proposal 2 Alternative 2: The NW requests *eutra*, *nr* and/or *eutra-nr* capabilities in one UECapabilityEnquiry and the UE ensures that the *featureSets* in the *UE-EUTRA-Capabilities* and in the *UE-NR-Capabilities* contain all feature set IDs that the *featureSetCombinations* in the *UE-NR-Capabilities* and in the *UE-MRDC-Capabilities* refer to.](#_Toc527725279)

[Proposal 3 Alternative 2: If RAN2 agrees Proposal 2, the NW stores only UE capabilities enquired with the same filter setting. When storing UE capabilities for another filter setting in the CN (AMF or MME), these replace the previously stored capabilities.](#_Toc527725280)

[Proposal 4 Alternative 2: If RAN2 agrees Proposal 2, extend the procedural text in section 5.6.1.4 so that the UE includes also the *featureSets* for a corresponding request for EN-DC received in the same *UE-CapabilityEnquiry* (if any).](#_Toc527725281)

[Proposal 5 Alternative 2: If RAN2 agrees Proposal 2, remove the *eutra-nr-only* flag from the UECapabilityEnquiry in EUTRA and change the procedure so that the UE includes both the *UE-NR-Capabilities* and the corresponding *UE-MRDC-Capabilities* when the NW requests “*eutra-nr*”. If the network does not request “*nr*”, too, the UE omits the *supportedBandCombinations* list and the *featureSets* required only for NR SA in the *UE-NR-Capabilities*.](#_Toc527725282)

[Proposal 6 Alternative 3: The network is allowed to include both NR- and EUTRA band numbers even when requesting capabilities for only one RAT-type. The UE includes *featureSets* based on the provided filter (*FreqBandList*) and not based on the included *supportedBandCombinations*.](#_Toc527725283)

[Proposal 7 Alternative 3: If the eNB includes the *eutra-nr-only* flag, the UE omits *featureSets* which it would only refer to from NR-only band combinations. The eNB may include in UECapabilityEnquiry:s for “*eutra*” and/or “*nr*”.](#_Toc527725284)

[Proposal 8 Alternative 4: Remove the dependencies between UE-MRDC-Capabilities and UE-NR/EUTRA-Capabilities by including the *featureSets*NR and *featureSets*EUTRA as OCTET STRINGs into the UE-MRDC-Capabilities. The UE only includes featureSets in accordance with the *supportedBandCombinations* in the same UE capability IE.](#_Toc527725285)

[Proposal 9 Discuss whether the NW should be able to store and use capabilities for more than one filter.](#_Toc527725286)

[Proposal 10 Discuss the consistency and dependency of UE-MRDC-Capabilities and UE-NR-Capabilities.](#_Toc527725287)

# Annex A – UE Capability Enquiry in 36.331

#### 5.6.3.3 Reception of the *UECapabilityEnquiry* by the UE

The UE shall:

...

2> if the *ue-CapabilityRequest* includes *nr* and if the UE supports NR:

3> include the UE radio access capabilities for NR within a *ue-CapabilityRAT-Container*, with the *rat-Type* set to *nr* and in accordance with *requestedFreqBandsNR-MRDC* and as specified in TS 38.331 [X2, 5.6.1].

2> if the *ue-CapabilityRequest* includes *eutra-nr* and if the UE supports EN-DC:

3> include the UE radio access capabilities for EUTRA-NR within a *ue-CapabilityRAT-Container*, with the *rat-Type* set to *eutra-nr* and in accordance with in accordance with *requestedFreqBandsNR-MRDC* and as specified in TS 38.331 [82, 5.6.1].

1> submit the *UECapabilityInformation* message to lower layers for transmission, upon which the procedure ends;

# Annex B – UE Capability Enquiry in 38.331

### 5.6.1 UE capability transfer

#### 5.6.1.1 General



Figure 5.6.1.1-1: UE capability transfer

#### 5.6.1.2 Initiation

The network initiates the procedure to a UE in RRC\_CONNECTED when it needs (additional) UE radio access capability information.

#### 5.6.1.3 Reception of the *UECapabilityEnquiry* by the UE

The UE shall set the contents of *UECapabilityInformation* message as follows:

1> if the *ue-CapabilityRequest* includes *nr*:

2> include the *UE-NR-Capability* within a *ue-CapabilityRAT-Container* and with the *rat-Type* set to *nr*;

2> include band combinations supported by the UE into *supportedBandCombination* as specified in 5.6.1.4;

1> if the *ue-CapabilityRequest* includes *eutra* and if the UE supports EUTRA:

2> include the *UE-EUTRA-Capability* within a *ue-CapabilityRAT-Container* and with the *rat-Type* set to *eutra*;

1> submit the *UECapabilityInformation* message to lower layers for transmission, upon which the procedure ends.

Editor’s Note: FFS whether NR UECapabilityEnquiry is also used for EN-DC.

#### 5.6.1.4 Compilation of band combinations supported by the UE

The UE shall:

1> if *FreqBandList* is received:

2> if the received *FreqBandList* contains at least one of *maxBandwidthRequestedDL*, *maxBandwidthRequestedUL*, *maxCarriersRequestedDL* or *maxCarriersRequestedUL* for at least one of the bands:

3> compile a list of band combinations, candidate for inclusion in the *UECapabilityInformation* message, only consisting of bands included in *FreqBandList*, where for each band in the band combination, the parameters of the band do not exceed the corresponding parameters provided by the IEs *maxBandwidthRequestedDL, maxBandwidthRequestedUL, maxCarriersRequestedDL, maxCarriersRequested, ca-BandwidthClassDL-EUTRA or ca-BandwidthClassUL-EUTRA,* whichever are recevied.

2> else:

3> compile a list of band combinations, candidate for inclusion in the *UECapabilityInformation* message, only consisting of bands included in *FreqBandList*, and prioritized in the order of *FreqBandList*, (i.e. first include remaining band combinations containing the first-listed band, then include remaining band combinations containing the second-listed band, and so on);

2> for each band combination included in the candidate list:

3> if it is regarded as a fallback band combination with the same capabilities of another band combination included in the list of candidates as specified in TS 38.306 [xx]:

4> remove the band combination from the list of candidates;

2> include all band combinations in the candidate list into *supportedBandCombination*;

2> include the received *FreqBandList* in the field *appliedFreqBandListFilter* of the requested UE capability;

1> else:

2> include all band combinations supported by the UE into *supportedBandCombination,* excluding fallback band combinations with the same capabilities of another band combination included in the list of band combinations supported by the UE;

1> if the requested *rat-Type* is *nr*:

2> include the *featureSets* for the *supportedBandCombinations* included above;

2> include the *featureSetCombinations* corresponding to the *supportedBandCombinations* and for the *featureSets* included above;

1> if the requested *rat-Type* is *eutra-nr*:

2> include the *featureSetCombinations* corresponding to the *supportedBandCombinations* included above and to the *featureSets* included in a corresponding capability request for *rat-Type* set to *nr*.

NOTE: For EN-DC, the network needs the capabilities for RAT types *nr* and *eutra-nr* and it uses the *featureSets* in the *UE-NR-Capabilities* together with the *featureSetCombinations* in the *UE-MRDC-Capabilities* to determine the UE capabilities for the supported MRDC band combinations. Hence, the IDs used in the *featureSets* must match to the IDs referred to in *featureSetCombinations*.

# References

1. R2-1814979, “Relation of feature sets and band combinations”, Ericsson, RAN2-103bis, Chengdu, China