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Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

# 1 Scope

The present document is intended to capture findings produced in the context of the study on optimizations of UE radio capability signalling.

The study is expected to proceed as follows:

- Study the size of UE Radio Capability signaling

- Study mechanisms to optimise the UE Radio Capability signalling over the air while addressing the limitations of radio protocol interface,

- Solutions using UE capability identity,

- Solutions using other means (i.e. segmentation, compression).

The study shall consider the possibility to change UE radio capabilities.

As part of the study and in coordination with other WGs especially RAN WGs it should be concluded whether to proceed with normative work.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 38.331: "NR; Radio Resource Control (RRC) protocol specification".

[3] 3GPP TR 23.743: "Study on optimisations of UE radio capability signalling".

[4] 3GPP TS 23.501: "System Architecture for the 5G System".

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

**example:** text used to clarify abstract rules by applying them literally.

# 4 Void

# 5 UE Radio Capability Signaling Size Analysis

## 5.1 UE Radio Capability size estimation

For LTE, the primary overhead introduced by Rel-15 parameters is *FeatureSetsEUTRA-r15*. The theoretical overhead of *FeatureSetsEUTRA-r15* can exceed 10 kbytes.

In practical deployment, the size of *featureSetsEUTRA-r15* is variable depending on the number of DL/UL feature sets per band and the number of DL/UL feature sets per CC, in some cases the size of *featureSetsEUTRA-r15* can be several kbytes, and the total size of *UE-EUTRA-Capability* can be ~4 kbytes with realistic assumptions.

For NR and EN-DC, based on the newly introduced structure for UE capability in Rel-15, the size of the UE capability is dominated by *rf-Parameters*, *featureSetCombinations* and *featureSets*. The estimated theoretical maximum size of UE radio capabilities for NR or EN-DC (based on the maximum sizes in ASN.1) can approximate to 10000 kbytes,

In practical deployment, the supported bands/band combinations for a device is limited, and the eNB/gNB can for example request the UE to provide UE radio capabilities for a restricted set of band combinations. According to LTE experience and analysis of the NR capability, the estimated practical size of *rf-Parameters* is about 11~12 kbytes based on ~1024 band combinations and up to 4 bands per band combination.

The size of *featureSetCombinations* is highly variable depending on the number of feature set combinations and the number of feature sets per band, the size of *featureSets* is variable depending on the number of DL/UL feature sets per band and the number of DL/UL feature sets per CC. However, in some cases either the size of *featureSetCombinations* or *featureSets* can significantly exceed the size limitation of PDCP PDU. For example, with 256 feature set combinations, 8 feature sets per band, and 4 bands per band combination, the feature set combination list occupies ~22 kbytes.

## 5.2 Limitations on different interfaces

The estimated theoretical maximum size of UE radio capabilities is extremely large. The estimated practical size of UE radio capabilities can be reduced, and the estimated size of "several tens of kilo-octets" appears to be valid.

For RAN interfaces, the size limitation of PDCP PDU is 9000 bytes for NR and 8188 bytes LTE, and there are no limitations for SCTP based interface. For core network interfaces, the size for the RAN transparent container is limited to 50 kbytes for GTP based S10 interface and N26 interface, but no upper limit is defined for HTTP based N14 interface.

## 5.3 Analysis

It is hard for the size of UE radio capabilities to respect the limitation of Uu interface both for NR and LTE, and it can even exceed the limitation of GTP based interfaces.

The issue of exceeding the size limitation exists mainly for:

1) UE radio capabilities reporting via Uu interface in NR scenario and LTE scenario;

2) UE radio capabilities transfer between two MMEs (S1 based handover) as well as between MME and AMF (handover between LTE and NR).

# 6 UE Radio Capability Signaling Optimizations

## 6.1 Solutions using UE capability Identity

### 6.1.1 UE capability Identity

#### 6.1.1.1 Description

This section describes the use of a UE capability identity, i.e. a short value that can be used as a representation of all or part of the UE capability.

RAN2 preference is for a single capability identity covering all capability containers (i.e. *UE-NR-Capability*, *UE-EUTRA-Capability*, and *UE-MRDC-Capability*), as opposed to separate identity values for the different containers.

The identity based mechanism is intended to coexist with, rather than replace, the legacy capability transfer signalling. It is also intended to coexist with NAS initiated changes of capability. In case of NAS change of capability, RAN2 understand that if the new capability set has an ID assigned, the capability ID signalling can be used to update the capability; if the new capability set does not have an ID assigned, the legacy capability signalling can be used to transfer the new capability. In a context where network-assigned capability IDs are supported, after the UE indicates a changed capability with legacy signalling, RAN2 assume the network may assign a capability ID to the new set.

RAN2 assume the capability ID is known to the NG-RAN during the connection setup procedure.

RAN2 assume that if the UE has an ID for its current capability set, it will signal the capability ID at least in case the network indicates support for the feature.

In5G, all capability requests will be filtered. The filter is included as a part of the signalled UE capabilities so that the gNB can determine if it should request more capability information from UE's moving into the cell.

In a context where network-assigned capability IDs, RAN2 have discussed filtering and the impacts on capability signalling, and concluded that:

- It is possible for the network to use different filters in different parts of the PLMN.

- UE provides capability to the network based on the filter and if an ID is assigned then the ID is associated to whatever capabilities it has transferred earlier.

- The Capability ID is unique within a PLMN - i.e. the UE can provide capability ID anywhere within this PLMN (this does not imply that Capability ID to capability set mapping needs to be known throughout the PLMN).

Further enhancement on current filtering function is to be considered in normative phase.

#### 6.1.1.2 Signalling for transfer of UE capability identity

##### 6.1.1.2.1 Approach 1: Transfer via RRC signalling

The transfer of UE capability in RRC signalling is shown in Figure 6.1.1.2.1-1. The UE sends a UE capability ID in an RRC message, which could be either the *RRCSetupComplete* message or the *UECapabilityInformation* message. The subsequent handling of the UE capability ID is discussed in subclause 6.1.1.3. In this alternative, the UE capability ID is visible to the NG-RAN at the time of connection setup.



Figure 6.1.1.2.1-1: RRC transfer of UE capability ID using *RRCSetupComplete*

Subsequent to the signalling of Figure 6.1.1.2.1-1, it is possible to transfer the UE capability ID also to the CN, e.g. in the Initial UE Message. This allows visibility of the ID in both NG-RAN and CN if necessary.

RRC signalling allows the RAN to know the UE capability ID directly (i.e. without the involvement of the AMF), and if sent early in the connection procedure, it can enable RAN caching for early configuration of the UE capability. RRC signalling does not preclude that the UE capability ID is provided to AMF.

RAN visibility of the capability ID is considered beneficial for RAN caching of the UE capability set, signalling reduction on network interfaces, and early RRM decisions.

After considering SA3 requirement (R2-1900087) on the security protection of UE capability ID, this approach is not considered valid.

##### 6.1.1.2.2 Approach 2: Transfer via NAS signalling

The transfer of UE capability in NAS signalling is shown in Figure 6.1.1.2.2-1.The UE sends a UE capability ID to the CN using a NAS message before the CN sends the Initial Context Setup Request to the NG-RAN. The subsequent handling of the UE capability ID is discussed in subclause 6.1.1.3. In this alternative, the UE capability ID is visible to the CN at the time of the NAS message (i.e. before initial context setup).



Figure 6.1.1.2.2-1: NAS transfer of UE capability ID

Subsequent to the signalling of Figure 6.1.1.2.2-1, it is possible to transfer the UE capability ID also to the NG-RAN, e.g. in the Initial Context Setup Request. This allows visibility of the ID in both NG-RAN and CN if necessary.

NAS signalling of the ID enables a solution transparent to RRC.

#### 6.1.1.3 Interaction between NG-RAN and CN for management of UE capability identity

##### 6.1.1.3.1 Summary of approaches

After the UE capability ID is transferred from the UE to either the NG-RAN or the CN, an entity in the network is responsible for mapping the ID to the UE capability set.

If the ID is first provided to the NG-RAN (e.g. by RRC signalling as described in subclause 6.1.1.2.1), there are three alternatives: The mapping of the ID to UE capability set can be stored at the NG-RAN, the CN, or both. In case the mapping is stored in both NG-RAN and CN, there are different solutions depending on whether the capability ID is transferred to the network via RRC or NAS signalling. The different approaches are described in the following sections.

##### 6.1.1.3.2 Approach 1: Mapping stored at NG-RAN only

If the mapping is stored at the NG-RAN only, no capability-related interaction with the CN is required and the capability exchange can proceed as shown in Figure 6.1.1.3.2-1.



Figure 6.1.1.3.2-1: NG-RAN identification of UE capability without CN interaction

In the procedure of Figure 6.1.1.3.2-1, step 1 may involve either RRC signalling (as in subclause 6.1.1.2.1) or NAS signalling (as in subclause 6.1.1.2.2, with subsequent transfer of the ID from the CN to the NG-RAN). Step 5 (the Initial Context Setup Request from CN to NG-RAN) may or may not include a request for UE capability, depending on whether the CN has already stored capability information for this UE.

If the NG-RAN is not able to identify the UE capability in the association table, it needs to request it from the CN in step 3 (the Initial UE Message). If neither the NG-RAN nor the CN is able to identify the UE capability, the NG-RAN initiates a UE capability enquiry procedure (and updates the association table accordingly). The latter case is shown in Figure 6.1.1.3.2-2.



Figure 6.1.1.3.2-2: NG-RAN and CN unable to identify UE capability

The benefits of having the mapping visible at the RAN include enabling RAN caching and reducing overhead on network interfaces.

##### 6.1.1.3.3 Approach 2: Mapping stored at CN only

If the mapping is stored at the CN only, the capability exchange can proceed as shown in Figure 6.1.1.3.3-1.



Figure 6.1.1.3.3-1: CN identification of UE capability and delivery to NG-RAN

In the procedure of Figure 6.1.1.3.3-1, step 1 may involve either RRC signalling (as in subclause 6.1.1.2.1, with subsequent transfer of the ID from the NG-RAN to the CN) or NAS signalling (as in subclause 6.1.1.2.2). If the CN is not able to identify the UE capability in the association table in step 2, it requests the NG-RAN to retrieve the UE capability in step 3, resulting in a UE capability enquiry procedure as shown in Figure 6.1.1.3.3-2.



Figure 6.1.1.3.3-2: CN unable to identify UE capability

The benefits of having the mapping visible at the core network include the ability to use the CN as a "master" repository of the mapping (rather than e.g. distributed storage across all gNBs), the ability for the RAN to refer to the CN when it is not aware of the mapping, and access to the capability mapping also for UEs in RRC\_IDLE.

##### 6.1.1.3.4 Approach 3: Mapping stored at CN and NG-RAN, using NAS signalling

If the mapping is stored at the CN and the NG-RAN and the transfer of the UE capability ID uses NAS signalling, the capability exchange can proceed as shown in Figure 6.1.1.3.4-1.



Figure 6.1.1.3.4-1: NG-RAN and CN identification of UE capability (with NAS signalling)

In the procedure of Figure 6.1.1.3.4-1, if the CN is not able to identify the UE capability in step 2, it requests in step 3 for the NG-RAN to deliver the UE capability. If the NG-RAN is not able to identify the UE capability in step 4, it performs a UE capability enquiry procedure, as shown in Figure 6.1.1.3.4-2.



Figure 6.1.1.3.4-2: NG-RAN unable to identify UE capability

##### 6.1.1.3.5 Approach 4: Mapping stored at CN and NG-RAN, using RRC signalling

If the mapping is stored at the CN and the NG-RAN and the transfer of the UE capability ID uses RRC signalling, the capability exchange can proceed as shown in Figure 6.1.1.3.5-1.



Figure 6.1.1.3.5-1: NG-RAN and CN identification of UE capability (with RRC signalling)

In the procedure of Figure 6.1.1.3.5-1, if the NG-RAN is not able to identify the UE capability in step 2, it requests in step 3 for the CN to deliver the UE capability and the CN delivers it with the subsequent Initial Context Setup Request. If the CN is not able to identify the UE capability in step 4, it requests it from the NG-RAN along with the Initial Context Setup Request. If neither the NG-RAN nor the CN can identify the UE capability, the NG-RAN performs a UE capability enquiry. The latter case is shown in Figure 6.1.1.3.5-2.



Figure 6.1.1.3.5-2: NG-RAN and CN unable to identify UE capability

### 6.1.2 UE capability Identity combined with other means

#### 6.1.2.1 Solution using Hash-based Identification of UE radio capabilities

##### 6.1.2.1.1 Description

*On HASH-based ID's as described in solution #3 in 23.743[3], RAN2 has identified that, to create a hash-Capability ID the UE needs to do this assuming some specific capability information. It is not obvious what capability information the UE would have the hash operate on to create the ID. Further, there are aspects related to the length of the ID, for which the length would need to be longer than other ID solutions.*

*RAN2 concludes that HASH-based ID's offer very little possibilities to explore additional advantages over those already possible with the solutions described in the SA2 interim conclusions.*

#### 6.1.2.2 UE Capability ID with delta set of UE Radio Capabilities

##### 6.1.2.2.1 Description

*On 'delta signalling' as described in solution #9 in 23.743[3], RAN2 understands that all the impacts of 'delta signalling' (i.e. some additional capability information alongside the capability ID) would be within the RAN2 specifications and therefore it should be RAN2 decision to conclude on support of this feature.* *RAN2 has not yet concluded whether to support or not of this feature.*

## 6.2 Solutions using other means

### 6.2.1 Segmentation of capabilities

#### 6.2.1.1 Description

This section describes the segmentation approach to transfer UE capabilities. If the capability size is over 9000 bytes for NR and 8188 bytes for LTE, then capabilities are segmented into smaller pieces.

#### 6.2.1.2 Signalling for transfer of UE capabilities in segments

A signalling diagram to transfer capabilities in segments is shown in Figure 6.2.1.2-1. In the first step, the eNB/gNB requests capabilities. The UE constructs capabilities and segments the capabilities to the pieces not exceeding the maximum PDCP SDU size. Segments are transmitted to the network by the lower layers. Once the eNB/gNB has received the segments, it recombines the segmented UE radio capability information.



Figure 6.2.1.2-1: Signaling diagram of UE capability segmentation

#### 6.2.1.3 Segmentation structure

##### 6.2.1.3.1 Segmentation at RRC level

In the segmentation of UE capabilities in the RRC level, for each segment, a type (e.g. notLastSegment, lastSegment) as well as a segment number is added. The RRC segmentation can be done in different ways as described below.

Option 1: "hard" split RRC Segmentation:

This approach is similar to ETWS/CMAS in LTE and NR. The total UE radio capability information is encoded as one structure (message or information element) similar to non-segmented case. This is then split into multiple segments in bits. The network can only decode the complete capabilities after assembling all parts, rather than decoding each part.

Option 2: "soft" split RRC Segmentation:

UE radio capability information is encoded separately in parts and carried by multiple messages or information elements (smaller than 9000 bytes for NR or 8188 bytes for LTE). The network can decode and process every segment and combine the content after all the segments are received.

##### 6.2.1.3.2 Segmentation at PDCP level

On the Transmitting side,

1. PDCP segments the huge RRC message (i.e. RRC PDU) into multiple PDCP SDUs;

2. The size of each PDCP SDU does not exceed 9000bytes for NR or 8188 bytes for LTE;

3. The last PDCP SDU is tagged with end-marker in the corresponding PDCP PDU header.



Figure 6.2.1.3.2-1: Illustration of UE capability segmentation at PDCP level

On the Receiving side:

1. PDCP receives and stores the PDCP SDUs;

2. In PDCP reception buffer, following the in-order delivery principle, UE will reassemble the RRC PDU from the first PDCP SDU to the last PDCP SDU tagged with end-marker.

- In the example shown in Figure 6.2.1.3.2-2, SN#2 is the last received PDCP SDU amongst SN#1 to SN#3.

- Before receiving PDCU SDU with SN#2, UE does not deliver PDCP SDU with SN#1 to upper layer since it is not tagged with end-marker;

- After receiving PDCP SDU with SN#2, UE reassembles the RRC msg#1 from PDCP SDUs with SN#1#2#3;

3. UE delivers the reassembled RRC message to RRC layer, and delete the associated PDUs.



Figure 6.2.1.3.2-2: Illustration of concatenation on huge RRC message

### 6.2.2 Uplink Capability Signalling Compression (UCSC)

UCSC is a technique to minimize the redundancy in the UE capability information sent by the UE to the network. The NG-RAN informs the UE whether it supports compression in the capability enquiry. Depending on the UE capability to support compression, the UE responds with compressed or uncompressed capability information. A possible candidate for the compression algorithm is DEFLATE. The compression configuration may include the dictionary identifier, when pre-defined dictionaries are used. Capability ID can be used as a dictionary ID.



Figure 6.2.2-1: Block diagram of UE capability compression operation

# 7 Conclusion

## 7.1 Solutions using UE capability Identity

Based on the study, RAN2 recommends that UE capability Identity transfer via NAS signalling, in section 6.1.1.2.2, is introduced in the normative phase. In addition, UE capability ID in *UECapabilityInformation* message should also be supported (only after AS security is activated).

RAN2 also concludes that it is possible for the network to use different filters in different parts of the PLMN. If an ID is assigned by network, then the ID is associated to whatever capabilities the UE has transferred earlier. In context of PLMN assigned ID, the capability ID is unique within a PLMN.

On hash-based ID, RAN2 recommends not to pursue the solution.

On delta signaling with capability ID, RAN2 has not yet concluded whether to support or not of this feature.

## 7.2 Solutions using other means

RAN2 recommends that RRC level segmentation with hard split to be specified in any follow on WI.

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2018-10 | RAN2 #103bis | R2-1813777 | - | - | - | Skeleton TR | 0.0.1 |
| 2019-03 | RAN2 #105 | R2-1902690 |  |  |  | TR 37.873 v0.1.0 as agreed by RAN2 in email discussion [105#27] after RAN2 #105 | 0.1.0 |
| 2019-03 | RAN#83 | RP-190296 |  |  |  | Version submitted to RAN#83 for approval | 1.0.0 |
| 2019-03 | RAN#83 |  |  |  |  | Approved and upgraded to version 16.0.0 | 16.0.0 |