3GPP TR 23.743 V16.0.0 (2019-03)

Technical Report

3rd Generation Partnership Project;

Technical Specification Group Services and System Aspects;

Study on optimisations on UE radio capability signalling

(Release 16)

** 

The present document has been developed within the 3rd Generation Partnership Project (3GPP TM) and may be further elaborated for the purposes of 3GPP.  
The present document has not been subject to any approval process by the 3GPPOrganizational Partners and shall not be implemented.  
This Report is provided for future development work within 3GPPonly. The Organizational Partners accept no liability for any use of this Specification.  
Specifications and Reports for implementation of the 3GPP TM system should be obtained via the 3GPP Organizational Partners' Publications Offices.

Keywords

3GPP, 5G, Architecture, Latency, Mobility

***3GPP***

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis

Valbonne - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

***Copyright Notification***

No part may be reproduced except as authorized by written permission.  
The copyright and the foregoing restriction extend to reproduction in all media.

© 2019, 3GPP Organizational Partners (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC).

All rights reserved.

UMTS™ is a Trade Mark of ETSI registered for the benefit of its members

3GPP™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners  
LTE™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners

GSM® and the GSM logo are registered and owned by the GSM Association

Contents

Foreword [6](#__RefHeading___Toc4684655)

1 Scope [7](#__RefHeading___Toc4684656)

2 References [7](#__RefHeading___Toc4684657)

3 Definitions and abbreviations [8](#__RefHeading___Toc4684658)

3.1 Definitions [8](#__RefHeading___Toc4684659)

3.3 Abbreviations [8](#__RefHeading___Toc4684660)

4 Architectural Requirements and Assumptions [8](#__RefHeading___Toc4684661)

4.1 Architectural Requirements [8](#__RefHeading___Toc4684662)

4.2 Architectural Assumptions [8](#__RefHeading___Toc4684663)

5 Key Issues [8](#__RefHeading___Toc4684664)

5.1 Key Issue #1: How are the UE Radio Capabilities identified? [8](#__RefHeading___Toc4684665)

5.1.1 Description [8](#__RefHeading___Toc4684666)

5.2 Key Issue #2: Where are the UE radio capabilities stored? [9](#__RefHeading___Toc4684667)

5.2.1 Description [9](#__RefHeading___Toc4684668)

5.3 Key Issue #3: How are the UE radio capabilities managed? [9](#__RefHeading___Toc4684669)

5.3.1 Description [9](#__RefHeading___Toc4684670)

6 Solutions [10](#__RefHeading___Toc4684671)

6.1 Solution #1: UE manufacturer-specific UE capability ID [10](#__RefHeading___Toc4684672)

6.1.1 Introduction [10](#__RefHeading___Toc4684673)

6.1.2 Functional Description [10](#__RefHeading___Toc4684674)

6.1.3 Procedures [10](#__RefHeading___Toc4684675)

6.1.4 Impacts on existing entities and interfaces [10](#__RefHeading___Toc4684676)

6.1.5 Evaluation [10](#__RefHeading___Toc4684677)

6.2 Solution #2: UE capability ID indicated in Access Stratum and N2 [10](#__RefHeading___Toc4684678)

6.2.1 Introduction [10](#__RefHeading___Toc4684679)

6.2.2 Functional Description [10](#__RefHeading___Toc4684680)

6.2.3 Procedures [11](#__RefHeading___Toc4684681)

6.2.4 Impacts on existing entities and interfaces [11](#__RefHeading___Toc4684682)

6.2.4.1 Registration procedure [12](#__RefHeading___Toc4684683)

6.2.4.2 UE Triggered Service Request [14](#__RefHeading___Toc4684684)

6.2.4.3 RAN retrieval of UE Radio Capability [15](#__RefHeading___Toc4684685)

6.2.5 Evaluation [15](#__RefHeading___Toc4684686)

6.3 Solution #3: Solution using Hash-based Identification of UE radio capabilities [15](#__RefHeading___Toc4684687)

6.3.1. Introduction [15](#__RefHeading___Toc4684688)

6.3.2 Functional Description [15](#__RefHeading___Toc4684689)

6.3.3 Procedures [16](#__RefHeading___Toc4684690)

6.3.4 Impacts on existing entities and interfaces [16](#__RefHeading___Toc4684691)

6.3.5 Evaluation [16](#__RefHeading___Toc4684692)

6.4 Solution #4: Provisioning of UE Radio Capability using UDR [17](#__RefHeading___Toc4684693)

6.4.1 Introduction [17](#__RefHeading___Toc4684694)

6.4.2 Functional Description [17](#__RefHeading___Toc4684695)

6.4.3 Procedures [17](#__RefHeading___Toc4684696)

6.4.3.1 Provisioning UE Radio Capability Information to UDR [17](#__RefHeading___Toc4684697)

6.4.3.2 Update and sharing of UE Radio Capability Information using UDR [18](#__RefHeading___Toc4684698)

6.4.4 Impacts on existing entities and interfaces [20](#__RefHeading___Toc4684699)

6.4.5 Evaluation [20](#__RefHeading___Toc4684700)

6.5 Solution #5: UE radio capability reporting and management using UE-capability-ID [20](#__RefHeading___Toc4684701)

6.5.1 Introduction [20](#__RefHeading___Toc4684702)

6.5.2 Functional Description [21](#__RefHeading___Toc4684703)

6.5.3 Procedures [21](#__RefHeading___Toc4684704)

6.5.4 Impacts on existing entities and interfaces [23](#__RefHeading___Toc4684705)

6.5.5 Evaluation [23](#__RefHeading___Toc4684706)

6.6 Solution #6: UE capability ID indicated in Access Stratum and N2 and local RAN Storage [23](#__RefHeading___Toc4684707)

6.6.1 Introduction [23](#__RefHeading___Toc4684708)

6.6.2 Functional Description [24](#__RefHeading___Toc4684709)

6.6.3 Procedures [24](#__RefHeading___Toc4684710)

6.6.4 Impacts on existing entities and interfaces [24](#__RefHeading___Toc4684711)

6.6.4.1 Registration procedure [25](#__RefHeading___Toc4684712)

6.6.4.2 UE Triggered Service Request [27](#__RefHeading___Toc4684713)

6.6.4.3 RAN retrieval of UE Radio Capability [28](#__RefHeading___Toc4684714)

6.6.4.4 Local (R)AN Storage of dictionary [28](#__RefHeading___Toc4684715)

6.6.5 Evaluation [29](#__RefHeading___Toc4684716)

6.7 Solution #7: Retrieve UE Radio Capability and store it in AMF per UE Capability ID [29](#__RefHeading___Toc4684717)

6.7.1 Introduction [29](#__RefHeading___Toc4684718)

6.7.2 Functional Description [29](#__RefHeading___Toc4684719)

6.7.3 Procedures [29](#__RefHeading___Toc4684720)

6.7.3.1 Registration [29](#__RefHeading___Toc4684721)

6.7.3.2 Retrieval of UE Radio Capability [31](#__RefHeading___Toc4684722)

6.7.4 Impacts on existing entities and interfaces [31](#__RefHeading___Toc4684723)

6.7.5 Evaluation [32](#__RefHeading___Toc4684724)

6.8 Solution #8: Solution for identifying UE radio capabilities using PLMN-specific UE Capability ID [32](#__RefHeading___Toc4684725)

6.8.1 Introduction [32](#__RefHeading___Toc4684726)

6.8.2 Functional Description [33](#__RefHeading___Toc4684727)

6.8.3 Procedures [33](#__RefHeading___Toc4684728)

6.8.4 Impacts on existing entities and interfaces [33](#__RefHeading___Toc4684729)

6.8.5 Evaluation [33](#__RefHeading___Toc4684730)

6.9 Solution #9: UE Capability ID with delta set of UE Radio Capabilities [33](#__RefHeading___Toc4684731)

6.9.1 Introduction [33](#__RefHeading___Toc4684732)

6.9.2 Functional Description [34](#__RefHeading___Toc4684733)

6.9.3 Procedures [34](#__RefHeading___Toc4684734)

6.9.4 Impacts on existing entities and interfaces [34](#__RefHeading___Toc4684735)

6.9.5 Evaluation [34](#__RefHeading___Toc4684736)

6.10 Solution #10: Solution based on network-controlled capabilities sending and UE Capability ID allocation [35](#__RefHeading___Toc4684737)

6.10.1 Introduction [35](#__RefHeading___Toc4684738)

6.10.2 Functional Description [36](#__RefHeading___Toc4684739)

6.10.3 Procedures [36](#__RefHeading___Toc4684740)

6.10.4 Impacts on existing entities and interfaces [42](#__RefHeading___Toc4684741)

6.10.5 Evaluation [42](#__RefHeading___Toc4684742)

6.11.1 Solution #11: Standardized UE Capability ID [42](#__RefHeading___Toc4684743)

6.11.1 Introduction [42](#__RefHeading___Toc4684744)

6.11.2 Functional Description [42](#__RefHeading___Toc4684745)

6.11.3 Procedures [43](#__RefHeading___Toc4684746)

6.11.4 Impacts on existing interfaces and entities [43](#__RefHeading___Toc4684747)

6.12 Solution #12: Bulk Provisioning of UE Radio Capability from AF [43](#__RefHeading___Toc4684748)

6.12.1 Introduction [43](#__RefHeading___Toc4684749)

6.12.2 Functional Description [43](#__RefHeading___Toc4684750)

6.12.3 Procedures [43](#__RefHeading___Toc4684751)

6.12.3.1 Bulk provisioning of UE Radio Capability [43](#__RefHeading___Toc4684752)

6.12.3.2 On-demand UE Radio Capability Information Retrieval from AF [45](#__RefHeading___Toc4684753)

6.12.4 Impacts on existing entities and interfaces [46](#__RefHeading___Toc4684754)

6.12.5 Evaluation [46](#__RefHeading___Toc4684755)

6.13.1 Solution #13: "Self-learning" logic for progressive building of a dictionary [46](#__RefHeading___Toc4684756)

6.13.1 Introduction [46](#__RefHeading___Toc4684757)

6.13.2 Functional Description [46](#__RefHeading___Toc4684758)

6.13.3 Procedures [47](#__RefHeading___Toc4684759)

6.13.4 Impacts on existing interfaces and entities [47](#__RefHeading___Toc4684760)

6.13.5 Evaluation [47](#__RefHeading___Toc4684761)

6.14 Solution #14: RAN mapping of 'Capability Pointer' to Full UE capability with Backward Compatibility [47](#__RefHeading___Toc4684762)

6.14.1 Introduction [47](#__RefHeading___Toc4684763)

6.14.2 Functional Description [48](#__RefHeading___Toc4684764)

6.14.3 Procedures [48](#__RefHeading___Toc4684765)

6.14.4 Impacts on existing entities and interfaces [48](#__RefHeading___Toc4684766)

6.14.5 Evaluation [48](#__RefHeading___Toc4684767)

6.15 Solution #15: Network assigned capability ID with AMFI and Hash fields [49](#__RefHeading___Toc4684768)

6.15.1 Introduction [49](#__RefHeading___Toc4684769)

6.15.2 Functional Description [49](#__RefHeading___Toc4684770)

6.15.3 Procedures [49](#__RefHeading___Toc4684771)

6.15.4 Impacts on existing entities and interfaces [50](#__RefHeading___Toc4684772)

6.15.5 Evaluation [51](#__RefHeading___Toc4684773)

7 Evaluation [51](#__RefHeading___Toc4684774)

8 Conclusions [51](#__RefHeading___Toc4684775)

Annex A: Maximum supportable information element size [55](#__RefHeading___Toc4684776)

Annex B: Change history [56](#__RefHeading___Toc4684777)

# 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

With the increase of the size of UE radio capabilities driven by additional bands supported by RAN specifications and UE support of significantly more band combinations, the size of the UE Radio Capabilities has and will significantly grow from Rel-15 onwards, an efficient approach to signal UE Radio Capability information is therefore needed.

This study item shall address two issues:

- Optimizations of system procedures pertaining to the transfer UE Radio Capabilities related information to RAN.

- Optimizations of system procedures related to transfer UE Radio Capabilities impacting the Core Network.

The overall goal is to study mechanisms to reduce the signalling over Uu, CN-RAN, CN-CN and RAN-RAN interfaces as well as the processing load in core and RAN (taking into account how frequently those message transfers and corresponding processing occurs) working in collaboration with RAN WGs for the related RAN interfaces and CT WG4 for the CN interfaces and NFs.

At minimum, the study shall consider the UE Radio Capabilities related aspects and any other optimisation which is deemed necessary in collaboration with RAN WGs. The study also considers scenarios where the UE radio capabilities change based on various events triggered in NAS (e.g. when certain services are not supported in one system/access and the UE wants to stay registered in another system/access, the UE may disable the radio capability for accessing the first system).

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 23.502: " Procedures for the 5G System".

[3] 3GPP TS 23.501:" System Architecture for the 5G System; Stage 2".

[4] 3GPP TS 23.222: "Common API Framework for 3GPP Northbound APIs".

[5] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification".

[6] 3GPP TS 33.501: "Security architecture and procedures for 5G System".

[7] 3GPP TS 23.401: "General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access".

[8] 3GPP TS 29.501: "5G System; Principles and Guidelines for Services Definition; Stage 3".

[9] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification".

# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] apply.

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] apply.

# 4 Architectural Requirements and Assumptions

## 4.1 Architectural Requirements

The solution for the UE radio capability signaling optimizations shall take the following requirements into account:

a) Solutions shall support UE Radio Access Capabilities > 65 536 bytes.

b) Solutions shall provide fast, reliable, low processing complexity mechanisms for frequently used procedures (at least Service Request, RRC Connection Resume, X2&Xn handover, secondary gNB addition).

c) The "UE Capability ID" should reflect the actual UE capabilities and not rely on parameters that may be faked, modified, or do not reflect the actual capabilities (e.g. IMEI and IMEISV might not fulfil this requirement)

NOTE: Even the same UE model with identical software version may have different UE capabilities e.g. due to customization based on vendor - operator agreements (sometimes the UE capabilities also differ depending on the PLMN the device roams on) and would therefore present different "UE Capability IDs" depending e.g. on the PLMN the UE roams.

d) The solution must ensure that malicious implementations (outside of the operator's network) do not update the network with incorrect UE Radio Capabilities that corresponds to UE capability ID that are used by other UE's.

e) Solution should be flexible enough to cope with additional UE capabilities that might be added by 3GPP in future releases.

f) Solutions should not require any GTPv2 based interface (e.g. N26, S10) to carry an Information Element of greater than 50 000 octets.

g) Solutions should not require any HTTP request or response based on TS 29.501 [8] (e.g. for N14) to carry an Information Element of greater than 124 000 octets.

NOTE: Annex A provides background information on this requirement.

## 4.2 Architectural Assumptions

Editor's note: This clause will define the underlying architectural assumptions.

# 5 Key Issues

## 5.1 Key Issue #1: How are the UE Radio Capabilities identified?

### 5.1.1 Description

In TSG SA#79 and TSG RAN#79 discussion took place on defining mechanisms for optimizing the UE radio capability signalling. RAN sent an LS to TSG SA (cc' SA WG2) indicating: "... conceptual work should be performed in SA WG2 and RAN WG2 (with potential involvement of other relevant WGs such as RAN WG3 and CT WG1) since the network should store and manage such UE capability IDs".

Some form of efficient signaling of the UE Radio Capabilities, is to be investigated, which may also rely on an efficient representation of UE capabilities.

Solutions shall take into account a device may have certain features upgraded, e.g. due to a new SW release, or disabling of certain radio capabilities.

The discussion in TSG RAN and SA WG2 previously considered some options for such efficient representation:

1. Using a hash function over the UE capability;

2. Using components or all of IMEI-SV, i.e., TAC + SVN;

3. Using a newly defined identifier.

Other options are possible and can be considered.

The study will also determine whether any identifier used for such efficient representation needs to be globally unique (i.e. standardised), or PLMN-specific or manufacturer-specific.

This key issue will investigate what is the most appropriate form of such efficient representation.

## 5.2 Key Issue #2: Where are the UE radio capabilities stored?

### 5.2.1 Description

In LTE/EPS and 5GS Rel-15, the UE radio capabilities are stored in the CN when the UE is in CM-IDLE and the following principles apply in terms of retrieval and storage of UE radio capabilities:

- The AMF/MME stores the UE Radio Capabilities that are forwarded by the RAN in a N2 or S1 message.

- When a UE establishes a connection, the AMF/MME includes the last received UE capabilities as part of the INITIAL CONTEXT SETUP REQUEST message sent to the RAN.

- Usually during handover preparation, the source RAN node transfers both the UE source RAT capabilities and the target RAT capabilities to the target RAN node, in order to minimize interruptions.

- UE radio capabilities are not transferred during inter-MME and from MME to AMF (and vice-versa) mobility but are transferred in inter-AMF mobility inside 5GC.

This key issue investigates whether, the UE radio capabilities will be stored in RAN or CN. The NF(s) where the UE radio capabilities are stored will be determined depending on the conclusions reached for key issue #3 "Management of UE radio capabilities", and specifically whether the signalling optimised scheme applies to 5G System only or both 5G System and EPS will need to be considered.

## 5.3 Key Issue #3: How are the UE radio capabilities managed?

### 5.3.1 Description

When some form of efficient representation of the UE Radio Capabilities that represents the actual UE Radio Capabilities is used, the existing procedures for signalling and retrieval of UE Radio Capabilities may be affected.

This key issue will study the procedures e.g. new procedures or changes in the existing procedures required in order to accommodate the signalling-optimised scheme in the management of UE radio capabilities.

Based on the solutions proposed for the procedures it will be decided as part of this key issue whether the signalling-optimised scheme applies only inside the 5G System or both in 5G System and EPS.

Any new or modified procedure (if needed) for UE radio capability retrieval shall co-exist with the Rel-15 mechanisms that apply in EPS and 5GS.

# 6 Solutions

## 6.1 Solution #1: UE manufacturer-specific UE capability ID

### 6.1.1 Introduction

This solution addresses Key Issue #1 (How are the UE capabilities identified?).

### 6.1.2 Functional Description

In this solution the UE Radio Capabilities are identified with a UE capability ID that has the following salient characteristics:

- The UE capability ID is a short pointer (e.g. 2-3 octets; the exact size is to be determined by RAN) that together with the UE manufacturer information (e.g.TAC field in the PEI) uniquely identifies a set of UE Radio Capabilities.

Editor's note: The detailed manufacturer information will be discussed in normative work.

- The UE manufacturer information uniquely identifies the UE manufacturer.

- The UE capability ID is assigned by the UE manufacturer.

- The UE is configured with one or more UE capability IDs that map into distinct set of UE Radio Capabilities.

- At any given instant the UE has only one UE capability ID that is indicated to the network.

- The UE capability ID identifies the UE radio capabilities set that can be specific to one or multiple RAT types.

### 6.1.3 Procedures

Solutions to other key issues will explain how the UE capability ID is used in relevant procedures.

### 6.1.4 Impacts on existing entities and interfaces

Solutions to other key issues will explain how the UE capability ID impacts existing entities and interfaces.

### 6.1.5 Evaluation

Editor's note: This clause provides an evaluation of the solution.

## 6.2 Solution #2: UE capability ID indicated in Access Stratum and N2

### 6.2.1 Introduction

This solution addresses Key Issues #2 (Where are the UE radio capabilities stored?) and X3 (How are the UE radio capabilities managed?).

### 6.2.2 Functional Description

This solution has the following salient characteristics:

- UE indicates the UE capability ID (e.g. as defined in clause 6.1) in initial access stratum signalling to the RAN node, which further conveys it to the AMF using N2 signalling.

- If there is no UE Radio Capabilities corresponding to the UE capability ID, an indication that the UE Radio Capabilities is not available is also conveyed to the AMF along with the UE capability ID.

- The dictionary used for translation of the UE capability ID *[possibly in combination with PEI or another parameter, depending on the solution to Key Issue #1]* into an explicit set of UE Radio Capabilities is stored in the AMF or in a stand-alone Network Function in the 5GC that can be queried by the AMF.

NOTE: The indication that the UE Radio Capabilities is not available is applicable when the UE radio capabilities are identified by means of the UE capability ID alone.

### 6.2.3 Procedures

If the UE is configured with one or more UE capability IDs, it provides one of these parameters in initial access stratum signalling. The UE capability ID and an optional indication that UE radio capabilities is not available is conveyed to the AMF in an N2 message.

The AMF uses the UE capability ID *[possibly in combination with PEI or another parameter, depending on the solution to Key Issue #1]* to retrieve the explicit set of UE Radio Capabilities. The explicit set of UE Radio Capabilities is stored locally in the AMF or is fetched from a stand-alone Network Function in the 5GC architecture.

If the indication that the UE radio capabilities is not available is received and if the AMF is successful with the retrieval, the AMF signals the explicit set of UE Radio Capabilities to the RAN in the N2 REQUEST message.

If the AMF is unable to retrieve the explicit set of UE Radio Capabilities corresponding to the UE capability ID *[possibly in combination with PEI or another parameter, depending on the solution to Key Issue #1]* or if the UE's radio capabilities is available in the RAN, the AMF shall not send any UE Radio Capability information to the RAN in that message. This triggers the RAN to request the UE Radio Capabilities from the UE and to upload it to the AMF using an N2 notification message.

### 6.2.4 Impacts on existing entities and interfaces

This clause illustrates the changes to existing procedures in TS 23.502 [2]. Only the impacted steps in the call flows are described. New text is provided in italics.

#### 6.2.4.1 Registration procedure



Figure 6.2.4.1-1: Registration procedure (same as TS 23.502 [2] Figure 4.2.2.2.2-1)

1. UE to (R)AN: AN message (AN parameters, Registration Request (Registration type, SUCI or 5G-GUTI or PEI, last visited TAI (if available), Security parameters, Requested NSSAI, [Mapping Of Requested NSSAI], UE 5GC Capability, PDU Session status, List Of PDU Sessions To Be Activated, Follow on request, MICO mode preference, Requested DRX parameters, UE support of Request Type flag "handover" during the attach procedure) and the list of PSIs).

*The AN parameters may also include a UE Capability ID.*

NOTE: The UE Capability ID can be included if the Registration type indicates Initial Registration or Mobility Registration Update.

3. (R)AN to new AMF: N2 message (N2 parameters, Registration Request (as described in step 1) and UE access selection and PDU session selection information).

*The N2 parameters also include the UE Capability ID if it was provided by UE in step 1.*

*When there is no UE radio capabilities corresponding to the UE capability ID in the RAN, the N2 parameters also includes an indication that the UE radio capabilities is not available.*

11. [Conditional] new AMF to UE: Identity Request/Response (PEI).

*If the UE Radio Capability ID was included in step 3 the AMF uses the UE Capability ID [possibly in combination with PEI or another parameter, depending on the solution to Key Issue #1] to determine the explicit UE Radio Capability based on preconfigured mapping information. When there is no UE radio capabilities corresponding to the UE Capability ID in the AMF, the determination of the UE Radio Capability may involve a query to a stand-alone NF that stores the translation dictionary. If the determination of the UE Radio Capability is successful the AMF stores the UE Capability ID and optionally the UE Radio Capability in the UE context, overwriting any existing stored values.*

21. New AMF to UE: Registration Accept (5G-GUTI, Registration Area, Mobility restrictions, PDU Session status, Allowed NSSAI, [Mapping Of Allowed NSSAI], [Configured NSSAI for the Serving PLMN], [Mapping Of Configured NSSAI], Periodic Registration Update timer, LADN Information and accepted MICO mode, IMS Voice over PS session supported Indication, Emergency Service Support indicator, Accepted DRX parameters, Network support of Interworking without N26).

*If the UE Radio Capability is available in the AMF, the UE Radio Capability is provided to NG-RAN by AMF and an indication that the UE radio capabilities is not available is received at step3, as part of the UE context in this step.*

Editor's note: It is FFS whether there is a benefit in sending the UE Radio Capability to NG-RAN earlier in this call flow.

#### 6.2.4.2 UE Triggered Service Request



Figure 6.2.4.2-1: UE Triggered Service Request procedure (same as TS 23.502 [2] Figure 4.2.3.2-1)

12. AMF to (R)AN: N2 Request (N2 SM information received from SMF, security context, AMF Signalling Connection ID, Handover Restriction List, Subscribed UE-AMBR, MM NAS Service Accept, list of recommended cells / TAs / NG-RAN node identifiers).

*If the UE Radio Capability is available in the AMF, the AMF adds the UE Radio Capability in the N2 Request message to the (R)AN nodes.*

#### 6.2.4.3 RAN retrieval of UE Radio Capability

Similar procedure already exists in TS 23.502 [2] clause 4.2.8a (UE Capability Match Request procedure). It is proposed here as a new stand-alone procedure for clarity.

*If the AMF has not provided the UE Radio Capability as part of establishment of UE context in the RAN, the RAN retrieves the UE Radio Capability over the radio interface and notifies the AMF using the N2 UE Capability Info Indication message.*



Figure 6.2.4.3-1: RAN retrieval of UE Radio Capability (new)

*1. If the (R)AN has not already received the UE radio capabilities from the AMF, the (R)AN requests the UE to upload the UE radio capability information.*

*2. The UE provides the (R)AN with its UE radio capabilities sending the RRC UE Capability Information.*

*3. The (R)AN sends the UE Radio Capability to the AMF. The AMF stores the UE Radio Capability without interpreting it for further provision to the (R)AN as per TS 23.501 [3] clause 5.4.4.1.*

### 6.2.5 Evaluation

Editor's note: This clause provides an evaluation of the solution.

## 6.3 Solution #3: Solution using Hash-based Identification of UE radio capabilities

### 6.3.1. Introduction

This solution addresses Key Issue 1: "How are the UE Radio Capabilities identified?"

### 6.3.2 Functional Description

The following solution proposes to use a HASH value to identify UE Radio Capabilities. The UE calculates a HASH value of the UE Radio Capabilities and sends the HASH value to network and the network will determinate if corresponding UE Radio Capabilities is already available. If the corresponding UE Radio Capability is not available then it needs to be retrieved from the UE. When the network receives the UE Radio Capabilities, RAN needs to calculate the HASH value in order to validate that the HASH value corresponds to the uploaded UE Radio Capabilities before accepting them.

The RRC Protocol defines how to signal the UE Radio Capability in TS 38.331 [5] for NR.

The HASH value is calculated of the ASN.1 coded representation of the UE radio capabilities using SHA (Secure Hash Algorithm) algorithm. The HASH value is used as UE Capability ID.

Editor's note: Which one of the different SHA families (SHA-2 or SHA-3) to use and which function within the hash family is FFS. The different versions differ in size of the hash and how secure it is calculated. For example, if 128 bit hash is used, which fits into current protocols, the probability for conflicts is very low. This needs to be evaluated with RAN and SA WG3.

The solution on Key Issue 2 will cover how the HASH value (UE Capability ID) is signalled between the UE and network. Solution on Key Issue 2 will also cover procedure how to signal the corresponding UE Radio Capability information from the UE to RAN if it is not available in the network.

NOTE: Different UE implementations may store the UE Radio Capability in different orders. UE's from different vendors, with the same radio capability, may have different hashes if the order of the capabilities is different.

Instead of a single HASH value (UE Capability ID), a list of one or more HASH values (UE Capability ID's) will be used, one for each sub-set of the UE Radio Capabilities. This also implies that when the UE sends a list of UE Capability ID's then the network will handle them one by one. For example, some of the UE Capability ID's and corresponding UE Radio Capabilities might be available in RAN or CN and the remaining UE Radio Capability ID's need to be downloaded again from the UE. It is the UE implementation that defines into which sub-set each UE Radio Capability IE belongs to and each sub-set has its own HASH value (UE Capability ID). If the size of each sub-set is less than current maximum allowed size defined by RAN then additional segmentation in RAN is not needed. Current size limitation defined by RAN PDCP frame size is 9000 octets for NR and 8188 octets for E-UTRA.

Option 1: With the assumption that each subset of UE Radio Capabilities is calculated with SHA-256 the probability is very low that two different UE Radio Capabilities have the same hash value so we do not specify any solution for that.

Option 2: The UE Capability ID is extended to also include a device manufacturer unique identifier, this could for example be the same as proposed in solution #1 to use the TAC code. The UE vendor also need to ensure that the two different UE Radio Capabilities does not have the same HASH value via re-arrange the order of the individual UE Radio Capabilities to ensure unique hash.

### 6.3.3 Procedures

Solutions to Key Issue 2 will define procedures on how the HASH value (UE capability ID) is used in relevant procedures and how RAN will retrieve UE Radio Capability from the UE.

The only addition in this solution is that after RAN has retrieved the UE Radio Capabilities then RAN needs to calculate the same HASH value to validate that the retrieved UE Radio Capabilities corresponds to the HASH value (UE Capability ID) before accepting it.

### 6.3.4 Impacts on existing entities and interfaces

Solutions to Key Issues 2 will explain how the UE capability ID impacts existing entities and interfaces. The only additional impact is that the UE and RAN needs to calculate the HASH value from the UE Radio Capability.

### 6.3.5 Evaluation

This solution supports that the network is protected against malicious updates of UE Capability ID's and corresponding UE Radio Capabilities.

This solution option1 does not accommodate for collisions especially about the network will be able to detect them. For instance, if the 64Kbyte radio capabilities of UE A produce after HASH a UE-Capability-1 of 256 bits, but UE B with different set of radio capabilities produce after HASH UE-Capability-1 the network will not be able to detect this collision without additional information. Even if such occurrence is rare, any occurence can lead impacted UEs of the same type being in continuous mis-operation or no service.

The Option 2 in the solution fully accommodate in preventing any hash collisions.The UE Capability ID is comprised of a UE manufacturer information (e.g. TAC field in the PEI) and the hash of the actual UE Radio Capability, allowing the vendor to ensure that no hash collisions is possible for different UE Radio capabilities.

## 6.4 Solution #4: Provisioning of UE Radio Capability using UDR

### 6.4.1 Introduction

The solution addresses key issue #2. It proposes that Application Function (e.g., owned by UE manufacturer, or operator) provisions to the UDR the representation of UE radio capability (e.g., UE Radio Capability ID) and corresponding UE radio capabilities. In this solution, the UE Radio Capability and corresponding UE Radio Capability ID compose the UE Radio Capability Information. The UDR can notify the UE Radio Capability Information to the AMF if the AMF subscribes change event of UE Radio Capability. Also this solution allows the AMF updates the UE Radio Capability Information to the UDR after the AMF resolves the capabilities, the identifier, and the association between them.

### 6.4.2 Functional Description

This solution has the following characteristics:

- AF provisions UE Radio Capability ID and corresponding UE Radio Capabilities to the Network.

- NEF exposes API for UE Radio Capability provisioning to the AF.

- NEF updates the UE Radio Capability Information to the UDR.

- UDR can notify the updated UE Radio Capability Information to the subscribed AMF.

- AMF is able to associate the UE Radio Capability ID and the full UE Radio Capabilities from the UE. AMF is also able to update the UE Radio Capability Information to the UDR.

### 6.4.3 Procedures

#### 6.4.3.1 Provisioning UE Radio Capability Information to UDR

In this clause, the procedure for provisioning of UE Radio Capability is described.



Figure 6.4.3-1: Provisioning of UE Radio Capability information to UDR

Editor's note: It is FFS whether to use existing service operation for this procedure.

1. The AMF triggers Nnef\_DM\_Subscribe service operation to the NEF in order to subscribe notification of the UE Radio Capability Information from the UDR. The UE Radio Capability Information is composed of the UE Radio Capability and corresponding UE Radio Capability Identifier. In the Nnef\_DM\_Subscribe service operation, the AMF indicates the type of data is for UE Radio Capability Information and includes its AMF ID to be identified by the UDR.

NOTE: In order to synchronize UE Radio Capability Information among AMFs in the PLMN, AMF should request subscription to UDR for the UE Radio Capability Information when the AMF is initiated.

2. The NEF triggers Nudr\_DM\_Subscribe service operation based on the information received in the step 1. The UDR performs authorization whether the AMF can subscribe notification of the UE Radio Capability Information. If authorized, the UDR stores received subscription request. If the UDR detects the AMF hasn't been notified any UE Radio Capability Information, the UDR may decide to provision all the UE Radio Capability Information stored in the UDR. In this case, the UDR can notify to the AMF with UE Radio Capability Information as in the step 8.

3. If there is new type of UE with different UE Radio Capabilities combination, the AF invokes Nnef\_RadioCapability\_Provisioning Request service operation to the NEF. The AF includes UE Radio Capability Information in this message. The AF can include set of UE Radio Capability Information if there are various type of UEs to provision UE Radio Capability Information.

In the case of architecture without CAPIF support, the AF is locally configured with the API termination points for this service operation. In case of architecture with CAPIF support, the AF obtains the service API information from the CAPIF core function as specified in TS 23.222 [4].

4. The NEF authorized the AF request based on the operator policy.

5. The NEF acknowledges the execution of Nnef\_RadioCapability\_Provisioning\_request..

6. The NEF invokes Nudr\_DM\_Update to the UDR. In this message, NEF includes the received UE Radio Capability Information from the step 3.

7. The UDR updates the UE Radio Capability. The UDR sends Nudr\_DM\_Update response to the NEF.

8. The UDR detects that the related subscription for notification of the updated UE Radio Capability Information. The UDR notifies to the NEF of the update UE Radio Capability Information by invoking Nudr\_DM\_Notify service operation. In this message, the UDR includes the update UE Radio Capability Information, and the AMF ID which needs to be notified.

9. The NEF triggers Nnef\_DM\_Notify service operation based on the information received in the step 8.

#### 6.4.3.2 Update and sharing of UE Radio Capability Information using UDR

In this clause, the procedure for update and sharing of UE Radio Capability is described.



Figure 6.4.3-2: Update of UE Radio Capability information to UDR and sharing to other AMF

1. During The UE performs registration NAS procedure (e.g., Registration procedure, Service Request procedure),. If the UE is configured with the UE Radio Capability IDs, it provides it in initial access stratum signalling. The UE Radio Capability ID is conveyed to the AMF in an N2 message.

2. If the AMF cannot figure out its explicit set of the UE Radio Capabilities corresponding to the UE Radio Capability ID received from the UE, the AMF.

If the NG-RAN doesn't have the UE Radio Capability for the UE, the NG-RAN performs RRC procedure to retrieve the explicit set of UE Radio Capabilities. If the NG-RAN has the UE Radio Capability for the UE, the NG-RAN provides the UE Radio Capabilities to the AMF. The AMF may decide to allocate UE Radio Capability ID (e.g., PLMN specific ID) or to use the received UE Radio Capability ID from the UE, if there is no mapping for the retrieved UE Radio Capabilities. The AMF associates the UE Radio Capabilities to the UE Radio Capability ID, and the AMF stores this information. The AMF provides the UE Radio Capability Information to the NG-RAN. If the AMF allocates new UE Radio Capability ID to the UE, the AMF performs UE Configuration Update procedure to provide the new UE Radio Capability ID.

NOTE 1: It is assumed that AMF can use allocation function of UE Radio Capability ID which may be located in centralized entity in order to avoid collision of UE Capability ID allocation. How AMF interacts with are out of scope.

2. The AMF invokes Nnef\_DM\_Update to the NEF. In this message, AMF includes the stored UE Radio Capability Information in the step 1. The NEF invokes Nudr\_DM\_Update service operation based on the received information from the AMF. The UDR updates the received UE Radio Capability Information. The UDR sends Nudr\_DM\_Update response with acknowledge of the update request.

NOTE 2: In order to avoid poisoning the UDR for UE Radio Capability Information, the UDR may consider counter for the received UE Radio Capability Information. If the received UE Radio Capability Information matches the one that was previously received by the Nudr\_DM\_Update service operation, the UDR increases a counter. If the counter reaches the threshold defined by the operator, the UDR stores the UE Radio Capability. Regardless of operation related to the counter, the UDR responds to the AMF with acknowledge of the update request.

3. The UDR detects that AMF 2 has subscribed for notification of the updated UE Radio Capability Information. The UDR notifies to the AMF 2 of the update UE Radio Capability Information by invoking Nudr\_DM\_Notify service operation to the NEF. In this message, the UDR includes the update UE Radio Capability Information. The NEF invokes Nudr\_DM\_Notify service operation to the AMF based on the received information from the UDR.

NOTE 3: It is assumed that AMFs in the PLMN have subscribed the notification of update of UE Radio Capability Information to UDR, in order to synchronize updated UE Radio Capability Information.

### 6.4.4 Impacts on existing entities and interfaces

NEF: New API exposure to AF for UE Radio Capability Information provisioning. New Nnef service operation to AMF for subscription and update of the UE Radio Capability Information. The NEF (supporting provisioning/subscribe/update/notification of UE Radio Capability Information) doesn't have to depend on deployment of other NEF features e.g., external exposure for monitoring event.

AMF: Use Nnef service for the UE Radio Capability Information Subscription and Update.

The AMF is able to associate unknown UE Radio Capability ID received from the UE with explicit set of the UE Radio Capabilities.

UDR: Need to update the UDR to support subscription/notification and update of the UE Radio Capability information (Table 5.2.12.2.1-1 in TS 23.502 [2] to be updated to add a new data set).

### 6.4.5 Evaluation

Editor's note: This clause provides an evaluation of the solution.

Solution #4 describes how UE Radio Capability IDs and the corresponding capabilities can be distributed to the AMFs of a network. The source of this information is an Application Function that can either be owned by the operator or, if a suitable relationship exists between them, a UE manufacturer. It provides a standardised, multi-vendor, way to ensure that manufacturer-assigned IDs and the associated capabilities are available as quickly as possible in the AMFs. This ensures that the AMFs are able to recognise such UE Radio Capability IDs when they are included in registration procedures by UEs and so to avoid the need to allocate and manage operator-assigned IDs for those UEs, and to avoid the need for the UE to provide its full capabilities during its initial registration.

Use of a subscribe/notify approach ensures that only those AMFs that require UE Radio Capability ID and corresponding UE Radio Capabilities receive them.

The solution also describes a mechanism for allowing a network to learn a new UE manufacturer-assigned ID directly from interaction with a UE. An AMF receiving an unknown UE manufacturer-assigned ID provides this to the UDR (via the NEF) and other AMFs in the network can be immediately updated with this ID. As described above this avoids the need to allocate and manage operator-assigned IDs for other UEs that subsequently use this ID, and avoids the need for those UEs to provide its full capabilities during initial registration. This procedure can be described as "self-learning", but carries the risk of the UDR database being poisoned by maleficent UEs. Mechanisms to avoid this are described in Solution #13.

## 6.5 Solution #5: UE radio capability reporting and management using UE-capability-ID

### 6.5.1 Introduction

Editor's note: This clause lists the key issue(s) addressed by this solution.

This is a solution for key issues #2 and #3.

UE radio capability reporting will initially consist of possible pre-configured UE-capability-ID as part of initial Registration procedure. If the UE is not configured with UE-capability-ID, it will not report any capability profile at initial Registration and wait for one to be allocated by the AMF when the UE radio capabilities are successfully retrieved.

There does not seem to be a requirement to support multiple UE-capability-IDs *simultaneously*, but it may be possible to allow the UE to support multiple profiles and select the profile with each connection establishment. For example, a voice centric and a data centric profile; the UE capabilities may change after an OTA upgrade; or the UE may need to switch between two capability profiles optimized for two different regions or areas frequently visited by the UE. Both profiles may be common across many UEs, that are using one or the other. Thus, there may not be an increase in memory/resource usage in the network when both capability profiles are already saved in the network.

Alternatively, when the capabilities change the UE can re-Register indicating to AMF that radio capabilities have changed using the "UE radio capability update" flag as defined in TS 23.501 [3], clause 5.4.4.1.

### 6.5.2 Functional Description

Editor's note: This clause outlines solution principles and documents any assumptions made.

For the UE capabilities reporting:

- If the UE has pre-configured one or more UE-capability-ID(s) either manufacturer assigned or PLMN specific it will report one of the UE-capability-ID(s) ciphered as part of the initial Registration procedure.

- The UE may update its UE-capability-ID e.g. when changing from voice to data centric (and vice versa) and report its updated UE-capability-ID in a new Registration procedure.

- The AMF tries to retrieve the UE capabilities corresponding to the UE-capability-ID UE has reported and (if successful) provides the UE capabilities to the RAN in the initial UE context setup.

- If the UE has no pre-configured UE-capability-ID, the UE reports nothing during the registration procedure.

- The AMF will not include UE capabilities in the initial UE context setup, and the RAN will query the capabilities as in Rel-15 procedures defined in TS 23.501 [3]. Then the AMF may assign a corresponding UE-capability-ID for subsequent reporting (once it receives the UE capabilities from the RAN in the UE Capability Info Indication message).

- The AMF may modify the UE-capability-ID associated with an existing set of UE capabilities.

- When the UE modifies the radio capabilities, the UE may optionally provide a new UE-capability-ID (if available) via NAS signaling, e.g., based on device upgrade.

### 6.5.3 Procedures

Editor's note: This clause describes high-level procedures and information flows for the solution.

The following figures show the detailed UE Radio capabilities procedures based on the description above:

- Figure 6.5.3-1 shows the call flow where the UE provides a UE-capability-ID as part of the registration procedure for the case where the network has the corresponding UE capabilities

- Figure 6.5.3-2 shows the call flow where either (a) the UE does not provides a UE-capability-ID as part of the registration procedure; or (b) the network does not have the corresponding UE capabilities.

- Figure 6.5.3-3 shows the call flow where the network modifies the UE-capability-ID.

- Figure 6.5.3-4 shows the call flow where the UE modifies the set of UE radio capabilities and the corresponding UE-capability-ID.



Figure 6.5.3-1: UE provides a UE-capability-ID as part of the registration procedure where the network has the corresponding UE radio capabilities



Figure 6.5.3-2: Either (a) UE does not provides a UE-capability-ID as part of the registration procedure; or (b) the network does not have the corresponding UE capabilities



Figure 6.5.3-3: Network modifies the UE-capability-ID with UE Configuration Update



Figure 6.5.3-4: UE modifies the set of UE capabilities and the corresponding UE-capability-ID

### 6.5.4 Impacts on existing entities and interfaces

Editor's note: This clause describes impacts to existing entities and interfaces.

UE, AMF and NG-RAN need to support the procedures indicated in this solution.

### 6.5.5 Evaluation

Editor's note: This clause provides an evaluation of the solution.

This solution assumes UE sending the UE Capability ID in NAS (initial registration procedure) in ciphered form and as such provides protection.

## 6.6 Solution #6: UE capability ID indicated in Access Stratum and N2 and local RAN Storage

### 6.6.1 Introduction

This solution addresses Key Issues #2 (Where are the UE radio capabilities stored?) and #3 (How are the UE radio capabilities managed?).

This solution targets the use of UE Capability IDs that are standardized whereby the UE Capability ID uniquely identifies a set of UE Radio Capabilities. The UE provides a UE Capability ID and optionally a complementary set of UE Radio Capabilities that together identify the usable set of Radio Capabilities of a UE i.e. the Radio Capabilities the UE wishes to use in the network. Similar to Solution #2, this solution proposes the dictionary of UE Capability IDs be stored in the Core Network, but in addition enables local RAN storage as well.

### 6.6.2 Functional Description

This solution has the following salient characteristics:

- UE indicates the UE capability ID and optionally a complementary set of UE Radio Capabilities in initial access stratum signalling to the RAN node, which further conveys these to the AMF using N2 signalling.

- The dictionary used for translation of the UE capability ID into an explicit set of UE Radio Capabilities is stored in the AMF or in a stand-alone Network Function in the 5GC that can be queried by the AMF and locally stored (replicated) in the (R)AN.

- The AMF stores as part of the UE context, the UE capability ID and, if received, the complementary set of UE Radio Capabilities.

### 6.6.3 Procedures

If the UE is configured with one or more UE capability IDs, instead of providing its full UE Radio Capabilities, it provides one of these UE Capability IDs and optionally a complementary set of Radio Capabilities (if applicable) in initial access stratum signalling to the RAN. The UE capability ID and the optional complementary set of Radio Capabilities are then conveyed to the AMF in an N2 message.

The AMF uses the received UE capability IDto retrieve the associated explicit set of UE Radio Capabilities from the dictionary. Retrieval is either done locally in the AMF or fetched from a stand-alone Network Function in the 5GC architecture depending on where the dictionary is hosted.

If the AMF is successful with the retrieval i.e. the UE Capability ID is in the dictionary, the AMF signals the associated explicit set of UE Radio Capabilities to the RAN in the N2 REQUEST message.

If the AMF is unable to retrieve the explicit set of UE Radio Capabilities corresponding to the UE capability ID, the AMF shall not send any UE Radio Capability information to the RAN in that message. This triggers the RAN to request the UE Radio Capabilities from the UE and to upload it to the AMF using an N2 notification message.

When setting up the UE context upon registration (update) the AMF stores:

- The UE Capability ID or the associated explicit set of UE Radio Capabilities; and

- if available, the complementary set of Radio Capabilities.

### 6.6.4 Impacts on existing entities and interfaces

This clause illustrates the changes to existing procedures in TS 23.502 [2]. Only the impacted steps in the call flows are described. New text is provided in italics.

#### 6.6.4.1 Registration procedure



Figure 6.6.4.1-1: Registration procedure (same as TS 23.502 [2] Figure 4.2.2.2.2-1)

1. UE to (R)AN: AN message (AN parameters, Registration Request (Registration type, SUCI or 5G-GUTI or PEI, last visited TAI (if available), Security parameters, Requested NSSAI, [Mapping Of Requested NSSAI], UE 5GC Capability, PDU Session status, List Of PDU Sessions To Be Activated, Follow on request, MICO mode preference, Requested DRX parameters, UE support of Request Type flag "handover" during the attach procedure) and the list of PSIs).

*The AN parameters may also include a UE Capability ID and optionally a complementary set of UE Radio Capabilities.*

*NOTE 1: The UE Capability ID, complementary set of UE Radio Capabilities can be included if the Registration type indicates Initial Registration or Mobility Registration Update.*

3. (R)AN to new AMF: N2 message (N2 parameters, Registration Request (as described in step 1) and UE access selection and PDU session selection information).

*The N2 parameters also include the UE Capability ID and optionally a complementary set of UE Radio Capabilities, if provided by the UE in step 1, as well as an indication whether or not the UE Capability ID is known by the RAN.*

11. [Conditional] new AMF to UE: Identity Request/Response (PEI).

*If the UE Radio Capability ID was included in step 3 the AMF uses the UE Capability ID [possibly in combination with PEI or another parameter, depending on the solution to Key Issue #1] to determine the corresponding explicit UE Radio Capabilities based on preconfigured mapping information (i.e. disctionary). The determination of the UE Radio Capability may involve a query to a stand-alone NF that stores the translation dictionary. If the determination of the UE Radio Capabilities is successful the AMF stores in the UE context the UE Capability ID and optionally the associated UE Radio Capabilities, as well as the complementary set of UE Radio Capabilities, overwriting any existing stored values for this UE.*

21. New AMF to UE: Registration Accept (5G-GUTI, Registration Area, Mobility restrictions, PDU Session status, Allowed NSSAI, [Mapping Of Allowed NSSAI], [Configured NSSAI for the Serving PLMN], [Mapping Of Configured NSSAI], Periodic Registration Update timer, LADN Information and accepted MICO mode, IMS Voice over PS session supported Indication, Emergency Service Support indicator, Accepted DRX parameters, Network support of Interworking without N26).

*If the UE Radio Capabilities corresponding to the UE Capability ID are available in the AMF, the UE Radio Capabilities are provided to NG-RAN by AMF as part of the UE context in this step in case NG-RAN indicated in step 3 that the UE Capability ID was unknown.*

Editor's note: It is FFS whether there is a benefit in sending the UE Radio Capability to NG-RAN earlier in this call flow (similar to Solution #2).

#### 6.6.4.2 UE Triggered Service Request



Figure 6.6.4.2-1: UE Triggered Service Request procedure (same as TS 23.502 [2] Figure 4.2.3.2-1)

1. UE to (R)AN: AN message (AN parameters, Service Request (List Of PDU Sessions To Be Activated, List Of Allowed PDU Sessions, security parameters, PDU Session status)).

*The UE provides its UE Capability ID as part of the AN parameters.*

*NOTE: This is used by the RAN with local storage capabilities to request the corresponding set of UE Radio Capabilities if unknown. Alternatively the AMF could keep track of whether or not the UE Capability ID (as part of the UE Context it holds) is known to the RAN, depending on the version of the dictionary the AMF knows the RAN to hold.*

2. (R)AN to AMF: N2 Message (N2 parameters, Service Request, UE Context request).

*If the UE Capability ID received from the UE is unknown to the (R)AN, the RAN provides an indication to the AMF together with the UE Context request to request the associated set of UE Radio Capabilities from the AMF.*

12. AMF to (R)AN: N2 Request (N2 SM information received from SMF, security context, AMF Signalling Connection ID, Handover Restriction List, Subscribed UE-AMBR, MM NAS Service Accept, list of recommended cells / TAs / NG-RAN node identifiers).

*In the N2 Request message to the (R)AN nodes, the AMF includes, if available and if requested by the (R)AN in step 2, the set of UE Radio Capabilities associated to the UE Capability ID of the UE. It also includes if available the complementary set of UE Radio Capabilities of the UE.*

#### 6.6.4.3 RAN retrieval of UE Radio Capability

Similar procedure already exists in TS 23.502 [2] clause 4.2.8a (UE Capability Match Request procedure). It is proposed here as a new stand-alone procedure for clarity.

*If the AMF has not provided the UE Radio Capability as part of establishment of UE context in the RAN, the RAN retrieves the UE Radio Capability over the radio interface and notifies the AMF using the N2 UE Capability Info Indication message.*



Figure 6.6.4.3-1: RAN retrieval of UE Radio Capability (new)

*1. If the (R)AN has not already received the UE Radio Capabilities from the AMF for this UE, the (R)AN requests the UE to upload the UE radio capability information.*

*2. The UE provides the (R)AN with its UE Radio Capabilities sending the RRC UE Capability Information.*

*3. The (R)AN sends the UE Radio Capability to the AMF. The AMF stores the UE Radio Capability alongside the UE Capability ID of the UE, for further provision to the (R)AN as per TS 23.501 [3] clause 5.4.4.1.*

#### 6.6.4.4 Local (R)AN Storage of dictionary

This procedure describes how the primary dictionary and updates thereof recording the associations between UE Capability IDs and UE Radio Capabilities can be provided by the Core Network to the (R)AN for local storage. This procedure articulates around the following points:

- The primary (parent) dictionary is stored in the Core Network (AMF or dedicated NF)

- The dictionary is pushed to the RAN by the Core Network when necessary

Editor's note: This clause is a placeholder. The procedure if FFS.

### 6.6.5 Evaluation

Editor's note: This clause provides an evaluation of the solution.

## 6.7 Solution #7: Retrieve UE Radio Capability and store it in AMF per UE Capability ID

### 6.7.1 Introduction

This solution address Key Issue #2 and Key Issue #3.

NOTE: The details of the NGAP signalling will be specified in coordination with RAN3.

### 6.7.2 Functional Description

During Registration procedure, the UE includes UE Capability ID in NAS Registration Request, message as a non-cleartext IE ensuring that the information is encrypted when transmitted over the radio interface::

- NG-RAN includes in the NGAP INITIAL UE MESSAGE carrying the NAS Registration Request, support for UE Capabilities ID handling indicator;

NOTE: Whether support for UE Capability ID handling is indicated at each Idle/Connected transition or at NG setup procedure will be decided in coordination with RAN3.

- at subsequent initial context setup, the AMF includes UE Capability ID and an indicator whether the associated UE Radio Capabilities are available in the AMF in the NGAP INITIAL CONTEXT SETUP REQUEST message.

- If the NG-RAN did not indicate to AMF that it supports UE Capabilities ID handling and the UE Radio Capabilities associated with the UE Capability ID received in the NAS Registration Request message are available in the AMF, then the AMF includes the UE Radio Capabilities in the NGAP INITIAL UE CONTEXT SETUP REQUEST message.

- If the NG-RAN indicated to AMF that it supports UE Capabilities ID handling, then at reception of the NGAP INITIAL CONTEXT SETUP REQUEST message, NG-RAN verifies if the UE Radio Capabilities indicated by the UE Capability ID are available in the NG-RAN;

- If the UE Radio Capabilities indicated by the UE Capability ID are neither available in the NG-RAN nor in the AMF, NG-RAN retrieves the UE Radio Capabilities from the UE, stores it in in NG-RAN if supported and stores it in the AMF;

- If the UE Radio Capabilities indicated by the UE Capability ID are indicated as available in the AMF but are not available in the NG-RAN, NG-RAN retrieves the UE Radio Capabilities from the AMF and stores it in in NG-RAN;

- When the AMF receives the UE Radio Capability for the UE Capability ID from the NG-RAN, the AMF stores this info independent of the UE Context, and this info will be used for later other UEs with the same UE Capability ID.

- If available, which means that the UE Radio Capability for this UE Capability ID has been retrieved earlier, then the available info will be used for this UE. The AMF includes both UE Radio Capability and UE Capability ID to the NG-RAN in NGAP INITIAL CONTEXT SETUP message when required.

### 6.7.3 Procedures

### 6.7.3.1 Registration

The existing procedure (i.e. clause 4.2.2.2.2) in TS 23.502 [2] is reused, and only changes to the existing steps are described.

**4.2.2.2.2 General Registration**



Figure 4.2.2.2.2-1: Registration procedure

1. UE includes UE Capability ID in NAS Registration Request message as a non-cleartext IE, see TS 33.501 [6]. NG-RAN indicates to AMF whether NG-RAN supports UE Capability ID handling.

NOTE: If there is no shared security context between the UE and AMF, non-cleartext IEs of the NAS Registration Request will be provided to the AMF in NAS Security Mode Complete message in step 9.

### 6.7.3.2 Retrieval of UE Radio Capability



Figure 6.7.3-1: AMF request RAN to retrieve UE Radio Capability

0. The UE Capability ID is stored in the AMF during Registration.

1. When there is a need for the AMF to send NGAP INITIAL CONTEXT SETUP REQUEST e.g. at Service Request, and if the NG-RAN indicated support for UE Capabilities ID handling in the NG-RAN,, the AMF includes UE Capability ID and indicates if the UE Radio Capabilities for the UE Capability ID are available in the AMF.

If NG-RAN did not indicate that it supports UE Capabilities ID handling and the UE Radio Capabilities are available in the AMF, AMF includes the UE Radio Capability ID and the UE Radio Capabilities.

1a. NG-RAN responds with NGAP INITIAL CONTEXT SETUP RESPONSE.

2. If the UE Radio Capabilities are not available in NG-RAN and AMF indicates UE Radio Capabilities availability, NG-RAN retrieves the UE Radio Capabilities from the AMF.

3. If the UE Radio Capabilities are not available in NG-RAN and not available in AMF,NG-RAN to requests the UE to upload the UE radio capability information associated with UE Capability ID.

4. The UE provides the NG-RAN with its UE radio capabilities associated with the UE Capability ID sending the RRC UE Capability Information.

5. The NG-RAN sends the UE Radio Capability to the AMF. The AMF stores the UE Radio Capability associated with the UE Capability ID.

This information will be used for all UEs using the same UE Capability ID.

### 6.7.4 Impacts on existing entities and interfaces

Impacted entities:

UE: Include UE Capability ID in Registration Request message as a non-cleartext IE;

AMF:

Indicates UE Capability ID and UE Radio Capabilities availability using NGAP INITIAL CONTEXT SETUP including UE Capability ID but not including UE Radio Capabilities;

Store UE Radio Capabilities for a UE Capability ID on NF level instead of on UE Context level, and use this info for all UEs using the same UE Capability ID;

Includes both UE Radio Capabilities (if available) and UE Capability ID in NGAP INITIAL CONTEXT SETUP REQUEST REQUEST.

NG-RAN:

Retrieve UE Radio Capabilities and UE Capability ID from the UE.

Upload the UE Radio Capability using NGAP UE Capability Info Indication message.

Impact on interface:

5GC-NAS

NGAP

RRC

Editor's note: Impact on NG-RAN is to be confirmed by RAN group.

### 6.7.5 Evaluation

Editor's note: This clause provides an evaluation of the solution.

The solution provides a way to signal the UE Capability ID integrity protected and encrypted over the air. This will improve security, since unencrypted UE Capability ID's might reveal information that could be used maliciously.

Also, the AMF will be able to receive the UE Capability ID even if the current gNB does not support FS\_RACS. This may save memory in the AMF, and if the UE moves to a gNB that does support FS\_RACS, it will be possible to make full use of the feature.

Compared to the alternative when the UE Capability ID is signalled with RRC, the gNB will receive the capabilities with some delay, since the gNB will receive the UE Capability ID after registration is complete. However, the capability ID will only have to be received from the UE at initial registration, so this is not expected to have any practical impact.

## 6.8 Solution #8: Solution for identifying UE radio capabilities using PLMN-specific UE Capability ID

### 6.8.1 Introduction

Editor's note: This clause lists the key issue(s) addressed by this solution.

The following requirements apply to this solution:

1. It shall be possible to optionally identify the UE capabilities with a manufacturer assigned identifier (as in solution #1 of the present document)

2. If manufacturer assigned identifier is not used, a PLMN specific one can be used by serving AMF

3. It shall be possible for the network or the device to change the UE Capability ID associated with a device, e.g., due to a SW upgrade enabling new capabilities on the device side or for remapping or OAM procedures in the network side.

UE Capability ID format is split in two name/number-spaces:

- Globally assigned by UE manufacturer as in solution #1 - Operator specific - this could be preconfigured by operators as part of device certification, or assigned by the operator the first time any UE reports these capabilities on the network

Additionally, the UE Capability ID may be permanent or semi-statically associated with a device. Since a device may have certain features upgraded, e.g., due to a new SW release, a more flexible approach would be to allow the capability-profile-ID to be semi-statically defined and not associated with a permanent device ID such as IMEI.

### 6.8.2 Functional Description

Editor's note: This clause outlines solution principles and documents any assumptions made.

UE radio capabilities are identified by a newly defined UE Capability ID. The format of UE Capability ID is split in

1. A manufacturer specific (as in sol.1 of TR 23.743) UE Capability ID(s) can be optionally configured in the UE e,g. upon manufacturing.

2. If UE is configured with Manufacturer specific UE Capability ID, UE reports that at initial Registration in a PLMN based on capabilities it wants to use.

3. Serving PLMN AMF:

i. if it has access to mapping of Manufacturer specific UE Capability ID to radio capabilities can provide stored radio capabilities to RAN.

ii. if it does NOT have access to mapping of Manufacturer specific UE Capability ID or does not want to use it can query the UEs radio capabilities and then provide an PLMN specific UE Capability ID for future indications e.g. using UE Configuration Update as defined in Figure 6.5.3-3.

4. If UE is configured with PLMN-specific UE Capability ID it provides the PLMN specific one on this PLMN only.

5. Else if UE is not configured with any UE Capability ID, query capabilities and then provide a PLMN specific UE Capability ID for future indications.

If memory for storing UE radio capabilities is a concern, it is up to AMF implementation to provide the same PLMN specific UE Capability ID to multiple different UEs with the same radio capabilities e.g. same model/manufacturer.

NOTE: How long the same PLMN-specific UE Capability ID can be kept in the UE and AMF depends on local operator policy.

### 6.8.3 Procedures

Editor's note: This clause describes high-level procedures and information flows for the solution.

None.

NOTE: How to handle PLMN specific UE Capability ID in case there is no PLMN-wide support of certain UE radio capabilities and RAN filtering is applied will be resolved in key issues 2 and 3.

### 6.8.4 Impacts on existing entities and interfaces

Editor's note: This clause describes impacts to existing entities and interfaces.

UE, NG-RAN, and CN (if radio capabilities are stored there) will have to manage UE radio capabilities using UE Capability ID.

### 6.8.5 Evaluation

Editor's note: This clause provides an evaluation of the solution.

This solution builds on top of solution 1 and allows UE Capability ID to be assigned by (serving) PLMN if Manufacturer UE Capability ID is not used.

## 6.9 Solution #9: UE Capability ID with delta set of UE Radio Capabilities

### 6.9.1 Introduction

This solution addresses Key Issue #1 "How are the UE Radio Capabilities identified?" using a combination of a UE Capability ID (manufacturer specific, standardized or PLMN specific) and of an optional explicit delta set of UE Radio Capabilities to represent a full usable set of UE Radio Capabilities.

The use of a delta set of UE Radio Capabilities enables:

- *Simplifying* the definition and management of UE Capability IDs and their dictionary to focus on "basic" sets of UE Radio Capabilities.

*- Differentiating* between UE vendors supporting the same UE Capability ID(s)

A delta set of UE Radio Capabilities allows, together with a UE Capability ID, indicating a full usable set of UE Radio Capabilities that cannot otherwise be represented by this UE Capability ID alone. A corollary is that a delta set of UE Radio Capabilities can then be exploited to avoid explicitly sending a full usable set of UE Radio Capabilities when a UE Capability ID is available in the UE but that is not able to represent this set.

NOTE: This may be the case e.g. when the UE holds a PLMN-assigned UE Capability ID1 but wishes to use a different set of radio capabilities for which it has no assigned UE Capability ID2 - in this case the UE only needs to signal UE Capability ID1 with a delta set in order to signal the capabilities it wishes to use as opposed to signalling the full set of capabilities.

Editor's note: The feasibility to define a delta set of UE Radio Capabilities is under study in RAN2.

### 6.9.2 Functional Description

The functional characteristics of this solution are the following:

- A UE Capability ID uniquely identifies a set of UE Radio Capabilities.

- This UE Capability ID together with optionally a delta set of UE Radio Capabilities identify the usable set of UE Radio Capabilities of a UE.

- At any point in time the UE uses at most a single UE Capability ID and optionally a delta set of UE Radio Capabilities

NOTE 1: The usable set of UE Radio Capabilities may not necessarily be the full set of UE Radio Capabilities the UE features. The UE may hold one or more UE Capability IDs and corresponding optional one or more complementary sets of UE Radio Capabilities, among which it can choose a suitable combination that it wishes to use as applicable.

NOTE 2: The delta set of UE Radio Capabilities is never identified by a UE Capability ID.

### 6.9.3 Procedures

Impact to procedures for using a delta set of UE Radio Capabilities together with a UE Capability ID are documented in clause 6.6.3 - where a UE Capability ID is signalled, a delta set of UE Radio Capabilities can be signalled as an option.

### 6.9.4 Impacts on existing entities and interfaces

Impact to existing entities and interfaces are documented in clause 6.6.4

### 6.9.5 Evaluation

From a signalling standpoint:

- The use of a UE Capability ID with a delta set of UE Radio Capabilities is more efficient than the use of a full explicit set of UE Radio Capabilities

- The use of a UE Capability ID alone is more signalling efficient than that of a UE Capability ID with a delta set of UE Radio Capabilities

A UE may have one or more UE Capability IDs available, but none able to represent the full set of UE Radio Capabilities it wishes to use at a given time. In this case, a delta set can be used together with this a UE Capability ID in order to avoid signalling this full set explicitly.

The use of a delta set of capabilities allows to use the benefits of the UE Capability ID to limit the signalling load, whenever a UE Capability ID is available in the UE (that is known to the network) regardless whether this UE Capability ID corresponds exactly to the set of radio capabilities the UE wants to use.

Delta signalling requires associated complexity to signal both the UE Capability ID and the delta set, store them in the UE context and combine the delta set and the UE Capability ID's set into a complete set.

When delta signalling is used with a manufacturer allocated UE Capability ID, the delta signalling will be applied as long as the UE uses radio capabilities not exactly corresponding to an available UE Capability ID. This will result in less signalling load compared to providing radio capabilities without a UE Capability ID. It requires the associated complexity and processing to use the delta set. A delta set is never used if a UE Capability ID exists that corresponds exactly to the UE radio capabilities the UE intends to use.

NOTE: Whether support for delta signalling in combination with manufacturer assigned UE Capability ID is needed is not concluded

When delta signalling is used with a PLMN allocated UE Capability ID, the delta signalling will be applied to update the network with the radio capabilities not exactly corresponding to the available UE Capability ID until a new UE Capability ID is assigned to the UE. This will result in less signalling load compared to providing radio capabilities without a UE Capability ID. It requires the associated complexity and processing to use the delta set. A delta set is never used if a UE Capability ID exists that corresponds exactly to the UE radio capabilities the UE intends to use.

Not using a delta set systematically imposes to fall back to explicitly signalling the set of UE Radio Capabilities the UE wants to use whenever no UE Capability ID is available that corresponds exactly to this set of capabilities.

## 6.10 Solution #10: Solution based on network-controlled capabilities sending and UE Capability ID allocation

### 6.10.1 Introduction

This solution assumes that the network controls what UE Radio Capabilities the UE sends. The network may also allocate UE Capability IDs, i.e. a shorthand representation of the UE radio capabilities for the indication of UE radio capabilities. The system entities (including UE) are mutually aware of the ability of their peers to support the RACS feature and can fall back to Re1-15 operation if a peer is not supporting the feature. The main principles of the solution are:

1) Network controlled sending of UE radio capabilities (so UEs would provide the capabilities the network requests based on operator specific policy). To do so the network indicates to the UE a UE Radio Capability Form (URCF) the UE stores. The URCF is valid PLMN-wide and is PLMN-specific unless different PLMNs agree on using same URCF.

2) The UE would respond to the UE capability Enquiry from RAN including a URCF based on what the network requests

3) The network allocates UE Capability ID for the UE Radio Capabilities indicated by a UE.

4) The allocation of UE Capability IDs is optional if the network does not foresee that the capabilities indication from the UE would exceed a certain number of Octets the PLMN is comfortable to handle without UE Capability IDs.

5) The solution proposal also proposes how to distribute URCF and UE Capability IDs system-wide and detect support of the feature in UE and network elements.

The solution, like all others where sending of radio capabilities from UE is expected at some point, may require segmentation of UE radio capabilities over the Radio interface, if the URCF may result in a UE radio capability indication exceeding the PDCP maximum payload size. This is in scope of RAN WGs to assess.

### 6.10.2 Functional Description

The Network provides the UE with information on which UE Radio Capabilities the network is interested the UE to indicate support of by means of a UE Radio Capabilities Form (URCF). This is an evolution of the filtering mechanisms defined already in RAN TSs which need to be discussed together with RAN WGs.

Editor's note: It is to be discussed with RAN WGs whether a single URCF and matching UE Capability ID per UE is used in a signalling transaction or multiple can be used at the same time (e,g, if the overall capabilities filtering is based on RAT etc. and multiple RAT capabilities are sent in one transaction, then multiple URCFs and related Capability Id may be needed).

The URCF for a UE is valid PLMN-wide and is operator defined based on own criteria. The advantage vs. a local validity at a RAN node is that there is in principle no need to indicate the UE radio capabilities more than once in a PLMN, and this helps with mobility vs. a solution where URCF had a local validity.

A URCF that indicates the UE to provide all its radio capabilities can also be defined, if this is the operator policy, i.e. a URCF encoding may also be defined by 3GPP to ask the UE to provide all its capabilities, if so desired. This is particularly handy e.g. for UEs that are supposed to support few capabilities (e.g. a simple IoT device), or if an operator prefers to pull all the UE capabilities rather than a specific subset it is interested in.

A UE may store the URCF for a PLMN for future use.

Different URCF types may be defined in a PLMN. The PLMN Operator decides which URCF to provide to a UE based on its own criteria.

The URCF is signalled alongside a version number and type of the URCF. The radio capabilities the UE sends report also the version of URCF and its type if it has received one from the PLMN, i.e. the UE provides, the capabilities to the network based on the received URCF (if the network provides one), or using the traditional way to signal the capabilities (if the network does not provide a URCF).

It shall be possible for a network which uses the URCF to create UE Capability IDs of UE radio capabilities by UEs, so the UE and the network nodes can use this instead of sending the UE capabilities info based on URCF all the time. The UE Capability IDs are centrally managed by a URCF Management function (UMF). The UE Capability IDs can then be used to indicate, alongside the URCF version number and type, the UE radio capabilities in a very succinct way. Note that multiple UE Capability IDs can he used by a single UE for same URCF depending on various settings it may operate with, which may cause a different indication of UE radio capabilities to the network. If a UE has no UE Capability ID in a certain setting/configuration, it sends the capabilities based on URCF and it may receive a UE Capability ID from the PLMN.

A UE stores the latest URCF and related UE Capability IDs for the H-PLMN. It may also store the URCF and related UE Capability IDs for other PLMNs it visits. The UE Capability ID can be used among network nodes to exchange the UE radio capabilities values as part of the UE context, if the peer is known to support the feature. If a peer does not support the feature, the UE radio capability info for the UE is provided using to the peer by using the Rel-15 encoding. In a network where not every node supports the URCF and UE Capability IDs, the AMF an NG-RAN shall be ready to receive the capabilities using the rel-15 method for the UE.

When the URCF changes for a PLMN, the UE and network nodes erase the old URCF-related UE Capability IDs.

### 6.10.3 Procedures

1) When the interfaces between NG-RAN nodes (see figure 6.10.3-2) and between NG- RAN and the AMF (see figure 6.10.3-1) are established, the current URCF types and their version is exchanged, if the nodes have one. The URCFs with the higher version number prevails if peers exchange the same URCF type with different version number over Xn. If no URCF is available, a node that supports the feature indicates its support, e.g. by an empty URCF with version zero (this is a stage three decision). If a peer node is detected to not support the feature, then the Rel-15 UE Radio capability information exchange is used with the peer function/entity (i.e. UE radio capabilities for a UE are exchanged between network entities based on the Rel-15 specifications).



Figure 6.10.3-1: N2 setup includes the AMF providing the RAN with URCF information



Figure 6.10.3-2: Xn setup includes URCF handshaking

2) A URCF may be updated by the CN towards the RAN nodes (see figure 6.10.3-3) at any time with an indication of when this is going to be a valid URCF (so there is an absolute time when the change happens network-wide).



Figure 6.10.3-3: The AMF provides new URCF to the RAN, when one becomes available

Neighbouring RAN nodes may also handshake on a common understanding of the URCF (see figure 6.10.3-4).



Figure 6.10.3-4: When a RAN node receives a new URCF, it may provide it to the Xn peers to handshake

3) When a new URCF is introduced in the PLMN, all CN nodes invalidate the locally stored information for the UEs that use these, so this causes the UE to provide a new UE RAN capability the next time they transition to connected mode. A UE in connected mode continues to be handled with the current UE Radio capabilities until it receives a UE configuration update message or a Registration Accept informing a new URCF has been introduced. If so, the UE obtains a URCF by entering idle mode, registering including a "UE Radio Capability Update" indication, and the network will provide it with the new URCF upon triggering the UE Capabilities Enquiry. Network nodes should be able to handle UEs that remain in connected mode and so understand recent URCF types and versions. If a UE is RRC inactive, a change of URCF causes release of the UE with indication that URCF has changed, unless the UE is known to not support RACS.

4) When the UE registers, it declares the version and type of the URCF it knows for the PLMN or its support of the feature if it has no URCF yet. If the UE knew already a UE Capability ID of its current Radio capabilities, it provides it also. If the UE does not support the feature then Rel-15 Operation is used with the UE. If a new URCF version is available for the UE, the network provides an indication to the UE a new URCF is available in the registration accept, so that the UE stops using the current URCF and related UE Capability IDs.

5) UE support of the RACS feature is indicated towards the RAN by the AMF by inclusion of the URCF type used for the UE, when the AMF sends an Initial Context Setup Request message to establish the context in the RAN without the UE Radio capabilities, so the RAN knows whether to use the URCF feature in the UE capability enquiry or not. The AMF also signals whether the UE has no (current version of) URCF yet. See figure 6.10.3-5.



Figure 6.10.3-5: AMF indicates the RAN the UE supports URCF handling and whether it has no current URCF

6) If the UE supports the feature, but does not have a (current) URCF, the UE is provided with one in the RRC UE Capability Enquiry by the NG-RAN.

7) If the UE supports the feature and the current URCF is provided or is already stored in the UE when it receives the RRC UE Capabilities Enquiry, the UE shall report its capabilities based on the URCF in the RRC UE Capabilities Information, or possibly with a UE Radio capability UE Capability ID if the network already provided one for the currently active UE Radio Capabilities.

8) When the UE supporting the feature responds with a UE Capabilities Information based on URCF, the NG-RAN provides this to the CN using a N2 UE Capability Info Indication. See figure 6.10.3-6. The UE Capability Enquiry includes a URCF if the RAN is informed that the UE has no current URCF.



Figure 6.10.3-6: UE Capability enquiry including passing URCF to the UE

9) If the AMF, if it receives no UE Capability ID in the UE Capabilities Info Indication from the NG-RAN, it queries the UMF to obtain a UE Capability ID. The UMF provides the UE Capability ID (either new or existing one, depending on whether a match with existing UE Capability ID and related capabilities was detected by UMF). The NG-RAN shall be provided with the UE Capability ID via a UE context modification request (see figure 6.10.3-7).



Figure 6.10.3-7: the AMF provides a UE Capability ID for a UE context

The AMF is always assisted by an external centralised entity in the PLMN for the task of allocating and managing and allocation UE Capability IDs and managing the URCFs (the URCF Management Function, UMF).

10) When the NG RAN node obtains a UE Capability ID, it provides it to the UE, and locally stores only the UE Capability ID as a reference to the UE capabilities, and the mapping to its meaning is retained so other UE contexts for other UEs can refer to it. See figure 6.10.3-8 where the RAN can proceed to update UEs with UE Capability ID when their capabilities for the URCF they use matches the UE Capability ID definition. This step may be initiated locally by the RAN when it has a UE Capability ID, for all applicable UEs.



Figure 6.10.3-8: The RAN provides the UE Capability ID of its Capabilities for the current URCF

11) The UE Radio capability info UE Capability ID, if already known in the RAN, is immediately configured in the UE and sent to the AMF even if the UE provided capabilities without using a UE Capability ID yet. See figure 6.10.3-9 which summarises both the case where the UE already knows a UE Capability ID, and the case where the UE does not yet know it, but the RAN has a UE Capability ID matching the UE capabilities.



Figure 6.10.3-9: The RAN immediately provides the UE with a UE Capability ID it is aware of, and needs only to pass the UE Capability ID to the CN

12) If a UE Radio Capabilities Info UE Capability ID is not understood by an AMF, it can be resolved from the UMF which stores the URCF(s) and the related UE Capability IDs. See figure 6.10.3-10.



Figure 6.10.3-10: resolution of an unknow UE radio Capabilities UE Capability ID

13) If an AMF receives no UE Capability ID from the UE that is RACS capable and used the URCF to send the UE RAN capabilities in the UE radio Capability Info, it may request the UMF to allocate a UE Capability ID (see figure 6.10.3-11). When a UE Capability ID is allocated the point 9 procedure is then followed.



Figure 6.10.3-11: Allocation of a UE Capability ID

14) AMFs may subscribe to UE Capability ID Allocation information. This may be useful when a new UE Capability ID is created so resolution step is avoided. The UE Capability ID includes the URCF type and version it relates to.



Figure 6.10.3-12: subscribe/notify service allowing an AMF to receive UE Capability IDs

15) The AMF may update all its attached RAN nodes with the UE Capability ID's information it receives from the UMF via an AMF Configuration Update message.



Figure 6.10.3-13: AMF provides new UE Capability ID to a RAN node

16) NG-RAN nodes may handshake on the support of new UE Capability IDs received from the AMF or peer NG-RAN nodes.



Figure 6.10.3-14: a NG-RAN node may update its neighbouring NG-RAN nodes on a new UE Capability ID

17) If a NG-RAN node receives an unknown UE Capability ID from the UE in a RRC UE Capability Information message, then the NG-RAN node can request the mapping to related radio capabilities from AMF as shown in figure 6.10.3.15. The AMF, if it does not know the mapping, it gets it from the UMF.



Figure 6.10.3-15: A NG-RAN node provides a capabilities UE Capability ID to the AMF and requests resolution to the related UE radio capabilities

### 6.10.4 Impacts on existing entities and interfaces

AMF: Support of URCF and UE Capability ID handling.

NG-RAN: Support of handling of URCF and UE Capability IDs.

UE: Support of handling of URCF and UE Capability IDs.

### 6.10.5 Evaluation

Benefits:

- The solution is designed to handle fully backward compatibility between RAN and CN, between RAN nodes, between RAN and UE, between CN and UE.

- It offers the UE Capability ID mechanism as a way to optimise the transport of the UE Radio capabilities information in UE contexts quite significantly in both the CN and the RAN, it offers a succinct way for UEs to provide the UE Radio Capability Info over the Radio Interface.

- It is fully open and not UE vendor dependent, it is fully network controlled and there is no need to provision a database with UE vendor specific information or maintaining it explicitly with the encoding of UE Capability IDs, as the UE Capability IDs can be automatically created and managed by UMF.

- The URCF setting policy can be defined by the operator. An operator may tune at will what it is according to its criteria.

- A PLMN-wide self-configuration of URCF in network nodes and UE Capability IDs is defined to avoid OAM based provisioning.

Requirement:

- A new function needs to be introduced in the network to coordinate the allocation of UE Capability IDs and provide resolution/distribution of unknown/new UE Capability IDs and or URCFs.

## 6.11.1 Solution #11: Standardized UE Capability ID

### 6.11.1 Introduction

This solution addresses Key Issue #1 "How are the UE Radio Capabilities identified?" using a standardized UE Capability ID. It is related to Solution #6.

### 6.11.2 Functional Description

The functional characteristics of this solution are the following:

- The UE Capability ID uniquely identifies (i.e. points to) a set of UE Radio Capabilities.

NOTE 1: The size of the UE Capability ID should be determined by RAN2 as a function of the number of anticipated *realistic* combination of Radio Capabilities - a handful of octets are deemed sufficient

- The UE Capability ID is standardized.

NOTE 2: GSMA/3GPP are considered viable candidates for such effort

- The UE Capability ID and optionally a complementary set of UE Radio Capabilities identify the usable set of UE Radio Capabilities of a UE.

NOTE 3: The usable set of UE Radio Capabilities may not necessarily be the full set of UE Radio Capabilities the UE features. The UE may hold one or more UE Capability IDs and corresponding optional one or more complementary sets of UE Radio Capabilities, among which it can choose a suitable combination that it wishes to use as applicable.

### 6.11.3 Procedures

To be addressed under Key Issue #3.

### 6.11.4 Impacts on existing interfaces and entities

To be addressed under Key Issues #2 and #3.

## 6.12 Solution #12: Bulk Provisioning of UE Radio Capability from AF

### 6.12.1 Introduction

The solution addresses key issue #2. It proposes that the AF provisions to the AMF via NEF the representation of UE radio capability (e.g., UE Radio Capability ID) and corresponding UE radio capabilities. In this solution, UE Radio Capability Information is composed of the UE Radio Capability and corresponding UE Radio Capability ID. The NEF provisions the UE Radio Capability Information to the AMFs in the PLMN by using bulk provisioning method. The AMF can retrieve the UE Radio Capability information from AF via NEF if AMF has no UE Radio Capability Information stored.

### 6.12.2 Functional Description

This solution has the following characteristics:

- The AF is integrated with the data base for UE Radio Capability Information, in which the information can be provided by UE manufacture or operator. The AF is able to provision UE Radio Capability Information (UE Radio Capability ID and corresponding UE Radio Capabilities) to the AMF(s). The AMF can trigger the API for UE Radio Capability provisioning if the UE Radio Capability information is updated.

- The NEF exposes API for UE Radio Capability provisioning to the AF. The NEF authorizes that the AF provisions the UE Radio Capability Information.

- The NEF retrieves AMF address from the NRF.

- The NEF performs bulk provisioning to all AMFs in the PLMN.

- The AMF exhibits service operation for UE Radio Capability Provisioning. Consumer of this service operation is NEF.

- The AMF can retrieve the UE Radio Capability information from AF via NEF if AMF has no UE Radio Capability Information stored.

### 6.12.3 Procedures

#### 6.12.3.1 Bulk provisioning of UE Radio Capability

In this clause, the procedure for bulk provisioning of UE Radio Capability is described.



Figure 6.12.3-1: Bulk Provisioning of UE Radio Capability information to AMFs

1. The AF triggers Nnef\_RadioCapability\_Provisioning Request service operation to the NEF. The AF includes UE Radio Capability Information in this message. The UE Radio Capability information is composed of UE Radio Capabilities and the corresponding identifier (e.g., UE Radio Capability ID). The AF can include multiple sets of UE Radio Capability Information.

If CAPIF is not supported, the AF is locally configured with the API termination points for this service operation. If CAPIF is supported, the AF obtains the service API information from the CAPIF core function as specified in TS 23.222 [4].

2. The NEF authorized the AF request based on the operator policy.

3. The NEF acknowledges the execution of Nnef\_RadioCapability\_Provisioning\_request. The NEF stores the received UE Radio Capability Information in order to provision to AMFs in the PLMN after invoking NF discovery service operation. The NEF may cache the UE Radio Capability Information provisioned by the AF.

4. The NEF invokes Nnrf\_NFDiscovery\_Request to the NRF. In this message, the NEF indicates NF Type as AMF. The NEF includes the expected NF service name for the provisioning request (i.e., Namf\_Provisioning service operation).

5. The NRF authorizes the Nnrf\_NFDiscovery\_Request. If allowed, the NRF provides the set of address of discovered AMFs to the NEF via Nnrf\_NFDiscovery\_Request Response message. The NEF stores the set of address of AMFs.

The NEF can register with the NRF for any newly registered AMF by invoking Nnrf\_NFStatus\_Subscribe. If NEF gets notified from the NRF for the newly registered AMF in the PLMN, the NEF can trigger Namf\_Provisioning\_Request service operation in order to provide the cached UE Radio Capability Information to the AMF.

6. Based on the information of the discovered AMFs in the PLMN from step 5, the NEF invokes bulk Namf\_Provisioning\_Request to discovered AMFs in order to provision UE Radio Capability Information. In this message, one or set of UE Radio Capability Information received from the step 3 are included.

NOTE: Namf\_Provisioning service operation is not per UE operation.

7. The AMF stores the received UE Radio Capability Information. The AMF acknowledges to the NEF by sending Namf\_Provisioning\_Response. The AMF uses the UE Radio Capability Information to identify UE Radio Capability when UE requests registration with UE Radio Capability ID.

8. The NEF may notify to the AF that the UE Radio Capability Information is successfully provisioned to the all AMF in the PLMN, based on the local policy.

If the AF is trusted in the PLMN and allowed to invoke Namf\_Provisioning service operation, the AF can directly use Nnrf service operation to discover AMFs and can directly use Namf service operation to provision the UE Radio Capability Information.

#### 6.12.3.2 On-demand UE Radio Capability Information Retrieval from AF

This section applies in the case that the AMF has no UE Radio Capability Information or cannot derive UE capabilities according to the capability ID received from the UE (e.g. the database is not up to date). The AMF acquires UE Radio Capability Information from the AF via NEF. This procedure ensures the AMF always has up to date UE Radio Capability information.



Figure 6.12.3-2: On-demand UE Radio Capability from AF

1. UE provides UE capability ID and AF information e.g. manufacture information or PLMN information to the AMF.

2. AMF receives the UE capability ID and the AF information, e.g. manufacture information, and obtains UE capabilities according to the stored UE Radio Capability Information for the received UE Capability ID for this AF.

3. If AMF has no UE Radio Capability Information for the AF information or cannot derive UE capabilities according to the capability ID received from the UE, the AMF acquires UE Radio Capability information from the AF via NEF. The AMF requests from the NEF UE Radio Capability Information, and if the NEF has the UE Radio Capability Information, then NEF responds to the AMF.

Regardless of step 1 and step 2, if AMF determines that the stored UE Radio Capability Information is not up to date then based on local configuration, the AMF can trigger step 3 to retrieve the up to date UE Radio Capability Information from the AF.

4-5. If the NEF does not have the UE Radio Capability Information, the NEF requests the AF to provide the UE Radio Capability Information, and the AF provides the UE Radio Capability Information based on the request.

NOTE: The NEF is expected to support CAPIF functions for external exposure if the AF is the third party.

6. The NEF stores the newly provisioned UE Radio Capability Information and responses to the AMF.

7. AMF based on the newly provisioned UE Radio Capability Information, derives UE Radio Capability and transfers to the RAN if applicable.

### 6.12.4 Impacts on existing entities and interfaces

NEF: new API exposure for UE Radio Capability Information provisioning. The NEF can cache the UE Radio Capability Information received by the AF to provision to the AMF. The NEF can store the address of AMFs in the PLMN after querying to the NRF.

AMF: new Namf service to allow for requesting and provisioning of UE Radio Capability Information. AMF can trigger service operation to retrieve UE Radio Capability Information from the AF.

### 6.12.5 Evaluation

The AF provides the UE Radio Capability Information to the related AMFs via bulk provisioning method when the AF generates or updates the UE Radio Capability Information. This method decreases the O&M configuration cost for the operator. And on-demand retrieval from AF can provide the AMF up to date UE Radio Capability Information if the AMF has no such information. Otherwise, the AMF will retrieve UE explicit radio capabilities form the UE, which will cost extra Uu and N2 interface signalling.

Step 4/5 of the procedure described in 6.12.3.2 that, the AF (if owned by the operator) could allocate a PLMN-specific UE capability ID if the ID provided by the UE is not known, or if no UE capability ID is provided by the UE. This provides a centralised way for the operator to allocate PLMN-specific IE capability IDs that are unique.

The database of UE Radio Capability Information is part of the AF in this solution, Use of the AF for this could reduce the amount of signalling in the network as it enables to provision the information to all AMFs proactively.

## 6.13.1 Solution #13: "Self-learning" logic for progressive building of a dictionary

### 6.13.1 Introduction

This solution is an add-on solution that can be combined with other solutions in this TR. It proposes a logic for progressive building of a dictionary (UE capability ID <=> radio capability) in the network and is particularly targeting the manufacturer-based UE capability ID, as defined in Solution #1.

### 6.13.2 Functional Description

When manufacturer-based UE capability ID is used (as proposed in Solution #1), the network can progressively build the dictionary in a "self-learning" process, as described below:

- Upon connection to the network the UE indicates the manufacturer-based UE capability ID and the network queries a DataBase (DB).

- If the DB does not recognize the UE capability ID, the network requests the UE to explicitly signal the radio capability. The network forwards the explicitly signalled capability to the DB, which stores it and tags the corresponding UE capability ID as being "under validation". The validation process is needed in order to prevent fraudulent or misbehaving UEs from poisoning the dictionary DB.

- When subsequently another UE indicates the same manufacturer-based UE capability ID, the network proceeds in the same way. If the explicitly signalled radio capability matches the one that was previously reported to the DB by other UE(s), the DB increases a counter. This step is repeated until an operator-defined threshold is reached for the counter.

- When the operator-defined threshold is reached, the UE capability ID is tagged in the DB as "validated".

- For UEs that subsequently indicate the same UE capability ID, the network queries the DB, but does not request the UE to explicitly signal its capabilities because the UE capability ID is tagged as "validated".

The logic and the counter described above are collocated with the dictionary DataBase (DB). The DB location will be determined as part of other solutions (e.g. could be a new NF in the Core Network).

In some cases the network may apply region-specific filters in RAN leading the UE to report only a subset of its capabilities. In such cases the UE can still indicate the manufacturer-based UE capability, and in addition:

- When the network queries the DB with the UE capability ID, it also indicates the UE location.

- When the network requests the UE to explicitly signal the radio capability, the network forwards the explicitly signalled capability to the DB with an indication that this is a "partial" capability.

- The validation logic in the DB is similar to the one described earlier, except that it is performed on regional basis (e.g. the validation counters are specific to a region).

### 6.13.3 Procedures

To be addressed as part of other solutions.

### 6.13.4 Impacts on existing interfaces and entities

To be addressed as part of other solutions.

The specification impact of this solution is limited to tagging of a UE capability ID as "validated" on the interface with the DB (in replies from the DB). For instance, if the DB is a standalone NF in the 5GC network, the "validated" tagging applies to the UE capability ID parameter signalled on the AMF-DB interface in the DB=>AMF direction.

To support RAN caching, the "validated" tag needs to be supported on N2 in the AMF=>RAN direction.

To support region-specific filters in RAN, a "partial" tag needs to be applied to the explicitly signalled capability at least on the interface between AMF and DB in the AMF=>DB direction.

### 6.13.5 Evaluation

This is an add-on solution that can be combined with other solutions.

The self-learning logic can be applied regardless whether the master dictionary is in the CN or in the OAM plane.

The self-learning logic can be applied in centralized manner (one master dictionary per PLMN) or distributed manner (one master dictionary per region or per node). The centralized manner obviously provides overall savings in terms of signalling volume on the radio, however, it may require standardization of backend interfaces for dissemination of information that is used for validation purposes.

NOTE: The self-learning principles of this solution require SA WG3 clearance before the normative aspects of this solution described in clause 6.13.4 can be progressed.

## 6.14 Solution #14: RAN mapping of 'Capability Pointer' to Full UE capability with Backward Compatibility

### 6.14.1 Introduction

This is a Release 16 study. Hence the interaction with Rel-15 NG-RAN/AMF and pre-Rel-16 E-UTRAN/MME needs to be considered.

In this proposal, backward compatibility solutions are based on mechanisms developed as part of the rSRVCC from GERAN to E-UTRAN work, and the Rel-15 CR that allows the MME to assist with handover from UTRAN to E-UTRAN (CR 3423r5 to TS 23.401 [7]).

In this solution, the UE supplies the network with a "fallback UE radio capability" IE as well as a "Capability Pointer". The "fallback UE radio capability" can be used by Rel-16 CN nodes when communicating with pre-Rel-16 RAN nodes. The use of a "fallback UE radio capability" avoids pre-Rel-16 RAN nodes needing to retrieve a "full" UE Radio Access Capability over the radio interface.

The UE ensures that the "fallback UE radio capability" is sufficiently small to be carried by the legacy interfaces (e.g. is less than 2500 bytes). The mechanism by which the UE selects which capabilities to include in the "fallback UE radio capability" is left to the UE implementation.

This solution uses a RAN cache to map between the "Capability Pointer" (which could be e.g. the "TAC+config-ID") and the Full UE Radio Access Capability.

The UE is pre-configured (or Over The Air updated) with one, or more likely, a set of "Capability Pointers". The different "Capability Pointers" could be used to correspond to when e.g. 2G or 3G or MBMS is enabled/disabled.

### 6.14.2 Functional Description

1) At N2 and S1 (interface) Setup, the RAN and MME/AMF exchange information on whether they support the "new Rel-16 mechanism".

NOTE 1: Knowledge of the MME/AMF support level is useful in the RAN node when the RAN node is connected to a mix of supporting and non-supporting MMEs or AMFs.

2) Using the existing Release 8 EPS/Release 15 5GC Attach/Registration procedures, the Updated UE provides the Updated MME/AMF with the "Capability Pointer" and a "fall back" UE Radio Access capability (rather than the Full UE Radio Access Capability).

NOTE 2: If the UE is in very poor coverage at Attach time, a "reduced size" fall back capability could be provided, and the UE waits until it moves into normal coverage to provide the regular "fall back capability".

3) The Updated RAN performs the mapping between "Capability Pointer" and the Full UE Radio Access Capability.

How the Updated RAN node gets the information to do this mapping is independent of this proposal (e.g. via RAN O&M; the UE; new N2/S1 UE-non-associated procedure; enquiry to EIR; etc.), although if it is obtained from the UE, some extra signalling will be used to differentiate the Full Capability from the Fallback Capability).

4) In the Service Request (and other UE-specific N2/S1 connection establishment) procedures, the Updated MME/AMF provides an Updated RAN node with only the e.g. "Capability Pointer" and NOT the Full (or "fall back") UE Radio Access Capability.

5) In the S1/N2 handover procedures, Updated RAN nodes only send the e.g. "Capability Pointer".

- If the Updated target MME/AMF knows (from step 2) that the target RAN node is not updated, then the MME/AMF adds the "fall back" UE Radio Access capability.

- if the target MME/AMF and target RAN node are both not updated (and the MME does not support Rel-15 CR 3423r5 to TS 23.401 [7]), then the target RAN node can obtain the UE Radio Access Capability from the UE (as in the case of rSRVCC from GERAN to E-UTRAN).

6) At X2/Xn (interface) Setup, the RAN nodes exchange information as to whether they support the "new Rel-16 mechanism".

At X2/Xn handover; secondary node addition for dual connectivity; and RRC Resume the 'source' RAN node uses this 'support' information to determine whether to only send the "Capability Pointer", or, to send the Full UE Radio Access Capability.

NOTE 3: The exact details of X2/Xn handover and secondary node addition are for RAN WGs.

7) Path Switch signalling with the MME/AMF following X2/Xn handover from a legacy RAN node to an Updated RAN node allows the MME/AMF to send the "Capability Pointer" to the Updated RAN node for use in its subsequent procedures.

### 6.14.3 Procedures

These can be readily derived from the previous clause.

### 6.14.4 Impacts on existing entities and interfaces

MME, AMF, eNB, NG-RAN are impacted.

UE is impacted in sending the "fallback UE radio capability", as well as the "capability pointer".

### 6.14.5 Evaluation

The use of a "fallback UE radio capability" of relatively modest size (e.g. < 2500 bytes) for inter-RAT / inter-CN node handover:

a) avoids other signalling procedures for other UEs being queued and delayed by the attempted transmission of large UE Radio Access Capabilities to a legacy node.

b) avoids a large UE Radio Access Capability having to be "not sent" by the source RAN node (owing to legacy and/or R15 signalling interface constraints) and the target RAN node then having to systematically retrieve that large UE Radio Access Capability across the new cell's radio resources.

c) allows pretty accurate radio resource allocation by the target RAN node and less service discontinuity in the case that a large UE Radio Access Capability has to be "not sent" by the source RAN node.

Conversely, the use of a fallback capability means that a pre-Rel-16 RAN node that can handle larger UE radio capabilities might not utilise the UE's full performance.

Updating the X2, Xn, S1 and N2 interface "Setup" signalling to exchange information on the support level for the RACS feature is an essential Release 8 Self Organising Network concept.

Updating the Path Switch signalling between RAN and MME/AMF allows for a mix of upgraded and non-upgraded RAN nodes to be handled effectively over X2/Xn interfaces.

## 6.15 Solution #15: Network assigned capability ID with AMFI and Hash fields

### 6.15.1 Introduction

Editor's note: This clause lists the key issue(s) addressed by this solution.

The solution addresses key issue #1, #2 and #3. It is an add-on to solution #5 and #8: Solution for identifying UE radio capabilities using PLMN-specific UE Capability ID. It describes how the capability ID's can be allocated, assigned to UE's and managed by the AMF's in a distributed manner.

### 6.15.2 Functional Description

Editor's note: This clause outlines solution principles and documents any assumptions made.

The PLMN assigned UE capability ID is made up of three fields:

\* AMFI (AMF Identifier) - 3 Byte: The AMFI of the AMF that allocated the capability ID.

\* Hash - e.g. 3 bytes long: A hash of the UE capabilities.

\* Enumerator - i.e. 2 bits - If the AMF have allocated several capability ID's for different capability sets with the same Hash, the enumerator is used to separate them.

When an UE makes the first initial registration to the PLMN with a specific set of capabilities, the serving AMF may assign an UE Capability ID to the UE. If the capability set is in the mapping database of the AMF, the same capability ID will be used, and if not, the AMF will allocate a new capability ID with its own AMFI, and assign it to the UE.

The mapping databases in the AMF's and gNB's will be updated dynamically as UE's move in the network.

Duplicate capability ID's will occur when different AMF's have assigned capability ID's defining the same set of capabilities. Duplicates will be removed continuously to limit database size.

### 6.15.3 Procedures

Editor's note: This clause describes high-level procedures and information flows for the solution.

When an UE makes the first initial registration to the PLMN with a specific set of capabilities, the network will request the capabilities from the UE. The AMF will then calculate the Hash, and compare it to the Hash of capability ID's stored in its database. If there is no entry with the Hash, the AMF will allocate a new capability ID consisting of the AMFI, Hash and an enumerator. The AMF will assign the capability ID to the UE and add an entry to the mapping database.

If there is already one or more entries with the same Hash, the AMF will compare the stored capabilities with the capabilities from the UE in a bit-wise manner. If it corresponds to an already stored capability, the corresponding cap ID will be assigned to the UE. If there is no corresponding capability stored, the AMF will assign the UE a new capability ID consisting of the AMFI, Hash and an enumerator.

When setting the enumerator, the AMF will use the value 0 if the AMF have not previously allocated ID's with the same hash, and for later allocated capability ID's for different capability sets with the same hash, the enumerator is increased.

It is not required that the rest of the network is updated when a new Capability ID is allocated. If the UE, moves to another AMF through handover or idle mode mobility, and the target AMF does not have the mapping, the capabilities will be transferred from the old AMF, and the new AMF will store the mapping. If the UE makes an initial registration including Capability ID to a new AMF that does not have the mapping, the network will receive the capabilities from the UE, using legacy functionality, or the AMF may request it from the AMF that allocated the Capability ID.

If several UE's with the same capability, i.e. UE's of the same model and settings, registers to the PLMN for the first time, at about the same time, but to different AMF's, there may be several capability ID's allocated for the same capability set. This is acceptable, and the cap ID's are valid. However, in order to minimize the size of mapping tables, duplicates should be removed when possible. The AMF will be able to detect duplicates, and remove them by this method:

When a new mapping is stored in the database, the AMF will control if there are other mappings with the same hash. If there is, the old and the new capabilities are compared in a bit-wise manner, and if there are identical capabilities with different cap ID's, duplicates are detected. The node will select which capability ID to use based on the enumerator and the AMFI. The cap ID with lowest enumerator will be selected. If the enumerator is the same, the cap ID is selected based on the AMFI, using a pre-defined priority order. The capability ID not selected will be marked as obsolete in the database, and linked to the selected cap ID. All UE's using the obsolete capability IE's will be re-assigned the selected cap ID.

Also the gNB may detect duplicates and re-assign capability ID's, using the same method.

In order to avoid that the number of allocated capability ID's grows unlimited, it should be allowed for the network to re-cycle capability ID's that have not been used for a long time. In order to allow that, an expire time should be defined for the capability ID's. e.g. if an UE have not used a specific network assigned capability ID for X months, the UE should delete the ID.

Legacy UE's may also be assigned UE Capability ID's using this solution. In that case, the capability ID will not be signalled to the UE, and the UE will have to transmit the UE Capabilities at every registration, so there is no resource saving over the air, but the ID will be included in the UE Context at HO and idle mode mobility, so transmission time will be saved on the X2 and N2 interfaces, and memory may be saved for storing the capabilities. Also the gNB may save processing time since it will not have to parse the full capabilities.

### 6.15.4 Impacts on existing entities and interfaces

Editor's note: This clause describes impacts to existing entities and interfaces.

Impacts of Capability ID signalling is dependent on which solution is used for signalling of the capability ID.

Impacts for defining capability ID's, assigning it to UE's and maintaining and updating the database are:

UE: The UE should be prepared to be allocated an UE Capability ID. If several ID's have been allocated for the same set of capabilities, the latest assigned shall be used.

AMF: The AMF is responsible of defining UE Capability ID's, assign it to UE's and manage a database of UE Capability mappings.

When changing AMF at handover or idle mode mobility, the UE Capability set should be transferred to the new AMF if needed. It could either always be included in the UE context, together with the UE capability ID, or only the capability ID is sent. In that case, if the mapping is not known by the AMF, the gNB could request the capabilities from the UE using the legacy methods, or a new functionality could be standardized for the AMF to request the mapping, either from the old AMF, or from the AMF that assigned the capability ID.

Also, at registration, if the mapping of the UE capability ID is not known by the gNB or AMF, the gNB could use the legacy method to request the capabilities from the UE, or the AMF could request if from the AMF that assigned the capability ID.

Also legacy UE's may be assigned UE Capability ID's using the same method. In that case, the UE capability ID will not be signalled to the UE, but it will be included in the UE Context.

### 6.15.5 Evaluation

Editor's note: This clause provides an evaluation of the solution.

The solution provides a method to assign PLMN specific capability ID's in a distributed manner, so that each AMF may allocate capability ID's independently with no need for a central database. The AMFI of the PLMN specific capability ID needs to be standardized for multi-vendor deployment scenarios.

For deployments of distributed Radio capability databases or multiple UE capability ID allocating network entities not part of AMF, an alternative where an identifier to the allocating entity is included in the ID can be considered as a variant of the solution described here.

The Hash part of the ID ensures an effective data-base lookup with a quick way to find the capability ID of a specific set of capabilities. The solution also provides a method to easily find and remove duplicate entries if different AMF's have allocated capability ID's for the same set of capabilities.

The solution will require that the AMF can verify if sets of radio capabilities are identical or not, i.e. will increase AMF processing.

The solution causes increased signalling volume on AMF to AMF interface and may run into issues with maximum information element size.

# 7 Evaluation

Editor's note: This clause will provide a general evaluation of the solutions.

In the case when a UE Capability ID is available in the UE (that is known to the network), but this UE Capability ID does not correspond exactly to the set of radio capabilities the UE wants to use, solution #9 (UE Capability ID with delta set of capabilities) enables to benefit from the UE Capability ID by limiting the signalling load in the system, since only a delta set is signalled together with a UE Capability instead of the full explicit set of capabilities. This solution requires associated complexity for signalling and storing the UE Capability ID and a delta set, as well as for combining the corresponding capabilities into a full set of capabilities.

# 8 Conclusions

For key issue #1 (How UE radio capabilities are identified?) the following principles are agreed:

- The UE capability ID is a short pointer (few octets, the exact size is to be determined by RAN WG2) that is used to uniquely identify a set of UE Radio Capabilities;

- The UE capability ID is assigned either by the serving PLMN or by the UE manufacturer, as follows:

- *Manufacturer-specific:* The UE Capability ID may be assigned by the UE manufacturer in which case it is accompanied with the UE manufacturer information (e.g. TAC field in the PEI). In this case, the UE Capability ID uniquely identifies a set of UE Radio Capabilities for this manufacturer, and together with this UE manufacturer information uniquely identify this set of UE Radio Capabilities in any PLMN;

- *PLMN-specific:* If a manufacturer-assigned UE Capability ID is not used by the UE or the serving network, or it is not recognised by the serving network, the serving core network may allocate UE Capability IDs for the UE corresponding to different sets of UE Radio capabilities the PLMN may receive at different times from the UE. In this case, the UE Capability IDs the UE receives are applicable to the serving PLMN and uniquely identify the corresponding sets of UE Radio Capabilities in this PLMN;

- The type of UE Capability ID (Manufacturer-specific or PLMN-specific) needs to be distinguished when a UE Capability ID is signalled;

NOTE 1: Which one of Manufacturer-specific or PLMN-specific and associated procedures for assignment are mandatory or optional in the UE, will be decided in normative phase of the work.

- When the UE Capability ID is allocated by the serving PLMN the same PLMN-specific UE Capability ID can be provided to multiple different UEs with the same radio capabilities or different PLMN-specific UE Capability ID can be provided to multiple different UEs with the same radio capabilities. The strategies for allocating PLMN-specific UE Capability ID are based on local policy;

NOTE 2: When the UE Capability ID is allocated by the serving PLMN, the method that the core network detects that the same UE Radio Capabilities are signalled by multiple different UEs or the same "model" in order to allocate the same PLMN-specific UE Capability ID from SA2 point of view is left up to implementation or can be decided by RAN.

- The network indicates to the UE whether the assigned PLMN-specific UE Capability ID is also valid in equivalent PLMNs (as per the EPLMN list).

- The UE stores the PLMN-specific UE Capability ID in non-volatile memory when in RM-DEREGISTERED state and can use it again when it registers in the same PLMN and if applicable, in equivalent PLMNs thereof. The UE shall keep track of the set of UE Radio Capabilities associated with each of the assigned PLMN-specific UE Capability ID.

NOTE 3: It is assumed that UE does not need to store the access stratum information (i.e. UE-EUTRA-Capability and UE-NR-Capability specified in TS 36.331 [9] and TS 38.331 [5], respectively) that was indicated by the UE to the network when the PLMN-specific UE Capability ID was assigned by the network. This assumption is to be reviewed based on RAN WG2 conclusions on the feasibility of Solution #9 (UE Capability ID with delta set of capabilities).

- The number of PLMN-specific UE Capability IDs that UE stores in non-volatile memory is left up to UE implementation. However to minimise the load (e.g. from radio signalling) on networks (e.g. at major airports), and to provide smoother inter-PLMN mobility (e.g. at land borders) the UE shall be able to store at least the latest 16 PLMN-assigned UE Capability IDs (along with the PLMN that assigned them and the UE's local configuration at the assignment time).

- It shall be possible for a UE to change the set of UE Radio Capabilities in time and signal the associated UE capability ID, if available.

- In a RACS supporting PLMN, if filtering of radio capabilities applies in RRC, this filter is recommended to be as much as possible of wider scope (preferably PLMN-wide) and correspond e.g. to the super-set of bands, band-combinations and RATs the PLMN deploys and not only the specific RAN node or region.

NOTE 4: If the filter configured in RAN node does not have wide enough scope, it will be possible that during handover a target RAN node configured with a different filter and supporting more bands, may need to enquire the UE for radio capabilities again and re-allocation of UE Capability ID, which would lead to extra signalling.

- if a UE capability ID is assigned by a PLMN when a UE radio capability filter in RRC is used, then the UE capability ID is related to the Radio Capability Filter that was used.

- The network or the Manufacturer shall be able to change the UE Capability ID associated with a device, e.g., due to a SW upgrade enabling new UE Radio Capabilities on the device side (for the manufacturer assigned UE Capability ID) in the network side;

- At any given instance the UE has only one UE capability ID that is indicated to the network.

NOTE 5: Signalling of additional UE radio capabilities with per-RAT granularity is supported with current RAN specifications e.g. if RAN already has UE radio capability corresponding to RAT1, it can acquire the additional UE radio capability corresponding to RAT2, combine the two and send them to 5GC which can then assign a new UE Capability ID corresponding to the sum of the old capability (RAT1) and the additional capability (RAT2).

- Solution #9 (UE Capability ID with delta set of capabilities) is recommended for normative work, subject to feasibility being confirmed by RAN WG2.

- The mapping between a specific capability ID and a corresponding set of capabilities does not change once set.

For key issue #2 the following principles are agreed:

- The UE Capability ID and the corresponding UE radio capability (commonly referred to as "dictionary entry") are stored in a new function called UE Capability Management Function (UCMF). The UCMF is used for storage of dictionary entries corresponding to either PLMN-specific or Manufacturer-specific UE Capability IDs.

- Provisioning of Manufacturer-specific UE Capability ID entries in the UCMF is performed from an AF that interacts with the UCMF either directly or via the NEF (or via Network Management).

- For PLMN-specific UE Capability ID entries the UCMF also is the function that assigns the UE Capability ID values.

- The service interface exposed by the UCMF shall be specified. Its known consumers are AF, NEF and AMF. The AMF can be updated with new dictionary entries using either the Subscribe/Notify or Request/Response model.

NOTE 6: The service-based interface needs to be designed to cope with UE capability size exceeding 124,000 octets.

- Owing to the need to support UE Radio Access Capabilities > 65 536 bytes (i.e. > 524 288 bits), and, the need to support fast, reliable, low processing complexity mechanisms for frequently used procedures (at least Service Request, RRC Connection Resume, X2&Xn handover, secondary gNB addition), the full UE Radio Access Capabilities shall not normally be transferred as part of those procedures. This requires that the serving and target RAN stores a local copy of the mapping between the UE Capability IDs and the full UE Radio Access Capabilities for the UEs that frequently use that RAN node. In addition, the (TS 23.501 [3] clause 5.26) Configuration Transfer Procedure and (TS 23.401 [7] clause 5.15) RAN Information Management (RIM) procedures should be updated so that RACS supporting RAN nodes can be discovered across inter-CN node boundaries.

- From SA WG2 perspective it is expected that when a UE capability ID is assigned to a set of UE capabilities for which a UE capability filter was applied, the association to this filter is conveyed over the signalling interfaces inside the network and between the RAN and the UE when the mapping to the UE capability ID to the UE capabilities is signalled. Based on SA WG2 current understanding the information about the filter that was applied is expected to be part of the UE radio capability itself (this is subject to RAN2 discussion as RAN2 may apply some changes when they study RACS; e.g. SA WG2 has considered the *appliedFreqBandListFilter* parameter defined in TS 38.331 [5] containing a list of frequency bands and band combinations, as well as the set of parameters named *RF-Parameters-vXYZ* defined in TS 36.331 [9], where XYZ indicates the specification version when the parameter was introduced).

- when a RAN node receives a PLMN-assigned UE Capability and ID and associated UE Radio Capability Filter, and detects that the UE Radio Capability Filter is not valid anymore, the RAN node trigger radio capability enquiry and the serving core network will allocate a new UE Capability ID.

- AMF that supports the RACS feature is mandated to have access to full set of UEs radio capabilities and the mapping between UE Capability ID and corresponding UE radio capabilities for at least the UEs registered in this AMF;

- NG-RAN that supports RACS, is mandatory to be able to maintain local storage of UE radio capabilities and have access to the mapping between the UE Capability ID and the full set of UEs radio capabilities;

- A specific NG-RAN node that does not have the mapping between a specific UE Capability ID and the corresponding UE radio capabilities, shall be able to retrieve the mapping from CN.

- The serving AMF stores the UE Capability ID in the UE context if received and provides the capability ID to NG-RAN via N2 message, e.g. INITIAL CONTEXT SETUP REQUEST.

- The RACS capability can be configured and operated per PLMN ID in the RAN, to support network sharing MOCN configuration.

For key issue #3, the following principles are agreed:

- RACS procedures will apply to 5GS and EPS;

NOTE 7: some of the rationale for inclusion of EPS is as follows:

a) dependent upon operator deployment choices, inter system handover between EPS and 5GS may be frequent. If RACS is not supported by EPS then the N2 handover messages for handover to EPS, and, handover from EPS will need to carry the full UE Radio Access Capabilities. These very large signalling messages could then be prioritised over e.g. data packets for URLLC services on the backhaul to the gNB. In addition, these signalling messages might exceed the size limits of GTP-C on the S10/N26 interface and the handovers systematically fail. Hence not supporting RACS in EPS will have a negative impact on 5GS.

b) The RAN working groups are endeavouring to encode the NR Radio Access Capabilities more efficiently than the LTE Radio Access Capabilities. Owing to the need for the LTE RAC to be understood by legacy LTE eNBs, these NR efficiency mechanisms are not able to be used for LTE. As a result, it is likely that the LTE RAC will be (much) larger than the NR RAC and hence the need for the RACS feature is greater on LTE than on NR.

- Whether the assignment of PLMN-specific UE Capability ID for a given set of UE radio capabilities is performed in NAS e.g. using UE Configuration Update or other NAS procedure or using N2 and RRC signalling will be decided in normative phase;

- The UE signals that it supports RACS in NAS layer.

- The PLMN assigned UE capability ID is unique per PLMN and has PLMN-wide validity.

- If a PLMN-wide filter is used, the UE Capabilities Management Function can be used to provision this filter in the PLMN RAN nodes via the AMF/MME: subject to RAN 2 and RAN 3 confirmation, the PLMN-wide UE Capability filter is signalled then by the AMF/MMEs to the RAN using non-UE-specific signalling N2/S1.

- subject to RAN3 confirmation the AMF/MME may provide the UE capability ID and its mapping to UE radio capabilities to the RAN via N2/S1 signalling (UE-specific signalling when an ID is assigned to a UE, Non UE-specific signalling when the capability ID to UE radio capabilities mapping is pushed to the RAN by the AMF/MME according to AMF policies, or the RAN asks the AMF to resolve a UE capability ID of which the RAN does not know the related mapped UE radio capabilities).- From SA WG2 point of view, for UEs that support the RACS feature, for UEs that are already assigned with an applicable UE Capability ID, it is mandatory to signal the UE Capability ID in Initial Registration. If both PLMN assigned and manufacturer assigned UE Capability IDs are available, the UE shall signal the PLMN assigned UE Capability ID.

- The 5GS/EPS network may utilise the PLMN assigned UE Capability ID, without involving the UE, when the UE does not support the RACS feature.

- UE deletes the PLMN assigned UE Capability ID(s) for the related PLMN on receiving an indication from the network. Other conditions will be specified as part of stage-3 work.

- UE indicates the UE capability ID via NAS.

- For backwards compatibility, the X2, Xn, S1 and N2 interface "Setup" signalling needs to be updated to exchange information on the support level for the RACS feature.

- To allow for a mix of upgraded and non-upgraded RAN nodes over the X2/Xn interfaces, the UE Capability ID should be included in the Path Switch signalling between MME/AMF and RAN.

- For backwards compatibility between nodes that support the feature and nodes that do not support the feature, if a peer node is not supporting RACS, the source node attempts to send to the peer node the UE capabilities that map to the UE capability ID. However, owing to message size limits, this may lead to an inter-CN node handover systematically failing, or, requiring the retrieval of the UE capabilities across the target RAN node's radio interface.

Annex A:  
Maximum supportable information element size

In R3-185103/S2-1810011, RAN WG3 have indicated that the standards for the SCTP layer (used on S1, X2, N2 and Xn interfaces) do not impose any practical restrictions on information element or message size.

NOTE 1: The maximum SCTP message size is 2\*\*32 "chunks", and each "chunk" could be an IP packet of > 1 kbyte. Operators and vendors may be able to check the maximum SCTP packet re-assembly capability of their equipment by examination of the "a\_rwnd" value sent in SCTP frames.

In C4-186641/S2-1810021, CT WG 4 have indicated that:

a) For the GTPv2 based interfaces, e.g. MME - MME (S10) and MME - MSC (Sv) over which the RAN transparent container will be transferred, the maximum size of an IE is 65511 octets. Considering other mandatory and conditional IEs which needs to be sent along with the RAN transparent container, this implies that the size for the RAN transparent container is limited to 50000 octets.

NOTE 2: CT WG4 did not comment on the operation of GTPv2/UDP over an IPv6 based signalling link may be needed.

b) For the HTTP based N14 interface (AMF to AMF), there is no upper limit defined by CT4 to transfer the RAN transparent container.

Subsequently, in C4-187633, CT 4 informed SA 3 that:

*In HTTP payloads: They are encoded as JSON documents, and the definition of the Information Elements where SUCI may be included (JSON strings) do not specify any upper limit. Based on previous SA3 requests, CT4 have specified an upper bound on the size of the overall JSON body of HTTP requests and responses of 124,000 octets (see TS 29.501, subclause 6.2).*

Issues with large E-UTRAN Radio Capability IEs and SRVCC from E-UTRAN to UTRAN/GERAN have already been solved.

For SRVCC from 5GC to UMTS, it is agreed that there is no requirement for 'return handover' from UMTS to 5GC. Hence it is assumed that there is no need for the NG-RAN to supply the target UTRAN with any UE Capability information relating to NG-RATs (nor, for UTRAN specific reasons, any information relating to the UE's UTRAN radio capabilities). Therefore, MAP and SCCP/Iu interface signalling constraints are not applicable to this work.

Annex B:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2018-12 | SA#82 | SP-181101 | - | - | - | MCC Editorial update for presentation to TSG SA for Information | 1.0.0 |
| 2019-03 | SA#83 | SP-190190 | - | - | - | MCC Editorial update for presentation to TSG SA for Information | 2.0.0 |
| 2019-03 | SA#83 | - | - | - | - | MCC editorial update for publication (Rel-16) | 16.0.0 |