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| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Services and System Aspects;  Study on support of reduced capability NR devices;  Phase 2  (Release 18) | |
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| ***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 |
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# Foreword

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

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

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

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

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

In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# 1 Scope

The scope of the present document is to investigate solutions to support of RRC INACTIVE state with extended DRX cycle longer than 10.24s to enrich the power saving function as studied in TR 38.875 [5].

This study will address the following objective:

Support for enabling of eDRX cycle that is longer than 10.24s in RRC\_INACTIVE state with following two aspects:

1) Study the support of the eDRX cycle that is longer than 10.24s and up to 10485.76s for RRC\_INACTIVE state for RAN paging (e.g. PTW and eDRX cycle values).

2) Study the MT signalling and data handling for UE with long eDRX cycle in RRC\_INACTIVE state.

# 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 23.501: "System Architecture for the 5G System; Stage 2".

[3] 3GPP TS 23.502: "Procedures for the 5G System; Stage 2".

[4] 3GPP TS 38.300: "NR; NR and NG-RAN Overall Description; Stage 2".

[5] 3GPP TR 38.875: "Study on support of reduced capability NR devices".

[6] 3GPP TS 38.413: "NG-RAN; NG Application Protocol (NGAP)".

# 3 Definitions of terms and abbreviations

## 3.1 Terms

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

## 3.2 Abbreviations

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

# 4 Architectural Assumptions and Requirements

The following architectural assumptions and requirements apply:

- The current 3GPP system architecture in TS 23.501 [2] and TS 23.502 [3] is applied.

- Solutions are applicable to UE accessing 5GC via gNB.

# 5 Key Issues

## 5.1 Key Issue #1: Enabling long eDRX cycle support in RRC\_INACTIVE state

### 5.1.1 General description

To enable the support of long eDRX cycle (e.g. longer than 10.24s) in RRC\_INACTIVE state with the power saving benefit studied in TR 38.875 [5], following aspects need to be studied:

- How the long eDRX cycle values which are longer than 10.24s are supported in RRC\_INACTIVE state.

- How MT signalling and data are handled for a UE with a long eDRX cycle value in RRC\_INACTIVE state, e.g. enhancement to enable extended MT data buffering for UE in RRC\_INACTIVE state.

NOTE 1: RRC\_INACTIVE is defined as "CM-CONNECTED with RRC\_INACTIVE" in current 3GPP specification (See clause 5.3.3.2.5 of TS 23.501 [2] and clause 9.2.2.1 of TS 38.300 [4]). Solutions for CM-IDLE state are not excluded under this KI.

NOTE 2: Coordination with RAN WGs is needed for the KI.

# 6 Solutions

## 6.1 Solution #1: Power saving enhancement with long eDRX cycle support for UE in CM-CONNECTED with RRC\_INACTIVE state

### 6.1.1 Introduction

The solution applies to Key Issue #1 and covers both sub-aspects of the key issue.

### 6.1.2 Functional Description

The solution is based on existing Rel-17 long eDRX support for NR RedCap device in CM-IDLE mode with the following enhancement:

- eDRX cycle value for CM-CONNECTED with RRC\_INACTIVE state is extended from 10.24s up to 10485.76s (i.e. same eDRX cycle value range as for CM-IDLE mode).

- AMF is aware of UE RRC state and long eDRX parameters applied for UE in CM\_CONNECTTED with RRC\_INACTIVE state based on information notified by RAN.

- AMF also notifies the SMF/UPF to start data buffering/delivery since UE is not reachable or reachable due to power saving. The UPF/SMF is responsible for data buffering and triggers the MT data notification even in case of existing of N3 tunnel.

- Based on the eDRX parameters for CM-CONNECTED with RRC\_INACTIVE state, AMF can deduce the needed information and handle MT signalling and MT data the same way as UE is in CM-IDLE while UE is not reachable, i.e. the existing HLcom solutions can be applied to UE in power saving state when UE is in either in CM-IDLE or in CM\_CONNECTED with RRC\_INACTIVE state as long as AMF knows the information related to power saving.

- Based on the CN notification related to MT signalling or data, RAN triggers the paging when UE is reachable.

- UE performs both AS and NAS level mobility and periodic AS update based on existing Rel-17 functions.

- If extra AMF selection logic is needed for applying long eDRX in CM\_CONNECTED with RRC\_INACTIVE state, existing mechanisms (e.g., S-NSSAI) can be deployed by the operation based on configuration.

### 6.1.3 Procedures

#### 6.1.3.1 Notification of eDRX information between CN and gNB

This is an updated procedure based on clause 4.8.3 of TS 23.502 [3].



Figure 6.1.3.1-1: RRC state transition notification

1. The AMF sends a N2 Request to the NG-RAN (i.e. gNB) to request the RRC state transition report as described in TS 38.413 [6] (e.g. when AMF provides RRC Inactive Assistance Information for UE with reduced NR capability and has negotiated extended DRX longer than 10.24s).

2. The NG-RAN sends the UE Notification message to report the current RRC state for the UE (i.e. RRC Inactive state or RRC Connected state).

When NG-RAN reports RRC Inactive state for a UE using extended DRX longer than 10.24s in RRC Inactive state, the NG-RAN includes also the extended DRX information (i.e. eDRX cycle value and Paging Time Window) which triggers CN based MT signalling and data handling as in step 3 below.

2b. When the AMF has requested reporting about subsequent state transitions, the NG-RAN sends subsequent UE Notification messages to the AMF at every RRC state transition until the UE transitions to CM-IDLE or NG-RAN receives a Cancel UE State Notification message from the AMF.

NOTE: If the NG-RAN receives downlink data when executing step 3a/3b, the handling of such downlink data is implementation dependent.

3a. If the AMF receives extended DRX information when UE enters RRC Inactive state, the AMF stores the extended DRX information for RRC Inactive state and sends the Nsmf\_PDUSession\_UpdateSMContext request to the SMF enabling the data buffering. When UE enters RRC Connected state, the AMF also sends Nsmf\_PDUSession\_UpdateSMContext request to SMF enabling the data delivery.

3b. If data buffering is handled in UPF, the SMF updates the UPF with proper rules for MT data handling.

3c. The SMF sends the Nsmf\_PDUSession\_UpdateSMContext response.

4. The AMF can send a Cancel UE State Notification message to inform the NG-RAN that it should terminate notifications for a given UE when such report is not needed.

#### 6.1.3.2 Network triggered Connection Resume procedure

This is an updated procedure based on clause 4.8.2.2a of TS 23.502 [3] with enhancement for UE in CM-CONNECTED with RRC\_INACTIVE state and eDRX is longer than 10.24s.

The Network Triggered Connection Resume in RRC Inactive procedure is used when the network needs to signal (e.g. the N1 NAS PDU and/or downlink user plane PDU) with a UE in the RRC Inactive state. When the procedure is triggered by other NFs (e.g. SMSF, LMF, GMLC), the UPF (or SMF) in the following figure should be replaced by the respective NF (the corresponding services operations used by other NFs when they communicate with AMF may also be different from the service operation used by SMF/UPF). During the procedure, the NG-RAN (i.e. gNB) sends a RAN Paging to the UE in order to trigger the Connection Resume in RRC Inactive procedure.



Figure 6.1.3.2-1a: Network Triggered Connection Resume for UE in RRC Inactive



Figure 6.1.3.2-1b: Network Triggered Connection Resume for UE in RRC Inactive

1. When downlink data is received and the SMF/UPF is requested to perform buffering as specified in clause 6.1.3.1 above, UPF/SMF checks with AMF for the possibility of data delivery, similar to step 2 of clause 4.24.2 of TS 23.502 [3] with the following differences:

- If AMF determines that UE is not reachable in RRC INACTIVE state, the AMF provides the Estimated Maximum Wait time in the response message based on the stored extended DRX information for RRC INACTIVE in AMF (see clause 6.1.3.1 above). This handling is similar to CM-IDLE with eDRX. When the AMF provides the Estimated Maximum Wait time, it can consider the time needed for RRC level procedures (e.g. RRC RNA update procedure) when UE wakes up from the eDRX cycle.

2. When the AMF determines the UE reachable based on the stored extended DRX inform for RRC INACTIVE, the AMF informs SMF/UPF to deliver data. The NG-RAN receives downlink data (e.g. the N1 NAS PDU and/or the user plane PDU) for a UE in RRC INACTIVE State, the NG-RAN buffers the downlink data and triggers RAN Paging message.

As an alternative option, the AMF may notify the NG-RAN of MT service which can trigger the NG-RAN Paging. Then step for downlink data delivery will be executed after UE enters RRC\_CONNECTED mode as show in figure 6.1.3.2-1b above when SMF/UPF receives the notification as specified in step 3 of clause 6.1.3.1 above.

3. The NG-RAN sends the RAN Paging message to the UE.

4. If the UE is in RRC Inactive State, based on the RAN paging, the UE initiates the UE Triggered Connection Resume in RRC Inactive procedure (see clause 4.8.2.2 of TS 23.502 [3]). In case of RRC Resume failure, a NAS procedure is triggered by UE to enter RRC\_CONNECTED state.

### 6.1.4 Impacts on services, entities and interfaces

AMF:

- eDRX parameters for RRC\_INACTIVE state exchange on NGAP interface.

- Estimated Maximum Wait time calculation based on eDRX parameters from RRC\_INACTIVE state.

- Notification of MT service on NGAP interface (only needed if option as described in figure 6.1.3.2-1b is used).

gNB:

- eDRX parameters for RRC\_INACTIVE state exchange on NGAP interface.

- Notification of MT service on NGAP interface which triggers the RAN Paging (only needed if option as described in figure 6.1.3.2-1b is used).

SMF:

- Supports data buffering/delivery Indication from AMF even in case of the N3 tunnel existence.

UPF:

- none.

## 6.2 Solution #2: Long eDRX with RAN buffering

### 6.2.1 Introduction

This solution relates the KI#1 and proposes a solution where RAN initiates either extended buffering of MT data or notification to the AMF for UE unavailability due to use of long eDRX in RRC-Inactive.

### 6.2.2 Functional Description

This solution addresses KI#1 and the following principles are used:

- Allow eDRX >10,24s for RRC-Inactive.

- RAN anchor node configures the UE with eDRX value and PTW to be used during RRC-Inactive when releasing the UE to RRC-Inactive.

- The CM idle mode eDRX and PTW configuration are provided to NG-RAN in the RRC Inactive Assistance Information as described in TS 23.501 [2] and TS 38.413 [6].

- RAN is responsible for paging and will apply RAN paging strategy considering the UE PTW configuration.

- RAN either buffers MT data if it finds it feasible or triggers the UE context release (N2 msg).

NOTE 1: The N2 message could be the UE Context Release Request message which RAN use to notify the AMF of RAN paging failure. The message may need to be extended to include that the failure was due to eDRX configuration. TSG RAN3 is responsible for N2 messages and their format.

- If MT NAS message can't be delivered to the UE within the NAS retransmission timer range i.e. <10.24s), then RAN triggers the UE context release (N2 msg - UE context release request), with cause value indicating that the UE is not currently reachable for MT signalling.

NOTE 2: The N2 message used to deliver the failure could be the UE Context Release Request message which RAN use to notify the AMF of RAN paging failure. The message may need to be extended to include that the failure was due to eDRX configuration. Sending an N2 notification instead of UE Context release request could be an alternative to prevent that the UE is moved to CM-Idle state in the AMF. TSG RAN3 is responsible for N2 messages and their format.

- As long as the RAN has not initiated UE context release, the Core Network behaves as in CM-CONNECTED state as specified in TS 23.501 [2].

Editor's note: This solution is based on extensive re-use of the existing procedures and therefore assumes HLcom procedures in CM-IDLE state. The support of HLcom in CM-CONNECTED state can be studied in separate solution and if found to be feasible, such solution is expected to be compatible with this solution.

- After the UE context release, the Core network moves to CM-IDLE state, where it can initiate HLcom procedures, see clause 5.31.8 of TS 23.501 [2].

NOTE 3: The Support of HLcom feature in CM-IDLE depends on AMF and SMF supports the corresponding HLcom features as the support of HLcom feature is optional for the network. The AMF selection is done during the registration procedure and could be based on a combination of request for long eDRX and the 'NR RedCap indication' provided by RAN as specified in rel-17.

RAN is responsible for RAN based paging within a RAN Notification Area (RNA). Long eDRX may increase the possibility that the UE has moved outside the RNA and possibly further away from the RNA. It is proposed that UE mobility and buffered MT data in the old RAN anchor Node should be handled based on the following principles:

- If the new gNB, inside or outside the RNA, has an Xn interface between the old RAN anchor node and the new gNB, then the new gNB can retrieve the UE context (as specified in TS 38.413 [6]) and also retrieve the MT data that has been buffered in the old gNB and delivers the data to the UE.

- If the new gNB is outside the RNA and has NOT an Xn interface between the new gNB and old RAN anchor node, the new gNB is not able to retrieve the UE context and extended buffered Data from the old RAN anchor node. To avoid systematic failure to deliver the extended buffered data to the UE, it is proposed that the new gNB can request assistance from the Core Network in retrieving the UE context and extended buffered data.

NOTE 4: UE context retrieval via CN needs to be coordinated with RAN WGs

- In addition to the new gNB requesting assistance to retrieve the buffered data, the old gNB may request the AMF to escalate the paging in a wider area. The old RAN node may include, in the N2 message, how many POs that remains in the PTW.

NOTE 5: To make efficient use of this alternative, the N2 message should be sent while there are POs remaining in the PTW.

### 6.2.3 Procedures

#### 6.2.3.1 MT Signalling for UE in RRC-Inactive state with long eDRX.



Figure 6.2.3.1-1: MT signalling for UE is in RRC-Inactive with long eDRX

0. UE is in RRC-Inactive/CM-Connected state configured by the RAN node to apply long eDRX in RRC-Inactive Inactive and the AMF is in CM-CONNECTED state as specified in TS 23.501 [2] clause 5.3.3.2.5.

NOTE 1: The eDRX value could be either the value received by the AMF during the registration or a different eDRX value configured by RAN when the UE is released to RRC-Inactive.

1. The AMF send NAS message towards the UE.

2. The RAN node determines when the UE will become reachable next time according to the eDRX scheme. If the UE will become reachable before NAS retransmission timer expires, then the RAN may buffer the NAS message and page the UE and deliver the NAS message to the UE according to step 6.

3. [Conditional] If the RAN node determines e.g. based on awareness that the UE will not become reachable before the NAS retransmission timer expires, it indicates failure to deliver the NAS message.

NOTE 2: The N2 message used to deliver the failure could be the UE Context Release Request message which RAN use to notify the AMF of RAN paging failure. The message may need to be extended to include that the failure was due to eDRX configuration. RAN WG3 is responsible for N2 messages and their format.

4. The AMF releases the UE context and moves to CM-IDLE state.

NOTE 3: The AMF may use the eDRX value stored in the MM UE context to determine when the UE becomes reachable again.

5. Optional: Following the CM-IDLE state procedures, the AMF may retransmit the NAS message in conjunction to the next PTW. This step includes CN paging prior to sending the NAS message to the RAN node.

6. RAN B pages the UE and delivers the MT NAS message.

#### 6.2.3.2 MT Data for UE in RRC-Inactive state with long eDRX.



Figure 6.2.3.2-1: MT data for UE is in RRC-Inactive with long eDRX

0. UE is in RRC-Inactive/CM-Connected state configured by the RAN node to apply long eDRX in RRC-Inactive and the AMF is in CM-CONNECTED state as specified in TS 23.501 [2] clause 5.3.3.2.5.

NOTE 1: The eDRX value could be either the value received by the AMF during the registration or a different eDRX value configured by RAN when the UE is released to RRC-Inactive.

1. MT Data for the UE is forwarded to the RAN node.

2. The RAN node determines when the UE will become reachable next time according to the eDRX scheme. The RAN may decide to buffer the DL data until next PTW, then the RAN will page the UE and deliver the DL data to the UE according to step 5.

3. [Conditional] If the RAN node determines that it is not able to buffer the MT data for the remaining eDRX cycle, it indicates failure to page the UE.

NOTE 2: The N2 message used to deliver the failure could be the UE Context Release Request message which RAN use to notify the AMF of RAN paging failure. The message may need to be extended. RAN WG3 is responsible for N2 messages and their format.

4. The AMF releases the UE context and moves the UE to CM-Idle state. RAN drops the MT data after receiving the UE Context Release message. Following the existing CM-IDLE state procedures, the AMF may escalate the paging to wider area. If the AMF is able to reach the UE by paging, then the AMF triggers data forwarding from the old RAN node to the new RAN node instead of sending the UE Context Release message to the old RAN node.

NOTE 3: The AMF may use the eDRX value stored in the MM UE context or how many POs that remains in the PTW, if provided in step 3, to determine when the UE becomes reachable again. Data forwarding between two RAN nodes could reuse steps used for N2 based handover in clause 4.9.1.3 of TS 23.502 [3].

NOTE 4: To make efficient use of this alternative, the N2 message in step 3 should be sent while there are POs remaining in the PTW.

5. RAN pages the UE and delivers the DL data.

#### 6.2.3.3 Procedure how to handle UE mobility outside the RNA.



Figure 6.2.3.3-1: Procedure for handling UE mobility outside the RNA

0. UE is in RRC-Inactive/CM-Connected state configured by the RAN node to apply long eDRX in RRC-Inactive and the AMF is in CM-CONNECTED state as specified in clause 5.3.3.2.5 of TS 23.501 [2].

NOTE 1: The eDRX value could be either the value received by the AMF during the registration or a different eDRX value configured by RAN when the UE is released to RRC-Inactive.

1. MT Data to the UE is forwarded to the old RAN node.

2. The UE detects that it is outside the configured RNA and send an RNA Update due to mobility to the new RAN node.

3. If the new RAN is not able to retrieve the UE context from the old RAN node e.g. due to lack of Xn interface, then the new RAN node will send a N2 message requesting assistance from the AMF to retrieve the UE context.

4. The AMF, based on the received UE temporary (i.e. I-RNTI which includes the ID of the old RAN node), tries to retrieve the UE context from the old RAN node. If the AMF is not able to retrieve the UE context, then the AMF responds to the new RAN node with a failure to do so. Based on this failure the new RAN node will reject the RNA Update due to mobility.

5. The AMF requests to retrieve the UE context from the old RAN node.

6. The Old RAN node forwards the UE context as a transparent container to the AMF and then the AMF forwards the UE context to the old RAN node

7. If the old RAN indicated to the AMF that the RAN has buffered data to the UE, then the AMF triggers data forwarding between the old RAN node and the new RAN node.

NOTE 2: It is proposed to reuse data forward principle/procedure from N2 based handover as specified in clause 4.9.1.3 of TS 23.502 [3].

8. If the new RAN node received DL data, the new RAN node delivers the data to the UE before releasing the UE with new RNA configuration. The new RAN node also performs path switch procedure according to clause 4.9.1.2.2 of TS 23.502 [3].

### 6.2.4 Impacts on services, entities and interfaces

UE:

- Support eDRX and PTW in RRC-Inactive, i.e. new RRC-Release configuration for RRC-Inactive.

gNB:

- Support sending failure indication to the AMF for UE unavailability due to long eDRX in RRC-Inactive.

- Support extended buffering of MT data.

- Support CN assisted AS UE context retrieval and data forwarding.

- Optional: Provide the remaining number of POs in the PTW when failing to page the UE within the RNA.

AMF:

- Support the indication of UE unavailability due to long eDRX in RRC-Inactive.

- Support CN assisted AS UE context retrieval and data forwarding.

## 6.2a Solution #2a: Additional HLcom support for Solution 2

### 6.2a.1 Introduction

This solution description is not a standalone solution, it is an extension to solution 2 to support the HLcom feature "UE Reachability" that would allow an AF to subscribe to a notification when the UE is reachable for DL data.

### 6.2a.2 Functional Description

As solution #2 with the following enhancements:

- The HLcom feature "UE Reachability" can be supported in CM-CONNECTED state. To support "UE Reachability" feature the following enhancement is needed. When the AMF receives the event subscription as specified in clause 4.15.3.2.1 of TS 23.502 [3] and the UE is in CM-CONNECTED state, the AMF checks the eDRX configuration for CM-IDLE in the UE context and provides an event notification to the AF via the NEF prior to the next reachability period based on the eDRX value stored in the UE context. It is assumed that RAN has configured the UE with eDRX value in RRC-Inactive which is a factor of the CM-IDLE value i.e. eDRX in RRC-Inactive = eDRX in CM-IDLE divided by N where N=1, 2, 3, ...

The other HLcom features "Availability after DDN failure" and "Downlink Data Delivery Status" as specified in clause 5.31.8 of TS 23.501 [2] is not supported by this enhancement of solution 2.

### 6.2a.3 Procedures

As in Solution 2.

### 6.2a.4 Impacts on services, entities and interfaces

As in Solution 2 with the following additional impact.

AMF:

- Support "UE Reachability" notification, when the AMF receives the event subscription as specified in clause 4.15.3.2 of TS 23.502 [3] and the UE is in CM-CONNECTED state.

## 6.3 Solution #3: MT signalling and data handling for UE with long eDRX cycle in RRC\_Inactive state and UPF buffering

### 6.3.1 Description

This solution resolves Key Issue #1 for MT signalling and data handling for UE with long eDRX cycle in RRC\_Inactive state.

As specified in TS 23.501 [2], NG-RAN decides the eDRX in RRC\_Inactive state based on the eDRX parameters in IDLE mode. NG-RAN also determines the buffer timer which is used to indicate the time needed for SMF/UPF to buffer the MT data. Before transitioning the UE into RRC\_Inactive state, NG-RAN sends the buffer indicator and buffer timer to the AMF to enable data buffering in Core Network.

Then when MT data arrives, the SMF/UPF will buffer the MT data and forward the buffered data to NG-RAN to trigger RAN based paging when the buffer timer expires. If the UE moves out of the original NG-RAN, the data is transfer between the original and new NG-RAN nodes as needed.

If there is a MO data when the UE is during the eDRX in RRC\_Inactive state, the NG-RAN forwards the MO data to UPF to disable the data buffering and any MT buffered data is sent to RAN. If the UE enters RRC\_CONNECTED without MO data then then RAN can inform the AMF that the UE is no longer in RRC\_Inactive and that can trigger delivery of buffered MT to RAN or delivery of MT signalling.

The AMF stores an indication of when the UE is in RRC\_Inactive with a long eDRX cycle and uses that indication to determine how to handle paging, how to respond to reachability and event exposure requests, enabling the use of HLcom and SMS over NAS with long eDRX cycles in RRC\_Inactive.

### 6.3.2 Procedures



Figure 6.3.2-1: high level procedure for MT data handling of UE with long eDRX in RRC\_Inactive state

1. The UE initiates the Registration Procedure and the eDRX parameters in CM-IDLE state are negotiated.

2. The AMF sends the Inactive Assistance Information to the NG-RAN. The eDRX parameters in CM-IDLE state are included as defined in clause 5.3.3.2.5 of TS 23.501 [2].

3. Before transitioning the UE into RRC\_Inactive state, NG-RAN determines the eDRX parameters for UE in RRC\_Inactive state.

4. If the eDRX cycle in RRC\_Inactive state is larger than 10.24s, NG-RAN may send the N2 message to inform the AMF that UE is entering RRC\_Inactive state to enable CN buffering. The buffer indicator and the buffer timer are included to indicate to the AMF to enable data buffering until the buffer timer expires. The CM state of the UE is not update by the indication from NG-RAN, i.e. the UE remains in CM-CONNECTED.

5. If the AMF receives the notification from NG-RAN that the UE will enter RRC\_Inactive state and need to buffer downlink data in the CN, AMF sends the buffer indication and buffer timer to SMF to enable data buffering. The AMF stores an indication that the UE is in RRC\_Inactive state with a long eDRX cycle and is therefore not reachable until buffer timer expires. Optionally, the buffer timer contains an initial buffer timer (i.e. time until the start of the first PTW) and re-buffer timer (i.e. the eDRX cycle length time between the start of subsequent PTWs) for the case when the UE remains in RRC\_Inactive.

If the AMF receives a Namf\_EventExposure\_Subscribe request for UE Reachability or Availability after DDN failure and if the AMF has stored the indication that the UE is in RRC\_Inactive with a long eDRX cycle then the AMF treats the request as if the UE was in CM\_IDLE and sends any responses or events for when UE can be paged (i.e. buffer timer expires).

For MT signalling the AMF takes into account the indication that the UE is in RRC\_Inactive state with a long eDRX cycle and triggers the MT signalling for when UE can be paged (i.e. buffer timer expires).

If the AMF receives a Namf\_MT\_EnableUEReachability Request while the AMF has an indication that the UE is in RRC\_Inactive with a long eDRX cycle, then the Namf\_MT\_EnableUEReachability Response is sent back to the requesting NF that the UE is not reachable until when UE can be paged (i.e. buffer timer expires).

6. The SMF may configure UPF with the new Buffering Action Rule and buffer timer to enable downlink data buffering for the UE until the buffer timer expires.

7. Based on the new BAR and buffer timer, the UPF starts the buffer timer with the initial buffer timer and enables data buffering for the UE in RRC\_Inactive state.

NOTE: When the initial buffer timer expires and there is no DL buffered data, the buffer timer is always restarted with the re-buffer timer value, unless there is a new value from RAN.

8. The UE may be moved to RRC\_Inactive state. This step may occur in parallel with steps 4 - 7. In case the UE was moved to RRC\_Inactive state before the UPF was reconfigured, the RAN node may buffer DL data that is forwarded to the RAN node for the duration of the eDRX cycle or discard the data based on RAN configuration.

9. When MT data arrives at the UPF, the UPF buffers it until the buffer timer expires.

10. The UPF may forward the buffered data to the NG-RAN when the buffer timer expires, so NG-RAN can trigger paging for the UE in time. The NG-RAN node buffers the data from the UPF during the paging procedure.

11. The NG-RAN sends the RAN Paging message to the UE.

12. The UE responds to paging from RAN.

13. The response to paging may not be in the same RAN node which moved the UE to RRC\_Inactive state. If the UE has moved away from of the RAN node that moved the UE to RRC\_Inactive state, the UE will initiate the RNAU procedure and the context will be transferred between the original RAN node and the new RAN node.

If there is no Xn interface between the original and the new RAN nodes, the Core Network can be used to transfer the UE context or buffered data from the original RAN node to the new RAN node. For the UE context in the original RAN node, the AMF can help to retrieve the UE context from the original RAN node and send it to the new RAN node in a container. Similarly, an indirect data forwarding path is built from the original RAN node, the anchor UPF and the new RAN node to enable the buffered data to be transferred.

14. The MT data is sent to UE.

15. If there is MO data/signalling triggered connection resume between UE and NG-RAN, the UE enters CM-CONNECTED state.

16. The NG-RAN notifies the AMF that the UE's RRC state has been changed from RRC\_Inactive to RRC\_CONNECTED state.

17. The AMF may also initiate the Nsmf\_PDUSession\_UpdateSMContext service to notify SMF about the state change.

18. Accordingly, the SMF decides disables the data buffering in the UPF and the UPF sends the any buffered data to RAN.

19. If the UE initiated connection resume is triggered by UL data traffic, the NG-RAN sends the UL data to the UPF, which triggers the UPF to disable the data buffering and forward any DL traffic.

### 6.3.3 Impacts on services, entities and interfaces

RAN:

- Derive the buffer timer and send it to AMF together with the buffer indicator.

- Proactively inform AMF about the RRC states of UE.

- Support CN assisted AS UE context retrieval and data forwarding.

AMF:

- Store the indication that the UE is in RRC\_Inactive with a long eDRX cycle until the buffer timer expires and replies to requests or sends events if relevant requests were received while it was set.

- Support CN assisted AS UE context retrieval and data forwarding.

UPF:

- Disable data buffering and forward buffered data when buffer timer expires or there is any UL data traffic.

- Restart buffer timer if there is no DL data buffered or new buffer timer from RAN.

SMF:

- Disable data buffering and forward buffered data when buffer timer expires or there is any UL data traffic.

## 6.4 Solution #4: RRC Inactive with CM-IDLE for eDRX>10.24s

### 6.4.1 Description

This solution proposes, for the case of RRC Inactive and eDRX>10.24s, to combine:

- On the RAN/RRC side, maintain RRC-Inactive state for fast resume procedure.

- On the CN/NAS side, use CM IDLE which implicitly already supports proper handling of high latency communications (HLcom) when the UE is unreachable for an extended period of time.

Currently, this CM and RRC state pair has not been defined, therefore this solution proposes how to support it with as minimal impact as possible compared to existing Rel-17 solutions.

The UE and AMF negotiate support of CM-IDLE with RRC inactive and idle mode extended DRX during registration procedure. The AMF provides indication of support of CM-IDLE with RRC Inactive along with the existing extended DRX information in the "RRC Inactive Assistance Information" (see clause 5.3.3.25 of TS 23.501 [2]).

Editor's note: Whether eDRX cycle and PTW values for RRC inactive and for RRC idle are the same or can be different, and how this affects the detailed content of UE/NW negotiation of parameters for eDRX in RRC inactive, is FFS.

When the UE is moved to CM-IDLE with RRC-Inactive, the NG-RAN initiates N2 suspend procedure towards the 5GC. When the UE moves back to RRC-Connected, the NG-RAN initiates N2 resume procedure.

When the UE is in CM-IDLE with RRC Inactive, all currently defined 5GC features related to UE being unreachable for CM-ILDE with extended DRX apply with the following addition:

- The AMF may send N2 paging message only towards the NG-RAN node where N2 suspension occurred with indication of paging in RRC Inactive with CM\_IDLE, and the NG-RAN node performs RAN paging in the RAN notification area.

- The AMF may e.g. if initial attempt(s) to reach UE using RAN paging fail, try regular CN paging, i.e. send N2 paging message without indication of RRC Inactive with CM-IDLE. In this case the RAN performs regular CN paging.

From UE perspective, when the UE enters RRC-Inactive with CM-IDLE, the behaviour is the same as for RRC-Inactive with CM-CONNECTED, i.e.:

- If the UE receives RAN paging, it attempts RRC resume procedure.

- If RRC resume fails the UE falls back to CM-IDLE with RRC Idle and initiates RRC connection establishment request.

- If the UE receives CN paging, it moves to CM-IDLE with RRC Idle and initiates RRC connection establishment request.

- If the UE steps outside RAN notification area, the UE initiates RAN Notification Area Update.

- The UE performs periodic RAN notification Area Update.

- The UE performs periodic registration update.

### 6.4.2 Procedures

#### 6.4.2.1 N2 suspend for UE entering RRC inactive with eDRX>10.24s



Figure 6.4.2.1-1: N2 Suspend for RRC Inactive / CM-IDLE

0. Based on the information received from the AMF, the NG-RAN node may decide to move the UE to CM-IDLE with RRC inactive if the NG-RAN intends to configure the UE with extended DRX longer than 10.24 seconds.

1. The NG-RAN shall initiate N2 suspend procedure as defined in clause 4.8.1 of TS 23.502 [3] with the addition of: NG-RAN provides RRC Inactive with CM-IDLE indication and provides RRC inactive eDRX cycle length and PTW. The AMF shall enter CM-IDLE with RRC inactive state.

2. The NG-RAN initiates RRC release with suspend indication towards the UE with eDRX>10.24s and RRC Inactive with CM-IDLE indication. The UE and the NG-RAN enters CM-IDLE with RRC inactive.

#### 6.4.2.2 UE paging and resume

When the UE is in CM-IDLE with RRC Inactive, all mobile terminated data handling, high latency communication, and network initiated procedures follow the procedures defined in TS 23.502 [3] when the UE is in CM-IDLE except for UE paging and connection resume.



Figure 6.4.2.2-1: UE paging and resume procedure

1. There is a trigger to page the UE, e.g. due to mobile terminated data, steps 1-3 of Network Triggered Service Request (clause 4.2.3.3 of TS 23.502 [3],). The AMF determines the start of PTW as provided by NG-RAN, and sends N2 paging message only towards the NG-RAN node where N2 suspension occurred with indication of paging in RRC Inactive with CM\_IDLE.

2. The NG-RAN initiates RAN paging in the RAN notification area.

3. When the UE receives RAN paging, it initiates RRC resume procedure from RRC inactive.

4 The NG-RAN proceeds with Steps 2-4 of clause 4.8.2 of TS 23.502 [3].

(Optional) Fallback to CN paging

5. If e.g. AMF initiated RAN paging fails, or e.g. due to paging retransmission strategy, the AMF may initiate CN paging.

6. If the UE receives CN paging, the UE moves to RRC idle/CM idle and initiates service request procedure.

### 6.4.3 Impacts on services, entities and interfaces

UE:

- Support of RRC inactive with CM-IDLE.

RAN:

- Extend N2 Suspend and N2 Resume procedures to CM-IDLE with RRC inactive with eDRX cycle and PTW indication.

- Extend the RRC Release message to release the UE to RRC-Inactive with CM-Idle.

- Support AMF triggered RAN paging.

AMF:

- Support of RRC inactive with CM-IDLE.

- Support of N2 paging with RRC inactive indication to trigger RAN paging.

- Extend the RRC-Inactive assistance information with the support for RRC-Inactive with CM-idle indication.

- Extend N2 suspend and N2 resume procedure to enter CM-IDLE with RRC inactive and CM-CONNECTED respectively.

## 6.5 Solution #5: Enabling UPF buffering per NG-RAN request for UE in RRC\_Inactive state with long eDRX cycle

### 6.5.1 Description

This solution resolves Key Issue #1.

In this solution, after the UE enters into RRC\_inactive state with long eDRX cycle, and when the NG-RAN receives MT data over the N3 tunnel, the NG-RAN buffers the MT data and sends a suspend indication to the network. When the network receives the suspend indication it starts the MT data buffering in the UPF. When the UE becomes reachable again, the NG-RAN triggers the paging procedure and the UE enters into RRC\_connected state. The NG-RAN then forwards the buffered MT data to the UE. If the NG-RAN has sent the suspend indication to the network, it sends resume indication to the network to disable the UPF buffering and start the delivery of MT data to the NG-RAN.

When the NG-RAN node receives N1 NAS message and it determines that it is not possible to transfer the N1 NAS message to the UE before the NAS retransmission timer expires, it sends N1 NAS Message Transfer Failure message to the AMF, with a cause value that the UE is temporarily not reachable and an expected waiting time value. The AMF starts a timer. Before the timer expires the AMF stops sending any further N1 NAS message to the NG-RAN. After the timer expires, the AMF starts to send the N1 NAS message to the NG-RAN and the NG-RAN triggers the paging procedure.

When the UE becomes RRC\_connected state due to any MO data or signalling, the NG-RAN sends resume indication to the network to enable the N1 message delivery and disable the UPF buffering. Then the network starts to transfer the buffered MT data or N1 NAS message to the NG-RAN.

When the UE moves outside of the RNA it triggers RNA update and the data buffered in the last serving NG-RAN node can be forwarded to the target NG-RAN node.

### 6.5.2 Procedures

#### 6.5.2.1 MT data handling of UE with long eDRX in RRC\_Inactive state



Figure 6.5.2.1-1: High level procedure for MT data handling of UE with long eDRX in RRC\_Inactive state

1. The MT data is sent to NG-RAN from the UPF over the N3 user plane connection.

2. Since the NG-RAN knows the UE is in eDRX cycle and not reachable for paging, it starts to buffer the downlink data.

3. The NG-RAN may determine to enabler the MT data buffering in the UPF (e.g. when the remaining UE unreachable time is long enough or when the RAN buffer will be overflown), it sends N2 Suspend Request to AMF, including an indication to enable the MT data buffer in UPF and keep the UE in CM-CONNECTED state. The NG-RAN may also provide an Expected Waiting Time so the UPF can determine the buffer time.

4. The AMF sends Nsmf\_PDUSession\_UpdateSMContext request to the SMF to enable MT data buffering in UPF. The AMF provides the Expected Waiting Time to the SMF. The AMF keeps the UE in the CM-CONNECTED state, i.e. keeping the N1 and N2 connection in the UE context.

5. The SMF sends N4 Session Modification procedure to enable the MT data buffering in UPF. The UPF starts to buffer further MT data while still keeping the N3 tunnel towards the NG-RAN, i.e. the UPF doesn't remove the N3 GTP-U tunnel endpoint identity in NG-RAN. The SMF use the Expected Waiting Time to set the buffer timer in the UPF.

6. The SMF sends Nsmf\_PDUSession\_UpdateSMContext Response to AMF.

7. The AMF sends N2 Suspend Response to the NG-RAN.

8. After step 5, the UPF starts to buffer further downlink data.

9. When the eDRX timer expires, the NG-RAN determines that the UE is reachable again. If there is any downlink data buffered in the NG-RAN, the NG-RAN sends paging request in all the cells of the RNA (RAN Notification Area).

10. When the UE receives paging request, it sends RRC Connection Resume request to the NG-RAN to resume the RRC connection.

11. The NG-RAN sends RRC Connection Resume to the UE to resume the RRC connection.

12. The UE sends RRC Connection Resume Complete to the NG-RAN. After this step, the RRC connection between the UE and NG-RAN is resumed.

13. The NG-RAN sends the buffered MT data to UE via the user plane connection between UE and NG-RAN.

14. If the NG-RAN has sent N2 Suspend Request to AMF in step 3, it sends N2 Resume Request to AMF to enable the MT data transfer over N3 user plane connection.

15. The AMF sends Nsmf\_PDUSession\_UpdateSMContext request to the SMF to enable MT data transferring.

16. The SMF sends N4 Session Modification procedure to enable the MT data transferring in UPF.

17. The SMF sends Nsmf\_PDUSession\_UpdateSMContext Response to AMF.

18. The AMF sends N2 Suspend Response to the NG-RAN.

19. The UPF stops the MT data buffering.

20. The UPF sends the buffered MT data and further received MT data towards the NG-RAN via the N3 user plane connection between the NG-RAN and UPF.

#### 6.5.2.2 MT N1 message handling of UE with long eDRX in RRC\_Inactive state



Figure 6.5.2.2-1: high level procedure for MT N1 message handling of UE with long eDRX in RRC\_Inactive state

1. The AMF determines to send N1 NAS message to the UE, so it sends N1 Message Transfer to the NG-RAN.

2. Since the NG-RAN knows the UE is in eDRX cycle and based on the remaining unreachable time, the UE is not reachable before the NAS retransmission timer expires, the NG-RAN rejects the N1 Message Transfer, with a cause value indicating that the UE is temporarily not reachable. The NG-RAN may also include an Expected Waiting Time in the rejection message.

3. Based on implementation the AMF may reject the request which triggers the N1 message. The rejection message may include an Expected Waiting Time received from the NG-RAN.

4. The AMF starts a timer according to the received Expected Waiting Time from NG-RAN. Before the timer expires the AMF doesn't try to deliver any further N1 NAS message to the NG-RAN. The AMF keeps the UE in the CM-CONNECTED state, i.e. keeping the N1 and N2 connection in the UE context.

5. When the timer expires, and the AMF receives further request for N1 NAS message delivery it sends N1 Message Transfer to the NG-RAN.

6. The NG-RAN determines that the UE is reachable and it sends Paging request in the RNA.

7. When the UE receives paging request, it sends RRC Connection Resume request to the NG-RAN to resume the RRC connection.

8. The NG-RAN sends RRC Connection Resume to the UE.

9. The UE sends RRC Connection Resume Complete to the NG-RAN. After this step, the RRC connection between the UE and NG-RAN is resumed.

10. The NG-RAN sends the N1 NAS message to the UE over the RRC connection.

### 6.5.3 Impacts on services, entities and interfaces

NG-RAN, when the UE is in RRC\_Inactive state:

- After receiving and buffering the MT data, the NG-RAN sends suspend indication to AMF to enable the UPF buffering.

- Reject the N1 message transfer with cause value and expected waiting time value.

- When the UE becomes in RRC\_connected state, the NG-RAN sends resume indication to AMF to disable the UPF buffering and enable the delivery of MT data and MT N1 message.

AMF:

- Handling of suspend indication and resume indication from NG-RAN.

- Handling of N1 message transfer failure.

SMF:

- Handling of suspend indication and resume indication from AMF.

UPF:

- Enable/Disable the UPF buffering while keeping the N3 tunnel.

## 6.6 Solution #6: Converged Solution for handling RRC inactive with eDRX>10.24s.

### 6.6.1 Introduction

The solution applies to Key Issue #1 and covers both sub-aspects of the key issue. The solution is meant to converge Solutions #1 (clause 6.1), #3 (clause 6.3), and #4 (clause 6.4).

### 6.6.2 Functional Description

If the AMF has indicated support of eDRX>10.24s for CM-CONNECTED with RRC Inactive, and has provided idle mode eDRX cycle length, the NG-RAN (i.e. gNB) may at any point configure the UE with eDRX>10.24s when moving the UE to CM-CONNECTED with RRC Inactive.

NOTE: Whether the NG-RAN needs to use same eDRX cycle length as in idle mode eDRX, will be determined in normative phase based on RAN WGs feedback.

When the UE is moved to RRC-Inactive with eDRX>10.24s, the NG-RAN notifies the AMF via N2 signalling. The AMF enters a substate of CM-CONNECTED, denoted "CM-CONNECTED with RRC Inactive and eDRX>10.24s". In this state, the AMF follows similar behaviour as for CM-IDLE when the UE is unreachable when interacting with other NFs.

When the UE is CM-CONNECTED with RRC Inactive state and eDRX>10.24s, DL data is buffered in CN and NAS procedures are not executed, except paging procedure when UE is considered reachable by AMF, until the UE returns to RRC-Connected state.

When the UE moves back to RRC-Connected, the NG-RAN notifies the AMF via N2 signalling.

UE performs both AS and NAS level mobility and periodic AS update based on existing Rel-17 functions.

### 6.6.3 Procedures

#### 6.6.3.1 UE entering CM-CONNECTED with RRC Inactive and eDRX>10.24s



Figure 6.6.3.1-1: UE entering CM-CONNECTED with RRC Inactive and eDRX>10.24s.

1. The UE initiates the Registration Procedure and the eDRX parameters in CM-IDLE state are negotiated.

2. The AMF sends the Inactive Assistance Information to the NG-RAN. The eDRX parameters in CM-IDLE state are included as defined in clause 5.3.3.2.5 of TS 23.501 [2]. The AMF also includes support of CM CONNECTED with RRC Inactive and eDRX>10.24s.

3. Before transitioning the UE into RRC\_Inactive state, NG-RAN determines the eDRX parameters for UE in RRC\_Inactive state.

4. When the NG-RAN decides to transition the UE to RRC Inactive state with eDRX>10.24s, the NG-RAN sends N2 message to AMF indicating the UE is transitioning to RRC Inactive with eDRX>10.24s.

NOTE 1: Whether the N2 message to be used is a new message or an existing message, e.g. N2 notification, will be decided during normative work.

5. For each of the PDU sessions for which user plane resources have been activated, the AMF invokes Nsmf\_PDUSession\_UpdateSMContext Request (PDU Session ID, Cause, Operation type, User Location Information, Age of Location Information, N2 SM Information (Secondary RAT usage data)) towards SMF. The Operation Type is set to a value that indicates to stop user plane DL data transmissions towards the UE and enable data buffering. The SMF starts data buffering for MT data if the data buffering is handled in SMF.

NOTE 2: Whether an existing Operation Type is used, e.g. "UP Suspend", or another value is used can be decided during normative work.

6. If data buffering is handled in UPF, the SMF updates the UPF with proper rules for MT data handling.

7. The SMF sends the Nsmf\_PDUSession\_UpdateSMContext response.

8. The AMF sends N2 response to NG-RAN confirming CM-CONNECTED with RRC Inactive and eDRX>10.24s state. The AMF enters CM-CONNECTED with RRC Inactive and eDRX>10.24s state.

9. NG-RAN initiates RRC Release with Suspend procedure configuring eDRX>10.24s. The UE enters CM connected with RRC Inactive and UE performs both AS and NAS level mobility and periodic AS update based on existing Rel-17 functions.

#### 6.6.3.2 UE triggered Connection Resume procedure

Figure 6.6.3.2-1 shows the call flow for UE triggered Connection Resume procedure when the UE is in CM-CONNECTED with RRC Inactive and eDRX>10.24s.



Figure 6.6.3.2-1: UE Triggered Connection Resume procedure

1. UE to NG-RAN: RRC message (Resume ID).

The UE initiates the transition from RRC Inactive state to RRC Connected state, see TS 38.300 [4]. The UE provides its Resume ID needed by the NG-RAN to access the UE's stored Context.

2. [Conditional] NG-RAN performs UE Context Retrieval.

UE Context Retrieval is performed when the UE Context associated with the UE attempting to resume its connection is not locally available at the accessed NG-RAN. The UE Context Retrieval procedure via NG-RAN is specified in TS 38.300 [4].

NOTE 1: Steps 1 and 2 are the same as steps 1 and 2 in 4.8.2.2 of TS 23.502 [3], with no impact.

3a. [Conditional] N2 Path switch procedure.

If the accessed NG-RAN is not the same as the NG-RAN that configured RRC Inactive, the accessed NG-RAN node initiates N2 Path Switch procedure, i.e. steps 1 to 8 of clause 4.9.1.2.2 and including Xn data forwarding.

3b. [Conditional] RRC Connected indication

3b.1 If the NG-RAN is the same as the NG-RAN that configured RRC Inactive (and still has UE context locally), the NG-RAN send N2 message to AMF indicating the UE is in CM-CONNECTED.

NOTE 2: Whether this message is new or an existing one, e.g. N2 notification message, is to be decided during normative work.

3b.2 The AMF invokes Nsmf\_PDUSession\_UpdateSMContext Request indicating the UE has resumed RRC connection for each SMF that applies.

3b.3 N4 session modification procedure is triggered by SMF. If data buffering is handled in UPF, the SMF updates the UPF with appropriate rules to no longer buffer data.

3b.4 The SMF sends the Nsmf\_PDUSession\_UpdateSMContext response.

3b.5 The AMF sends N2 response to NG-RAN confirming CM-CONNECTED.

4. NG-RAN sends RRC message to UE confirming to the UE that the UE has entered RRC Connected state.

NOTE 3: Steps 3 and 4 can be executed in parallel.

#### 6.6.3.3 Network triggered Connection Resume procedure

When the UE is in CM-CONNECTED with RRC Inactive and eDRX>10.24s, all mobile terminated data handling, high latency communication, between AMF, SMF, UPF, SMSF and any other NF follow same signalling flow as for CM-IDLE.

Network triggered Connection Resume procedure may be triggered by MT data, or a network initiated NAS procedure from SMF and UPF as shown in Figure 6.6.3.3-1. When the procedure is triggered by other NFs (e.g., SMSF, LMF, GMLC), the UPF (or SMF) in the following figure should be replaced by the respective NF (the corresponding service operations used by other NFs when they communicate with AMF may also be different from the service operations used by SMF/UPF).

During the procedure, the NG-RAN (i.e. gNB) sends a RAN Paging to the UE based on N2 message from AMF in order to trigger the UE triggered Connection Resume procedure in clause 6.6.3.2.



Figure 6.6.3.3-1: Network Triggered Connection Resume procedure

1. There is a trigger in the AMF to Resume the RRC Connection for a UE.

1a. When downlink data is received and the SMF/UPF is requested to perform buffering as specified in clause 6.6.3.1 above, UPF/SMF checks with AMF for the possibility of data delivery, similar to step 2 of clause 4.24.2 of TS 23.502 [3] with the following differences:

- If AMF is in CM-CONNECTED with RRC Inactive and eDRX>10.24s, and determines that UE is not reachable in RRC INACTIVE state based on the information provided from NG-RAN in clause 6.6.3.1, the AMF provides the Estimated Maximum Wait time in the response message based on the stored extended DRX information for RRC INACTIVE in AMF (see clause 6.6.3.1). This handling is similar to CM-IDLE with eDRX. When the AMF provides the Estimated Maximum Wait time, it can consider the time needed for RRC level procedures (e.g. RRC RNA update procedure) when UE wakes up from the eDRX cycle.

1b. A need for network initiated NAS procedure or N2 procedure, including the case of MT data delivery, may be triggered in the AMF if the AMF consider UE is reachable when the UE state is CM-CONNECTED with RRC Inactive and eDRX>10.24s.

2. The AMF sends N2 message to NG-RAN with request for the UE to be transitioned to RRC connected. The N2 message is triggered by either pending DL data buffered in the CN or pending MT NAS message as specified in step 1b.

NOTE: The N2 message is new or an existing one, e.g. N2 notification message, is to be decided during normative work.

3 The NG-RAN performs RAN paging.

4. When the UE receives RAN paging, it initiates Connection Resume, which triggers UE triggered Connection Resume procedure (see clause 6.6.3.2).

5a. User Plane PDUs are sent from UPF.

5b. AMF starts Network initiated NAS procedure, transmits DL NAS PDU and starts the corresponding NAS retransmission timer, or starts N2 procedure.

### 6.6.4 Impacts on services, entities and interfaces

AMF:

- eDRX parameters for RRC\_INACTIVE state exchange on NGAP interface.

- Estimated Maximum Wait time calculation based on eDRX parameters from RRC\_INACTIVE state.

- Notification of MT service on NGAP interface.

- New CM-CONNECTED substate, and potentially new N2 message.

gNB:

- eDRX parameters for RRC\_INACTIVE state exchange on NGAP interface.

- Notification of MT service on NGAP interface which triggers the RAN Paging.

- Potentially new N2 message.

SMF:

- Supports data buffering/delivery Indication from AMF even in case of the N3 tunnel existence.

UPF:

- none.

# 7 Evaluation

## 7.1 General

There are six solutions proposed to address the objective to enable long eDRX when the UE is in RRC-Inactive. The table below is to provide an overview of these solution. The solutions being:

**Solution 1:** Power saving enhancement with long eDRX cycle support for UE in CM-CONNECTED with RRC\_INACTIVE state.

**Solution 2:** Long eDRX with RAN buffering.

**Solution 3:** Solution #3: MT signalling and data handling for UE with long eDRX cycle in RRC\_Inactive state and UPF buffering.

**Solution 4:** RRC Inactive with CM-IDLE for eDRX>10.24s.

**Solution 5:** Enabling UPF buffering per NG-RAN request for UE in RRC\_Inactive state with long eDRX cycle.

**Solution 6:** Converged solution for handling RRC inactive with eDRX>10.24s.

Table 7.1-1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Solution #1 | Solution #2 | Solution #3 | Solution #4 | Solution #5 | Solution #6 |
| State Combination(s) | RRC Inactive/CM-Connected | RRC Inactive/CM-Connected | RRC Inactive/CM-Connected | RRC Inactive/CM-Idle | RRC Inactive/CM-Connected | RRC Inactive /CM-Connected and long eDRX (New AMF sub-state) |
| Node that configure the UE eDRX in RRC-Inactive | RAN (at RRC Release) | RAN (at RRC Release) | RAN (at RRC Release) | RAN (at RRC Release) | RAN (at RRC Release) | RAN (at RRC Release) |
| AMF awareness of RRC-Inactive state needed in CM-CONNECTED | Yes | No | Yes | Yes | Yes | Not explicitly (AMF aware of long eDRX.) |
| User data Buffering | UPF/SMF | RAN or UPF/SMF  If RAN fails to buffer according to configured eDRX, RAN will initiate AN release procedure towards the CN. UE is moved to CM-Idle in the CN and the state in the UE remains as CM-Connected. | UPF | UPF/SMF | RAN and UPF  RAN sends a N2 Suspend request indicate start of CN/UPF buffering after receiving DL data(remaining eDRX Timer). | UPF/SMF |
| MT Signalling | AMF is aware of eDRX information | AMF -> RAN forward NAS msg.  If the UE is not reachable then: RAN -> AMF releases UE context with Notification that UE is in eDRX cycle. UE is moved to CM-Idle.  AMF may try again later based on eDRX information | AMF is aware of buffer timer (initial and re-buffer timers) | AMF is aware of eDRX information | AMF -> RAN forward NAS msg.  If the UE is not reachable then: RAN -> AMF Notification that UE is in eDRX cycle (remaining eDRX Timer). UE remains in RRC-Inactive and CM-Connected. AMF suspend MT signalling based on Timer. | AMF is aware of eDRX information |
| UE RRC Release timing. | UE may be released before AMF is notified | N/A | UE may be released before AMF is notified | UE is released after AMF responds to the N2 suspend as specified in clause 4.8.1 of TS 23.502 [3] | N/A | UE is released after AMF responds to the N2 request |
| Signalling when UE moves from RRC Connected to RRC Inactive | RAN-> AMF Notification (eDRX config)  AMF-> SMF -> UPF PDU session modification | None | RAN-> AMF Notification (buffer timer)  AMF-> SMF -> UPF PDU session modification (buffer timer) | RAN-> AMF Suspend message (eDRX config)  AMF-> SMF -> UPF PDU session modification | None, when the transition occurs.  During the RRC\_Inactive period RAN-> AMF Suspend message (eDRX config)  AMF-> SMF -> UPF PDU session modification may occur. | RAN-> AMF Suspend message (eDRX config)  AMF-> SMF -> UPF PDU session modification |
| Signalling when UE moves from RRC Inactive to RRC Connected | RAN-> AMF Notification  AMF-> SMF -> UPF PDU session modification | None | RAN-> AMF Notification and then AMF-> SMF -> UPF PDU session modification for MO triggered connection resume. | RAN-> AMF Resume message  AMF-> SMF -> UPF PDU session modification | Only if RAN sent a N2 Suspend request to start of DL data buffering, then RAN will send a N2 Resume request once the UE is in RRC-Connected state. | RAN-> AMF Resume message  AMF-> SMF -> UPF PDU session modification |
| Information exchanged among NFs | AMF communicates with other NFs on the UE reachability the same way as in CM-IDLE modes deducing UE reachability information based on gNB provided eDRX value. | None  EN: It is FFS whether and how the AMF may support UE reachability notification based on IDLE mode eDRX information also in CM-Connected. | AMF communicates with other NFs on the UE reachability based on the buffering information provided by gNB. | AMF communicates with other NFs on the UE reachability the same way as in CM-IDLE modes deducing UE reachability information based on gNB provided eDRX value. | AMF communicates with other NFs on the UE reachability based N1 message transfer failure provided by gNB and may reject requests from other NFs based on it. | AMF communicates with other NFs on the UE reachability the same way as in CM-IDLE modes deducing UE reachability information based on gNB provided eDRX value. |
| Paging | SMF/ UPF forwards buffered data based on Estimated Maximum Wait time to trigger RAN paging  If UE does not respond data will be dropped | RAN trigger paging based on UE eDRX configuration  If UE does not respond data will be dropped.  Optional: RAN may escalate to AMF for paging within RA. | UPF forwards buffered data based on "buffer timer" to trigger RAN paging.  If UE does not respond data will be dropped. | AMF send a paging request with new indication to trigger RAN paging.  If UE does not respond AMF can escalate CN paging within RA. | Based on MT data/N1 message buffered in RAN, RAN trigger paging based on UE eDRX configuration. The UPF forwards buffered data based on "**buffer timer**".  If UE does not respond MT data/N1 will be dropped if the buffer in RAN is overflown. | AMF send a paging request with new indication to trigger RAN paging.  If UE does not respond AMF can escalate CN paging within RA. |
| Mobility within RNA | UE trigger RNAU  New RAN node fetch UE context from anchor RAN node and perform path switch | UE trigger RNAU  New RAN node fetch UE context from anchor RAN node and perform path switch | UE trigger RNAU  New RAN node fetch UE context from anchor RAN node and perform path switch | UE trigger RNAU  New RAN node fetch UE context from anchor RAN node and perform path switch | UE trigger RNAU  New RAN node fetch UE context from anchor RAN node and perform path switch | UE trigger RNAU  New RAN node fetch UE context from anchor RAN node and perform path switch |
| Mobility outside RNA | UE trigger RNAU  RAN fetch UE context if Xn.  If RAN is unable to fetch the UE context, RAN release UE to RRC Idle.  No UE state change notification to CN  If UE has MO data, the UE will perform SR from Idle | UE trigger RNAU  a) RAN fetch UE context if Xn.  b) RAN fetch UE context via AMF (buffered data will be forwarded)  If RAN is unable to fetch the UE context, RAN release UE to RRC Idle.  No UE state change notification to CN  If UE has MO data the UE will perform SR from Idle | UE trigger RNAU  a) RAN fetch UE context if Xn.  b) RAN fetch UE context via AMF (buffered data will be forwarded)  If RAN is unable to fetch the UE context, RAN release UE to RRC Idle.  No UE state change notification to CN  If UE has MO data the UE will perform SR from Idle | UE trigger RNAU  RAN fetch UE context if Xn.  If RAN is unable to fetch the UE context, RAN release UE to RRC Idle.  No UE state change notification to CN  If UE has MO data the UE will perform SR from Idle | UE trigger RNAU  RAN fetch UE context if Xn.  If RAN is unable to fetch the UE context, RAN release UE to RRC Idle.  No UE state change notification to CN  If UE has MO data the UE will perform SR from Idle | UE trigger RNAU  RAN fetch UE context if Xn.  If RAN is unable to fetch the UE context, RAN release UE to RRC Idle.  No UE state change notification to CN  If UE has MO data the UE will perform SR from Idle |
| UE signalling in RRC-Inactive | UE performs only periodic update signalling at AS. | UE performs only periodic update signalling at AS. | UE performs only periodic update signalling at AS. | UE performs periodic update signalling at both AS and NAS. | UE performs only periodic update signalling at AS. | UE performs only periodic update signalling at AS. |

## 7.2 Key Aspects

### 7.2.1 Overview

RRC-Inactive/CM-Connected was specified in Rel-15 as a new efficient state for 5G UEs. The key benefits for RRC-Inactive/CM-Connected compared to RRC-Idle/CM-Idle are the following:

- UE can resume the AS connection without performing e.g. AS security setup, and save several RRC message interactions between the UE and RAN.

- There is no RAN and CN interaction when the UE change state RRC-Inactive to/from RRC-Connected, if not required.

- User plane reconfiguration is not needed.

The area in which the UE move around in without the UE needs to perform Update due to mobility maybe much smaller than compared to RRC-Idle. In RRC-Inactive the area is defined by the Radio Notification Area (RNA) consisting of a set of RAN nodes. In RRC-Idle then the area is the whole Registered Area (RA) consisting of a set of Tracking Areas. This may result in more frequent Updates due to mobility.

### 7.2.2 Buffering of Downlink data

Two methods of buffering are proposed in the solutions with the main difference being DL data buffering in RAN or in the CN. Solution 2 and solution 5 allow buffering of the DL data in RAN. Solutions 1, 3, 4, 5 and 6 allows DL data in the Core Network either in the SMF or UPF in RRC\_INACATIVE state.

#### 7.2.2.1 Core Network DL data buffering

To enable DL data buffering in the Core Network, the RAN needs to signal to the AMF that the UE has changed its RRC state to RRC-Inactive with long eDRX. This initial N2 message will trigger the communication among CN NFs i.e. the AMF uses the Nsmf\_PDUSession\_UpdateSMContext Request to trigger the SMF to start the modification procedure towards UPF. Solution 4 and 6 ends these steps after the N2 response from the AMF to the RAN which allows the RAN to release the UE to RRC-Inactive. Solution 1 and 3 performs the these steps either after the UE is released or in parallel to that the UE is released. For solution 1 and 3 there is a risk that DL data can be forwarded to RAN after the UE is released which means that this DL data needs to be buffered in RAN or discarded by RAN.

The UE CM state in the AMF after this indication from RAN differs. Solutions 1, 3 and 5 leave the AMF in CM-CONNECTED state, the AMF knows that the UE is not reachable due to long eDRX and can apply the same procedures specified for UE that is unreachable in CM-IDLE state. Solution 4 moves the AMF to CM-IDLE with RRC-Inactive where selected CM-IDLE state procedures are applicable. Solution 6 moves the AMF to new substate of CM-CONNECTED state where the AMF can apply the same procedures specified for UE that is unreachable in CM-IDLE state. Solution 2 can move the UE to CM-IDLE based on a RANs decision and allow the CN to buffer using the existing procedures, however the UE is no longer in RRC\_Inactive.

The advantage of DL data buffering in UPF/SMF is that it has already been specified for 5G-CIoT devices. It is expected that the existing HLcom mechanism can be re-used for extended CN buffering.

The negative side is that enabling CN buffering would require RAN/CN interaction, exchanging 5- 6 messages every time the UE change RRC state from RRC-Connected to RRC-Inactive and 6 more messages every time the UE resumes to RRC-Connected. This RAN/CN signalling is independent of whether or not any DL data was sent to the UE.

#### 7.2.2.2 RAN DL data buffering

RAN is specified from Rel-15 to buffer DL data when the UE is released to RRC-Inactive.

The advantage of having the DL data buffering in RAN is that this is legacy behaviour for a UE in RRC-Inactive. There is no RAN/CN interaction when the UE change RRC state between RRC-Connected - RRC-Inactive - RRC-Connected. Thus, extending this capability means extending the buffering capacity of RAN . Furthermore, Solution 2 allows a deployment where RAN decides whether to support extended buffering or not. If the RAN chooses to not support extended buffering, then CN buffering (HLcom) is used instead by releasing the UE to CM-IDLE state. In that case, the RAN informs the AMF. Solution 5 reuses existing RAN buffer capability(e.g. around 1.28 or 2.56s). When the RAN determines that it cannot buffer any more downlink data, it informs the AMF to start CN buffering. The CN is not impacted if the RAN receives very few downlink packets during the UE unreachable time.

The negative side with RAN buffering for a UE in RRC-Inactive is that legacy buffering is only for typically around 1.28 or 2.56s, which now will be extended to a much longer time. This may affect the accumulated amount of data to be buffered.

### 7.2.3 Mobile Terminated signalling

#### 7.2.3.1 AMF aware of RRC-Inactive with long eDRX

Solution 1, 3 and 6 makes the AMF aware of the non-reachability in CM-Connected by the N2 message sent from RAN when the UE is released to RRC-Inactive with long eDRX. This allows the AMF to schedule DL NAS message considering the UE power save state in RAN. Solutions 1 and 3 expect the AMF to run a subset of idle mode procedures in CM-CONNECTED state. Solution 6 uses new CM-state in the AMF to run a subset of CM-IDLE state procedures in that new state.

Solution 4 allows the same behaviour but avoids violating CM-CONNECTED state design principles in the AMF by introducing a new state combination RRC-Inactive/CM-IDLE with behaviour that is a subset of the AMF CM-IDLE behaviour.

Solution 5 allows the same indication to be issued by the RAN only on event driven basis if there is DL NAS message towards the UE in long eDRX. The advantage of this approach is that if eDRX is configured for a UE and the RAN does not receive DL NAS message for the UE, then the AMF will never be aware that the UE is using long eDRX power saving. When the UE becomes reachable the RAN can trigger RAN paging without CN involvement. This may reduce the signalling latency.

#### 7.2.3.2 AMF unaware of RRC-Inactive with long eDRX

In Solution 2 and 5 the AMF is unaware of that the UE is in RRC-Inactive state and may not be reachable for a DL NAS message. That may result in that the DL NAS message is sent towards the UE at a timing when the UE will not monitor POs until the NAS retransmission timer expires.

To handle this, solution 5 proposes that RAN sends a notification as a response to the DL NAS message informing the AMF about the UE power save. This is the event discussed in 7.2.2.1. The AMF may try again once the UE is reachable again. The UE remains in RRC-Inactive/CM-Connected state in the network.

To handle the above situation, solution 2 reuses the legacy RAN paging failure and RAN initiate the AN release procedure. The negative effect with using the RAN paging failure is that the UE is moved to CM-Idle in the CN and RRC-Idle in RAN, but the UE is still locally in RRC-Inactive/CM-Connected. When the UE tries to resume the RRC connection it will be rejected, and the UE will need to perform RRC establishment procedure followed by NAS Service Request if the UE has UL data to transmit.

### 7.2.4 UE mobility outside RNA without Xn reference point.

The UE will wake-up after the long eDRX and search for a suitable cell and resynchronize to the network. This will be done prior to the PTW. When the UE detects that it is outside the RNA it will perform RNA update due to mobility and the new RAN node will try to fetch the UE context based on the I-RNTI. If there is no Xn and the RAN node is unable to fetch the UE context the RAN node will reject the RRC Resume (RNAU) and the UE is moved to RRC-Idle. RAN does not inform the AMF about this. The UE will need to perform RRC establishment procedure followed by NAS Service Request if the UE has UL data to transmit. This is legacy behaviour and applies to all solutions.

For solutions 4 and 6 the above does not affect the handling of the buffered DL data as the DL data is buffered in the CN and the CN can use legacy CN paging after the initial RAN based paging in the old RAN node failed. Typically, the same applies to solution 1 and 3. This may cause additional signalling latency.

Solutions 1, 2, 3 and 5 may have buffered DL data in the old RAN node and this data will be lost if nothing is done to forward the data to the new RAN node. Solution 1 proposes that the handling of the buffered DL data is done based on implementation. Solution 2 and 3 propose to specify CN assisted UE context/DL data forwarding from the old RAN node to the new RAN node.

### 7.2.5 High Latency Communication with RRC-Inactive

In solution 1, 3, 4 and 6, RAN informs the AMF and triggers CN buffering every time the UE is released to RRC-Inactive with long eDRX, These solutions can support the specified HLcom features in clause 5.31.8 of TS 23.501 [2] depending on if the extended buffering is done in the SMF or UPF. To support Downlink Data Delivery Status then the buffering needs to be done in the SMF. To support of UE Reachability and Availability after DDN failure notification buffering in the UPF is enough.

Solution 2 does not inform the AMF when the UE is released to RRC-Inactive when RAN handles the MT data/signalling, do not support the HLcom features as defined in clause 5.31.8 of TS 23.501 [2] when the UE is in CM-Connected. In solution 5 the RAN may also decide to inform the AMF to start the CN MT data/signalling handling and after that the HLcom feature in the CN can be applied.

UE reachability notification can be supported even if the AMF is not informed about UE RRC state change. A solution that is based on that the AMF is aware of the negotiated long eDRX for CM-IDLE is described in Solution #2a in clause 6.2a.

# 8 Conclusions

## 8.1 Conclusions for Key Issue #1: Enabling long eDRX cycle support in RRC\_INACTIVE state

The following aspects are concluded as principles for the normative work:

- It is agreed to support MT data signalling handling in CN when the UE is unreachable due to long extended DRX in RRC inactive.

- When the gNB sends an indication to the CN and provides unreachability information (e.g., eDRX values negotiated between UE and gNB for RRC\_INACTIVE state), the CN applies the HLcom functionality based on gNB provided unreachability information (as described in solution #6).

- If the gNB has indicated the UE has entered RRC\_INACTIVE to the CN, the gNB also notifies the CN about the RRC State transition back to RRC\_CONNECTED (as described in solution #6).

NOTE 1: When to send the indication to the AMF is up to gNB implementation.

NOTE 2: If the indication of UE transition to RRC\_INACTIVE is not sent (or sent after UE has entered RRC\_INACTIVE) by the gNB then until CN receives it the CN cannot apply HLcom functionality and other NFs will not be aware of the UE reachability, and certain HLcom related services provided to the AF via NEF would not be available. Downlink data transmitted from the UPF to RAN might be discarded and not delivered to the UE.

NOTE 3: Further coordination with RAN WGs may be needed during the normative phase.

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2022-05 | SP#96 | SP-220423 | - | - | - | MCC editorial update for presentation to TSG SA#96 for information | 1.0.0 |
| 2022-09 | SP#97-e | SP-220839 | - | - | - | MCC editorial update for presentation to TSG SA#97-e for approval | 2.0.0 |
| 2022-09 | - | - | - | - | - | MCC editorial update for publication (Rel-18) | 18.0.0 |
| 2022-12 | SP#98-e | SP-221088 | 0001 | - | F | Conclusion update for KI#1 | 18.1.0 |