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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 TR is to investigate further 5GC/EPC enhancements to support satellite access using the work done in Release 17 as baseline with the following 5GC/EPC areas for study:

- Possible enhancements to support of Discontinuous coverage with the following areas of focus:

- Architectural enhancements to support discontinuous coverage for mobility enhancement (e.g. paging enhancement).

- Architectural enhancements considering prediction, awareness and notification of UE wake-up time, power saving optimizations.

# 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 23.503: "Policy and Charging Control Framework for the 5G System".

[5] 3GPP TS 23.401: "General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access".

[6] 3GPP TS 23.682: "Architecture enhancements to facilitate communications with packet data networks and applications".

[7] 3GPP TS 24.301: "Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3".

[8] 3GPP TS 24.008: "Mobile radio interface Layer 3 specification; Core network protocols; Stage 3".

[9] 3GPP TS 26.531: " Data Collection and Reporting; General Description and Architecture".

[10] 3GPP TS 23.288: "Architecture enhancements for 5G System (5GS) to support network data analytics services".

[11] 3GPP TR 23.700‑61: "Study on Seamless UE context recovery".

[12] 3GPP TS 38.300: "NR; NR and NG-RAN Overall description; Stage-2".

[13] 3GPP TS 23.122: "Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode".

[14] 3GPP TS 24.501: "Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3".

# 3 Definitions of terms and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1], in TS 23.501 [2] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1] or in TS 23.501 [2].

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1], in TS 23.501 [2] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1] or in TS 23.501 [2].

<ABBREVIATION> <Expansion>

# 4 Architecture assumptions and Principles

Discontinuous satellite coverage for satellite access in the context of this study is characterized by the fact that Uu interface is available for the UE less than 100% of the time, due to predictable patterns of satellite coverage.

The architecture for satellite access to 5GC as defined in TS 23.501 [2] is used as a baseline.

The architecture for satellite access to EPC as defined in TS 23.401 [5] is used as a baseline.

The solution defined for support of discontinuous coverage in EPC as defined in TS 23.401 [5] could be used as a baseline.

Solutions should be applicable to both EPS and 5GS. Discontinuous satellite coverage under EPC and 5GC interworking is not considered.

Solutions shall minimize the impact on 5GS and EPS system protocols.

# 5 Key Issues

## 5.1 Key Issue #1: Mobility Management enhancement with discontinuous satellite coverage

### 5.1.1 General description

In Rel-17, Tracking Area and therefore RAT specific MME configuration has been introduced in EPS in order to allow support for discontinuous coverage for satellite access in EPS.

The key issue intends to study the essential issues for mobility management related to discontinuous coverage modelling. At least the following aspects need to be further studied:

- Identify gaps in rel.17 solution designed in EPS (e.g. concerning minimizing a period of no coverage and/or minimizing power consumption), considering at least below aspects:

a) Study how UE determines that it has to remain with no service or it has to attempt to register on available different RAT's/ PLMNs to receive the normal service during discontinuous coverage in current NTN RAT.

NOTE: Consider dependencies with RAN2 and CT1 since inter-RAT selection and PLMN selection related specifications are in control of RAN2 and CT1.

b) Study how to reduce the impact to target RAT or system due to large number of UEs triggering signalling load on the target RAT or system to receive normal service.

- Propose solution to resolve these gaps.

## 5.2 Key Issue #2: Power saving enhancement for UE in discontinuous coverage

### 5.2.1 General description

For a UE using a NG-RAN that provides discontinuous coverage (e.g. for satellite access with discontinuous coverage), the UE may be out of network coverage at a certain time. The UE may then attempt to scan for available cell due to the UL traffic or NAS layer signalling, e.g. Periodic Registration. In Rel-17, the UE in EPS may deactivate the access stratum when there is no network coverage, however there might still be some additional issues, e.g. whether de-registration occurs due to any inconsistency of CM states between UE and CN and, the usage of eDRX in CM-IDLE state, etc.

Therefore, for power saving mechanisms, like MICO mode and eDRX in CM-IDLE state, how to apply the power saving mechanism to ensure that the UE does not attempt PLMN access when there is no coverage still needs to be studied.

The key issue intends to study architectural enhancement for UE in discontinuous coverage.

At least the following aspects need to be investigated:

- Based on the coverage information of the UE:

- whether and how to enhance the power saving mechanisms, e.g. PSM, MICO mode and eDRX in CM-IDLE state, in order to make sure that the UE:

- does not attempt PLMN access when there is no network coverage; and

- when there is network coverage the UE attempts PLMN access as needed e.g. to transfer signalling, transfer data or receive paging, etc.

NOTE: Network coverage can be provided by any RAT supported by the UE.

# 6 Solutions

## 6.0 Mapping of solutions to key issues

Editor's note: This clause describes the mapping between solutions and key issues.

Table 6.0-1: Mapping of solutions to key issues

|  |  |
| --- | --- |
|  | Key Issues |
| Solutions | 1 | 2 |  |  |
| 1 |  | X |  |  |
| 2 |  | X |  |  |
| 3 |  | X |  |  |
| 4 | X |  |  |  |
| 5 |  | X |  |  |
| 6 | X |  |  |  |
| 7 | X | X |  |  |
| 8 | X |  |  |  |
| 9 |  | X |  |  |
| 10 | X | X |  |  |
| 11 | X | X |  |  |
| 12 | X |  |  |  |
| 13 | X |  |  |  |
| 14 | X |  |  |  |
| 15 | X | X |  |  |
| 16 | X | X |  |  |

## 6.1 Solution #1: Power Saving based on AMF awareness of coverage information

### 6.1.1 Description

This solution resolves Key Issue #2 about the power saving enhancements for UE in discontinuous coverage.

In order to make sure the UE is kept in power saving mode without any uplink MO signalling request, this solution enhances the AMF to derive power saving parameters, e.g. eDRX parameters, periodic registration timer and the active time for MICO mode, based on the coverage information. Then only when UE is within the network coverage, the periodic registration update request would be initiated or the UE would wake up to monitor the paging occasion.

As the discontinuous coverage information it taken into account when determining the parameters for eDRX, MICO mode the existing procedures for reachability (including exposure), MT data buffering, etc can be reused.

The available eDRX cycles may not match the timing of the coverage for a UE. Then this occurs the network can provide the UE with an eDRX cycle that is a divisor of the coverage time. For example, if there is coverage in 60 mins time, and the available eDRX cycles would be 20mins, 40min, 80min, then the 20min cycle should be selected (example is for illustration and is not using actual eDRX cycle time values). When combined with the UEs knowledge of when there is no network coverage the UE will avoid waking up. The network knows the UE coverage and therefore can avoid paging the UE. When there is available network coverage, the UE can wake up according to the eDRX parameters and the network can page the UE as usual.

### 6.1.2 Procedures

#### 6.1.2.1 Power saving enhancement for 5GS

Before moving the UE to CM-IDLE state, the NG-RAN or AMF may decide to trigger the AN release procedure based on the coverage information.



Figure 6.1.2.1-1: High-level procedure for power saving enhancement in 5GS

0. When UE detects it is about to leave network coverage, it may use an existing AS procedures to request release from RRC\_CONNECTED.

1. If the RAN detects that the UE in CM-CONNECTED is about to be out of network coverage based on the coverage information or if it receives the release request, the (R)AN may trigger the AN release procedure to move UE into CM-IDLE state before entering the non-coverage area.

2. The RAN may send an N2 UE Context Release Request message to the AMF.

3. If the AMF detects that the UE in CM-CONNECTED is about to leave the current network coverage based on the coverage information, the AMF may trigger the AN release procedure to move UE into CM-IDLE state when the UE is still within the network coverage.

4. During the AN release procedure, AMF may determine the power saving parameters for the UE based on the discontinuous coverage information. The coverage information may be derived by the AMF based on the satellite assistance information from RAN, e.g. satellite id, satellite ephemeris. The power saving parameters can be periodic registration timer, active time for MICO mode and the eDRX parameters. This is to make sure the UE is kept in power saving mode without initiating any MO signalling requests when it is out of network coverage. The active time may be used to keep UE reachable before the UE moves outside of coverage.

NOTE 1: It is assumed the UE is in a fixed location, mobile in limited area or mobile with known/predictable trajectories. Based on the known mobility pattern, including the time it covers, and coverage information of the UE, the AMF can help to derive the power saving parameters.

NOTE 2: The periodic registration timer may also be the Strictly Periodic Registration Timer.

5. AMF may trigger the UE Configuration Update procedure to update the power saving parameters.

6. The AMF sends an N2 UE Context Release Command to the (R)AN.

7. The RAN requests the UE to release the (R)AN connection. Upon receiving (R)AN connection release confirmation from the UE, the (R)AN deletes the UE's context.

8. The (R)AN confirms the N2 Release by returning an N2 UE Context Release Complete (List of PDU Session ID(s) with active N3 user plane, User Location Information, Age of Location Information) message to the AMF.

9. [Conditional] AMF to SMF: For each of the PDU Sessions in the N2 UE Context Release Complete, the AMF invokes Nsmf\_PDUSession\_UpdateSMContext Request in order to release N3 resources as defined in clause 4.2.6 of TS 23.502 [3].

NOTE 3: The UE may deactivate the AS layer and/or withhold sending MO traffic when there is no network coverage for power saving.

#### 6.1.2.2 Power saving enhancement for EPS

Before moving outside network coverage, the UE triggers the Tracking Area Update procedure for power saving parameters update.

NOTE 1: A similar mechanism can also be applied for 5GS where the UE uses the Registration procedure instead.



Figure 6.1.2.2-1: High-level procedure for power saving enhancement in EPS

0. Based on coverage information, the UE may determine that it is about to move outside network coverage and trigger the TAU procedure towards the MME.

1. The UE sends the TAU request message to the MME to request an update of the power saving parameters.

NOTE 1: The TAU request may not only be triggered by coverage information, e.g. periodic TAU timer.

2. The MME may determine the power saving parameters for the UE based on the discontinuous coverage information. The coverage information may be derived by the MME based on the UE location and the satellite assistance information from RAN, e.g. satellite id, satellite ephemeris. The power saving parameters can be periodic TAU timer, active time for PSM and the eDRX parameters. This is to make sure the UE is kept in power saving mode without initiating any MO signalling requests when it is out of network coverage. The active time may be used to keep UE reachable before the UE moves outside the coverage.

NOTE 2: It is assumed the UE is in a fixed location or mobile in limited area.

3. The MME returns the TAU Accept message with the updated power saving parameters to the UE.

### 6.1.3 Impacts on services, entities and interfaces

**RAN:**

- Trigger AN release based on the coverage information for the UE or request from the UE.

- Send satellite assistance information to AMF/MME.

**AMF:**

- Trigger AN release based on the coverage information for the UE.

- Configure the power saving parameters based on the coverage information for the UE.

- derive the coverage information based on the satellite assistance information and UE location.

**MME:**

- Configure the power saving parameters based on the coverage information for the UE.

- Derive the coverage information based on the satellite assistance information and UE location.

**UE:**

- Trigger the Tracking Area Update procedure or AN release when it is about to leave outside the network coverage.

## 6.2 Solution #2: predictive Power Saving Mode

### 6.2.1 Description

This solution resolves Key Issue #2 about the power saving enhancements for UE in discontinuous coverage.

In the proposed solution:

- The CN (MME or AMF) is aware of the motion of the satellites of the constellation and is able to extrapolate the position of the different satellites of the constellation, as well as the period of time during which the satellites are visible at a given terrestrial location.

Editor's note: How the AMF / MME can obtain the satellite ephemeris is FFS.

- The UE is capable of PSM operation, and as per R17 assumption for NTN access, is equipped with GNSS receiver.

- The UE, when requesting periodic update timer value and active time, indicates its current position and may also indicate its extrapolated position at the time of the next expected periodic update. e.g.: UE located in latitude/longitude (t0) request 3hours and indicates latitude/longitude (t0+3h).

- In MME response, if PSM is accepted, the network may indicate periodic update timer value different from the requested timer to accommodate with the satellites movement, for the UE to be under coverage for the next periodic tracking area update.

- If no coverage is foreseen by the MME at the time and the extrapolation position requested by the UE, the MME may perform linear extrapolation on UE position to find the closest possible coverage time.

- The periodic update timer value provided by AMF is either a new full timer value or an offset on the value of requested timer, to coincide next TAU with when the UE will be in coverage, according MME hypothesis and knowledge on UE and satellites movements.

Editor's note: The final choice for correction time value type and coding is FFS either in SA2 or RAN2 due to its signalling relation.

- Note that specifying an offset value, with different possible unit values, may enable more accurate time than providing absolute timer value. (For example, the GPRS timer 3 format currently used implies a granularity of 1 hour if the assigned timer period is larger than ~5 hours).

### 6.2.2 Procedures

In the existing PSM procedure, as stated in specifications (TS 23.682 [6], TS 24.301 [7], and TS 24.008 [8]):

UE requests the PSM by including a timer with the desired value in the ATTACH REQUEST, or TAU REQUEST. By the way the UE reports how often and for how long it needs to be active in order to transmit and receive data. However, the final values are determined by the network.

In the proposed solution, ATTACH REQUEST, or TAU REQUEST are complemented by the following IEs, if PSM is requested by the UE:

- UE current position (mandatory in case of satellite access).

- UE position extrapolated at the end of requested sleep time (optional).

MME makes assumption of linear UE movement based on above information and compares UE future trajectory with prediction of satellites coverage in the zone. The value returned as extension timer correspond to the closest point to UE extrapolated position where UE will find coverage.

ATTACH ACCEPT, or TAU ACCEPT is complemented by the following IEs, if PSM is accepted by the network:

- New timer extension value or Offset on timer extension value, with same or similar coding as defined by GPRS timer 3 in TS 24.008 [8].

Editor's note: The final choice for correction time value type and coding is FFS either in SA WG2 or RAN WG2 due to its signalling relation.

### 6.2.3 Impacts on services, entities and interfaces

**UE:**

- Computes its current and extrapolated location depending on its local PSM configuration.

**RAN:**

- None.

**MME:**

- Obtain information on future coverage given satellites motion.

- Configure the power saving parameters based on the coverage information for the UE.

## 6.3 Solution #3: Power Saving based on UE awareness of coverage information

### 6.3.1 Description

**General**

This solution addresses Key Issue #2 about the power saving enhancements for UE in discontinuous coverage.

The solution is based on the Rel-17 approach agreed in TS 23.401 [5] and clarifies how it works with PSM and MICO. It is based on the following existing pre-Rel-18 features and functionalities:

- The UE is aware of its location and the satellite coverage information

- In the case of Power Saving Mode (PSM), the UE can request an Active Time value and Periodic TAU Timer value in the TAU Request. The MME takes the UE requested values into account and assigns an Active Time value and Periodic TAU Timer value in the TAU Accept.

- In the case of MICO mode with Active Time, the UE can request an Active Time value during the Registration procedure. The AMF takes the UE requested values into account and assigns the Active Time value in the Registration Accept.

- In the case of eDRX, the UE requests eDRX parameters (e.g. cycle length) during the Registration/TAU procedure. The AMF/MME takes the UE requested values into account and assigns the eDRX parameters in the Registration/TAU Accept.

- HLCOM can be applied while the UE is in PSM/MICO mode to buffer data in the network, or notify the AF about UE reachability, as applicable.

- Tracking Area or RAT specific MME configuration of implicit deregistration timer can be used to ensure that the UE is not deregistered in case the UE is out of coverage when the Periodic TAU Timer expires.

**Power Saving Mode (PSM)**

The UE determines based on its knowledge of its location and the satellite ephemeris data when it will have coverage and when it will not have coverage.

In this solution the UE enters PSM based on current specification. The UE leaves PSM based on the existing specification triggers i.e. when it is during the active time or due to an MO event but only when it has coverage (based on the coverage information) and there is a need to contact the network.

As per existing standard, the network will not try to page the UE while it is in PSM. The only time the network may page the UE is during the Active Time for the period of Active Time directly after the UE has moved to IDLE state. During other times, the NW will wait for the UE to initiate connectivity with the network, using e.g. TAU or SR procedures.

When the UE uses PSM, the UE requests an Active Time and may request a Periodic TAU Timer value in the TAU Request. In this solution the UE can take the coverage information into account when requesting these values. Since these timers start when the UE moves to IDLE mode, if the UE is in CONNECTED state the UE will need to take into account an expected time for how long the UE will remain in CONNECTED state. For example, if there is 15 more minutes until the UE loses coverage, and 4 hours of out-of-coverage after that, the UE could select an Active Time value of 10 minutes and Periodic TAU Timer value of 4h20min. Normally a PSM UE may chose a shorter Active Time in order to move back to PSM as fast as possible.

When the UE again has coverage, the UE may access the PLMN and initiate signalling as per existing standard, e.g. a TAU or SR, e.g. if there is UL data or the periodic TAU timer has expired. The UE could then request new Active Time and Periodic TAU Timer values based on coverage information as described above. The UE may also trigger a TAU specifically to request new Active Time value and Periodic TAU Timer value, as described in bullet w in clause 5.5.3.2.2 of TS 24.301 [7]. The UE could trigger such request when it enters coverage or is about to lose coverage.

**MICO**

MICO mode is very similar to PSM with the difference that the use of Active Time is optional and that the UE cannot request a Periodic Registration Timer value.

In this solution the UE enters MICO mode based on current specification. The UE can initiate transition to CM-CONNECTED based on existing specification but only when it has coverage (based on the coverage information) and there is a need to contact the network.

As per existing standard, the network will not try to page the UE while it is in MICO mode. The only time the network may page the UE is when Active Time is used, and in that case for the period of Active Time directly after the UE has moved to IDLE state. During other times, the NW will wait for the UE to initiate connectivity with the network, using Registration or SR procedures.

In case MICO with Active Time is used, the UE can take the coverage information into account when requesting Active Time value. Similar to PSM mode, the UE may need to use an expected time for how long the UE will remain in CONNECTED state when determining a suitable Active Time based on coverage information.

**Common to PSM and MICO**

The solution does not guarantee that the UE cannot lose coverage while the UE is in CONNECTED state or while the Active Time timer is running. For example, if the UE loses coverage during the Active Time timer is running, the AMF/MME may page the UE without getting a reply. The UE may also not have coverage when the TAU timer expires e.g. in case the UE has moved to a new location during the out-of-coverage period. However, as in rel-17, the solution is stable to handle such cases. TAI or RAT specific MME configuration is used to ensure that the UE is not deregistered in those cases and HLCOM can be used to buffer DL packets in the network or to notify the AF about reachability status. Also, by using UE-provided Active Time and Periodic TAU Timer values based on coverage information, the risk for such failed paging or missed Periodic TAU Timers is reduced.

**eDRX**

If the UE decides to request for extended idle mode DRX, the UE includes an extended idle mode DRX parameters information element in the Registration Request message, as described in TS 23.501 [2] (for 5GS), or Tracking Area Update as described in TS 23.682 [6] (for EPS). The AMF/MME will then provide the eDRX parameters to the UE based on UE requested values, subscription data, etc.

In this solution, the UE can request eDRX parameters based on its awareness of the coverage information. The eDRX cycle length is defined in TS 24.008 [8] and can only express certain fixed values. The available eDRX cycles may therefore not match the timing of the coverage and out-of-coverage for a UE. The UE may in this case request a eDRX cycle length that is less than the coverage window to ensure that the UE is reachable within the window. TAI or RAT specific AMF/MME configuration can be used to allow the AMF/MME to use the UE requested value when assigning the eDRX parameter in the reply to the UE.

When the UE is out of coverage, the AMF/MME may page the UE based on the eDRX cycle but without getting a reply from the UE. TAI or RAT specific AMF/MME configuration is used to ensure that the UE is not deregistered in those cases and HLCOM can be used to buffer DL packets in the network or to notify the AF about reachability status.

Editor's note: Additional enhancements to reduce failed paging attempts is FFS.

### 6.3.2 Procedures

The call flow below illustrates an example for PSM. The handling of MICO mode and eDRX is similar. All signalling is based on existing procedures and protocols.



Figure 6.3.1-1: Example of PSM usage in case of discontinuous coverage

### 6.3.3 Impacts on existing nodes and functionalities

The solution has no protocol impacts.

UE and AMF/MME functional impacts:

- The UE to take coverage info into account to 1) stay in PSM/MICO mode while out of coverage and 2) (optionally) request Active Time, Periodic TAU Timer and eDRX parameters based on coverage info.

- The MME/AMF to honour the UE requested Active Time value (for MICO and PSM), Periodic TAU Timer value (for PSM) and eDRX parameters (for eDRX) when using satellite RAT type. This behaviour could be based on Tracking Area or RAT specific MME configuration.

The normative impacts would be to describe the above two bullets.

### 6.3.4 Solution evaluation

The solution is based on existing EPS/5GS power saving solutions and protocols and has therefore minimal impact to Rel-17.

Letting the UE handle the awareness of coverage information has the following benefits:

- The UE can be aware of its location also during out-of-coverage times, e.g. by periodically determining its position using GNSS. The network would however need to rely on predicted UE mobility information that is not always available and that, when available, may not be very reliable.

- The UE anyway needs satellite ephemeris information in order to access NTN. The information received from RAN is limited but can be used, e.g. to determine when the UE will lose coverage. Other solution candidates for how UE can become aware of coverage information are available in the TR.

- No need for MME/AMF to be aware of satellite-specific information such as ephemeris, that is more RAN related than CN related.

The solution does not guarantee that CN will never try to page a UE while it is out of coverage but based on Rel-17 approach this can be handled without deregistering the UE. HLCOM can be applied for data buffering and reachability notifications to the AF.

## 6.4 Solution #4: Mobility Management enhancement based on coverage information and UE location

### 6.4.1 Description

This solution attempts to resolve part of the Key Issue #1 about the mobility management enhancements for UE in discontinuous coverage.

In the network with satellite access, the network resource may be scarce and a cell may cover several TAs. To save the network resource for paging, it is proposed that the TA where the UE is geographically located may be regarded as the last known TA for the first paging if the TA where the UE is geographically located is:

- known by the AMF; and

- determined in coverage based on information from the RAN when the Paging is needed.

### 6.4.2 Procedures



Figure 6.4.2-1: high-level procedure for Paging in last known TA

1. In the case of satellite access, before sending the UE Context Release Command message to the RAN, the AMF may initiate the Location Reporting procedure to ask for the last known location of the UE. The RAN provides all broadcast TAIs for the selected PLMN to the AMF as part of the ULI. The RAN also reports the TA where the UE is geographically located if this TA can be determined. The RAN may also report the coverage information (e.g. ephemeris data) to the AMF in Location Reporting procedure.

Editor's note: It is FFS what satellites ephemeris (e.g. all or a part of the satellites ephemeris in the RAN) will be provided to CN and whether the satellites ephemeris are available in a given RAN node.

2-4. The AMF initiates the UE Context Release procedure.

5. When the Paging is needed and the sub-area based paging (e.g. first page in the last known cell-id or TA and retransmission in all registered TAs) is determined to apply, the TA where the UE is geographically located could be regarded as the last known TA if the TA where the UE is geographically located is:

- Known by the AMF; and

- Determined in coverage based on the coverage information (e.g. ephemeris data) from the RAN when the Paging is needed.

NOTE: Whether first page in the TA where the UE is geographically located is up to the AMF implementation.

### 6.4.3 Impacts on services, entities and interfaces

**AMF:**

- The TA where the UE is geographically located may be used to determine the last known TA.

- The coverage information (e.g. ephemeris data) may be used to determine whether a TA is in coverage.

**RAN:**

- Provide to the AMF the TA where the UE is geographically located if this TA can be determined.

- Provide to the AMF the coverage information (e.g. ephemeris data).

## 6.5 Solution #5: Power Saving based on updating parameters before releasing signalling connection

### 6.5.1 Description

This solution resolves Key Issue #2 about the power saving enhancements for UE in discontinuous coverage.

To make sure that the UE does not attempt to access the network when there is no coverage, and that the UE is aware of the coverage returning and attempts to access the network as needed, it is proposed that the AMF determine the power saving parameters (e.g. eDRX parameters, periodic registration timer, Extended Connected Time and the active time for MICO mode) based on the coverage information, e.g. the ephemeris data, from RAN, and provide the power saving parameters to the UE before releasing the signalling connection.

The Extended Connected Time as described in clause 5.31.7.3 of TS 23.501 [2] can be used by AMF, for example in the case that it has determined that if UE is released to IDLE state, it may not be possible for UE to get back into connected mode to deliver downlink data before UE enters into no service due to discontinuous coverage.

### 6.5.2 Procedures



Figure 6.5.2-1: Procedure for updating parameters before releasing signalling connection

1. The UE is registered in the network.

2. The RAN may be requested to send coverage information (e.g. the ephemeris data of a satellite access system that the UE is using) to the AMF using the Location Report procedure before the RAN sends the N2 UE CONTEXT RELEASE REQUEST message to the AMF.

Editor's note: It is FFS what satellites ephemeris (e.g. all or a part of the satellites ephemeris in the RAN) will be provided to CN, whether the satellites ephemeris are available in a given RAN node, and whether the CN can get the satellites ephemeris using ways other than the Location Reporting procedure.

3. The gNB may initiates the AN release procedure by sending the N2 UE CONTEXT RELEASE REQUEST message to the AMF.

4-5. The AMF may initiate the Location Reporting Control procedure to ask for the coverage information from the RAN.

 Using the coverage information, the AMF determines the power saving parameters (e.g. eDRX parameters, periodic registration timer, Extended Connected Time and the active time for MICO mode) for the UE.

NOTE： If NWDAF is deployed, the AMF may use predicted information about the UE's mobility provided by NWDAF.

 The extended connected time as described in clause 5.31.7.3 of TS 23.501 [2] can also be applied by AMF to the UEs which have not requested for MICO mode.

6. The AMF initiates the UCU procedure to update the power saving parameters in the UE.

7-9. The AMF initiates AN Release procedures.

10. Using the received power saving parameters, UE can determine when the UE could not access the network, and when (e.g. the coverage is recovered) could attempt to access the network if needed.

### 6.5.3 Impacts on services, entities and interfaces

**RAN:**

- Send coverage information (e.g. the ephemeris data of a satellite access system that the UE is using) to the AMF.

**AMF:**

- Ask RAN to send coverage information (e.g. the ephemeris data of a satellite access system that the UE is using) to the AMF.

- Update the power saving parameters based on the coverage information from the RAN and send the power saving parameters to the UE or the RAN.

**UE:**

- Update the power saving parameters during the UCU procedure.

## 6.6 Solution #6: Discontinuous coverage architecture

### 6.6.1 Description

The solution applies especially on LEO and MEO satellites, as the coverage area of GEO satellite is typically static projection on the Earth surface and thus the coverage area can be handled the same way as in terrestrial networks.

Both UE and the network are expected be aware of out-of-coverage times under discontinuous satellite coverage. UE needs this information to optimise its power budget and to know when it needs to listen to paging. The network needs the same knowledge in order to avoid paging the UE that is known to be not reachable. The same unreachability information is also shared by the AMF to any NF that might have subscribed to UE reachability monitoring information. If the network supports HLcom, then core network buffering of DL data can be triggered when DL packet targeted towards unreachable UE is received in the CN.

NWDAF may be used as a possible optimisation to improve the accuracy of the UE Unreachability Period in those cases when the network has got sufficient information on the UE mobility to predict its trajectory. Since the satellite ephemeris data is assumed to be broadcast via SIB, the capacity limitations might not allow the distribution of the full satellite constellation information. Consequently, the UE might only receive information of a few selected satellite neighbours from NG-RAN. For static UE, that might be sufficient, but for moving UE it is possible to improve the accuracy of the UE reachability prediction if the properties of the whole satellite constellation and the observed UE trajectory is taken into account. This is the task where the NWDAF can help by providing the AMF with more accurate estimate than the one received from the UE that determines the Unreachability Period based on limited amount of data on the available satellites.

### 6.6.2 High level architecture principles

Figure 6.6.2-1 shows the call flow for the AN to inform the UE of satellite ephemeris. The UE uses this information to negotiate with the AMF in NAS signalling Unreachability Period that is thus known by both the UE and the AMF.

The AMF uses the negotiated information to determine when the UE would be reachable and when it is not reachable.



Figure 6.6.2-1: UE negotiates Unreachability Period with the AMF using satellite ephemeris information

Procedure for NG-RAN to inform the UE of satellite ephemeris and the UE to negotiate unreachability period with the AMF.

1. NG-RAN informs the UE of the satellite ephemeris of the serving cell in RRC signalling. The UE determines how long the UE is still covered by the serving cell.

Editor's note: It is TBD by RAN WG2 whether the ephemeris can be signalled in SIB.

2. UE includes Unreachability Period in its Registration Request. The Unreachability Period tells the AMF the foreseen unreachability period caused by discontinuous satellite coverage in the UE location.

NOTE: The encoding of the unreachability period in terms of start and end time or start time and duration is left for stage 3 specifications.

3. The AMF may request for UE Unreachability Period estimate from the NWDAF. If the NWDAF has got sufficient history of UE trajectory and the ephemeris of the satellite constellation, it returns UE Unreachability Period estimate to the AMF.

Editor's note: NWDAF information to be used for the service gap estimate is TBD.

4. AMF stores the Unreachability Period as part of the UE context in AMF and considers the UE as "not reachable" during that period. The AMF echoes back the UE requested Unreachability Period to acknowledge it has taken notice of it.

 Any procedures that apply on UE that is not reachable due to e.g. MICO mode or eDRX, apply also during Unreachability Period, so that the AMF does not page the UE, notifies the UE reachability as "unreachable" to those NFs that have subscribed to UE reachability notifications. Extended DL data buffering in the CN applies if it is supported in the network.

 The AMF assigns a Periodic Update Timer that allows the UE to omit periodic updates until the next foreseen connectivity period.

5. UE is not reachable due to coverage gap caused by discontinuous coverage. If the UE finds coverage before the end of Unreachability Period, it may initiate UL signalling or send UL data. The UE may initiate an additional registration update procedure if it finds unpredicted coverage before the end of Unreachability Period.

6. DL data targeted for the UE arrives while the UE is not reachable due to discontinuous coverage.

7. Upon receiving DL Data Notification, the SMF requests DL data transfer from the AMF

8. The AMF knows based on Unreachability Period received from the UE in step 2 in the previous registration procedure that the UE is not reachable. The AMF includes the corresponding Estimated Maximum Wait time as specified in clause 4.2.3.3 of TS 23.502 [3].

9. If extended DL data buffering is supported in the SMF, then the SMF initiates data DL data buffering as specified in TS 23.502 [3]

### 6.6.3 Impacts on services, entities and interfaces

This solution impacts the following system entities.

AN:

- Capability to send satellite ephemeris to the UE.

Remote UE:

- Capability to determine Unreachability Period based on the satellite ephemeris information.

- Capability to indicate the Unreachability Period in Registration Request.

AMF:

- Capability to consider UE as unreachable after negotiating Unreachability Period.

- Optionally, acquiring better UE reachability estimate from NWDAF.

NWDAF:

- Capability to determine UE unreachability period based on satellite constellation and whatever UE history information might be available.

## 6.7 Solution #7: Utilizing discontinuous coverage wait timer for satellite discontinuous coverage scenario

### 6.7.1 Description

This is a candidate solution for part of Key Issue #1 and Key Issue #2. For KI#1, the solution aims to solve the scenario when the UEs have to remain with no service and when the coverage recovers how to reduce the impact on the target system, i.e. the NTN RAN is the Quasi-earth-fixed satellite that offers the coverage in a limited period in the same geographical area by steering the beam.

This solution proposes to introduce a new timer, named discontinuous coverage wait (DCW) timer, to address both the signalling overload situation and the power saving situation when UEs are using access type and/or RAT type that offer discontinuous coverage, especially:

- When the UEs (in CM-IDLE state) using an NTN RAN that provides discontinuous coverage in the same geographical area lose coverage, and the discontinuous coverage period is larger than the CN assigned Periodic Registration Update timer, the UEs may simultaneously initiate the Periodic Registration Update procedure when they recover to be in coverage (i.e. the same satellite is steered to serve the same area) due to the expiration of Periodic Registration Update timer. Signalling overload will occur.

- When the UEs (in CM-IDLE state) using an NTN RAN that provides discontinuous coverage in the same geographical area lose coverage, and the discontinuous coverage period is larger than the CN assigned Periodic Registration Update timer, the UEs may have some buffered uplink data to deliver when they recover to be in coverage (i.e. the same satellite is steered to serve the same area) and simultaneously initiate the service Request procedure and Periodic Registration Update procedure and. Signalling overload will occur.

- When the UEs (in CM-CONNECTED state) using an NTN RAN that provides discontinuous coverage in the same geographical area lose coverage and there is UL traffic ongoing, the UEs may immediately initiate the Service Request procedure when they recover to be in coverage (i.e. the same satellite is coming to serve the same area). Signalling overload will occur.

The DCW timer consists of two parts:

 DCW timer = (T2-T1) + DCW value (i.e. random value in DCW range)

- The discontinuous period (T2-T1), used to ensure the UEs do not initiate any 5G NAS signalling to 5GCN within this period. The period value is calculated by the UE based on the RAN broadcasting satellite ephemeris data, e.g. time information on when the ongoing satellite is to end serving the area (e.g. T1) and when the incoming satellite is to start serving the area (e.g. T2).

- The DCW value, is used by the UE to determine how long to wait before triggering the 5G NAS signalling after the discontinuous period. The DCW value is generated within a DCW range that is provided by 5G CN via Registration procedure or UE Configuration Update procedure.

While the timer is running, the UE shall not initiate any 5G NAS signaling to 5G CN.

Upon the expiration of the DCW timer, the UE shall initiate the 5G NAS signalling. From the perspective of 5G CN, either the Periodic Registration Update procedure and/or the Service Request procedure will arrive in a random way, as shown in Figure 6.7.1-1.



Figure 6.7.1-1: Random 5G NAS signalling with DCW timer

Editor's note: Whether the geographical distribution is sufficient for randomization with steerable beam offering Quasi-earth-fixed satellite is FFS.

### 6.7.2 Procedures



Figure 6.7.2-1: High-level Procedure for utilizing DCW timer

0a. The NTN RAN broadcasts its satellite ephemeris data, from which UE can determine when the coverage will lose (i.e. T1) and when the coverage will recover (i.e. T2).

NOTE 1: The provision of how the satellite broadcasts its ephemeris data depends on RAN work group discussion.

NOTE 2: The NTN RAN is assumed to be a Quasi-earth-fixed satellite as defined in TS 38.300 [12].

0b. The AMF determines the DCW range based on the operator policy and provides the DCW range to the UE via Registration procedure or UE Configuration Update procedure.

1. The UE generates DCW value based on the received DCW range and determines the DCW timer based on both the generated DCW value and satellite ephemeris data.

2a. The AN Resources are released between UE and NTN RAN, and the discontinuous coverage period starts.

2b. When the UE detects the AN resource is released, the UE triggers the DCW timer.

3. The DCW timer expires.

4. The UE initiates to send the 5G NAS signalling to the AMF. The 5G NAS signalling can be used to establish the Periodic Registration Update procedure and/or Service Request procedure.

### 6.7.3 Impacts on services, entities and interfaces

**NTN RAN:**

- Broadcast satellite ephemeris data that includes e.g. time information on when the ongoing satellite is to end serving the area (e.g.T1) and when the incoming satellite is to start serving the area (e.g. T2).

**UE:**

- Receive the DCW range.

- Receive satellite ephemeris data.

- Generate DCW value within the range of DCW range.

- Calculate DCW timer based on both the generated DCW value and satellite ephemeris data.

- Run the DCW timer.

**AMF:**

- Send DCW range to the UE via Initial Registration procedure or UE Configuration Update procedure.

- Determine the DCW range based on the operator policy.

## 6.8 Solution #8: Leaving Coverage Notification

### 6.8.1 Description

This solution resolves part of Key Issue #1 about the mobility management enhancements to avoid unnecessary paging UE in discontinuous coverage.

The UE may enter IDLE mode when the UE is within the network coverage and leave the network coverage while the UE is in IDLE mode, for example, a mobile UE may leave coverage and return to coverage in a non-predictable way e.g. due to being mobile. In this case, the network may still believe that the UE is reachable and attempt to page the UE, but in fact the UE is out of network coverage and the paging would fail. To avoid unnecessary paging, the UE notifies the network it is leaving network coverage and when it returns to coverage, so the network always knows when the UE is in or out of coverage.

### 6.8.2 Procedures

#### 6.8.2.1 Leaving Coverage Notification Procedure in 5GS

This procedure is used by the UE and network to a) enable the use of the Leaving Coverage Indication, b) when the UE leaves coverage and c) when the UE returns to coverage when using 5GS.



Figure 6.8.2-1: Procedure for Leaving Coverage Notification

1. The UE sends Registration Request to the AMF.

2. If the UE is using a RAN that provides discontinuous coverage and the MICO Indication is not included in the Registration Request, the AMF sends Registration Response including a Leaving Notification Indication to the UE. The Leaving Notification Indication indicates that the UE shall notify the network it is leaving network coverage.

NOTE: The network can take other information into consideration when determining whether to include the Leaving Notification Indication in the Registration Response, for example mobility patterns.

3. The (R)AN connection may be released and the UE enter IDLE mode using the AN Release Procedure, see clause 4.2.6 of TS 23.502 [3].

4. The UE determines that it is about to leave network coverage based on coverage information, e.g. satellite ephemeris, while in either CONNECTED or IDLE mode.

5. The UE sends a Service Request or Registration Request, including a Leaving Coverage Indication. The Leaving Coverage Indication indicates that the UE is about to leave the network coverage. Upon receipt of Leaving Converge Indication, the AMF considers the UE unreachable. Whether Service Request or Registration Request is used may depend upon e.g. the UE connected state etc.

6. The AMF sends N2 UE Context Release Command to the (R)AN.

7. The (R)AN connection is released.

8. When the UE enters network coverage, the UE sends Service Request or Registration Request, to the AMF and the network the UE is back in coverage and reachable again. The existing procedures are used to determine which NAS Message e.g. Service Request or Registration is used, i.e. the only solution adds a triggering condition to enter CM\_CONNECTED on returning to coverage.

#### 6.8.2.2 Leaving Coverage Notification Procedure in EPS

This procedure is used by the UE and network to a) enable the use of the Leaving Coverage Indication, b) when the UE leaves coverage and c) when the UE returns to coverage when using EPS.

The procedure in clause 6.8.2.1 with the following modifications is used:

- Throughout: The TAU procedure instead of the Registration Procedure is used.

- Steps 1 & 2: The ATTACH procedure may additionally be used.

- Step 6: S1 UE Context Release Command and the S1 release procedure, see clause 5.3.5 of TS 23.401 [5], instead of the N1 UE Context Release Command and the AN Release Procedure is used.

### 6.8.3 Impacts on services, entities and interfaces

**AMF/MME:**

- Send Leaving Notification Indication to the UE if the UE is using a RAN that provides discontinuous coverage.

**UE:**

- Send Leaving Coverage Indication when it is about to leave the network coverage.

## 6.9 Solution #9: Modification of Timers when in or out of Coverage

### 6.9.1 Description

This solution resolves Key Issue #2 about the power saving enhancements for UE in discontinuous coverage.

In this solution, AMF/MME sends to UE a future periodic registration timer/TAU timer which is to be activated when UE leaves satellite coverage during the Registration/Attach procedure.

The future periodic registration timer/TAU timer can be set so that the UE does not need to perform Periodic Registration or TAU while out of coverage while allowing the network to maintain its preferred timer settings while in coverage automatically.

How the future periodic registration timer/TAU timer which is used while out of coverage can be determined by other solutions and this solution provides the future periodic registration timer/TAU timer in addition to the periodic registration timer/TAU timer while in coverage.

### 6.9.2 Procedures

Figure 6.9.2-1 shows the procedure to send the future periodic registration timer/TAU timer during any registration, attach or any TAU procedure.



Figure 6.9.2-1: High-level procedure for power saving enhancement in 5GS/EPS

1. The UE initiates Registration/Attach/TAU procedure by sending Registration/Attach/TAU request to AMF/MME.

2. The AMF/MME determines a future periodic registration timer/TAU timer which is to be activated when UE leaves satellite coverage considering satellite coverage information.

 For UEs with no mobility, the AMF/MME may determine the future periodic registration timer/TAU timer based on the UE location and the satellite coverage information.

 For UEs moving in limited area or with known/predictable trajectories, the AMF/MME may determine the future periodic registration timer/TAU timer based on the UE location, the known/predicted mobility pattern and the satellite coverage information.

NOTE: The future periodic registration timer/TAU timer can be determined by other solutions or existing behaviour.

 The AMF/MME may also determine power saving parameters which is to be used when UE is in satellite coverage and RRC\_IDLE, e.g. active time, periodic registration timer/TAU timer, eDRX parameters etc.

3. The AMF/MME sends Registration/Attach/TAU Accept message to UE including the future periodic registration timer/TAU timer which is to be activated when UE leaves satellite coverage.

 The AMF/MME also sends to UE the power saving parameters which is to be used when UE is in satellite coverage and RRC\_IDLE.

4. If the UE is in satellite coverage and RRC\_IDLE, the UE activates the received power saving parameters. When the UE leaves the satellite coverage, the UE stops the power saving parameters and activates the future periodic registration timer/TAU timer.

 The UE determines it leaves satellite coverage based on broadcast satellite ephemeris.

5. The AMF/MME predicts when the UE leaves the satellite coverage and activates the future periodic registration timer/TAU timer.

When the future periodic registration timer/TAU timer expires, the UE initiates registration/TAU procedure as normal and may be assigned another the future periodic registration timer/TAU timer during the registration/TAU procedure.

### 6.9.3 Impacts on existing nodes and functionalities

**AMF/MME:**

- determines a future periodic registration timer/TAU timer which is to be activated when UE leaves satellite coverage based on the UE location, the known mobility pattern if UE moves with known mobility pattern and satellite coverage information.

- activates the future periodic registration timer/TAU timer at the timer when the UE is predicted to leave coverage.

**UE:**

- stop using current power saving parameters and activate the future periodic registration timer/TAU timer when UE leaves satellite coverage.

## 6.10 Solution #10: UE Reachability Events with Expected in Coverage Time

### 6.10.1 Description

This is a solution for KI#1 Mobility Management enhancement with discontinuous satellite coverage as the AF can understand the UE status, and can also assist with Key Issue #2: Power saving enhancement for UE in discontinuous coverage. It can help avoid the AF starting long running procedures with a UE that will be out of coverage before those procedures complete.

An AF may subscribe to the SCEF or NEF for UE Reachability for downlink data transfer, however the AF does not know for how long the UE will remain reachable for downlink data transfer. If UE Reachability for SMS is requested then the event sent to the AF can include "maxUEAvailableTime" which provides the time the UE is expected to be reachable for SMS delivery.

If the UE is using discontinuous coverage then when the UE becomes reachable the SCEF/NEF sends the UE monitoring event indicating that a UE has become reachable for paging. The AF can then use this event to trigger downlink services or operations on the UE.

The UE monitoring event for reachability is extended to include a time for which the UE is expected to be in coverage and can be used assist the AF to understand reachability of the UE.

Editor's note: How the AMF/MME determines the UE available time and whether enhancements in addition for how it is determined for UE Reachability for SMS is FFS.

The Maximum Response Time used in the existing monitoring event provides similar, but not the same information about the UE and is a configuration parameter and a parameter included in the monitoring events and is under control of the network on a per UE basis. The Maximum Response Time is a) provided by the AF to the SCEF/NEF in order to set the active time, b) used by the network to consider how long to keep a connection and c) how early to send the monitoring event for a UE using eDRX.

The in coverage time can be used to complement the existing monitoring events parameters which are provided to the AF. For example, active time in PSM/MICO which could be set to the remaining time during the in-coverage window when the UE moves to IDLE, but requires the UE have changed to IDLE, meaning the UE has to have been in CONNECTED and then released, whereas the in coverage time does not depend on this.

### 6.10.2 Procedures

No new procedures are defined for providing the time the UE will remain in coverage and therefore reachable.

For reporting the in coverage time for a UE using 5GS, the procedures defined in TS 23.502 [3] clause 4.15.3 and the associated service operations of Namf\_EventExposure\_Notify are reused with the additional information included for the expected in coverage time when the AMF determines the UE is using satellite access becomes reachable.

For reporting the in coverage time for a UE using EPS, the procedures defined in TS 23.682 [6] clause 5.6.3.3 are reused with the additional information included for the expected in coverage time when the MME determines the UE is using satellite access becomes reachable.

This allows the AF to reuse the existing event exposure procedures for UE Reachability with the enhancement for the time in coverage to determine when to send data or determine which application level procedures to perform.

### 6.10.3 Impacts on existing nodes and functionalities

**AMF:**

- Include the expected in coverage time in the Namf\_EventExposure\_Notify event for UE reachability if the UE is using satellite access.

**MME:**

- Include the expected in coverage time in the Monitoring Indication sent to the SCEF for UE reachability if the UE is using satellite access.

**NEF/SCEF:**

- Provide the expected in coverage time to the AF if received from the AMF/MME, for the AF to take into account.

## 6.11 Solution #11: Combined UE Management Architecture

### 6.11.1 Description

This is a solution for Key Issue #1: Mobility Management enhancement with discontinuous satellite coverage and Key Issue #2: Power saving enhancement for UE in discontinuous coverage.

When the UE is out of coverage, a UE is unreachable and any paging from the network will not succeed. The UE mobility patterns may be known to either the UE, network, both the UE and network or neither.

This solution combines proposed solutions for different cases of mobility and a solution for when the mobility pattern is not known therefore providing a complete solution for UE power saving and reachability management.

The solution has 2 phases. 1st phase when the UE is released, either at the end of a coverage window by the CN or the requested by the UE, or during a coverage period when the UE is not expected to return to CONNECTED during a coverage window. The 2nd phase is when the UE returns to coverage and the actions the UE takes when it returns to coverage.

Throughout the solution it is expected that the UE is aware of the coverage available from satellites and the UE, if it knows there is no coverage at a time, chooses not to attempt to activate its AS and initiate a connection or attempt to receive paging from the network.

If at any point between coverage periods, if the UE needs to connect to the network (e.g. for MO traffic or signalling) can detect coverage using a TN or NTN it can choose to initiate a connection, otherwise it is expected the UE will disable its AS procedures. Whether and how the UE choose to deactivate its AS when it is not required to receive paging or initiate a connection to the network is up to the UE implementation or maybe addressed by other solutions.

The UE maybe in RRC\_CONNECTED at the end of a coverage period, or at any point during a coverage period and transitioning from RRC\_CONNECTED to RRC\_IDLE. If the UE is in RRC\_CONNCETED the UE may send a Registration Request to the network to transfer its understanding of its mobility pattern before the UE is released. If the UE is in RRC\_IDLE or RRC\_CONNECTED at the end of a coverage period, the UE may send a Registration Request to the to notifying the network it is leaving network coverage. In both cases, after the Registration procedure the UE is released.

The UE sends a Registration Request to inform the network about 4 different cases related to discontinuous coverage:

1. The UE believes itself to be stationary or moving on a predictable trajectory.

2. The UE understands it mobility and can predict a location it will be in the future and/or the time it will return to coverage at a location.

3. The UE does not have an understanding of its mobility because it is not predictable.

4. The UE is about to leave network coverage or has returned to network coverage and the UE has been requested to notify the network about its leaving network and returning to coverage in an earlier Registration procedure.

The network may use additional information to help determine the UE mobility in addition to the indications from the UE. This can include interactions with the NWDAF or other mobility information, for example mobility patterns provisioned by an AF to the network or other sources of information.

Taking into account the UEs indication about its mobility state, the network can combine it with information it holds and respond to the UE.

The response to the UE can be to:

1. Provide the UE with an eDRX cycle the UE should follow, if there is no satellite coverage available to the UE at a specific location

2. Enable MICO/PSM mode for the UE, providing a periodic registration timer to the UE that coincides with coverage in the future so that the UE performs Periodic Registration or TAU when it returns to coverage.

3. Provide an indication that the UE should inform the CN when it leaves and subsequently returns to coverage in the future at an unpredictable time and use MICO/PSM mode until the UE returns to coverage. The CN should provide a periodic registration timer to the UE that covers the longest expected period out of coverage.

If the UE is provided with an eDRX cycle, the CN may take into account the coverage at the predicted position when paging the UE. This may mean that some PTWs are skipped and this should be taken into account when responding to requests or providing a reachability time for the UE.

Editor's note: Whether MICO/PSM mode or a different indication of unreachability in the AMF/CN is FFS.

### 6.11.2 Procedures

#### 6.11.2.1 5GS UE Leaving Coverage Procedure

This procedure is used when the UE is leaving coverage.



Figure 6.11.2.1-1: UE Leaving Coverage Procedure

1a. RAN detects the UE is leaving coverage and initiates N2 UE Context Release Request if the UE is in RRC\_CONNECTED.

1b. The UE sends a Registration Request including:

- [Optional] a time when it expects to return to coverage, and/or

- [Optional] where the UE believes it will be when it returns to coverage, and/or

- [Optional] an indication that it does not know when or where it will be back in coverage.

- [Optional] an indication that the UE is leaving coverage if the UE has previously received a Leaving Notification Indication instructing the UE to notify the network when it is leaving the network coverage.

 The UE may be in RRC\_IDLE or RRC\_CONNECTED when it determines it needs to send the Registration Request.

1c. If the AMF detects that the UE is about to leave the current network coverage based on the coverage information, the AMF may trigger this procedure to move UE into CM-IDLE state when the UE is still within the network coverage.

2. [Optional] The AMF make request predicated mobility and coverage information from the NWDAF.

3. If the AMF had provided the UE with a Leaving Notification Indication and the UE is indicating that it is leaving coverage then a Registration Accept is sent, otherwise the AMF takes into account the UEs indications in Registration Request about mobility to determine whether to:

- Provide the UE with an eDRX configuration the UE should follow, if there is no satellite coverage available to the UE at a specific location.

- Enable MICO/PSM mode for the UE, providing a periodic registration timer to the UE that coincides with coverage in the future so that the UE performs Periodic Registration or TAU when it returns to coverage.

- Provide the UE with a Leaving Notification Indication so the UE informs the CN when leaves or returns to coverage in the future and use MICO/PSM mode until the UE is out of coverage. The CN should provide a periodic registration timer to the UE that covers the longest expected period out of coverage.

 The AMF uses the UEs indications in the Registration Request, its knowledge of mobility and coverage, if available, and information from the NWDAF, if available, to determine what to indicate to the UE for handling the out of coverage period. The AMF always provides a Periodic Registration Timer value, taking into account the coverage and how the UE will handle the out of coverage period.

 If Registration Request was received in Step 1b, then the AMF responds with Registration Accept (step 3b) otherwise the AMF uses the UE Configuration Update procedure (step 3a).

4. Steps 2 onwards of the AN Release Procedure as defined in clause 4.2.6 of TS 23.502 [3].

#### 6.11.2.2 EPS UE Leaving Coverage Procedure

For the procedure for a UE leaving coverage in EPS is the same as the 5GS procedure in clause 6.x.2.2. with the following modifications:

- Throughout: The TAU procedure instead of the Registration Procedure is used.

- Steps 1b & 3b: The ATTACH procedure may additionally be used.

- Steps 2 and 3a: The NWDAF and UCU procedure are not available in EPS, so these steps don't apply.

- Step 4: S1 UE Context Release Command and the S1 release procedure, see clause 5.3.5 of TS 23.401 [5], instead of the N1 UE Context Release Command and the AN Release Procedure is used.

#### 6.11.2.3 EPS and 5GS UE Returning to Coverage Procedure

This procedure is used when the UE returns to coverage if it was instructed to inform the network during the leaving coverage procedure that it has returned to coverage or e.g. if the time the UE returns to coverage is different from the expected time as determined in the leaving procedure.

If 5GS is used then the Registration procedure as defined in clause 4.2.2.2 of TS 23.502 [3] is reused and if EPS is used then Tracking Area Update procedure is used as defined in TS 23.401 [5].

Editor's note: It is FFS whether enhancements are required based on whether MICO or a different mode is used while the UE is out of coverage.

The triggers the UE uses to detect coverage can be UE implementation dependent or defined by other solutions. The UE may take into account any previously received satellite ephemeris/coverage information from RAN, its expected or known position and time to determine whether to look for coverage.

### 6.11.3 Impacts on existing nodes and functionalities

**UE:**

- Provide the AMF/MME with indications about its mobility predictability, including extrapolated future location and/or time in coverage, whether it is stationary/predictable mobility or not predictable.

- Send indications to the AMF/MME when it is leaving coverage/returning to coverage if instructed to do so.

**RAN:**

- Trigger AN Release for a UE if it is about to leave coverage.

**MME/AMF:**

- Obtain information on future coverage given satellites motion.

- Trigger AN Release if the UE is about to leave coverage (5GS only).

- Configure the power saving parameters or Leaving Notification Indication based on the coverage information for the UE, indications from UE, information from the NWDAF (5GS only) and other information the MME/AMF may hold/have been provisioned with.

- Consider the UE unreachable while out of coverage.

## 6.12 Solution #12: Minimize discontinuous coverage by inter-RAT handover processing

### 6.12.1 Description

This solution resolves Key Issue #1 about how UE determines to remain with no service or to attempt to register on available different RAT's/ PLMNs to receive the normal service during discontinuous coverage in current NTN RAT.

The UE can detects it is about to move outside network coverage in current NTN access based on the ephemeris information. Meanwhile, it can also dectects the other available access. Both the accesses can have the same RAT type but belong to different Satellite Operators, or have different RAT type but can belong to same SO. Besides, the other available access can be TN access (e.g. E-UTRAN, NR). In this solution, both the source access network and the target access network are WB-E-UTRAN satellite accesses which have different RAT type and belong to different SOs. Inter-RAT handover for the UE may cause serving PLMN change in this solution.

### 6.12.2 Procedures



Figure 6.12.2-1: Inter-RAN handover for UE using satellite access with discontinuous coverage

0. When UE detects it is about to leave network coverage of LEO-A and MEO-B is available to access, it reports the radio condition measurements in which MEO-B access the UE wants to access is included to source eNB. This detection can be based on the UE current location and ephemeris information of LEO-A and MEO-B.

NOTE 1: The solution is available for the case when UE detects there is other available access. If there is no other available access, the UE determines to remain with no service until returns to the next coverage.

1. Triggered by radio condition measurements report, the source eNB determines to perform handover based on the available RAT(s). The source eNB sends the handover required message to the source MME to request the CN to establish resources in the target eNB, target MME and the serving GW. The target eNB identifier and the UE current location information needs to be included in the message.

NOTE 2: how to determine inter-RAT handover for the UE by eNB depends on RAN WGs work.

Editor's note: It is FFS whether and how this handover procedure can be triggered by MME and/or RAN. Whether the existing handover procedures in TS 23.401 [5] can be re-used can be further studied.

2. The source MME determines from the target eNB identifier that the type of handover is an inter-RAT handover. The source MME selects the target MME based on "MME selection" as described in TS 23.401 [5]. The source MME initiates the handover resource allocation procedure by sending a Forward Relocation Request to the target MME. Information such as UE identity, UE current location, target eNB id, etc are included in the message.

3. If the PLMN serving the UE changes, when receiving Forward Relocation Request from source MME, the target MME should verify the PLMN is whether allowed to operate at the present UE location based on the UE subscription information received from HSS. If it is not allowed to operate, the handover is failed.

Editor's note: whether and how to identify the UE location information from source network is FFS.

4. The target MME determines if the serving GW is to be relocated, e.g., due to PLMN change. If the Serving GW is to be relocated, the target SGSN selects the target Serving GW as described in TS 23.401 [5] on "Serving GW selection function", and sends a Create Session Request message to the target serving GW. The target Serving GW allocates its local resources and returns a Create Session Response to the target MME.

5. The target MME requests the target eNB to establish the radio network resources by sending the Relocation Request message. The target eNB allocates the resources and returns the applicable parameters to the target MME in the message Relocation Request Acknowledge.

6. Indirect Data Forwarding Tunnel is created if needed.

7. The target MME sends the Forward Relocatioin Response message to the source MME. In the message, Serving GW change indication indicates a new Serving GW has been selected. The Target to Source Transparent Container contains the value from the Target eNB to Source eNB Transparent Container received from the target eNB.

8. Corresponding to step 7, Indirect Data Forwarding Tunnel is created.

9. The source MME completes the preparation phase towards source eNB by sending the Handover command message. The source eNB gives a command to the UE to handover to the target access network.

10. The UE moves to the target eNB and executes the handover according to the parameters provided in the message delivered in step 9.

11. Forward relocation completes in the execution phase to finish inter-RAT handover before moving outside LEO-A network coverage.

### 6.12.3 Impacts on existing nodes and functionalities

**UE:**

- Detects it's about to leave from the current satellite access coverage and other available access based on the ephemeris information.

- Provides measurements about available accesses to RAN.

**RAN:**

- Determines whether to perform inter-RAN handover for the UE based on measurements, the available RATs, etc.

**MME:**

- If the target access is satellite access and PLMN serving for the UE changes, performs UE location verification to meet regulatory requirements.

## 6.13 Solution #13: Applicability of no service in discontinuous coverage

### 6.13.1 Description

When UE enters into discontinuous coverage it has two options either to remain in no service or it can look for alternate RAT or PLMN to receive normal services. But based on what it has to make this decision is not very clear. This solution proposes that HPLMN can guide UE on this aspect. Based on multiple factors HPLMN have better idea what UE should do in such a situation for example:

a) There can be some delay tolerant UEs who are OK to remain in no service during discontinuous coverage. If such UEs trigger signalling and register on alternate PLMN those can unnecessarily incur cost to the HPLMN. At the same time there can be normal smartphones who are required to continue to receive services by looking for a source which can provide normal services to the UE.

b) Based on alternate PLMN/RAT which is providing service to UEs, for example in few countries the roaming partner may incur less cost but in some other country it may incur higher cost.

c) Based on subscription plans of the UE, etc.

Based on above factors, or based on local operator policy UDM in HPLMN is configured with parameter DisCoNoserviceapplicability parameter and further this solution proposes this parameter is configured by HPLMN into the UE, based on which UE will determine it has to remain in no service or it has to look for alternate source(PLMN or RAT) which can provide normal services to the UE.

Editor's note: DisCoNoserviceapplicability value can it be influenced from external AF through NEF is FFS.

### 6.13.2 Procedures



Figure 6.13.2-1: UE parameter update for DisCoNoserviceapplicability parameter

1) UDM decides to perform UE parameter update to update DisCoNoserviceapplicability parameter.

2 to 6a) UDM uses the UE Parameters Update via UDM Control Plane Procedure as described in clause 4.20 of TS 23.502 [3] to configure the DisCoNoserviceapplicability parameter into the UE.

7) Each time UE detects that it has entered into discontinuous coverage, the UE:

a) If DisCoNoserviceapplicability is set to true then UE will remain in no service during the discontinuous coverage duration and wait for completion of discontinuous coverage to resume normal services.

b) If DisCoNoserviceapplicability is set to false then UE will perform PLMN selection procedure as described in TS 23.122 [13] to receive normal services from alternate RAT or different PLMN.

Editor's note: Can UE inputs/preferences for e.g. based on battery level etc can also be considered while making a decision is FFS.

### 6.13.3 Impacts on services, entities and interfaces

This solution impacts the following system entities.

**UDM:**

- To configure DisCoNoserviceapplicability parameter in the UE using UE parameter update procedure.

**UE:**

- Based on the DisCoNoserviceapplicability parameter UE determines if it can remain in no service or it can trigger registration on alternate RAT or PLMN to receive normal services.

## 6.14 Solution #14: Wait timer for discontinuous coverage

### 6.14.1 Description

When discontinuous coverage occurs this will happen for all the UEs which were served by satellite access in a given area, if all these (or at least majority) of this UEs look for alternate PLMN or RAT then it can create spike of signalling load on the target system which can have negative impacts to target system. Similar problem was studied as part of the MINT work item. Thus, in Rel-17 as part of MINT work item the concept of wait timer was introduced, so that when coverage from serving network is lost all UEs does not attack the target system at the same time, there registration attempts are randomised. See below references:

**Clause 5.40.6 of TS 23.501 [2]:**

"*To prevent signalling overload in PLMN providing Disaster Roaming, the HPLMN or registered PLMN:*

*- may provide disaster roaming wait range information to control when the UE can initiate the registration for Disaster Roaming service upon arriving in the PLMN providing Disaster Roaming service as specified in TS 23.122 [13] and TS 24.501 [14];"*

**Clause 4.24 of TS 24.501 [14]:**

"*Upon selecting a PLMN for disaster roaming as specified in TS 23.122 [13]:*

*a) if the UE does not have a stored disaster roaming wait range, the UE shall perform a registration procedure for disaster roaming services on the selected PLMN as described in clause 5.5.1; and*

*b) if the UE has a stored disaster roaming wait range, the UE shall generate a random number within the disaster roaming wait range and start a timer with the generated random number. While the timer is running, the UE shall not initiate registration on the selected PLMN. Upon expiration of the timer, the UE shall perform a registration procedure for disaster roaming services as described in clause 5.5.1 if still camped on the selected PLMN.*"

It is proposed to reuse the same solution even for discontinuous coverage.

Editor's note: Is geographical distribution not sufficient for randomization? is FFS.

### 6.14.2 Procedures

Either reuse the disaster roaming wait range configuration (hereafter called as discontinuous coverage wait range) or the new discontinuous coverage wait range is configured in the UE by the HPLMN as part of registration procedure or using UE Parameters Update via UDM Control Plane Procedure as described in clause 4.20 of TS 23.502 [3]. The registered PLMN can also configure the discontinuous wait range in the UE during registration procedure.

When the UE detects discontinuous coverage, selects the different PLMN or alternate RAT of the same PLMN to continue to receive the services and if the UE has a stored discontinuous coverage wait range, the UE shall generate a random number within the discontinuous coverage wait range and start a timer with the generated random number. While the timer is running, the UE shall not initiate registration on the selected PLMN or alternate RAT. Upon expiration of the timer, the UE shall perform a registration procedure.

If the UE does not have stored discontinuous coverage wait range timer then UE will attempt registration procedure on selected PLMN or alternate RAT immediately following the legacy procedures.

### 6.14.3 Impacts on existing nodes and functionalities

Editor's note: This clause captures impacts on existing 3GPP nodes and functional elements.

**UE:**

- If the preference is to reuse the existing disaster roaming wait range configuration then UE can re-use the same configuration as discontinuous coverage wait range and determine when to attempt or access the new PLMN or different RAT when discontinuous coverage is detected.

- If the preference is to go with new discontinuous coverage wait range configuration then UE can use respective configuration and determine when to attempt or access the new PLMN or different RAT discontinuous coverage.

**AMF or UDM:**

- To provide discontinuous coverage wait range configuration to the UE.

## 6.15 Solution #15: Solution to support Provision of Coverage Data to a UE

### 6.15.1 Description

This solution supports portions of KI#1 and KI#2 and consists of procedures for providing this coverage data to a UE that supports IP PDU Sessions.

The content of coverage data can include a coverage map which shows the expected coverage by one or more satellite RATs one or more locations and for a particular time in the future. A set of coverage maps can then be provided for each of a sequence of times occurring at fixed periodic intervals, such as at intervals of one minute. The locations supported by a coverage map can correspond to grid points in a rectangular (or possibly hexagonal) array, as illustrated by the rectangular array shown in Figure 6.15.1-1.



Figure 6.15.1-1: Coverage Data Map for a set of Grid Point Locations

In Figure 6.15.1-1, each grid point (dot) represents one location. These locations (i.e. grid points) can be spaced apart by a fixed distance (e.g. 10 to 100 kms). The absolute location of each grid point can then be known by specifying an absolute (global) location for just one grid point in the array (e.g. a centre grid point or a grid point at one corner). The expected satellite coverage at the location of each grid point.

A coverage map (or set of maps) can be provided to a UE by a server via user plane. Two alternative solutions can be used for this part.

The first solution is based on an HTTPS query from a UE to a server. The UE also provides a temporary ID to the server that is pre-configured in the server and verifies permission for the UE (e.g. a subscription) to receive the coverage data.

With the second solution, the DCAF/AF functionality and architecture as defined in TS 26.531 [9] and TS 23.288 [10] could be extended to expose network data analytics to a UE.

Editor's note: Whether and how DCAF/AF functionality is FFS.

### 6.15.2 Procedures

#### 6.15.2.1 Obtaining Coverage Data using an HTTPS Query to a Server

The procedure is in two parts. First the UE obtains a URI for the server and a temporary ID that is already pre-configured in the server. Then the UE sends an HTTPS request to the server (identified by the URI) and includes the temporary ID.

Editor's note: Applicability of an HTTPS query to 3GPP specs and 3GPP WGs is FFS.

Figure 6.15.2.1-1 shows the first procedure for 5GS. A procedure for EPS can be analogous using an Attach or TAU. The procedure is based on NAS but could use some other protocol layer instead - e.g. RRC.



Figure 6.15.2.1-1: Procedure to Request a URI and temporary ID

1. The UE sends a Registration Request to the serving AMF (e.g. for an initial registration, periodic registration or registration update) and includes a request for a URI and Temporary ID to enable provision of coverage data. Some additional parameters might be included to indicate applicable location(s) in case different servers are used to provide coverage data for different locations (e.g. for different countries).

2. The serving AMF may verify the UE subscription to receive coverage data.

Editor's note: It is FFS why the AMF needs to verify the location requested or whether the AMF only provides information for areas it serves.

3. The AMF determines a server applicable to the location(s), a URI for the server and a temporary ID for the UE.

Editor's note: The generation, sharing and configuration of the security information are FFS and requires coordination with SA WG3.

4. The AMF returns the UE and temporary ID in the Registration Accept. The AMF may also indicate a limitation on usage of the URI and temporary ID - e.g. a maximum number of requests to the server or a maximum time duration of usage.

Editor's note: If is FFS whether and how the AMF determines the additional information in the response.

Figure 6.15.2.1-2 shows the second procedure which can be the same for both 5GS and EPS.



Figure 6.15.2.1-2: Procedure to Request Coverage Data from a Server

1. The UE sends an HTTPS Request (e.g. an HTTPS GET) to the server indicated by the URI obtained in the first procedure. The HTTPS Request includes the temporary URI (if applicable) and parameters indicating the location of coverage data, an area of coverage data (e.g. a size of a rectangular or circular area), a time period of coverage data, one or more satellite RATs, an applicable serving PLMN.

2. The server verifies that the temporary ID is valid.

3. The server returns the requested coverage data to the UE according to the request at step 1.

Editor's note: The generation, sharing and configuration of the security information are FFS and requires coordination with SA WG3.

#### 6.15.2.2 Obtaining Coverage Data using an DCAF and NWDAF

Editor's note: The details of these procedures are FFS.

This procedure is an alternative to the procedure in clause 6.X.2.1 and is more focused on PLMN provision of coverage data rather than provision by a third party like a satellite operator.

Since Rel-17, the DCAF functionality which is part of the AF was introduced to enable the NWDAF to perform data collection from an Application. Given the communication path between NWDAF and the DCAF has been introduced for data collection, it is extend the existing DCAF/AF functionality and architecture as defined in TS 26.531 [9] to expose network data analytics related to the UE to assist the UE's determination for coverage information.

Editor's note: The feasibility of this clause needs further discussion and to be checked with eNA\_Ph3 and SA WG4.

The following assumptions are made:

- The UE can Subscribe/Request to NWDAF via DCAF to request the information from 5GC (e.g. the Analytics result from the NWDAF).

- The communication services and functional architecture between UE and DCAF is in the scope of SA4 and shall be compatible with the existing architecture defined in TS 26.531 [9].

A user plane data collection from UE application client is in clause 6.2.8 of TS 23.288 [10] in Rel-17. A UE Application is configured the address of DCAF by the Application server. The UE establishes a connection to the DCAF over user plane via a PDU session. The DCAF communicates with the UE and collects data from the UE Application to NWDAF.

Editor's Note: It is FFS how the Application server determines the address.

The same procedure for user plane connection between the UE and DCAF (R2 interface in TS 26.531 [9]) is proposed to be used by the UE to request data exposure from NWDAF.

The following information can be exposed to the UE via the support of the DCAF based on network consent acquired by UE:

- Satellite ephemeris from any satellite operators the UE may be able to access.

- Other RAT information the UE may be able to access.

Editor's note: How to extend the interaction between UE and DCAF as defined in TS 26.531 [9] to enable UE to subscribe/request information to/from 5GC NF (e.g. NWDAF) via DCAF is in SA WG4 scope.

The SLA between the operator and an External Provider of the related information to NWDAF further include the Supported Analytics ID list.

The Supported Analytics ID indicates the Analytics outputs that allowed by the operator to expose to the UE. The Supported Analytics ID list will be stored in DCAF.

The External Provider will provision the Supported Analytics IDs to UE with means out of scope of 3GPP.

The UE requested data exposure procedure is described in Figure 6.15.2.2-1.



Figure 6.15.2.2-1: UE requested data exposure procedure

1. The UEs Direct Data Collection Client to send the Analytics Request to DCAF via signalling defined in TS 26.531 [9]. The DCAF address is provided to UE using a PCO when the UE establishes the PDU session to access DCAF. The requested Analytics ID(s) are included in the signalling to DCAF.

 DCAF can retrieve the UE IP address from the source IP address of the received packet.

2. UE ID retrieval procedure is described in clause 6.15.2.2.

3. DCAF discovers the NWDAF that supports the Analytics ID received in step 1.

 For DCAF in trusted domain, DCAF sends Nnrf\_nwdafdiscovery \_request to NRF to discovery the NWDAF. The request message shall include the Analytics ID and the S-NSSAI.

 For DCAF in untrusted domain, DCAF sends Nnef\_EventExposure\_subscribe with AF specific Identifier to NEF. NEF determines the S-NSSAI for the AF specific and sends Nnrf\_nwdafdiscovery \_request to NRF to discovery the NWDAF. The request message shall include the Analytics ID and the S-NSSAI

4. NRF sends the Nnrf\_nwdafdiscovery\_response with the discovered NWDAF identity.

5. DCAF subscribes to NWDAF for the analytics request with UE Identity and Analytics ID(s). Step 5a is for DCAF in trusted domain and step 5b is for DCAF in untrusted domain.

 Before step 5b, the AF asks the NEF for authorization information to check if the UE is allowed to obtain analytics ID from the network. The NEF determines the authorization information for the UE based on local policy and the UE subscription data from the UDM about whether the UE has subscribed to the service that obtaining some specific analytics ID from network. Then the NEF sends the authorization information to the AF.

6. If NWDAF does not have available analytics result for the requested analytics ID, the NWDAF will trigger the analytics procedures for the analytics ID(s). NWDAF performs user consent check to UDM to determine if the analytics procedure is allowed or not.

7. Analytics procedure is performed as described in TS 23.288 [10]. NWDAF may combine data it received from various sources e.g. OAM, external satellite providers etc in order to determine the analytics results.

8. NWDAF sends analytics result to DCAF. Step 8a is for DCAF in trusted domain and step 8b is for DCAF in untrusted domain.

NOTE: The security aspects of exposure of network data must be evaluated by SA3.

9. DCAF sends the analytics result to UE application client via application layer signalling.

10-11. If a Subscribe/Notify service operation is invoked in step 5, the NWDAF may further notify the analytics to UE e.g. periodically). NWDAF notifies the analytics result to DCAF. Step 11a is for DCAF in trusted domain and step 11b is for DCAF in untrusted domain.

12. DCAF exposes the requested analytics to UE application client.

For DCAF in trusted domain, since the supported pairs of S-NSSAI+DNN for the PDU session established for UE to DCAF are configured in the DCAF, DCAF may also retrieve the S-NSSAI+DNN for the PDU sessions that used by the UE sent the Analytics request. DCAF provides the UE IP address and the S-NSSAI to request UE ID from BSF as described in Figure 6.15.2.2-2.



Figure 6.15.2.2-2: UE ID Retrieval by DCAF in trusted domain

1. DCAF sends the Nbsf\_Management\_Discovery request to BSF with UE IP address, DNN and S-NSSAI to retrieve the session binding information of the UE.

2. BSF provides SUPI to DCAF via Nbsf\_Management\_Discovery response message.

For DCAF in untrusted domain, the supported pairs of S-NSSAI+DNN are configured in NEF. DCAF provides UE IP address to NEF and NEF retrieves the UE ID from BSF by reusing the procedure as described in clause 4.15.10 of TS 23.502 [3]. Figure 6.15.2.2-3 is the UE ID Retrieval procedure by DCAF in untrusted domain.



Figure 6.15.2.2-3: UE ID Retrieval by DCAF in untrusted domain

1. DCAF requests to retrieve UE ID via the Nnef\_UEID\_Get service operation. The request message shall include UE address and AF Identifier.

NOTE: The case where UE IP address provided by the AF to the NEF corresponds to an IP address that has been NATed (Network and Port Address Translation) is not supported in this Release.

2. The NEF authorizes the DCAF request.

3-4. The NEF may use the Nbsf\_Management\_Discovery service operation with UE address to retrieve the session binding information of the UE. BSF provides the SUPI / GPSI, S-NSSAI and DNN to NEF.

 NEF stores the SUPI / GPSI, S-NSSAI and DNN for the UE address.

5-6. NEF interacts with UDM to retrieve the AF specific Identifier from UDM and further responds to DCAF.

### 6.15.3 Impacts on existing nodes and functionalities

#### 6.15.3.1 Obtaining Coverage Data using an HTTPS Query to a Server

**UE:**

- Request and obtain a URI and temporary ID from an AMF or MME using NAS.

- Request and obtain coverage data from a server using HTTPS.

**AMF/MME:**

- Verify a UE subscription to receive coverage data and provide a URI to a server and temporary ID to the UE using NAS.

**Server:**

- Receive a request for coverage data from a UE using HTTPS, verify the temporary UE ID and provide coverage data.

#### 6.15.2.2 Obtaining Coverage Data using an DCAF and NWDAF

**DCAF:**

- Receives analytics request from UE via HTTP signalling to be defined in TS 26.531 [9].

- Discovers NWDAF for the received analytics request from UE.

- Sends analytics request to NWDAF.

- Receives analytics response from NWDAF.

- Sends the received analytics result to UE with signalling to be defined in TS 26.531 [9].

- Checks with NEF about authorization information for the UE if it is allowed to obtain analytics ID from the network.

**NEF:**

- Checks about authorization information for the UE based on local policy, the UE subscription data about whether the UE has subscribed to the service that obtaining some specific analytics ID from network.

**NWDAF:**

- Support coverage data encoded as a binary coverage map.

- Provide coverage data in response to a request from a DCAF.

**UE:**

- Send an analytics request to a DCAF for coverage data and receive coverage data in a response.

- Support coverage data encoded as a binary coverage map.

### 6.15.4 Solution evaluation

Editor's note: This clause captures how each solution solves KIs and what other properties it may have.

## 6.16 Solution #16: Solution to support a UE Triggered Generalized Unavailability Period

### 6.16.1 Description

This solution supports portions of KI#1 and KI#2. The solution is based on "Solution #2: UE provided Unavailability Period" in clause 6.2 of TR 23.700-61 [11] where an unavailability period for an event that is unavoidable is indicated by a UE to a serving AMF using a Registration Update. In that solution, the events that may be supported currently include:

a) Silent reset at Modem;

b) Security patch updates;

c) OS upgrade;

d) Modem SW updates; and

e) Device reboot upon Modem setting changes via OMA-DM.

This solution though can be generalized to indicate UE unavailability for other events that are unavoidable such as satellite discontinuous coverage or UE power savings combined with satellite discontinuous coverage.

NOTE 1: UE power savings combined with satellite discontinuous coverage refers to a period of power savings for a UE that includes one or more periods of (expected) no satellite coverage. The UE can then determine a preferred period of unavailability that starts at or before a first period of no satellite coverage and ends after this period and possibly subsequent periods of no satellite coverage have ended and thus during a period of satellite coverage. The network (AMF or MME) then does not need to know the details of the one or more periods of no satellite coverage and can just support a single overall period of UE unavailability. If the UE were to instead indicate unavailability for each separate period of no satellite coverage, the UE power savings could be much less and the network (AMF or MME) might need to process a much larger number of separate unavailability periods.

The principles of the solution are as follows and are aligned with principles described in clause 6.2.1 of TR 23.700‑61 [11].

(a) The UE determines a period of impending unavailability based on one or more of: data on satellite coverage availability, power savings requirements, SW upgrade, patching or reboot of the UE, and possibly other unavoidable events.

NOTE 2: The solution depends on UE access to data on satellite coverage availability which may be supported as in Release 17 or by some other new solution in Release 18.

(b) The UE indicates the period of unavailability to an AMF in a Registration Update or to an MME in a TAU. The UE could also indicate the events or events causing the unavailability.

NOTE 3: The event(s) may be useful for data analytics though may not affect support by an AMF or MME.

(c) The AMF or MME may set the periodic registration or TAU timer to a value equal to or slightly larger than the unavailability period provided by the UE. During this unavailability period the AMF or MME maintains the UE context in CM-IDLE or ECM-IDLE, and considers the UE unreachable. Functions for High latency Communication (HLCom) may be used to buffer incoming data or functions applicable to MICO mode may be used (e.g. for very long periods of unavailability).

(d) When the period of unavailability ends or if the UE becomes available before the unavailability is expected to end (e.g. if the UE obtains satellite access or access using a TN RAT before a satellite coverage gap is expected to end), the UE triggers a registration update or TAU and does not provide an indication of an unavailability period. The AMF or MME may then provide the UE with a normal periodic registration or TAU timer. If the UE is now using a different RAT, the context in the previous AMF or MME will be transferred.

(e) When the period of unavailability ends at the expected time and is due to an unavoidable event common to many UEs (e.g. discontinuous satellite coverage), the UE, if requested by the MME or AMF, can delay sending of the registration update or TAU for bullet (d) by a time delay indicated by the MME or AMF.

NOTE 4: The time delay in bullet (e) may need to be small (e.g. 1 minute or less in the case of discontinuous satellite coverage) and can avoid a large number of UEs sending a registration update or TAU at the same time which might otherwise congest the network.

### 6.16.2 Procedure for UE Triggered Generalized Unavailability Period

Figure 6.16.2-1 shows a procedure performed by a UE and AMF to support a Generalized UE Unavailability Period for NR satellite access. A procedure for LTE or NB-IoT satellite access would be similar. The procedure is based on the procedure in clause 6.2.3 of TR 23.700‑61 [11]. A similar procedure to the one shown in Figure 6.16.2-1 would be used for EPS with initial Registration replaced by an initial Attach and Registration for unavailability replaced by a TAU.



Figure 6.16.2-1: UE Triggered Generalized UE Unavailability Period

1. During an initial Registration procedure, the UE provides an indication of support of "Generalized Unavailability Period" in the Registration Request, and the AMF indicates whether this is supported in the Registration Accept message.

2. The UE determines a period of impending unavailability based on any of e.g.: satellite coverage unavailability, power savings requirements (when combined with satellite unavailability), SW upgrade or reboot of the UE or some other unavoidable event. The determination of the unavailability is implementation dependent and assumes the UE has the necessary data (e.g. for satellite coverage in the case of satellite coverage unavailability).

3. The UE sends a Registration Request sometime before the unavailability starts indicating the Unavailability period and may indicate an event or events causing the unavailability.

NOTE: The Registration Request can be a mobility Registration Request or could be left up to CT WG1 to decide.

4. The AMF responds with a Registration Accept. The AMF may set the periodic registration timer to a value equal or slightly greater than the unavailability period provided by the UE. For an event common to many UEs (e.g. discontinuous satellite coverage), the AMF may indicate a time delay (e.g. fixed or random) to the UE for re-accessing the PLMN.

5. The AMF stores the information that the UE is in unavailability period in the UE context, and considers the UE unreachable until the UE performs a registration update again. In this state, all HLCom features apply if supported, e.g. extended data buffering, downlink data buffering status report, etc.

6. The UE becomes available either due to normal termination of the unavailability period or because the UE became available earlier - e.g. if the UE obtains PLMN access using some NTN or TN RAT before a period of satellite unavailability was expected to end.

7. The UE triggers a registration update to resume regular service. The UE does not include an unavailability period in the Registration Request. Depending on whether the UE has changed PLMN, TAI or RAT type and whether the periodic registration timer has expired, the Registration may be an initial Registration (e.g. if the UE has changed PLMN), "mobility" or "periodic" Registration. If the UE becomes available due to normal termination of the unavailability period, the UE delays sending of the registration update for the time delay indicated at step 4.

Editor's note: If the periodic registration timer did not expire and the UE has UL data to send, the UE might send a Service Request instead. This is FFS.

8. The AMF responds with Registration Accept. The AMF assigns a new periodic registration timer not applicable to an unavailability period.

### 6.16.3 Impacts on existing nodes and functionalities

**UE:**

- Determination of a generalized unavailability period.

- Negotiating and signalling an unavailability period to an AMF (or MME).

- Notifying an AMF (or MME) after exiting unavailability and possibly after a small time delay.

**AMF/MME:**

- Support of an unavailability period indication in Registration or TAU procedure.

- Storing unavailability period in UE context.

- Handling of MT data and control plane procedures for an unreachable UE (no new procedures compared to HLCom).

- Assigning a time delay to a UE for re-accessing the PLMN.

### 6.16.4 Solution evaluation

For EPS, the solution is backward compatible with Release 17. If the UE is Release 18 but the MME is Release 17, the MME will not indicate support for the generalized unavailability period in an Attach Accept. If the UE is Release 17 but the MME is Release 18, the UE will not indicate support for the generalized unavailability period in an Attach Request and TAU Request. In these cases, both entities can use the solution for Release 17.

The solution does not require any support for satellite discontinuous coverage in an MME or AMF e.g. the AMF or MME does not need to receive data on satellite coverage or determine itself whether and when a UE will have a coverage gap.

The solution is multi-purpose and can support UE unavailability for several different unavoidable types of events and not just for satellite coverage gaps.

The solution can avoid a large number of UEs re-accessing a serving PLMN at the same time after a coverage gap has ended.

## 6.X Solution #X: <Solution Title>

Editor's note: This clause describes a solution addressing one or more key issues identified in clause 5. The structure of the clauses can be adjusted. The list of key issues which this solution attempts to resolve should be clearly indicated.

### 6.X.1 Description

Editor's note: This clause will describe the solution principles and architecture assumptions for corresponding key issue(s). (Sub) clause(s) may be added to capture details.

### 6.X.2 Procedures

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

### 6.X.3 Impacts on existing nodes and functionalities

Editor's note: This clause captures impacts on existing 3GPP nodes and functional elements.

### 6.X.4 Solution evaluation

Editor's note: This clause captures how each solution solves KIs and what other properties it may have.

# 7 Overall Evaluation

Editor's note: This clause provides the evaluations of the solutions of clause 6.

# 8 Conclusions

Editor's note: This clause provides the conclusions for the study.

Annex A:
<Informative annex title >

Annex B:
Change history

|  |
| --- |
| Change history |
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
| 2022-02 | SA2#149e | S2-2201626 | - | - | - | Skeleton | 0.0.0 |
| 2022-02 | SA2#149e | S2-2201627 | - | - | - | Scope | 0.1.0 |
| 2022-02 | SA2#149e | S2-2201628 | - | - | - | Architectural assumptions | 0.1.0 |
| 2022-02 | SA2#149e | S2-2201629 | - | - | - | Key Issue on Mobility Management enhancement with discontinuous satellite coverage | 0.1.0 |
| 2022-02 | SA2#149e | S2-2201630 | - | - | - | Key Issue on Power saving enhancement for UE in discontinuous coverage | 0.1.0 |
| 2022-02 | SA2#149e | S2-2201631 | - | - | - | Solution for Power Saving based on AMF awareness of coverage information | 0.1.0 |
| 2022-04 | SA2#150e | S2-2203380 | - | - | - | Solution for predictive Power Saving Mode | 0.2.1 |
| 2022-04 | SA2#150e | S2-2203381 | - | - | - | New solution for KI#2 on Power Saving mechanisms in case of discontinuous coverage | 0.2.1 |
| 2022-04 | SA2#150e | S2-2203382 | - | - | - | Solution for Mobility Management enhancement based on coverage information and UE location  | 0.2.1 |
| 2022-04 | SA2#150e | S2-2203383 | - | - | - | Solution for KI#2 Power Saving based on updating parameters before releasing signalling connection  | 0.2.1 |
| 2022-04 | SA2#150e | S2-2203384 | - | - | - | Solution#1 Update for Power Saving based on AMF awareness of coverage information | 0.2.1 |
| 2022-04 | SA2#150e | S2-2203385 | - | - | - | Solution discontinuous coverage architecture | 0.2.1 |
| 2022-04 | SA2#150e | S2-2203386 | - | - | - | Updates to KI#1 on MM enhancement with discontinuous satellite coverage | 0.2.1 |
| 2022-04 | SA2#150e | S2-2203387 | - | - | - | Key Issue: Support of 5GS Aspects of Discontinuous Coverage | 0.2.1 |
| 2022-04 | SA2#150e | S2-2203388 | - | - | - | Key Issue: Coverage using Alternative RATs | 0.2.1 |
| 2022-05 | SA2#151e | S2-2205120 |  |  |  | KI #2, Sol #3: Update to resolve editor's note | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205362 |  |  |  | KI #2, Sol #1: Update to resolution of EN and mobility updates | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205363 |  |  |  | KI #2, Sol #5: Update to clarify on Extended Connected Time | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205364 |  |  |  | KI #1&2, New Sol:<utilizing discontinuous coverage wait timer for satellite discontinuous coverage scenario> | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205365 |  |  |  | KI #1, New Sol: Leaving Coverage Notification | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205366 |  |  |  | KI #2, New Sol: Modification of Timers when in or out of Coverage | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205367 |  |  |  | KI#1 and KI#2, New Sol: UE Reachability Events with Expected in Coverage | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205368 |  |  |  | KI#1 and KI#2, New Sol: Combined UE Coverage Management Architecture | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205369 |  |  |  | KI#1, New Solution on minimizing discontinuous coverage by inter-RAT handover processing | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205370 |  |  |  | KI #1, New Sol: Handling when UE enters discontinuous coverage | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205371 |  |  |  | KI #1, New Sol: Wait timer for discontinuous coverage. | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205372 |  |  |  | New Solution for KI#1, KI#2: Provision of Coverage Data to a UE | 0.3.0 |
| 2022-05 | SA2#151e | S2-2205373 |  |  |  | New Solution for KI#1, KI#2: Support of UE Triggered Generalized Unavailability Period | 0.3.0 |