**SA WG2 Meeting ##152-e S2-220xxxx**

**17-26 August 2022, Electronic Meeting**

**Source: Sateliot, GateHouse**

**Title: Solution for paging enhancement under discontinuous coverage based on definition and management of UE-specific Tracking Areas**

**Document for: Discussion**

**Agenda Item: XXX**

**Work Item / Release: FS\_5GSAT\_Ph2 / Rel-18**

*Abstract: A solution that reduces the paging overhead under discontinuous coverage by the implementation of UE-specific Tracking Areas.*

# 1. Introduction/Discussion

In Rel-18 FS\_5GSAT\_Ph2 study item, it is proposed to study the support of the UE in discontinuous coverage as shown below:

* *WT#1: Discontinuous coverage*

*WT#1.1: Architectural enhancements to support discontinuous coverage for mobility enhancement (e.g. paging enhancement)*

*WT#1.2: Architectural enhancements considering prediction, awareness & notification of UE wake-up time, power saving optimizations.*

This contribution provides a candidate solution for part of Key Issue #1 in TR 23.700-28v0.3.0.

The solution being proposed is a paging enhancement aimed at reducing the paging-signalling load in NB-IoT deployment scenarios with discontinuous coverage. In particular, the proposed solution may be especially relevant for scenarios using (1) large satellite beam footprints (e.g. beam diameter of hundreds of kms, as considered for Set-3 and Set-4 scenarios in TR 36.763v17.0.0) and (2) earth-moving cells (satellite cells provisioned by beam(s) whose coverage area slides over the Earth surface such as the case of NGSO satellites generating fixed or non-steerable beams).

Paging requires the system to know where the UE is located. In terrestrial networks, tracking of UE location is done through Tracking Areas (TA), which are defined as a set of cells (the smallest TA consists of a single cell). Each cell belonging to a given TA broadcast a Tracking Area Code (TAC) associated to that TA. Hence, TAs are not strictly geographically defined, but are dictated by the placement and coverage range of set of cells that form part the TA, which are commonly fixed with respect the surface of Earth.

In NTN, irrespective of whether the satellite beams may be fixed or moving over the Earth, the definition of TAs has been also considered to be geographically fixed on ground (i.e. earth-fixed TA). However, to implement earth-fixed TAs in the case of earth-moving satellite beams, the tracking area code (i.e. TAC) broadcasted in a satellite cell has to be changed while the satellite beam coverage sweeps on the ground and crosses the boundaries of the (fictitious/planned) earth-fixed TA regions. To facilitate such an implementation, NTN has also added the capability (referred to as "soft switch" option) for one cell to broadcast more than one TAC per PLMN as a means to reduce the amount of Tracking Area Updates (TAUs) for UEs that happen to be located at the border areas of the earth-fixed TAs (Note that the earth-fixed TA boundaries are indeed not known to UEs, which only receive the TACs broadcasted by the moving satellite cells). However, when using this "soft switch" option, the more TACs a cell broadcast, the heavier paging load it experiences [see section 7.3.1.1 in 3GPP TR 36.763 V17.0.0 (2021-06)].

Such an increase of paging signalling load in Earth-moving cells is further amplified when considering large beam footprints (e.g., as reported in TR 36.763v17.0.0, beam diameter sizes between 234 km and 1700 km are considered for LEO-600 systems under Set-3 and Set-4). This situation is graphically illustrated in Figure 1. For the sake of simplicity in the representation but with no loss of generality, earth-fixed TAs are represented using a rectangular grid layout over the Earth surface and the TA size is considered to be comparable to the beam size (note that TA areas much larger than the beam size will be detrimental from a signalling paging load perspective while TA areas smaller than the beam size does not provide any advantage as all the UEs under the beam coverage will be receiving multiple TACs but with no possibility to discriminate in which particular TA they are located). Figure 1 also illustrates the fact that subsequent passes of the satellite over the same area is likely to show some shift due to different periods between Earth rotation and satellite orbits, so it is not feasible to arrange the TA layout to coincide with the satellite earth-track.



Figure 1 – Illustration of a configuration with earth-moving satellite beams and earth-fixed (conventional) tracking areas.

As can be observed from Figure 1, if paging is only to be based on TA information (i.e. no finer UE location information is used), the satellite beam coverage may partially overlap with up to four TAs (e.g. situation represented as “satellite beam coverage at time T3” in the figure) and number of pageable UEs can become extremely large, with the associated problems of increased paging resources overhead in the RAN and high rates of paging failures since most of the UE may not be indeed reachable from the current position of the satellite beam.

A potential solution to solve this issue is the definition of a UE-specific TA (referred to in the following as UE-TA), which is seen as a customised tracking area established for each UE by means of a geo-fenced, geographical area specification based on the UE position. The UE-TA area can be defined in various ways, for example, by parameterising a geometric figure (such as a circle, ellipse or polygon) or by means of a set of geographic coordinates for the vertexes of the tracking area. For example, it its simplest form, a UE-TA can be specified as a circle parametrised by its centre and radius, which can be encoded in few bytes. Remarkably, in addition to considering the UE location, the size and shape of the UE-TA might be established based also on mobility conditions (e.g. larger UE-TA for fast-moving UEs and smaller UE-TAs for static or quasi-static UEs) and deployment/service characteristics (e.g. device density). Multiple UEs can be assigned to the same UE-TA. Figure 2 illustrates the concept of UE-TA with earth-moving satellite beams and proposed UE specific tracking areas (UE-TAs).

Such a solution will allow:

* Paging the terminals based on UE-TAs, reducing the paging signalling load (i.e. only UEs whose UE-TA overlaps with the beam coverage will be paged)
* Optimizing paging of terminals under the coverage of the satellite beam (i.e. the scheduling of paging requests can be adjusted to the movement of the satellite).
* Achieving a better trade-off between paging signalling load and TAU signalling, thanks to being able to adjust the size of the TA to the specific mobility conditions of UEs (e.g. extremely small UE-TAs can be established for stationary UEs)
* Establishing UE-TAs along heavier trafficked areas such as trade-routes.
* Dynamically changing the size and shape of UE-TAs.



Figure 2 – Illustration of a configuration with earth-moving satellite beams and proposed UE specific tracking areas (UE-TAs).

# 2. Text Proposal

It is proposed to capture the following changes vs. TR 23.700-28.

\* \* \* \* First change (All new text) \* \* \* \*

## 6.X Solution X: UE-specific Tracking Areas

### 6.X.1 Description

This is a candidate solution for part of Key Issue #1. In particular, the solution proposed in this contribution is a paging enhancement aimed at reducing the paging-signalling load in NB-IoT deployment scenarios with discontinuous coverage. In particular, the proposed solution may be especially relevant for scenarios using (1) large satellite beam footprints (e.g. beam diameter of hundreds of kms, as considered for Set-3 and Set-4 scenarios in TR 36.763v17.0.0) and (2) earth-moving cells (satellite cells provisioned by beam(s) whose coverage area slides over the Earth surface such as the case of NGSO satellites generating fixed or non-steerable beams). The proposed solution is also applicable to scenarios beyond discontinuous coverage. In the proposed solution:

* When UE registers into the network (i.e. network attach) or perform TAU, UE indicates its current position.
* The CN (MME or AMF) defines a UE-specific Tracking Area (UE-TA) based on the UE position. The TA can be specified by means of a regular form (e.g. a circle, ellipse, polygon) or a collection of coordinates. The size and shape of the UE-TA can be adapted to the mobility conditions of the UE (e.g. larger UE-TA for fast-moving UEs and smaller UE-TAs for static or quasi-static UEs) and other deployment/service considerations (e.g., commercial traffic (ship, plane …) routes, device density). The specification of the UE-TA may leverage the work on Geographical Area Description (GAD) in 3GPP TS 23.032 V17.2.0.
* Upon acceptance of the registration/TAU procedure, the UE is notified with the UE-TA parameters.
* The UE uses the provided UE-TA and the knowledge of its location to determine whether the UE stays within the registered UE-TA or moves outside. In the latter case, a mobility registration update procedure is triggered to update the UE-TA.
* The CN is aware of the motion of the satellites of the constellation and is able to trigger paging based on UE-TAs (i.e. only UEs whose UE-TA overlaps with the beam coverage will be paged)
* The use of UE-TAs and earth-fixed (conventional) TA is not mutually exclusive (i.e. UE can be registered in a (conventional) TA or list of TA, and in addition, in a UE-TA.

TBC (some of the text in section 1 may be moved/accommodated here)

### 6.X.2 Procedures

#### 6.X.2.1 Registration/TAU based on UE-TA

Figure 3 illustrates the high-level procedures for network registration/attach and Tracking Area Update (TAU) using the proposed UE-specific Tracking Areas (UE-TAs).



Figure 3 – High-level procedures for registration/attach and TAU with the proposed UE specific tracking areas (UE-TAs).

For network registration/attach with UE-TA, the steps illustrated in Figure 3 are as follows:

1. When registering/attaching to the network, the UE provides its location (with some granularity, after security).
2. The MME/AMF determines the specification of the UE-TA. This will be based on UE location and additional knowledge the MME/AMF may have with respect to mobility patterns and/or most likely locations and/or subscription information. This additional knowledge may be acquired via interactions with NWDAF and/or subscriber databases (steps 2a and 2b in the message chart).

Note: Multiple UEs can be assigned to the same UE-TA specification.

1. The assigned UE-TA specification is provided to the UE upon acceptance of the registration/attach request.
2. The UE monitors its position to check whether it remains within or outside the assigned UE-TA specification.

For TAU procedure with UE-TA, the steps illustrated in Figure 3 are as follows:

1. The UE detects it is outside the assigned UE-TA
2. A TAU procedure is triggered, with the UE providing its location (with some granularity, after security).
3. The MME/AMF determines the specification of a new UE-TA for the UE according to the new location. As for the registration/initial attach, the determination of the UE-TA will be based on UE location and additional knowledge the MME/AMF may have with respect to mobility patterns and/or most likely locations and/or subscription information. This additional knowledge may be acquired via interactions with NWDAF and/or subscriber databases (steps 7a and 7b in the message chart).
4. The assigned UE-TA specification is provided to the UE upon acceptance of the TAU request.
5. The UE monitors its position to check whether it remains within or outside the assigned UE-TA specification.

#### 6.X.2.2 Paging triggering based on UE-TA registration

Figure 4 illustrates the high-level procedure for paging triggering from MME/AMF using the proposed UE specific tracking areas (UE-TAs). The following steps are indicated:

1. The MME/AMF determines the time or a time window for the triggering of the paging procedure. This determination may be based on:
   1. UE-TA specification assigned to the UE
   2. Knowledge on satellite constellation coverage (e.g. ephemeris, beam footprint size)
   3. PSM configuration
2. The MME/AMF starts the paging procedure towards the RAN node that is going to provide the coverage at the estimated paging time or paging window time.

Note: The considerations on paging time or paging window time are FFS.

1. The RAN triggers the paging requests over the service link when indicated



Figure 4 – High-level procedures for paging trigger from MME/AMF using the proposed UE specific tracking areas (UE-TAs).

6.X.3 Impacts on services, entities and interfaces

**UE:**

- Provides its current location when registering or in TAU procedures.

- Stores the UE-TA specification received from the network and monitors whether its location remains within the UE-TA or moves outside.

- Triggers mobility registration update procedures if the UE detects by itself that it has moved outside the registered UE-TA.

**RAN:**

*- none*

**AMF/MME:**

- Determines the UE-TA parameters based on the UE location and additional information such as mobility patterns/service characteristics/deployment characteristics that may be available. The specification of the UE-TA may leverage the work on Geographical Area Description (GAD) in 3GPP TS 23.032 V17.2.0.

- Sends the UE-TA parameters to the UE during the registration/TAU procedures.

- Triggers paging for a given UE based on the UE-TA parameters and knowledge of the motion and coverage of the satellites of the constellation (i.e. overlapping of UE-TA and satellite coverage).

\* \* \* \* End of changes \* \* \* \*