**3GPP SA WG2 Meeting #162 S2-2405016**

**Changsha, China, April 15 – 19, 2024 (revision of S2-2404995, S2-2402443)**

**Source: LG Electronics, NEC**

**Title: KI#2, Sol#20: Update to resolve ENs**

**Document for: Approval**

**Agenda Item: 19.1**

**Work Item / Release:** **FS\_5GSAT\_ARCH\_Ph3 / Rel-19**

*Abstract of the contribution: This contribution proposes to update Solution #20 to resolve ENs.*

# 1 Discussion

This paper proposes to update solution#20 by resolving the following ENs by introducing the attach and MO data delivery procedures.

Editor's note: It is FFS that how the only eNB onboard satellite can be EPS attached and transitioned to the Connection suspend.

Editor's note: It is FFS that the procedures for Mobile Originated Data Delivery in User Plane CIoT EPS Optimisation for Store and Forward Operation.

To address following ENs, the assumption to stationary UE is removed. Instead, it is clarified that the UE can perform TAU if it is moved to the other TA areas. Also, the MME determines TAU timer considering the time period until the satellite cover the location of the UE again based on the coverage information on when and which areas (e.g. suported TAI list and valid period) will be covered by the serving satellite. The MME additionally takes into account the TAU timer in addition to the feeder link availability information when delivering DL data to the satellite.

Editor's note: It is FFS how to preconfigure the UE is stationary for S&F operation.

Editor's note: It is FFS how the MME determines to forward the DL data to the satellite when feeder link is available or other additional considerations are needed to store it further in the Core Network.

The following EN is resolved with clarification for the impact on UL and DL delays.

Editor's note: It is FFS for the impact on how long the UL and DL delays will be.

Also, following EN is updated with more clarification.

Editor's note: It is FFS that how to manage S1 interface connection regarding S&F during the connection between eNB and MME is interrupted.

The Solution is updated to support Control Plane CIoT optimisation.

# 2 Text Proposal

It is proposed to agree the following changes into TR 23.700-29v0.4.0.

\* \* \* \* Start of 1st Change \* \* \* \*

6.20 Solution #20: Solution on enabling S&F operation and data delivery with only eNB onboard satellite

6.20.1 Description

This solution resolves KI#2 Store and Forward operation with only eNB onboard satellite.

This solution assumes the following:

- Only eNB is embedded and the eNB can buffers data for Store and Forward operation and no other Core Network function is embedded in the satellite.

- UE and MME negotiate about the support of Store and Forward operation capability during attach procedure.

- MME and eNB store in the UE context that the UE is operate in Store and Forward operation mode.

- It is assumed that there is only one satellite serving the UE for Store and Forward Operation.

- The satellite broadcasts that it supports Store and Forward operation in the SIB and satellite ID. The UE operates for S&F operation mode accesses the satellite based on this information.

- During the feeder link is unavailable, it is assumed that the S1 interface is maintained between the satellite eNB and MME. (e.g. S1 suspend/resume)

- The satellite eNB shall Store and Forward the received message between the UE and MME.

- It is assumed that the UE communicate with the same serving satellite based on the satellite ID broadcasted from the serving satellite during the attach procedure.

- The eNB and MME know that they support S&F operation each other based on the pre-configuration or in the S1 SETUP REQUET and S1 SETUP RESPONSE message, the eNB and the MME indicate to each other that they support S&F operation.

Editor's note: It is FFS that how to manage S1 interface connection regarding S&F during the connection between eNB and MME is interrupted and will be determined by RAN3.

The solution reuses the Control Plane CIoT EPS Optimisation and User Plane CIoT EPS Optimisation functionality including Connection Suspend procedure and Connection Resume procedure. Also, functions for High latency communication are reused to invoke extended buffering of MT data at the S-GW when the UE is not reachable.

When the MME receives Downlink Data Notification from S-GW, MME cannot know whether and when the downlink data can be forwarded to the serving satellite that is associated with the MME because the MME does not aware whether feeder link is available. Also, S-GW cannot know how long it should buffer the data before the feeder link available.

In Rel-18, the MME can use satellite coverage availability information to support satellite access by UEs with discontinuous coverage operation. Satellite coverage availability information may be provisioned to the MME by O&M and it describes when and where satellite coverage is expected to be available in an area.

This solution introduces feeder link availability information to support the store and forward operation for eNB embedded in the satellite. This information may also be provisioned to the MME (How the information is provisioned to the MME is out of scope of this solution). Feeder link availability information contains e.g.:

- For each satellite, satellite ID and orbit information.

- Gound gateways connected to each MME and/or location of ground gateway (e.g. Cell, TA, Geographical location).

- Time windows when gateways are connectable via feeder link for each satellite.

Based on the above information, the MME can know when each satellite is available via feeder link through the ground gateway connected to the MME. It is also preconfigured to the MME and eNB with the information on when and which areas (e.g. supported TAI list and valid period) will be covered by the satellites. This can be used to determine whether to forward the MT data for the UE to the satellite for store and forward operation.

The MME can derive Downlink Buffering Duration time as the expected time until the feeder link could be available to the serving satellite based on the feeder link availability information. MME provide it to the S-GW and S-GW stores Downlink Data Buffer Expiration Time based on the Downlink Buffering Duration time received from the MME.

6.20.2 Procedures

6.20.2.1 Attach Procedure

The procedure for Initial Attach for S&F operation is depicted in Figure 6.20.2.1-1. The steps enclosed in dashed line boxes are executed when either only service link or feeder link is available.



Figure 6.20.2.1-1: Attach Procedure with eNB onboard satellite

1. UE provides Attach Request to the satellite broadcasts that it supports Store and Forward operation in the SIB with S&F support indication in the UE Core Network Capability when the UE operate for S&F operation mode and the UE also indicates Control Plane/User Plane CIoT EPS Optimisation supported in Preferred Network Behaviour. The RRC message contains the Attach Request contains S&F indication. The UE calculate the orbital period of the satellite based on the ephemeris information of the SIB from eNB. The UE will suspend the NAS procedure based on this information even if the RRC Connection is released, until it receives the NAS message from the MME. The eNB and UE stores UE context including the UE ID.

NOTE: Details of the UE context stored for next RRC connection will be determined by RAN.

 For the case of UEs attaching with Control Plane CIoT EPS Optimisation with no user plane establishment, steps 12, 15 to 17, 20, 21 are replaced by S1 AP NAS Transport and RRC Direct Transfer messages that just transport the NAS Attach Accept and NAS Attach Complete messages.

2. Based on the S&F indication in the RRC message, the eNB supporting Store and Forward operation stores the UE request until the feeder link is available. When the eNB in satellite detect that a feeder link is available, based on the pre-configuration or support of S&F operation from MME, forward attach request to the MME via ground gateway.

3-4. The MME triggers the authentication procedure and the MME forwards the authentication message to the eNB. The eNB stores the message until the service link is available again. The MME determines NAS timer to suspend the NAS procedure until the satellite connect to the MME again based on the preconfigured coverage information.

5. When the service link is available, based on the orbital period calculated by the UE, the UE establish RRC Connection to the same eNB to resume the attach procedure and the eNB forwards the message from the MME to the UE based on the UE ID in step 1.

6-11. The attach procedure continues.

12. The MME stores in the UE context that the UE operates in Store and Forward operation mode. The MME sends Initial Context Setup Request to eNB. The eNB stores in the UE context that the UE operates in Store and Forward operation mode. Attach Accept message contains S&F support indication in the UE Core Network Capability and indicates the CIoT EPS Optimisations accepted by the MME in the Supported Network Behaviour information.

 If the MME does not allow the UE to operate in Store and Forward operation mode, the MME rejects the UE request and indicate the eNB to release the UE contexts using UE Context Release Command. For the UE that operates in Store and Forward operation mode, the eNB releases the UE context after forwarding the Attach Reject message to UE.

 For the case of UEs attaching with Control Plane CIoT EPS Optimisation with no user plane establishment, S1 AP NAS Transport message is used to send NAS Attach Accept message.

13. For the UE that operates in Store and Forward operation mode with User Plane CIoT EPS Optimisations, the MME triggers steps 10-13 in Figure 6.20.2.2-1 to trigger suspend mode and release the S1-U bearer.

14. RRC Security Mode is performed.

15. RRC Connection Reconfiguration includes Attach Accept message. The MME provides TAU timer considering the time period until the satellite cover the location of the UE again based on the coverage information on when and which areas (e.g. supported TAI list and valid period) will be covered by this serving satellite.

 If the eNB received an S1-AP Downlink NAS Transport message (e.g. containing the Attach Accept message), the eNB sends a RRC Direct Transfer message to the UE.

16-17. UE sends RRC Connection Reconfiguration Complete and Direct Transfer (Attach Complete) consecutively.

18. UE may send Uplink data at this step.

19. Based on the procedure performed at step 13, the eNB sends RRC message to suspend the RRC Connection towards the UE including UE Resume ID.

20-21. When the feeder link is available, eNB sends Initial Context Setup Response and Attach Complete message consecutively to the MME.

22. Steps 5-8 in Figure 6.20.2.4-1 may be performed to send MO data.

6.20.2.2 MT Data delivery in CIoT EPS Optimisation for Store and Forward Operation if feeder link is available



**Figure 6.20.2.2-1: MT Data delivery in CIoT EPS Optimisation for Store and Forward Operation if feeder link is available**

0. The UE is EPS attached and in ECM-Idle mode. For the UE that operates in User Plane CIoT EPS Optimisations is in ECM-Idle mode with suspend.

1. S-GW receives a downlink data packet for a UE, it buffers the downlink data packet.

2. The S-GW sends a Downlink Data Notification message to the serving MME for the UE.

3. The MME checks that the UE is operating as a Store and Forward operation mode. If it is, based on the feeder link availability information and last known UE location, the MME further checks if there is a feeder link to the serving satellite eNB which will cover the UE.

4. The MME detects that there is a feeder link with satellite and can be reached to the satellite at the time of receiving Downlink data notification, the MME response with Downlink Data Notification Ack message. If there is a reachable feeder link.

 When the feeder link is available but the MME determines that the serving satellite will not cover the area where the UE is located (e.g. coverage change due to the Earth rotates) based on the preconfigured coverage information, the DL data need to be buffered in the Core Network. Based on the TAU timer provided by the MME, the UE can trigger TAU with another satellite that supports Store and Forward operation in the SIB if the UE cannot find the current serving satellite after the TAU timer expires, or if the UE find a satellite broadcasting new TA that is not in the list of TAIs that the UE registered with the network, and the serving satellite can be changed. In this case, the MME determine DL buffering duration time considering the TAU timer provided to the UE in addition to the feeder link availability information, and provide it to S-GW as in step 4 of Figure 6.20.2.3-1. Then, steps 4-6 in Figure 6.20.2.3-1 are performed. After the serving satellite change, the UE context in the old satellite can be released by the (old) MME when the (old) MME connects to the old satellite via feeder link.

5. [UP CIoT] The MME sends S1-AP message to the eNB for User Plane activation between the satellite and the S-GW if the MME determines that the feeder link to the MME is available. The S1-AP message include the information that buffering data in the satellite is needed for Store and Forward operation, and UE location information (e.g. TA) for assistance information when paging.

Editor's note: What S1-AP message will be used is FFS and will be determined by RAN3.

 If the eNB receives S1-AP message from MME at step5, the eNB checks whether it serves the area corresponding to the UE location information in the received S1-AP message. If so, the eNB paging the UE and the UE initiated Connection resume procedure as clause 5.3.5A of TS 24.301 [17] is performed and the rest of this procedure is skipped. Otherwise, continues step 6.

6-8. [UP CIoT] The eNB sends UE Context Resume Request message to the MME to re-activate the S1-U bearers. The MME requests the S-GW to re-activate the S1-U bearers for the UE. The MME sends UE Context Resume Response to the eNB after Modify bearer with S-GW.

9. [UP CIoT] Downlink data is transferred from the S-GW to the eNB and the eNB buffers the downlink data.

9a-9c. [CP CIoT] The MME sends a Modify Bearer Request message to activate S11-U. Then, Buffered Downlink data is sent by the S-GW to the MME and the MME encrypts and integrity protects Downlink data.

10. [UP CIoT] The MME may send S1-AP message to the eNB to indicates that the feeder link will be unavailable.

Editor's note: What S1-AP message will be used is FFS and will be determined by RAN3.

[CP CIoT] The MME includes Downlink data using a NAS PDU in this Downlink S1-AP message.

11-13. [UP CIoT] The eNB sends UE Context Suspend Request and S1-U bearer is released.

 After this step, feeder link between satellite and MME become unavailable. During the feeder link is unavailable, the S1 interface is maintained between the eNB and MME.

14. When the satellite covers the TA where the UE is located which is received at step 5, eNB sends paging request to send stored data to the UE.

15. [UP CIoT] The UE sends the RRC Connection Resume message and the UE becomes RRC Connected state.

 [CP CIoT] The UE sends Control Plane Service Request NAS message over RRC Connection request. and S1-AP initial message.

16. Stored Downlink data in the satellite is forwarded to the UE by UP or CP using a NAS PDU in this Downlink S1-AP message.

17. While the Service link is still up, further Uplink data can be transferred from the UE to the satellite and the satellite stores the uplink data until the feeder link is available again and forward the data.

18. [UP CIoT] The eNB sends RRC message to suspend the RRC Connection towards the UE including UE Resume ID based on the preconfigured coverage information.

6.20.2.3 MT Data delivery in CIoT EPS Optimisation for Store and Forward Operation if the feeder link is unavailable

****

**Figure 6.20.2.3-1: MT Data delivery in CIoT EPS Optimisation for Store and Forward Operation if the feeder link is unavailable**

0. The UE is EPS attached and in ECM-Idle mode. For the UE that operates in User Plane CIoT EPS Optimisations is in ECM-Idle mode with suspend.

1. The S-GW receives a downlink data packet for a UE, it buffers the downlink data packet.

2. The S-GW sends a Downlink Data Notification message to the serving MME for the UE.

3. The MME checks that the UE is operating as a Store and Forward operation mode. If it is, based on the feeder link availability information, the MME further checks if there is a feeder link to the satellite eNB which will cover the UE.

4. The MME detects that there is no feeder link with satellite and cannot be reached to the satellite at the time of receiving Downlink data notification, shall invoke extended buffering depending on operator configuration. The MME derives Downlink Buffering Duration time that expected time before the feeder link can be available to the serving satellite based on the feeder link availability information. the MME indicates Downlink Buffering Requested to the S-GW in the Downlink Data Notification Ack message and includes a Downlink Buffering Duration time.

 If the MME determines that the serving satellite will not cover the area where the UE is located (e.g. coverage change due to the Earth rotates) based on the preconfigured coverage information, the MME can determine DL buffering duration time considering the TAU timer provided to the UE in addition to the feeder link availability information.

5. A S-GW that receives a Downlink Buffering Requested indication in a Downlink Data Notification Ack message stores a new value for the Downlink Data Buffer Expiration Time based on the Downlink Buffering Duration time and continues buffering the Data until the Downlink Data Buffer Expiration Time expires.

6. If the MME determines that the feeder link become available based on the feeder link availability information and the MME has provided Downlink Buffering Requested indication in a Downlink Data Notification Ack at step 4, the MME triggers step 5 of Figure 6.20.2.2-1 to activate user plane data for User Plane CIoT EPS Optimisation case or the MME triggers step 9a of Figure 6.20.2.2-1 to activate S11-U for Control Plane CIoT EPS Optimisation case. Then the procedure continues to the step 18 of Figure 6.20.2.2-1.

NOTE 1: The feeder link may be available when the same serving satellite returns to the MME or if the UE performed TAU with the new satellite (due to TAU timer expiration or mobility), when the new satellite is connected to the MME with the feeder link.

NOTE 2: The UL and DL delays depend on the orbital period of the satellite, and multiple orbital periods may be required. For example, if the satellite can find the UE or gateway within its orbital period, the UL and DL delays will be less than the orbital period. However, if the satellite cannot find the UE or gateway within its orbital period, the UE will trigger TAU which requires 2 more orbital periods, resulting in 3 orbital periods. If re-authentication is required during the TAU, additional 2 orbital periods are required, resulting in 5 orbital periods.

#### 6.20.2.4 MO Data Delivery in CIoT EPS Optimisation for Store and Forward Operation



Figure 6.20.2.4-1: MO Data delivery in CIoT EPS Optimisation for Store and Forward Operation

0. The UE is EPS attached and in ECM-Idle mode. For the UE that operates in User Plane CIoT EPS Optimisations is in ECM-Idle mode with suspend and Steps 10 - 13 in Figure 6.20.2.2-1 is performed before the feeder link between eNB and MME become unavailable.

1. [CP CIoT] The UE sends the RRC Connection Resume message and the UE becomes RRC Connected state.

 [UP CIoT] The UE establishes RRC connection including an integrity protected NAS PDU. The NAS PDU carries the EPS Bearer ID and encrypted Uplink Data.

2. [UP CIoT] The UE sends Uplink data to the satellite.

3. The satellite may forward stored downlink data to the UE by UP or CP using a NAS PDU in this Downlink S1-AP message.

4. [UP CIoT] The eNB sends RRC message to suspend the RRC Connection towards the UE including UE Resume ID based on the preconfigured coverage information.

5. [UP CIoT] After Feeder link become available, steps 6-8 in Figure 6.20.2.2-1 are performed to activate S1-U bearer.

6. [UP CIoT] eNB forwards stored uplink data to the S-GW.

7. [UP CIoT] Buffered downlink data can be transferred from the S-GW to the satellite and the satellite stores the downlink data until the service link is available again.

8. [CP CIoT] The NAS PDU sent in step 1 is relayed to the MME by the eNodeB using a S1-AP Initial UE message.

9. [CP CIoT] The MME checks the integrity of the incoming NAS PDU and decrypts the data it contains.

10. [CP CIoT] The MME sends a Modify Bearer Request message to activate S11-U if the S11-U connection is not established.

 If the UE's Location and/or Info IEs and/or UE Time Zone and Serving Network id are received from MME, the Serving GW shall send the Modify Bearer Request message (RAT Type, MO Exception data counter) to the PDN GW.

11. [CP CIoT] The MME forwards the stored uplink data to the S-GW and S-GW forward it to the P-GW.

12. [CP CIoT] Buffered downlink data can be transferred from the S-GW to the MME.

13. [CP CIoT] If Downlink data are received in step 12, the MME encrypts and integrity protects the Downlink data.

14. [UP CIoT] Steps 10-13 in Figure 6.20.2.2-1 are performed to trigger suspend mode and release the S1-U bearer.

6.20.3 Impacts to Services, Entities and Interfaces

**UE:**

- Suspend the NAS procedure based on the orbital period calculated based on the ephemeris information in the SIB from eNB.

- RRC connection indicates S&F mode operation.

- Trigger TAU with another satellite that supports Store and Forward operation in the SIB if the UE cannot find the current satellite after the TAU timer expires.

**eNB:**

- New S1-AP message from MME for User Plane activation and indicates that buffering data in the satellite is needed for Store and Forward operation, and includes the UE location information (e.g. TA) for assistance information when paging.

- New S1-AP message from MME indicates that the feeder link will be unavailable.

- Support user plane activation with S-GW when the eNB is not connected with UE.

- Support RRC Connection resume with UE when the eNB is not connected with CN.

- Paging for stored data/signalling when the eNB covers the area corresponding to the UE location information (e.g. TA) provided by MME.

- Preconfigure when and which areas (e.g. supported TAI list and valid period) are covered by the satellites.

- Support Store and Forward the NAS message between the UE and the MME for the UE operates in S&F mode.

- During the feeder link is unavailable, support to maintain the S1 interface between the eNB and MME. (e.g. suspend/resume)

- UE Context in eNB includes whether the UE is operating in Store and Forward operation mode

- New IEs in SIB to broadcast that it supports Store and Forward operation.

- Indicates to the MME that it supports S&F operation in the S1 SETUP REQUEST message.

**MME:**

- Support feeder link availability information.

- Derive Downlink Buffering Duration time based on the feeder link availability information.

- UE Context in MME includes whether the UE is operating in Store and Forward operation mode

- New S1-AP message to the eNB for User Plane activation and indicates that buffering data in the satellite is needed for Store and Forward operation. It also includes the UE location information (e.g. TA) for assistance information when paging.

- New S1-AP message to the eNB indicates that the feeder link will be unavailable.

- Preconfigure when and which areas (e.g. supported TAI list and valid period) are covered by the satellites.

- During the feeder link is unavailable, support to maintain the S1 interface between the eNB and MME. (e.g. suspend/resume)

- Determine the periodic TAU timer provided to the UE based on the based on the coverage information on when and which areas (e.g. supported TAI list and valid period) will be covered by the satellite

- Store DL/UL NAS data when service link or feeder link is not available.

- Indicates to the eNB that it supports S&F operation in the S1 SETUP RESPONSE message.

\* \* \* \* End of Changes \* \* \* \*