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**Title: Solution for improved paging in MUSIM devices (KI#1,2,3)**

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**Agenda Item: 8.4**

**Work Item / Release: FS\_MUSIM**

*Abstract of the contribution: Propose a solution for how a MUSIM UE can optimise paging and coordinated leaving*

# Discussion

The Assumption underlying this solution are the following:

1. The UE is aware it has >1 USIM active. By active we define a USIM that is related to a SUPI or IMSI registered with a PLMN.
2. The UE is aware of potential paging occasion conflict and can take action to remedy to such conflicts or make sure the impact of resources waste is minimised. There is no need for network side detection of such conflicts.
3. The UE may also have some User Preferences or Settings that indicate what service classes a UE is interested to receive (if at all) on which USIM. This can also be used to further optimise the system behaviour while the UE is connected to a PLMN using one USIM and other USIMs are in CM-IDLE and thus can receive MT services.
4. We cannot assume any two USIMs are served by the same PLMN nor same nodes (AMFs or SMFs) inside the PLMN if both are registered in the same PLMN. This may also be impossible even if the USIMs register with the same PLMN as AMF for one USIM may be on a different Slice Set than other USIMs. In other words, the network is not assumed to spend any effort to initiate actions on behalf of MUSIM UEs or derive that a UE is using multiple USIMs based on network side intelligence. It is only the UE responsibility to provide any assistance to the network to improve the system behaviour when it is using multiple USIMs.

Based on the above assumptions, the following considerations can be made:

1. Since each USIM is registered independently and is associated to an independent PEI or IMEI, only the UE can detect at any time whether it has >1 active USIM and initiate any actions.
2. The UE can transition at any time from behaving single USIM UE to behaving a MUSIM UE as soon as the UE registers a second USIM.
3. The UE can transition at any time from behaving as a MUSIM UE to behaving as single USIM UE as soon as the UE remains with only a single registered USIM.
4. It is the UE responsibility to inform the registered PLMN for each USIM about changes deriving from the UE behaving a MUSIM UE or no longer behaving as a MUSIM UE, including any need to modify the paging behaviour.
5. If there are settings or user preferences in the UE limiting at any point in time what MT services classes can be accepted at the UE for a certain USIM, only the UE can be aware of these settings. So, to avoid needless paging the UE could gracefully assist the PLMN(s) it is registered with each USIM by providing some assistance information indicating which MT service classes the UE is not interested in or ready to accept (depending on whether a blacklist or whitelist approach is chosen).
6. As a particular case of bullet 5, it is responsibility of the UE t to indicate that it is not interested in any MT service paging for one USIM.
7. The Service classes in Observation#5 must be standardised. Any nonstandard service classes or individual service setting cannot be recognised in the network, hence the only way to apply any user setting or preference is to receive the application layer data that allows the identification of the MT service, before any evaluation on the action to take can be performed. It follows that the concept of indication of Service class in the paging message is not required as the classification that can be done is only up to the granularity that allows the network to set any paging indication. So, a paging filtering policy per USIM can be defined to prevent the paging at the same level of granularity.
8. any paging filtering based on paging classes can also apply for the case of UE in RRC inactive. In this case the CN provides to the RAN the filter and the classification is done at the SMF/UPF.

# Solutions high level principles

It is proposed that the following solutions principles are consequent to the above observations:

1. The UE detects whether it is single USIM or MUSIM at any point in time
2. When the UE detects it is MUSIM, it can inform the PLMN for each USIM and indicate to the network MUSIM assistance information in RM/MM messages (see also bullet 6 for more details)
3. When the UE detects it transitions back to single USIM, it can indicate this to the PLMN of the remaining USIM by RM/MM message not including MUSIM information. This needs not be instantaneous and may wait till next RM/MM event.
4. When a MUSIM UE detects potential of paging conflict, it can indicate to one PLMN of one USIM (or, in >2 USIMs case, to all applicable PLMNs) assistance information to avoid paging conflict, e.g. a Replacement UE\_ID for paging occasion computation.
5. The MUSIM Assistance Information may include the number of USIMs that are currently active so the PLMN may tune its paging strategy according to this information (e.g. the number of paging attempts from CN and/or RAN could be modified based on this information)
6. If there are any user preferences or settings that prevent certain MT services classes on certain USIM while another USIM is CM-Connected, then the UE can add Paging Filtering Rules to the assistance information to the PLMN for each such USIM. The UE sets or un-sets in the PLMN such paging filtering information when the settings and preferences become effective or are no longer applicable respectively in the UE.
7. If a UE has active ongoing services in one USIM and determines it does not intend to respond to paging on a second USIM (before, or upon receiving a page on a second USIM), then the UE shall inform the PLMN of the second USIM to stop paging the UE by providing related Assistance Information.

# Proposal

It is proposed that the following text is included in TR 23.761

**PROPOSED CHANGES**

6.X Solution #X: Using MUSIM Assistance Information

6.X.1 Introduction

This solution addresses KI#1, 2 and 3

The Assumption underlying this solution are the following:

1. The UE is aware it has >1 USIM active. By active we define a USIM that is related to a SUPI or IMSI registered with a PLMN.
2. The UE is aware of potential paging occasion conflict and can take action to remedy to such conflicts or make sure the impact of resources waste is minimised. There is no need for network side detection of such conflicts.
3. The UE may also have some User Preferences or Settings that indicate what service classes a UE is interested to receive (if at all) on which USIM. This can also be used to further optimise the system behaviour while the UE is connected to a PLMN using one USIM and other USIMs are in CM-IDLE and thus can receive MT services.
4. We cannot assume any two USIMs are served by the same PLMN nor same nodes (AMFs or SMFs) inside the PLMN if both are registered in the same PLMN. This may also be impossible even if the USIMs register with the same PLMN as AMF for one USIM may be on a different Slice Set than other USIMs. In other words, the network is not assumed to spend any effort to initiate actions on behalf of MUSIM UEs or derive that a UE is using multiple USIMs based on network side intelligence. It is only the UE responsibility to provide any assistance to the network to improve the system behaviour when it is using multiple USIMs.

Based on the above assumptions, the following considerations can be made:

1. Since each USIM is registered independently and is associated to an independent PEI or IMEI, only the UE can detect at any time whether it has >1 active USIM and initiate any actions.
2. The UE can transition at any time from behaving single USIM UE to behaving a MUSIM UE as soon as the UE registers a second USIM.
3. The UE can transition at any time from behaving as a MUSIM UE to behaving as single USIM UE as soon as the UE remains with only a single registered USIM.
4. It is the UE responsibility to inform the registered PLMN for each USIM about changes deriving from the UE behaving a MUSIM UE or no longer behaving as a MUSIM UE, including any need to modify the paging behaviour.
5. If there are settings or user preferences in the UE limiting at any point in time what MT services classes can be accepted at the UE for a certain USIM, only the UE can be aware of these settings. So, to avoid needless paging the UE could gracefully assist the PLMN(s) it is registered with each USIM by providing some assistance information indicating which MT service classes the UE is not interested in or ready to accept (depending on whether a blacklist or whitelist approach is chosen).
6. As a particular case of bullet 5, it is responsibility of the UE to indicate that it is not interested in any MT service paging for one USIM.
7. The Service classes in point 5 must be standardised or associated to well identified traffic parameters (like DSCP/TOS values, protocols number, port numbers). Any nonstandard service classes or individual service setting cannot be recognised in the network, hence the only way to apply any user setting or preference is to receive the application layer data that allows the identification of the MT service, before any evaluation on the action to take can be performed. It follows that the concept of indication of Service class in the paging message is not required as the classification that can be done is only up to the granularity that allows the network to set any paging indication. So, a paging filtering policy per USIM can be defined to prevent the paging at the same level of granularity.
8. Any paging filtering based on paging classes can also apply for the case of UE in RRC inactive. In this case the CN provides to the RAN the filter and the classification is done at the SMF/UPF.
9. The assistance information may also include specific information on the fact the UE supports MUSIM, how many USIMs and maybe whether it can receive paging only according to a certain pattern (e.g. in ODD or EVEN DRX cycles, or at specific DRX cycles, or other periodic or absolute time information – how to number DRX cycles and identify Even and Odd can be left to RAN WGs, e.g. it could be based in their order of appearance in the SFN sequence and agreeing whether the first is value 0 or 1 )

6.X.2 Functional Description

When a UE detects it is operating as MUSIM UE (i.e. it has active registrations with >1 USIM) , it provides indication to the PLMNs it registered with that it is a MUSIM UE.

The indication may be based on inclusion in the registration request. Attach or TAU or service request messages of MUSIM Assistance Information.

If the UE becomes single USIM because only one registered USIM is left, when the UE registers with this USIM again in the related PLMN but it does not provide any indication it is MUSIM UE (i.e. it does not include any assistance information). This registration may not need to wait for the next periodic or mobility related registration trigger.

When the AMF or MME receive assistance information, they store it in the UE context.

When some of the information is relevant for RRC Inactive state, then the assistance information may be provided to the RAN in PLMNs that support RRC-INACTIVE, when the UE context is configured in the RAN.

The assistance information may include:

1. indication of the number or USIMs so the network may tune its paging strategy as it may e.g. modify the number of paging attempts based on its own policies. It may include indications of periodicity for UE reachability also (e.g. in terms of DRX cycles, or in terms of time period starting from a certain n absolute time, to be resynched periodically to compensate for relative clock drift between the UE and the network).
2. Indication of a Replacement UE\_ID for paging or any other information RAN WGs may decide is relevant to modify the timing for PF/PO to avoid overlapping POs across USIMs. If this is a Replacement UE\_ID, this is used in the RAN to compute the PF and PO for the UE. The page message itself is still related to the UE\_ID the UE has obtained from the CN, but the Replacement ID is just used for paging PF/PO computation. Then there are no overlapping PF/PO across USIMs, then this information is not present. When the UE has provided a Replacement PF/PO, this is kept until this would create an overlapping PF/PO for the USIM, in which case the UE updates the network by e.g. omitting the information or by suggesting an alternate Replacement UE\_ID. This Replacement UE\_ID is passed to the RAN in the N2 Paging message for Idle mode, or to the RAN in the UE Context for storage when the UE is RRC-Inactive.
3. Paging Filtering rules, e.g. a whitelist or blacklist of classes of MT service the UE is respectively ready or not ready to accept for the USIM. This information may be updated by a further registration message when the UE needs not such filtering, or user settings or preferences change. This filter is passed to the RAN for the UE in RRC inactive state, and the filtering is based on classification performed at the UPF for user plane. MT control plane filtering is done in AMF if the rules include filtering of MT/ control plane services. When MT control plane services filtering is set in the Assistance Information, then the RAN notifies the AMF when the UE enters RRC inactive state. If the UE intends to temporarily stop paging on a USIM it sends the Paging filtering information in assistance information with an empty whitelist or a match all blacklist. If the MUSIM assistance information has no filtering rules, then the UE is paged for all services.
4. The UE may, upon receiving a paging message, respond with a Service Request message including in RRC and NAS layer a "stop paging" indication that causes the RAN and the CN to stop paging. The CN stops paging the UE by including in the stored MUSIM assistance information in the AMF or MME a filter that causes the UE to not be paged again (see bullet 3). The UE can lift this state by providing assistance information to the CN by a registration message that allows the UE to be paged again at least for certain MT Services
5. The paging filtering may reuse the PPD mechanism:   
     
   - In CM-IDLE, when the DL data comes, the UPF sends the DSCP in TOS of IP header towards the SMF and SMF will determine whether to send notification to AMF. If so, the SMF includes the PPI, the ARP and the 5QI of the corresponding QoS Flow, and the indication indicating the DL data matches the Paging filtering rule, in the N11 message sent to the AMF. If the UE is in CM IDLE the AMF determines if the paging needs to be sent to UE based on PPI.  
   - In case of RRC-Inactive state, when the DL data comes and the N3 tunnel is active, the UPF adds the DSCP value in DL PDU and RAN decides whether to page the UE based on the Paging filtering rule for PPD

6.X.3 Procedures

#### 6.X.3.1 Providing MUSIM assistance information to the CN

This procedure in figure 6.x.3.1-1 is described using the 5GS but it equally applies to EPS.

The UE provides the MUSIM assistance information in registration procedure and a supporting network acknowledges the reception of the MUSIM assistance information. Figure 6.x.3.1-1 describes in a very high-level manner the procedure. This procedure can be executed at any time whenever the UE needs to update the network with relevant MUSIM Assistance Information. If the UE is RRC connected with the other USIM in the same or another PLMN, this message procedure first requires creating a long enough gap in the RAN serving the other USIM.



Figure 6.x.3.1-1: Providing MUSIMG assistance information to a PLMN in Registration messages

1. The UE includes MUSIM Assistance Information in a Registration Request Message for one USIM.
2. The AMF takes action based on the MUSIM assistance information and stores it in the UE context. The AMF may later provide to the RAN the assistance information relevant to the RAN by N2 message. The RAN stores Assistance Information that applies and retains it when the UE moves to RRC inactive. The AMF may pass some paging filtering rules to the SMF(s) so it can refrain from triggering paging the UE for certain service classes when the UE is CM-IDLE towards the AMF. Whether the paging filters are then also passed to the UPF for the relevant PDU sessions is FFS.
3. The AMF acknowledges support of MUSIM assistance information.

#### 6.X.3.2 Stopping paging on one PLMN

Figure 6.x.3.2-2 shows the UE can request the RAN and CN to stop paging upon receiving a paging message by responding with a SR that includes a stop paging indication. This indication to stop paging install a match all paging filter in the UE context in AMF and SMF that blocks DL paging. To lift this condition the UE must update the MUSIM Assistance Information by a registration procedure (see 6.x.3.1). If the UE is RRC connected with the other USIM in the same or another PLMN, this message procedure first requires creating a long enough gap in the RAN serving the other USIM, or, alternately, use a similar stop paging message in the PLMN serving the other USIM



Figure 6.x.3.2-2: UE cause the network to stop paging

Note that the RAN immediately releases the connection when it receives the Stop Paging indication in RRC MSG 5. The AMF does not establish any user plane when the MUSIM assistance Information includes Stop Paging indication.

A PLMN may also be provisioned with a timer that lifts the effects of a stop paging indication, or the UE can provide a UE specific timer if this is used to indicate the intention of the UE to return within the specific time. The UE may also indicate a periodicity for stopping paging and resuming paging.

### 6.X.3.3 Paging procedure when the UE is in CM-IDLE



**Figure 3 Paging White List based paging delivery in CM-IDLE state**

Step 1: Downlink data arrives for the UE.

Step 2-3: UPF informs SMF and SMF forwards to AMF with the information related to the DL packet, such as existing parameter, ( PPI, ARP, 5QI), and If needed, new information (e.g. DSCP) which is used to match the filtering rule in AMF.

Step-4a: If the paging is determined, AMF and RAN sends paging to UE as existing mechanism;

Step-4b: If the UE is simultaneously registered over 3GPP and non-3GPP accesses in the same PLMN, and the DL data is for the non-3GPP access and UE is in CM-CONNECTED state for non-3GPP access and in CM-IDLE for 3GPP access, the AMF may decide to send the NAS Notification message containing the 3GPP Access Type to the UE over non-3GPP access

Step-5: When receiving the paging, UE will establish the RRC Connection and initiate the Service Request procedure as existing mechanism does.

### 6.X.3.4 Procedure for paging in RRC inactive



Figure x Paging White List based paging delivery in CM-IDLE state

1. NG-RAN receives the DL data in RRC\_Inactive mode. NG-RAN determines in this case to send the paging based on the Paging White List and information (e.g. by matching the DSCP added by UPF in GTP-U header).

2. NG-RAN pages the UE in the RNA

### 6.X.3.5 Coordinated leaving using the MUSIM assistance information

MUSIM Assistance Info is also proposed to the network to resolve KI#3 as per the following description.



Figure 6.X.3.5-1 UE leaving from USIM-1 PLMN

When UE determines to leaves to from USMI-1 to USIM-2’s network, it sends NAS (Service Request or registration message I step 1a) or AS (RRC Request in step 1b) message with MUSIM Assistance Info. Then AMF and RAN uses the MUSIM Assistance Info to determine whether to page the UE based on the filtering rules included in the Assistance Info and, importantly for KI#3, handle the reachability or connectivity of the UE in the PLMN (the Assistance info may also include information that drives the RRC connection release or suspension, a pattern according to which the UE may be reachable (e.g. in terms of DRX cycles mapped to SFN), or the time interval indicating absence and time of return, or periodicity of absence,

The UE may update the PLMN upon "return to the PLMN" using the following procedure



Figure 6.X.3.5-1 UE leaving from USIM-1 PLMN

The UE returns to the PLMN and in a service request or registration (step 1a) or RRC message (step 1b) provides MUSIM assistance information updating the presence pattern/time etc. in the PLMN. The UE then is connected or reachable according to the information in the MUSIM assistance information..

6.X.4 Impacts on existing entities and interfaces

UE: detection of #of active USIMs and support of the MUSIM Assistance Information and procedures as specified above

RAN: calculation of PF/PO based on MUSIM Assistance Information, paging filtering based on the filter provided in a MUSIM Assistance Information, support of Service request specific cause code indicating stop paging

MME/AMF: support of storing and resending MUSIM Assistance Information to the RAN. PF/PO calculation, provision of MUSIM Assistance Information, provision of filtering rules to the SMF.

SMF/UPF: classification in Classes of Service and filtering per UE according to the paging filters provided in the MUSIM Assistance Information, Classification and Marking in DL for UEs for which filtering applies in RRC inactive mode.

**End of PROPOSED CHANGES**