3GPP TSG-RAN WG2 Meeting #119-e R2-220xxxx

Online, August 17-29, 2022

Agenda Item: 8.4.2.1

Source: MediaTek Inc.

**Title: Report of [Post119-e][036][feMob] Time Chart**

Document for: Discussion and decision

# Introduction

In RAN2#119-e meeting, we discussed the latency and interruption of L1/L2-based inter-cell mobility objective of Rel-18 NR further mobility enhancement WI. Then we have the following post-meeting email discussion.

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| * [Post119-e][036][feMob] Agreements, time chart, LS out (MediaTek)

Scope: Capture WI agreements, Capture a mobility timing chart for L1L2 mobility, as a reference - include all pieces of procedures that may be optimized impacted FFS etc (acc to current agreements). LS out to RAN1 and RAN3 on the RAN2 progress, and ask to take into account.  Intended outcome: Endorsed Report or Stage-2 CR with appendix etc, Approved LS out Deadline: Short (Can start before the meeting has ended).  |

In this document, we discuss the timing chart for L1/L2-based inter-cell mobility. The concluded timing chart will be captured as a reference in a running stage-2 CR or a report.

Related assumptions in Chair’s note are copied below.

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| * Assumption: HO interruption time for L1/L2-based inter-cell mobility is the time from UE receives the cell switch command to UE performs the first DL/UL reception/transmission on the indicated beam of the target cell. FFS if TRS tracking after HO and CSI RS measurement should also be included, i.e. the time to use a high-performance beam (can be clarified further).
* Assumption: To reduce HO interruption time, investigate e.g. solutions to reduce the time for UE reconfiguration (already in the WID), downlink and uplink synchronization after handover decision (other parts of dynamic switch not precluded).
* R2 assumes that L2 is continued whenever possible (e.g. intra-DU), without Reset, with the target to avoid data loss, and the additional delay of data recovery.
* Measurement delay can/may be considered in this work
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# Discussion

Based on procedure and latency analyses in companies’ contributions and online discussions, Rapporteur prepares the following time chart model, in an attempt to include components of mobility latency mentioned by companies. Notice that we do not intend to define any kind of delay requirements in RAN2; the purpose of this discussion is to have a reference model about the components that contribute to mobility latency, based on which we can study enhancements for mobility latency reduction.

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**Figure 1. Components of mobility latency for L1/L2-based inter-cell mobility (before enhancement)**

The meaning of components is shown below.

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| **Component** | **Meaning** | **Value** |
| TRRC | Processing time for *RRCReconfiguration* carrying candidate configurations | Up to Xms |
| Tprocessing,1 /Tprocessing,2 | Time for UE processing, before and after cell switch command, respectively. This may include L2/3 reconfiguration, RF retuning, baseband retuning, security update if needed, etc. | Up to Yms |
| Tmeas | The time UE measures target cell (from target appears to cell switch command) |  |
| Tcmd | Time for processing L1/L2-command (HARQ and parsing) | Up to Zms |
| Tsearch | Time required to search the target cell | 0ms (if cell is known)Up to 15ms (if cell is unknown) |
| TΔ | Time for fine tracking and acquiring full timing information | SMTC periodicity (typ. 20ms) |
| Tmargin | Time for SSB post-processing | Up to 2ms |
| TIU | interruption uncertainty in acquiring the first available PRACH occasion in the new cell | Typ. 15ms |
| TRAR | Time for RAR delay | Typ. 4ms |

Note: Tprocessing is divided into two parts if some processing can be done before cell switch command.

Definition of HO interruption

According to Chair’s note, HO interruption time for L1/L2-based inter-cell mobility is the time from UE receives the cell switch command to UE performs the first DL/UL reception/transmission on the indicated beam of the target cell. This is similar to the definitions used in previous works (e.g., TR 36.881 and Rel-16 DAPS). However, there is also an FFS: if TRS tracking after HO and CSI RS measurement should also be included, i.e., the time to use a high-performance beam. We first invite companies to comment on this FFS.

**Q1: Should the time to use a high-performance beam be included in HO interruption time model?**

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| **Company** | **Yes/No** | **Comments** |
| **Huawei, HiSilicon** | **FFS** | The intention of this email seems not to conclude the FFS part. Maybe we can just capture it as FFS and further update if needed in future meetings. |
| **Xiaomi** | **Yes** | Many companies are proposing the solution of avoiding RACH to the target cell. If the RACH is not used, the UE would anyway require the TCI switching time in order to switch to the target cell. We see no strong motivation of considering the TCI switching delay after the RACH, since the RACH procedure will provide a proper DL beam to the UE. |
| **MediaTek** | **See comments** | Our understanding is that with L1/L2 mobility, L1 measurement and tracking of RS corresponding to the target beam should be done before the cell switch command. Then if UE is to use a CSI-RS (high performance) beam, the CSI-RS measurement is covered in Tmeas, and TRS tracking /post-processing can be covered in TΔ and Tmargin. The exactly naming and value should be discussed in RAN4. From RAN2 perspective, our point is that we do not need to have separate components for SSB and CSI-RS measurement/tracking. |
| **vivo** | **Yes** | UE cannot perform data transmission/reception well based on the default QCL associated with default SSB after HO is completed. In our view, the real purpose of this WID is to reduce the data reception/transmission latency due to mobility. Hence, we think the TRS tracking after HO and CSI RS measurement should also be included in HO interruption time model.Besides, in Rel-17, ICBM was introduced to achieve high data rate via fast beam switching without serving cell change, i.e. UE can use a high-performance beam from an additional PCI. With L1/2 mobility, fast beam switching would be extended to inter-cell mobility scenarios. Obviously, before high-performance beam of target cell was applied, high data rate transmission, i.e. the main target for L1/2 mobility, cannot be achieved. Therefore, in our understanding, the L1/2 mobility is not really completed before UE starts using the high-performance beam of target cell. Hence, TRS tracking after HO and CSI RS measurement should also be included in HO interruption time model. |
| **Futurewei** | **No** | It appears current definition of HO service interruption is simple and clear. For service interruption, we really care when the first message will be received after HO. |
| **Intel** | **No** | This could be considered as a part of latency model, but not interruption time.In our view, the L1/L2 inter-cell mobility is the continuation of Rel-17 FeMIMO, and the unified TCI state associated to an additional PCI should be used before UE receives the Cell Switch Command. In this case, the latency for TCI-state switch, i.e., the application of a high-performance beam, is also a part of L1/L2 mobility latency that needs to be addressed in this WI. But this is not counted as interruption time, because the data transmission/reception has already been recovered before that. |
| **LGE** | **FFS** | Agree with HW. |
| **Apple** | **FFS** | Same view as Huawei. |
| **CATT** |  | Agree with the intention to use a high-performance beam on target cell as early as possible. We think the related enhancements can be first discussed in RAN1, and RAN2 may discuss their potential impact based on RAN1 output.  |
| **OPPO** | **No** | We understand the TRS tracking after HO is not a part of HO interruption time.Fine time tracking based on SSB is already considered as a component in current HO interruption time model, i.e. TΔ, after which UE is able to communicate with NW relying on SSB measurement. And if we rely on R17 ICBM to implement L1/L2 inter-cell mobility, inter-cell L1 measurement as well as inter-cell beam indication are finished before/upon HO command reception, which will not impact the HO interruption. For the high-performance beam indicated by inter-cell TCI state indication, it refers to an SSB of non-serving cell due to the restriction that UE can only support L1-RSRP measurement on SSBs of PCIs different from serving cell in R17 ICBM.  |

The term “UE processing” considers the steps to configure the UE for target cell, such as L2/3 reconfiguration, RF retuning, baseband retuning, security update, etc. The exact steps may depend on the scenario (intra- vs. inter-frequency, intra- vs. inter-DU), as analyzed in [5]. We now discuss the details of UE processing time.

**Q2: What steps are included in the time for UE processing? Please consider different scenarios.**

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| **Company** | **Comments** |
| **Huawei, HiSilicon** | ASN.1 decoding and validity checking (in existing T38.331, TRRC only includes processing of the configuration to be applied immediately, e.g. in CHO, the UE is not required to decode and do validity checking within TRRC), L2/3 reconfiguration, baseband retuning, RF retuning |
| **Xiaomi** | We think that this “UE processing” is the same as Tprocessing defined in RAN4 TS 38.133. |
| **MediaTek** | L2/3 reconfigurations, baseband retuning, RF retuning. ASN.1 decoding and validity checking can also be considered if we mandate UE to do that right after receiving candidate configurations. |
| **vivo** | For all the scenarios, the time for UE processing includes ASN.1 decoding and validity checking, the L2/3 reconfiguration, and baseband retuning. In addition, the time for UE processing also includes RF retuning for inter-freq scenarios. |
| **Futurewei** | We agree UE processing including configuration process and UE frequency operations. |
| **Intel** | The UE processing time includes L2/3 reconfiguration, RF retuning, baseband retuning, security update. And the L2/3 reconfiguration includes reconfiguration of L2 protocol stacks, and potential PDCP re-establishment/recovery, RLC re-establishment, and MAC reset.Considering different scenarios:1. in intra-CU handover case, PDCP configuration including security algorithm and security key can be unchanged, and hence, PDCP re-establishment is not needed.
2. in intra-CU inter-DU handover case, it may be necessary to reconfigure RLC and MAC entities due to different DU entities, and hence, RLC re-establishment and MAC reset are needed.
3. in intra-DU handover case, RLC and MAC configurations can remain, and hence, RLC re-establishment is not needed. Partial MAC reset (for features related to PHY measurements on target cell) may be still needed.
4. baseband retuning is needed in any case, as UE needs apply new PHY layer configuration including target cell PCI and new C-RNTI for RS sequence generation and scrambling in PHY layer.
5. RF retuning is needed for inter-freq cell change.
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| **LGE** | L2 reset, AS security update, and baseband/RF retuning.L2 reset and/or AS security update may be skipped in intra-DU L1L2 inter-cell mobility. Hence, RAN2 can consider L2 reconfiguration and security as major components of UE processing for optimizing L1L2 mobility.Since baseband retuning is an inevitable step for a UE when executing L1L2 mobility, it seems to be inherent in L1L2 mobility. So, baseband retuning may not be a component for optimizing L1L2 mobility.RF retuning is necessary for a UE upon executing inter-frequency L1L2 mobility. But we don’t think that optimizing RF retuning for L1L2 mobility is a RAN2 work. |
| **Apple** | We agree with comments from the above companies on the UE processing: L2 reset, AS security update, and baseband/RF retuning, and even before all of that, the ASN.1 decoding, validity checking and configuration. But we are wondering where this UE processing is to be applied/used/defined. The picture above does not capture this. In our view, it is better to first see how we place this ‘UE processing’ to actually define what it includes. |
| **CATT** | In general “UE processing” includes RF/baseband retuning, L2/3 reconfiguration( no security key change). But we think ASN.1 decoding is another general issue that is not limited to the scope of this WI.Besides, maybe it can also include the L1 measurement configuration decoding and applying.For intra-DU case,(assuming that L2 configurations are same between source cell and target cell, but physical configurations can be different between cells, so the UE processing includes,* Physical layer reconfiguration: RF retuning, baseband retuning

For intra-CU inter-DU case, (assuming that L2 configurations and physical configurations can be different between cells), * L2 reconfiguration(i.e. MAC reset, RLC reestablishment, PDCP data recovery),
* Physical layer reconfiguration: RF retuning, baseband retuning
 |
| **OPPO** | For L1/L2 mobility, UE processing includes compliance check, L2 reconfiguration, RF retuning, baseband retuning.L2 protocol handling is different for inter-DU and intra-DU case, i.e. for intra-DU case, L2 reset/reconfiguration can be omitted, while MAC reset and RLC re-establishment and PDCP data recovery are required for inter-DU case. RF retuning is required for inter-frequency scenario. And baseband retuning may be related to PHY resources/configurations. |

In legacy handover delay requirements, the time for UE processing (Tprocessing) is considered after receiving handover command (see e.g., Clause 6.1.1 in TS 38.133). For L1/L2-based inter-cell mobility, we see some different views. For example, it is mentioned in [16] that UE may process and apply the configuration(s) for candidate target cells for L1/L2 based inter-cell mobility right away when this as received. In other words, UE processing in L1/L2-based inter-cell mobility may be done (partially) before or after cell switch command. To address this, in Figure 1, we divide the “Tprocessing” into “Tprocessing,1” and “Tprocessing,2”, capturing UE processing before and after cell switch command, respectively.

We now discuss how to model UE processing time in L1/L2-based mobility latency model. We see three options:

* Option 1: UE processing happens after cell switch command, and is considered as a part of the interruption
* Option 2: UE processing happens both before and after cell switch command, and only the latter part is considered as a part of the interruption
* Option 3: UE processing happens before cell switch command, and is NOT considered as a part of the interruption

If Option 2 is preferred, we should also discuss which parts are done after cell switch command (i.e., included in handover interruption)

**Q3: How should UE processing be modelled in L1/L2-based inter-cell mobility latency analysis? If Option 2 is preferred, please indicate which steps are done after cell switch command.**

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| **Company** | **Option** | **Comments** |
| **Huawei, HiSilicon** | Option2 | We assume RRC ASN.1 decoding and validity check of the pre-configuration shall be before L1/L2 HO CMD, in order to reduce the interruption time. We expect this to be the dominant component of UE processing delay.Applying parameters is after the L1/L2 HO CMD. |
| **Xiaomi** | Option 1 | We think that “Tprocessing” as defined in RAN4 is for the RF retuning, which is difficult to be performed before the reception of the L1/L2 cell switching command, because the UE may only use single RF chain while switching from once cell to another. If companies consider to reduce the “Tprocessing”, we may need to ask RAN4 to evaluate the feasibility. |
| **MediaTek** | Option 2 | UE can actually do beyond RRC ASN.1 decoding and validity check before cell switch command if UE’s hardware/software supports that. For example, UE can configure RLC/MAC/PHY for candidate CG if it has two protocol stacks. |
| **vivo** | Option 2 | We think the configuration of the candidate cell should be provided to UE before cell switch command, and should not be considered as HO interruption time. Other procedure such as applying the configuration of target cell, L2/3 reconfiguration, RF retuning, baseband retuning, TRS tracking and CSI RS measurement should be either performed before or after cell switch command, but only the later part of these procedures account for HO interruption time. |
| **Futurewei** | Option 2 | We think option 2 is reasonable. |
| **Intel** | Option 2 | UE applies the configuration of candidate cells only after it receives cell switch command. The RRC ASN.1 decoding and validity check of the pre-configuration could be done before cell switch command. |
| **LGE** | Option2 | We assume that UE applies the pre-configured target cell configuration corresponding to the target cell ID upon receiving a cell switch command, which means that the latency caused by decoding and validity check of the pre-configuration is included in Tprocessing,1.L2 reset and AS security update may occur when applying the preconfiguration. So, Tprocessing,2 includes the latency caused by L2 reset and AS security update. |
| **Apple** | Option 1 is preferred | We do not want the UE to process the RRC configuration with the intention to be applied in the future… is there a guarantee that NW does not provide any other RRC message between this and potentially a L2/L1 switch later…? We cannot restrict the NW to always follow the RRC message with a L2/L1 switch. In many ways, this is similar to CHO, only that NW triggers when the UE should apply (instead of UE doing it). UE preprocssing the RRC message leads to delta config issues, in case there is another RRC message.Also, we will not be able to implement conditional L2/L1 mobility if the UE processes the RRC message earlier… we should allow multiple potential L2/L1 canddiate cells for the UE to check and perform a CHO like L2/L1 mobility. It would be inefficient if RAN2 designs L2/L1 mobility where L3 based CHO is already present, but L2/L1 based CHO is not!!! |
| **CATT** | Option 2 | For some of the candidate cell configuration (e.g. L1 measurement configuration for the candidate cells if it is included in the candidate cell configuration), it can be applied before cell switch command.For the configuration of target cell (e.g. L2 reconfiguration (including MAC reset, RLC reestablishment), RF retuning, baseband retuning on target cell), it should be applied after cell switch command. |
| **OPPO** | See comments | It depends on whether UE performs compliance check before HO command reception.We think legacy way as in CHO can be followed, i.e. it is up to UE implementation whether compliance check is performed upon the reception of candidate configurations for L1/L2 mobility. Therefore, we slightly prefer not to specify any behaviors which might be left to UE implementation in this interruption time model.  |

Measurement delay

Chair’s note mentions that measurement delay may also be considered in this work. Rapporteur’s understanding (based on e.g., [10]) is that measurement delay means the time it takes for UE to perform measurement and reporting to trigger cell switch after a better cell (target) appears. Since it is before the cell switch command, it may not be a part of HO interruption, but it does contribute to the overall latency for UE to access a better cell.

**Q4: How should measurement delay be considered in the illustration for components of mobility latency?**

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| **Company** | **Comments** |
| **Huawei, HiSilicon** | We could distinguish the following components- Time between "target cell appears" and "UE measures the target cell"- Time between "UE measures the target cell" and "UE reports the measurement"- Time between "UE reports the measurement "and "UE receives the L1/L2 handover command"We could add these steps on the figure. |
| **Xiaomi** | We agree with the Rapporteur that the measurement delay does contribute to the overall latency required for accessing the target cell, and we are open for solutions reducing such latency. However, while providing the analysis for interruption, we think that we could focus on the user plane interruption time, which does not include the measurement delay,. |
| **MediaTek** | Different kinds/parts of measurement delay may be shown in the illustration. But we need not to count measurement delay in any kind of formula for mobility latency, since the value varies a lot. The main purpose is to show that a too long measurement period may delay UE’s access towards a better cell. |
| **vivo** | We agree with rapporteur that measurement is not part of HO interruption. But we are open to discuss solutions to reduce the delay for measurement and reporting.  |
| **Futurewei** | We agree with rapporteur that measurement delay does not contribute to service interruption due to HO. But it is part of the overall HO latency from the mobility (source/target) condition change to the cell switch completion. In high UE speed, high frequency, small cell coverage scenarios, more responsive mobility mechanism is required to handle fast mobility condition changes. In those scenarios, long measurement delay will cause high HFR. So cell switch based on L1 measurement is a right decision. The measurement delay illustrated in Figure 1 looks fine. The overall HO latency has to be short enough to allow our targeted minimum ToS of the target (consider target appears 🡪 target disappears). Need some more discussion.  |
| **Intel** | As mentioned in RAN2 agreement, the start point of the whole latency is the time from UE receives the cell switch command. So we don’t think measurement delay is part of mobility latency. But we are open to discuss how to make measurements more efficient for L1/L2 mobility. |
| **LGE** | We agree with MediaTek’s comments.We think either L1 measurement reporting (MR) or L3 MR triggers L1L2 mobility. Which MR will trigger L1L2 mobility depends on the network implementation.Especially for L1 MR based L1L2 mobility, L1 MR needs to be enhanced for reporting an L1 measurement of a candidate cell. It is described in WID as the following RAN1-led objective:* L1 enhancements for inter-cell beam management, including L1 measurement and reporting, and beam indication [RAN1, RAN2]

Before discussing L1 MR based L1L2 mobility, we need to wait for RAN1 progress for the above objective.RAN2 first focus on RAN2-centric work e.g. investigate whether L3 MR is sufficient for L1L2 mobility or not. |
| **Apple** | Measurement related aspects/delays are important, but they do not need to be part of handover interruption chart. |
| **CATT** | Agree with Rapporteur’s understanding. Measurement delay does not cause interruption.So it seems not critical whether measurement delay is illustrated in the timing chart or not. Anyway RAN1/RAN2 will work on L1 measurement enhancement. |
| **OPPO** | Agree with MediaTek. Measurement delay does contribute to L1/L2 mobility latency but we see no need to conclude it as HO interruption time. |

Finally, we’d like to know if the example analysis of components for mobility latency is agreeable, or any modification is needed.

**Q5: Any suggestions for the analysis of components for mobility latency**

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| **Company** | **Comments** |
| **Intel** | Since the end time of the latency model is the time when UE performs the first DL/UL reception/transmission on the indicated beam of the target cell, the last step should be transmission of MSG3 or the time instant when CSI-RS beam takes effect, but not just reception of RAR. As RAR still uses SSB beam, but not CSI-RS beam which we think is the “indicated beam”. |
| **Apple** | We do NOT agree to putting values to the interruption chart (for eg 5ms/10 ms etc) without actual discussion/agreement. For number we could just add variable names, and add values to it after discussions.  |

# Conclusion

It is proposed to discuss and decide on the following proposals:

# Reference

1. R2-2206982 Target Performance Enhancements for L1L2-based Inter-cell Mobility MediaTek Inc. discussion
2. R2-2206992 On the Target Performance Enhancements for L1L2 based Mobility CATT discussion Rel-18 NR\_mob\_enh2-Core
3. R2-2207315 NR mobility issues and goals for improvement Futurewei discussion Rel-18 NR\_mob\_enh2-Core
4. R2-2207340 L1/L2 Mobility – General Concepts and Configuration Qualcomm Incorporated discussion Rel-18
5. R2-2207380 Discussion on latency model of L1 L2 mobility Intel Corporation discussion Rel-18 NR\_mob\_enh2-Core
6. R2-2207407 Consideration on L1/L2 signalling based mobility Fujitsu discussion Rel-18 NR\_mob\_enh2-Core
7. R2-2207466 Latency reduction aspects of L2/L1 mobility Apple discussion Rel-18 NR\_mob\_enh2-Core
8. R2-2207496 Target scenario and latency reduction in L1/L2 based mobility NEC discussion Rel-18 NR\_mob\_enh2-Core
9. R2-2207537 Discussion on Dynamic switch mechanism among candidate serving cells KDDI Corporation discussion
10. R2-2207637 L1/L2 mobility target performance enhancements Huawei, HiSilicon discussion Rel-18 NR\_mob\_enh2-Core
11. R2-2207655 Analysis of HO latency and possible enhancements for L1/L2 mobility OPPO discussion Rel-18 NR\_mob\_enh2-Core
12. R2-2207752 Discussion on basic model for L1 L2 mobility vivo discussion Rel-18 NR\_mob\_enh2-Core
13. R2-2207806 Latency Evaluation of L1 or L2 based mobility Xiaomi discussion Rel-18 NR\_mob\_enh2-Core
14. R2-2207857 Initial discussion of L1/L2 mobility Sharp discussion Rel-18 NR\_mob\_enh2-Core
15. R2-2208185 Target enhancements and latency model for L1/2 triggered handover Interdigital, Inc. discussion Rel-18 NR\_mob\_enh2-Core
16. R2-2208200 Latency analysis for L1/L2 based inter-cell mobility Ericsson discussion Rel-18 NR\_mob\_enh2-Core
17. R2-2208212 Prerequisites and benefits of Lower Layer Mobility Nokia, Nokia Shanghai Bell discussion Rel-18 NR\_mob\_enh2-Core
18. R2-2208213 Basic details of Lower Layer L1/L2 Mobility Nokia, Nokia Shanghai Bell discussion Rel-18 NR\_mob\_enh2-Core
19. R2-2208367 Discussion on L1 L2 mobility performance enhancement ASUSTeK discussion Rel-16 NR\_mob\_enh2-Core
20. R2-2208455 Initial considerations on L1L2 mobility CMCC discussion Rel-18 NR\_mob\_enh2-Core
21. R2-2208522 L1/L2 mobility scenarios and latency LG Electronics discussion Rel-18
22. R2-2208528 Scenario and Target Performance Enhancements for L1/L2 mobility Samsung discussion NR\_mob\_enh2-Core
23. R2-2208559 Initial Consideration on L1-L2 Signaling Based Mobility ZTE Corporation,Sanechips discussion Rel-18 NR\_mob\_enh2-Core