**3GPP TSG RAN WG1 email discussion [5G-ACIA]**

**E-meeting, August 17–28, 2020**

**Source: Huawei, HiSilicon**

**Title: Discussion on URLLC and IIoT features for performance evaluation in response to 5G-ACIA**

**Document for: Discussion and Decision**

# Introduction

In the TSG-RAN#88e plenary meeting, the scope of the WID on enhanced Industrial Internet of Things (IoT) and URLLC support was revised and one LS was sent from the 5G-ACIA (Alliance for Connected Industries and Automation) organization to 3GPP RAN and RAN1 on NR Rel-16 URLLC and IIoT performance evaluation. Specifically, the LS asks 3GPP RAN and RAN1 to perform similar SLSs as described in TR 38.824 by employing Rel-16 eURLLC/IIoT features for industry use cases in TS 22.104, considering the refined simulation assumptions compared to the simulation assumptions captured in technical report (TR) 38.824 for NR Rel-16 URLLC study item (SI).

The refined simulation assumptions at least include the new channel model defined for indoor factory scenario in NR Rel-16 [4], use of survival time and some other updated parameters if necessary.

In the TSG-RAN#89e plenary meeting, the following was agreed:

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| proposal: - Start an offline email-based activity to provide evaluation results for 5G-ACIA - One company volunteers as moderator  - Proposes a work plan to follow - Ericsson is willing do this - Discussions are on the RAN1\_NR reflector  - Email activity only during short periods (< week) distributed across the time allocated to the activity  - No email activity in weeks before/during/after RAN1 meetings or RAN defined inactive periods - All companies should strive to limit email activity as much as possible - Outcome of the offline discussion will directly go to RAN without need for discussion in RAN1 nor need for LS  from RAN1 to RAN - Target completion by RAN#91 - At RAN#91, RAN will decide on a response LS to 5G-ACIA |

Generally, we think that it is meaningful to consider more realistic scenarios (e.g., the new channel model, survival time, etc.) proposed by 5G-ACIA for further performance evaluations, in order to provide more reference values to players in the vertical industry, especially in the IIoT area.

In this document we give our view on the URLLC features to be included in the evaluation according to first stage of the email discussion:

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| 1. 12-16 October 2020
	* Discussion on which URLLC features to include in the evaluations and simulation assumptions
2. 14-18 December 2020
	* First round of simulation results
3. 22-26 February 2021
	* Second round of simulation results
4. 8-12 March 2021
	* Finalization of the report to RAN#91
 |

In order to define the URLLC features that shall be evaluated it is important to have a clear understanding of the underlying scenario with its requirements and simulation assumptions. These aspects are discussed firstly in the following section before the URLLC features that shall be included in the evaluation are proposed.

# Simulated scenario, requirements and performance metric

**Scenario:**

The use case of *motion control* is requested for performance evaluation in the LS, in which also a typical deployment option is described. This scenario is copied in Figure 1 below for easy reference. In this deployment, the controller/master is connected to the base station with a wire, while the sensors/actuators are connected to the base station wirelessly. That is, the sensors/actuators can be treated as 5G UEs and only the wireless links between base station and these 5G UEs are concerned.



Figure 1 - 5G deployment option with L2 connectivity-based motion control in one production domain [2]

**Requirements and performance metric:**

The requirements of motion control are presented in TS 22.104 in [5] and they are also included in the LS from 5G-ACIA [2]. Three use cases are listed and the corresponding requirements which are copied below for easy reference. Note that the second use case, which is marked in yellow and denoted UC#2 should be prioritized for performance evaluation.

Table 1 - Service performance requirements for motion control (Table 5.2-1, TS 22.104 [5])

| Characteristic parameter | Influence quantity |
| --- | --- |
| Communica­tion service availability: target value (note 1) | Communication service reliability: mean time between failures | End-to-end latency: maximum (note 2) (note 12a) | Service bit rate: user experienced data rate (note 12a) | Message size [byte] (note 12a) | Transfer interval: target value (note 12a) | Survival time (note 12a) | UE speed (note 13) | # of UEs | Service area (note 3) |
| 99,999 % to 99,99999 % | ~ 10 years | < transfer interval value | – | 50 | 500 μs  | 500 μs | ≤ 75 km/h | ≤ 20 | 50 m x 10 m x 10 m |
| 99,9999 % to 99,999999 % | ~ 10 years | < transfer interval value | – | 40 | 1 ms  | 1 ms | ≤ 75 km/h | ≤ 50 | 50 m x 10 m x 10 m |
| 99,9999 % to 99,999999 % | ~ 10 years | < transfer interval value | – | 20 | 2 ms  | 2 ms | ≤ 75 km/h | ≤ 100 | 50 m x 10 m x 10 m |
| NOTE 1: One or more retransmissions of network layer packets may take place in order to satisfy the communication service availability requirement.NOTE 2: Unless otherwise specified, all communication includes 1 wireless link (UE to network node or network node to UE) rather than two wireless links (UE to UE).NOTE 3: Length x width (x height).NOTE 12: Maximum straight-line distance between UEs. NOTE 12a: It applies to both UL and DL unless stated otherwise.NOTE 13: It applies to both linear movement and rotation unless stated otherwise.  |

The performance metric proposed by 5G-ACIA is different from that adopted in 3GPP TR 38.824. In TR 38.824, *a UE is said to satisfy the requirements if the target reliability is achieved within a given E2E latency budget*. The corresponding E2E latency is 2 ms and the corresponding target reliability is 99.9999%. With respect to the detailed simulation, the E2E latency is divided into two parts, the latency of the core network (CN) and the latency of the air interface. The evaluation in 3GPP TR 38.824 only considers the performance of the air interface, and 1 ms latency (out of the whole 2 ms E2E latency) is considered to be available for data transmission in the air interface. Furthermore, although the target reliability defined in TS 22.104 is the reliability of a logical link, how to derive the reliability requirement of the air interface link from this target reliability has not been discussed in 3GPP, and for simplicity, it is assumed that the target reliability of the air interface link is equal to the target reliability of the logical link. As a result, in the simulations, a large number of packets for delivery are generated for each UE in both downlink and uplink. And for each transmission link of each UE, one records the number of packets which can be successfully transmitted/received within 1 ms latency and computes the reliability as the ratio between the number of successful packets (as N1) and the number of total generated packets (as N2), i.e., N1/N2.

However, in 5G-ACIA, *a UE is said to satisfy the requirements if the communication service availability (CSA) is achieved within a given E2E latency budget*. A key parameter related to the CSA computation is the survival time, and the formula for CSA computation is provided in the LS [2], which is copied below for easy reference.

$CSA=1-\sum\_{n=2}^{\infty }P\_{E}\left(n\right)\frac{nT\_{I}-T\_{S}}{nT\_{I}}$ (1)

where $T\_{I} $and $T\_{S}$ are the duration of one transfer interval (TI) and the duration of survival time window, and $P\_{E}\left(n\right)$ defines the probability of occurrence of exactly *n* consecutive message/TB reception errors, assuming $T\_{S}\geq T\_{I}$ . With respect to the use case of motion control for performance evaluation, $T\_{S}=T\_{I}$ is assumed as shown in Table 1 in the LS [2]. Similar to the simulation in 3GPP, one can assume that for each message/TB delivery, a half of the E2E latency (i.e., the transfer interval) is available for the transmission in the air interface and only the packet reliability of the air interface is considered during the computation of $P\_{E}\left(n\right)$.

***Proposal 1: Adopt the scenario that is regarded by 5G-ACIA as the prioritized use case as the baseline for the evaluation, i.e.:***

| Communica­tion service availability: target value (note 1) | Communication service reliability: mean time between failures | End-to-end latency: maximum (note 2) (note 12a) | Service bit rate: user experienced data rate (note 12a) | Message size [byte] (note 12a) | Transfer interval: target value (note 12a) | Survival time (note 12a) | UE speed (note 13) | # of UEs | Service area (note 3) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 99,9999 % to 99,999999 % | ~ 10 years | < transfer interval value | – | 40 | 1 ms  | 1 ms | ≤ 75 km/h | ≤ 50 | 50 m x 10 m x 10 m |

***Proposal 2: For performance evaluation of motion control,***

* ***The latency budget of the air interface is a half of the E2E latency budget;***
* ***Only the reliability of air interface is considered during computing the packet error probability;***
* ***A UE is said to satisfy the requirements if the achieved CSA is no more than the target requirement.***
	+ - ***The CSA can e.g. be computed from (1),*** $CSA=1-\sum\_{n=2}^{\infty }P\_{E}\left(n\right)\frac{nT\_{I}-T\_{S}}{nT\_{I}}$

In 3GPP TR 38.824, *URLLC capacity* or *UE availability* are used as performance metric. Specifically, one can evaluate the maximum number of UEs in which case all UEs can be guaranteed to satisfy the reliability and latency requirements, or the percentage of UEs who satisfy the reliability and latency requirements. Also, the metric of resource utilization is provided by many companies to show the cost to carry the URLLC service. In comparison, four metrics from 5G-ACIA are needed for evaluation, including *the distribution of CSA of all UEs*, *the distribution of latency of all UEs*, *the percentage of UEs satisfying requirements* and *the resource utilization*. Obviously, the distributions of CSA and latency are related to the percentage of UEs satisfying requirements, but can provide more information to see the performance gap to the ideal result where all UEs satisfy the CSA and latency requirements.

***Observation 1: According to the LS from 5G-ACIA, the following four results are adopted as performance metric***

* ***The CDF of CSA distribution of all UEs;***
* ***The CDF of latency distribution of all UEs;***
* ***The percentage of UEs satisfying CSA and latency requirements;***
* ***The resource utilization.***

# Simulation assumptions

It should be assumed that the simulation assumptions shown in Table A.2.2-1 in TR 38.824 are taken as baseline for the evaluation. In addition, the LS from 5G-ACIA also provides suggestions on updating some of the parameters as shown in Table 2 below. For comparison, the corresponding assumptions that we used in Rel-16 eURLLC SI are also included in Table 2.

The most complicated assumption is the traffic model. Three options are provided from 5G-ACIA as shown in Table 2 below. The options are copied below for easy review.

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| * Opt1: All UEs’ DL messages arriving at NG-RAN node in the first transfer interval are uniformly randomly distributed within the TI time window.
* Opt2: All UEs’ DL messages arriving at NG-RAN node in the first transfer interval are in one burst.
* Opt3: All UEs in one service area are divided into several groups. DL messages of UEs in the same group will arrive at NG-RAN node in one burst with the following assumptions.
* Number of groups within a service area: 2.
* Number of UEs in a group: all groups have equal number of UEs.
* 3GPP can determine to use either a pre-defined value or a random value for the burst arrival time differences between different groups.
 |

The simulation of randomly distributed traffic across the UEs would impose a heavy load on RAN1 since it would require a huge simulation effort to be re-done. Also, in practical motion control, some actuators always work in a cooperative manner to accomplish one task, and the message for these actuators are always generated synchronously. Therefore, Opt3 is preferred for DL traffic modelling.

***Proposal 3: For the DL traffic model used in the evaluation, assume option 3, i.e. all UEs in one service area are divided into several groups. DL messages of UEs in the same group will arrive at NG-RAN node in one burst.***

* ***Number of groups within a service area: 2.***
* ***Number of UEs in a group: all groups have equal number of UEs.***
* ***3GPP can determine to use either a pre-defined value or a random value for the burst arrival time differences between different groups.***

For the DL-UL traffic arrival relationship, two options are provided by 5G-ACIA as shown below. Option 1 is to assume decoupled traffic arrival time instants whereas Option 2 defines a timing relationship between DL and UL traffic. These two options are both reasonable and suitable for different service logicalities. However, to reduce the simulation burden, it is our preference to adopt Option 1 for the evaluations.

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| * Option 1: DL and UL traffic arrival times are independent.
* Option 2: UL traffic arrives at some pre-defined time x, where x can be, e.g., half of the transfer interval, after the respective DL traffic arrival time.
 |

***Proposal 4: For the DL-UL traffic arrival time relationship, adopt Option 1, DL and UL traffic arrival time instants are independent.***

In Table 2 below, we have listed the simulation assumption proposed by 5G-ACIA that in our view should be adopted as the starting point for the evaluations. For easier comparison, we have also included the values used for the simulations in the TR.

***Proposal 5: For performance evaluation of motion control, take the simulation settings from “Value from 5G-ACIA” in Table 2 below as the starting point for the evaluation.***

Table 2 - Comparison of key simulation assumptions used in 3GPP TR 38.824 and proposed by 5G-ACIA

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Value from 5G-ACIA** | **Value used in TR 38.824** |
| **Service area** | 50m x 10m | NA |
| **Inter-BS/TRP distance & Layout** | Depending on the number of TRPs, which are evenly deployed in the factory hall. Simulation company should provide the number of BSs/TRPs used in the simulation. | ISD = 20 m, and layout is as follows.cid:image001.jpg@01D460C3.1788FD90 |
| **BS/TRP antenna height** | 1.5 m for InF-SL and InF-DL8 m for InF-SH and InF-DH. | 10 mNote: Other value (e.g. 3 m) is not precluded for evaluation |
| **Channel model** | UC #2 (Note 1): InF-DH > InD-DL > InF-SH > InF-SL (Note 2) | ITU InH for 4 GHzCompanies report the modification of the channel model |
| **E2E latency & air interface latency** | E2E latency: 1 ms for UC #2Air interface latency: NA | E2E latency: 2 msAir interface latency: 1 ms  |
| **Carrier frequency & duplexing model & Simulation bandwidth** | 4 GHz: 100 MHz, TDD30 GHz: 160 MHz, TDD | 4 GHz, 40 MHz, FDD & TDD30 GHz, 160 MHz, TDD |
| **TDD DL-UL configuration** | Simulation company should report the used DL-UL configuration.Due to symmetric DL/UL traffic, 1:1 DL-UL configuration is recommended. | Simulation company should report the used DL-UL configuration. |
| **Number of UEs**  | Up to 50 per service area, e.g., 10, 20, 40 and 50. | Up to 40 per cellNote: Example of the number of users for evaluation can be 5, 10, 20, 30 and 40.  |
| **UE distribution** | All UEs randomly distributed within the respective service area. | 100% of users are indoor |
| **UE mobility** | Linear movement: 75 km/h | Linear movement: 3 km/h and/or 30 km/hNote: which one to use is up to companies and other value(s) are not precluded |
| **Message size** | 48 bytes | 32 bytes |
| **DL traffic model** | * Opt3: All UEs in one service area are divided into several groups. DL messages of UEs in the same group will arrive at NG-RAN node in one burst with the following assumptions.
* Number of groups within a service area: 2.
* Number of UEs in a group: all groups have equal number of UEs.
* 3GPP can determine to use either a pre-defined value or a random value for the burst arrival time differences between different groups
 | DL & UL: Periodic deterministic traffic model with data arrival interval 2 ms |
| **UL traffic model** | * Option 1: DL and UL traffic arrival times are independent.
 |
| **Reliability requirement** | CSA: 99.9999% (UC #2) See Table 7.1‑1, lower bound of CSA requirement for UC #2 is chosen for reduced simulation burden. | CSA: NoReliability: 99.9999% (Only PER is considered) |
| **Note 1**: UC #2 is the second use case shown in Table 1 in the LS [2], as marked in yellow in the LS. **Note 2**: InF-DH, InD-DL, InF-SH and InF-SL are four sub-scenarios summarized in the IIoT channel model [4], and the channel models for these four sub-scenarios are different. Meanwhile, “*x* > *y*” means the simulation for channel model *x* is prioritized. |

# Rel-16 URLLC enhancements to be evaluated

In this section, we are discussing the Rel-16 URLLC enhancements that should be included or excluded from the evaluation.

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| --- | --- | --- |
| **Rel-16 URLLC enhancement** | **Comment** | **Included** |
| PDCCH monitoring enhancements | This is needed for sporadic traffic where frequent monitoring is required.  | No |
| DCI enhancements | The DCI overhead is large for small packets, the compact DCI is useful in this context. | Yes |
| UCI enhancements, sub-slot based HARQ-ACK codebook | Could be useful from the latency perspective.  | Yes |
| Independent HARQ ACK codebooks for services with different priorities | No need to support. In the evaluations we look at URLLC only | No |
| Mini-slot based PUSCH repetition | For periodic traffic, more RBs can be allocated to a transmission instead of a smaller number of RB with some repetitions.Also, the scenario is InF and hence the UE is not power-limited. A larger RB allocation is therefore feasible. | No |
| UL grant free enhancements, multiple configurations | Since only one service is included and this service is periodic with a periodicity of 1 ms (or maybe 2ms), one set of configured grant configuration is sufficient. | No |
| DL SPS with one slot periodicity | Useful for periodic traffic with short periodicity | Yes |
| Inter and intra UE multiplexing enhancements | Only needed for eMBB/URLLC services. This is not considered here | No |

***Proposal 6: The following Rel-16 URLLC enhancements are included in the evaluations.***

* ***DCI enhancements,***
* ***UCI enhancements, sub-slot based HARQ-ACK codebook,***
* ***DL SPS with one slot periodicity.***

# Conclusions

In this paper we discuss the scenario, requirements, performance metric and simulations assumptions for the evaluation of the URLLC enhancements according to the LS from 5G-ACIA. We also make a proposal on the eURLLC enhancements to be included.

***Proposal 1: Adopt the scenario that is regarded by 5G-ACIA as the prioritized use case as the baseline for the evaluation, i.e.:***

| Communica­tion service availability: target value (note 1) | Communication service reliability: mean time between failures | End-to-end latency: maximum (note 2) (note 12a) | Service bit rate: user experienced data rate (note 12a) | Message size [byte] (note 12a) | Transfer interval: target value (note 12a) | Survival time (note 12a) | UE speed (note 13) | # of UEs | Service area (note 3) |
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| 99,9999 % to 99,999999 % | ~ 10 years | < transfer interval value | – | 40 | 1 ms  | 1 ms | ≤ 75 km/h | ≤ 50 | 50 m x 10 m x 10 m |

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***Proposal 3: For the DL traffic model used in the evaluation, assume option 3, i.e. all UEs in one service area are divided into several groups. DL messages of UEs in the same group will arrive at NG-RAN node in one burst.***

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* ***3GPP can determine to use either a pre-defined value or a random value for the burst arrival time differences between different groups.***

***Proposal 4: For the DL-UL traffic arrival time relationship, adopt Option 1, DL and UL traffic arrival time instants are independent.***

***Proposal 5: For performance evaluation of motion control, take the simulation settings from “Value from 5G-ACIA” in Table 2 below as the starting point for the evaluation.***

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| **Inter-BS/TRP distance & Layout** | Depending on the number of TRPs, which are evenly deployed in the factory hall. Simulation company should provide the number of BSs/TRPs used in the simulation. | ISD = 20 m, and layout is as follows.cid:image001.jpg@01D460C3.1788FD90 |
| **BS/TRP antenna height** | 1.5 m for InF-SL and InF-DL8 m for InF-SH and InF-DH. | 10 mNote: Other value (e.g. 3 m) is not precluded for evaluation |
| **Channel model** | UC #2 (Note 1): InF-DH > InD-DL > InF-SH > InF-SL (Note 2) | ITU InH for 4 GHzCompanies report the modification of the channel model |
| **E2E latency & air interface latency** | E2E latency: 1 ms for UC #2Air interface latency: NA | E2E latency: 2 msAir interface latency: 1 ms  |
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| **UE mobility** | Linear movement: 75 km/h | Linear movement: 3 km/h and/or 30 km/hNote: which one to use is up to companies and other value(s) are not precluded |
| **Message size** | 48 bytes | 32 bytes |
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 | DL & UL: Periodic deterministic traffic model with data arrival interval 2 ms |
| **UL traffic model** | * Option 1: DL and UL traffic arrival times are independent.
 |
| **Reliability requirement** | CSA: 99.9999% (UC #2) See Table 7.1‑1, lower bound of CSA requirement for UC #2 is chosen for reduced simulation burden. | CSA: NoReliability: 99.9999% (Only PER is considered) |
| **Note 1**: UC #2 is the second use case shown in Table 1 in the LS [2], as marked in yellow in the LS. **Note 2**: InF-DH, InD-DL, InF-SH and InF-SL are four sub-scenarios summarized in the IIoT channel model [4], and the channel models for these four sub-scenarios are different. Meanwhile, “*x* > *y*” means the simulation for channel model *x* is prioritized. |

***Proposal 6: The following Rel-16 URLLC enhancements are included in the evaluations.***

* ***DCI enhancements,***
* ***UCI enhancements, sub-slot based HARQ-ACK codebook,***
* ***DL SPS with one slot periodicity.***

# References

1. RP-201310, Nokia, Nokia Shanghai Bell, “Revised WID: Enhanced Industrial Internet of Things (IoT) and ultra-reliable and low latency communication (URLLC) support for NR”, TSG-RAN#88e, Electronic meeting, June 29-July 3, 2020.
2. RP-201279, 5G-ACIA, “LS on 3GPP RN Rel-16 URLLC and IIoT performance evaluation”, TSG-RAN#88e, Electronic meeting, June 29-July 3, 2020.
3. 3GPP TR 38.814 V16.0.0 (2019-03), Study on physical layer enhancements for NR ultra-reliable and low latency case (URLLC).
4. 3GPP TR 38.901 V16.1.0 (2019-12), Study on channel model for frequencies from 0.5 to 100 GHz.
5. 3GPP TS 22.104, “Service requirements for cyber-physical control applications in vertical domains.”