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

E-mail discussion, February 22 - 28, 2020

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Title: Results for 5G-ACIA Performance Evaluation Round 2

Document for: Discussion

1 Introduction

Following the agreements discussed during the first round of the 5G ACIA e-meeting in December 2020 [1] and the plan agreed in Appendix 2, simulations assessing the URLLC/IIOT performance have been performed.

Conclusion on colleting simulation assumptions:

* The final Excel sheet can be found [here](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_91e/Inbox/Drafts/5G-ACIA%20December/Final%20Summary/Simulation%20assumptions%20for%20calibration%20Final.xlsx).

Conclusion on FR2 antenna assumptions:

* 2RX/TX is still the baseline
* Results for additional configurations can be provided

Conclusion on cell coordination:

* No coordination is baseline
* Results with cell coordination can be provided

Conclusion on MU-MIMO:

* SU-MIMO is baseline
* Results with MU-MIMO can be provided

Agreement for latency:

* For FR1 companies are encouraged to provide simulation results for one-shot transmission

Noted proposal for latency

* For the E2E latency, following assumptions are made:
	+ Components from table 5.7.1.1.1.-1 for DL and table 5.7.1.1.2.-1 for UL from TR 37.910 are used to calculate the E2E latency
		- In case re-tx is simulated, the alignment delay for the re-TX at the gNB side (which is not included in the tables from the TR 37.910) should also be added to the latency
	+ Companies report the UE processing delay and gNB processing delay, for other components, the values from table 5.7.1.1.1.-1 for DL and table 5.7.1.1.2.-1 for UL from TR 37.910 are assumed
* Supported by Intel, Huawei/HiSilicon, vivo, ITRI, ZTE

Conclusion on additional simulation assumptions:

* No consensus on CSA metric with no consecutive errors is mandatory
* Narrow down channel model to InF-DH explicitly
* Option-1 for DL traffic and Option-1 for UL traffic relationship to DL is still baseline. Additional results can be submitted
* Number of samples, minimum number of packets per UE and minimum number of UEs / network drops modelled are left to companies’ choice

Conclusions on format for submissions to round 2

* Companies will provide
	+ CDF of packet error rate for UL and DL
	+ CDF of CSA for UL and DL
	+ Tabulated values for percentage of UEs satisfying 1ms latency and 99.9999% reliability/CSA requirement for each simulated case
	+ CDF for coupling loss and geometry for calibration

 The goal is to provide performance evaluations to 5G-ACIA for their LS on 3GPP NR Rel-16 URLLC. The target date for the completion of this activity is TSG RAN Meeting #91e in March 2021.

We provide initial simulation results following the previous agreements on the 5G-ACIA evaluation in this contribution. Section 2 presents simulation parameters and models, whereas Section 3 includes results on frequency range 1 (FR1). Finally, conclusions are presented in Section 4.

2 Simulation Parameters and Models

## 2.1 Performance Metric

From 5G-ACIA LS, four performance metrics are provided:

1. CDF of packet error rate for UL and DL
2. CDF of CSA for UL and DL
3. Tabulated values for percentage of UEs satisfying 1ms latency and 99.9999% reliability/CSA requirement for each simulated case
4. CDF for coupling loss and geometry for calibration

## 2.1 Simulation Parameters for FR1

### 2.1.1 Network Topology

A factory hall of 120m x 50m x 10m, which is then fully covered by 12 service areas of 50m x 10m. BS antenna height is 8m for InF-DH. The number of BS is 12.

|  |  |
| --- | --- |
| Inter-BS distance | 20 m as in TR 38.824 (reproduced in Figure 1 below) for the factory automation use case. |
| BS antenna height | 8 meters |
| Channel model | InF-DH |



Figure 1. Base station layout for factory automation use case in TR 38.824.



Figure 2. Service area for factory automation

### 2.1.2 Traffic model downlink and uplink

For both downlink and uplink, Option 1 is chosen, hence*:*

* ***Option-1****: all UEs’ messages both in DL and UL arriving at NG-RAN node in the first transfer interval are uniformly random distributed within the TI time window.*

In addition, *“For DL-UL traffic arrival time relationship”* the option 1 is considered*.*

* ***Option-1:*** *DL and UL traffic arrival time instants are independent*

### 2.1.3 Number of UEs per cell

In the 5G-ACIA scenario, the UEs are randomly distributed within the respective service area.

|  |  |
| --- | --- |
| Number of UEs per service area | {10, 20, 40, 50} for FR1; The UEs are randomly distributed in each service area. |

### 2.1.4 Other assumptions

The same parameters are assumed in 5G-ACIA LS and TR 38.824, and summarized below.

|  |  |
| --- | --- |
| Duplex | TDD |
| Carrier frequency | 4 GHz for FR1 |
| Simulation bandwidth | 100 MHz for FR1 |
| SCS | 30 kHz for FR1 |

### 2.1.5 TDD Frame and slot structure

TDD DL-UL configuration in the simulations used 1:1 DL-UL configuration. {S}, S={D=6,G=2,U=6}.

In addition, the following SPS, CG configurations are used:

* UL CG with one 6-symbol mini-slot configuration.
* DL SPS with one 6-symbol mini-slot configuration.

Regarding the signalling overhead, one DL symbol per slot is used for PDCCH and one UL symbol per slot is assumed for PUCCH/SRS transmission. Thus, 5 symbol DL/UL duration is assumed for scheduling SPS PDSCH/CG PUSCH respectively. In the first round discussion, it was concluded that there was no time for scheduling re-transmission within 1ms at FR1, so we used one shot transmission for FR1.

### 2.1.6 Summary

A summary of simulation parameters and models can be seen as below.

|  |  |
| --- | --- |
| Parameters | 5G-ACIA LS |
| Factory hall size  | 120x50 m |
| Room height  | 10 m |
| Inter-BS/TRP distance  | 20 m  |
| BS/ antenna height  | 8m for InF-DH |
| Layout – BS/TRP deployment | 12 BS |
| Channel model  | InF-DH |
| Carrier frequency and simulation bandwidth | TDD4 GHz: 100 MHz |
| TDD DL-UL configuration  | {S}, S={D6,G2, U6} |
| Number of UEs per service area | 10, 20, 40, 50 for FR1 |
| UE distribution  | All UEs randomly distributed within the respective service area. |
| Message size  | 48 bytes |
| DL traffic model  | DL traffic arrival with option-1 |
| UL traffic model  | UL traffic is symmetric with DL, and DL-UL traffic arrival time relationship with option-1  |
| CSA requirements  | UC-#2: 99.9999% |
| E2E latency & air interface latency | E2E latency: 1 ms for UC#2 in Appendix 1 |
| UE speed | Linear movement: 75 km/h |
| UE Tx Power | 23 [dBm]  |
| BS Tx Power | 31 [dBm]  |
| BS Antenna Configuration | Ceiling-mount pattern4 Tx/Rx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (1, 2, 2, 1, 1; 1, 2) dH = dV = 0.5 λ |
| UE Antenna Configurationl | Omnidirectional4 Tx/Rx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (1, 2, 2, 1, 1; 1, 2)dH = dV = 0.5 λStatic panel selection |
| Receiver Noise Figure | 5dB for BS and 9dB for UE |
| Clutter information | Cluster density: 60%Cluster height: 6mCluster size: 2m |
| Addition model | Absolute time of arrival |
| UL CG / DL SPS configurations | UL CG and DL SPS with 6-symbol duration in mini-slot configuration. |
| UE processing capability | UE processing capability 2 |

### 2.1.7 Calibration of Coupling Gain and Geometry SINR

For calibration purpose, the coupling gain and geometry SINR for DL are provided in Figure 3.



Figure 3. Coupling gain and geometry SINR.

3 Simulation Results

## 3.1 Simulation Results for FR1

The first round simulation result is shown as Table 1. There are 10 UEs per service area, which means that there are 120 UEs in the whole system. It is seen that the percentage of UEs satisfying requirement is too low. The main reason is that the timing of DL SPS or UL CG configuration is not adequate with the traffic arrival time, so latency is easily larger than 1ms.

Table 1: First round evaluations results (percentage of UEs satisfying requirements and RU).

|  |  |  |
| --- | --- | --- |
|  | Resource Utilization | Percentage of UEs satisfying requirements |
| DL SPS | 56.8964% | 76.67% |
| UL CG | 56.9541% | 71.67% |

 However packet arrival is available to gNB in connection setup phase. The configuration of DL SPS and UL CG could be adjusted appropriately for the packet arrival pattern. For example, the resource allocation in time domain and the resource periodicity may be configured to minimize the gap of the DL/UL frame alignment delay. The simulation results are shown as Table 2.

Table 2: Evaluations results (percentage of UEs satisfying requirements and RU) for 16 PRB.

|  |  |  |
| --- | --- | --- |
|  | Resource Utilization | Percentage of UEs satisfying requirements |
| DL SPS | 29.21% | 100% |
| UL CG | 29.27% | 100% |

It is seen that the percentage of UEs satisfying requirement becomes 100% with modification of time domain resource allocation while minimizing frame alignment delay. Even though occupation granularity for each UE has been reduced from 32 PRBs to 16 PRBs.

**Observation 1: The configuration of DL SPS or UL CG depends on the characteristic of the traffic pattern to meet requirements, especially in resource allocation in time domain.**

We set allocation granularity to 4 PRBs for each UE to observe the changes in resource utilization. The simulation results are shown in Table 3.

Table 3: Evaluations results (percentage of UEs satisfying requirements and RU) for 4 PRB.

|  |  |  |
| --- | --- | --- |
|  | Resource Utilization | Percentage of UEs satisfying requirements |
| DL SPS | 7.326% | 91.67% |
| UL CG | 7.326% | 83.33% |

It is seen that the resource utilization is about one fourth of the value of 16 PRBs granularity. If one packet of a UE occupies less PRBs, the resource utilization of whole system can be lower, but MCS index should be set higher to convey the packet in each occupation, resulting in higher block error rates. That’s why the values of “percentage of UEs satisfying requirements” decrease while compressing the resource utilization.

**Observation 2: There is a resource utilization trade-off among a number of PRBs for one packet and a selection of MCS index.**

Simulation results of different numbers of UEs per service area with 4 PRBs occupation granularity are shown as Table 4.

Table 4: Evaluations results (percentage of UEs satisfying requirements and RU) for 4 PRB and different number of UE.

|  |  |  |
| --- | --- | --- |
| Number of users | Percentage of UEs satisfying requirements | Resource Utilization |
| DL | UL | DL | UL |
| 10 | 91.67 | 83.33 | 7.326% | 7.326% |
| 20 | 87.08 | 62.08 | 14.652% | 14.652% |
| 40 | 68.75 | 35 | 29.303% | 29.304% |
| 50 | 62.17 | 25.5 | 36.629% | 36.63% |

The percentage of UEs satisfying requirement severely decreases when the number of UEs is larger than 40. Interference may be one of factors. Take the uplink transmission as an example. When no specified resource allocation in frequency domain is applied, neighbouring UEs associated with different serving cells may be allocated in the same frequency resource. The case of 10 UEs has a larger proportion of UE with no interference in uplink transmission than the case of 50 UEs has, which means that there is no interference from other UEs affecting transmission quality in a major part, so that the values of “percentage of UEs satisfying requirements” of 10 UEs is higher than that of 50 UEs.

**Observation 3: Resource allocation in frequency domain may be also required to mitigate the interference to meet the requirements of CSA and latency, especially in the case of a large number of UEs.**

When the results of an enhanced resource allocation is available, the evaluation results will be updated in a later contribution. Other performance metric is shown as below:



Figure 4. CDF of Latency.



Figure 5. CDF of CSA.



Figure 6. CDF of Packet Error Rate.

## 3.2 Latency Calculation

For the E2E latency, the following agreements are discussed during the first round of the 5G ACIA e-meeting in December 2020. For FR1 companies are encouraged to provide simulation results for one-shot transmission and the components used from table 5.7.1.1.1.-1 for DL and table 5.7.1.1.2.-1 for UL from TR 37.910 are used to calculate the E2E latency.

We only consider one-shot transmission in FR1, so the components 1.1, 1.2, 1.3 and 1.4 are calculated as in the table of TR37.910. The value of 1.1 and 1.4 is Tproc,2/2 and Tproc,1/2, the Tproc,1 and Tproc,2 are defined as follows, while assuming N1=4.5, N2=5.5 OS under UE Processing capability 2 and 30kHz subcarrier spacing in FR1:





For scheduling UL CG and DL SPS are used. These can avoid PDCCH blocking and DCI errors. Since packet arrival is known by gNB, allocation in time and periodicity is optimized so that the DL/UL frame alignment delay is minimized.

The UL CG and DL SPS are set with one 6-symbol mini-slot configuration, so the E2E latency in one-shot transmission is 2.75+6+2.25 symbol time with alignment delay extra added. The alignment delay depends on the packet arrival in our simulation, which is less than 14 symbol time.The total latency is still smaller than 1ms, i.e., 28 symbol time.

4 Conclusions

 In this contribution, we have provided second-round system-level simulation results following the agreements related to the 5G-ACIA performance evaluation. The obtained results are summarized with the following observations:

**Observation 1: The configuration of DL SPS or UL CG depends on the characteristic of the traffic pattern to meet requirements, especially in resource allocation in time domain.**

**Observation 2: There is a resource utilization trade-off among a number of PRBs for one packet and a selection of MCS index.**

**Observation 3: Resource allocation in frequency domain may be also required to mitigate the interference to meet the requirements of CSA and latency, especially in the case of a large number of UEs.**

5 References

1. 3GPP 5G-ACIA, “Agreements on URLLC Features and Simulation Assumptions for 5G-ACIA”,
2. RP-202069, “Way forward and RAN work for 5G ACIA requested simulations”, Ericsson
3. TR 38.824.
4. TR 38.901.
5. TS 22.104.

Appendix 1. Performance requirements in TS 22.104

The services requirements of motion control are copied below from TS 22.104 V17.4.0.

TS 22.104 V17.4.0, Table 5.2-1: Periodic deterministic communication service performance requirements

| 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) | Remarks |
| 99.999 % to 99.999 99 % | ~ 10 years | < transfer interval value | – | 50 | 500 μs  | 500 μs | ≤ 75 km/h | ≤ 20 | 50 m x 10 m x 10 m | Motion control (A.2.2.1) |
| 99.999 9 % to 99.999 999 % | ~ 10 years | < transfer interval value | – | 40 | 1 ms  | 1 ms | ≤ 75 km/h | ≤ 50 | 50 m x 10 m x 10 m | Motion control (A.2.2.1) |
| 99.999 9 % to 99.999 999 % | ~ 10 years | < transfer interval value | – | 20 | 2 ms  | 2 ms | ≤ 75 km/h | ≤ 100 | 50 m x 10 m x 10 m | Motion control (A.2.2.1) |
| 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 12a: It applies to both UL and DL unless stated otherwise.NOTE 13: It applies to both linear movement and rotation unless stated otherwise.  |

Appendix 2. Activity plan

As it was agreed in [2]:

* *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*

Based on statements above, the following activity plan has been proposed:

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