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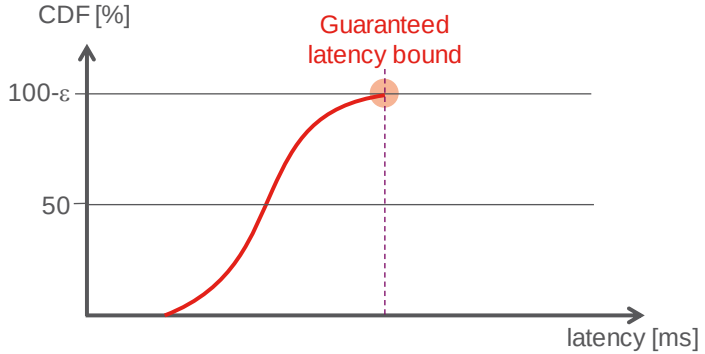
Document for: Discussion and Decision

# ON URLLC RELIABILITY EVALUATION

# URLLC SERVICE REQUIREMENTS (1)

- There is a large number of URLLC use cases
  - Documented in 3GPP TR 22.862
  - Documented in various white papers and publications
- Commonality between documented use cases
  - Often low latency communication
    - Can be down to 1 ms, and in some cases even lower
  - Often ultra-reliable communication
    - Guaranteeing with high probability (e.g. $p=1-10^{-5}$) correct delivery of a message within a delay bound
    - Delay bound can be low (e.g. 1 ms) or relaxed (e.g. 100 ms to several seconds)
  - Sometimes both high reliability and low latency are required

High reliability




Reliability in relation to latency where latencies are guaranteed up to the reliability level. The reliability is specified by the failure probability ε of packets which are not successfully delivered to the receiver within the latency bound, as they are either erroneous, lost or arrive too late.

# URLLC SERVICE REQUIREMENTS (2)

- **Observation 1:** There are many URLLC services with different requirements concerning the latency and required reliability. Latency requirements for the URLLC use cases in TR22.862 range from around 1 ms to several seconds.

- **Proposal 1:** NR design should be able to address a range of URLLC services concerning different latency & reliability requirements.

# URLLC DEPLOYMENT ASPECTS

- URLLC use cases (see e.g. TR 22.862) correspond to different deployments
  - Some URLLC use cases are local
    - e.g. for industrial automation
  - Some use cases are ubiquitous / wide-area
    - e.g. in the smart grid
    - e.g. general teleoperation

- Coverage for URLLC services depends on the service requirements; it decreases
  - for higher reliability
  - for a lower latency bound
  - for higher data rate

# URLLC DEPLOYMENT ASPECTS (2)

- **Observation 2:** Different URLLC (as e.g. described in TR 22.862) services correspond to different deployments, some use cases only apply to local deployments, others apply to wide-area deployments.

- **Observation 3:** The coverage for URLLC services depends on the service requirements and decreases for higher reliability, lower latency and higher data rate.

- **Observation 4:** It seems difficult to find **a single set** of URLLC assumptions concerning representative URLLC KPIs and deployment assumptions.

# 3GPP DEPLOYMENT SCENARIOS

› 3GPP TR 38.913 describes several deployment scenarios

- Indoor hotspot
- Dense urban
- Rural
- Urban macro
- High speed
- Extreme long distance coverage in low density areas
- Urban coverage for massive connection
- Highway Scenario
- Urban Grid for Connected Car
- Commercial Air to Ground scenario
- Light aircraft scenario
- Satellite extension to Terrestrial

› **Proposal 2:** For evaluation of a representative URLLC test case an appropriate deployment scenario should be assumed.

# URLLC SERVICES WITH LOCAL DEPLOYMENTS (1)

- All use cases with ultra-low latencies down to ~1ms or below are for local deployments, mostly around industrial automation (see e.g. [1][2])
  - Latencies between
    - 0.25ms – 20ms (factory automation)
    - 100ms – 1s (process automation)
  - Reliability in the range between $1\text{-}10^{-5}$ and $1\text{-}10^{-9}$
  - Range typically <100m, but can be several 100's of meters (mainly process automation)
    - Longer range in particular for more relaxed latency requirements
  - Mainly closed-loop control applications, with typically cyclic control loop operation

- **Observation 5:** Ultra-low latencies around 1ms are needed in particular in local environments

# URLLC SERVICES WITH LOCAL DEPLOYMENTS (2)

- Proposal for a URLLC test case for **very low latency & local deployments**
  - Deployment
    - Avoid specifying an "industrial" deployment test case (with e.g. own propagation models)
    - Use closest 3GPP deployment test case, which is "Indoor hotspot"
  - Traffic model proposed
    - Periodic data of small packets 50 bytes (typical [12-50] bytes),
    - with periodicity of the control cycle of 2 ms (typical [0.5-40] ms)

    } 200 kb/s per UE, constant rate
  - Delay & reliability requirement
    - Latency bound of 1 ms (half of control cycle, assuming zero-latency control loop processing)
    - Reliability of $1\text{-}10^{-5}$ (typical [$10^{-5}$ - $10^{-9}$])

- **Observation 6:** The URLLC reliability requirement in TR38.913 (1ms @ $1\text{-}10^{-5}$) matches a factory automation use case with local deployment.
- **Proposal 3:** The URLLC reliability KPI in TR38.913 (i.e. 1ms @ $1\text{-}10^{-5}$) should be evaluated for a local deployment, according to the "Indoor hotspot" deployment scenario

# URLLC SERVICES WITH WIDE-AREA DEPLOYMENTS (1)

- Use cases with ubiquitous availability / wide-area usage are
  - Connectivity for a smart energy grid
  - Teleoperation with haptic feedback (tactile internet)

- **Observation 7:** Suitable URLLC use cases according to [1,2,3,4,5] that correspond to wide area deployments could be e.g. teleoperation with haptic feedback or smart grid distribution automation.
- **Observation 8:** URLLC use cases according to [1,2,3,4,5] that correspond to wide area deployments have typically latency bounds which are larger than 1ms, e.g. 5-8ms.

# URLLC SERVICES WITH WIDE-AREA DEPLOYMENTS (2)

## Smart Grid

- Distribution automation and protection [1][3][4]
  - between secondary substations in medium voltage (1kV – 50 kV) smart grid distribution network
  - Range: up to 100km
  - E2e latency: 50 ms, expected 8 ms for RAN
  - Reliability: $1\text{-}10^{-5}$ to $1\text{-}10^{-6}$
  - Data rate: 200-1521 bytes messages
  - Suitable 3GPP deployment use cases are Urban Macro and Rural. The test case should be for rural deployments as worst case.

# URLLC SERVICES WITH WIDE-AREA DEPLOYMENTS (3)

## Teleoperation with haptic feedback (tactile Internet):

- Real-time remote control with haptic (kinesthetic + tactile) feedback [1][5]
  - Between control operator (master) and remote controlled system (slave)
  - Range: ubiquitous, proposed to use Urban macro deployment test case
  - E2e latency: 1-1000 ms, depending on dynamics of environment
    - <10ms environment for highly-dynamic environments
    - expected <5ms for RAN
  - Reliability: $1\text{-}10^{-5}$
  - Data rate: between 25.6 kb/s and 512 kb/s
    - Assuming 6 degrees-of-freedom (DoF) kinesthetic signals (6-24 byte packets per 20ms on average)
    - Assuming 10 DoF tactile signals (20-80 byte packets per 20ms on average)
    - Additional audio / video feedback often also available but not considered for URLLC

# URLLC EVALUATION METHODOLOGY (1)

- **Proposal 4**: To evaluate URLLC KPIs for NR, validate the reliability requirement for representative URLLC use cases, considering the channel quality at the cell edge with a representative deployment scenarios (e.g. factory automation, smart grid, teleoperation with haptic feedback).
  - "A message of [A] bytes is transmitted with reliability $1-10^{-[B]}$ within [C] ms at a channel quality of [D]."
  - The deployment scenario comprises also the number of UE antennas that are appropriate for the use case.
  - Evaluation parameters are: message size A, reliability target B, latency bound C, channel quality D, and number of UE antennas.

- **Proposal 5**: For the evaluation of URLLC KPIs
  - the channel quality [D] at the cell edge can be determined analytically via link budgets or via system-level simulations according to the specified deployment scenario,
  - the achievement of reliability [B] can be determined from link simulations for a given channel quality [D], message size [A], latency bound [C].

# URLLC EVALUATION METHODOLOGY (2)

**Table 1:** proposed use case and configurations for URLLC assessment or reliability

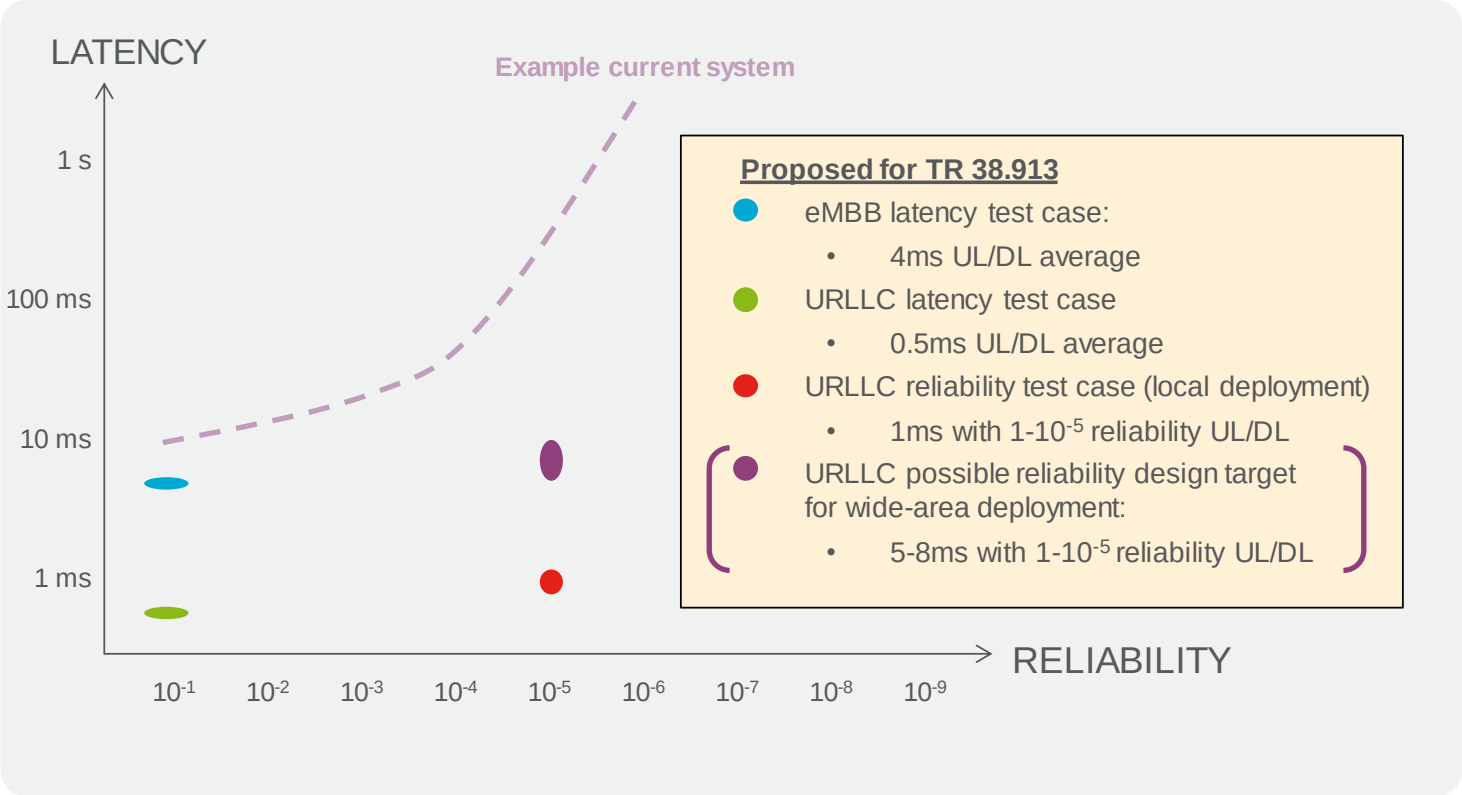
| Use cases | Reliability | Latency bound | File size | Link budget (*) |
|---|---|---|---|---|
| Factory automation | $10^{-5}$ | 1 ms | 50 bytes | Indoor hotspot |

(*) cell edge link budget to be determined from associated deployment scenario analytically or via link simulations

- **Proposal 6**: To evaluate the URLLC reliability KPI a configuration of parameters according to Table 1 in this contribution is proposed, where the current 1e-5 and 1ms requirement is mandatory, and further optional requirements can be added.
- **Proposal 7**: We propose to capture the conclusion of this contribution in TR 38.913.

# URLLC RELIABILITY TEST CASES

› **Observation 9**: If an optional URLLC reliability KPI should be evaluated for a wide-area test case a KPI target value according to a use case with wide-area deployment could be defined. A reliability KPI target of 5-8ms @ 1-$10^{-5}$ reliability, would be a suitable KPI for e.g. a “smart grid distribution automation” or “teleoperation with haptic feedback” use case.



# CONCLUSION (1)

› In this contribution we make the following observations:

- **Observation 1:** There are many URLLC services with different requirements concerning the latency and required reliability. Latency requirements for the URLLC use cases in TR22.862 range from around 1ms to several seconds.
- **Observation 2:** Different URLLC (as e.g. described in TR 22.862) services correspond to different deployments, some use cases only apply to local deployments, others apply to wide-area deployments.
- **Observation 3:** The coverage for URLLC services depends on the service requirements and decreases for higher reliability, lower latency and higher data rate.
- **Observation 4:** It seems difficult to find a single set of URLLC assumptions concerning representative URLLC KPIs and deployment assumptions.

# CONCLUSION (2)

› In this contribution we make the following observations:

- **Observation 5:** Ultra-low latencies are needed in particular in local environments
- **Observation 6:** The URLLC reliability requirement in TR38.913 (1ms @ $1\text{-}10^{-5}$) matches a factory automation use case with local deployment.
- **Observation 7:** Suitable URLLC use cases according to [1-5] that correspond to wide area deployments could be e.g. teleoperation with haptic feedback or smart grid distribution automation.
- **Observation 8:** URLLC use cases according to [1-5] that correspond to wide area deployments have typically latency bounds which are larger than 1ms, e.g. 5-8ms.
- **Observation 9**: If an optional URLLC reliability KPI should be evaluated for a wide-area test case a KPI target value according to a use case with wide-area deployment could be defined. A reliability KPI target of 5-8ms @ $1\text{-}10^{-5}$ reliability, would be a suitable KPI for e.g. a “smart grid distribution automation” or “teleoperation with haptic feedback” use case.

# CONCLUSION (3)

- Based on the discussion we propose the following :
  - **Proposal 1:** NR design should be able to address a range of URLLC services concerning different latency & reliability requirements.
  - **Proposal 2:** For evaluation of a representative URLLC test case an appropriate deployment scenario should be assumed.
  - **Proposal 3:** The URLLC reliability KPI in TR38.913 (i.e. 1ms @ $1\text{-}10^{-5}$) should be evaluated for a local deployment, according to the “Indoor hotspot” deployment scenario

# CONCLUSION (4)

- Based on the discussion we propose the following :
  - **Proposal 4:** To evaluate URLLC KPIs for NR, validate the reliability requirement for representative URLLC use cases, considering the channel quality at the cell edge with a representative deployment scenarios (e.g. factory automation, smart grid, teleoperation with haptic feedback).
    - "A message of [A] bytes is transmitted with reliability $1\text{-}10^{-[B]}$ within [C] ms at a channel quality of [D]."
    - The deployment scenario comprises also the number of UE antennas that are appropriate for the use case.
    - Evaluation parameters are: message size A, reliability target B, latency bound C, channel quality D, and number of UE antennas.
  - **Proposal 5:** For the evaluation of URLLC KPIs
    - the channel quality [D] at the cell edge can be determined analytically via link budgets or via system-level simulations according to the specified deployment scenario,
    - the achievement of reliability [B] can be determined from link simulations for a given channel quality [D], message size [A], latency bound [C].

# CONCLUSION (5)

› Based on the discussion we propose the following :

- **Proposal 6:** To evaluate the URLLC reliability KPI a configuration of parameters according to Table 1 in this contribution is proposed, where the current 1e-5 and 1ms requirement is mandatory, and further optional requirements can be added.

- **Proposal 7:** We propose to capture the conclusion of this contribution in TR 38.913.

# REFERENCES


[1] TR 22.862, V14.0.0. Feasibility Study on New Services and Markets Technology Enablers - Critical Communications

[2] Frotzscher, A.; Wetzker, U.; Bauer, M.; Rentschler, M.; Beyer, M.; Elspass, S.; Klessig, H., "Requirements and current solutions of wireless communication in industrial automation," in *Communications Workshops (ICC), 2014 IEEE International Conference on* , vol., no., pp.67-72, 10-14 June 2014

[3] 5G-Infrastructure-Association, “5G and Energy,” September 30, 2015. Available at https://5g-ppp.eu/white-papers/

[4] METIS, “Scenarios, requirements and KPIs for 5G mobile and wireless systems,” deliverable D1.1, April 2013, https://www.metis2020.com/wp-content/uploads/deliverables/METIS_D1.1_v1.pdf

[5] Steinbach, Liu, “Use Case on Teleoperation over the Tactile Internet,“ contribution to IEEE P1918.1 (Standardization on Tactile Internet) meeting, July 21 2016.

[6] R1-167061, “On URLLC design”, Ericsson

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