Deterministic 5G Ultra-Reliable And Low Latency Communication

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Ultra-reliable and low latency communication (URLLC) requirements

Use cases

› Motion control

› Control-to-control communication

› Smart grid

› ....

3GPP Technical Specification 22.104

3GPP Release-15 New Radio (NR) (2018)

Latency

› 0.5 ms Uplink (UL)/Downlink (DL)

Reliability

› 99.999 %

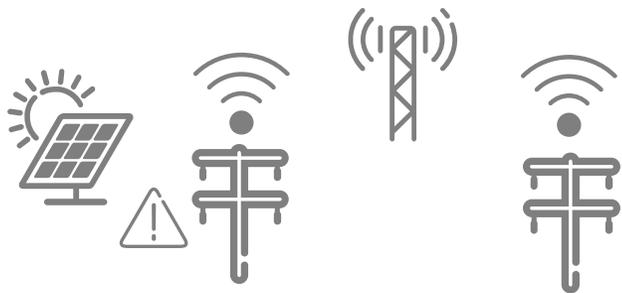**3GPP Technical Report 38.913**

3GPP Release-16 NR (2020)

Latency

› 0.5 ms UL/DL

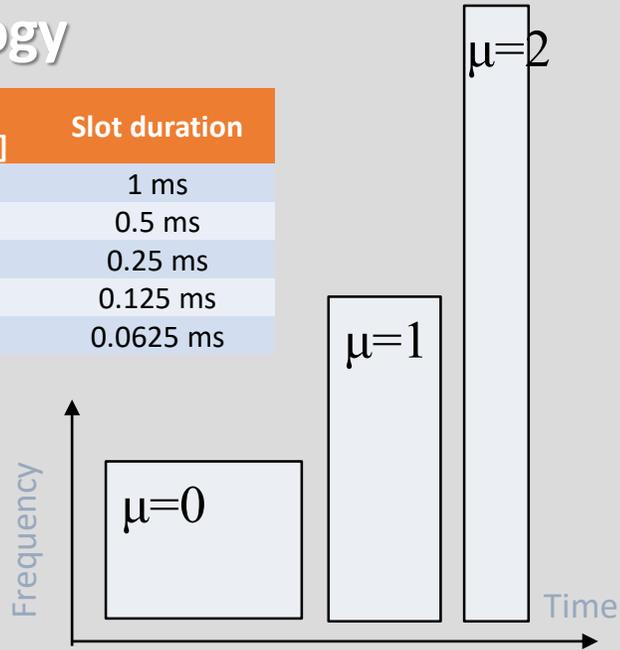**Reliability**

› 99.9999 %
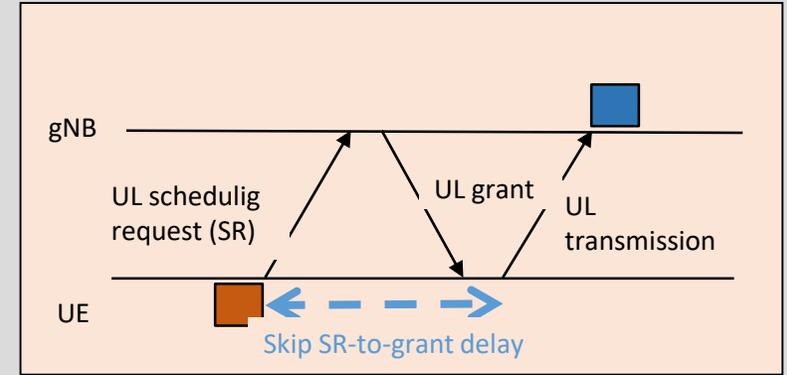
3GPP Technical Report 38.824

Low latency features

Numerology

μ	Sub-carrier spacing [kHz]	Slot duration
0	15	1 ms
1	30	0.5 ms
2	60	0.25 ms
3	120	0.125 ms
4	240	0.0625 ms

μ=2

μ=1

μ=0

Frequency

Time

Short transmissions

NR slot = 14 OFDM symbols (os)

Time allocation:
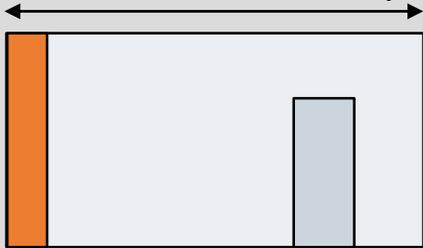- Type A (slot)
- Type B (2, 4 or 7 os)

Mini-slot

Grant-free

- DL semi-persistent scheduling (SPS)
- UL configured grant (CG)

gNB

UL schedulig request (SR)

UL grant

UL transmission

UE

Skip SR-to-grant delay

Pre-emption

Repair transmission

eMBB

URLLC

eMBB

DL Pre-emption indication

Out-of-order HARQ

- PUSCH (UL data channel) scheduling
- PDSCH (DL data channel) scheduling

Fast HARQ

DCI

DL Data

K1

K0

K2

UL Data

DL ACK

E.g., fastest case is K0 = K1 = K2 = 0 slots
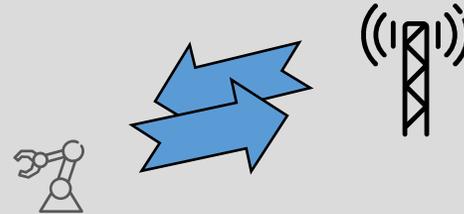
PDCCH monitoring

Multiple PDCCH (DL control channel) monitoring occasions within one slot
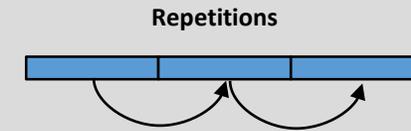
High reliability features

Robust physical channels

- Robust (low spectral efficiency) modulation coding scheme tables
- Channel quality indicator table for low BLER reporting
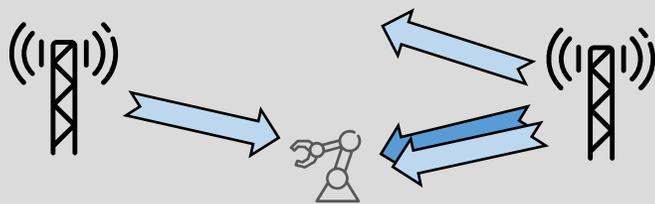- Robust PDCCH/PUCCH (DL/UL control channels)
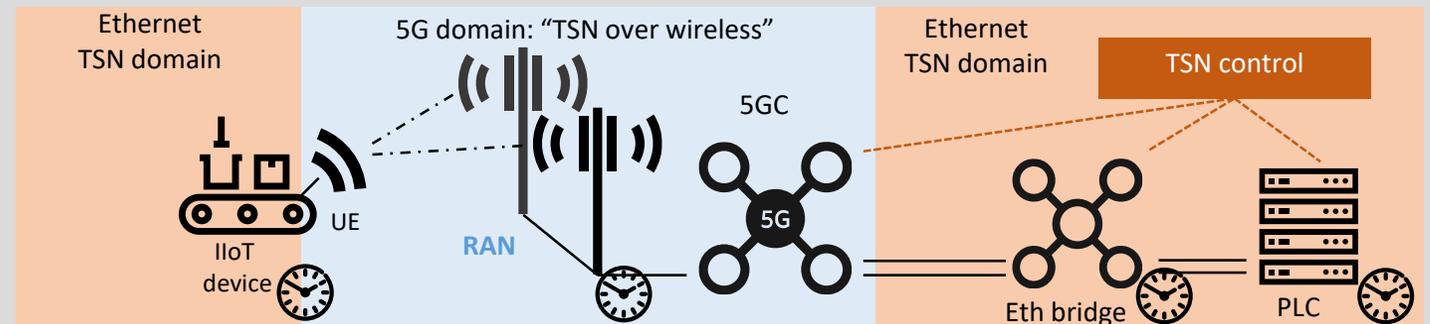
Antenna techniques

Automatic repetitions

Repetitions

PDCP duplication

Time-sensitive networking
- Reliable deterministic flow
- Accurate time delivery (or synchronization)

Ethernet TSN domain

5G domain: "TSN over wireless"

Ethernet TSN domain

TSN control

5GC

UE

RAN

IIoT device

5G

Eth bridge

PLC

Deterministic scheduling

Uplink

- Configured grant (CG)
  - Utilizes grant-free

UE's TOs for $K=4$ repetitions in CG resource

CG#1

CG#2

CG#3

CG#4
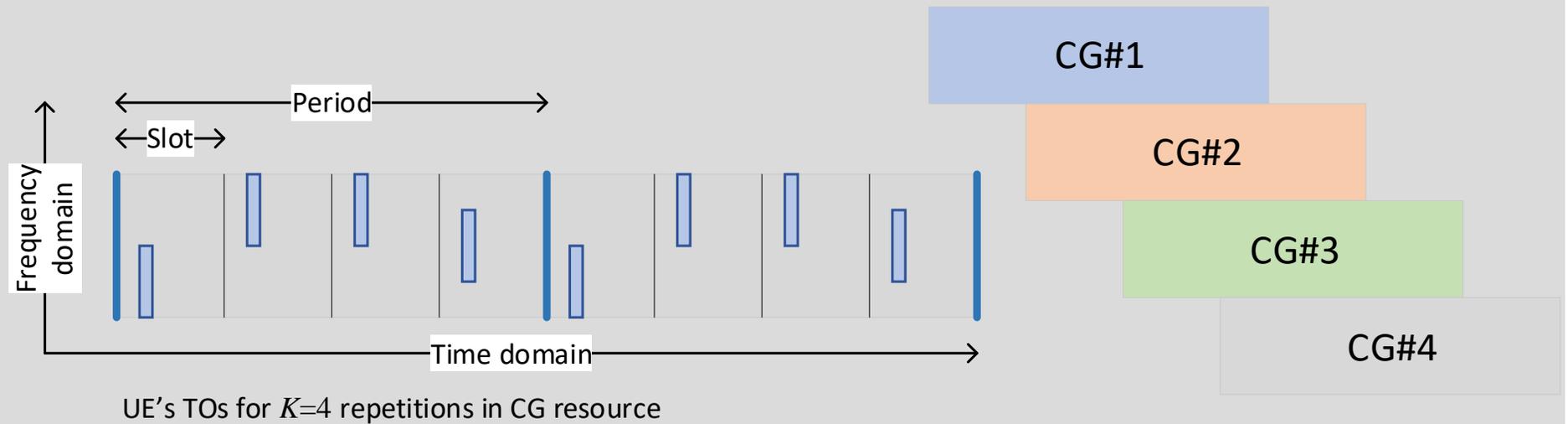
Downlink

- Short DL semi-persistent scheduling (SPS) periods, e.g., down to 2 os
- Multiple active DL SPS configurations per bandwidth part

Summary

— Progressing with 3GPP New Radio Release 16 work items
  — Targeting 99.9999 % reliability, 0.5 ms latency in either direction
  — Study items already finished
— Enhancements are being made to provide deterministic access and TSN integration
  — Uplink: Configured grant is standardized, which can be considered as a baseline
    — Further enhancements are undergoing
  — Downlink: Not as critical as uplink, but various proposals are under discussion
  — TSN capabilities are analyzed and being discussed in 3GPP Release 16
    — For e.g., accurate clock/time delivery from TSN clock to UE is analyzed at different 3GPP working groups, and accordingly proposals are being driven