# Wireless for Verticals


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# New user demands – with extremely diverse requirements

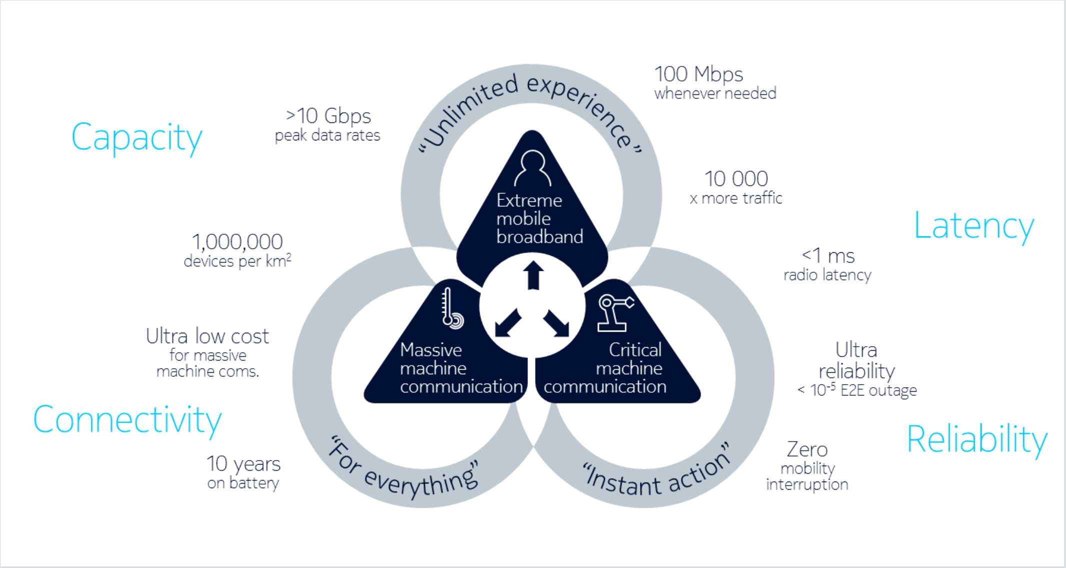
## 5G is more than 1 generation ahead of LTE

Devices
1.5 GB/day

Smart Factories
1 PB/day

Billions of sensors connected

Autonomous driving
1ms latency




Design and architecture principles:
flexible | scalable | automated | cloud native
software centric | dynamic network slicing



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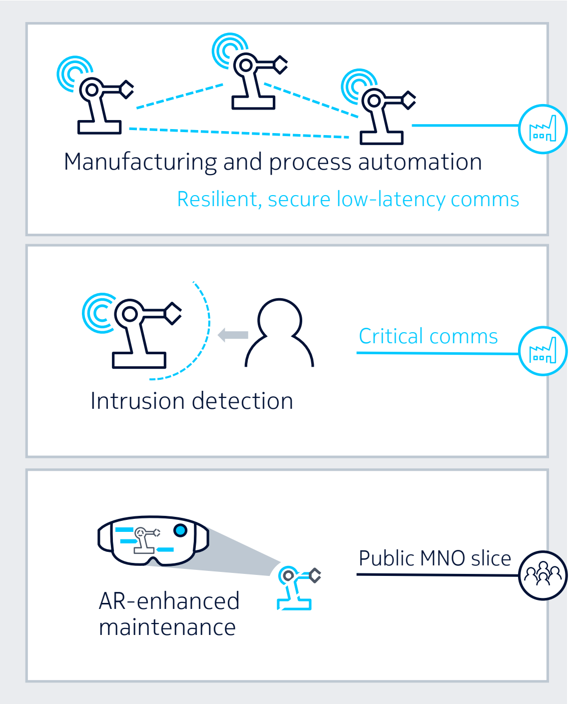
# 5G industry experience – enabling industry 4.0

## Resilient, secure low-latency communication




Wireline connections today

>90%

**Business case** $

| | |
|---|---|
| Overall costs for greenfield<br>2-5 times lower | # of sensors ↗<br>=<br>Payback period ↘ |
| Break even for wireline replacement<br>1 year | Reconfiguration cycle ↘<br>=<br>Payback period ↘ |

**5G Advantage**

### Ultra-low latency at scale
<1ms; 99.999% reliability

### Inherent security
by dedicated network slices

### Single company network
for all kinds of industrial applications

**Benefits**

### Removing cost
of cabling installation and maintenance

### Less reconfiguration time

### Less production capacity overprovisioning

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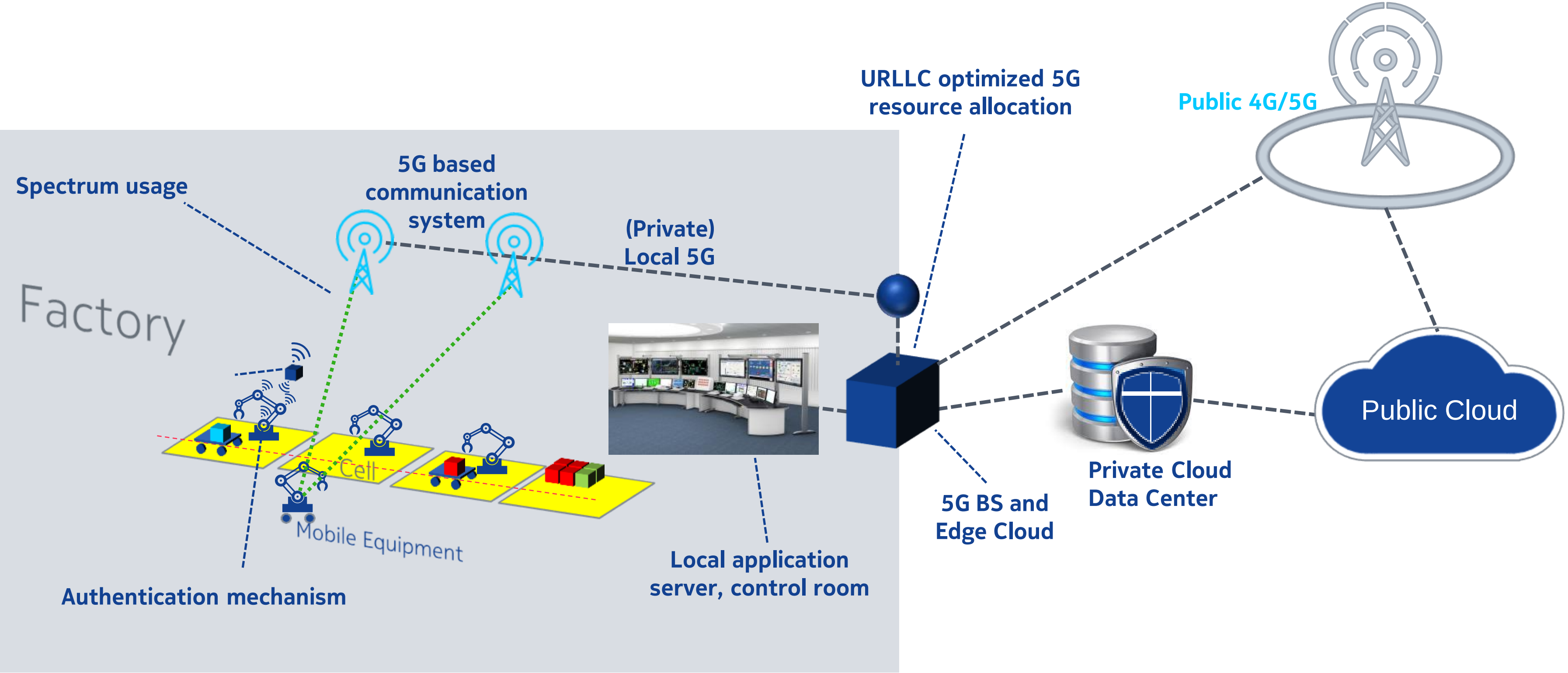
# Example deployment scenario for industrial communication



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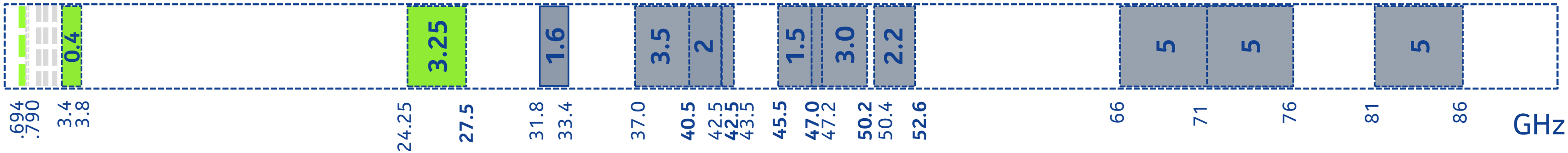
# 5G Pioneer Bands in Europe: 700 MHz, 3.4-3.8 GHz, 24.25-27.5 GHz

## 5G needs spectrum below 1 GHz, in between 1 and 6 GHz, and above 6 GHz




694-790 MHz
Wide area coverage
for mMTC* and URLLC*

700 MHz band targeted to become available latest 2020 in Europe
Re-use of existing 900/800 MHz grids allows for timely coverage
Pre-condition for new services like connected cars, smart sensors etc.

3.4-3.8 GHz
Urban coverage
for initial eMBB*

C-band is sparsely used in most parts Europe
Re-use of existing 1800/2100/2600 MHz grids
Carrier bandwidths of 100 MHz + allow for single Gbps data rates

24.25-27.5 GHz
Typically hot spots
of true eMBB*

Common tuning range with 28 GHz range (US, Korea) is expected to allow for common economies of scale.
Carrier bandwidths of several 100 MHz allow double digit Gbps data rates

* mMTC: massive machine type communication, URLLC: ultra reliable low latency communication, eMBB: enhanced mobile broadband

# Spectrum usage models: tools to match the needs

Need to cater for harmonization and global standards for economies of scale

**Mainstream approach, auctions of cleared spectrum**

**Exclusive use**
ensures
Quality of Service

**7/8/900, 18/21/2600, 3.5 GHz (EU), 26 GHz …**

**Complementary license model e.g. Licensed Shared Access**

**Exclusive shared use**
*exclusive* use on a *shared* and *binary* basis in time, location, and/or frequency with incumbent (government, defense etc.)
predictable Quality of Service

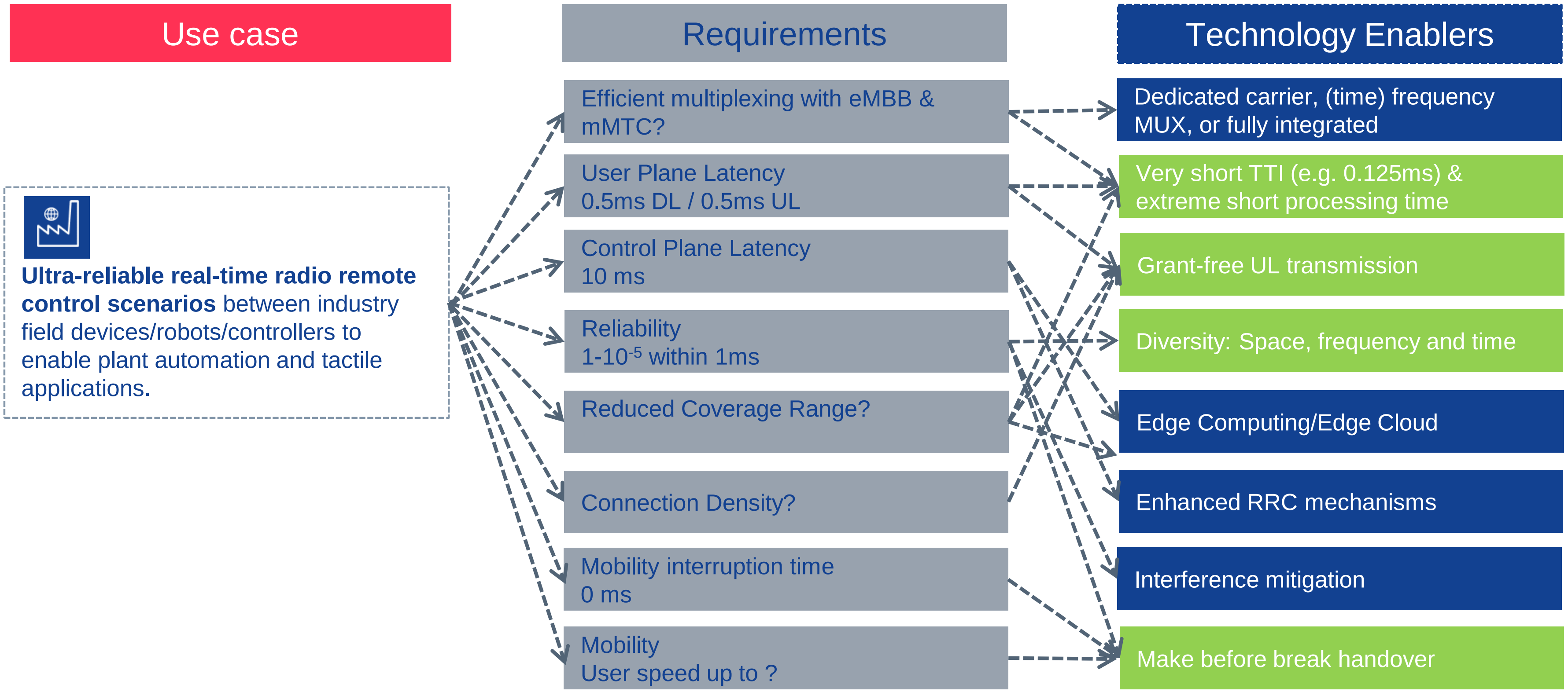
**2.3 GHz (EU), 3.5 GHz (US), …**

**Shared approach unlicensed (Wi-Fi, LTE-U, …)**

**Shared use**
unpredictable
Quality of Service

**2.4, 5 GHz, …**

# 5G URLLC requirements and Enablers



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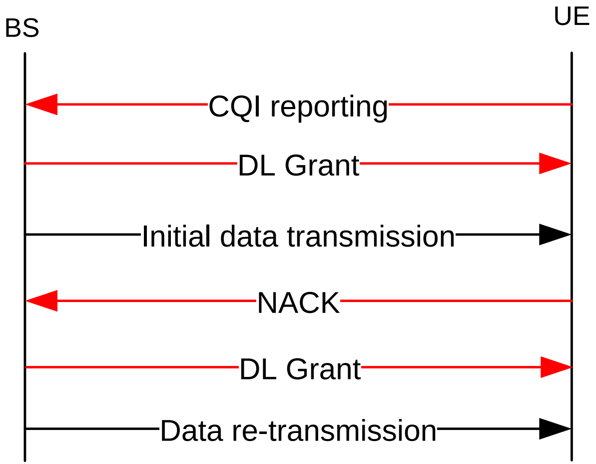
# Control channel reliability requirements for URLLC

- Source of errors:
  - CQI reporting
  - DL resource grant error($\varepsilon_{RG}$)
  - ACK/NACK error($\varepsilon_{NACK}$)
  - Data transmission errors($P_1, P_2, P_{1,2}$)




  - $P_{success} = 1 - \varepsilon =$

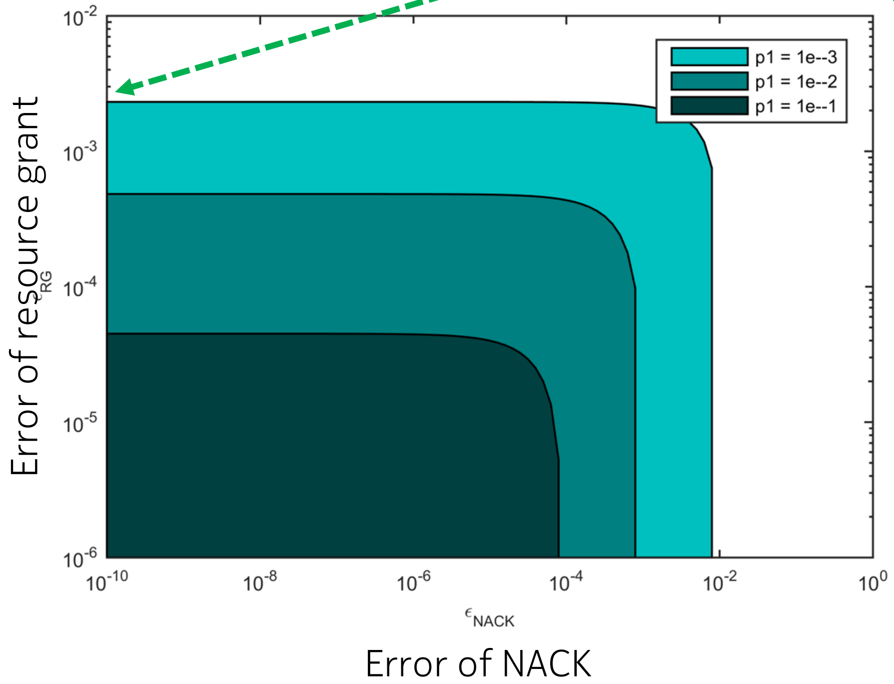
$$(1-\varepsilon_{RG})(1-P_1) + (1-\varepsilon_{RG})\,(1-P_1)\,(1-\varepsilon_{NACK})\,\left(1-\,P_{1,2}\right) + \varepsilon_{RG}\,(1-\varepsilon_{RG})\,(1-P_2)$$

**Error due to decoding scheduling grant**

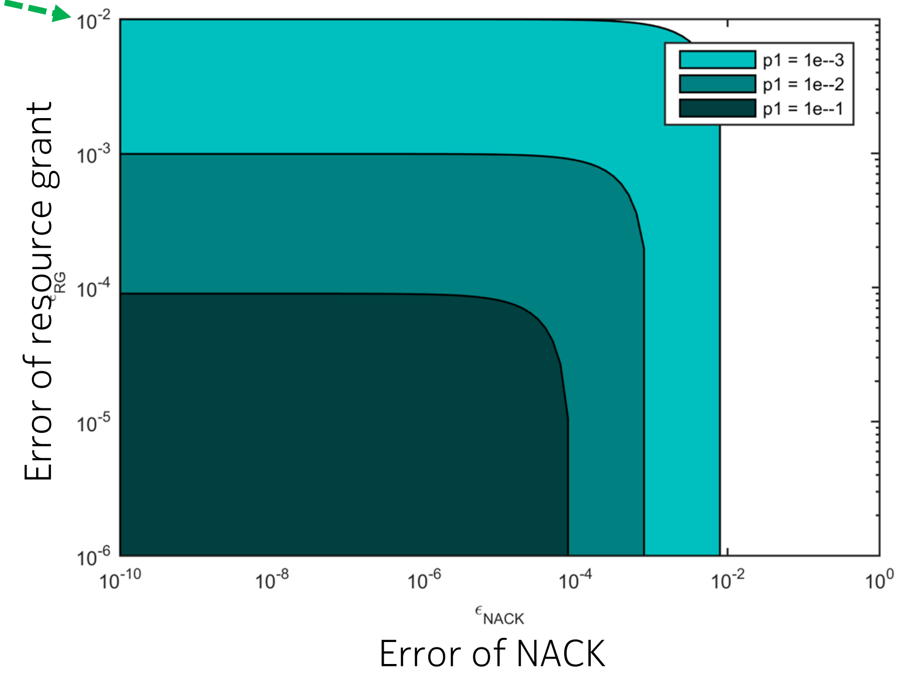
***Note: with semi-persitent scheduling (SPS), DL grant error for the first transmission can be removed.**

# Control channel reliability requirements for URLLC

SPS can relax the control channel reliability requirement




Dynamic scheduling




Semi-static scheduling

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# Signal Quality Outage Analysis in a Realistic Macro Network

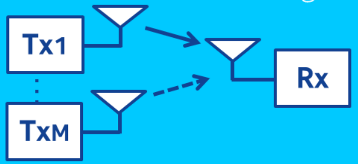
## Microscopic Diversity

MRC of the multiple Tx/Rx antenna paths to decrease the probability of large fades.


↑ **Diversity order** ↑ **Received power**

## Macroscopic Diversity

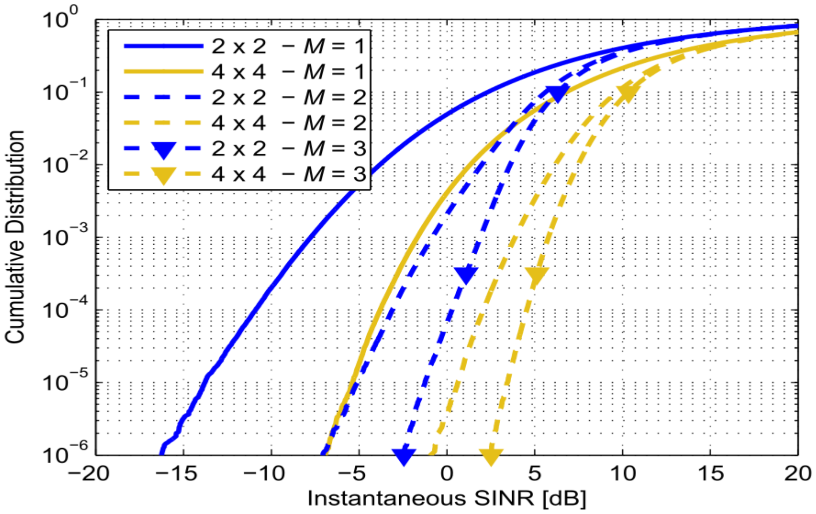
Simultaneous transmission of spatially-separated nodes with soft-combining at the receiver.




↑ **Diversity and redundancy order**

## Sufficient SINR outage is of significant importance for URLLC:

- Macro and micro diversity provide large gains.
- The gains from interference cancellation are not so attractive since it does not improve the diversity order of the distribution.
- 4x4 MIMO configuration with 3 macroscopic links achieves the target.



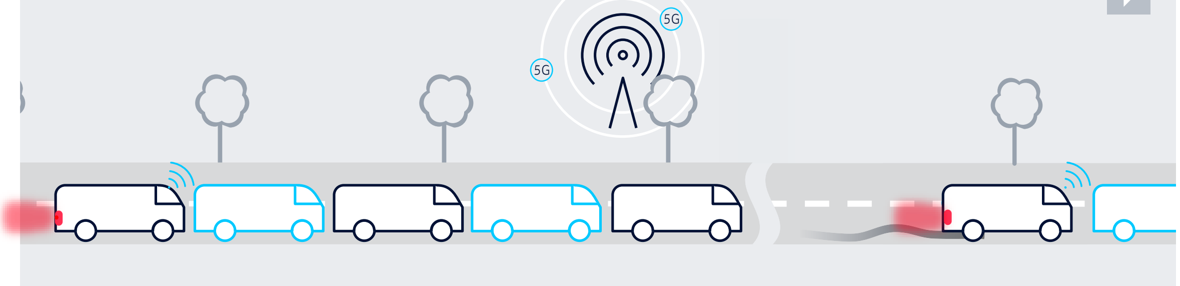

SINR performance with different levels of macroscopic diversity. M refers to the macroscopic diversity order.

# 5G truck platooning – automatically controlled convoys

## Cutting costs of transportation, increasing safety

### Efficient road usage, less congestion, higher safety



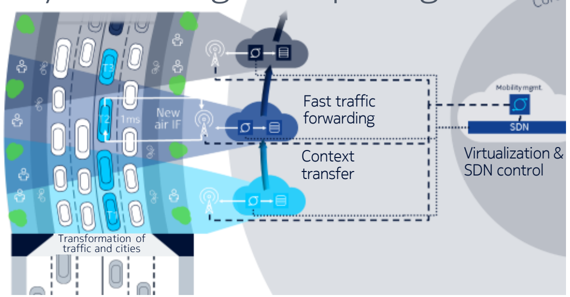

### Ultra-low latency
<1ms to avoid oscillation at tightly-knit convoy

### Enabling platoons >4
not feasible with truck-to-truck

### Inherent system security
by dedicated network slices

5G Advantage

### Dynamic edge computing




$ Business case

| | |
|---|---|
| Fuel savings lead truck<br>4% | Driver-truck-ratio<br>1 to 4 |
| Fuel savings following trucks<br>10% | Operator break even*<br>6 years |

### Revenue* in transportation
E2e fleet management service

### Society benefits
Efficient infrastructure use

*) CSP revenue calculated with 12.5% of cost savings for positive biz case

Benefits

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# A strong momentum towards connected automated driving

## 5G Automotive Association

Develop, test and promote communications solutions and accelerate their commercial availability and global market penetration

## MEC-View project

Multi-access Edge Computing (MEC) based recognition of objects using sensors installed at road side infrastructure to support automated driving

## Car2MEC project

Verify and evaluate MEC based low latency use cases and a distributed geoservice at the A9 motorway testbed near Munich

## European Automotive - Telecom Alliance

The main goal …is to promote the wider deployment of connected and automated driving in Europe

## 5GCAR project

5G system architecture to optimize end-to-end network connectivity for highly reliable and low-latency V2X services

## 5G NetMobil project

"Tactile internet"- architecture and principles for tactile connected driving to support low latencies and high reliability

# 5GXcast

- Multicast / Broadcast: Key enabler for several 5G use cases

## MULTIMEDIA & ENTERTAINMENT

UHDTV delivery

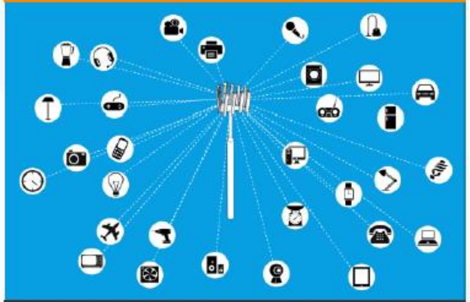
VR and AR

## CONNECTED AUTOMOTIVE

Infotainment

Safety

## INTERNET OF THINGS



Software Updates

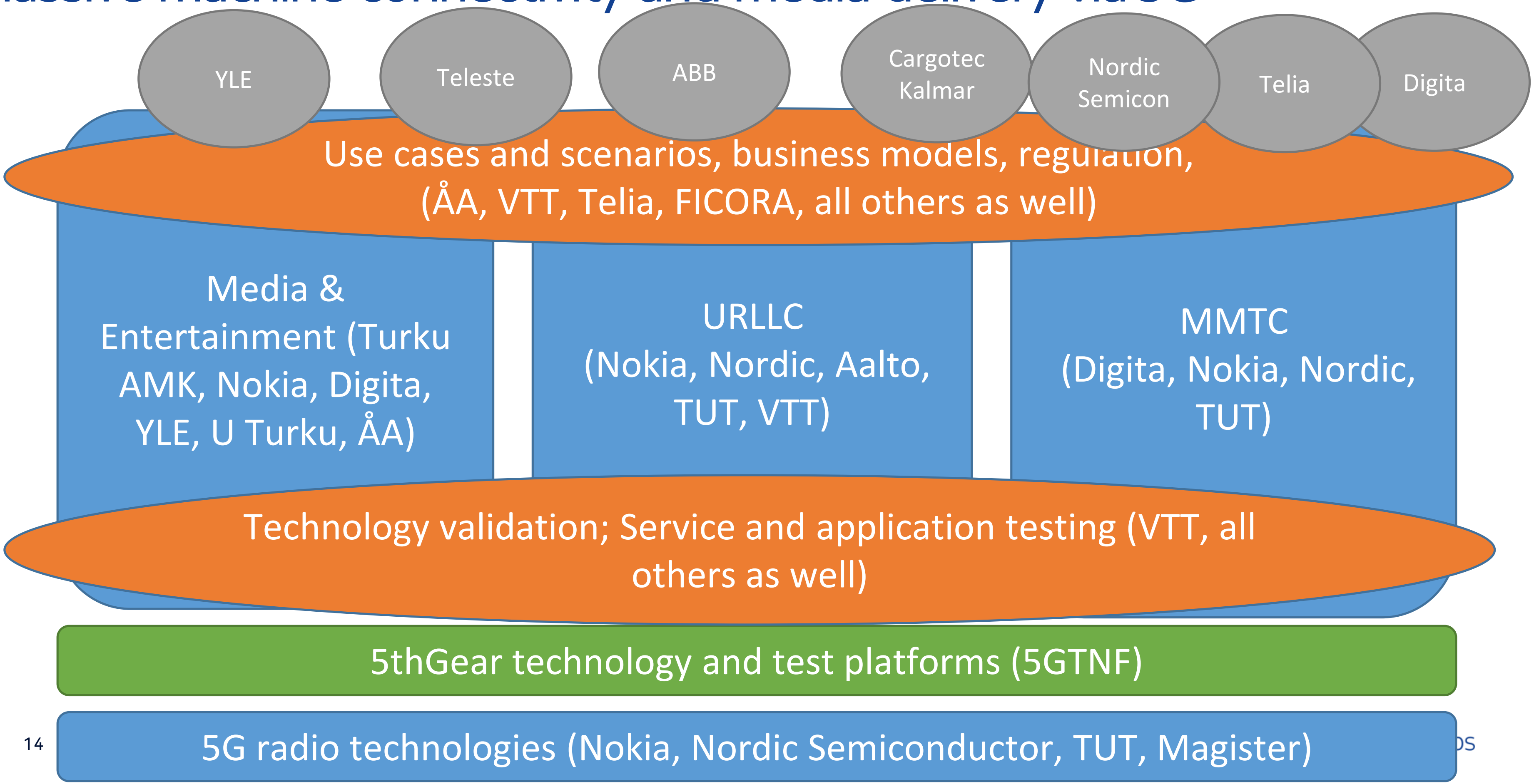
Common Control Messages

## PUBLIC WARNING AND SAFETY

Public Warning System

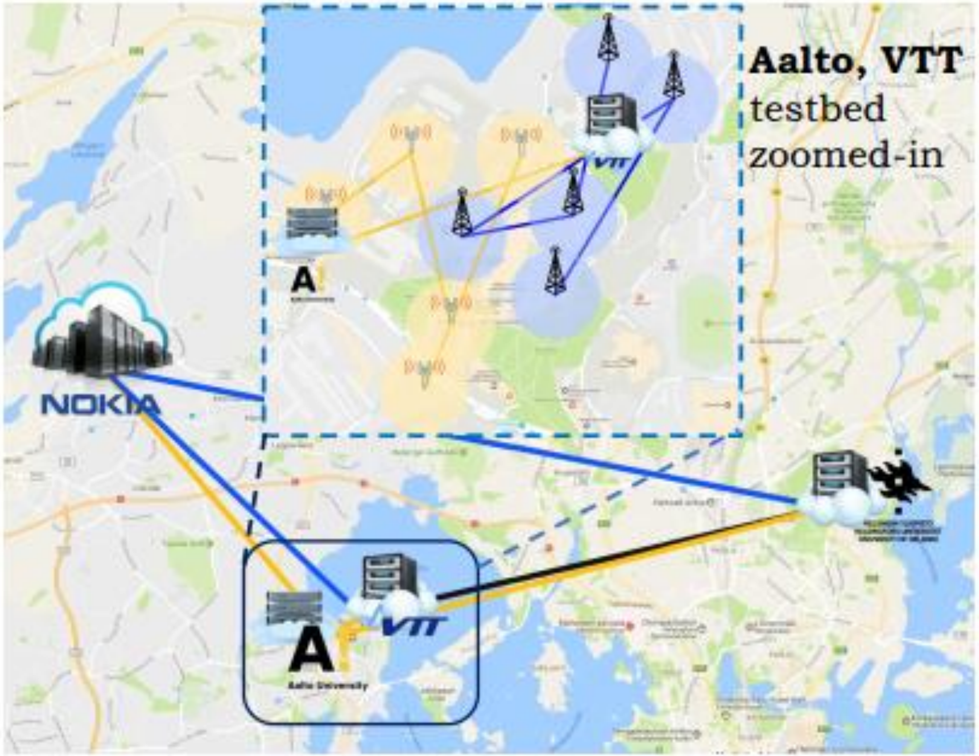
Tsunami and Earthquake Alert

# WIVE increases competitiveness of automated transport, smart grids, massive machine connectivity and media delivery via 5G



# 5G service and application testing for verticals

- Goal to test and experiment new vertical services in 4G/5G in realistic environments.
- Focus on URLLC, mMTC, and media content delivery.
- Vertical services implemented on top of 5G Test Networks of Finland (5GTNF) platforms.
- Aim at speeding up the roll out of new vertical services in 5G.




**TAKE-5 test network is one of the 5GTNF testbeds.**

# TUT and Nokia: optimal 5G waveforms

- CP-OFDM is the baseline 5G New Radio (NR) radio access waveform in both DL and UL, at least up to 40 GHz (TR38.802)
- However, to support efficient multiplexing of different services with different radio access numerologies (e.g. subcarrier spacing) inside one NR carrier, or asynchronous UL, different filtered CP-OFDM waveforms are of interest
  - Additional band-limitation processing, especially in base-stations, over selected parts of the transmit and receive spectrum at digital baseband
- TUT & Nokia have developed a specific processing solution, called fast convolution based subband filtered CP-OFDM (FC-F-OFDM)
  - Provides superior complexity vs. performance tradeoff for efficiently multiplexing signals with different SC spacing's (SCS) in frequency domain
  - Allows to maximize the number of allocated PRBs per given subband
  - Minimal overhead (maximum efficiency) in multiplexing different SCS

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