5G NPN for Process Monitoring

Niels König, Fraunhofer IPT

EuCNC & 6G Summit, 8 June 2021

The 5G-SMART project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 857008.
5G for Smart Manufacturing

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Project coordination: Ericsson, Technical coordination: ABB, Project start: June 2019, Project duration: 30 months, Contact: www.5gsmart.eu, coordination@5gsmart.eu

Integrate 5G in the manufacturing ecosystem

- Factory 5G deployment:
  - Business models
  - Business impact analysis
  - New manufacturing use cases
  - Evaluation of smart factory deployment options

Demonstrate, evaluate and validate 5G capabilities in three 5G-enabled industry field trials across Europe

- Time-critical, reliable process optimization and remote control from the cloud
- Non-time critical, in-factory communication for large number of devices, massive information exchange
- Channel measurements and electromagnetic compatibility (EMC) testing

Enhance 5G for smart manufacturing

- Study and propose:
  - New 5G features for, e.g., time-sync and TSN/industrial LAN integration
  - Factory 5G network architectures
  - Improved inter-cloud coordination
  - Industrial-centric framework for network management and configuration

Factory 5G deployment:

- Ericsson smart factory Kista
- IPT Fraunhofer shop floor Aachen
- Bosch factory Reutlingen

5G for enhanced industrial robotics applications

- Time-critical, reliable process optimization and remote control from the cloud
- Non-time critical, in-factory communication for large number of devices, massive information exchange
- Channel measurements and electromagnetic compatibility (EMC) testing

5G for enhanced industrial manufacturing processes

- Time-critical, reliable process optimization and remote control from the cloud
- Non-time critical, in-factory communication for large number of devices, massive information exchange
- Channel measurements and electromagnetic compatibility (EMC) testing

5G for enhanced semiconductor factory automation

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- Channel measurements and electromagnetic compatibility (EMC) testing
Production research from the cutting edge to 5G

The dividends sit on the cutting edge of the steel, but the speed of these cutting edges is a function of the machines that move them.

Georg Schlesinger, 1911

- Resolving fields of tension: Quality vs. Time vs. Costs
- Flexible production for both mass production and »mass customization«
- Decreasing tolerances collide with physical limits of manufacturing processes
- Strategy: Cognitive, self-optimizing processes
  - Process and product monitoring
  - Continuous process optimization (e.g., through AI)
- Greater networking and use of data in production

Source: Institut für Werkzeugmaschinen und Fabrikbetrieb, TU Berlin
Use Case – 5-axis milling of BLISKs

Pratt & Whitney
PW1100G Engine

BLISK = Blade integrated disc
Use Case – 5-axis milling of BLISKs

Rotation

FFT ICTM B3 & Excitation Freq. \( (v_c = 287 \text{ m/min}) \)

Amplitude \( [\mu m] \)

Frequency \( [\text{Hz}] \):

1000  2000  3000  4000  5000  6000  7000  8000  9000  10000

April 29, 2021
Use Case – 5-axis milling of BLISKs
5G multi-sensor platform for Monitoring of Workpieces & Machines

- Outboard sensors
  - Accelerometer
  - Temperature sensor
  - Strain gauge
- Onboard sensors
  - Accelerometer
  - Temperature sensor
  - Humidity sensor
  - Gyroscope
- STM32 as processing core
- u-blox SARA R5 for time sync
- 5G communication module (via Ethernet)
- Powerbank ready

Ethernet

SARA R5
SIM
STM32
SPI (3x)
5G multi-sensor platform use case requirements

Shop Floor – Process and Condition Monitoring

5G base station and 5G core

Digital twin
@Database
Data processing
@Virtual machines

Preprocessing
Sensor Configuration

GEM-VM

Factory Cloud

Hardware Gateway

NC
PLC

Versatile multi-sensor platform @machine tools

Versatile multi-sensor platform @workpieces

Sync for all data sources

A) Measurement data streams

B) Configuration data

C) M2M communication

wireless

wired
## 5G multi-sensor platform use case requirements

### Parameter sets for use case scenario ‘workpiece and process monitoring’

<table>
<thead>
<tr>
<th>Measurand</th>
<th>Frequency</th>
<th>Latency</th>
<th>Reliability</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements on external quantities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceleration</td>
<td>≤ 50 kHz</td>
<td>&lt; 10 ms</td>
<td>high</td>
<td>Process monitoring of the workpiece</td>
</tr>
<tr>
<td>Sound</td>
<td>≤ 50 kHz</td>
<td>&lt; 10 ms</td>
<td>medium</td>
<td>Scratching/Screaming</td>
</tr>
<tr>
<td>Temperature</td>
<td>≤ 100 Hz</td>
<td>&lt; 100 ms</td>
<td>medium</td>
<td>Thermal behavior</td>
</tr>
<tr>
<td>3-DOF Force</td>
<td>≤ 30 kHz</td>
<td>&lt; 10 ms</td>
<td>high</td>
<td>Mechanical load of clamping or machine</td>
</tr>
<tr>
<td>Torque</td>
<td>≤ 30 kHz</td>
<td>&lt; 10 ms</td>
<td>high</td>
<td>Cutting force</td>
</tr>
<tr>
<td>Strain</td>
<td>≤ 2 kHz</td>
<td>&lt; 10 ms</td>
<td>high</td>
<td>Cutting force</td>
</tr>
<tr>
<td>Requirements on positioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>≤ 10 Hz</td>
<td>&lt; 100 ms</td>
<td>low</td>
<td>Relative orientation, workpiece tracing, intralogistics</td>
</tr>
</tbody>
</table>

### Communication stream

<table>
<thead>
<tr>
<th>Measurand</th>
<th>Message size [Byte]</th>
<th>Transfer interval, target value (ms)</th>
<th>UE speed</th>
<th># UEs</th>
<th>Service area</th>
<th>Communication attributes</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement data</td>
<td>1024</td>
<td>15</td>
<td>&lt;0.5 m/s</td>
<td>&gt;10</td>
<td>15m²</td>
<td>Periodic, Non-deterministic, Asymmetrical</td>
<td>Time synch &lt;0.1 ms</td>
</tr>
<tr>
<td>Configuration data</td>
<td>1</td>
<td>&gt;1.000</td>
<td>N/A</td>
<td>&gt;10</td>
<td>15m²</td>
<td>Aperiodic, Non-deterministic, Asymmetrical</td>
<td></td>
</tr>
</tbody>
</table>

### Parameter sets for use case scenario ‘machine condition monitoring’

<table>
<thead>
<tr>
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### Communication stream

<table>
<thead>
<tr>
<th>Measurand</th>
<th>Communication service availability, target value</th>
<th>End-to-end latency, maximum</th>
<th>Service bit rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement data</td>
<td>≥ 99.999%</td>
<td>&lt;10 ms</td>
<td>Depending on sensor configuration</td>
</tr>
<tr>
<td>Configuration data</td>
<td>≥ 99.9%</td>
<td>Not relevant</td>
<td>Low</td>
</tr>
</tbody>
</table>
5G NPN setup at the 5G-Industry Campus Europe

- 5G-NSA and 5G-SA network at Fraunhofer IPT in operation since May 2020
  - 5G Radio running at 3.7 – 3.8 GHz (100 MHz TDD)
  - 4G Radio running at 2.3 – 2.32 GHz (20 MHz TDD)
  - Covered area: shopfloor of 3000 m² with multiple machine tools

- Latency (one way) < 10 ms achieved
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- Trial site is part of 5G-Industry Campus Europe
  - 5G-NSA indoor coverage for 4 shopfloors with total area of 7000 m²
  - 5G-NSA outdoor coverage with ~1 km² on the RWTH Aachen Campus
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- Each indoor network has a local breakout (Must-have for production!)
Conclusion

✓ Process monitoring use cases provide requirements towards 5G
✓ URLLC is in focus of many industrial applications
✓ Performance requirements can already be met with 5G NPN
✓ 5G-Industry Campus Europe is a large-scale industrial 5G testbed for testing multiple application of 5G in production
5G-SMART Grant Agreement No. 857008

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