Funksystem für industrielle Anwendungen – HiFlecs

Zukunft der Netze
Lübeck, 28.-29. September 2017

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TZI – Universität Bremen
Industry 4.0 Vision - highly flexible, work-sharing, geographically distributed production

- **Horizontal Integration**
  - Collaborative manufacturing networks

- **Vertical Integration**
  - Machines communicate with each other

Source: HP
Vertical Integration: Industrial Radio Requirements

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing</th>
<th>Process Automation</th>
<th>Augmented Reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency</td>
<td>&lt; 1ms</td>
<td>100 ms</td>
<td>10 ms</td>
</tr>
<tr>
<td>Jitter</td>
<td>&lt; 1us</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Reliability (PER)</td>
<td>1e-9</td>
<td>1e-5</td>
<td>1e-5</td>
</tr>
<tr>
<td>Data Rate</td>
<td>Kbit/s – Mbit/s</td>
<td>Kbit/s</td>
<td>Mbit/s-Gbit/s</td>
</tr>
<tr>
<td>Packet size</td>
<td>short</td>
<td>short</td>
<td>long</td>
</tr>
<tr>
<td>Range</td>
<td>10m - 100 m</td>
<td>100 m- 1km</td>
<td>10m - 100m</td>
</tr>
<tr>
<td>Massive communications</td>
<td>middle</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Determinism</td>
<td>strong</td>
<td>middle</td>
<td>no</td>
</tr>
</tbody>
</table>

Today's wireless technologies fail to meet requirements.
Different BMBF Research Programmes

„reliable wireless communication in industry“
Overview of research projects

- 8 autonomous projects for wireless communication
- Simultaneous accompanying research project
- Research grant ~ 40 Mio. €
- Very diverse composition of consortia:
  - Industrial SMEs and corporations
  - Relevant research institutions
  - Renowned Applied Universities/Universities
HiFlecs: Design of an Industrial Radio System

„Hochperformante, sichere Funktechnologien und deren Systemintegration in zukünftige industrielle Closed-Loop Automatisierungslösungen“

- Extremely low latency (< 1ms)
- Extremely high availability and reliability

Coordination:
Prof. Dr. Armin Dekorsy, University of Bremen
Requirement Profiles - HiFlecs

Profile A
- Driverless transport of large goods
- Marriage in vehicle assembly
- Shuttle vehicles in packaging machines

Profile B
- Industrial plant with decentralized drive technology
- Robot cell with product feed and removal of the peripheral axes
- Storage and retrieval machines or shuttle systems

Profile C
- High bay warehouse
- Robot cells with interchangeable tools

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission time [ms]</td>
<td>0.15</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>Update time [ms]</td>
<td>5.00</td>
<td>1.00</td>
<td>1.50</td>
</tr>
<tr>
<td>Data length [Bit]</td>
<td>1024</td>
<td>400</td>
<td>1600</td>
</tr>
<tr>
<td>Packet Loss Rate</td>
<td>$5 \times 10^{-7}$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Consecutive Losses</td>
<td>2</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>No. of devices</td>
<td>32</td>
<td>1000</td>
<td>100</td>
</tr>
</tbody>
</table>
Core Technologies

Adaptive PHY/MAC technologies
- Scalable latency and resource usage
- Use of multicast/broadcast-properties
- Dynamically reconfigurable hardware

Integrated information security
- Plug & Trust
- Physical layer security
- Latency optimized encryption

Coexistence-Management
- Cognitive spectrum sensing
- Self-regulated coexistence-management

Mapping of distributed application functionality
- Interface between application and radio
- Dynamic, distributed object model

HiFlecs Radio System
System Architecture, Interfaces, and Channels
Coexistence Management

**Challenge:**
- Fast and reliable classification of active wireless systems in a shared frequencies

**Approach:**
- Compressed Sensing based spectrum sensing
- Multi-layer convolutional neural network
  - 100% classification down to -5 dB SNR
Air Interface

**Challenge:** Treating real-time and best-effort traffic efficiently

**Desirable:** Inherent Broadcast/Multicast support

**Idea:** Utilization of Hybrid MAC technique, i.e. combination of contention and reservation based MAC techniques

Quasi Orthogonal Spreading Sequences (QOSS)  
Orthogonal Variable Spreading Factor (OVSF)
HiFlecs - New Waveform

Challenge
Problematic scenarios (OFDM):
- Inefficient spectrum usages (High Out-of-band Emissions)
- Low cost device with low-end power amplifiers (High PAPR)
- Large CP overhead under channels with large delay spread

Approach
Generalized Frequency Division Multiplexing
- Non-orthogonal

GFDM Evaluation

Low Out-of-Band Emissions
- Beneficial for higher order modulation schemes
  - Higher spectral efficiency
    - Lower inter-channel interference
    - More usable spectrum
- Low PAPR

Quelle: proWiLAN
Latency optimized SDR Baseband Implementation

- GFDM waveform
  - Low-complexity GFDM modulator/demodulator
  - Improved Schmidl&Cox synchronization

- Polar Codes
  - State-of-the-Art high throughput implementation
Encryption and Message Authentication

- Tight integration of encryption (AES) and authentication (CMAC) with baseband
- Low Latency Cipher Implementation

Physical-Layer Security based message authentication

- Avoids CMAC overhead, leads to reduced latency
- Promising authentication accuracy
Transmodul line of a packing machine

- Wireless data transmission between control module (SPS) and transport modules by HiFlecs
- Synchronization with delta-robot and linear measurement system via HiFlecs (cycle time 1ms)
HiFlecs within existing infrastructure

ZDKI

Extension / replacement of wired systems
ZDKI and 5G – our own view

Task: Extension / replacement of wired systems
TACNET 4.0
Hochzuverlässige und echtzeitfähige
5G Vernetzung für Industrie 4.0

5G Vernetzung für die Digitalisierung der Industrie
Produktion, Robotik, Internet der Dinge

Volumen
10,33 Mio. EUR
(60% Förderanteil)

Laufzeit
04/2017 - 03/2020

Verbundkoordinatoren
DFKI, Kaiserslautern
Prof. Dr. Hans D. Schotten
und
Nokia Bell Labs, München
Dr. Peter Rost
Thank you!