KUKA
Requirements for Time Sensitive Networks in Manufacturing

Why right now?
Because Industry 4.0 needs it!

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Senior Developer System Engineering
Our current product portfolio
Market position KUKA Roboter (sold Robots 2012)

1 1 2

Germany  Europe  World
KUKA AG - Strategy

Integrated software solutions and modular product platform

Robotic expertise  
Application and industry expertise  
Systems and process expertise  
Systems and process expertise

Global market access

1) In planning
Industrial Internet

- IIC covers five industries
  - Healthcare
  - Transportation
  - Energy & Utilities
  - Public Sector
  - Manufacturing

- There will not be only one M2M protocol over several industries

- Industry 4.0 covers only one industry: Industrial Automation
Industry 4.0: Industrial Automation for Manufacturing

Manufacturing

- Process Manufacturing
  - Oil
  - Natural Gas
  - Pharmaceutical
  - Food & Beverage
  - Chemical
  - Paints
  - Textiles
  - …

- Hybrid
  - Oil in Cans
  - Natural Gas in Bottles
  - Pharmaceutical in Pills
  - Food in Portions, Beverage in Bottles
  - Paints in Cans
  - …

- Discrete Manufacturing
  - Cans, Bottles
  - Cars, Trucks, Trains, Ships, Airplanes
  - Electronic Devices
    - Smart Phones
    - TV-Sets
    - Computers
  - Furniture
  - Toys
  - …
Why Industry 4.0? Challenges of the future

- In 2025 there are ~8 Billion people on earth, >half of them in the “Consumer-Class”
- People are getting older, in Germany we are getting less
- Consequences for Germany: Keep automated manufacturing in Germany, export products, export manufacturing technologies and manufacturing know how
- Robots and other machines as assistant systems for humans (Human Robot Coop.)
- Information sources and decision helpers through IT-systems like Smart Devices
Why Industry 4.0? Countries must Revitalize Manufacturing
What is Industry 4.0?

1. Industrial Revolution
   durch Einführung
   mechanischer Produktionsanlagen mithilfe von Wasser- und Dampfkraft

   - Ende: 18. Jhdt

2. Industrial Revolution
   durch Einführung
   arbeitsteiliger Massenproduktion mithilfe von elektrischer Energie

   - Beginn: 20. Jhdt

3. Industrial Revolution
   durch Einsatz von Elektronik und IT zur weiteren Automatisierung der Produktion

   - Beginn 70er Jahre: 20. Jhdt

4. Industrial Revolution
   auf Basis von Cyber-Physical Systems

   - Ende: heute

Mechatronic

Mass Production

Steam Power

Erstes Fließband, Schlachthöfe von Cincinnati 1870

Erster mechanischer Webstuhl 1784

Erste Speicherprogrammierbare Steuerung (SPS), Modicon 084 1969

Cyber Physical Systems

IEEE 802.1 TSN Standard Meeting
KUKA Roboter GmbH | R&D | Munz | 22.05.2015 | Seite 10

www.kuka-robotics.com

Quelle: DFKI 2011
**Industry 4.0 is the thorough Digitalization of the Manufacturing Industry**

“A fundamental new rule for business is that the Internet changes everything.”

Bill Gates, 1999

- …but in 1999 this only addressed the internet of people!
- The Internet of Things will change much more!
- I.e. Manufacturing
...receives the Industrie 4.0 realization suggestions paper from acatech
Industry 4.0 was invented in Germany

- Industry 4.0 is one of ten „Future Projects” of the German Government
  - 200 Mio. € grants
  - Controlled by the German Government
    - Minister for Economic Affairs & Energy Siegmar Gabriel
    - Minister for Education & Research Johanna Wanka
  - I am a vice chairman in the “Reference Architecture and Standardization” working group
- OPC UA is agreed as the standard protocol for M2M communication by the steering committee
- After German cars and German beer, Industry 4.0 is another perfect German export article...

Taiwan / China

- Terry Gou defines Industry 4.0 as:
  - Cloud computing
  - Big data
  - Mobile devices
  - Robots

- Employees related:
  - smart living
  - smart work networks

Taiwan

- This picture is used by the Taiwanese government to push the local enterprise to get involved in Industry 4.0 as fast as possible.

http://www.stockfeel.com.tw/%e5%b7%a5%e6%a5%ad4-0%e4%b8%8d%e5%90%8c%e6%96%bc%e8%b1%90%e7%94%b0%e7%94%9f%e7%94%a2%e6%96%b9%e5%bc%8f/
Japan

- **Robot Revolution Initiative**
  - Ministry of Economy, Trade and Industry (METI)

- **Industrial Value Chain Initiative**
  - Omron, Toyota, Denso, Fujitsu, Hitachi, Panasonic, Mitsubishi

China

- “Made in China” 2025
  - Ministry of Industry and Information Technology (MIIT)

http://www.miit.gov.cn/n11293472/n11293832/n11293907/n11368223/16489095.html
President Obama launched the „Nationwide Network for Manufacturing Innovation (NNMI)“
http://manufacturing.gov/welcome.html

On December 16, 2014, the President signed the “Revitalize American Manufacturing Act” into law

Cincinnati Mayor, John Carnely, signed a proclamation to state "Cincinnati to be Industry 4.0 Demonstration City"

Planned cooperation between the Industrial Internet Consortium (IIC) and Industry 4.0 Platform
  ▪ KUKA to join IIC
Industry 4.0 and Robots

- In many “Industry 4.0” pictures there are industrial robots carrying manufacturing processes

- The number of combinations robot / tool is getting more and more dynamic
  1. One robot changes process tools by automatic tool changer
  2. Mobile robots

- The same robot can carry a lot of different tools
- ➔ Robots are the most flexible automation devices
KUKA industrial robots are „partly completed machines“

- EU Machinery Directive 2006/42/EG:
  - …are not allowed to have CE marking
  - …must have assembly instructions and a declaration of incorporation
- Have „Hands“, but no Fingers…
  - …this makes them very flexible
  - …can grab several tools directly
Integration of process tools into robots

<table>
<thead>
<tr>
<th>Robot</th>
<th>Welding</th>
<th>Gluing</th>
<th>Screwing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td></td>
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</tr>
</tbody>
</table>

| Controllers |

IEEE 802.1 TSN Standard Meeting
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www.kuka-robotics.com
Integration of process tools into robots and robots into cells or machines

- There are at least 50+ other manufacturing processes a robot can carry
  - Gripping, Sawing, Drilling, Laser, Molding, Plasma Cutting, Water Cutting, Rivet, Trimming, Seam, Deburring, Grinding, Polishing, Painting…
- Each process comes with its own controller (PLC, embedded system)
- The robot controller must be able to communicate with all the process controllers dynamically (tool changer) and ad hoc (mobile)
- Such “process robots” are going to be integrated into “higher” systems:
  - Cells, Machines (PLCs, embedded controllers) ➔ Lines ➔ Halls ➔ Plants

Example:
- $1 \times 10 \times 5 \times 20 \times (6+6) \times 10 = 120,000$
  - Sensors/Actuators on proprietary field busses
- $1 \times 10 \times 5 \times 20 \times (6+6) = 12,000$
  - Controllers on OPC UA and TSN
Integration of process tools into robots

Robot Controller

Process Tool

Programmed

Robot Application in Robot Language

Handshake via I/O-Bits

Communication

Communication: Fieldbus

Configured

Handshake via I/O-Bits

Robots

Processes

White = done by the system integrator

Colour = done by device manufacturers
Integration of robots into cells or machines

- **Programmed**: done by the system integrator
- **Configured**: done by device manufacturers

**Communication**:
- Machine Application in Machine Language
- Robot Application in Robot Language

**Handshake via I/O-Bits**

**Communication: Fieldbus**
Example: EUROMAP 67

- Standardized Interface between injection molding machines and robots
  
  [Link](http://www.euromap.org/files/EU%2067_Ver_1.9_Aug2013.pdf)

  This EUROMAP recommendation defines the connection between the injection moulding machine and the handling device / robot. This is intended to provide interchangeability.

<table>
<thead>
<tr>
<th>DO0 : MAC: Mould Area Control (A3/C3)</th>
<th>DI0 : x</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO1 : A6 : Enable mould closure</td>
<td>DI1 : ZA6 : Mould closed</td>
</tr>
<tr>
<td>DO2 : A7 : Enable full mould opening</td>
<td>DI2 : ZA7 : Mould open position</td>
</tr>
<tr>
<td>DO4 : B3 : Enable ejector back</td>
<td>DI4 : ZB3 : Ejector back position</td>
</tr>
<tr>
<td>DO5 : B4 : Enable ejector forward</td>
<td>DI5 : ZB4 : Ejector forward position</td>
</tr>
<tr>
<td>DO6 : B5 : Enable core pullers 1 to 1</td>
<td>DI6 : x</td>
</tr>
<tr>
<td>DO7 : B6 : Enable core pullers 1 to 2</td>
<td>DI7 : x</td>
</tr>
</tbody>
</table>

- Bits based communication is by far too limited to fulfill the requirements of the future
- Bits can not take or return parameters
- Both sides must be programmed or at least configured
- Fieldbus communication must be configured
The Industry 4.0 Solution

Robotic as a Service®

Public Cloud

Private Cloud

Machine Controller
- SOA Server Offering “Machine Services”
- Semantic Self Desc.
- Communication

Robot Controller
- SOA Server offering “Movement” Services
- Semantic Self Desc.
- Communication

Process Controller
- SOA Server Offering “Welding” Services
- Semantic Self Desc.
- Communication

Programmed

Edge Cloud Controller

Public Cloud

Private Cloud

Machine Controller
- SOA Server Offering “Machine Services”
- Semantic Self Desc.
- Communication

Robot Controller
- SOA Server offering “Movement” Services
- Semantic Self Desc.
- Communication

Process Controller
- SOA Server Offering “Welding” Services
- Semantic Self Desc.
- Communication

Communication: OPC UA, TSN, Ethernet

HMIs in Smart Devices “anywhere”

White = done by the system integrator

Colour = done by device manufacturers
The enhanced communication stack of Industry 4.0

Normen sind ein Schlüsselfaktor für den Erfolg von Industrie 4.0

- eCl@ss
- ProStep

+ Pub/Sub
+ TSN
Standards are key to Industrie 4.0

- The secret of success: Interoperability!
- All Industrie 4.0 companies should agree on only one standard per task
OPC Foundation is going to start a TSN Working group on June, 8th 2015

Join the Effort

Invitation to participate in OPC UA Sub-working groups for Pub/Sub prototyping and Time Sensitive Networking

Ken, Tue, Jun 2, 10:56 AM
Show Details

OPC UA Working Group Members,

Over the last two face to face meetings the OPC UA working group began concrete work for the extension of the OPC Unified Architecture specifications with a publish-subscribe communication model. Since then, several new members joined the OPC UA working group and many expressed their interest in prototyping. In addition a proposal was accepted to evaluate the combination of the UDP secure multicast part of the publish-subscribe communication model with the upcoming Ethernet switch.

To keep working groups manageable and to have go evaluation, the subgroups will work closely with the OP Pub/Sub prototyping sub-group tasks:

- Review of OPC UA Publish-Subscribe specification
- Prototyping of OPC UA Publish-Subscribe model
- Work on possible optimizations
- Propose specification enhancements to IEC 61158
- Prepare a multivendor test and demonstration

TSN sub-group tasks:

- Make sure the UDP multicast Pub/Sub extension for OPC UA can be used with TSN in the future
- Prototyping of TSN with OPC UA
- Propose specification extensions regarding TSN to UA Working Group
- Provide feedback and requirements to TSN related standardization working groups

The kick-off meeting for both groups will take place as electronic meeting on June 8, 2015 at 10am EDT / 4pm CEST.

The two subgroups will share the collaboration SharePoint with the OPC UA working group.

https://opcfoundation.sharepoint.com/UA

Please reply to this email to register to participate in either or both of the subgroups. Please reply even if you expressed interest before since we need to add every individual participant to the respective sub-group in SharePoint.

Best regards,

OPC Foundation

Big support from > 20 automation companies

- ascolab, B&R, Beckhoff, Bosch Rexroth, Deutsche Telekom, Festo, Harting, Hirschmann/Belden, National Instruments, Sigmatek, Trumpf, TTTech
Packaging Use Case of B&R, Austria

"The addition of TSN and the publisher-subscriber model will greatly expand the range of potential OPC UA applications"  

Stefan Schönegger,  
Marketing Director B&R
**TRUMPF Laser Use Case 1**

**Benefit:** Production clock rate may reduced for at least 100ms per part

- **System:**
  - TRUMPF Laser with RT Linux
  - TRUMPF scanner optic for laser welding
  - TRUMPF Touch Panel PC with RT Linux
  - 100bT Ethernet connection

- **Requirements**
  - Deterministic response time from start of computer vision to Computer Visions result delivery.
  
  - Without deterministic data communication the time between two parts in a clocked production line has to be set to the worst case response time! This directly affects the quantity of pieces per shift.
TRUMPF Laser Use Case 2

Benefit: cost and complexity reduction for cabling and interfaces

- System: TRUMPF machine for laser cutting
  - PLC / NC for motion control
  - Laser
  - 100bT / 1000bT Ethernet connection

- Requirements
  - Single communication connection with complex non real-time data, i.e. diagnostic, files
  - deterministic commands between motion control and laser beam control

- With a single deterministic data connection between the components of a laser machine, costs may be reduced. Currently TRUMPF has to use fieldbus and OPC technology in combination to deal with complex data and deterministic cyclic data.
Before OPC UA
With Classic OPC

OPC Client/Servers based on Microsoft DCOM

On?  Yes
With OPC Unified Architecture

Can I see your ID

Here is my ID

On?

Please inform me if something goes wrong

Yes
With OPC UA Information Models

Who are you?
My name is R2-D2
I can navigate, lift, drill and cut
What can you do for me?
Can you lift me up to the second floor?
What is your weight?
200 kg
OK, let’s start
OPC UA is Object Oriented and SOA-ready

- >450 OPC Foundation members and thousands of OPC-compliant products
- Several Stack Implementations including several Open Source ones
- Frequently Plug Fests and Certification to ensure interoperability
- OPC UA is an information centric layered architecture
  - Object Oriented !!!
  - SOA-capable (offer, discover, interact with and use device capabilities)
  - Build in Security, not just added
  - Platform independent, Stacks available in C++, Java, .Net
- Scalable

- OPC UA is much more than a protocol
- IEC 62541 Standard
- OPC UA Server Fits in 10KB Object Code
DDS is “Data Centric”. Data Centricity was yesterday!
Combination of OPC UA and Fieldbuses today

Today’s usage of fieldbusses:
1. I/O Communication
2. M2M Peer to Peer

Real-time critical with $D_{\leq 1ms}$
Extending OPC-UA with Pub/Sub and TSN

Future usage of fieldbusses:
I/O Communication only

Real-time critical with $D_{\leq 1\text{ms}}$

Real-time Peer to Peer with services!
Other legacy and proprietary consortia standards will follow towards TSN

**TSN-based Protocols – Sharing the wire**

- OPC-UA
- OMG DDS
- 1722
- PROFINET
- IEC 61850
- ODVA / EthernetIP
- New Standard X
- Proprietary Protocol Y

**Standard foundation – shared among all nodes**
(HW, Driver, Timing, Interoperability, Network Configuration, etc)

**Key Idea:** AVnu can provide value for industrial markets by endorsing foundational TSN services in support of multiple industrial protocols.
Two main requirements from our Industry

1. No network or other configurations via configuration tools!
   - Just programming against APIs
   - Devices which cannot be programmed directly are configured via non real-time OPC UA
   - Network parameters must be mapped into an OPC UA data model

2. The CNC “god box” should not be necessary for regular work
   - Just necessary during system set up or changes
   - It configures all the infrastructure components
   - Those store their configuration in NVRAM
Thank you for the invitation and your Attention

- Questions?