Industry 4.0 Real-time/Cloud Communication Standards: OPC UA over TSN and over AMQP

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The KUKA Group

Integrated software solutions and modular product platform

Robotics expertise
Application and industry expertise
Systems and process expertise
Systems and process expertise

Global market access

Component
KUKA Robotics

Cell
KUKA Systems

Solution
Swisslog

Industries

Systems

Component:
- Industrial Robotics
- Service Robotics
- Medical Robotics

Cell:
- Technical Solutions
- Reis
- Automotive
- Aerospace

Solution:
- Warehouse Logistics
- Healthcare

Global market access

Robotics expertise
Application and industry expertise
Systems and process expertise
Systems and process expertise
Our Robot Portfolio, partly. Payloads from 3 to 1300 kg

Light Weight Robot (LWR)
„IIWA“
for Human Robot Collaboration (HRC)
Mobile Devices
Industry 4.0 is just another name for the Industrial IoT for Manufacturing

- Buildings
- **Energy *)
- Consumers@Home
- **Healthcare *)
- "Industrial" (Manufacturing *)
- Transportation *)
- Retail
- **Public Security & Safety *)
- IT & Networks (Infrastructure for the other sectors)

*) Covered by the IIC (Industrial Internet Consortium)
Germany’s Platform Industry 4.0

- Industry 4.0 is one of ten „Future Projects” of the German Government
- 1000 Mio. € grants
- Controlled by the German Government
  - Supervised by Chancellor Angela Merkel (visited KUKA in 03/15)
  - Minister for Economic Affairs & Energy Brigitte Zypries
  - Minister for Education & Research Johanna Wanka
- KUKA collaborates in the “Reference Architecture and Standardization” working group (Heinrich Munz)

Source: VDI/VDE Broschüre „Cyber-Physical Systems: Chancen und Nutzen aus Sicht der Automation“
The Automation Pyramid vanishes... regarding Communication

Source: VDI/VDE Broschüre „Cyber-Physical Systems: Chancen und Nutzen aus Sicht der Automation“

IEEE 802.1 Time Sensitive Networks
M2M Communication Mess in Industrial Automation today

- IEC 61158 “standardizes” 19!!! different field buses
- Connectors, Cables, physical layer, other parts of the communication stack are different
  ➔ No interoperability between different technologies 😞
- However: Interoperability is key to the success of Industry 4.0
  – Project components are put together on the plant floor by system integrators (not by developers !)

- Standard Ethernet is missing!
  – Why? No deterministic real-time! (so far)
  – TSN is the way out of this mess!

Source: HMS
Where does Time Sensitive Networking (TSN) come from and who else is using it?

• TSN is a working group within the IEEE 802.1 standardization group (Ethernet)

• TSN is the successor of AVB (Audio/Video-Bridging) and was renamed due its broader usage scope

• 1st Audio/Video, 2nd usage in cars, 3rd Industrial Automation
What is TSN (Time Sensitive Networking)?

- TSN not only is one single technology, but consist of >10 sub technologies
- The manufacturing industry needs only 3 of them with high priority
  1. Timesynchronization (IEEE 802.1 ASrev)
     - former IEEE 1588
  2. Time Triggered Scheduling (Qbv)
  3. Central, automized configuration (Qcc)

<table>
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<th>Priority</th>
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<th>2016</th>
<th>2017</th>
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<td>Qca</td>
<td>N</td>
<td>N</td>
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Source: General Electric
OPC UA TSN activities around the world

- TSN Testbed in Austin, TX within the Industrial Internet Consortium (IIC)
- OPC UA TSN Testbed @Fraunhofer ICGV in Augsburg (incl. Siemens)
- OPC UA TSN Shaper Group
  Spin off from the IIC TSN Testbed, pushing only OPC UA over TSN
- Latest: Profinet International (Siemens)
The current zoo of competing OPC UA TSN groups in a Gartner Hype Cycle
Platform Industry 4.0, LNI4.0, SCI4.0, IIC Relations
The communication Stack which must go into each automation node

- TSN addresses only layer 2

- For full interoperability, all layers in all nodes must be the same

- Industry 4.0 platform WG1, ZVEI and VDMA officially recommend OPC UA as the higher layer protocol including the semantic service descriptions
How does this fit into the Reference Architecture Model Industry 4.0 (RAMI 4.0)?
OPC UA in the RAMI4.0 (Reference Architecture Model Industry 4.0)

- Data and Service Description in the OPC UA Information Model
- Service centric (SOA)
- Web Service centric (SOA)
- Legacy Field Busses, domain specific protocols, DDS, etc.
- OPC Unified Architecture

Deterministic real-time enhancement
Cloud Federation enhancement

Legacy field buses on the integration layer are already building bridges to OPC UA
Typical Industry 4.0 architecture with OPC UA and field bus integration

(Source: Basic picture by EtherCAT Technology Group)

- Latest information from the last ETG Technical Committee Meeting Sept., 27th 2017 in Frankfurt:
  - ETG will define a profile, how EtherCAT telegrams shall be transported in TSN Networks
  - Not to replace EtherCAT by TSN, but to enhance its usage also in TSN networks
  - Imagine an EtherCAT Device/Coupler-head just being connected “somewhere” on a TSN switch port...
  - EtherCAT telegrams coexisting with OPC UA telegrams on the same cable
    - Both being real-time able
    - Migration path
Platform Industry 4.0 WG1, ZVEI and VDMA officially recommend OPC UA (only)

„Produkt online ansprechbar über TCP/UDP&IP mit mindestens dem Informationsmode II von OPC-UA“

https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2016/November/Welche_Kriterien_mussten_Industrie-4.0-Produkte_erfuellen_/ZVEI-LF_Welche_Kriterien_mussten_1_4.0_Produkte_erfuellen_17.03.17.pdf

Where do the semantic self descriptions (= OPC UA Companion Specifications) come from?

- Several Working Groups to develop OPC UA Companion Specifications for Machines and Devices already running under the roof of the VDMA

**VDMA Companion Specifications**
- Injection Molding + FS
- Vision + FS
- IAS + FS
- Robotic + FS

New:
- Functional Safety (FS)
- Electrical Drives + FS
- I/Os + Sensors + IO-Link + FS
- CNC & Other Machines
- Food
- Measurement
- AGVs (Logistic)
- …
OPC UA in the RAMI4.0 (Reference Architecture Model Industry 4.0)

- Data and Service Description in the OPC UA Information Model
- Service centric (SOA)
- Web Service centric (SOA)
- Legacy Field Busses, domain specific protocols, DDS, etc.
- Things
- Cloud Federation enhancement
- Deterministic real-time enhancement

Last but least: Cloud Federation with OPC UA over AMQP

- Req. 1: For Industry 4.0 we do not only want to do data collection
- Req. 2: There will be more than one (cascaded) clouds
- We also want to do out of the clouds (plural):
  - Browsing of the precious OPC UA information models
  - Subscribe OPC UA Data directly from the Servers
  - Call OPC UA methods
  - Do SW updates via OPC UA
  - And more OPC UA stuff...

\[\Rightarrow\] Not possible with Pub/Sub
\[\Rightarrow\] Keep OPC UA Clients also in the clouds
Thank you for your attention!
Why Cloud Federation?

• Every automation device of the future must/will have a semantic service description (created in VDMA WGs)
• This precious meta information for data and services should also be kept on their way through the firewalls/clouds (plural)
• If the device has a data point named “Motor2Temperature” we’d like to see the data of this data point in the cloud with exactly the same tag name, same for services...
• …without the need to manually configuring it in every cloud
• …without the need to configure its way through the clouds on every single hop
• ➔ The meta information sourcing in the OPC UA information model must be kept all along its way through the clouds
• Standard OPC UA cannot be transported through firewalls (Port # 4840), SOAP is outdated
• Client “above” initially must contact the servers “down” in the things ➔ ”wrong” direction
• It takes a transport protocol which turns the initial direction around and can be used through firewalls, in the internet and between clouds
• Message Broker protocols like MQTT or AMQP can do this
  – Communication initialization is done from the things or the edge to the broker “above” (“outbound”)
  – typically used for firewall/cloud, cloud/cloud communication
• Cloud “Routing” is needed for Cloud-to-Cloud communication ➔ “Cloud Federation”
Cloud Federation: Why AMQP and not MQTT?

• AMQP defines in the standard, how to add meta information to the data/services, MQTT does not
• MQTT just transports unstructured binary Byte packets
• Sender and receiver explicitly must know the semantic of the information
• JSON messages etc. could be added to the MQTT binary block “somehow”, but this is not standardized
• The standardization how to transport of OPC UA over AMQP is already work in progress in an OPC Foundation working group
  – Finalization expected for May 2017
  – For MQTT this also could be done, but nobody is working on it yet
• Political: MQTT was developed and still is driven by IBM, AMQP was developed and still is driven by a consortia (similar to OPC UA and TSN)
• There are two possible ways to use AMQP as a transport layer for OPC UA

1. Simple Publish/Subscribe Pattern
   – What to publish must be configured somewhere else :-(
   – No discovery from Client to Server possible :-(
   – No subscription from the client on single data points possible :-(
   – Services not defined (yet?) via Pub/Sub :-(

2. Standard Client/Server Pattern
   – The whole OPC UA functionality also is possible through the cloud :-)
   – OPC UA Server in the devices, OPC UA clients in the clouds :-)

• See also this White Paper “A Comparison of AMQP and MQTT”