

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

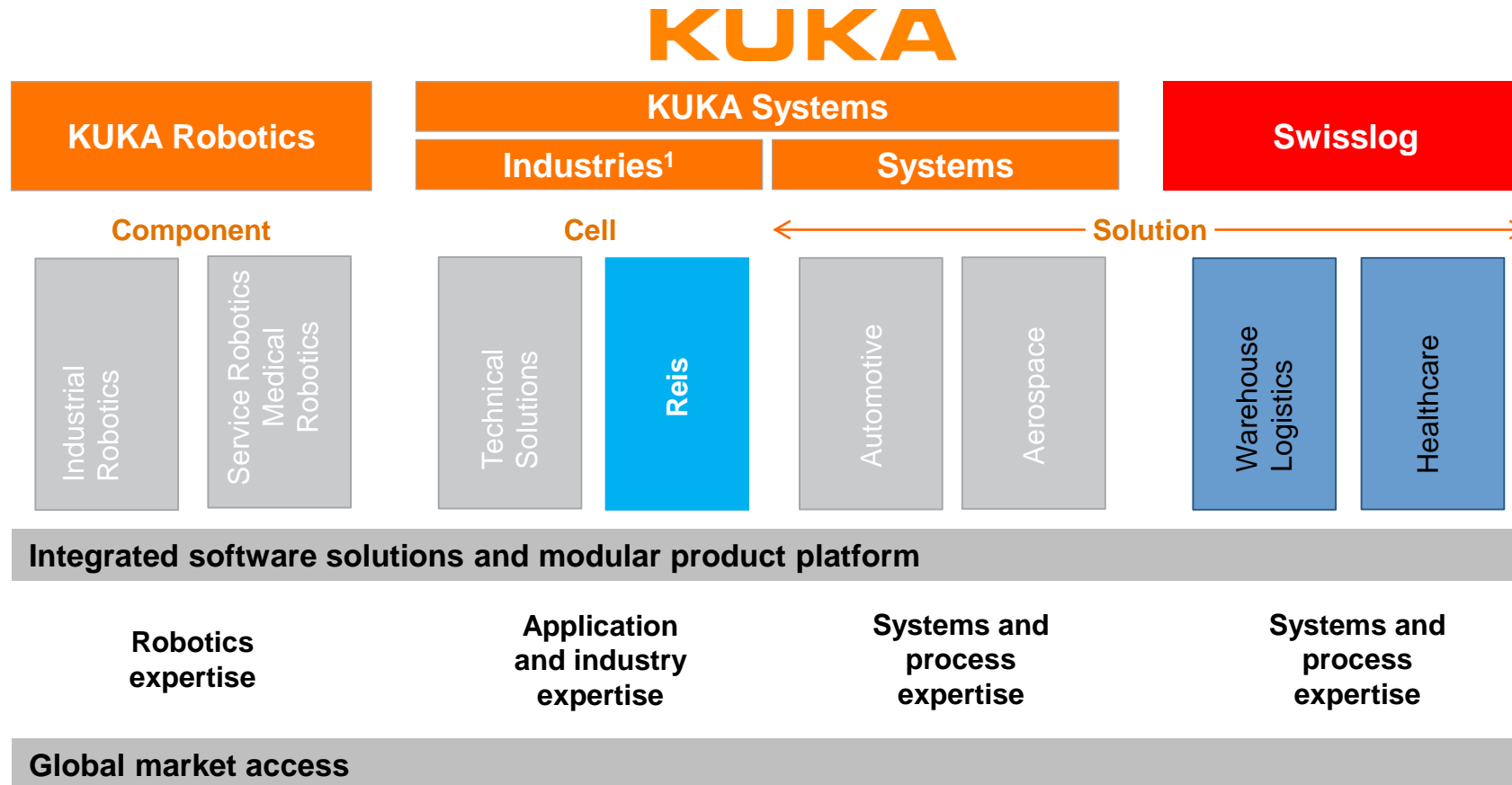
Heinrich Munz

Lead Architect Industry 4.0

KUKA Group



The KUKA Group



Our Robot Portfolio, partly. Payloads from 3 to 1300 kg



Light Weight Robot (LWR)
„IIWA“
for Human Robot Collaboration (HRC)



Small robots
„Agilus“

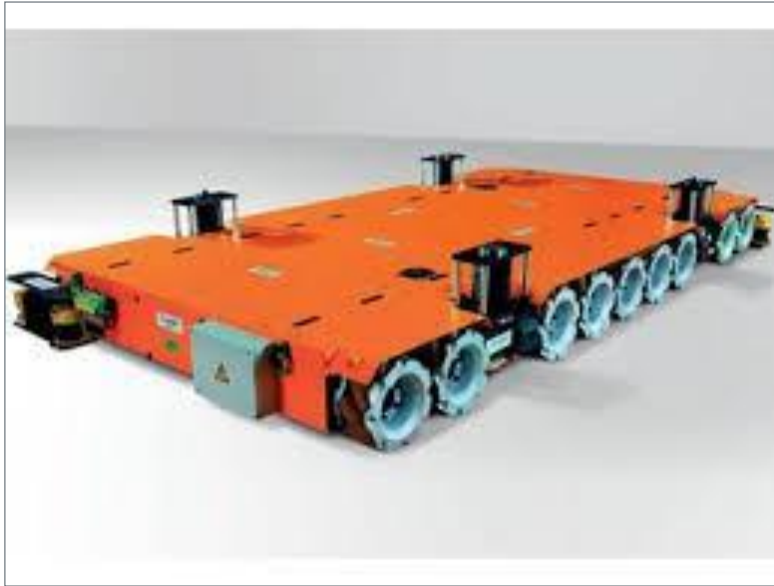
Low
payload

Middle
payload

High
payload

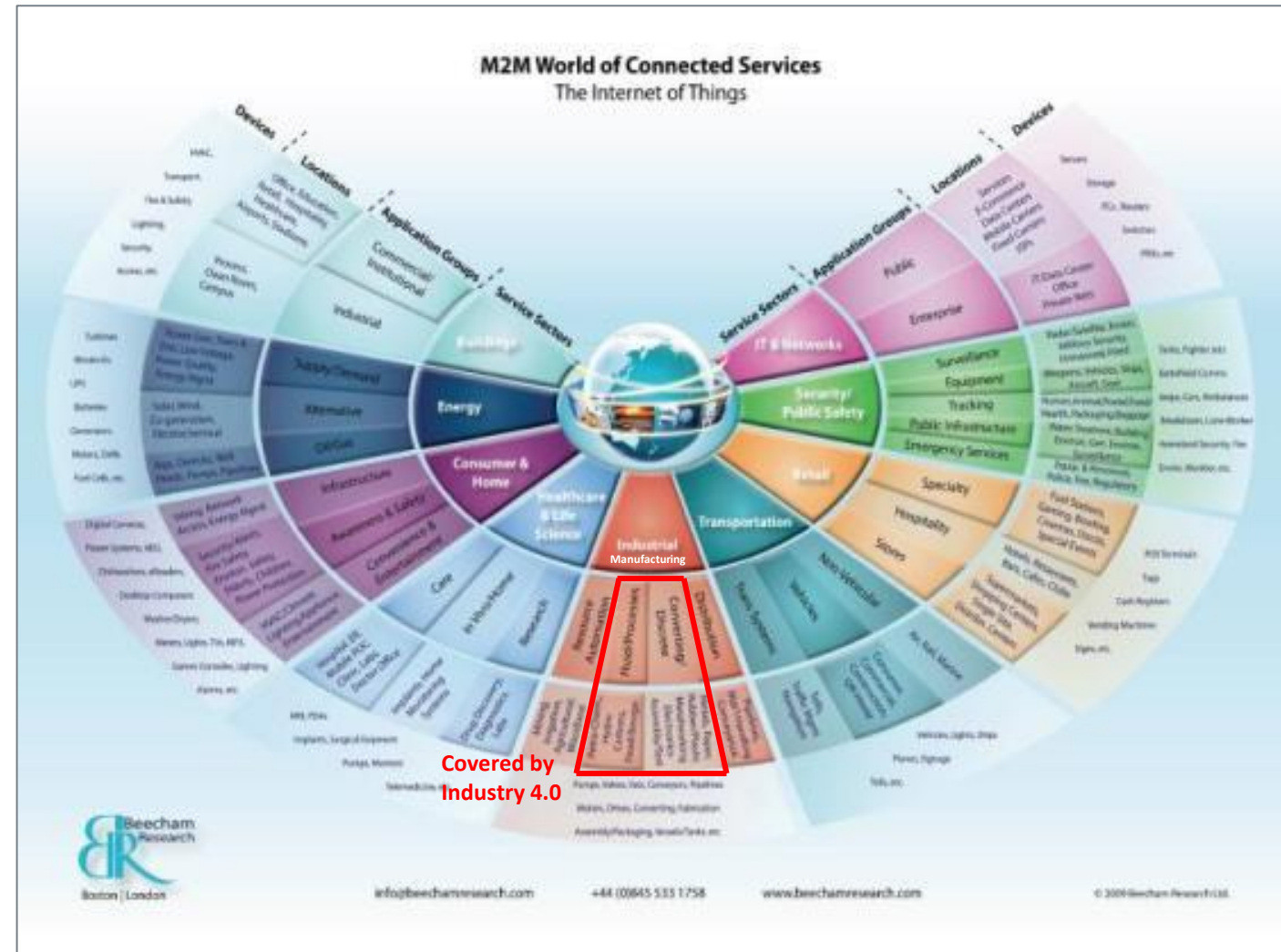
Highest
payload
„Titan“

Special
mechanics



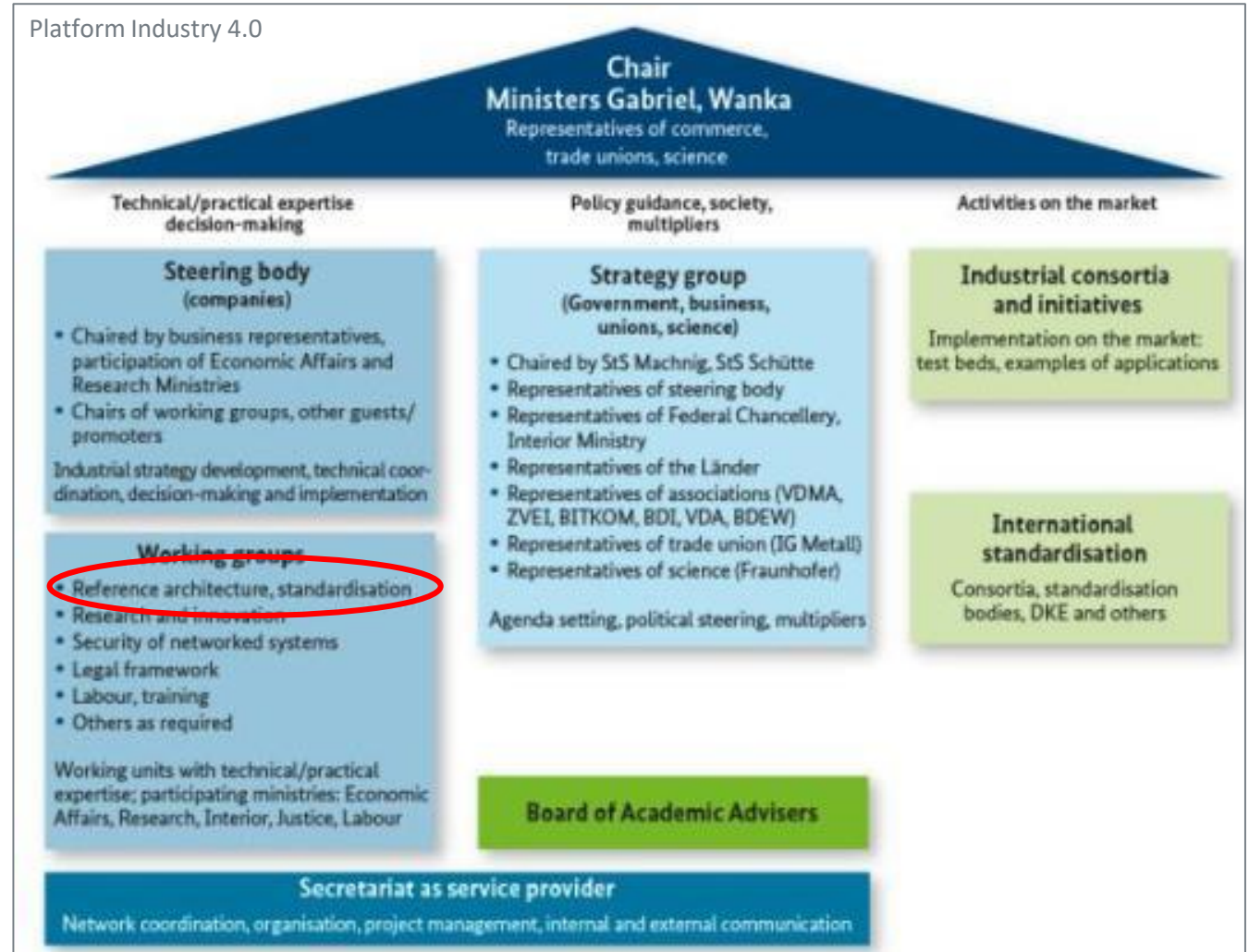
Industry 4.0 is just another name for the Industrial IoT for Manufacturing

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

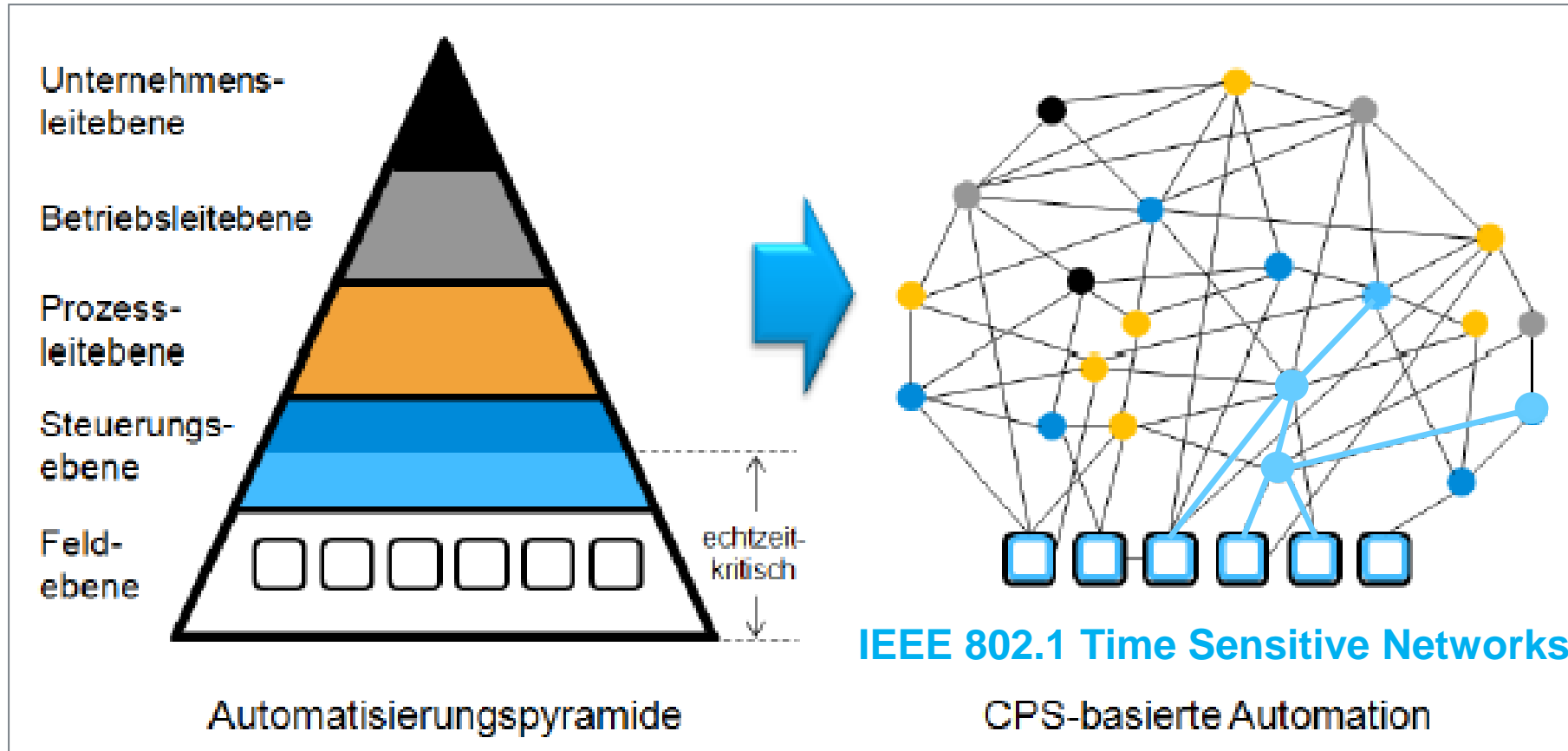


Germany's Platform Industry 4.0

- 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)



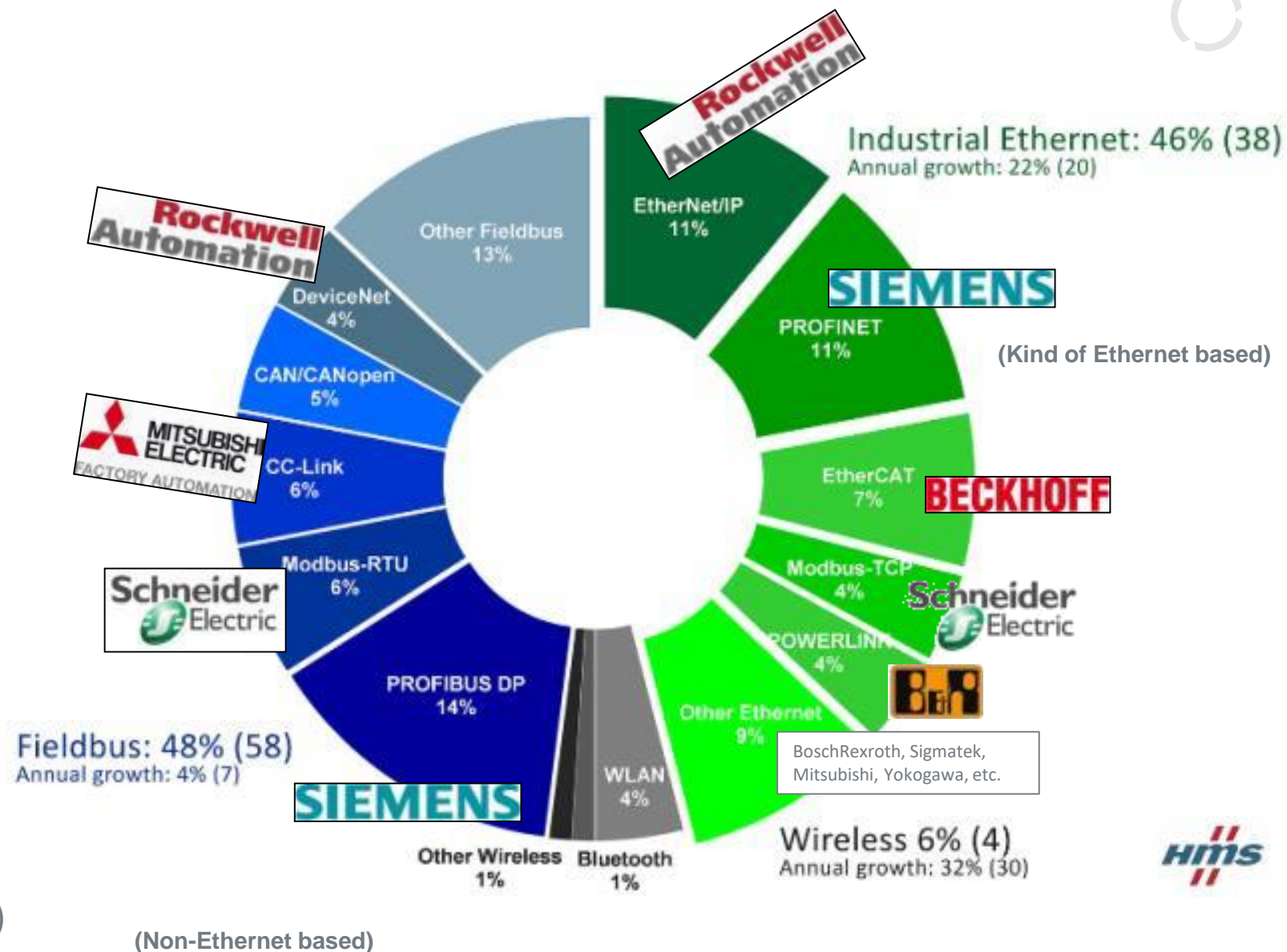
The Automation Pyramid vanishes... regarding Communication



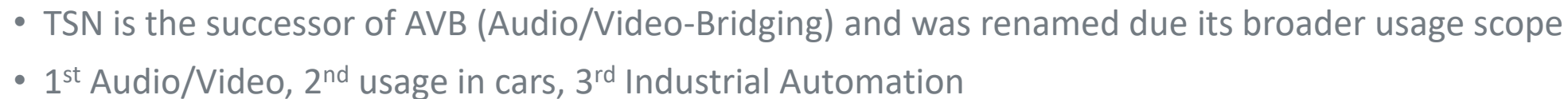
Source: VDI/VDE Broschüre „Cyber-Physical Systems: Chancen und Nutzen aus Sicht der Automation“

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!



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



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)

Priority	Requirement	Project(s)	2015	2016	2017
1	Network time synch with static config	ASrev	Y	Y	Y
1	Scheduling	Qbv	Y	Y	Y
1	Centralized config	Qcc, Restconf/Netconf 1722?	Y	Y	Y
2	Seamless redundancy including time synch	CB, ASrev	N	Y	Y
2	Ingress policing including BE limiting	Qci	Y/N	Y	Y
2	Frame preemption	Qbu	N	N	Y
2	L3 support		N	N	Y
3	Cyclic schedule	Qch	N	N	TBD
3	Credit based shaper	Qav	N	N	TBD
3	Stream management (SRP)	Qat	N	N	TBD
-	ISIS	Qca	N	N	TBD

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)

IIC TSN Topology

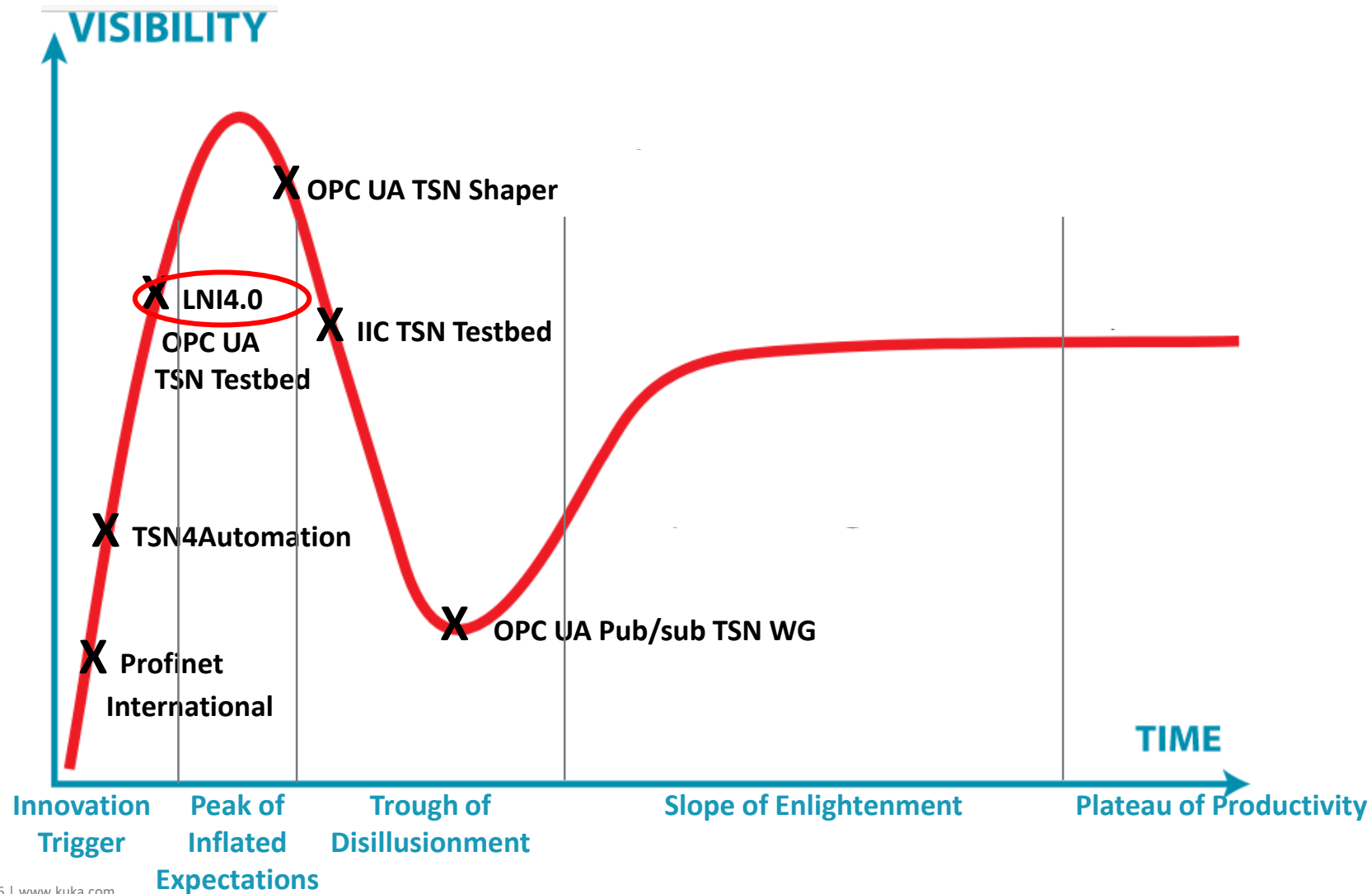


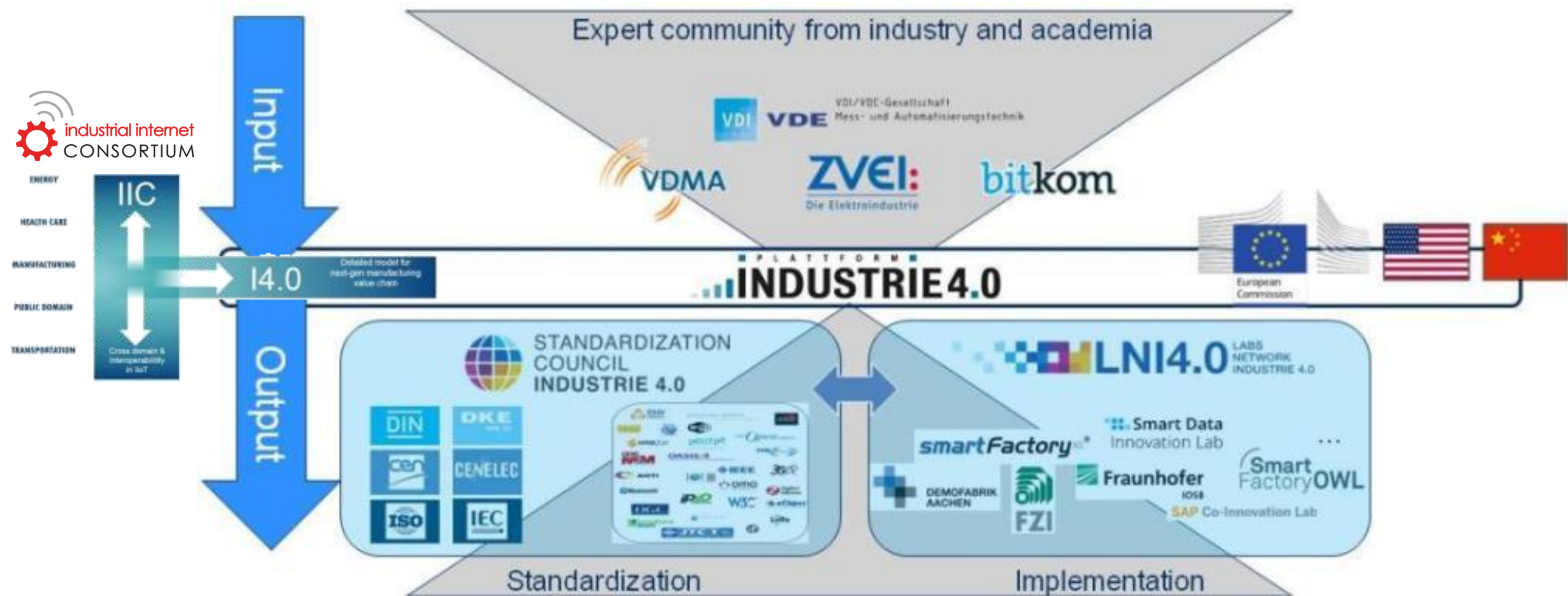
Machine networking with OPC UA

OPC UA

- For horizontal controller / controller communication
- Cross-vendor interoperability
- Procedure
 1. Client/Server (TCP/IP)
 2. Pub/Sub (UDP)
 3. Synchronization with TSN

The current zoo of competing OPC UA TSN groups in a Gartner Hype Cycle



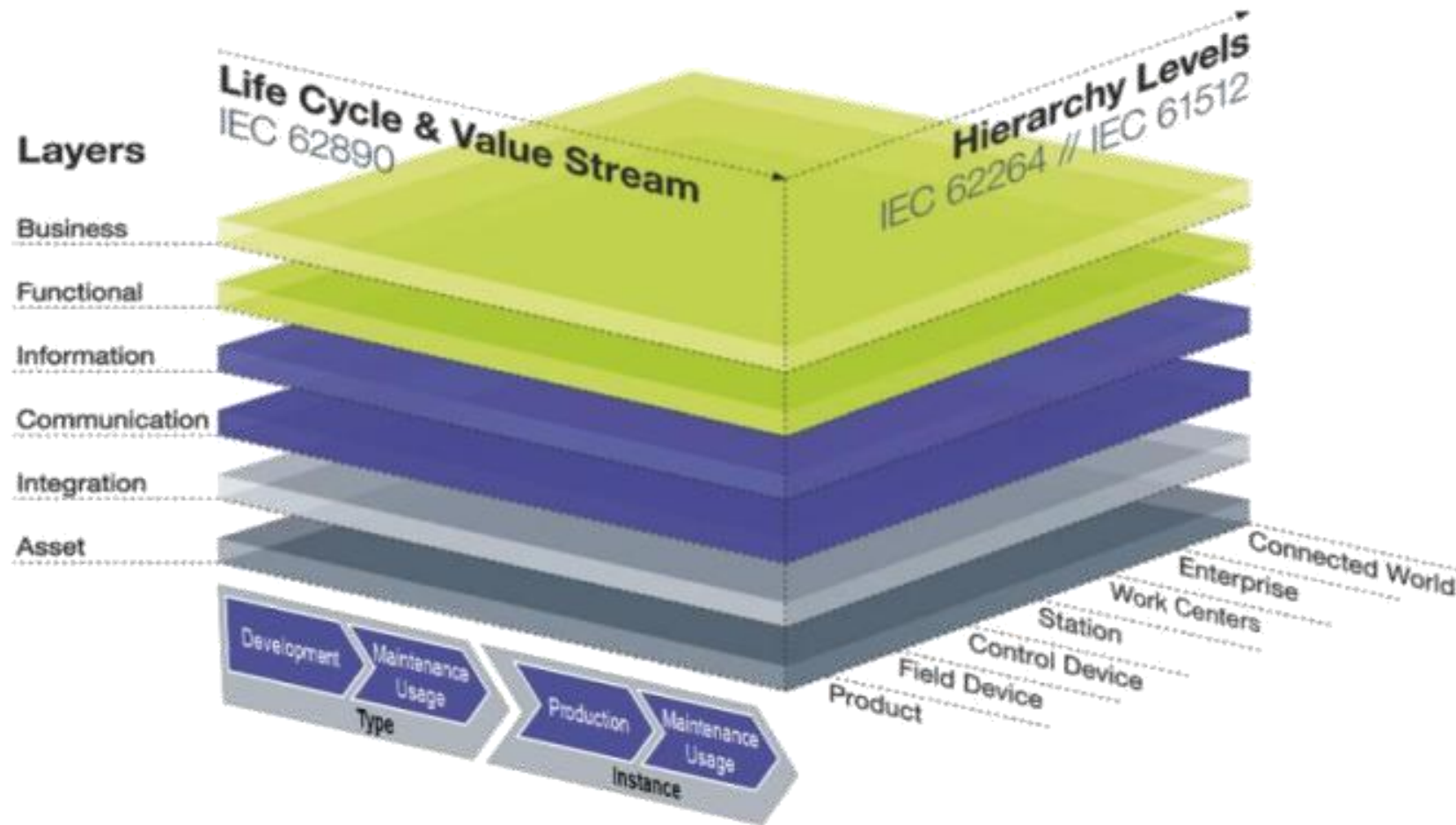


The communication Stack which must go into each automation node

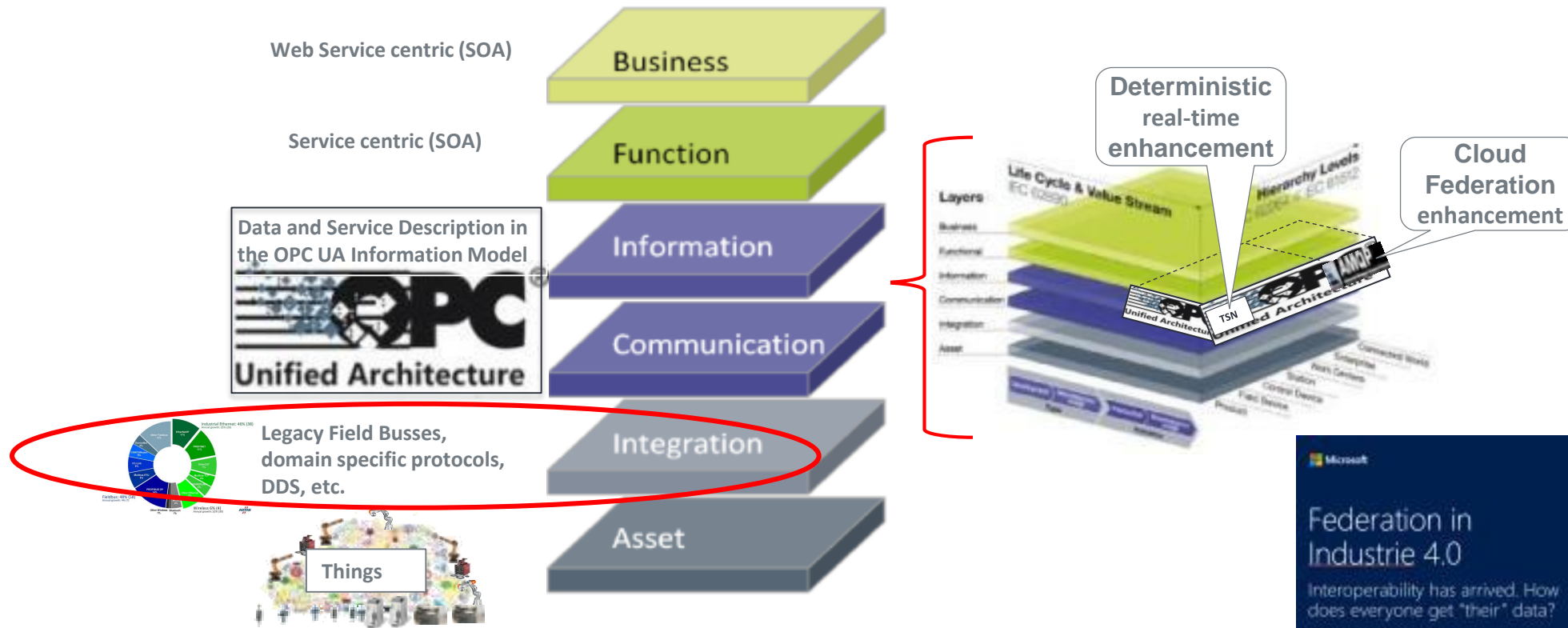
- TSN addresses only layer 2
- For full interoperability, all layers in all nodes must be the same
- Industry 4.0 platform WG1, ZVEI and VDMA officially recommend OPC UA as the higher layer protocol including the semantic service descriptions



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)



Legacy field buses on the integration layer are already building bridges to OPC UA

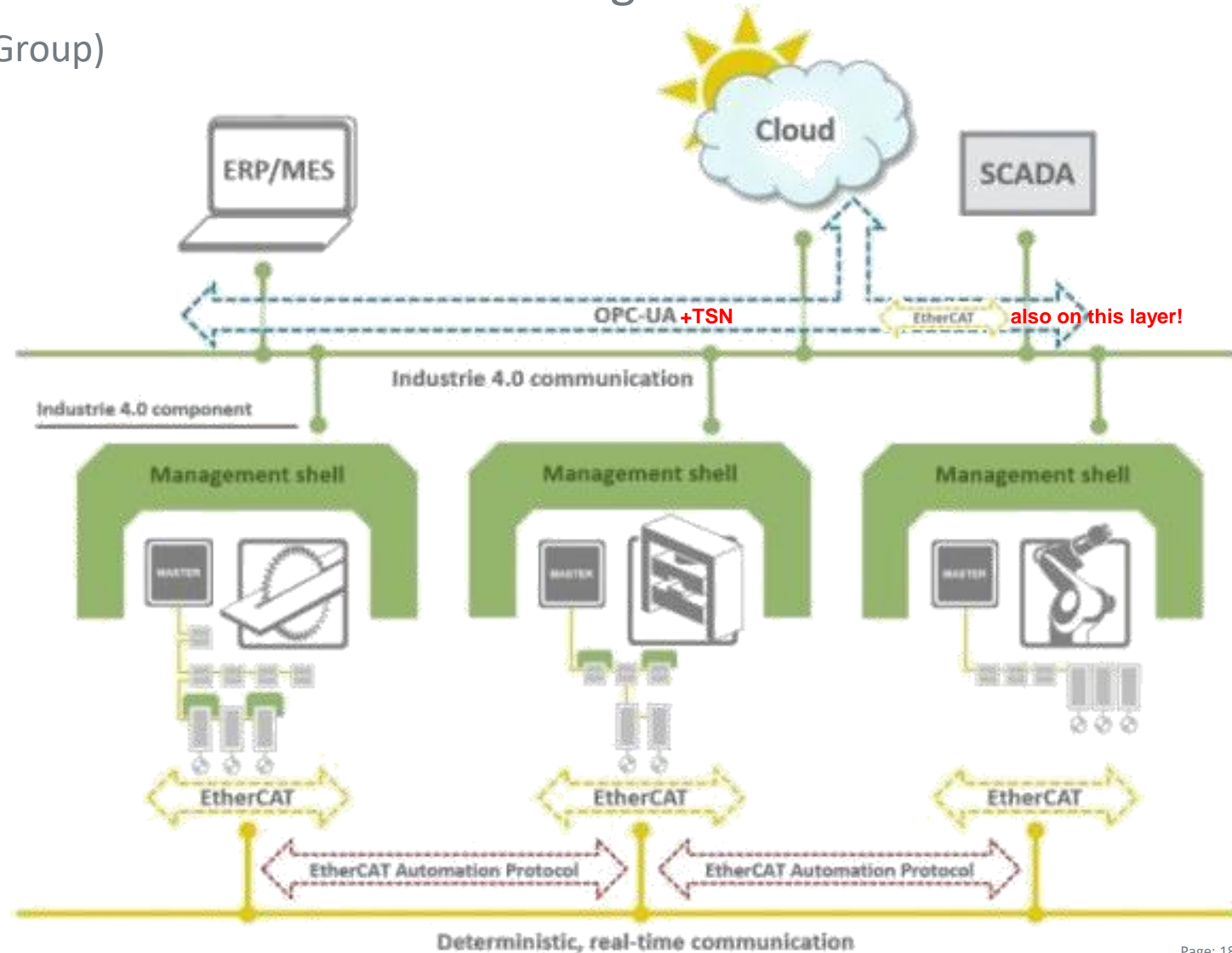
The collage includes the following elements:

- Sercos** logo with the tagline "the automation bus".
- PI PROFIBUS + PROFINET** logo.
- ETHERCAT** logo.
- OPC FOUNDATION** logo with the tagline "The Industrial Interoperability Standard".
- IO-Link** logo.
- CC-Link Partner** logo.
- Market&Technik** logo.
- Open DeviceNet Vendors Association** logo.
- News und Events** section with the text "Aktuelle Informationen, Pressenachrichten".
- OPC-UA Companion** section with the text "Sercos International hat angekündigt, die Kompatibilität zwischen der Sercos- und der OPC-UA-Technologie zu verbessern".
- Pressemitteilung** section with the text "Nachdem die EtherCAT auf der letzten Hannover Messe die Schnittstellen für die Spezifikationsarbeit durchgängige Kommunikation".
- PI und OPC Foundation** section with the text "PROFIBUS & PROFINET International (PI) und die OPC Foundation arbeiten bereits seit Jahren zusammen. Diese Zusammenarbeit wird intensiviert, um die Integration von OPC UA in die Systemarchitektur von PROFINET konsequent weiterzuführen".
- Embedding CANopen in the world of OPC UA** section with the text "October 12, 2015. CIA has scheduled a free-of-charge event discussing how to embed CANopen networks into the OPC UA world. The information day addresses CIA members as well as CANopen system designers (also non-members). Mathias Damm from the OPC foundation introduces OPC UA and the principles of embedding serial networks. CIA members are invited to present already existing OPC UA solutions in conjunction with OPC UA. In addition, CIA presents the activities that have been started to embed CANopen in internet-connected applications (Internet of Things). Afterwards, the attendees can discuss the possibilities of embedding CANopen in the world of OPC UA in detail. The information day on OPC UA is scheduled for December 15, 2015 (10:00 to 15:00) in Nuremberg (Germany). The preliminary program comprises:".
- IO-Link Consortium** section with the text "IO-Link Consortium signed a Memorandum of Understanding with the OPC Foundation (M&U) aims to define the desired level of cooperation between the two organizations as outlined below".
- At the 2010 Hannover Fair** section with the text "At the 2010 Hannover Fair, the CC-Link signed a memorandum of understanding with the OPC Foundation to integrate OPC UA technology into CC-Link SE. CC-Link SE is the world's first and only open global Ethernet for automation".
- Kathrin Voss, President & Executive Director** section with the text "der OPC Foundation und Sercos International arbeiten mit der DOVA in deren Machinery Initiative zusammen. Ein Kennzettel dient als Kennzettel bei der Einführung eines".

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_muessen_Industrie-4.0-Produkte_erfuellen_/ZVEI-LF_Welche_Kriterien_muessen_I_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)
 - ...



VDMA represents the broad manufacturer industry

VDMA has 3200 member companies

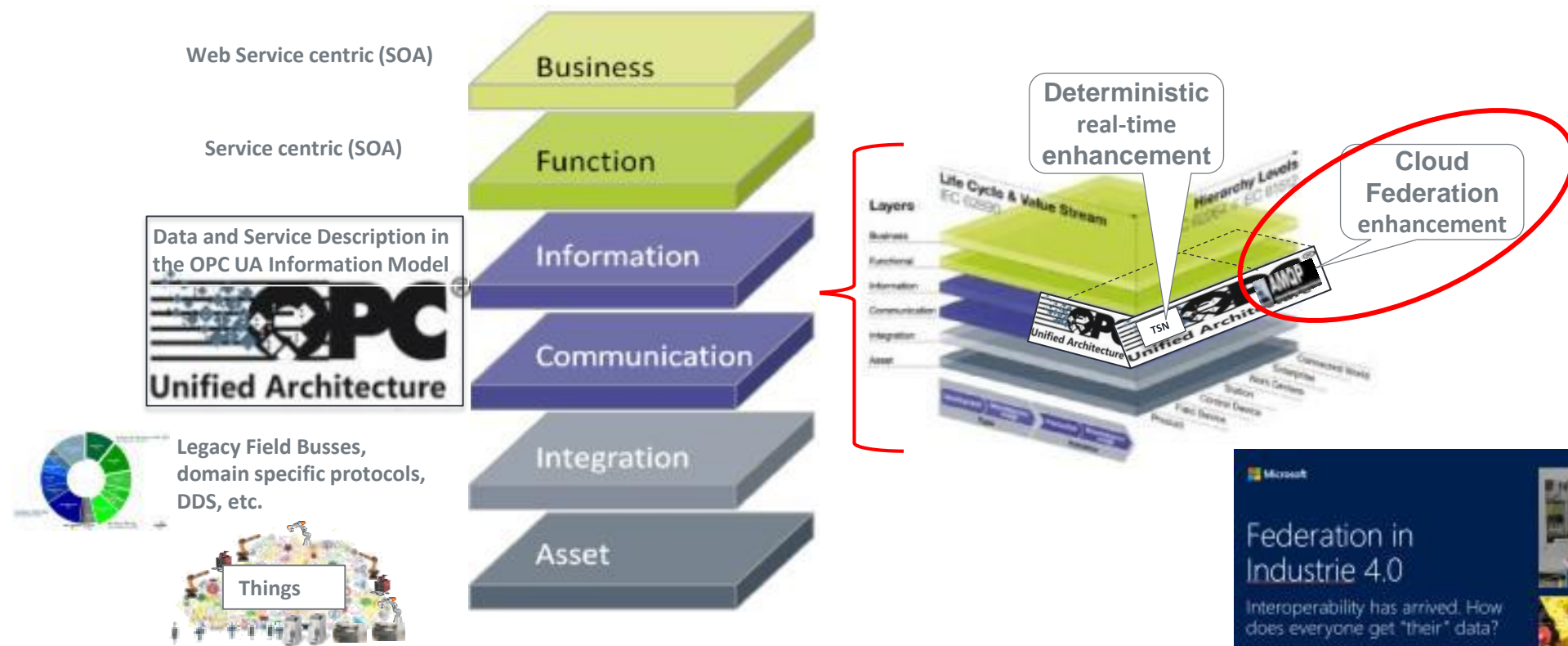


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|---|---|--|---|
| » Agricultural Machinery | » Fire Fighting Equipment | » Metallurgical Plants and Rolling Mills | » Robotics + Automation |
| » Air Conditioning and Ventilation | » Fluid Power | » Metallurgy | » Security Systems |
| » Air Pollution Control | » Food Processing Machinery and Packaging Machinery | » Micro Technologies | » Software |
| » Air-handling Technology | » Foundry Machinery | » Mining | » Surface Treatment Technology |
| » Building Control and Management | » Gas Welding | » Plastics and Rubber Machinery | » Textile Care, Fabric and Leather Technology |
| » Cleaning Systems | » Hydro Power | » Power Systems | » Textile Machinery |
| » Compressors, Vompresed Air and Vacuum Technology | » Integrated Assembly Solutions | » Power Transmission Engineering | » Thermal Turbines and Power Plants |
| » Construction Equipment and Building Material Machines | » Large Industrial Plant Manufacturing | » Precision Tools | » Thermo Process Technology |
| » Drying Technology | » Lifts and Escalators | » Printing and Paper Technology | » Valves |
| » Electrical Automation | » Machine Tools and Manufacturing Systems | » Process Plant and Equipment | » Waste Treatment and Recycling |
| » Electronics, Micro and Nano Technologies | » Machine Vision | » Productronic | » Wind Energy |
| » Engine Systems for Power and Heat Generation | » Materials Handling and Intralogistics | » Pumps + Systems | » Woodworking Machinery |
| » Engines and Systems | » Measuring and Testing Technology | » Refrigeration and Heat Pump Technology | |
| | | » Robotics | |

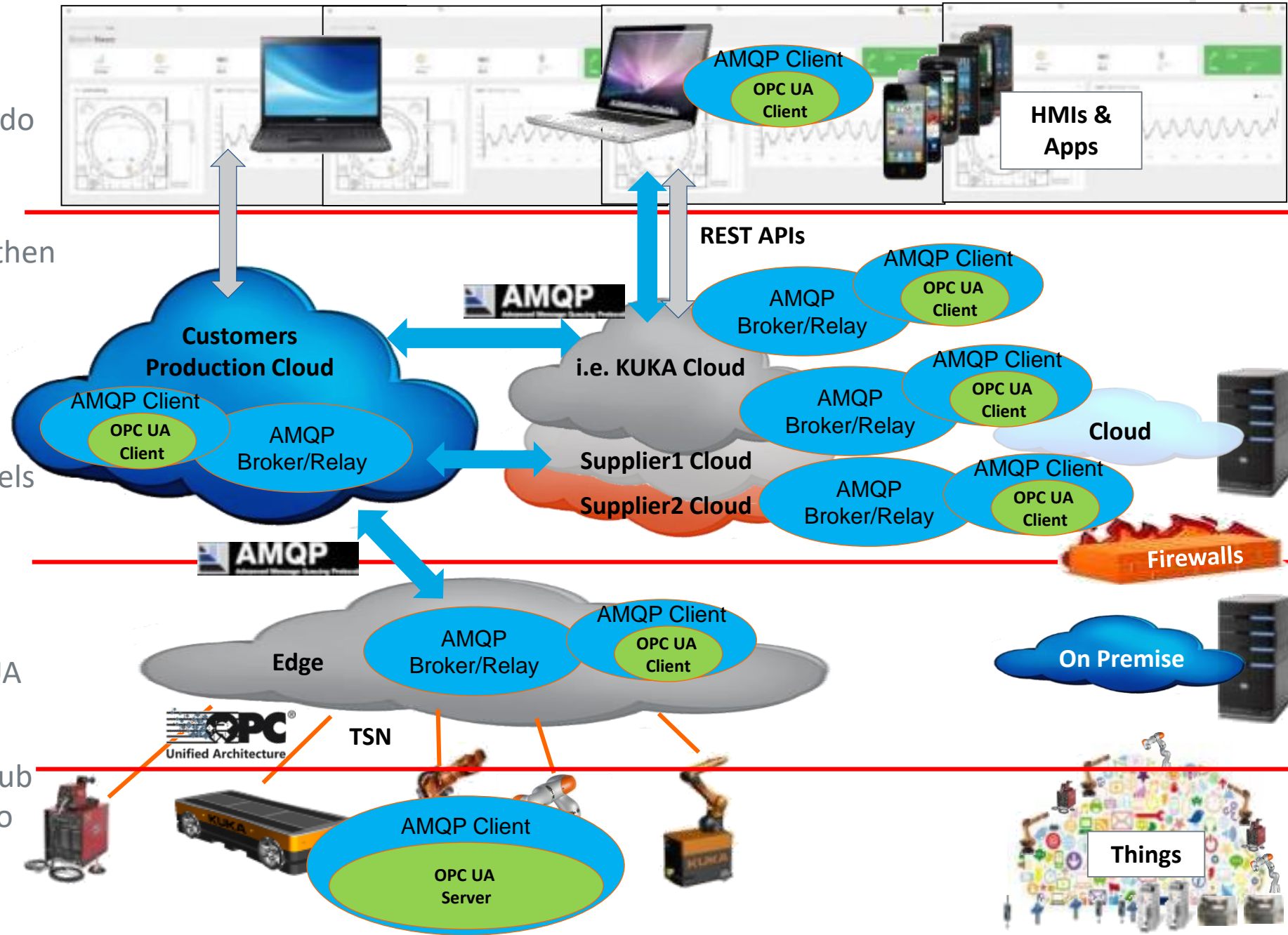
OPC UA CS under development

Awareness existent

OPC UA in the RAMI4.0 (Reference Architecture Model Industry 4.0)



- 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...
- ➔ Not possible with Pub/Sub
- ➔ 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 a 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, AQMP 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”

[https://lists.oasis-open.org/archives/amqp/201202/msg00086/StormMQ_WhitePaper - A Comparison of AMQP and MQTT.pdf](https://lists.oasis-open.org/archives/amqp/201202/msg00086/StormMQ_WhitePaper_-_A_Comparison_of_AMQP_and_MQTT.pdf)