Forging Trustworthy IIoT Systems Using OPC UA

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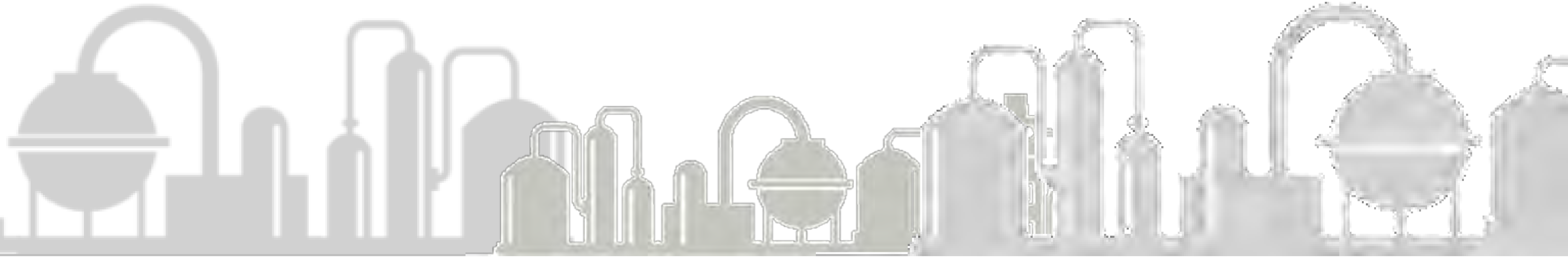
OPC Foundation Mission Statement

The mission of the OPC Foundation is to manage a global organization in which users, vendors and consortia collaborate to create data transfer standards for multi-vendor, multi-platform, secure and reliable interoperability in industrial automation.



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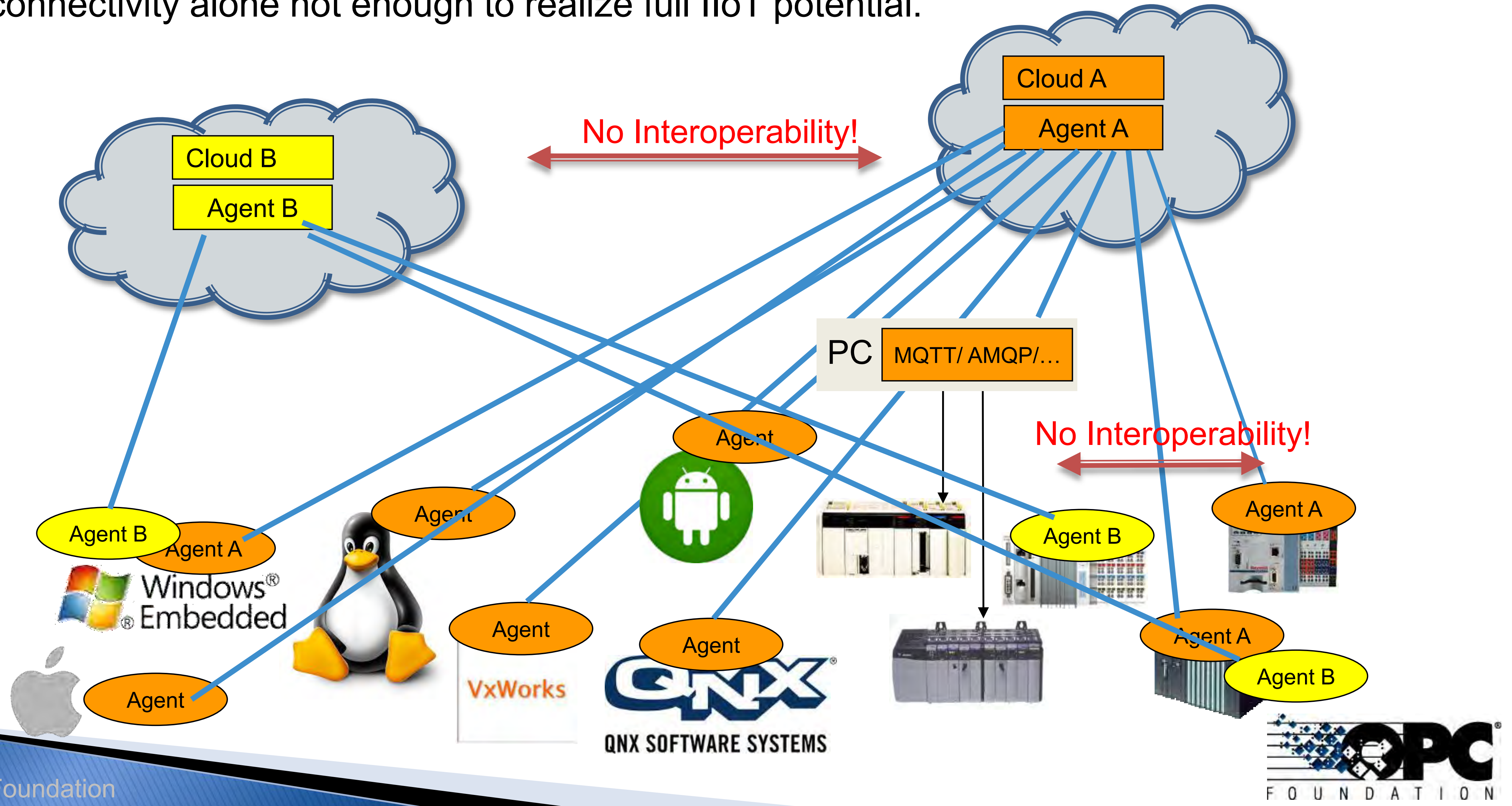
Connectivity without Interoperability

Data connectivity alone not enough to realize full IIoT potential.



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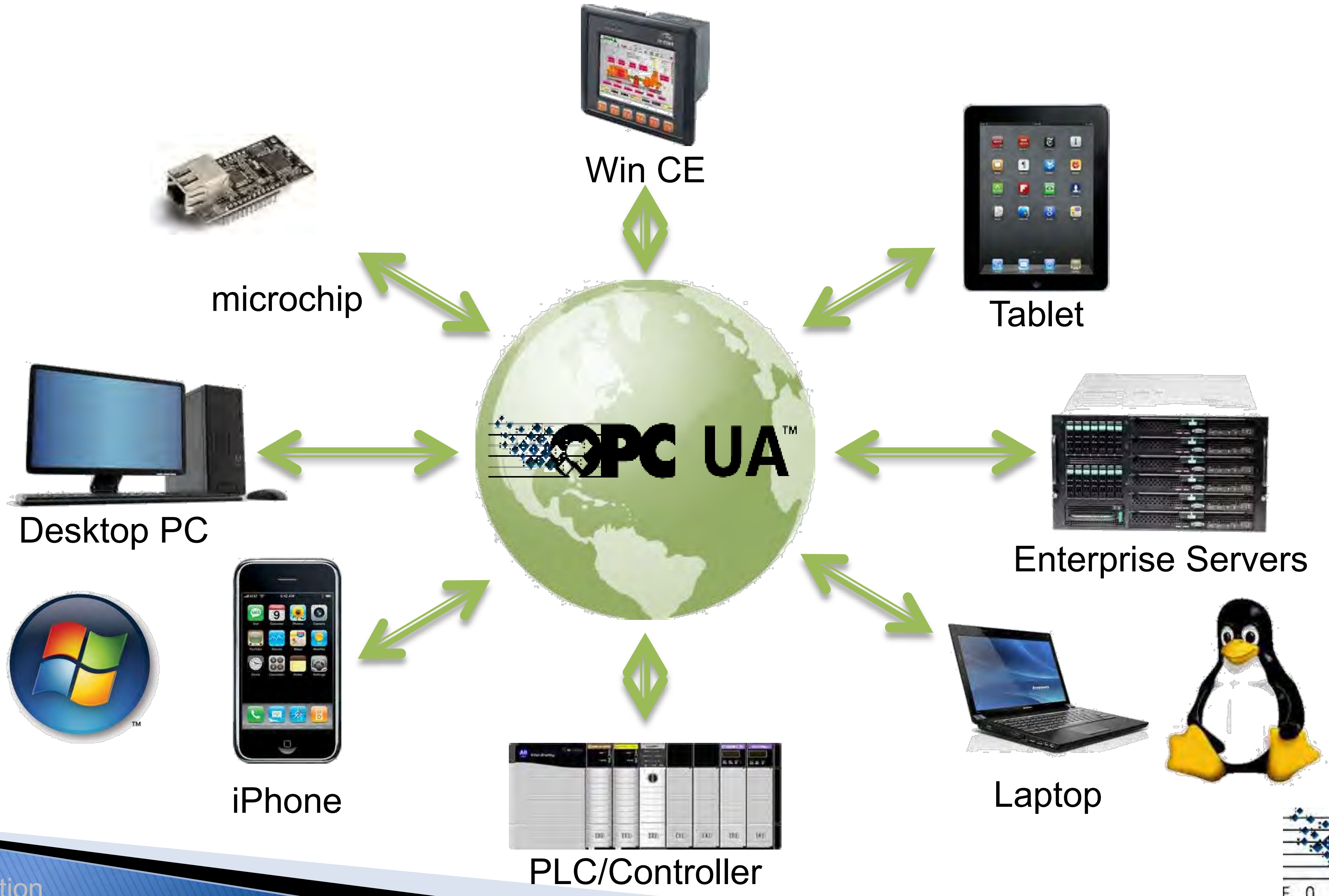
OPC Vision: Facilitating Industrial Interoperability



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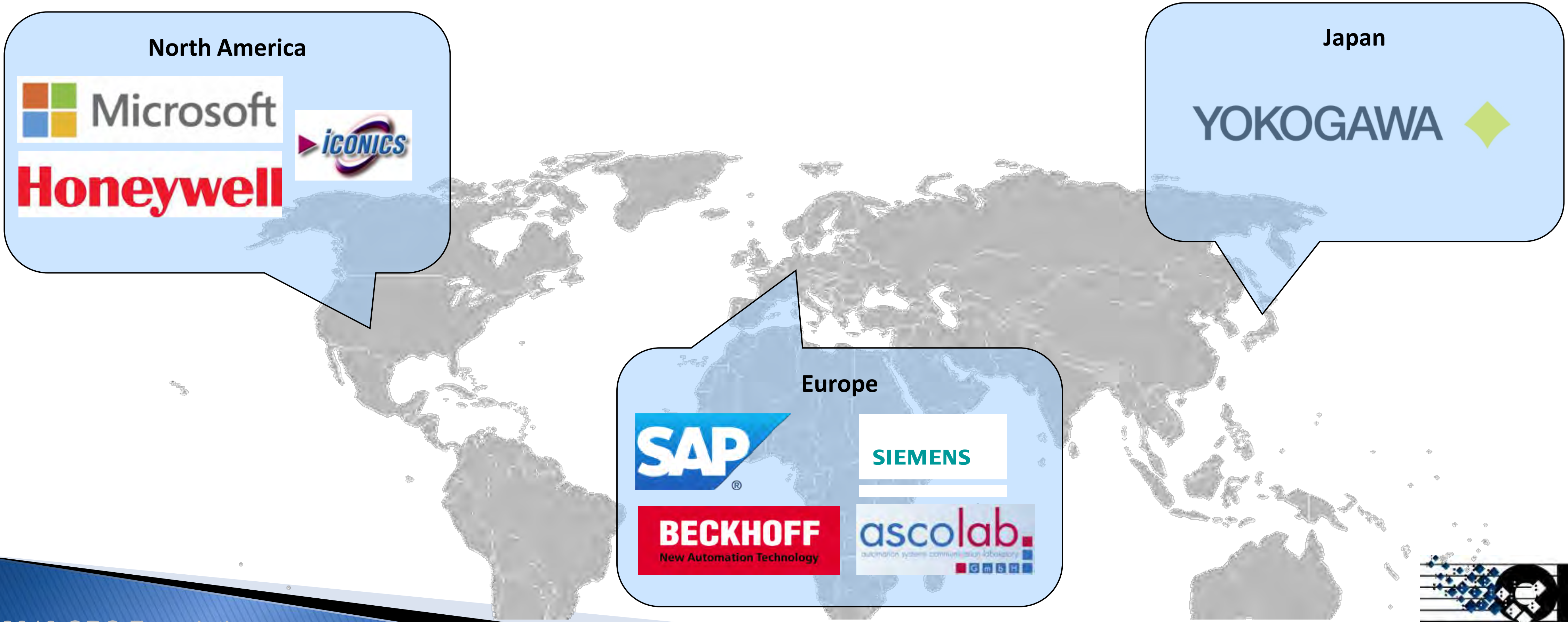
OPC UA

OPC Foundation: Board of Directors

- International board – democratic elections by members every year
  - Companies from Automation & IT
  - All over the world



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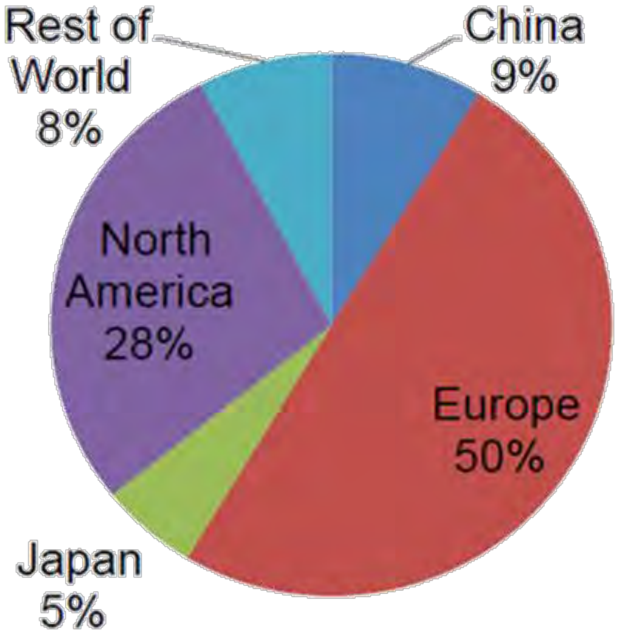
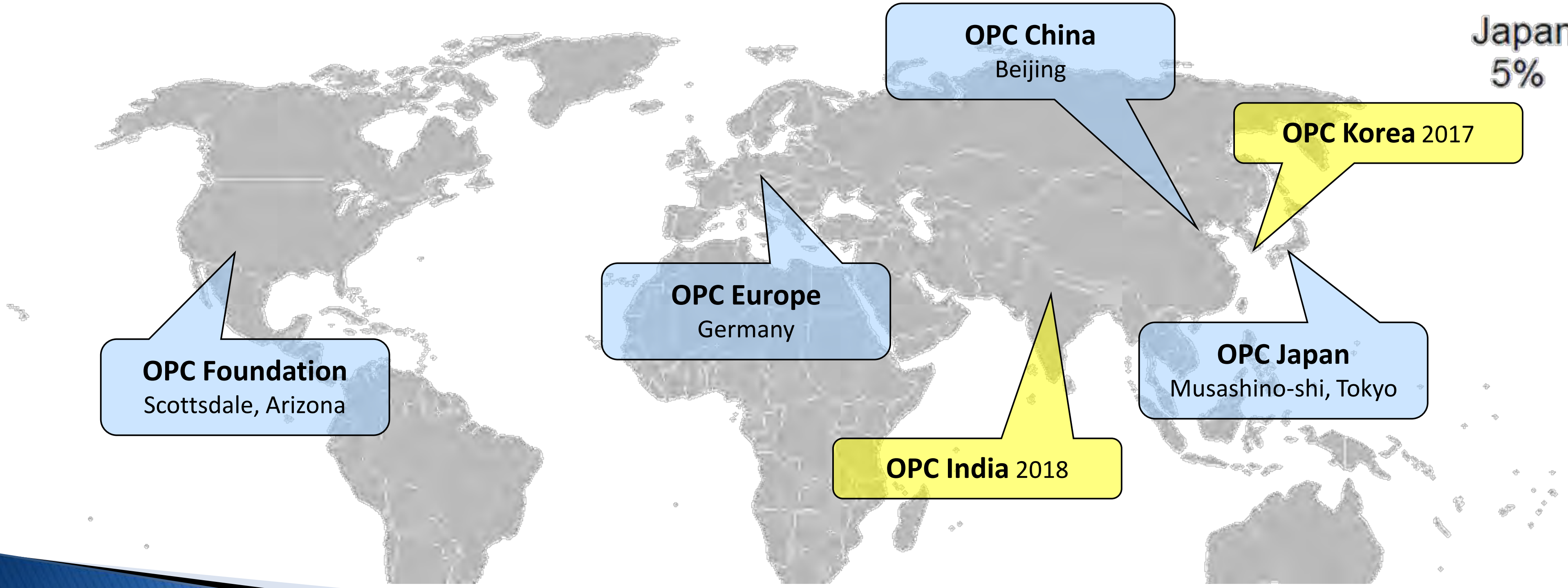
OPC Foundation: Membership



- An International Organization
  - Companies from Automation & IT
  - International standard IEC62541



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OPC Foundation Scottsdale, Arizona

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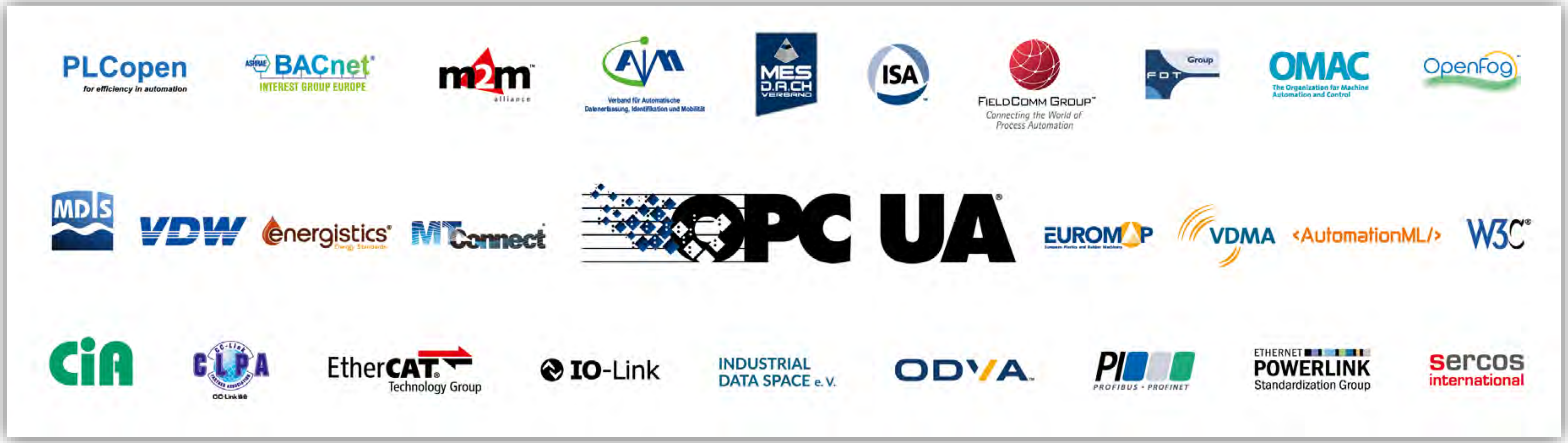
OPC UA: Enabling Standards Body Collaboration



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industrial internet® CONSORTIUM

Plattform INDUSTRIE 4.0

Made in China 2025

Internet +

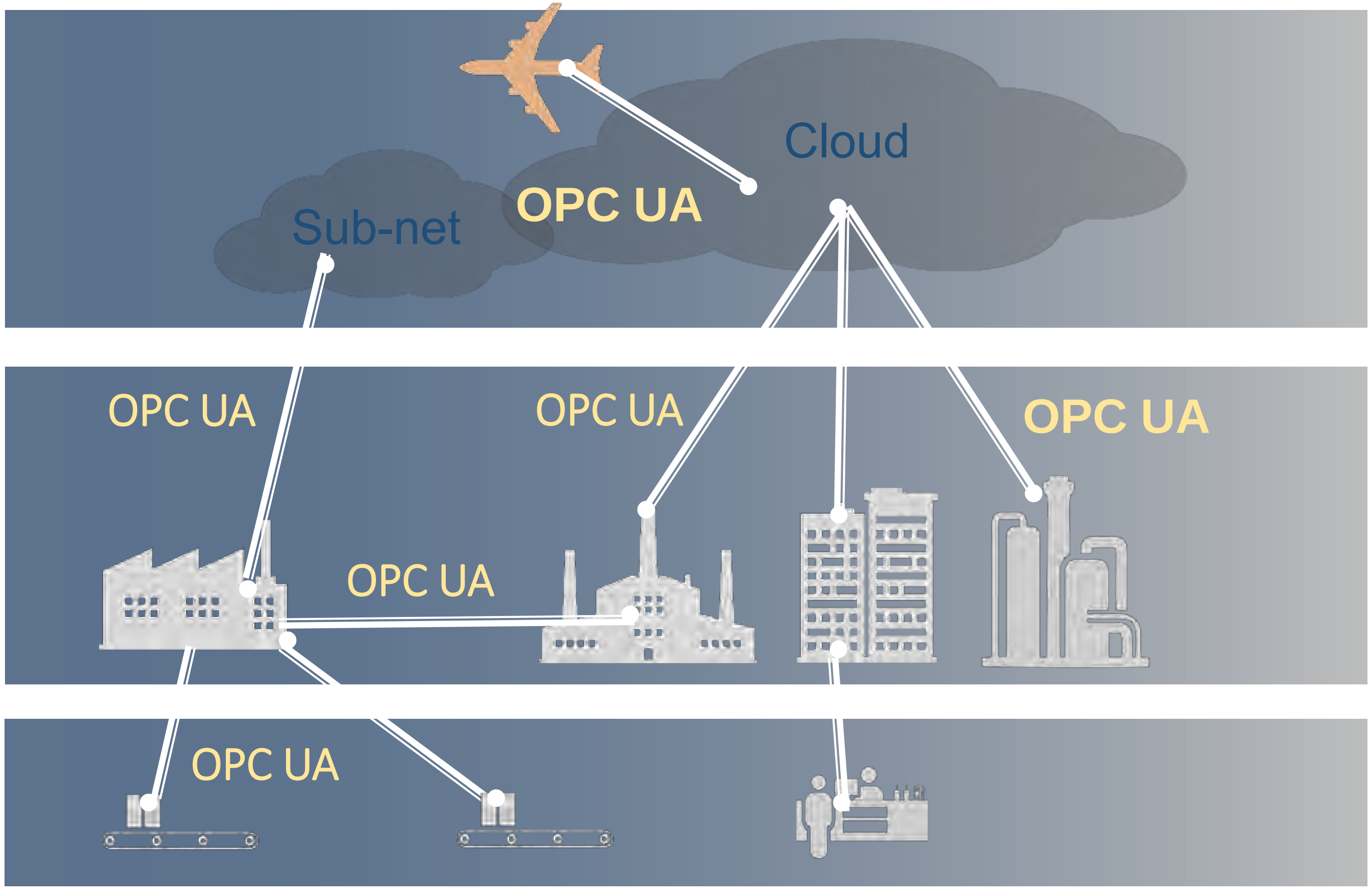
> “The only communication technology for industrial environments that I currently know of which provides integrated security functionality and also offers performance potential to tackle the challenges of Industrie4.0 is OPC UA.”

Holger Junker
Head of Cyber-Security in Critical IT-Systems
German Office for Information

Bundesamt
für Sicherheit in der
Informationstechnik

OPC UA In The IIoT Context

OPC UA – Paving the way for the IIoT



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IIoT & I4.0

- IIoT systems affect all aspects of a business so must be considered from multiple viewpoints (example from IIRA):

Business	• Business Value & ROI • Cost of Maintenance
Usage	• New device registration in plant and cloud system • How information is accessed, users added
Functional	• Component Interoperability in and across five functional domains: • **Control, Operations, Information, Applications, and Business**
Implementation	• Architecture, component distribution, topology • interfaces, protocols, behaviors, etc.

- Few standards meet the core connectivity standard criteria set out in IIRA
  - **OPC UA is a core connectivity standard (IIRA)**
  - **OPC UA is the main connectivity standard for I4.0 (RAMI)**

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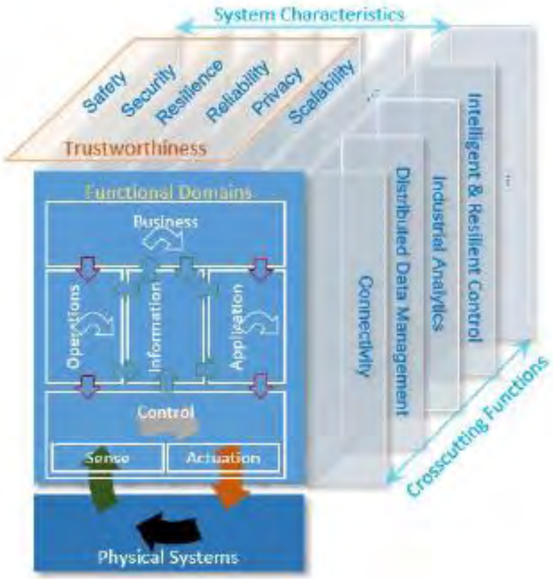
Next Gen Infrastructure: IIRA & RAMI

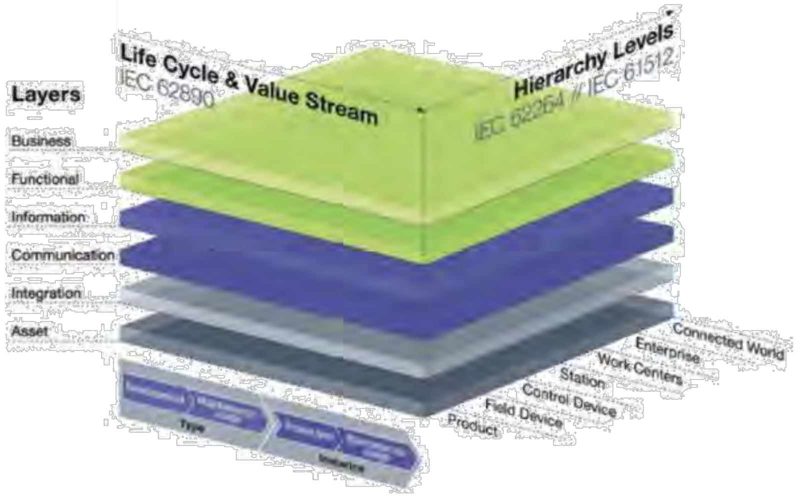
- **Frameworks** offer a structured, systematic way to discuss and evaluate solutions for IT and OT convergence.

Industrial Internet Reference Architecture (IIRA)



PLATTFORM INDUSTRIE4.0

Reference Architecture Model Industrie 4.0 (RAMI)



- Seamless, reliable, and cost effective system interoperability is crucial to IIoT

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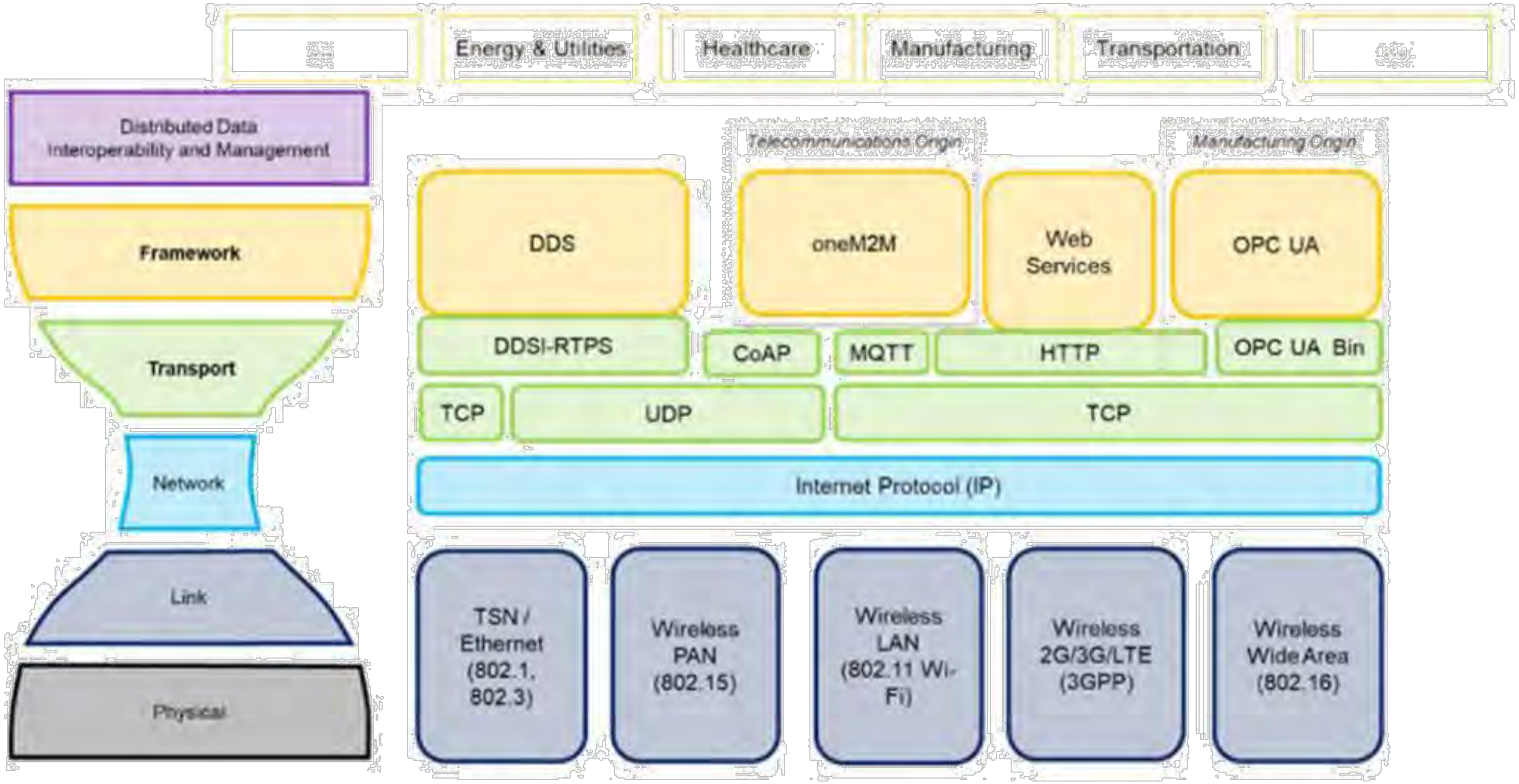
OPC UA: A Core IIRA Connectivity Standard



Source: Industrial Internet Consortium (www.iiconsortium.com)

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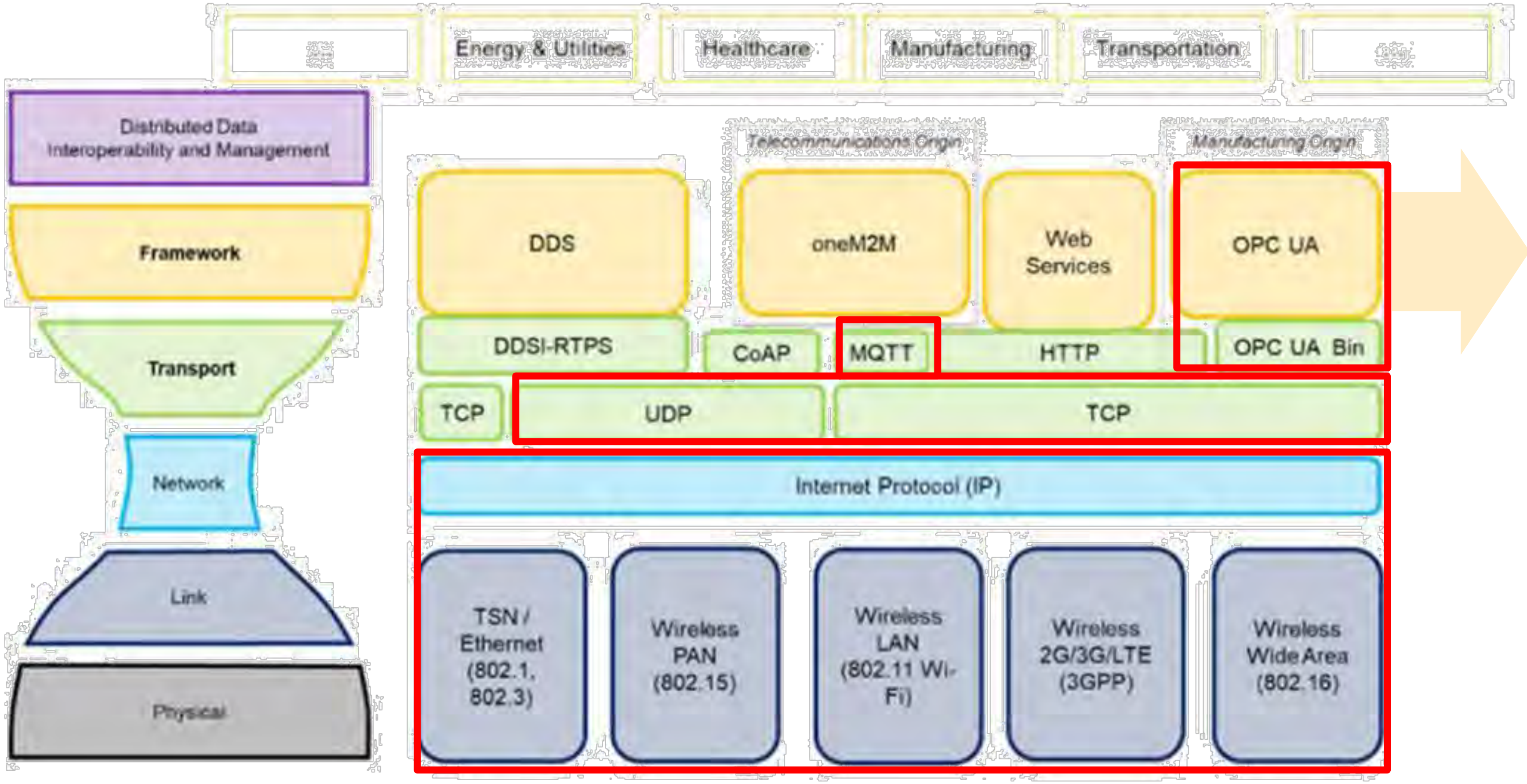
OPC UA Meets The Requirements

- Number of Core Data Standards kept as small as possible to minimize complexity



Source: Industrial Internet Consortium (www.iiconsortium.com)

CRITERIA EXAMPLES:

✓ Syntactic Interoperability
✓ Secure
✓ Performant
✓ Scalable
✓ Reliable
✓ Resilient
✓ Open Standard
✓ International Adoption
✓ Vendor Agnostic
✓ SDKs Available
(Open Source + Commercial)

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Data Security

Key Concepts

With Connectivity Comes the Need for Security

- Industrial Control System (ICS) Cyber attacks are accelerating

Stuxnet - Iran, 2010

Crash Override - Ukraine, 2016

Reuters

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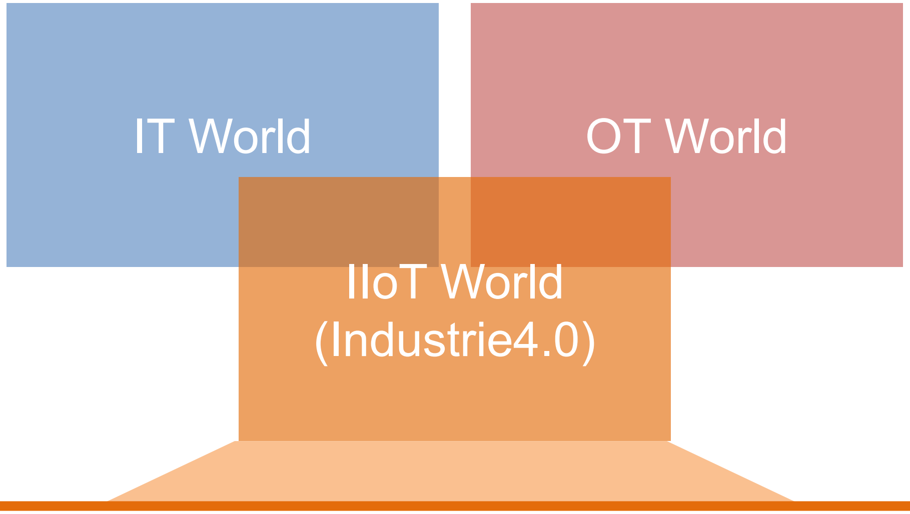
Trustworthiness: Key System Characteristics



Safety | **Security** | Resilience | Reliability | Privacy

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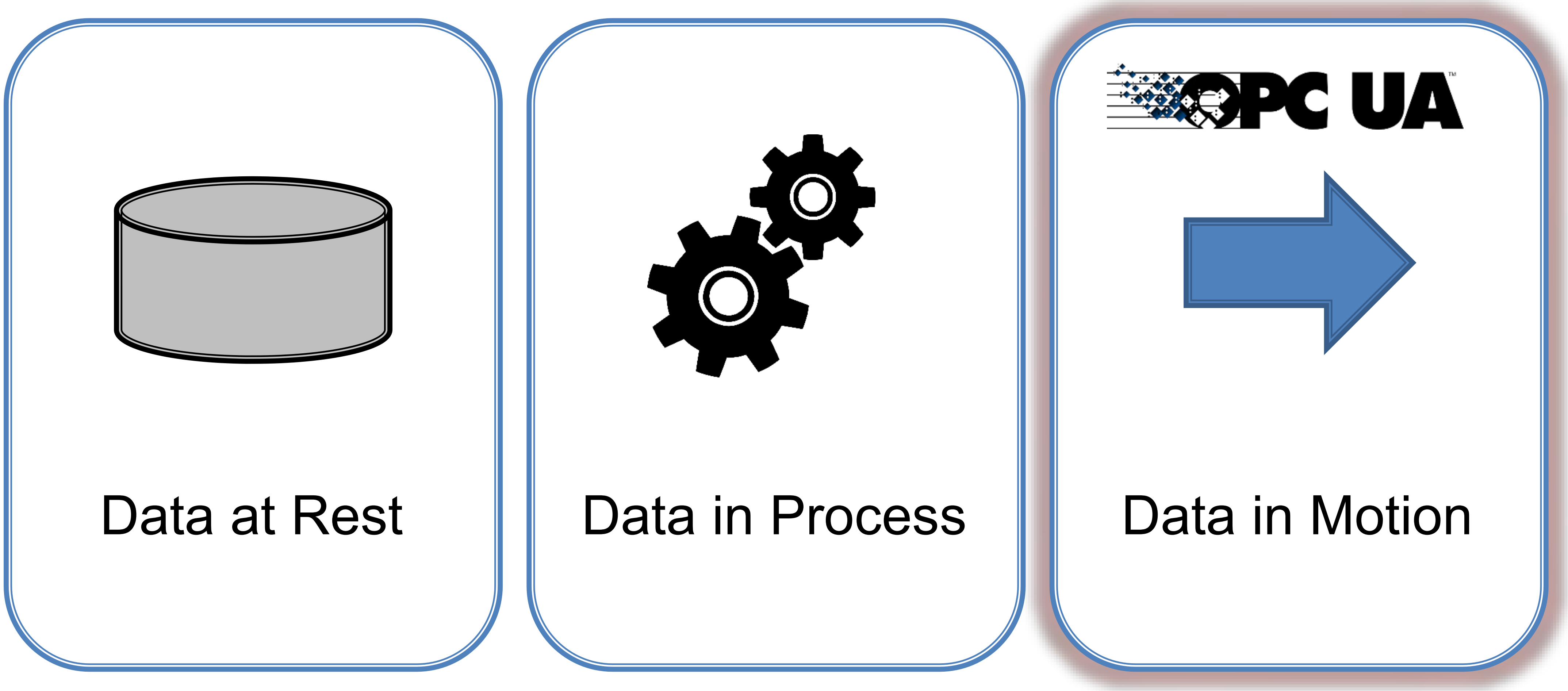
Data Security



Data at Rest

Data in Process

Data in Motion

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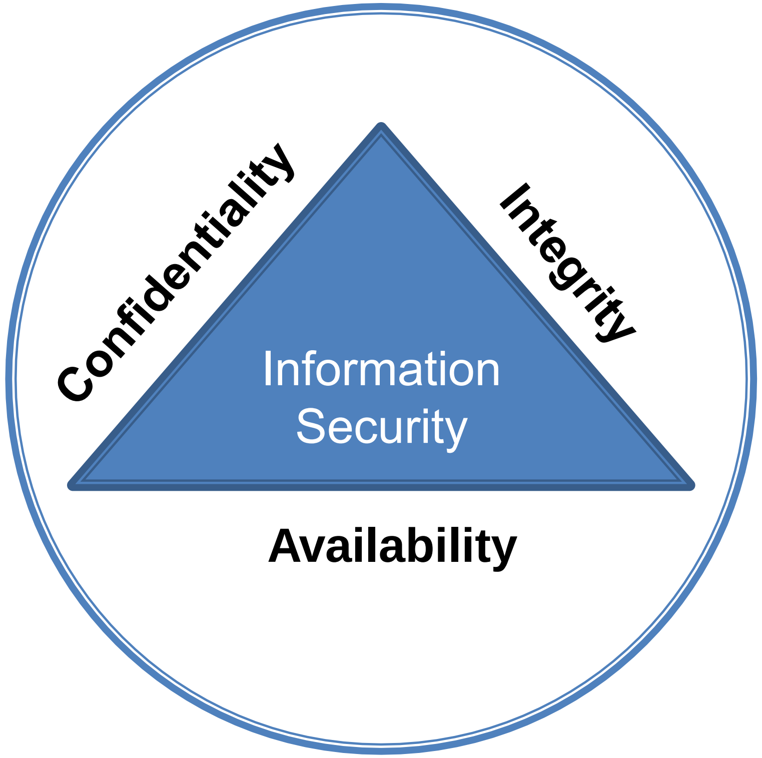
Key Security Concepts

- **Trusted Information (CIA triad)**
  - Confidentiality
  - Integrity
  - Availability

- **Access Control (AAA principle)**
  - Authentication
  - Authorization
  - Accounting (Auditability)



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OPC UA

Secure by Design

OPC UA: Secure By Design

1) Concepts
2) **Security Model**
3) Address Space Model
4) **Services**
5) Information Model
6) **Mappings**
7) **Profiles**
8) Data Access
9) Alarms and Conditions
10) Programs
11) Historical Access
12) **Discovery**
13) Aggregates
14) PubSub

Red: directly relevant for IT security

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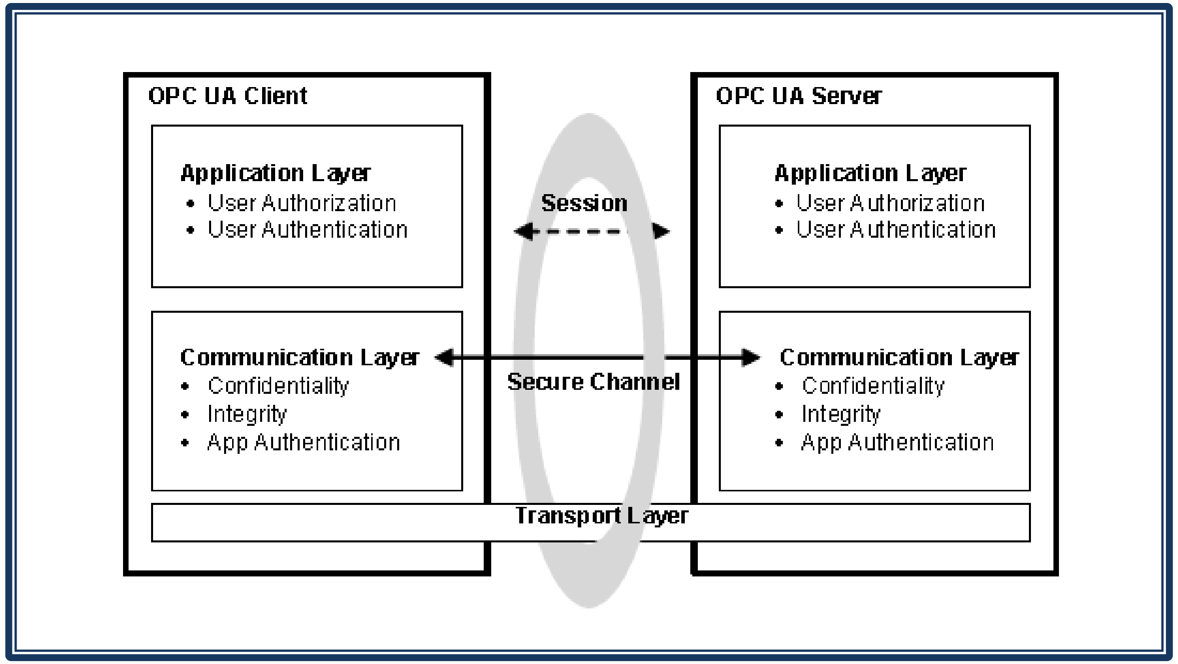
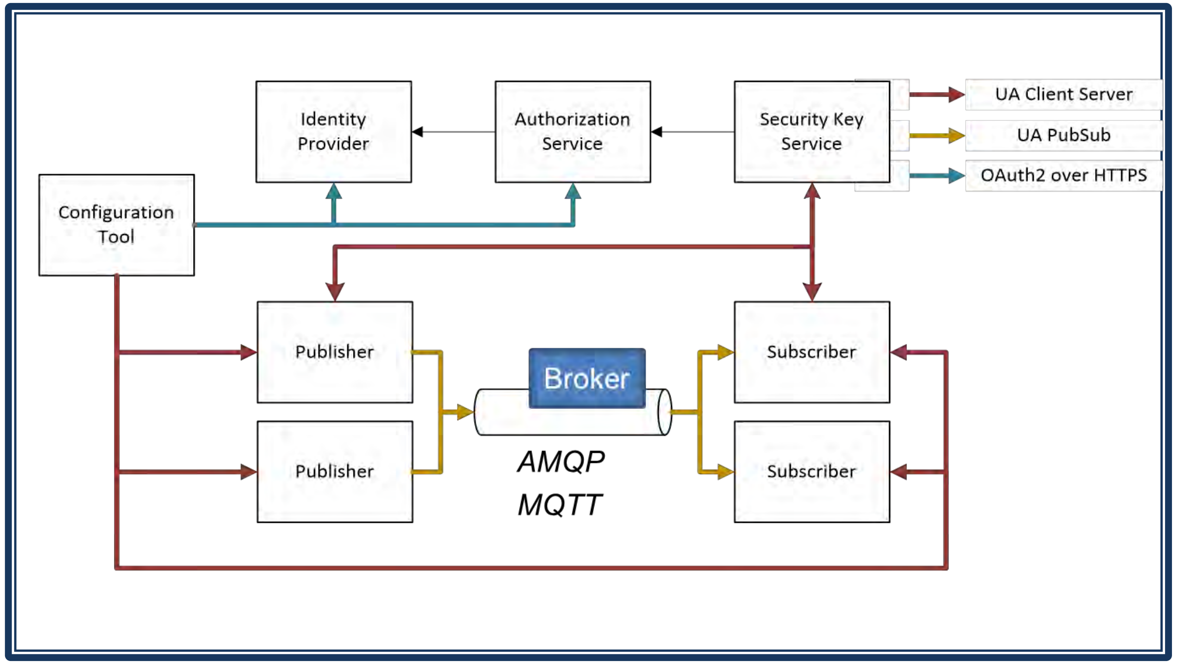
Solid Security Foundation

- OPC UA addresses the core security aspects:

Client-Server Architecture



Publish-Subscribe Architecture



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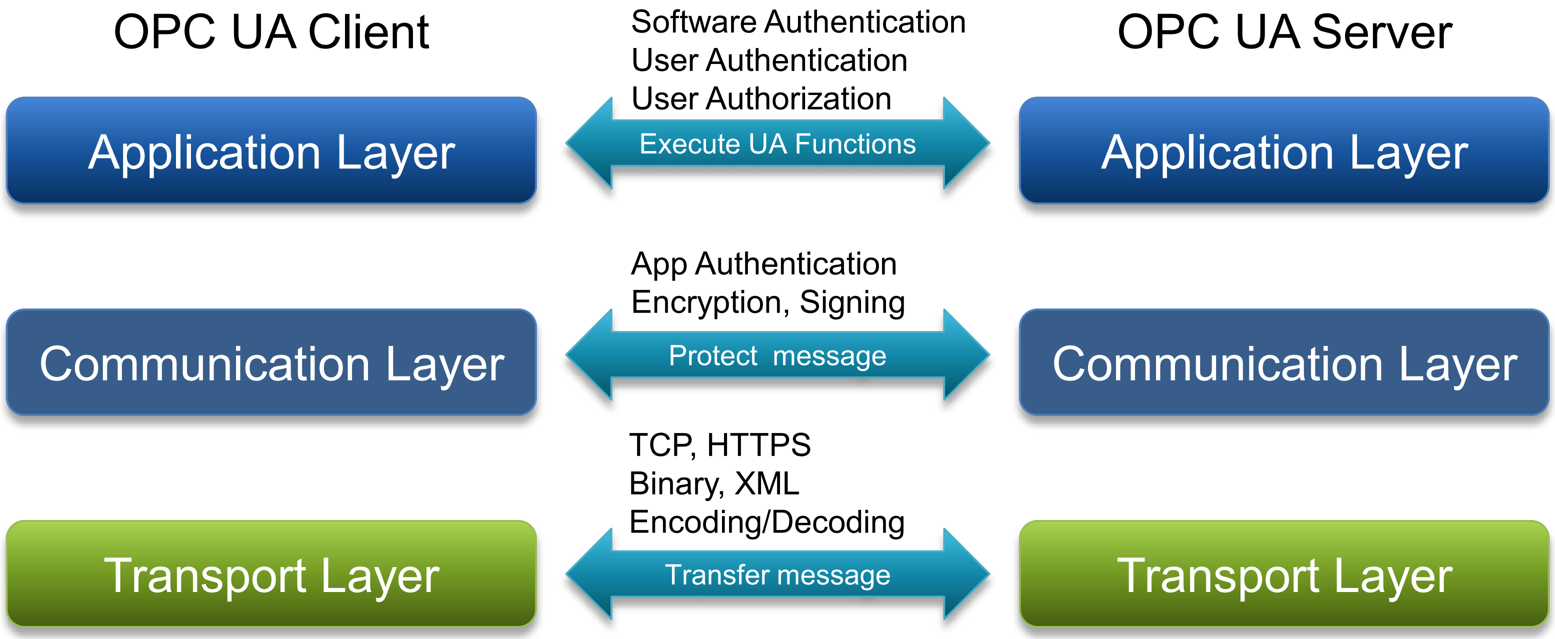
Layered Communications

- Layered conceptual communication model



OPC UA Client

OPC UA Server

Software Authentication
User Authentication
User Authorization

Application Layer ↔ Execute UA Functions ↔ Application Layer

App Authentication
Encryption, Signing

Communication Layer ↔ Protect message ↔ Communication Layer

TCP, HTTPS
Binary, XML
Encoding/Decoding

Transport Layer ↔ Transfer message ↔ Transport Layer

- Allow to choose appropriate abilities to meet various requirements
  - Level 3 Apps : **Internet accessibility** and **Security** (e.g. HTTP & XML, E & S)
  - Level 2 Apps : **High speed** and **Security** (e.g. UA TCP & BIN, S)
  - Level 1 Apps : **High speed** and **Small-footprint** (e.g. UA TCP & BIN)

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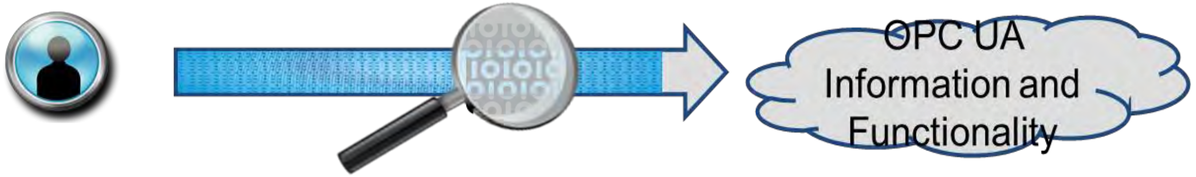
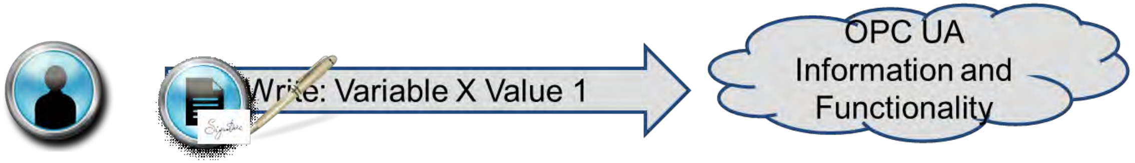
Communication Layer Security

- **Confidentiality** → Encrypting of Messages



- **Integrity** → Signing of Messages



- **Availability** → Minimal message processing before authentication

Examples:
- Restricting message size
- No security related error codes returned

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Communication & Application Layer Security

- Authentication of applications
  - Application instance certificates
  - Certificate Authority (CA)
- Authentication of users
  - Username / password, WS-Security Token or X.509 certificates,
  - Fits into existing infrastructures like Active Directory
- Authorization (Server Specific)
  - Fine-granular information in address space (Read, Write, Browse)
  - Writing of meta data, calling methods
- Auditability
  - Generating audit events for security related operations

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OPC UA Security

Assessment & Evolution

Examples of Attack Types Addressed

- **Message Flooding**
  - Minimize processing of packets before they are authenticated
- **Eavesdropping** – record and capture packets
  - Encryption
- **Message Spoofing** – attacker forges messages from client/server
  - Message signing, valid Session ID, Channel ID, timestamp, …
- **Message Alteration & Replay** – messages captured, modified, resent
  - Session IDs, *Secure Channel* ID, Timestamps, Sequence# and Request IDs
- **Malformed Messages**
  - Validating message structure and valid parameter values or discard
- **Server Profiling, Session Hijacking**, etc…

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Threats according to OPC UA Part 2

	Authentication	Authorization	Confidentiality	Integrity	Auditability	Availability
Message Flooding						X
Eavesdropping			X			
Message Spoofing		X		X		
Message Alteration		X		X		
Message Replay		X				
Malformed Messages				X		
Server Profiling	X	X	X	X	X	X
Session Hijacking	X	X	X			
Rogue Server	X	X	X		X	X
Compromising User Credentials		X	X			

Threats and Impact on Security Objectives

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Effectiveness of OPC UA Measures

Bundesamt für Sicherheit in der Informationstechnik

OPC UA Security Analysis

02/03/2017

security-Mode	Layer or Service	Denial of Service	Eavesdropping	Message Spoofing	Message Alteration	Message Replay	Malformed Messages	Server Profiling	Session Hijacking	Rogue Server	Compromising User credentials	Repudiation
None		🟨	🟥	🟥	🟥	🟩	🟧	🟧	🟩	🟧	🟩	🟨
Sign		🟨	🟥	🟩	🟩	🟩	🟩	🟨	🟩	🟩	🟩	🟩
SignAndEncrypt		🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟩	🟩	🟩	🟩

🟥 : no protection

🟧 : low protection

🟨 : Protection which restricts the possibilities of an attacker, but does not prevent this type of attack

🟩 : effective protection (attacks of this type require cryptographic attacks)

Source: BSI, "OPCUA Security Analysis" (02/03/2017)

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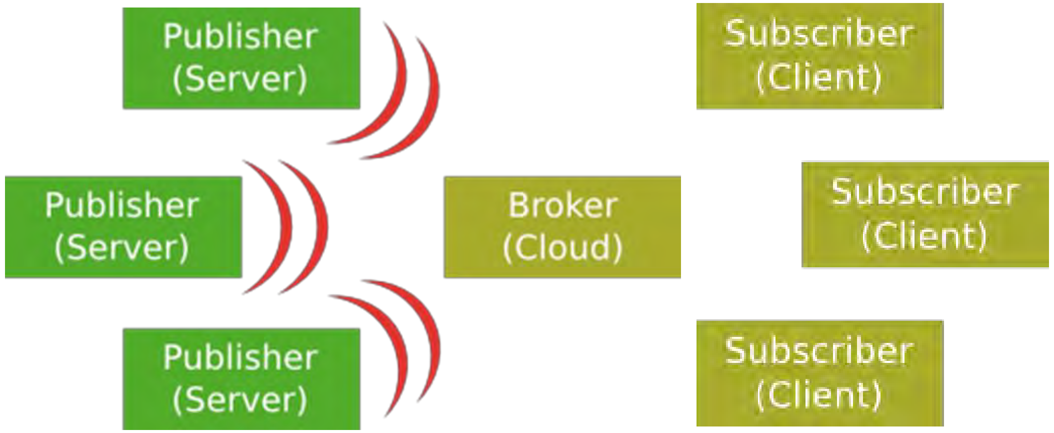
New Security related features in 1.04

- PubSub
  - JSON Web Token (JWT)
- Roles & Claim Based security
- Security Management
- Session-less Service calls



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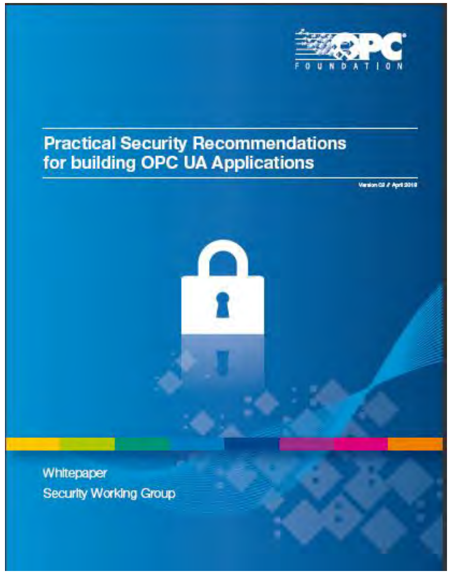
Conclusion



Practical Security Recommendations for building OPC UA Applications

Version 02 / April 2018

Whitepaper

Security Working Group

OPC UA is secure-by-design:

- Implements CIA
  - **Confidentiality** and **Integrity** by signing and encrypting messages
  - **Availability** by minimum processing before authentication
- Implements AAA
  - **Authentication** and **Authorization** of Users and Application instances
  - **Auditability** by defined audit events for OPC UA operations
- Facilitates use of different levels of security to match application/hardware
- OPC UA continually evolving to meet new threats and capabilities

Use of OPC UA security enhances overall system security (defense in depth)

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Thank You.

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