PROTOCOLS
INDUSTRIAL IOT

Software and Services Group
IoT Developer Relations, Intel

LEGAL NOTICES AND DISCLAIMERS

IIOT CONNECTIVITY CHALLENGE

The goal of the industrial internet is to enable seamless information sharing across domains and industries.

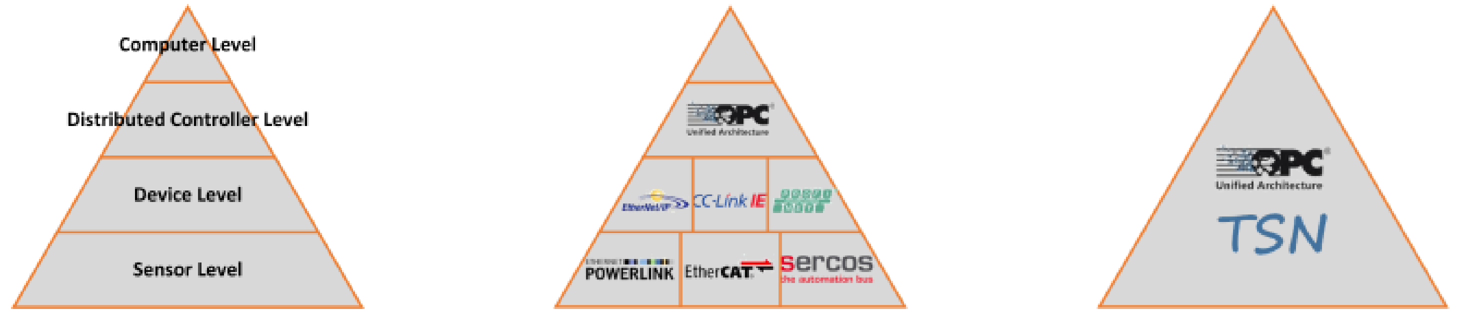
Past capital investments in equipment have created a myriad of domain specific connectivity technologies, tightly vertically integrated and optimized to solve domain specific needs.

IIoT systems usually integrate with **brownfield** technologies to preserve the capital investments, and **greenfield** technologies to spur innovation.

NETWORKING FOR AUTOMATION AND ROBOTICS

For machine-to-machine and process communication (the distributed controller level), the role **of OPC UA (IEC 62541) is rapidly increasing in significance alongside the traditional Ethernet-based M2M fieldbus systems** (PROFINET, EtherNet/IP, CC-Link IE).

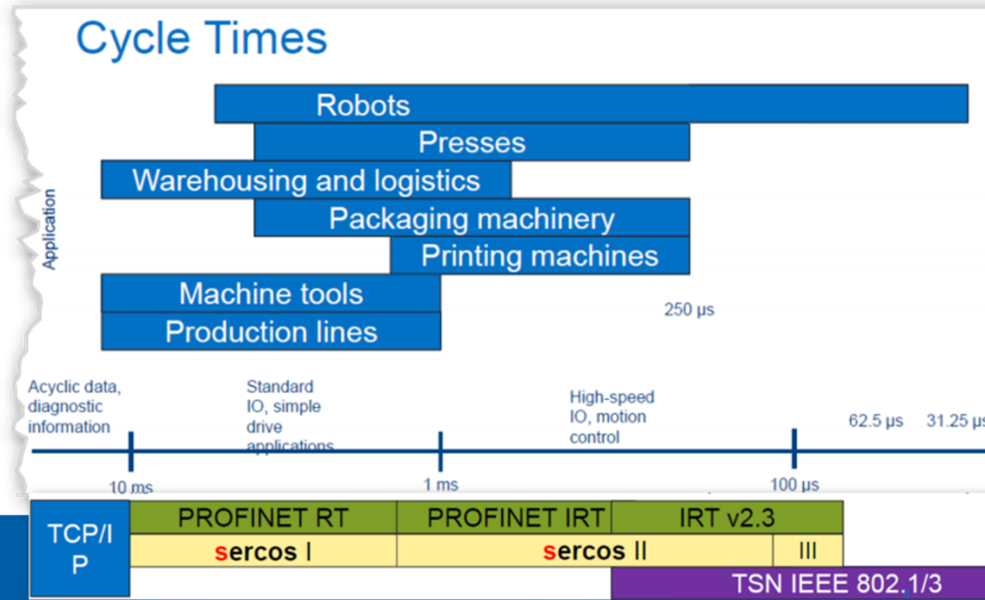
Although these technologies share common requirements, their implementations differ substantially. Hence, comparing them depends heavily on the intended application (process control, motion, I/O, centralized vs. decentralized control, etc.).



(a) Levels of the automation pyramid

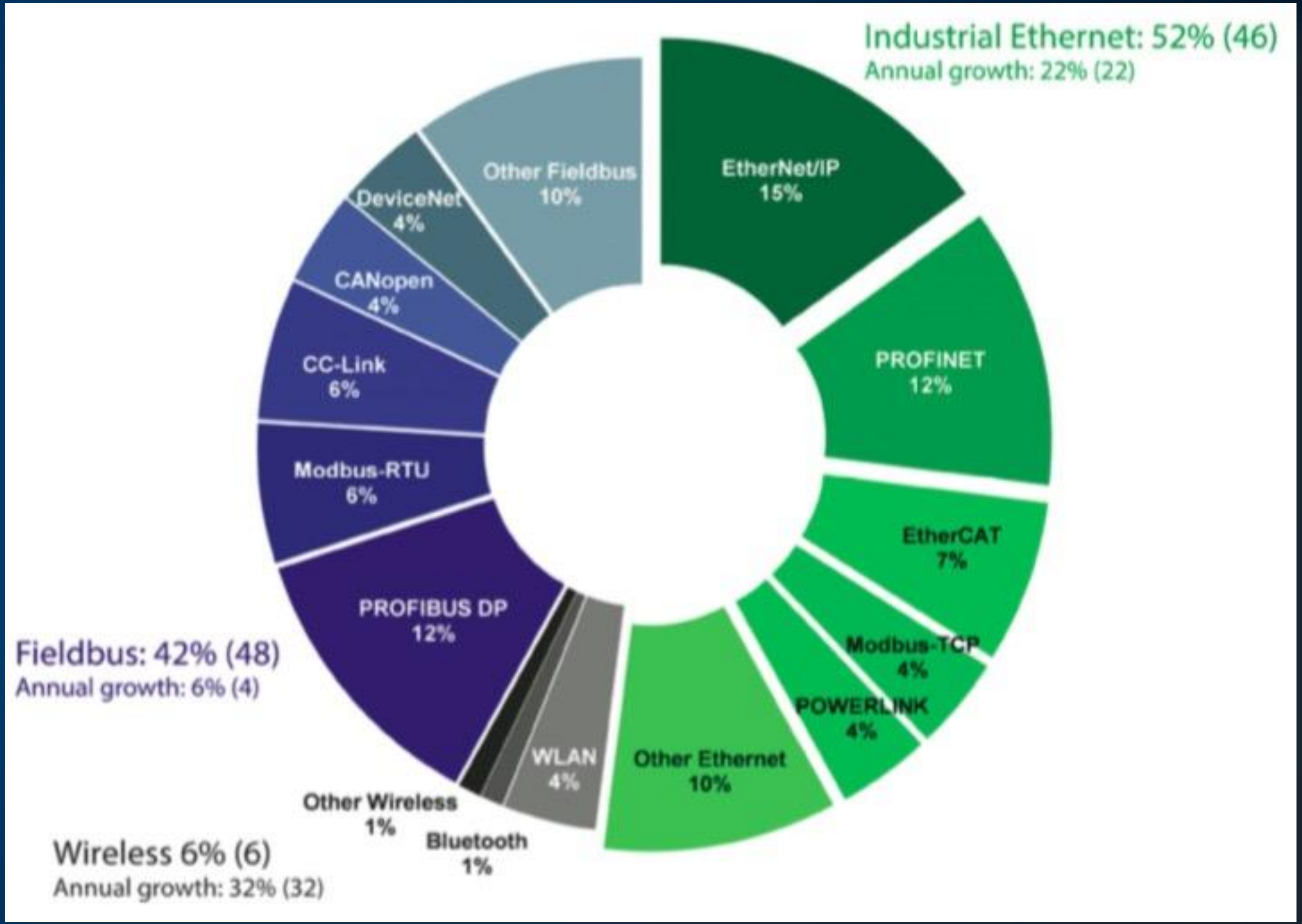
(b) Today's distinct ecosystems in the automation pyramid

(c) Holistic communication from the sensor to the cloud using OPC UA (and TSN)



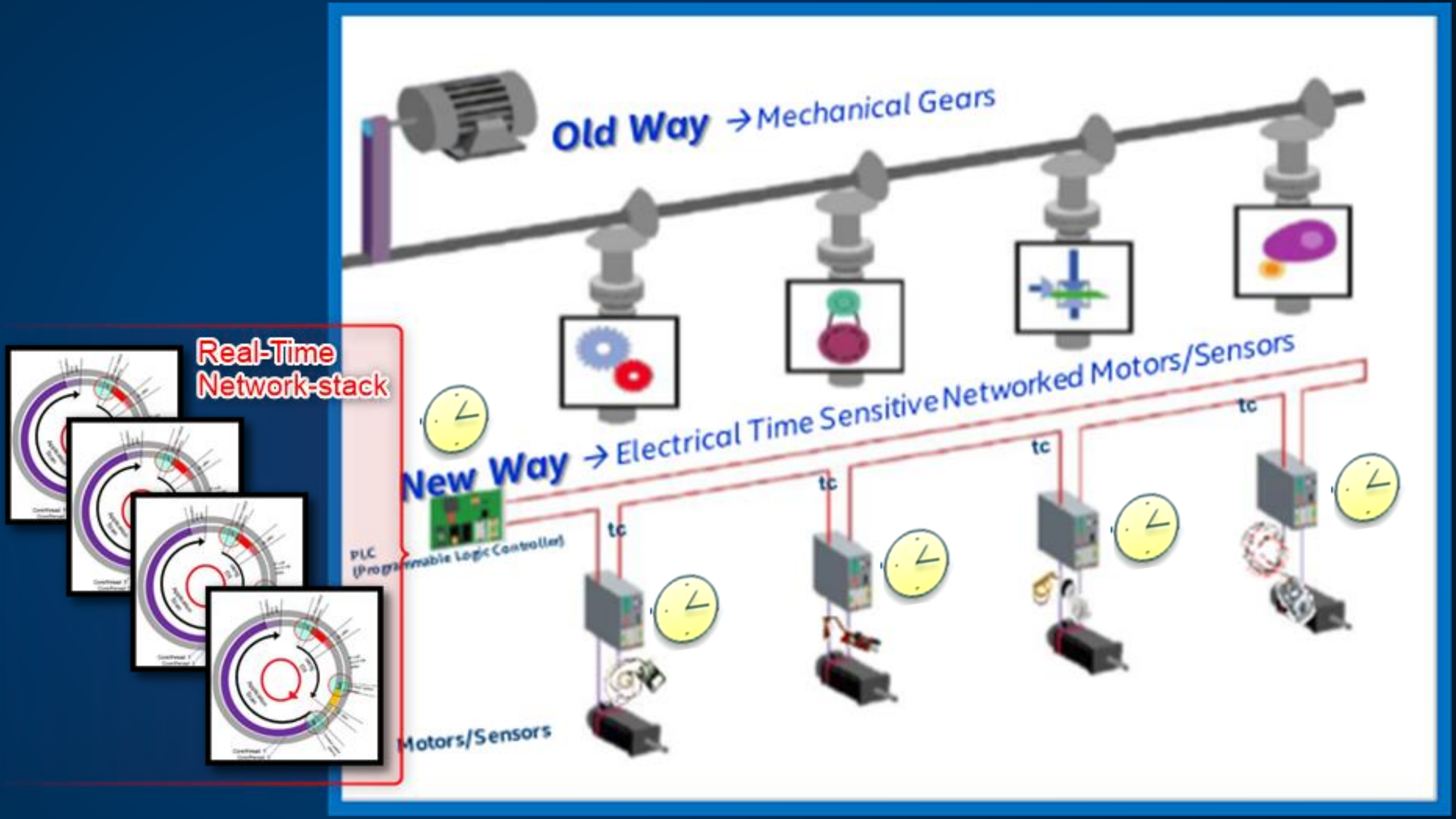
INDUSTRIAL ETHERNET MARKET SHARE

- Growth powered by IIoT (e.g OT/IT)
- Wireless redefining network picture
- Regional network variations :
  - EMEA - PROFINET and EtherNet/IP are dominant
  - US - Movement towards EtherNet/IP
  - Asia - no network stands out as truly market-leading: PROFINET, EtherNet/IP, PROFIBUS, EtherCAT, Modbus and CC-Link
- Fieldbuses expected to decline
  - PROFIBUS and Modbus still significant



NETWORKING FOR AUTOMATION AND ROBOTICS

- Time-Synchronized (IEEE 1588v2 or 802.1AS) real-time control.
- Down the wire updates
- Reduced OPEX
- Flexible function
- Reconfigurable production



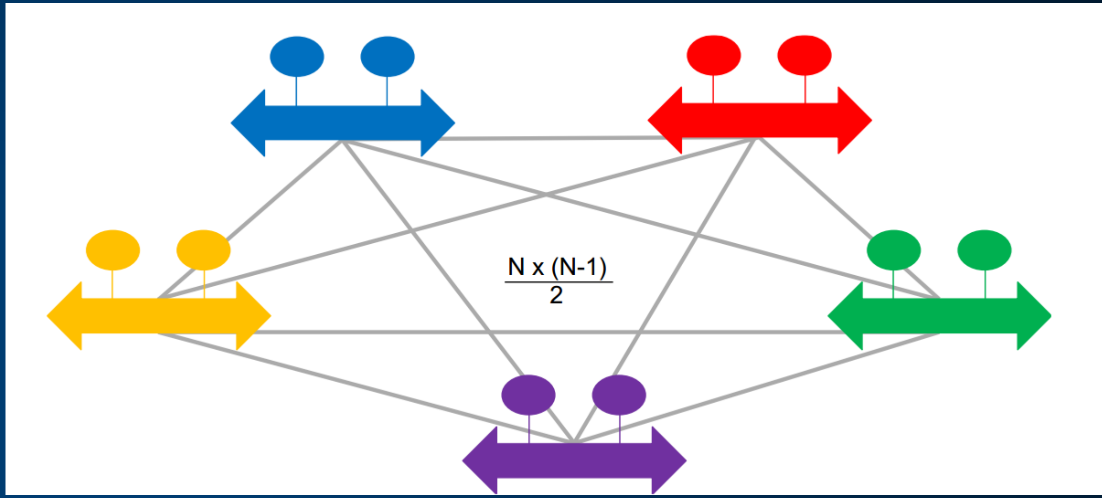
SCALABILITY MODEL NEEDS DOMAIN GATEWAYS

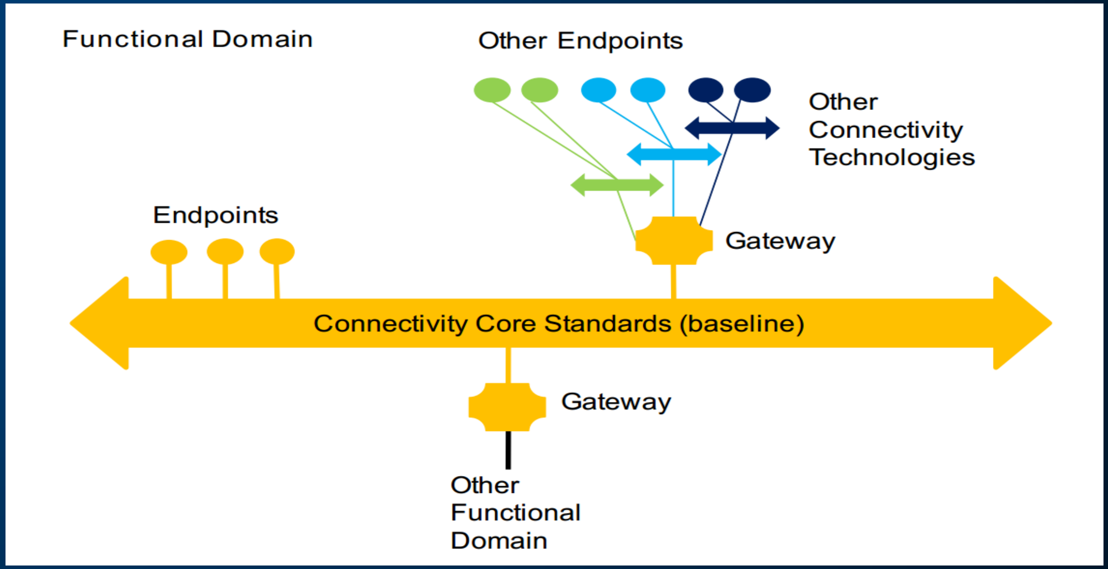
Complete connectivity rapidly becomes unmanageable.

$$N \times \frac{N-1}{2} = O(N^2)$$

To keep the connectivity architecture manageable, a connectivity technology standard is chosen as the baseline within a functional domain, and referred to as the "**connectivity core standard**"

To facilitate information exchange, one has to build bridges to each of the other connectivity technologies.





BRIDGING CORE CONNECTIVITY STANDARDS

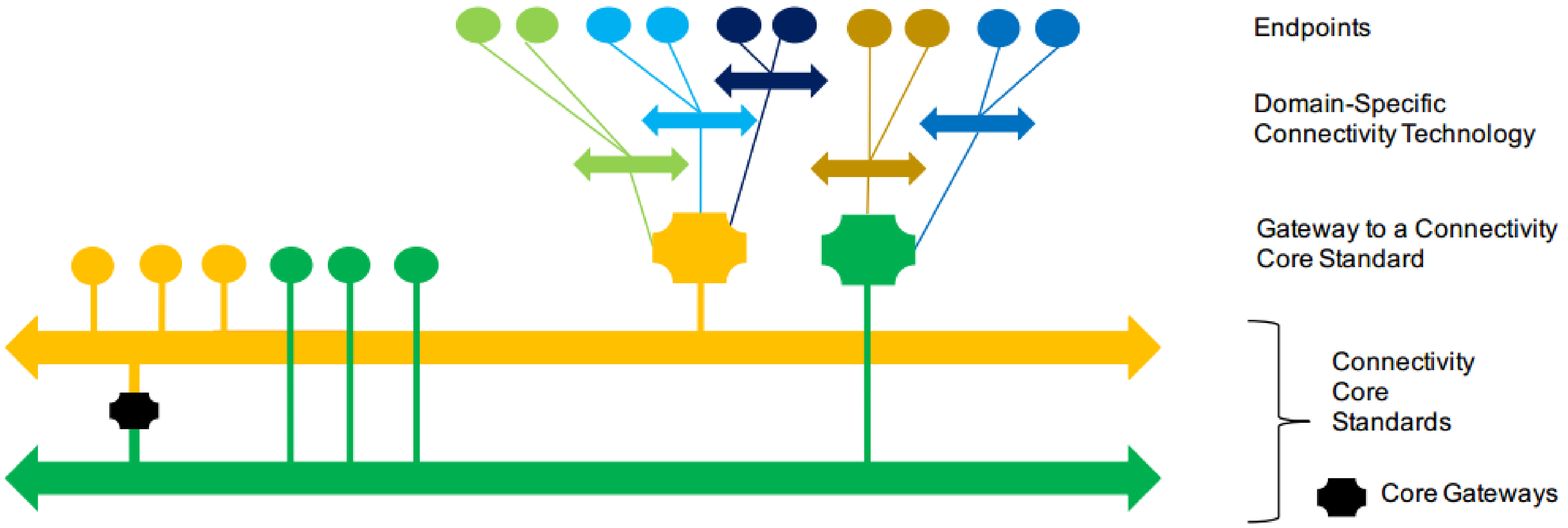


Figure 3-3: A standardized gateway between core connectivity standards can allow domain-specific endpoints connected to one core standard to communicate with domain-specific endpoints integrated over another core standard.

TOOLS: PROTOCOL ASSESSMENT TEMPLATE

The assessment template is intended to be a tool for understanding any connectivity technology in the context of the IIoT needs.

The worksheet is helpful for:

- understanding how a connectivity technology supports specific IIoT functional needs,
- evaluating a connectivity technology's trades-offs for typical IIoT considerations and
- determining a connectivity technology's suitability for a particular use case (once the specific requirements are understood).

Core Standard Criterion	Protocol Checklist
Provide **syntactic interoperability**	√
Open standard with strong **independent, international** governance	X
Horizontal in its applicability across industries	
Stable and **deployed** across multiple vertical industries	
Have **standards-defined *Core Gateways*** to all other core connectivity standards	
Meets connectivity **functional** requirements	
Meet **non-functional** requirements of performance, scalability, reliability, resilience	
Meet **security** and **safety** requirements	
Not require any single component from any single vendor	
Have readily-available SDKs both **commercial** and **open source**	

CONNECTIVITY FRAMEWORK CORE FUNCTIONS

- **Data Resource Model** – represents structured data objects that can change state over time
- **ID and Addressing** – provides the means to identify and address each data object
- **Data Type System** – provides a way to describe the constrains place on data, includes a method of evolving and versioning the data syntax
- **Publish/Subscribe** – supports the well-know pubsub pattern for decoupled data exchange
- **Request/Reply** - supports the well-know request/reply pattern for data exchange
- **Discovery** – must be able to find pubsub services, request/reply services, endpoints and datatypes.
- **Exception Handling** – mechanisms for handling disconnections, changes in configuration or quality, endpoint failures, etc…
- **Data Quality of Service** – QoS method implemented, best-effort vs. reliable delivery
- **Data Security** – confidentiality, integrity, authenticity and non-repudiation of the data
- **Data Governance** – is there a standards body that directs this protocol's evolution

IIOT CONNECTIVITY STACK MODEL

INDUSTRY
- Energy Sector
- Health Care
- Transportation
- Manufacturing
- ……

TRANSPORT
- DDS
- Web Services
- OPC-UA

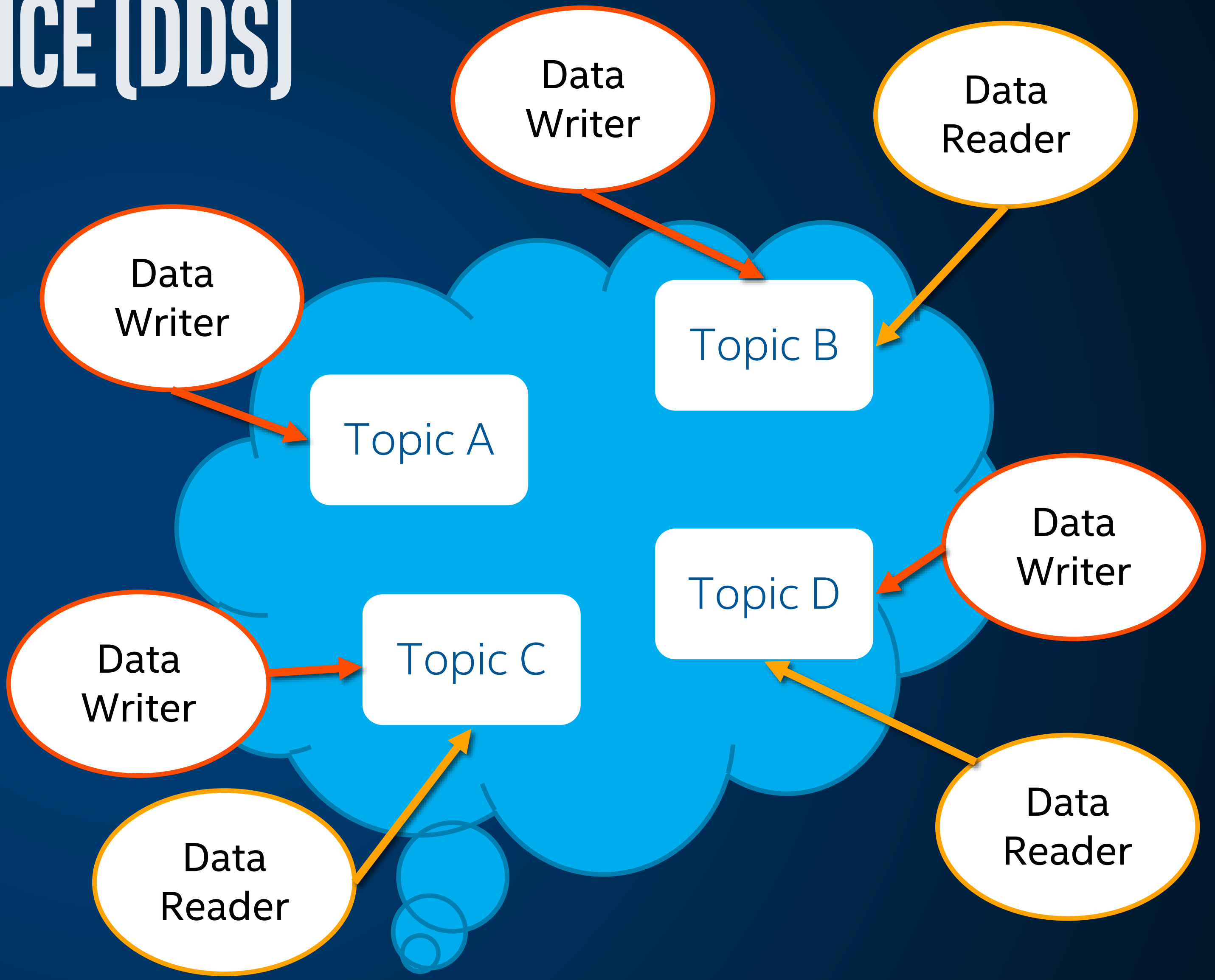
NETWORK
- RTSP
- CoAP
- MQTT
- HTTP
- OPC-UAB
- TCP
- UDP
- TCP

LINK
- IP Protocol

PHYSICAL
- TSN / Ethernet
- Wireless PAN
- Wireless LAN
- Wireless 2G/3G/LTE
- Wireless Wide Area

DATA DISTRIBUTION SERVICE (DDS)

The **Data Distribution Service** for real-time systems (**DDS**) is an Object Management Group (OMG) machine-to-machine(sometimes called middleware) standard that aims to enable scalable, real-time, dependable, high-performance and interoperable data exchanges using a publish–subscribe pattern. DDS addresses the needs of applications like financial trading, air-traffic control, smart grid management, and other big data applications. The standard is used in applications such as smartphone operating systems,[1] transportation systems and vehicles,[2] software-defined radio, and by healthcare providers. DDS was promoted for use in the Internet of things.[3]

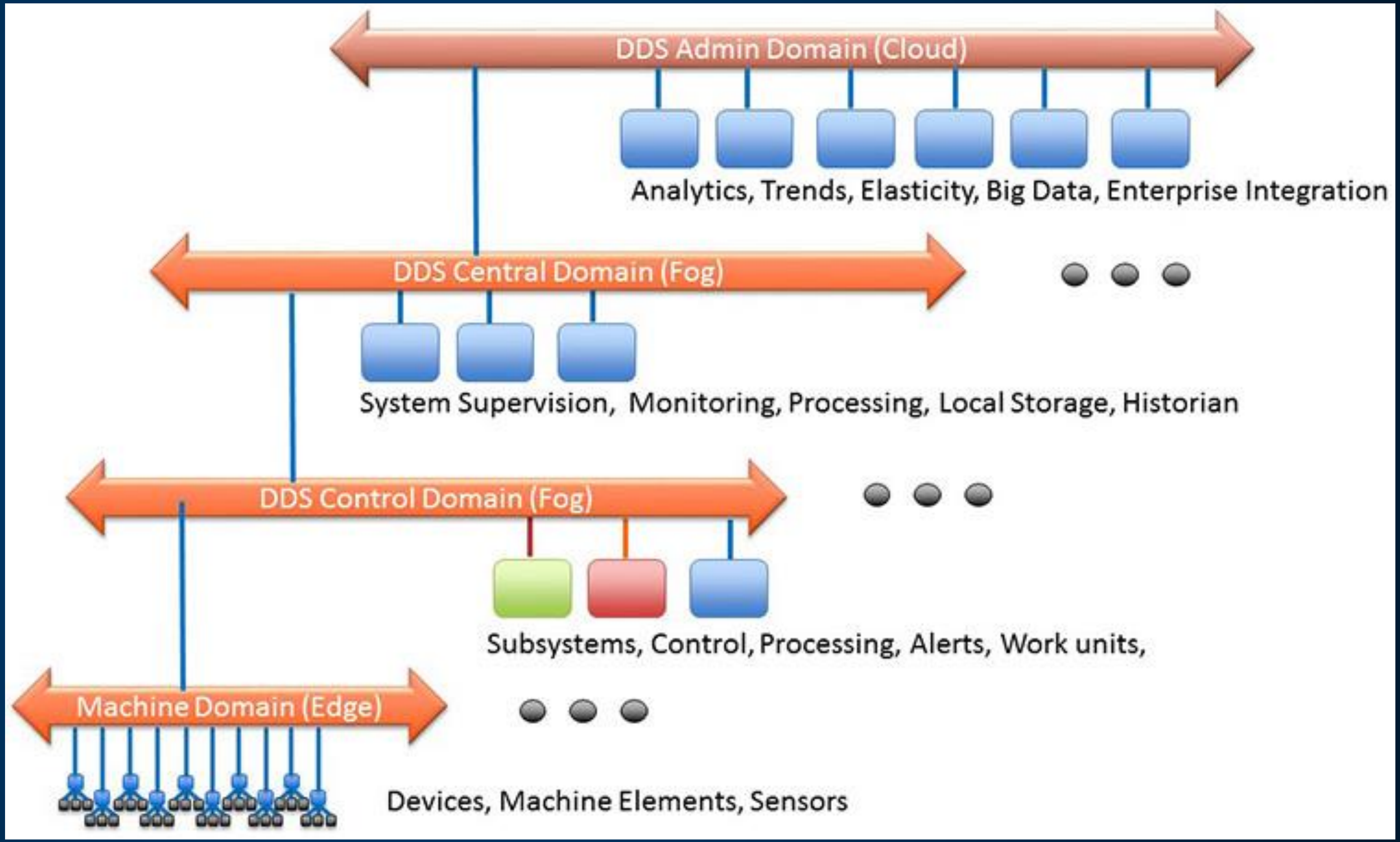


PROPERTIES OF DDS

Quality of Service

Dynamic Discovery

Scalable Architecture



DDS: FUNCTIONAL SUMMARY

DDS has been applied in multiple verticals to realize higher domain-specific interoperablity

open architecture specifications. These include:
• SGIP OpenFMB v1.0 (uses CIM extensions over DDS) - NAESB Standard
• MDPnP OpenICE Integrated Clinical Environment for Medical Device
Interoperability
• ROS: Robot Operating System (Open Source)
• EUROCAE ED-133 flight data exchange between air traffic control centers
• Generic Vehicle Architecture (GVA)
• Future Airborne Capability Environment (FACE)
• Open Mission Systems (OMS)
• Open Architecture Radar Interface Standard (OARIS)
• Unmanned Aircraft Systems Control Segment (UCS)
• Joint Architecture for Unmanned Systems (JAUS) over DDS
• Layered Simulation Architecture
• Navy Open Architecture

Core Standard Criterion	Protocol Checklist
Provide **syntactic interoperability**	√
Open standard with strong **independent, international** governance	√
Horizontal in its applicability across industries	√
Stable and **deployed** across multiple vertical industries	Military, Software Integration
Have **standards-defined *Core Gateways*** to all other core connectivity standards	Web Services, OPC-UA
Meets connectivity **functional** requirements	√
Meet **non-functional** requirements of performance, scalability, reliability, resilience	√
Meet **security** and **safety** requirements	√
Not require any single component from any single vendor	√
Have readily-available SDKs both **commercial** and **open source**	√

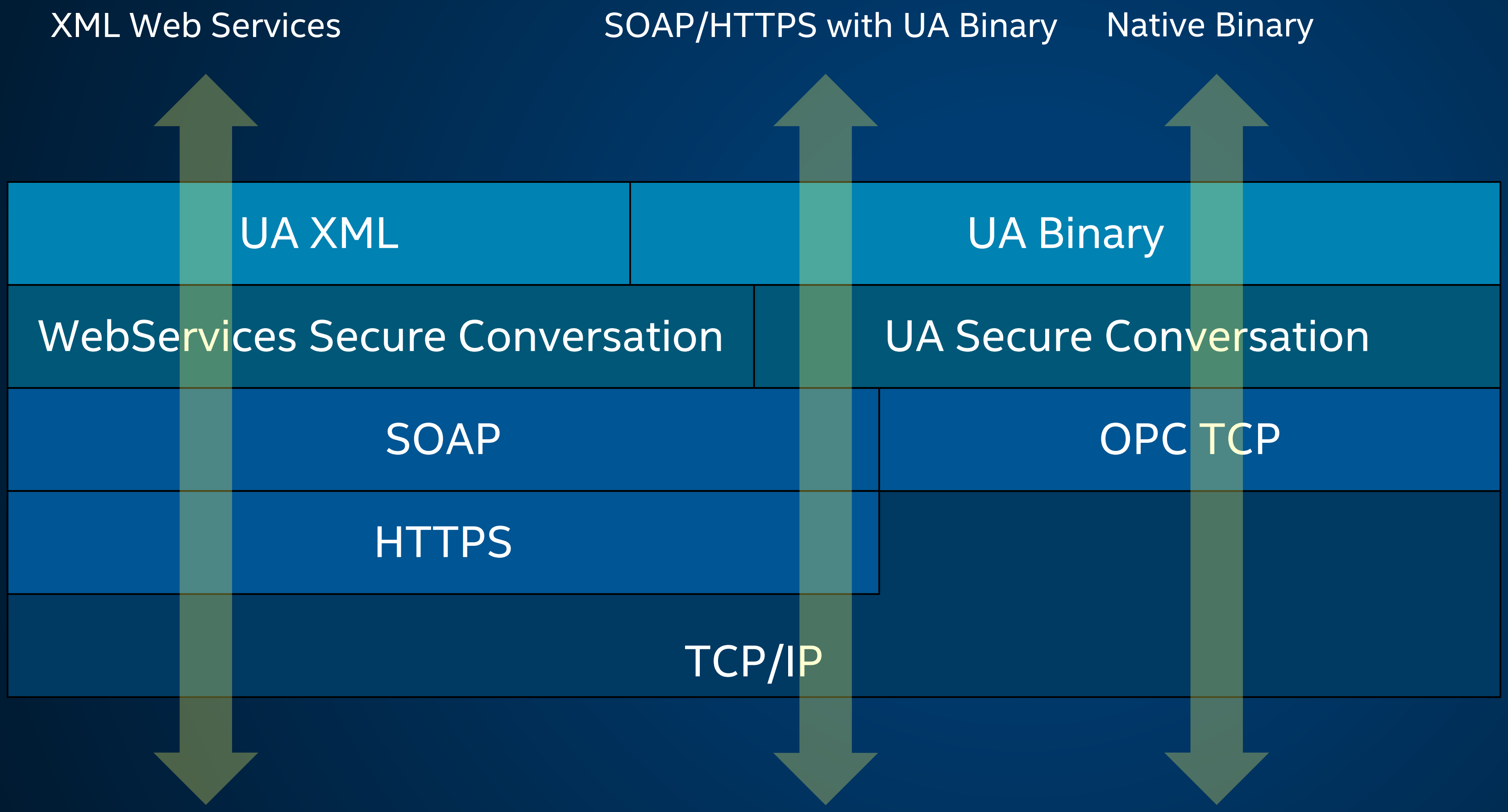
WHAT IS OPC-UA?

OPC UA is a protocol for industrial communication and has been standardized in the IEC 62541 series. At its core, OPC UA defines:

- **an asynchronous protocol** (built upon TCP, HTTP or SOAP) that defines the exchange of messages via sessions, (on top of) secure communication channels, (on top of) raw connections,
- **a type system** for protocol messages with a binary and XML-based encoding scheme,
- **a meta-model** for information modeling, that combines object-orientation with semantic triple-relations, and
- **a set of 37 standard services** to interact with server-side information models. The signature of each service is defined as a request and response message in the protocol type system.

The standard itself can be purchased from IEC or downloaded for free on the website of the OPC Foundation at https://opcfoundation.org/.

SECURE CLIENT/SERVER COMMUNICATIONS



- Authentication
- Authorization
- Encryption
- Data integrity

Protocol Stack diagram: GFDL-self/cc-by-sa3.0 https://de.wikipedia.org/wiki/Datei:Uaprotocols.png

RESILIENT COMMUNICATIONS

Redundancy

- OPC UA client and server high-availability
- Client: Active/Active
- Server: Passive/Active

Bidirectional “heartbeat”

- OPC UA clients and servers detect connection failures

Buffering

- OPC UA clients detect missing data and may request again

SOPHISTICATED INTERACTIONS

I need to drill this plate

Are you able to drill materials?

Yes, which one?

Steel

Fine, which diameter?

1 inch (2.54 cm)

Fine, please provide coordinates and depth

X: 10, Y: 5, Z: 1

Fine, I am available now

I am sending you the plate

Ok, waiting for it

OPEN62541 FEATURES

Communication Stack

- model – Support for all OPC UA node types (including method nodes) – Support for adding and reOPC UA binary protocol
- Chunking (splitting of large messages)
- Exchangeable network layer (plugin) for using custom networking APIs (e.g. on embedded targets)

Information model

- Support for all OPC UA node types (including method nodes)
- Support for adding and removing nodes and references also at runtime.
- Support for inheritance and instantiation of object- and variable-types (custom constructor/destructor, instantiation of child nodes)

Subscriptions

- Support for subscriptions/monitor items for data change notifications
- Very low resource consumption for each monitored value (event-based server architecture)

Code-Generation

- Support for generating data types from standard XML definitions
- Support for generating server-side information models (nodesets) from standard XML definitions

intel®