Communications & Connectivity

Industrial Internet Innovation Forum

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Agenda

1. How do we go from here to there?
   - Internet of People → Things
   - Connectivity vs. Communications vs. Interoperability

2. Evolution of the IIoT connectivity stack
   - Connectivity Framework
   - Connectivity Transport

3. Defining a long term stable IIoT architecture strategy
   - Embracing the old and the new
   - Connectivity core standards criteria

4. Selecting the right connectivity technology
   - Assessment template worksheets
   - Connectivity standards
How do we go from here to there?

Internet of People ➔ Things
Connectivity vs. Communications vs. Interoperability
How do we go from here to there?
Communicate

com·mu·ni·cate
/ˈkōˌmyōən′i kāt/ • n
verb
verb: communicate; 3rd person present: communicates; past tense: communicated; past participle: communicated; gerund or present participle: communicating

1. share or exchange information, news, or ideas.
   "the prisoner was forbidden to communicate with his family"
   synonyms: be in touch, be in contact, have dealings, interface, interact, commune, meet, liaise;
   More

   • impart or pass on (information, news, or ideas).
     "he communicated his findings to the inspector"
     synonyms: convey, tell, impart, relay, transmit, pass on, announce, report, recount, relate,
     present; More

   • convey or transmit (an emotion or feeling) in a nonverbal way.
     "the ability of good teachers to communicate their own enthusiasm"

   • succeed in conveying one's ideas or in evoking understanding in others.
     "a politician must have the ability to communicate"
     synonyms: get one's message across, explain oneself, be understood, learn how to communicate better

   • (of two people) be able to share and understand each other's thoughts

   • pass on (an infectious disease) to another person or animal.
     synonyms: transmit, transfer, spread, carry, pass on
     "the disease is communicated easily"

   • transmit (heat or motion).
     "the heat is communicated through a small brass grating"

   • (of two rooms) have a common connecting door.
     "he went into the communicating room to pick up the phone"
     synonyms: connect with, join up with, open on to, lead into "each bedroom communicates with a bathroom"
Communication(s)

**Communication**

/ˈkɑ,mjuːnɪkəʃən/

**noun** communication

1. the imparting or exchanging of information or news.
   "direct communication between the two countries will produce greater understanding" (synonyms: transmission, conveyance, divulgence, disclosure; More)
   - a letter or message containing information or news.
     plural noun: communications
     synonyms: message, statement, announcement, report, dispatch, communiqué, letter, bulletin, correspondence
     "an official communication"
   - the successful conveying or sharing of ideas and feelings.
     "there was a lack of communication between Pamela and her parents"
   - social contact.
     "she gave him some hope of her return, or at least of their future communication" (synonyms: contact, dealings, relations, connection, association, socializing, intercourse; More)

2. means of connection between people or places, in particular.
   - the means of sending or receiving information, such as telephone lines or computers.
     plural noun: communications
     synonyms: satellite communications
   - the means of traveling or of transporting goods, such as roads or railroads.
     "a city providing excellent road and rail communications"
   - the field of study concerned with the transmission of information by various means.

---

**Sharing or Exchanging of Information**

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**Origin**

<table>
<thead>
<tr>
<th>LATIN</th>
<th>LATIN</th>
<th>OLD FRENCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>communicare</td>
<td>communicatio</td>
<td>communicacion</td>
</tr>
</tbody>
</table>

late Middle English: from Old French communicacion, from Latin communicatio(n-), from the verb communicare 'to share' (see communicate).
Connectivity

**connectivity**
/kāˌnekˈtivədē,kəˌnekˈtivədē/

**noun**

nouns: connectivity

the state or extent of being connected or interconnected.

- **computing**
  capacity for the interconnection of platforms, systems, and applications.
  "connectivity between Sun and Mac platforms"

Infrastructure

**infrastructure**
/ˈɪnfrəˈstrɛktʃər/ 

**noun**

nouns: infrastructure; plural nouns: infrastructures

the basic physical and organizational structures and facilities (e.g., buildings, roads, and power supplies) needed for the operation of a society or enterprise.
Interoperability

*inter·op·er·a·bil·i·ty*
\[\text{in}(t)\text{er}·\text{ap}(\text{e})\text{r}·\text{e}·\text{bil}·\text{ed}·\text{e}/\]

**noun**
the ability of computer systems or software to exchange and make use of information.
"interoperability between devices made by different manufacturers"
- the ability of military equipment or groups to operate in conjunction with each other.
  "staff believe interoperability between forces is crucial to effectiveness"

Use over time for: interoperability

![Graph showing mentions over time](image)

**Ability to Exchange and Make Use of Information**
Interoperability requires a Suitable Connectivity Infrastructure for Meaningful Communications between...
People vs. Things...
Connectivity infrastructure provides support for Interoperability
Directly impacts ease of integration, interoperability, and composability
So, how do we go from here to there?
Industrial Internet Connectivity Framework (IICF): Feb 28, 2017

Comprehensive treatment of connectivity

As a means of building interoperable IIoT systems

https://www.iiconsortium.org/IICF.htm
IIoT Technical Foundation....Things are Coming Together!
IICF: Theory + Practice = Useful Guidance
Industrial Internet Connectivity Framework (IICF) Goals

**Accelerating IIoT**

- **Clarity**: Guide map to the rich but often confusing landscape of IIoT connectivity
- **Foundation**: Sets a stable long term foundation for IIoT interoperability
- **Guidance**: Useful, practical, tangible guidance for requirements assessment, technology evaluation and selection
Evolution of the IIoT Connectivity Stack

Connectivity Framework
Connectivity Transport
Core Functions & Typical Considerations
Levels of Interoperability

- **Level 6**: Conceptual Interoperability
- **Level 5**: Dynamic Interoperability
- **Level 4**: Pragmatic Interoperability
- **Level 3**: Semantic Interoperability
- **Level 2**: Syntactic Interoperability
- **Level 1**: Technical Interoperability
- **Level 0**: No Interoperability

Context of data objects is also shared

Structure of data is also shared

Compatible means of signaling and protocols

Historically: Vertical silos of interoperability

- Level 6: Conceptual Interoperability
- Level 5: Dynamic Interoperability
- Level 4: Pragmatic Interoperability
- Level 3: Semantic Interoperability
- Level 2: Syntactic Interoperability
- Level 1: Technical Interoperability
- Level 0: No Interoperability

Example Verticals:
- SCADA
- Industrial Automation
- Electric Utilities
- Medical
Future: Horizontal interoperability

Level 6
Conceptual Interoperability

Level 5
Dynamic Interoperability

Level 4
Pragmatic Interoperability

Level 3
Semantic Interoperability

Level 2
Syntactic Interoperability

Level 1
Technical Interoperability

Level 0
No Interoperability

Connectivity Framework

Connectivity Transport

Industrial Internet (IIoT)

Vertical Industry Data Models

Horizontal stack that can span across verticals!
Technical Interoperability Example...

Share byte sequences

Messages
Technical Interoperability Example...

Share byte sequences

| 0000 | 54 a0 50 cf b6 80 14 10 0f e2 3a 05 08 00 45 00 |
| 0010 | 00 90 4a ec 00 00 40 11 07 d4 c0 a8 59 e6 0a 00 |
| 0020 | 03 0f f4 22 1c f3 00 7c f3 13 52 54 50 53 02 01 |
| 0030 | 01 01 c0 a8 59 e6 00 00 49 03 00 00 00 01 09 01 |
| 0040 | 08 00 1a b6 c9 58 d6 7f 2b f1 15 07 50 00 00 00 |
| 0050 | 10 00 00 00 00 00 80 00 00 02 00 00 00 00 59 02 |
| 0060 | 00 00 70 00 10 00 ca c2 17 c3 18 36 3f 8e f1 16 |
| 0070 | 0e ee de f9 e8 86 01 00 01 00 00 01 00 00 05 00 |
| 0080 | 00 00 42 4c 55 45 00 00 00 00 55 00 00 00 00 0f 00 |
| 0090 | 00 00 1e 00 00 00 00 00 00 00 00 00 00 00 00 00 |

Messages
Syntactic Interoperability Example...

Share structured datatypes

Data (State, Events, Streams)

Messages

ShapeType

color

x

y

color (key)

string<128>

long

long
Syntactic Interoperability Example...

ShapeType

- color
- x
- y

Share structured datatypes

Data (State, Events, Streams)

Messages
Semantic Interoperability Example...

Data (State, Events, Streams)

Messages

Information (Data in Context)

Share data-objects in context

ShapeType

color

x

y

Car

Room

Car Color

Room Color

Row

Column

Temperature

Humidity

Temperature

Humidity

color
Where do we draw the line?

**ShapeType**
- Car

**color**
- Car Color

**x**
- Row

**y**
- Column

**ShapeType**
- Room

**color**
- Room Color

**x**
- Temperature

**y**
- Humidity

**Information (Data in Context)**

**Data (State, Events, Streams)**

**Messages**
Where do we draw the line?
Evolution of the IIoT Connectivity Stack

7-Layer OSI Stack Model (1994)

4-Layer Internet Stack Model (1989)

IIoT Considerations

IIoT Connectivity Stack Model (2017)
IIoT Connectivity Stack Model

Participant X

Information
- Distributed Data Interoperability and Management

Connectivity
- Framework
- Transport
- Network
- Link
- Physical

Networking
- Link
- Bits
- Frames
- Packets
- Messages
- Data (State, Events, Streams)

Participant Y

Information (Data in Context)

Connectivity
- Framework
- Transport
- Network
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- Physical

Networking
- Link
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- Messages
- Data (State, Events, Streams)

Distributed Data Interoperability and Management
IIoT Connectivity Stack Model

Information
- Distributed Data Interoperability and Management

Connectivity
- Framework
- Transport

Networking
- Network
- Link

Semantic Interoperability (Level 3)
Syntactic Interoperability (Level 2)
Technical Interoperability (Level 1)

Connectivity Task Group
- Document Focus

• Generally understood
• Beyond current scope
Applications, Analytics and others

Distributed Data Interoperability & Management

Semantic Interoperability (Level 3)

Connectivity Framework

Syntactic Interoperability (Level 2)

Connectivity Transport

Technical Interoperability (Level 1)

Connectivity Network

Connectivity Crosscutting Function

IIoT Horizontal Interoperability

Energy & Utilities
Healthcare
Manufacturing
Transportation

...
IIoT Connectivity Stack

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Participant Y

Information (Data in Context)

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Networking
- Link
- Bits
- Physical

Syntactic Interoperability
Framework Layer: Syntactic Interoperability

Connectivity Framework Layer

- Provides **syntactic interoperability** between endpoints
  - Share structured datatypes
    - Information is structured in a common and unambiguous data format
  - Meaning (interpretation of datatypes in context) is beyond the scope of this layer

- Connectivity Framework Layer Infrastructure
  - Any programming environment
  - Any computing platform
  - May observe data flows & optimize datatype sharing and delivery
Connectivity Framework Layer

Distributed Data Interoperability & Management

Framework

API

Governance

Quality of Service

Security

Publish-Subscribe
Request-Reply
Discovery
Exception Handling

Data Resource Model

Id and Addressing
Data Type System
Lifecycle (CRUD)
State Management

Connectivity Framework Functions

Connectivity Framework Functions

Syntactic Interoperability

Transport

Network

Link

Physical
Connectivity Framework Layer

Distributed Data Interoperability & Management

- **API**
  - Publish-Subscribe
  - Request-Reply
  - Discovery
  - Exception Handling

- **Data Resource Model**
  - Id and Addressing
  - Data Type System
  - Lifecycle (CRUD)
  - State Management

- **Governance**
  - Quality of Service
  - Security

- **Syntactic Interoperability**

- **Physical**
- **Link**
- **Network**
- **Transport**

Connectivity Framework Functions
<table>
<thead>
<tr>
<th>Connectivity Framework Functions</th>
<th>Framework</th>
<th>Governance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Publishing-Subscribe</td>
<td>API</td>
<td>Quality of Service</td>
</tr>
<tr>
<td>Request-Reply</td>
<td></td>
<td>Security</td>
</tr>
<tr>
<td>Discovery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exception Handling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Resource Model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Id and Addressing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Type System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifecycle (CRUD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>State Management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Connectivity Framework Layer**

Distributed Data Interoperability & Management

**Quality of Service**

**Security**

**Syntactic Interoperability**

**Transport**

**Network**

**Link**

**Physical**
Connectivity Framework Layer

Distributed Data Interoperability & Management

Connectivity Framework Functions

- Publish-Subscribe
- Request-Reply
- Discovery
- Exception Handling
- Data Resource Model
- Id and Addressing
- Data Type System
- Lifecycle (CRUD)
- State Management

Framework

API

Governance

Quality of Service

Security

Syntactic Interoperability

Transport

Network

Link

Physical

Id and Addressing

Data Type System

Lifecycle (CRUD)

Exception Handling

State Management

Discoverer

Request-Reply

API
Connectivity Framework Layer

Distributed Data Interoperability & Management

Connectivity Framework Functions

- Publish-Subscribe
- Request-Reply
- Discovery
- Exception Handling
- Data Resource Model
- Id and Addressing
- Data Type System
- Lifecycle (CRUD)
- State Management
- Quality of Service
- Security

API Governance

Transport

Network

Link

Physical
Connectivity Framework Layer

Distributed Data Interoperability & Management

Framework

API

Publish-Subscribe
Request-Reply
Discovery
Exception Handling

Data Resource Model

Id and Addressing
Data Type System
Lifecycle (CRUD)
State Management

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Quality of Service
Security

Syntactic Interoperability

Connectivity Framework Functions

Transport
Network
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Physical
Connectivity Framework Layer

Distributed Data Interoperability & Management

Framework

API

Governance

Connectivity Framework Functions

Publish-Subscribe
Request-Reply
Discovery
Exception Handling

Data Resource Model

Quality of Service

Security

Id and Addressing
Data Type System
Lifecycle (CRUD)
State Management

Syntactic Interoperability

Transport

Network

Link

Physical
IIoT Connectivity Stack

Participant X
- Distributed Data Interoperability and Management
- Framework
- Transport
- Network
- Link
- Physical

Information
- Distributed Data Interoperability and Management
- Information (Data in Context)

Connectivity
- Data (State, Events, Streams)
- Messages
- Packets
- Frames
- Bits

Networking
- Technical Interoperability

Participant Y
- Distributed Data Interoperability and Management
- Framework
- Transport
- Network
- Link
- Physical
Transport Layer: Technical Interoperability

Connectivity Transport Layer

- Provides **technical interoperability** between endpoints
  - Share byte sequences
  - Structure (interpretation of bytes in context) is beyond the scope of this layer

- Connectivity Transport Layer Infrastructure
  - Any computing platform
  - May observe byte flows & optimize byte sequence sharing and delivery
Connectivity Transport Layer

Distributed Data Interoperability & Management

Framework

Transport

Messaging Protocol

Communication Modes

Endpoint Addressing
Connectedness
Prioritization
Timing & Synchronization
Security

Network

Link

Physical

Connectivity Transport Functions

Technical Interoperability
Connectivity Transport Layer

Distributed Data Interoperability & Management

Framework

Transport

Messaging Protocol

Communication Modes

Technical Interoperability

Connectivity Transport Functions

Connectivity

Transport

Functions

Endpoints

Addressing

Connectedness

Prioritization

Timing & Synchronization

Security

Network

Link

Physical
Connectivity Transport Layer

Distributed Data Interoperability & Management

Framework

Transport

Messaging Protocol

Communication Modes

Endpoint Addressing
Connectedness
Prioritization
Timing & Synchronization
Security

Network

Link

Physical

Connectivity Transport Functions

Technical Interoperability
Connectivity Transport Layer

Connectivity Transport Functions

Distributed Data Interoperability & Management

Framework

Transport

Messaging Protocol

Communication Modes

Endpoint Addressing  Connectedness  Prioritization  Timing & Synchronization  Security

Network

Link

Physical
Connectivity Transport Layer

Distributed Data Interoperability & Management

Framework

Connectivity

Transport Functions

Connectivity

Transport

Messaging Protocol

Communication Modes

Endpoint Addressing

Connectedness

Prioritization

Timing & Synchronization

Security

Technical Interoperability

Network

Link

Physical
Connectivity Transport Layer

Distributed Data Interoperability & Management

Framework

Transport

Messaging Protocol

Communication Modes

Endpoint Addressing
Connectedness
Prioritization
Timing & Synchronization
Security

Technical Interoperability

Connectivity Transport Functions

Network
Link
Physical
Defining a long term stable IIoT architecture strategy

Embracing the old and the new

Connectivity core standards criteria
Fundamental $N^2$ Connectivity Challenge

- Brownfield
  - Existing technologies
  - May be specific to verticals
- Greenfield
  - Innovation

Reality Check
Accept that there will be multiple connectivity technologies

\[
O(N^2) = \frac{N \times (N-1)}{2}
\]
Gateways bridge to core connectivity standards:

- Delivers performance with flexibility
- Scales linearly (only have to map each “other” to one “core”)
- Supports dataflow security

Choose core standards that matches system needs
Connectivity Core Standards: “lingua franca” for IIoT interoperability

lingua franca

/ˌliNGgwə ˈfraNGkə/

noun: *lingua franca*; plural noun: *lingua francas*

a language that is adopted as a common language between speakers whose native languages are different
Connectivity Reference Architecture

Must not compromise:

- Syntactic Interoperability
- Functional Requirements
- Non Functional Requirements
  - Performance
  - Scalability
  - Reliability
  - Resilience
  - Security
  - Safety
**Core Gateway Standards between Core Connectivity Standards**

Endpoints

Domain-Specific Connectivity Technology

Gateway to a Connectivity Core Standard

Connectivity Core Standards

Core Gateways
Core Gateways enable Horizontal Interoperability

Few Core, Many Domain-Specific Standards

- Many Domain-Specific Connectivity Technologies
  - Common or de-facto connectivity technology or standard for a relevant industry or functional domain
  - Gateway will be needed to one of the core connectivity standards
  - Lots of these!

- Few Connectivity Core Standards
  - K Core Connectivity Standards
    - $K^{*}(K-1)/2 + (N-K)$
    - when $K \ll N$, $O(N^2) \rightarrow O(N)$
  - Must meet the Connectivity Core Standards Criteria
## Connectivity Core Standards Criteria

<table>
<thead>
<tr>
<th>Core Standard Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Provide <strong>syntactic interoperability</strong></td>
</tr>
<tr>
<td>2 Open standard with strong <strong>independent, international</strong> governance</td>
</tr>
<tr>
<td>3 <strong>Horizontal</strong> and neutral in its applicability across industries</td>
</tr>
<tr>
<td>4 <strong>Stable</strong> and <strong>deployed</strong> across multiple vertical industries</td>
</tr>
<tr>
<td>5 Have <strong>standards-defined Core Gateways</strong> to all other core connectivity standards</td>
</tr>
<tr>
<td>6 Meet the connectivity framework <strong>functional</strong> requirements</td>
</tr>
<tr>
<td>7 Meet <strong>non-functional</strong> requirements of performance, scalability, reliability, resilience</td>
</tr>
<tr>
<td>8 Meet <strong>security</strong> and safety requirements</td>
</tr>
<tr>
<td>9 Not require any single component from any single vendor</td>
</tr>
<tr>
<td>10 Have readily-available SDKs both <strong>commercial</strong> and <strong>open source</strong></td>
</tr>
</tbody>
</table>

*GREEN = Gating Criteria*
Selecting the right connectivity technology

Assessment Template Worksheets
Connectivity Standards
Assessment Template

- Which layers(s) of the Connectivity Stack does it provide?
  - May span multiple layers
- What Core Functions does it provide?
  - Prioritize the functions for your use case
- How does it rank against the Typical Considerations (of the layers spanned)?
  - Prioritize the considerations for your use case
- How does it impact system Architectural Qualities?
  - Prioritize the qualities for your use case
- How does it fit Core Connectivity Criteria?
  - Is a gateway to a Core Connectivity Standard available?
  - Is the gateway standardized?
Assessment Template Worksheets

Business Viewpoint

- Purpose
- Pedigree
- Vendor
- Maturity
- Stability
- Standards Body
- Openess

Usage Viewpoint

- Architecture
- Options
- Applications
- Usage
- Operations
- Security
- Gateways

Functional Viewpoint

- Core Framework Layer
  - Functions
- Core Transport Layer
  - Functions

Implementation Viewpoint

- System Architecture Considerations
- Data Considerations
- Performance Considerations
- Scalability Considerations
- Availability Considerations
- Deployment Considerations
- Network Layer Considerations
Theory meets Practice!

Theory

Science

Models

Practice

Reality

Standards
Relevant Connectivity Standards

Energy & Utilities
Healthcare
Manufacturing
Transportation

Distributed Data Interoperability and Management

Framework

Transport

Network

Link

Physical

Internet Protocol (IP)

Internet Protocol (IP)

DDS

oneM2M

Web Services

OPC-UA

OPC-UA Bin

DDS/RTTPS

CoAP

MQTT

HTTP

TCP

UDP

TSN / Ethernet (802.1, 802.3)

Wireless PAN (802.15)

Wireless LAN (802.11 Wi-Fi)

Wireless 2G/3G/LTE (3GPP)

Wireless Wide Area (802.16)
<table>
<thead>
<tr>
<th>Core Standard Criterion</th>
<th>DDS</th>
<th>Web Services</th>
<th>OPC-UA</th>
<th>oneM2M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Provide <strong>syntactic interoperability</strong></td>
<td>✓</td>
<td></td>
<td>Need XML or JSON</td>
<td>✓</td>
</tr>
<tr>
<td>2 Open standard with strong <strong>independent, international</strong> governance</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3 <strong>Horizontal</strong> and neutral in its applicability across industries</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>4 <strong>Stable</strong> and <strong>deployed</strong> across multiple vertical industries</td>
<td></td>
<td>Software Integration &amp; Autonomy ✓</td>
<td>Manufacturing</td>
<td>Home Automation</td>
</tr>
<tr>
<td>5 Have <strong>standards-defined Core Gateways</strong> to all other core connectivity standards</td>
<td>Web Services, OPC-UA*, oneM2M*</td>
<td>DDS, OPC-UA, oneM2M*</td>
<td>Web Services, DDS*, oneM2M*</td>
<td>Web Services, OPC-UA*, DDS*</td>
</tr>
<tr>
<td>6 Meet the connectivity framework <strong>functional</strong> requirements</td>
<td>✓</td>
<td>×</td>
<td>Pub-Sub in development</td>
<td>✓</td>
</tr>
<tr>
<td>7 Meet <strong>non-functional</strong> requirements of performance, scalability, reliability, resilience</td>
<td>✓</td>
<td>×</td>
<td>Real-time in development</td>
<td>Reports not yet documented or public</td>
</tr>
<tr>
<td>8 Meet <strong>security</strong> and safety requirements</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

GREEN = Gating Criteria  
* = work in progress  
✓ = supported, × = not supported
### Non-overlapping system aspect examples targeted by potential IIoT connectivity core standards

<table>
<thead>
<tr>
<th>System Aspect</th>
<th>Example User</th>
<th>Approach</th>
<th>Targeting Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Integration and Autonomy</td>
<td>You are a software architect. You are building a system or product line, and you control the architecture. You critically need to integrate components written by different programmers or even entire teams.</td>
<td>A data centric approach will define the interfaces, capture the dataflow, enable module evolution, and enforce interoperability between teams. This approach also eases redundancy, fast complex data flow, and selective data filtering.</td>
<td>DDS</td>
</tr>
<tr>
<td>Device Interchangeability</td>
<td>You are a device manufacturer, with the goal of making devices that will sell into many applications. The device offers services, such as configure, start, stop, etc. You have no idea how the device will eventually be used. Your users are likely not software experts; they just want to add or integrate the device into a workcell.</td>
<td>A device-centric approach will allow the device users to write generic software that will interoperate with competitor’s devices.</td>
<td>OPC-UA</td>
</tr>
<tr>
<td>Web and Mobile User Interfaces</td>
<td>You are building mobile apps or web browser based applications to provide the human machine interface. You need an easy way to support clean human interaction and access to backend services.</td>
<td>A RESTful approach will make it easy to connect to many types of enterprise systems and UI devices.</td>
<td>Web Services</td>
</tr>
<tr>
<td>Information &amp; Communications Technology (ICT) Integration</td>
<td>You are building a wide-area wireless system that needs to allow applications and devices to share data and information. The devices use various technology and domain-specific protocols. The applications and devices you integrate rely on leveraging the services provided by the communications provider network.</td>
<td>A common, standard services-layer approach enables applications and device to share data and information without forcing the application to understand multiple protocols implemented on the devices. The applications can thus run in the Platform Tier and seamlessly connect to diverse IoT devices in the field.</td>
<td>oneM2M</td>
</tr>
</tbody>
</table>
Summary

Accelerating IIoT
Industrial Internet Connectivity Framework (IICF)

IloT Connectivity Stack

Syntactic Interoperability

- API
  - Publish-Subscribe
  - Request-Reply
  - Discovery
  - Exception Handling
- Data Resource Model
- Id and Addressing
- Data Type System
- Lifecycle (CRUD)
- State Management
- Qualify of Service
- Security

Framework Layer

Transport Layer

Network
Accelerate Your IIoT...

Clarity
- Study the IICF

Foundation
- Use the IICF

Guidance
- Build your IIoT

Sets a stable long term foundation for IIoT interoperability

Guide map to the rich but often confusing landscape of IIoT connectivity

Useful, practical, tangible guidance for requirements assessment, technology evaluation and selection
1. Introduction
2. Connectivity Framework
3. Connectivity Reference Architecture
4. Connectivity Framework Layer
5. Connectivity Transport Layer
6. How to Assess a Connectivity Technology?
7. Connectivity Standards
8. Core Connectivity Standards
9. Other Connectivity Standards
10. Assessment Templates

https://www.iiconsortium.org/IICF.htm
Thank You!

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