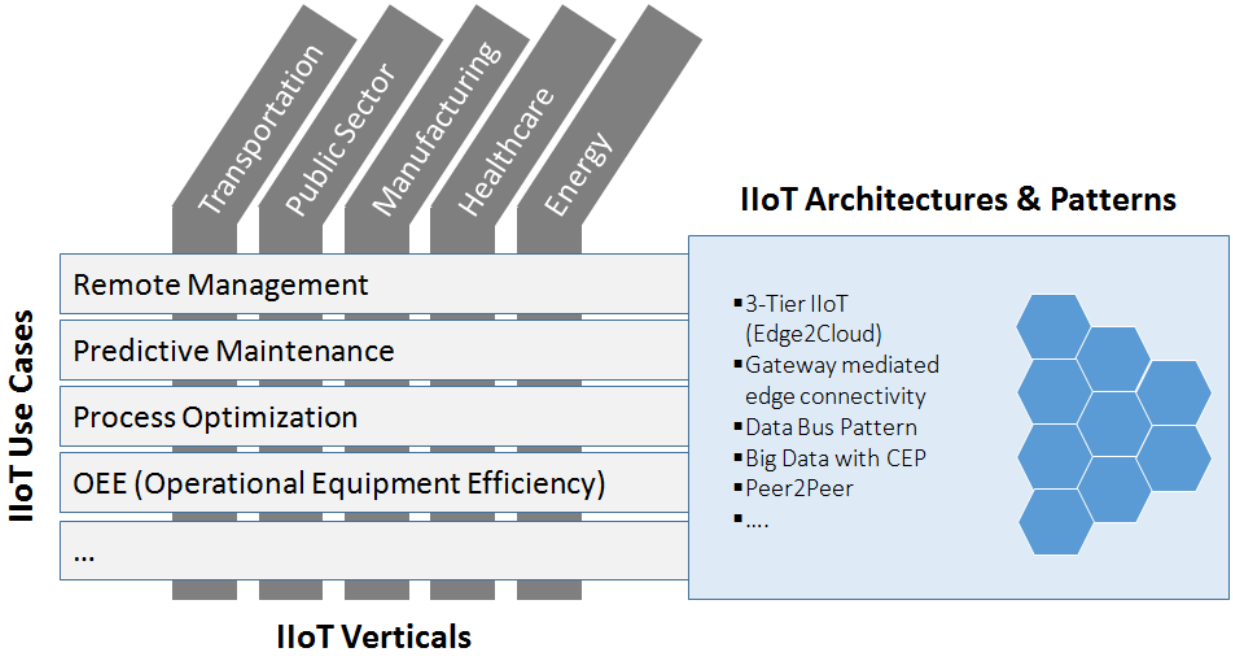
Establishing universal interoperability in the Industrial Internet of Things (IIoT) is a prerequisite for its proliferation. Unfortunately, ensuring interoperability is a complex endeavor. It is not a matter of agreeing on a small set of standards to rule the IIoT world, but about carefully orchestrating complex and partially competing protocols and standards on multiple levels, including device integration, gateway technologies, short-range wireless communication, long-range wireless communication, messaging, event processing, data management, analytics, cloud operations, and so on. Vertical and domain-specific standards also play an important role.

No single organization can deliver *the* one standard that solves all interoperability problems. This is why the IIC is launching the *Industrial Internet Interoperability Coalition* (I^3C). The goal of I^3C is to identify those hotspots that require special attention and place them on a heat-map. I^3C will then bring partners together to address clusters of interoperability hotspots with an integrative, holistic perspective.

IIC's IIoT Landscape

IIC is defining an IIoT landscape that provides an overview of the key verticals in IIoT, IIoT-specific use cases, and the required architectures and patterns to support these use cases.



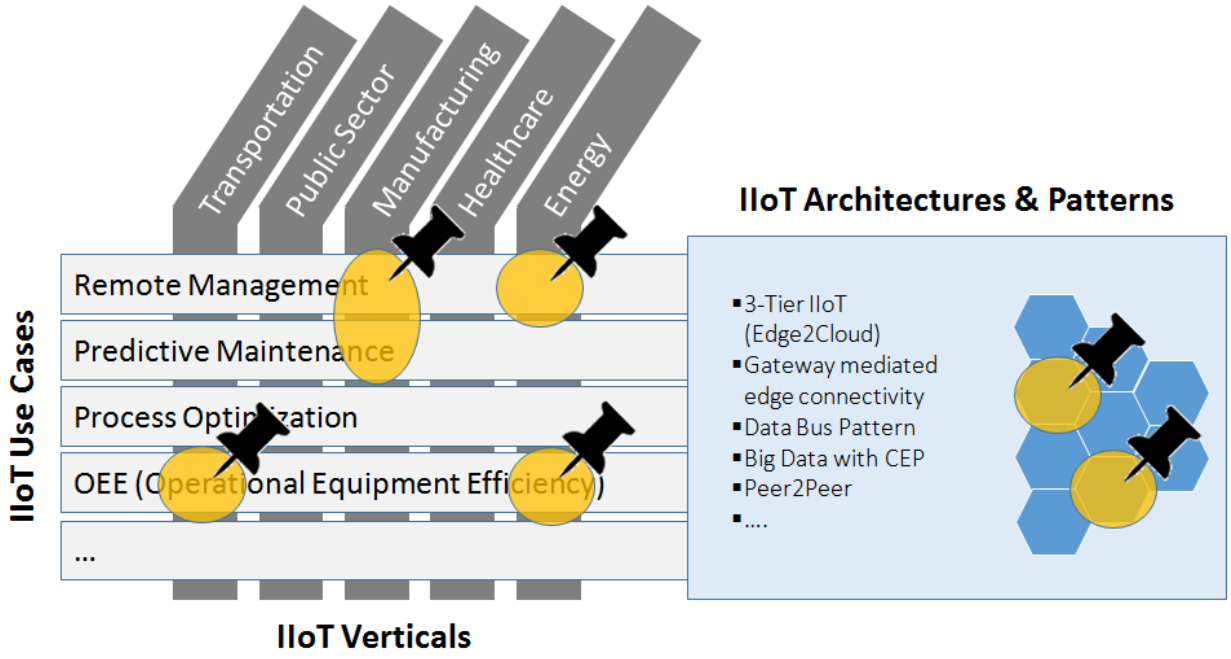
IIC´s IIoT Landscape

The key verticals identified include transportation, public sector, manufacturing, healthcare and energy. A set of IIoT use cases has been identified, many of which are applicable to multiple verticals, such as remote management of assets, predictive maintenance, process optimization and operational equipment efficiency. The IIC`s architecture task group has defined a reference architecture that defines architecture patterns to support these use cases, including the standard three-tier architecture (from edge to cloud), the gateway-mediated edge-connectivity pattern, the layered databus pattern and big data management with complex event processing.

IIoT Interoperability Heat-Map

The IIoT landscape is the foundation to identify current hotspots. Each hotspot usually addresses a combination of one or more verticals, use cases and architectures and patterns.

Developing and constantly updating the IIoT interoperability heat-map will be one of the key tasks of the I^{3}C.



IIoT Interoperability Heatmap

IIoT Interoperability Cluster

An integration of certain standards and technologies to solve interoperability problems in a defined set of verticals, use cases and architecture patterns often applies in other parts of the IIoT landscape. I^{3}C provides a mechanism where multiple interoperability hotspots can be grouped into an *IIoT interoperability cluster*. We discuss two examples below.

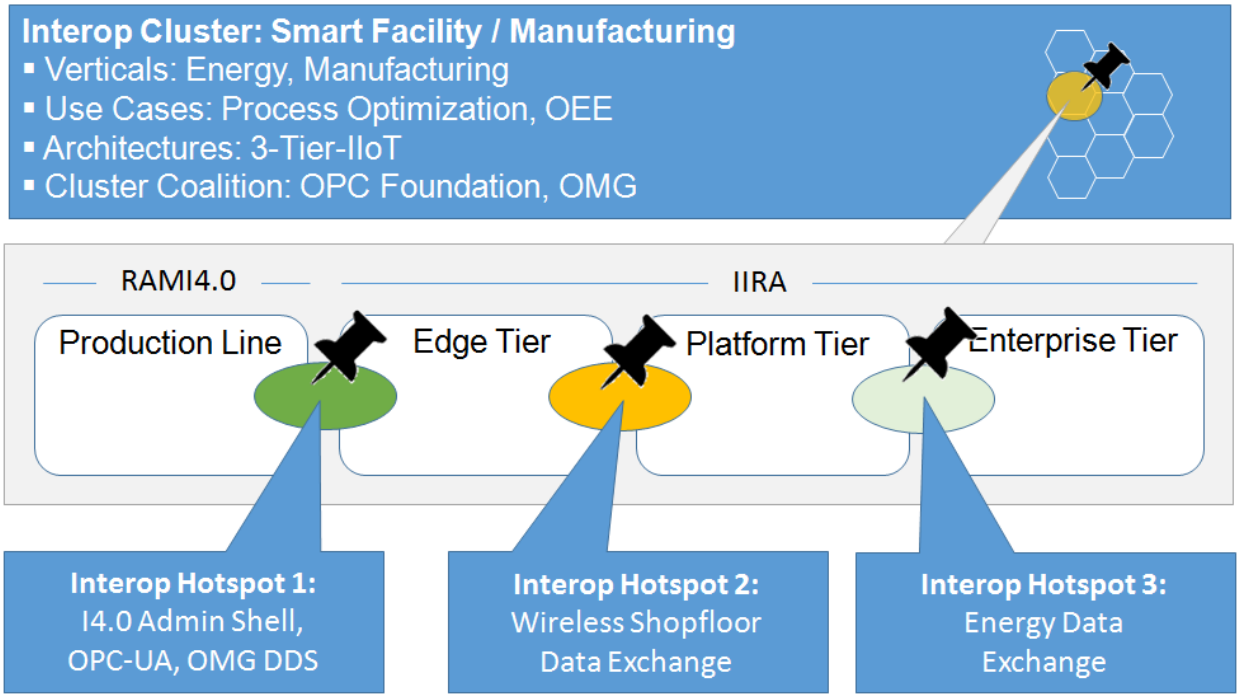
Smart Facility Operations in Manufacturing

The "Smart Facility Operations in Manufacturing" cluster supports use cases such as energy optimization in factories. Hence energy and manufacturing are verticals involved in this cluster. The supported use cases are process optimization and OEE, and the main architecture for this cluster is the three-tier architecture. Three hotspots have been identified in this cluster:

Heterogeneous data exchange: Both OPC-UA (for the manufacturing equipment) and DDS (for the energy management solution) are needed for exchange of energy consumption data. The OPC Foundation and the OMG have recently announced plans to enable interoperability between OPC-UA and DDS, which is an important prerequisite for this cluster. This enables interoperability beyond this cluster, since it is not vertical specific.

Specialized wireless infrastructure: The shop floor is a difficult environment for wireless data exchange because of the many metallic shields typically found there.

Energy data exchange: This hotspot relates to the reduction of peak energy consumption, based on the analysis of both historic energy consumption and production data, as well as planned production schedules.



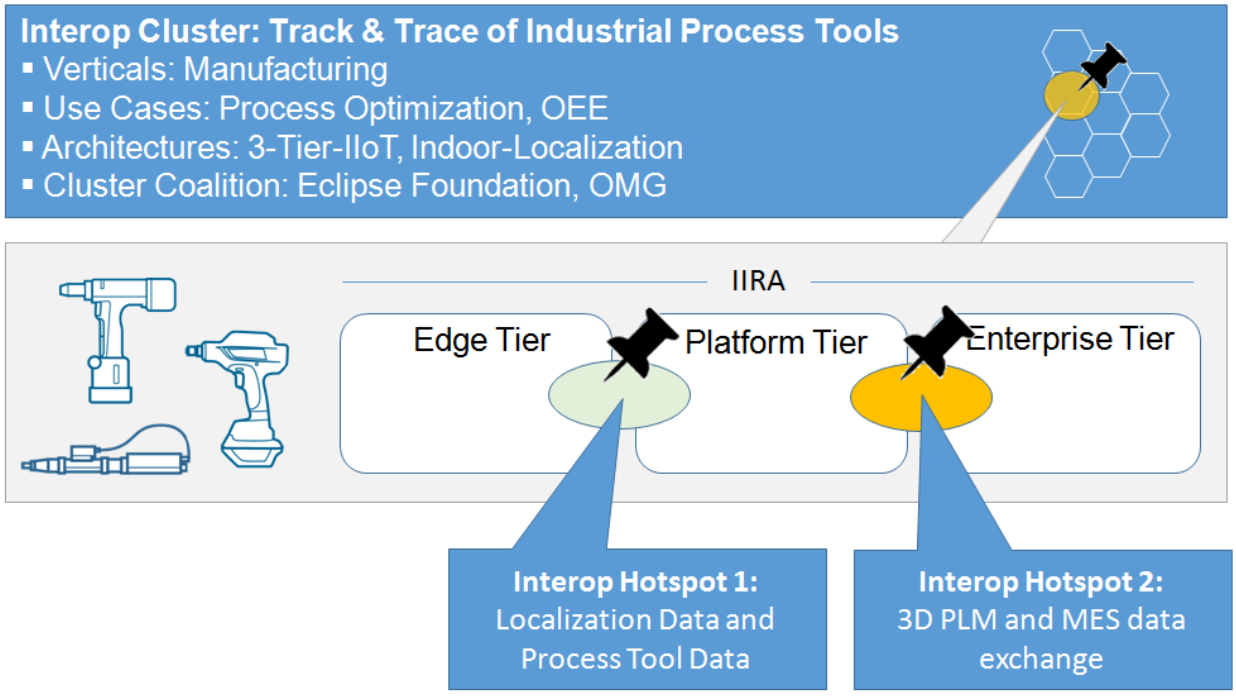
Example 1: Smart Facility Operations / Manufacturing

Track & Trace of Industrial Process Tools

The main vertical in "Track & Trace of Industrial Process Tools" is manufacturing. The use cases include process optimization and OEE. The architecture is three-tier, and the indoor-localization pattern is required.

This cluster has two hotspots.

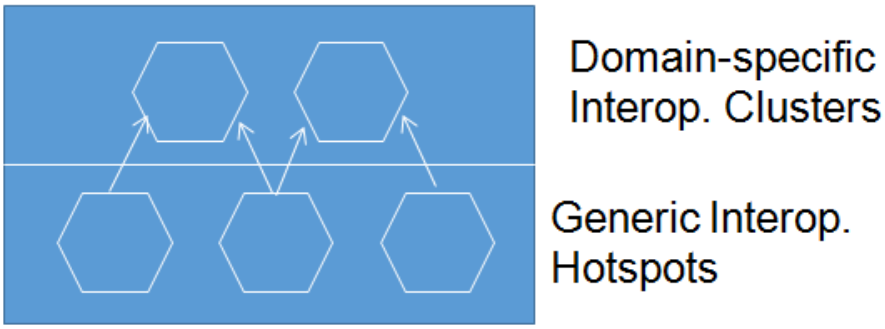
- Hotspot 1 relates to exchange of localization data (e.g. position of tightening tool in the shop floor) as well as process tool data (e.g. tightening curve with torque and angle for each tightening process)
- Hotspot 2 concerns exchange of 3D PLM data for positioning information, as well as MES data for process configuration information.



Example 2: Track & Trace of Industrial Process Tools

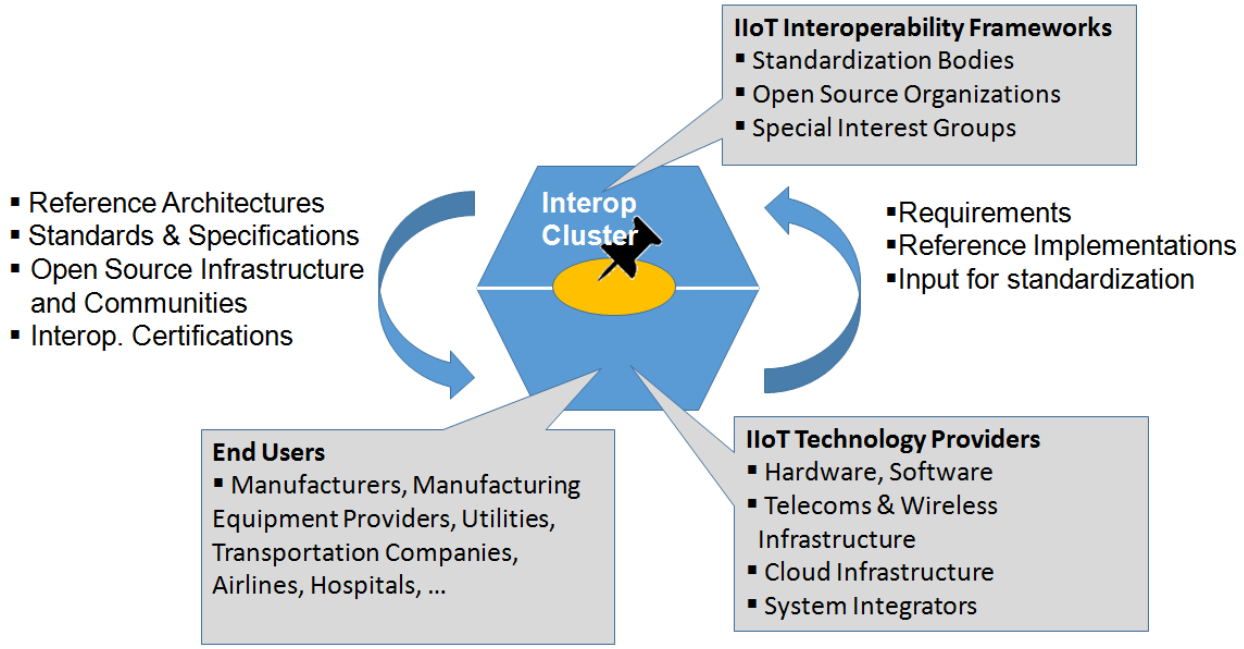
INTEROPERABILITY CLUSTER STRUCTURE

Hotspots cluster, often by vertical or use case. We anticipate that some hotspots will be domain and vertical independent, for example interoperability between OPC-UA and DDS is in principle vertical-independent. These generic solutions can then be used in multiple, vertical specific clusters, as shown below.



Domain-specific vs. generic interop areas

Each cluster brings together a coalition of standardization organizations, open-source organizations, special interest groups and IIoT technology providers. The former is responsible for defining the interoperability frameworks (including reference architectures and standards); the latter provides input for standardization as well as reference implementations.

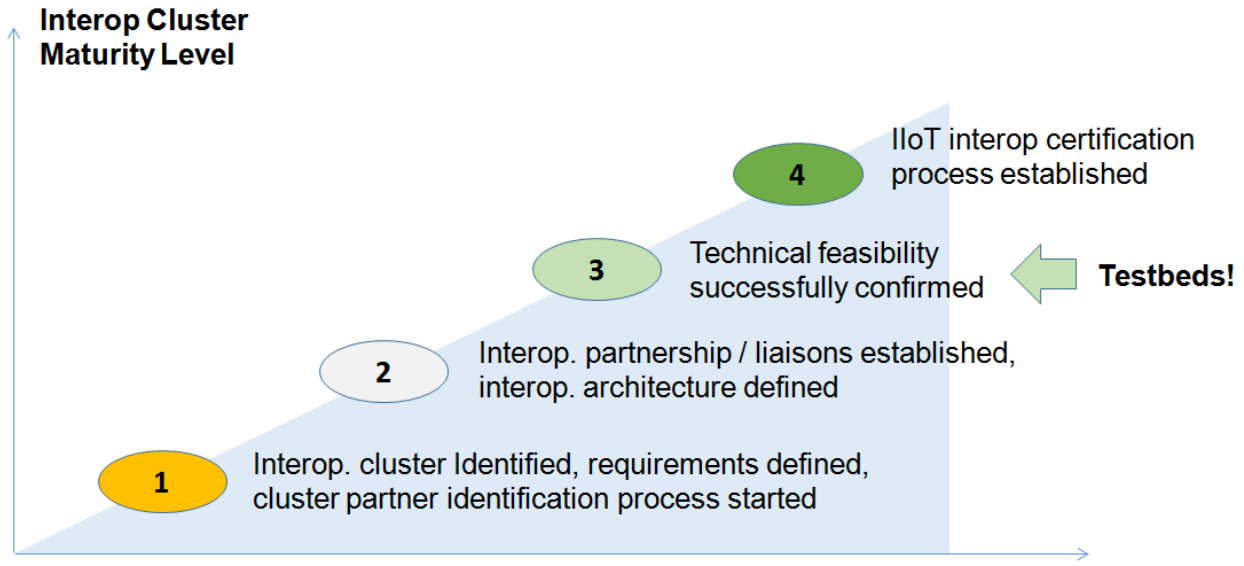


Interoperability Cluster Structure

INTEROPERABILITY CLUSTER MATURITY MODEL

Each cluster will undergo a maturation process. We anticipate the following steps:

1. During the identification phase, new requirements are defined and potential coalition partners for this cluster are identified.
2. The architecture is defined formally and a coalition of liaisons officially confirmed.
3. The technical feasibility is confirmed perhaps as a part of a testbed implementation
4. Finally, a formal certification process is established, which helps ensure that customers can choose from multiple vendors with the required certification.



Interoperability Cluster Maturity Model

SUMMARY

Interoperability in IIoT is extremely important, but difficult to achieve. The Industrial Internet Interoperability Coalition (I^3C) is an important step to establishing the structure, governance processes and partnerships required to establish an open and interoperable IIoT.

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The Industrial Internet Consortium is a global, member supported, organization that promotes the accelerated growth of the Industrial Internet of Things by coordinating ecosystem initiatives to securely connect, control and integrate assets and systems of assets with people, processes and data using common architectures, interoperability and open standards to deliver transformational business and societal outcomes across industries and public infrastructure. The Industrial Internet Consortium is managed by the Object Management Group® (OMG®). Visit www.iiconsortium.org.