Reference Architectures

CIOT AND IIOT

The Industrial Internet Consortium (IIC) and the Industrie 4.0 (I4.0) have defined reference models and architectures for IIoT systems.

As IIoT requirements are a superset of CIoT's we'll investigate the need of the former

Industrie 4.0 / RAMI 4.0

THE INTERNET OF THINGS AND SERVICES

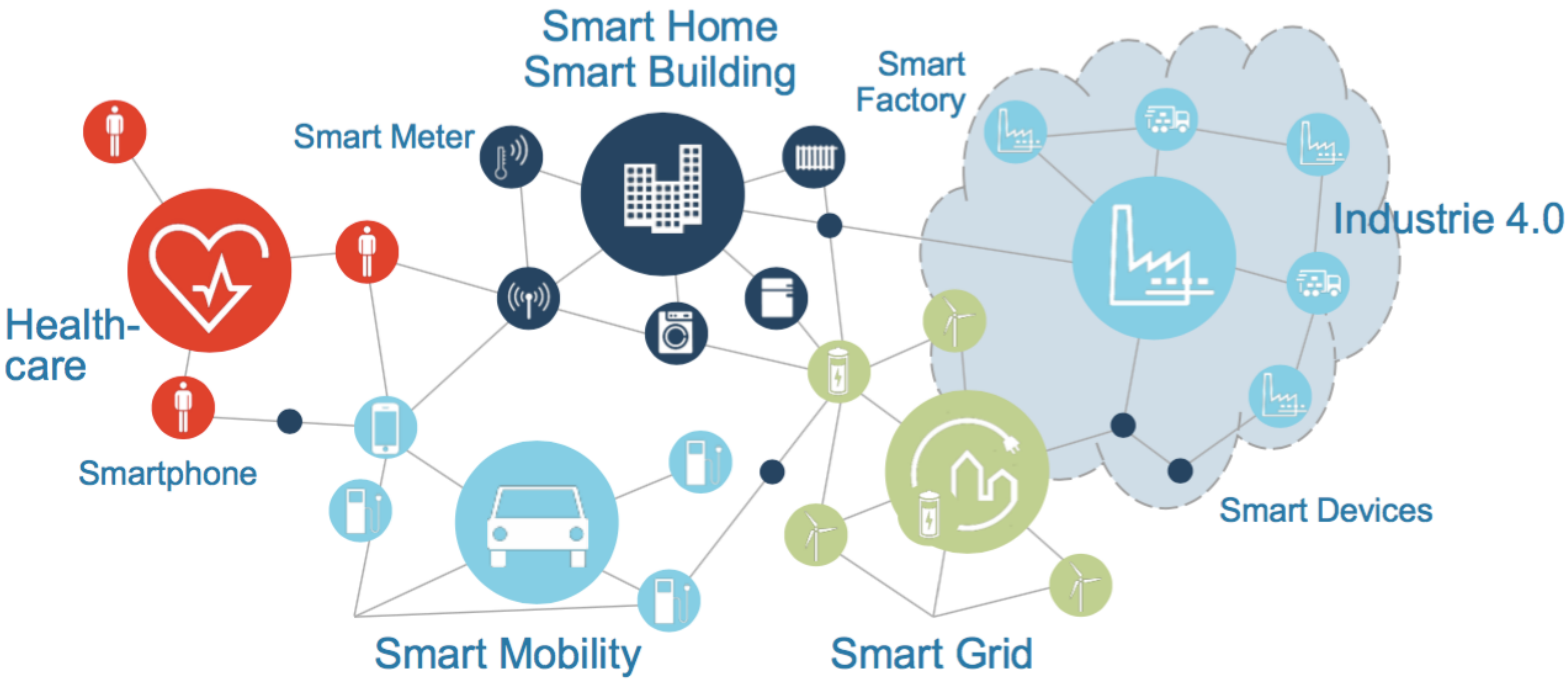


Image curtesy of Bosch Rexroth AG

INDUSTRIE 4.0 GOALS

I4.0 links production systems with information and communication technology

Customer and machine data are networked.
Machines mutually communicate to control and achieve flexible, efficient, production.

INDUSTRIE 4.0
DESIGN PRINCIPLES

Plattform INDUSTRIE 4.0

Interoperability. Machines, devices, sensors, and people can freely communicate with each other

Information Transparency. A **virtual representation** of the **physical world** is made available by enriching digital plant models with sensor data

Technical assistance. Leverage information to make more informed decisions and solving urgent problems on short notice. Physically support humans by conducting a range of tasks that are unpleasant, too exhausting, or unsafe for humans.

Decentralised Decisions. Autonomous decisions are the norm. Higher level delegation happens only in presence of interferences or conflicting goals

RAMI 4.0 GOALS

Group and coherently capture three extremely diverse perspective/aspects into a single model.

1. **Vertical Integration** (within the factory)

2. **End-to-End Engineering** (integrated administrative, commercial, and production processes)

3. **Horizontal Integration** (across factories)

REFERENCE ARCHITECTURE

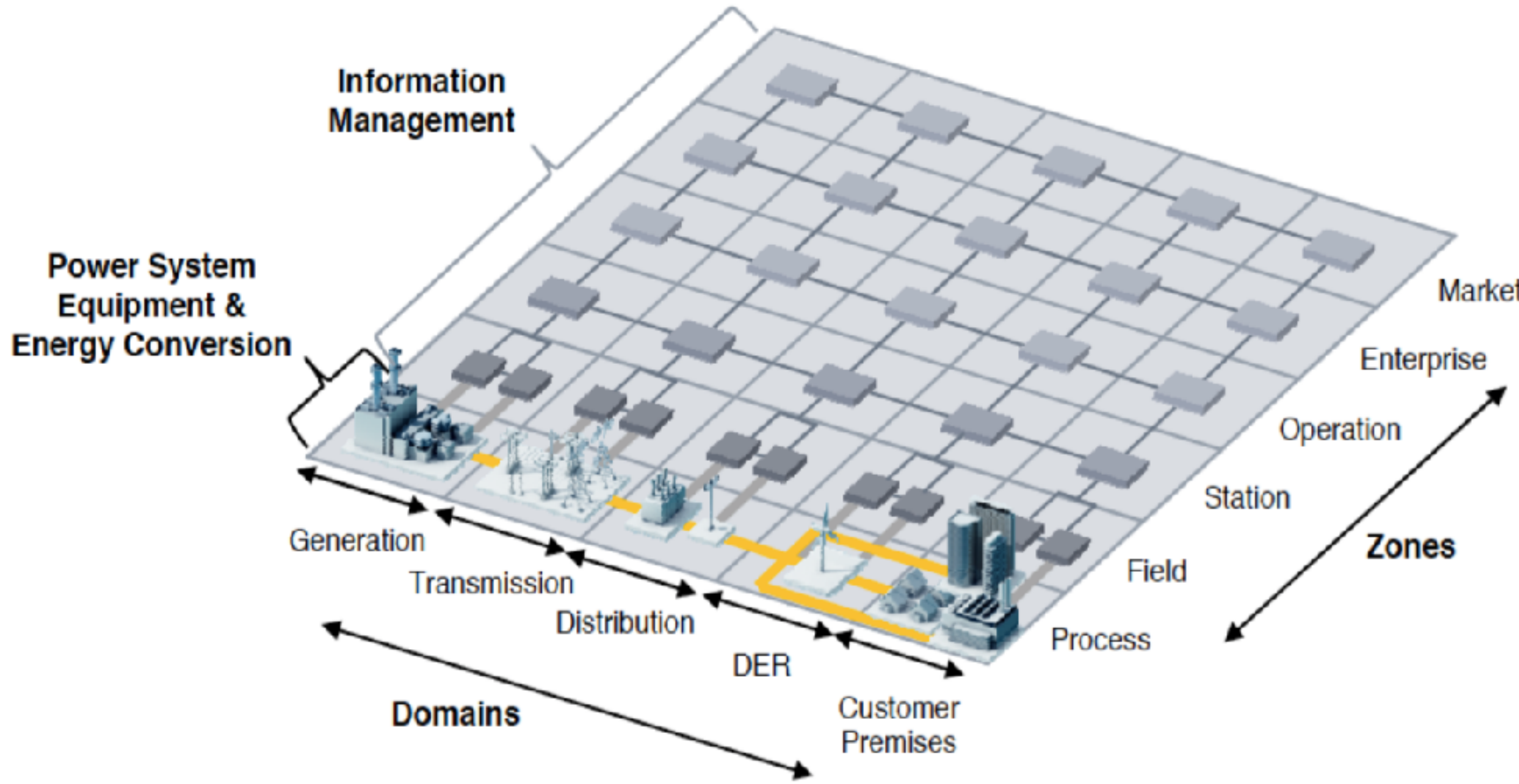
A Reference *Architecture* describes the *structure* of a system with its element types and their structures, as well as their *interaction* types, among each other and with their environment. Describing this, a Reference Architecture defines restrictions for an instantiation (concrete architecture). Through abstraction from individual details, a Reference Architecture is universally valid within a specific domain. Further architectures with the same functional requirements can be constructed based on the reference architecture. Along with *reference* architectures comes a *recommendation*, based on experiences from existing developments as well as from a wide acceptance and recognition by its users or per definition. [ISO/IEC42010]

In other terms, a Reference Architecture it is the specification of which language you should use to describe the system

Intermezzo: Smart Grid Architecture Model (SGAM)

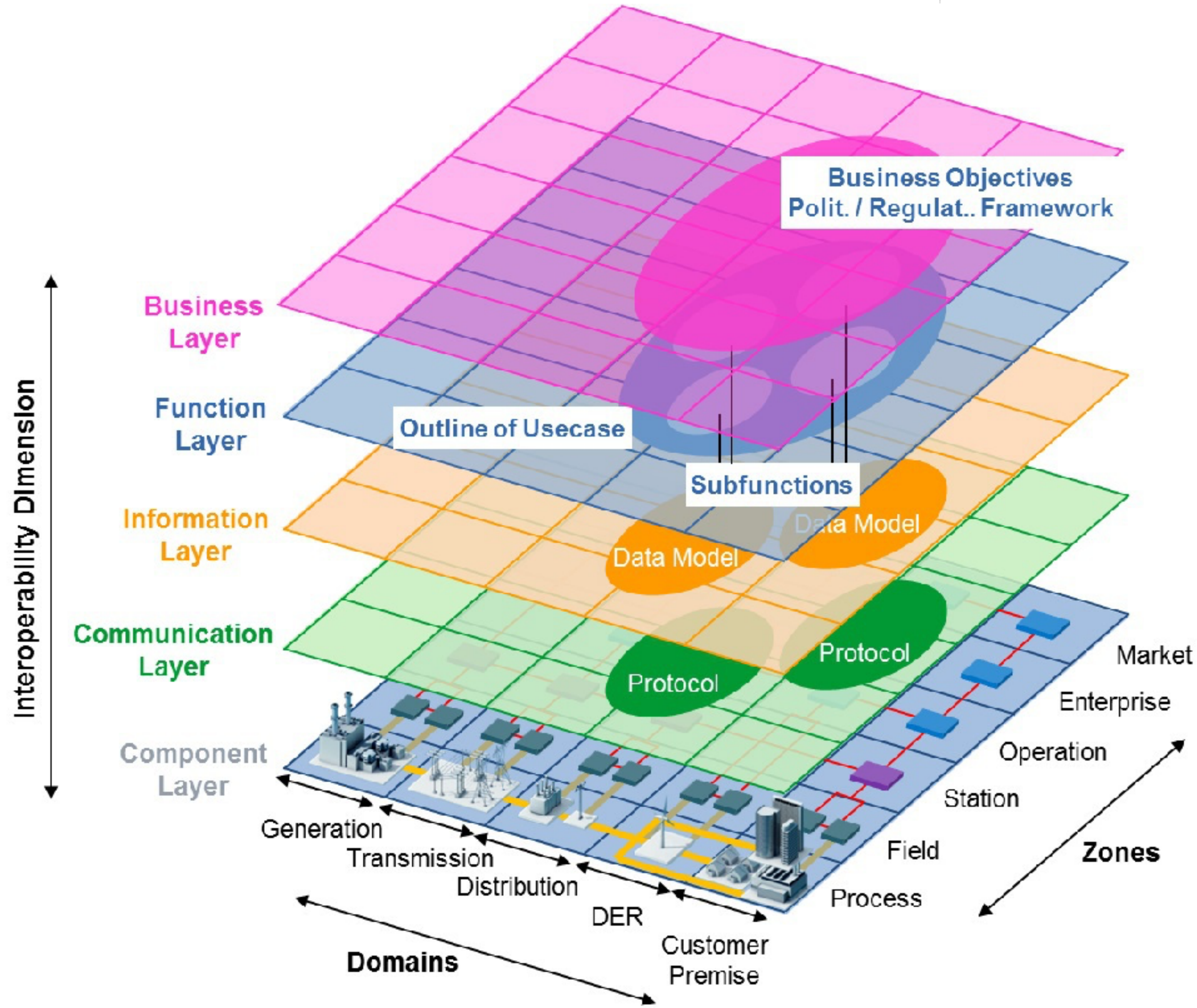
SMART GRID PLANE

This smart grid plane allows to represent the levels at which interactions between power system management take place



SGAM FRAMEWORK

SGAM consists of **five interoperability layers** that allow the **representation of entities and their relationships,** in the context of smart grid domains, and **information management hierarchies**



Back to RAMI4.0

RAMI 4.0

The Industrie 4.0 Reference Architecture (RAMI) is three dimensional and organises the **life-cycle/value streams** and the **manufacturing hierarchy levels** across the six layers of the IT representation of Industrie 4.0

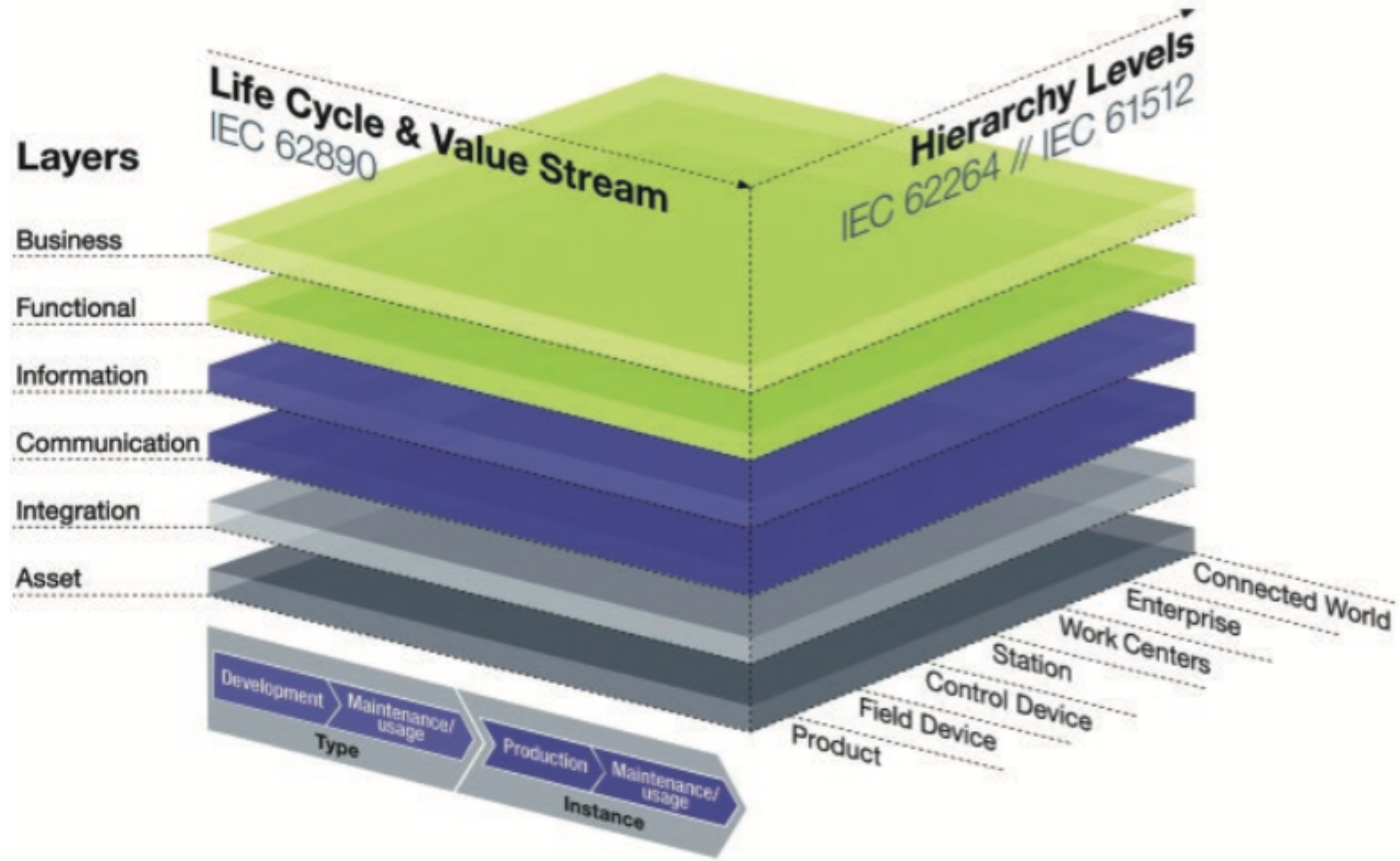
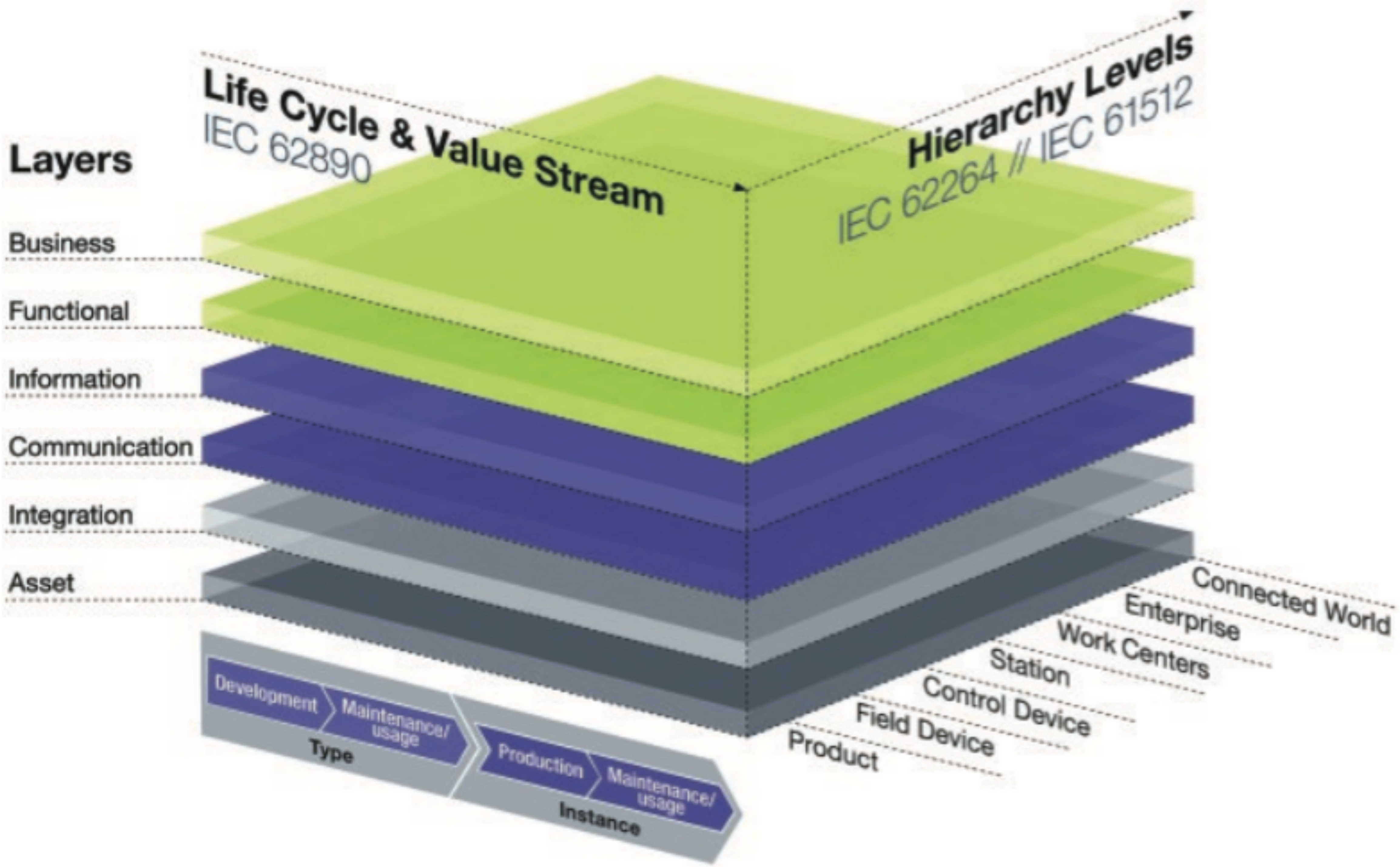
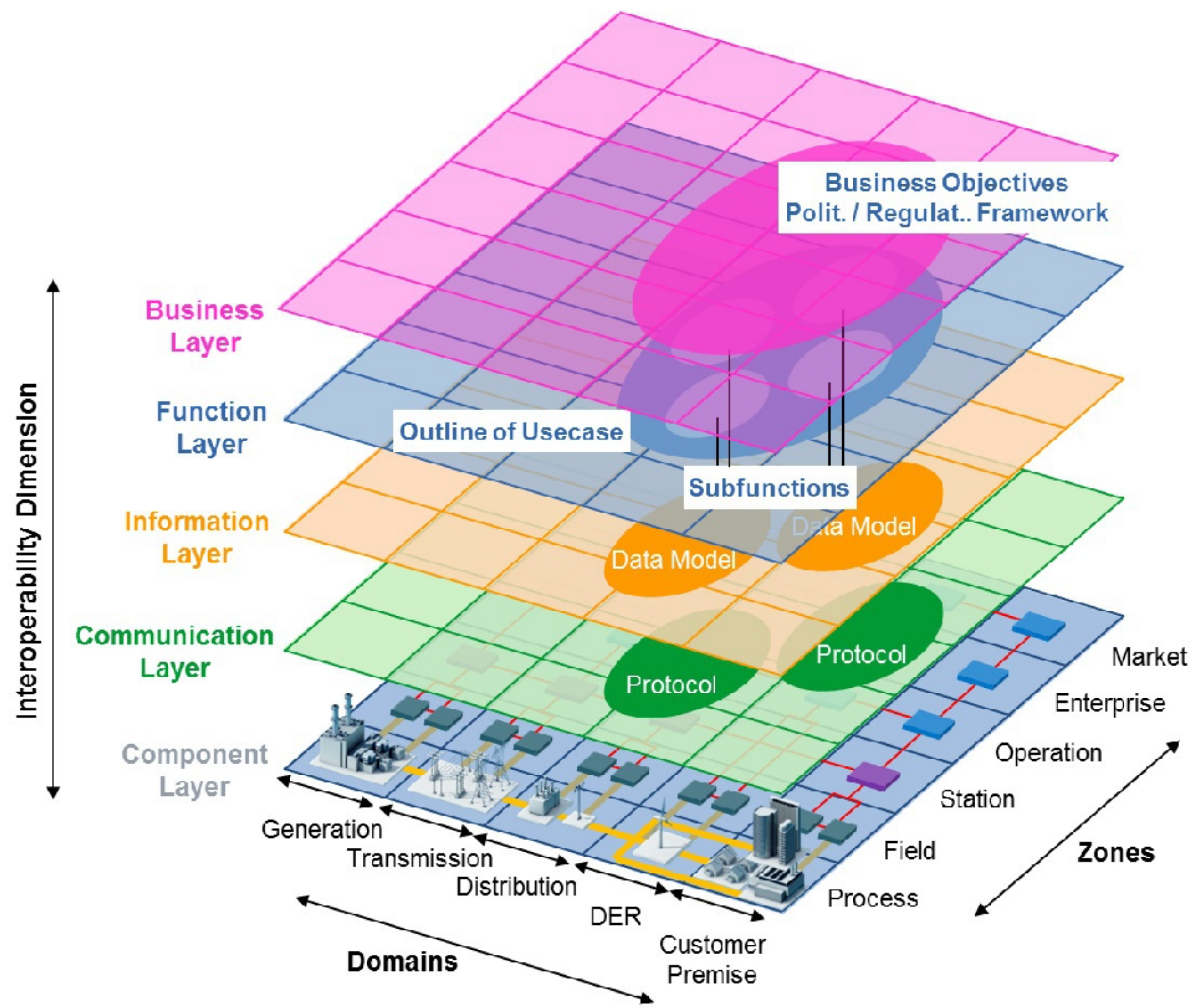


Image from: “Reference Architecture Model Industrie 4.0”

RAMI VS. SGAM

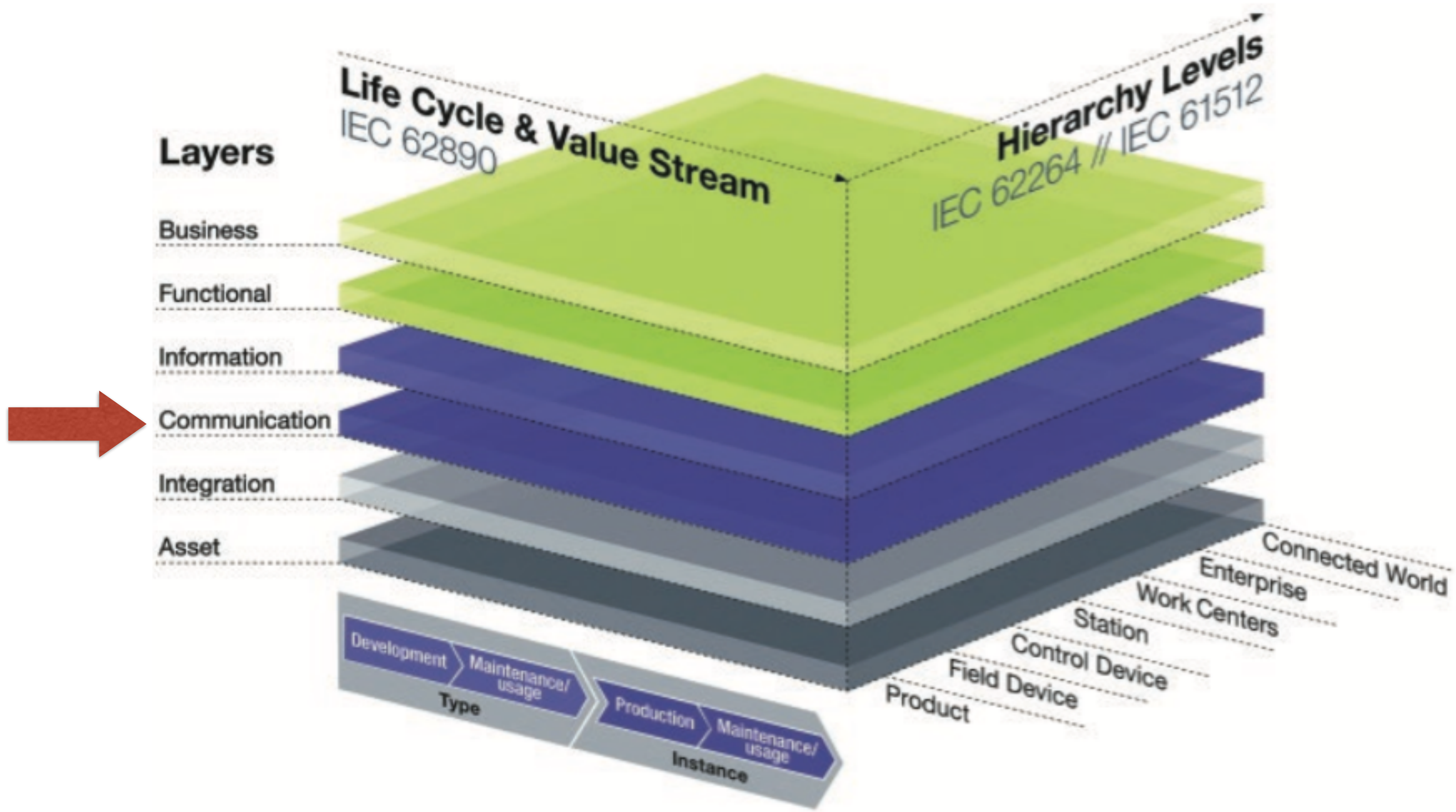

Layers
Business
Functional
Information
Communication
Integration
Asset
Life Cycle & Value Stream
IEC 62890
Hierarchy Levels
IEC 62264 // IEC 61512
Connected World
Enterprise
Work Centers
Station
Control Device
Field Device
Product
Development
Maintenance/ usage
Type
Production
Maintenance/ usage
Instance


Business Objectives
Polit. / Regulat.. Framework
Business Layer
Function Layer
Outline of Usecase
Subfunctions
Information Layer
Data Model
Data Model
Communication Layer
Protocol
Protocol
Component Layer
Interoperability Dimension
Generation
Transmission
Distribution
DER
Customer Premise
Domains
Market
Enterprise
Operation
Station
Field
Process
Zones

COMMUNICATION LAYER

Standardisation of communication, using a uniform data format, in the direction of the Information Layer.

Provision of services for control of the Integration Layer.



INFORMATION LAYER

Run time environment for processing of events.

Persistence of the data which represent the models.

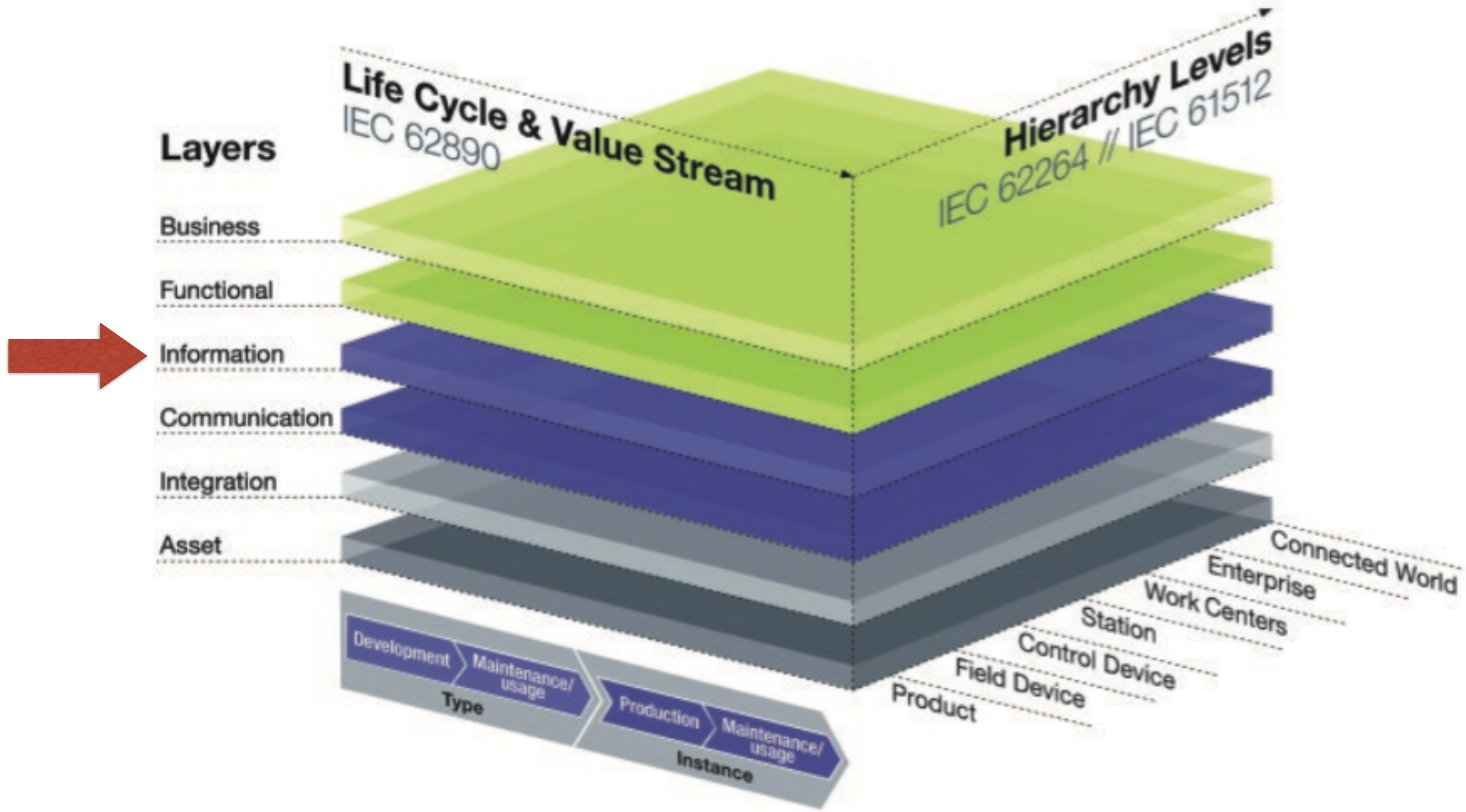
Ensuring data integrity.

Consistent integration of different data.

Obtaining new, higher quality data (data, information, knowledge).

Provision of structured data via service interfaces.

Receiving of events and their transformation to match the data which are available for the Functional Layer.

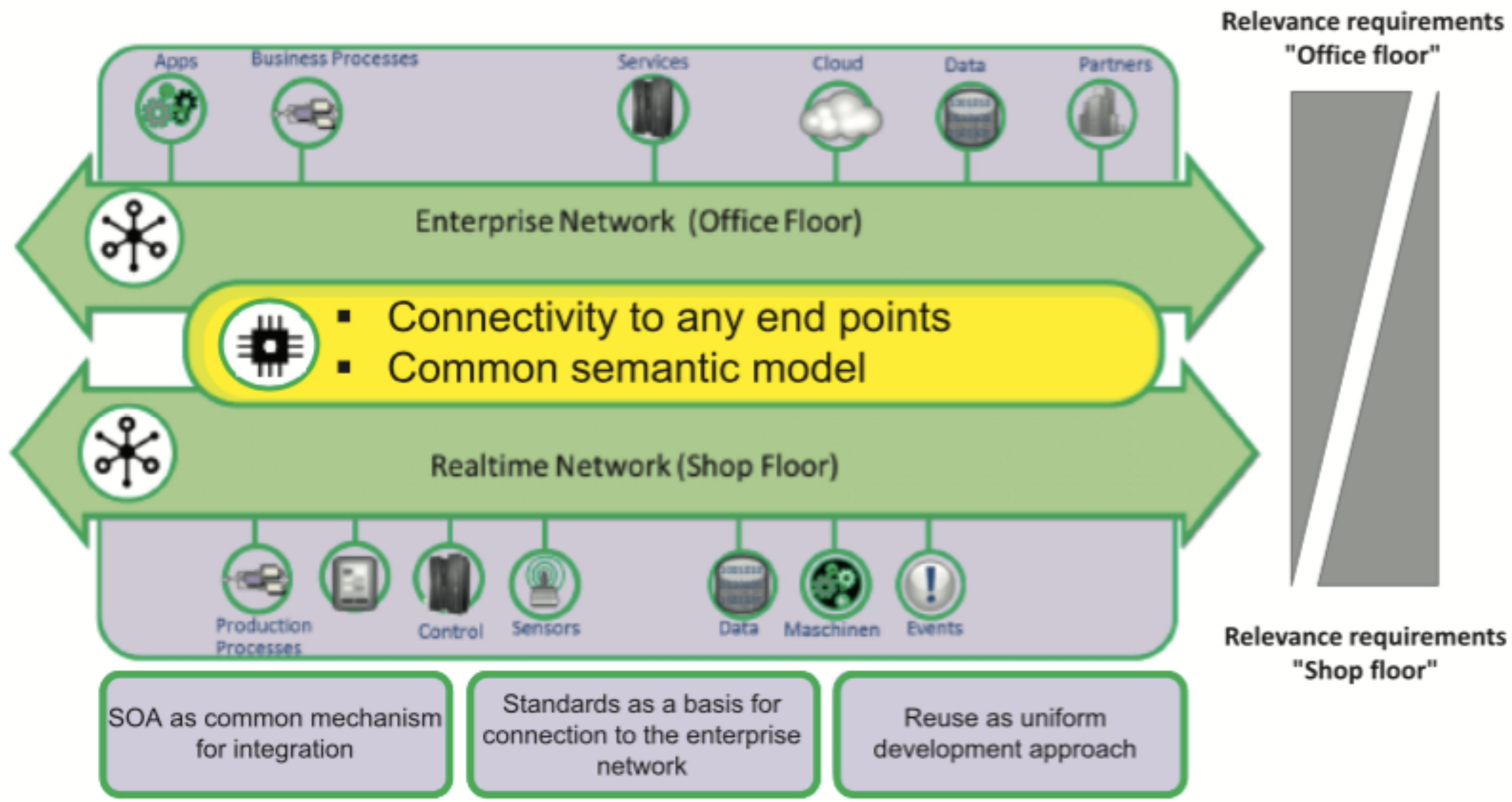


I4.0 COMPONENTS

To allow for **seamless integration** of the "Office Floor" and the "Shop Floor" I4.0 requires connectivity to any end points and a common semantic model.

Components must have certain common properties independently of the levels.

They are specified in the form of the I4.0 components.



I4.0 COMPONENTS REQUIREMENTS

A network of I4.0 components must be structured in such a way that connections between any end points (I4.0 components) are possible. The I4.0 components and their contents are to follow a common semantic model.

I4.0 COMPONENTS REQUIREMENTS

It must be possible to define the concept of an I4.0 component in such a way that it can meet requirements with different focal areas, i. e. "office floor" or "shop floor".

I4.0 COMPONENTS REQUIREMENTS

The I4.0 compliant communication must be performed in such a way that the data of a virtual representation of an I4.0 component can be kept either in the object itself or in a (higher level) IT system.

I4.0 COMPONENT

The ability to virtualise physical entities and make information available is key to RAMI4.0 and captured as part of the I4.0 Component

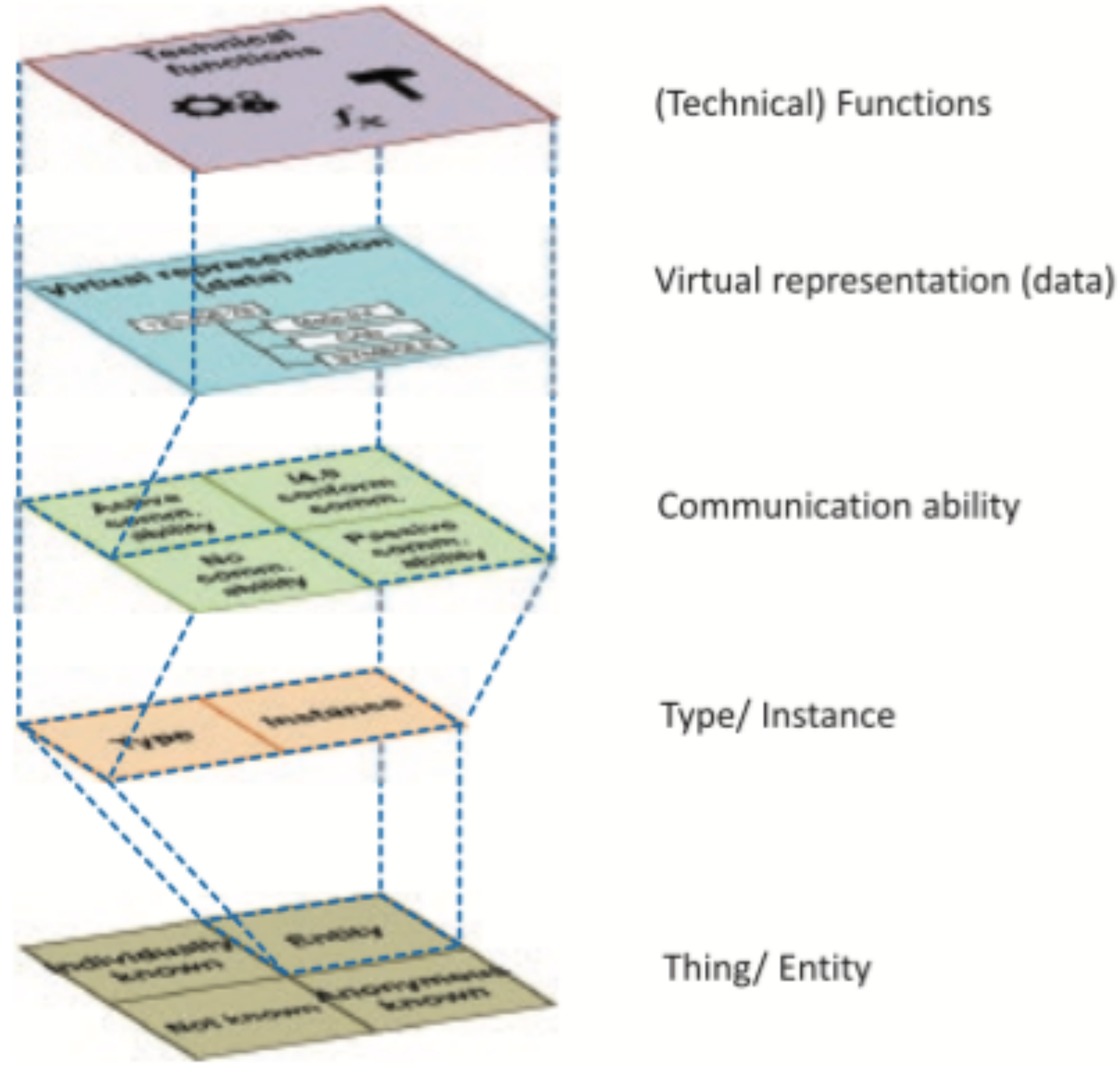


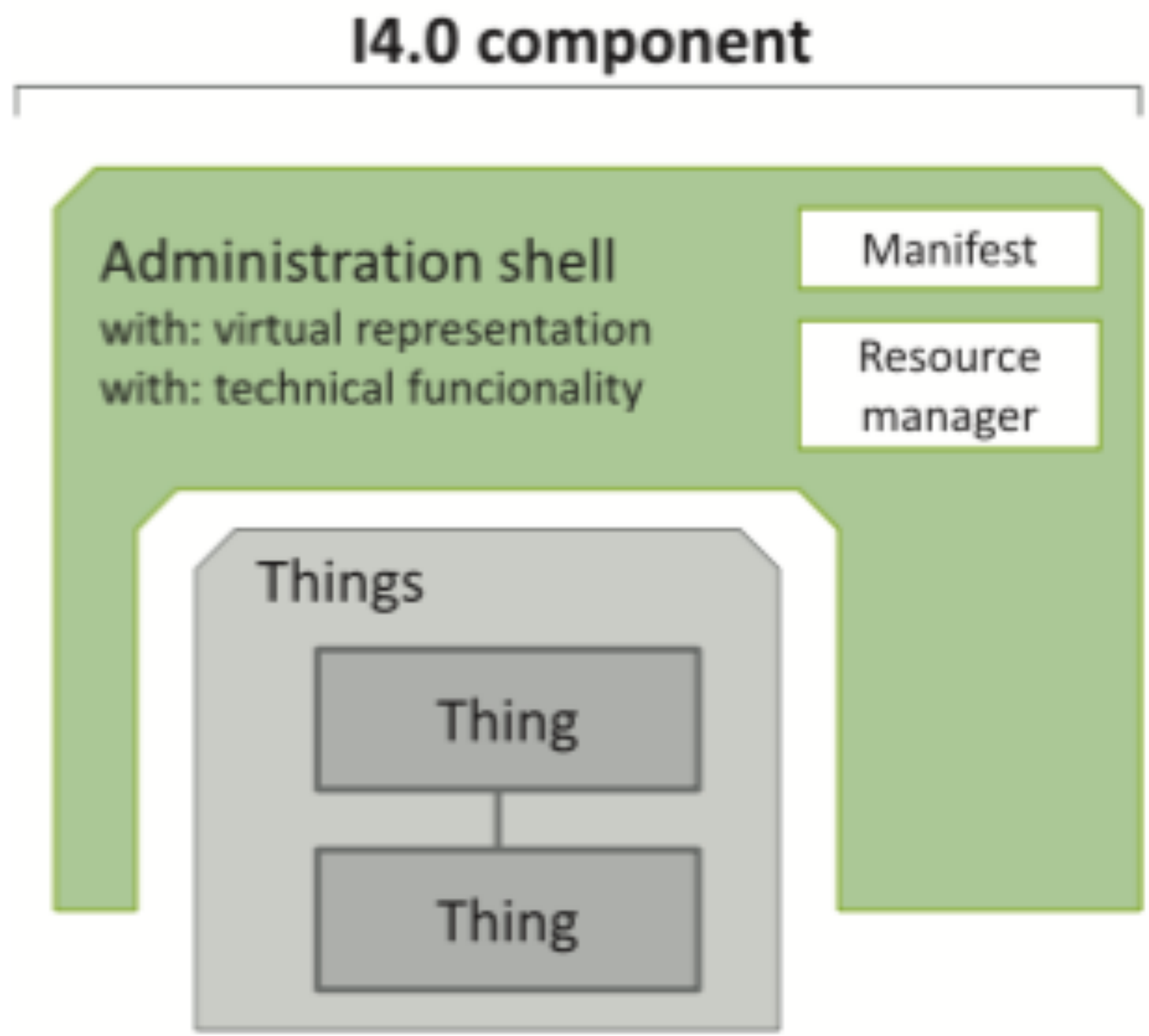
Image from: “Reference Architecture Model Industrie 4.0”

ADMINISTRATION SHELL

From a logical point of view, an **I4.0 Component** is made by **one or more objects** and an **administration shell**

The **administration shell** contains the **data** for **virtual representation and the functions of the technical functionality**.

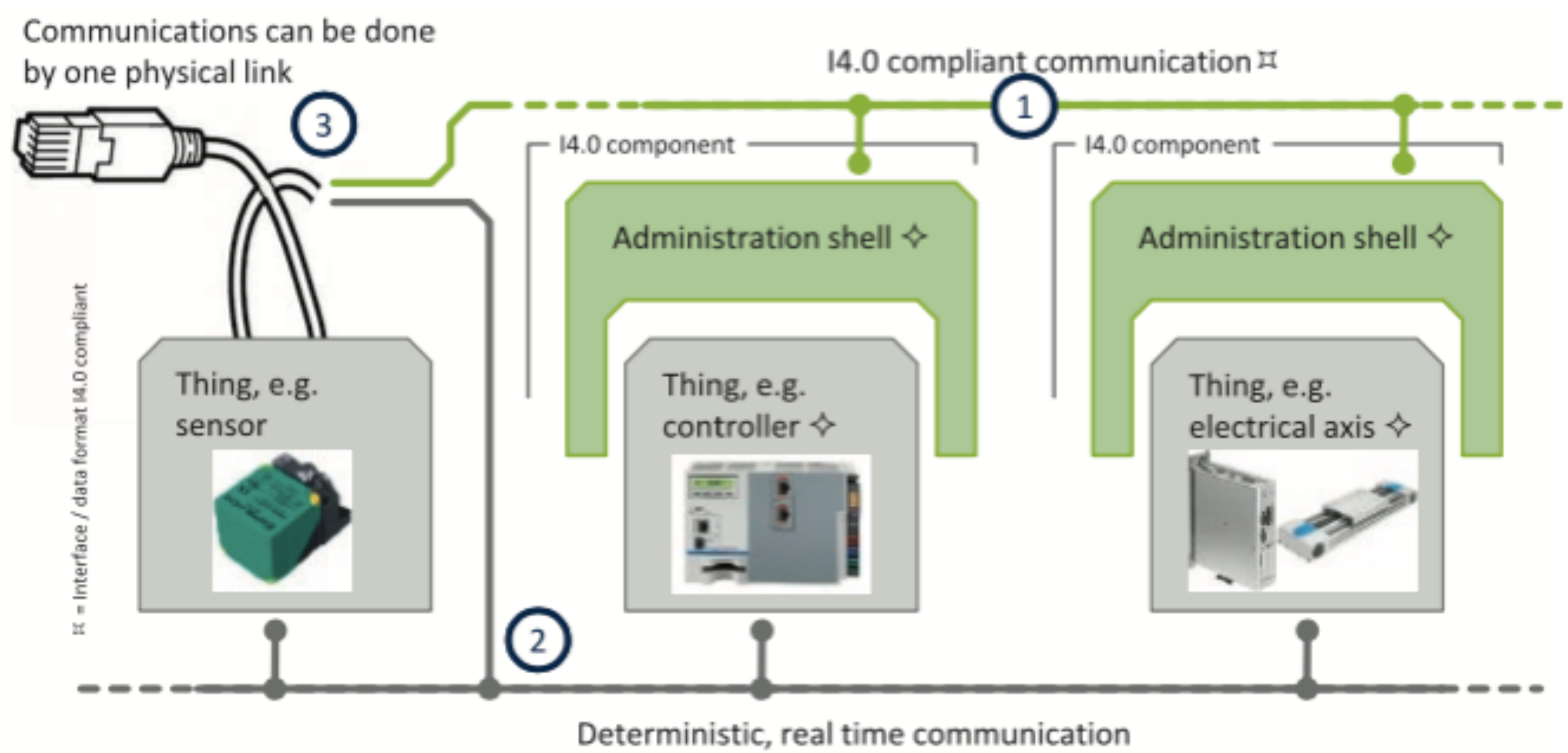
The mani fest, as part of the virtual representation, details the necessary administrative details on the I4.0 component.



SEPARABILITY OF FLOWS

I4.0 compliant communication does not have to implement deterministic or realtime communication itself, it can delegate to existing technologies.

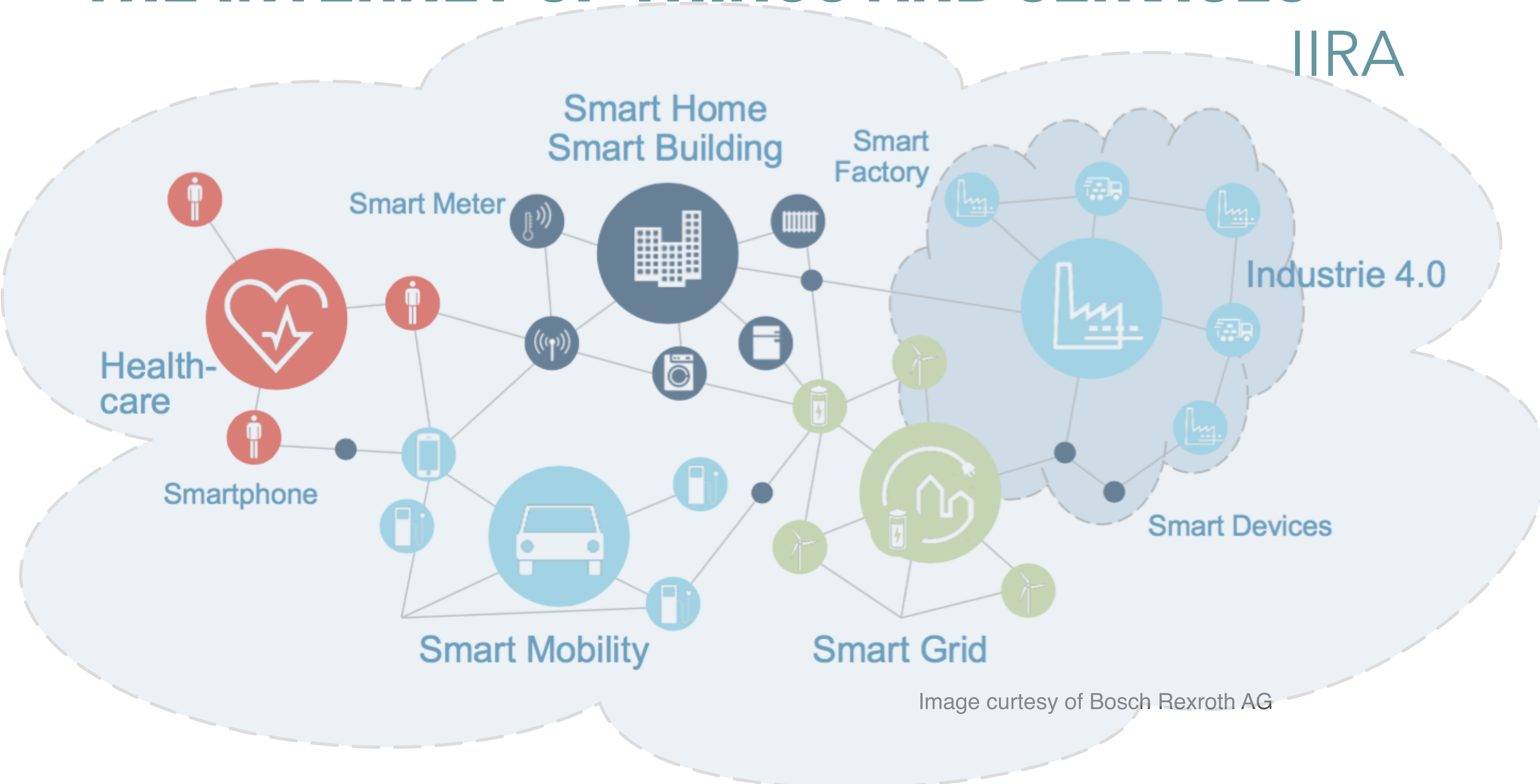
The Realtime Ethernet protocols which are standard today permit the expectation that it will be possible to effect both forms of communication via the same communications infrastructure.



IIRA

THE INTERNET OF THINGS AND SERVICES

IIRA



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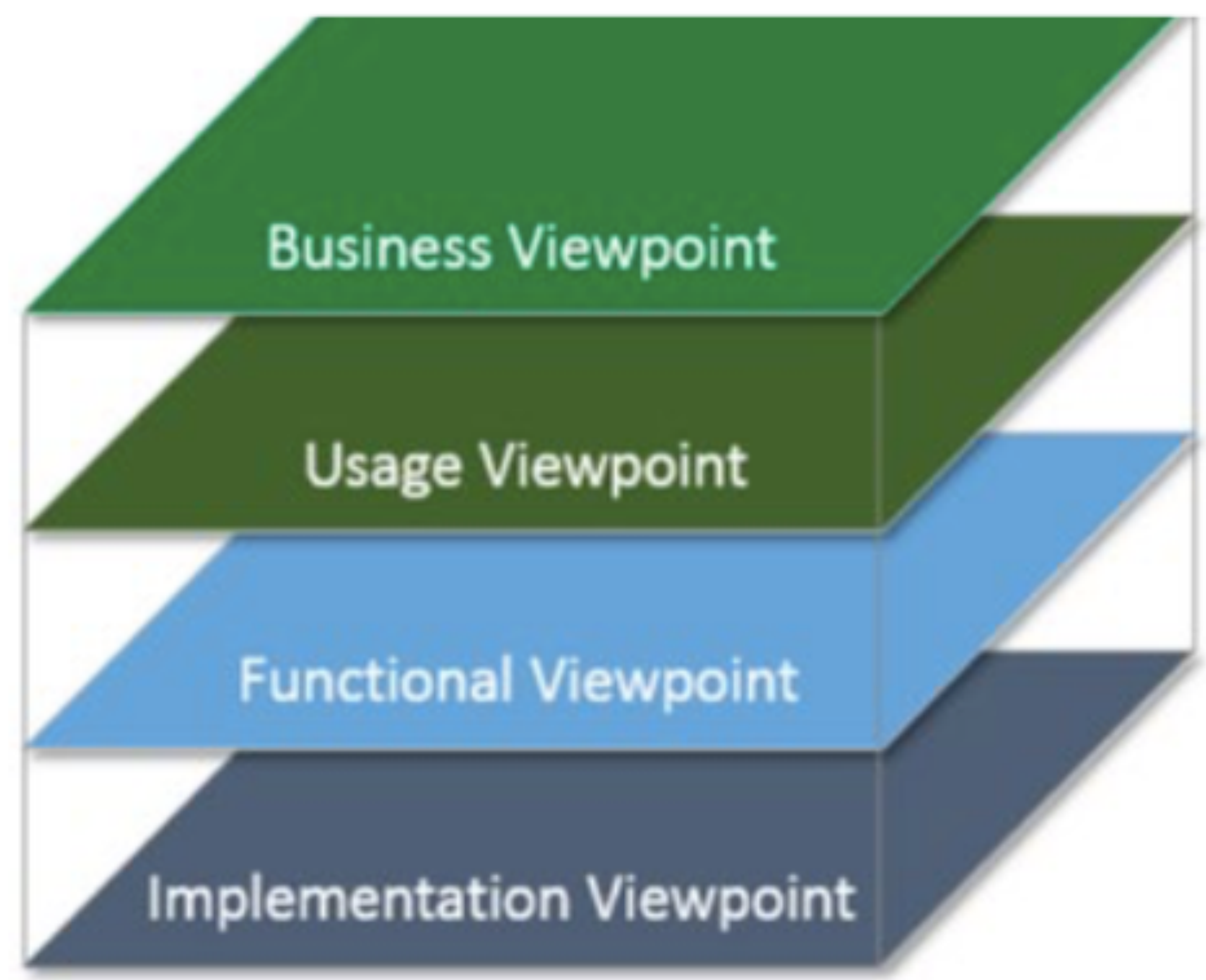
IIRA

The industrial internet architectural framework adopts
general concepts from the ISO/IEC/IEEE 42010:2011 standard which includes concerns, framework and viewpoints.

IISs are characterised by four viewpoints: Business, Usage, Functional, and Implementation



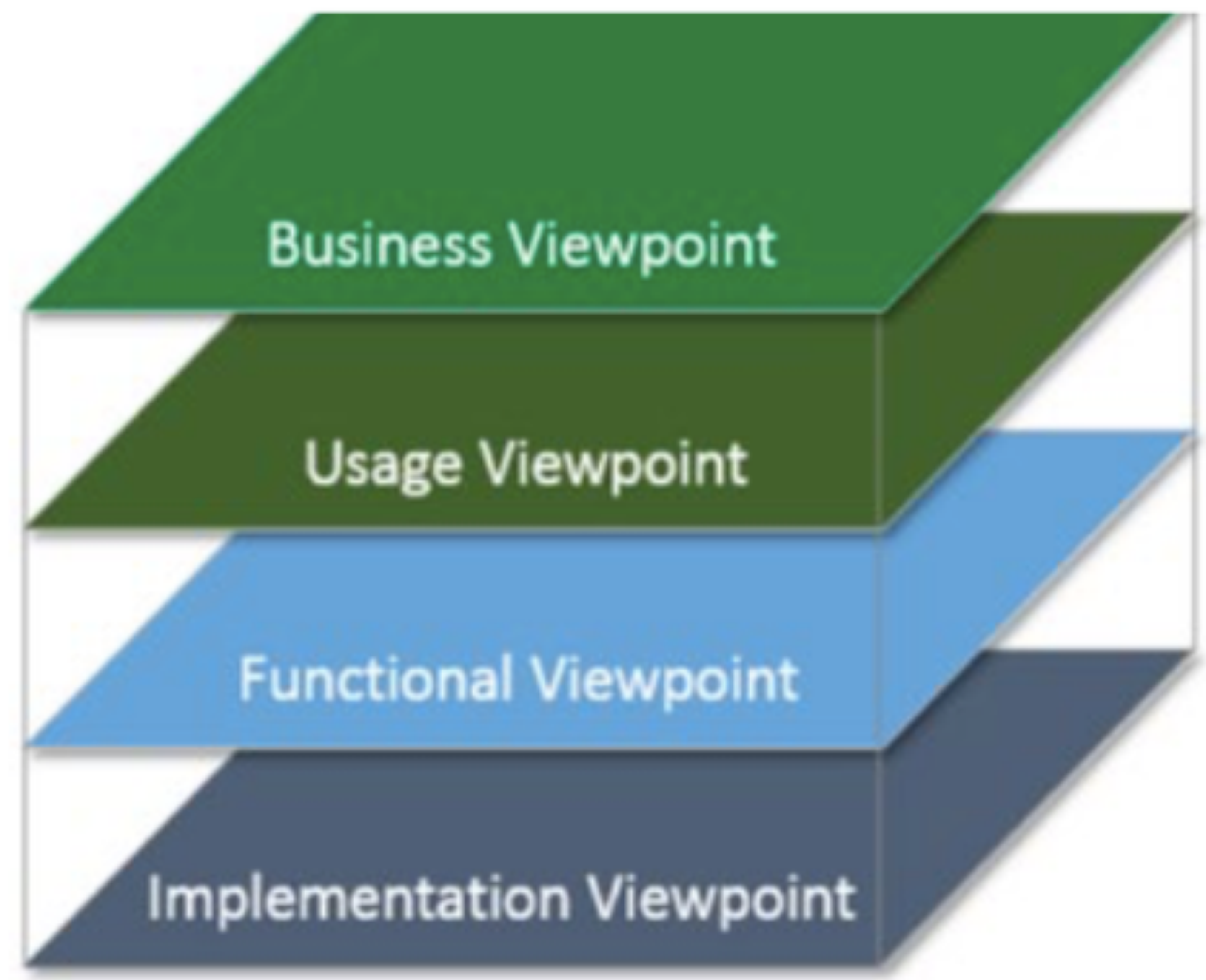
IIRA

The **Business Viewpoint** Identifies the business stakeholders

The **Usage Viewpoint** looks at the expected system usage

The **Functional Viewpoint** concerns the functional components of an IIS, their interrelationships and external interactions,

The **Implementation Viewpoint** concerns the technologies required to implement functional components.



IIRA FUNCTIONAL DOMAINS

The IIRA decomposes an Industrial Internet System (IIS) in five **functional domains**: **Control**, **Operation**, **Information**, **Application** and **Business**

Data flows and **control flows** take place in and **between** these **functional domains**.

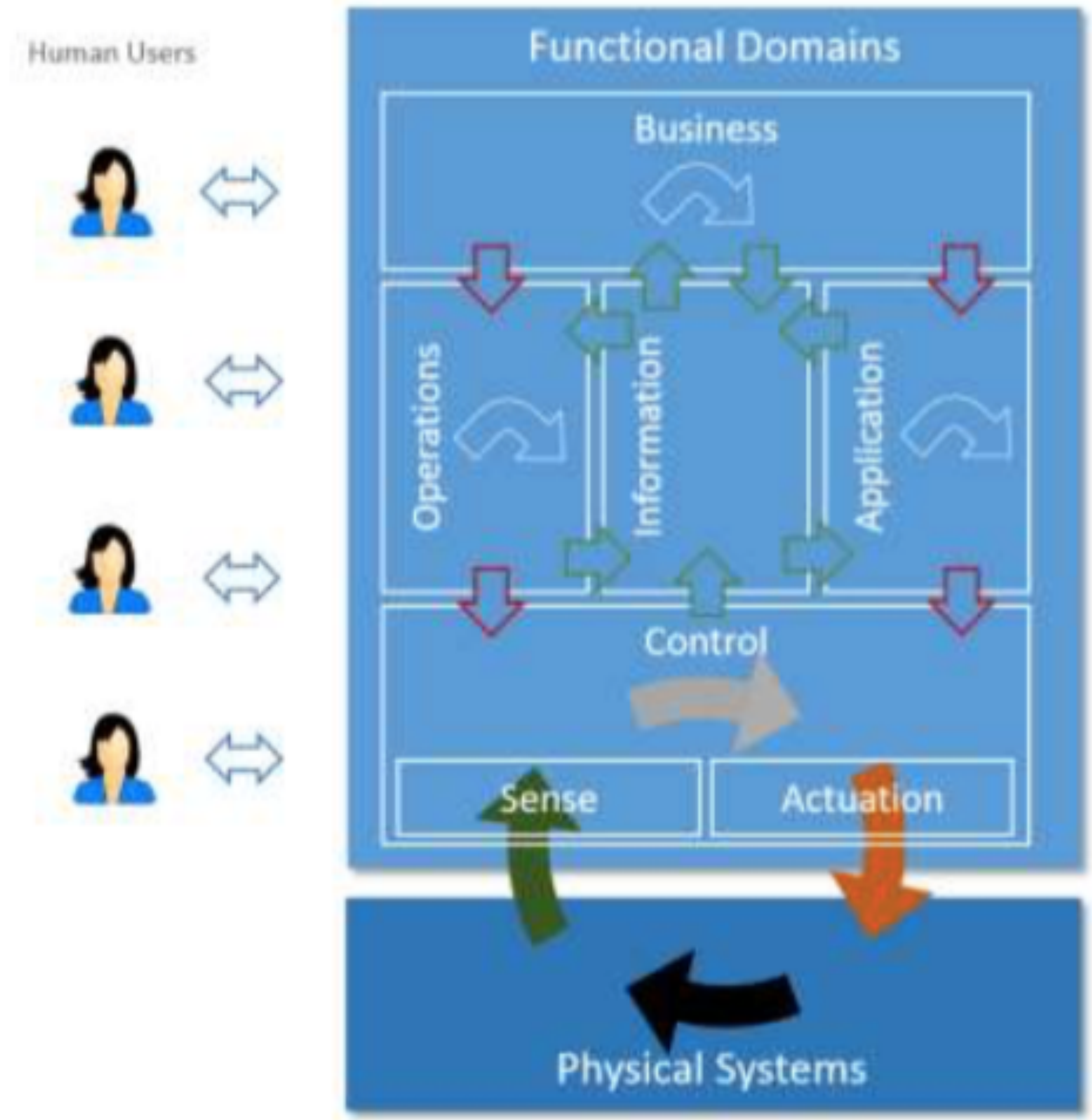
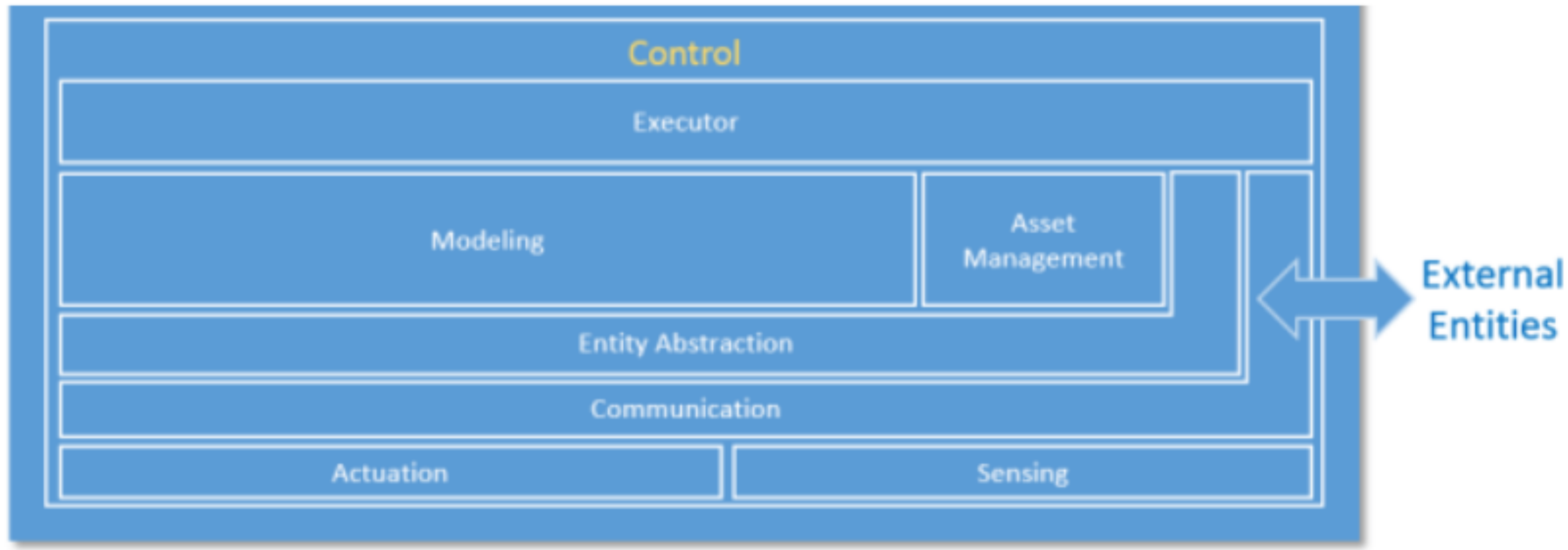


Image from: "Industrial Internet Consortium Reference Implementation v1.7"

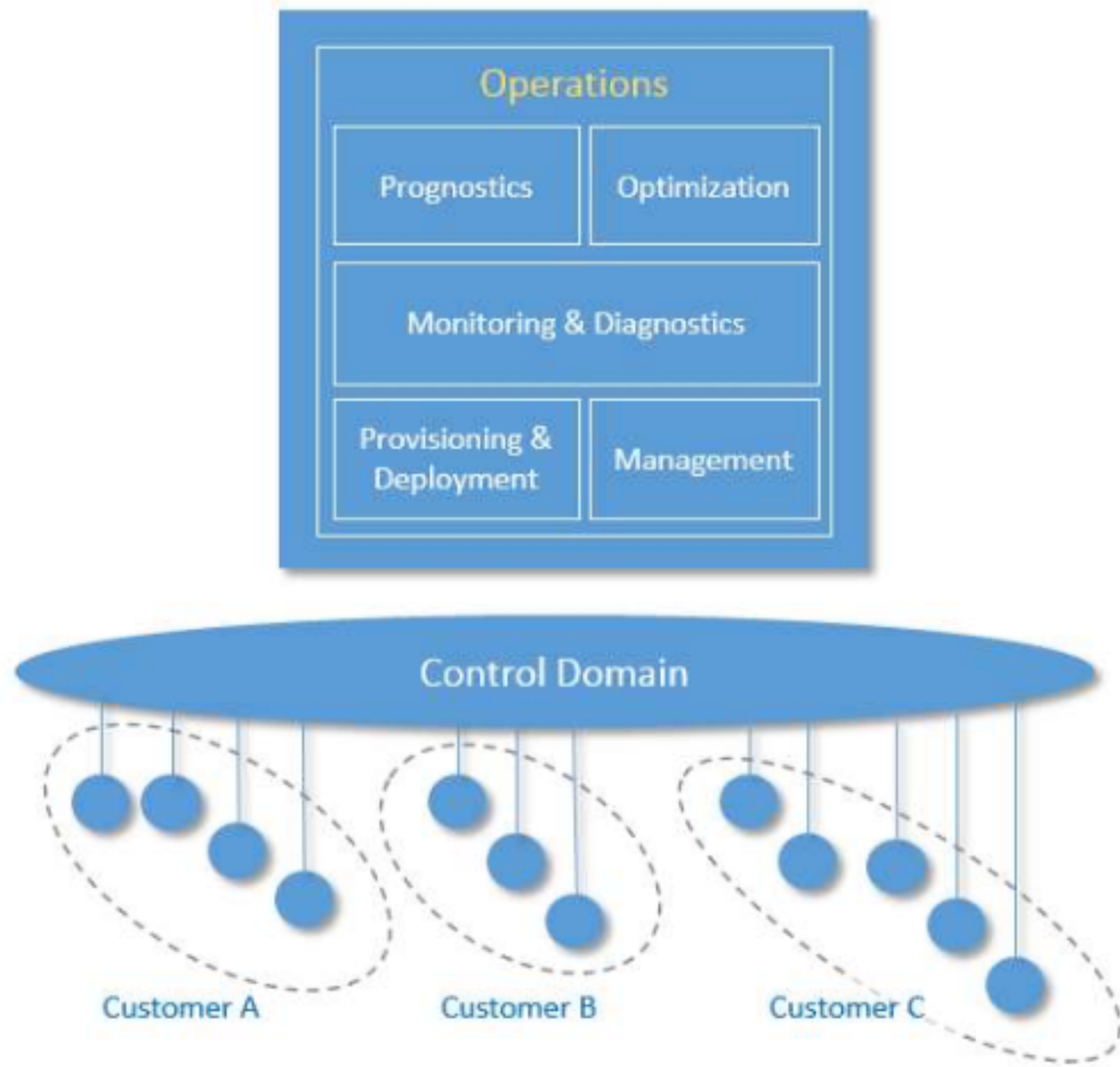
CONTROL DOMAIN

The control domain represents the collection of functions that are performed by industrial control systems. The core of these functions comprises fine-grained closed-loops, reading data from sensors, applying rules and logic, and exercising control over the physical system through actuators



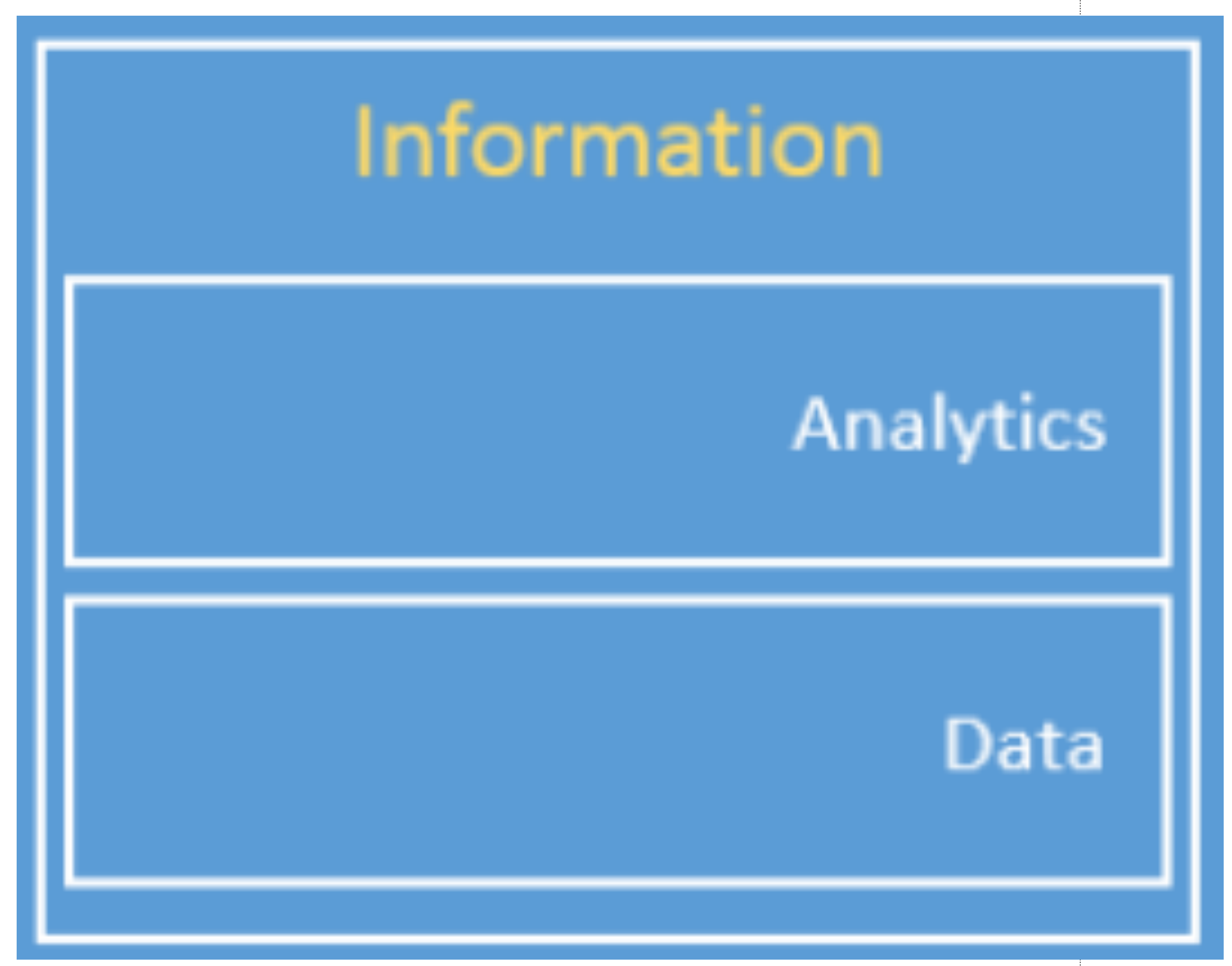
OPERATION DOMAIN

The operations domain represents the collection of functions responsible for the provisioning, management, monitoring and optimisation of the systems in the control domain. Existing industrial control systems mostly focus on optimising the assets in a single physical plant. The control systems of the Industrial Internet must move up a level, and optimise operations across asset types, fleets and customers.



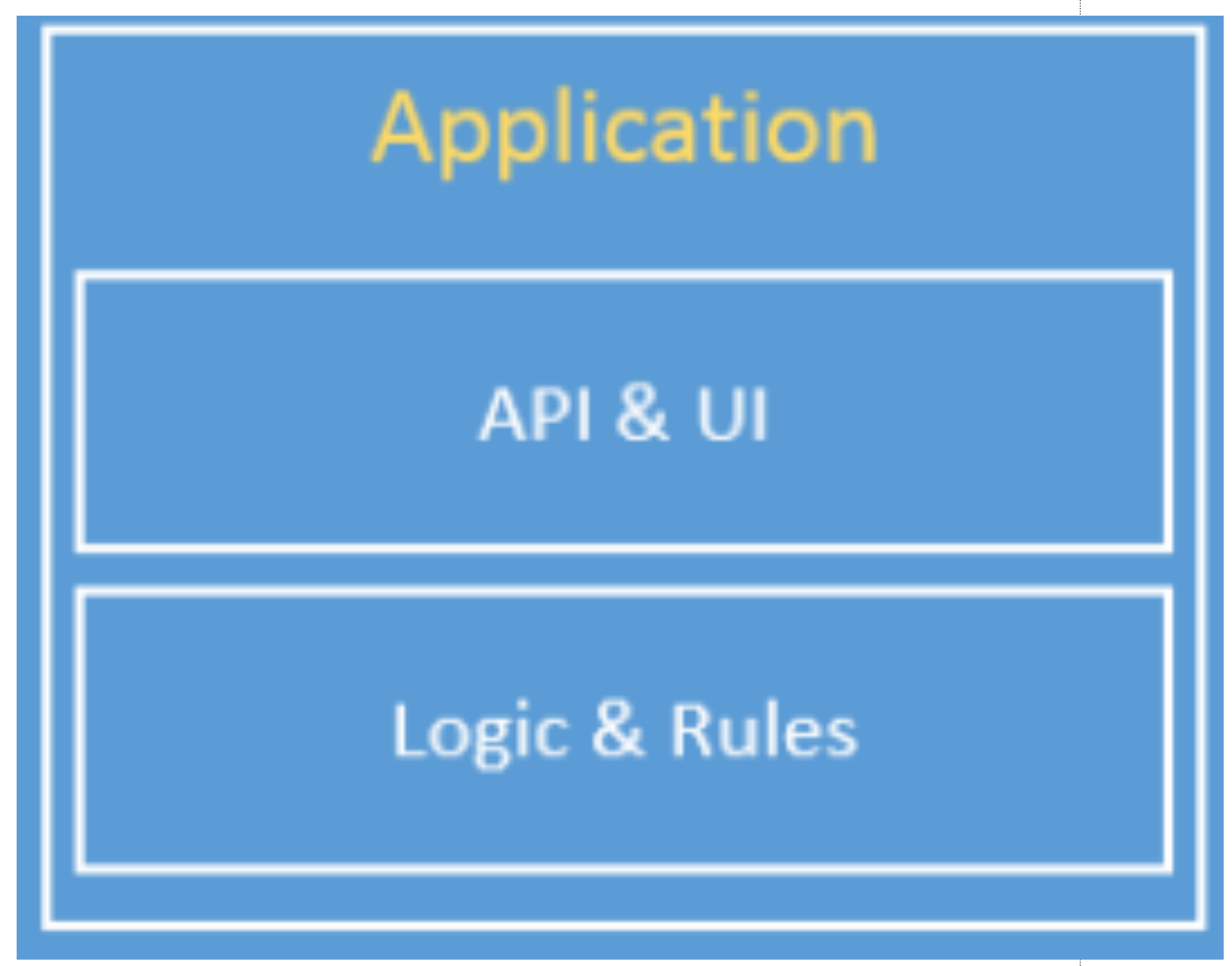
INFORMATION DOMAIN

The Information Domain represents the collection of functions for gathering data from various domains, most significantly from the control domain, and transforming, persisting, and modelling or analysing those data to acquire high-level intelligence about the overall system.



APPLICATION DOMAIN

The application domain represents the collection of functions implementing application logic that realises specific business functionalities. Functions in this domain apply application logic, rules and models at a coarse-grained, high level for optimisation in a global scope.

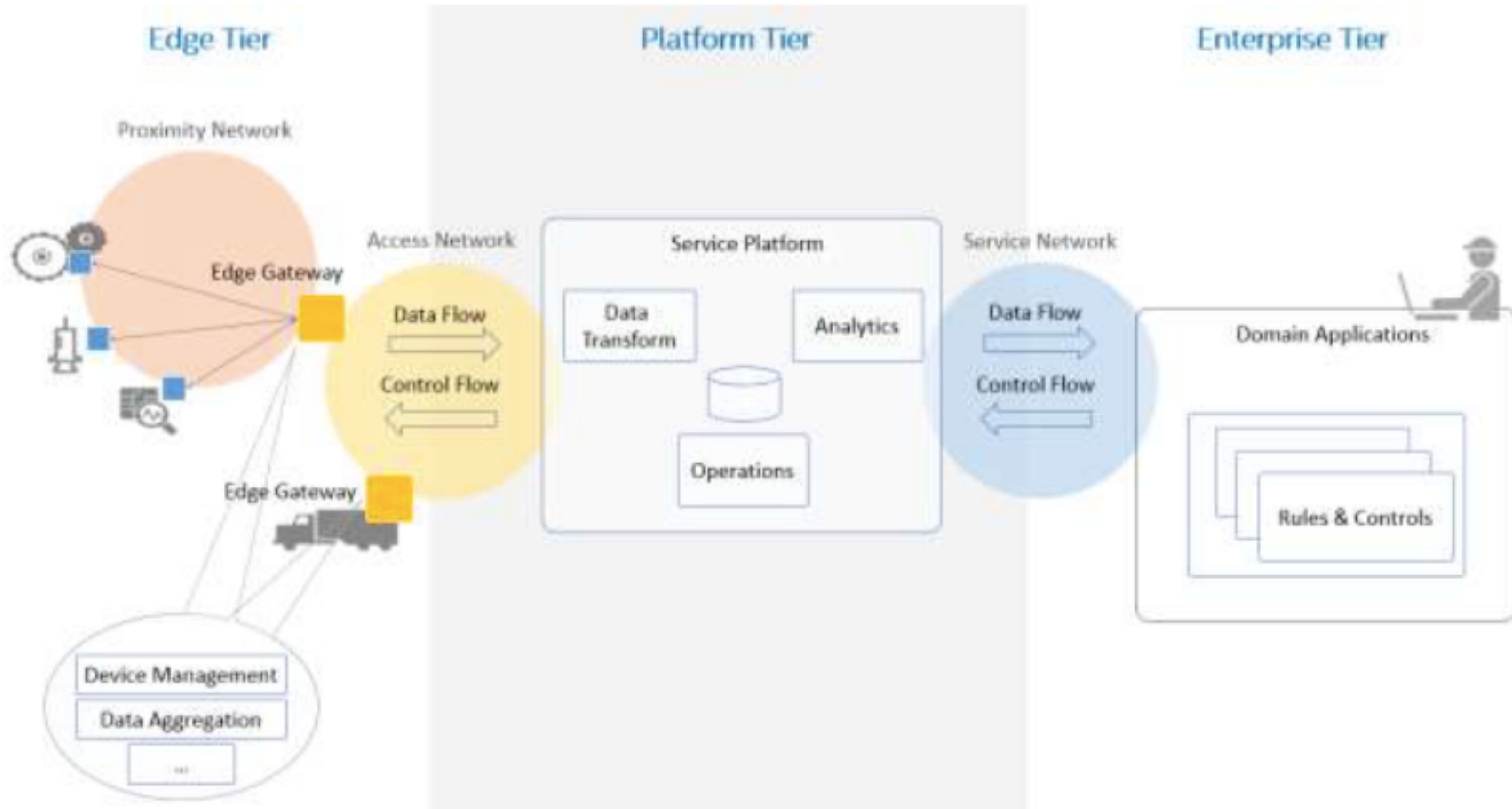


BUSINESS DOMAIN

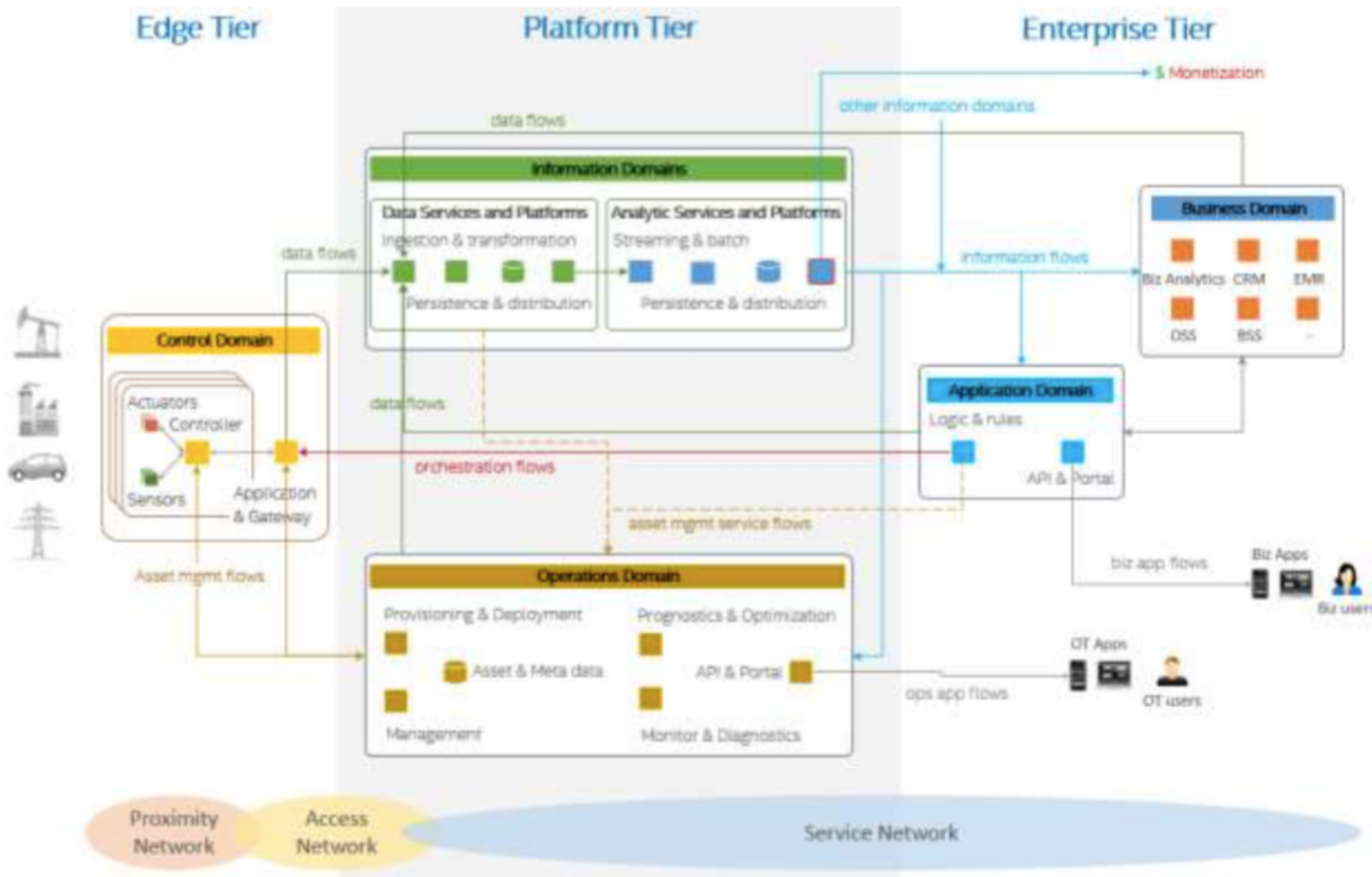
The application domain represents the collection of functions implementing application logic that realizes specific business functionalities. Functions in this domain apply application logic, rules and models at a coarse-grained, high level for optimization in a global scope.

IMPLEMENTATION VIEWPOINT

The implementation viewpoint is concerned with the technical representation of an Industrial Internet System and the technologies and system components required to implement the activities and functions prescribed by the usage and functional viewpoints.



FUNCTIONAL DOMAINS MAPPING



IIRA CONNECTIVITY

IIRA connectivity foresees the use of a Connectivity Core Standard (such as DDS) and then Gateways to integrate other connectivity technologies

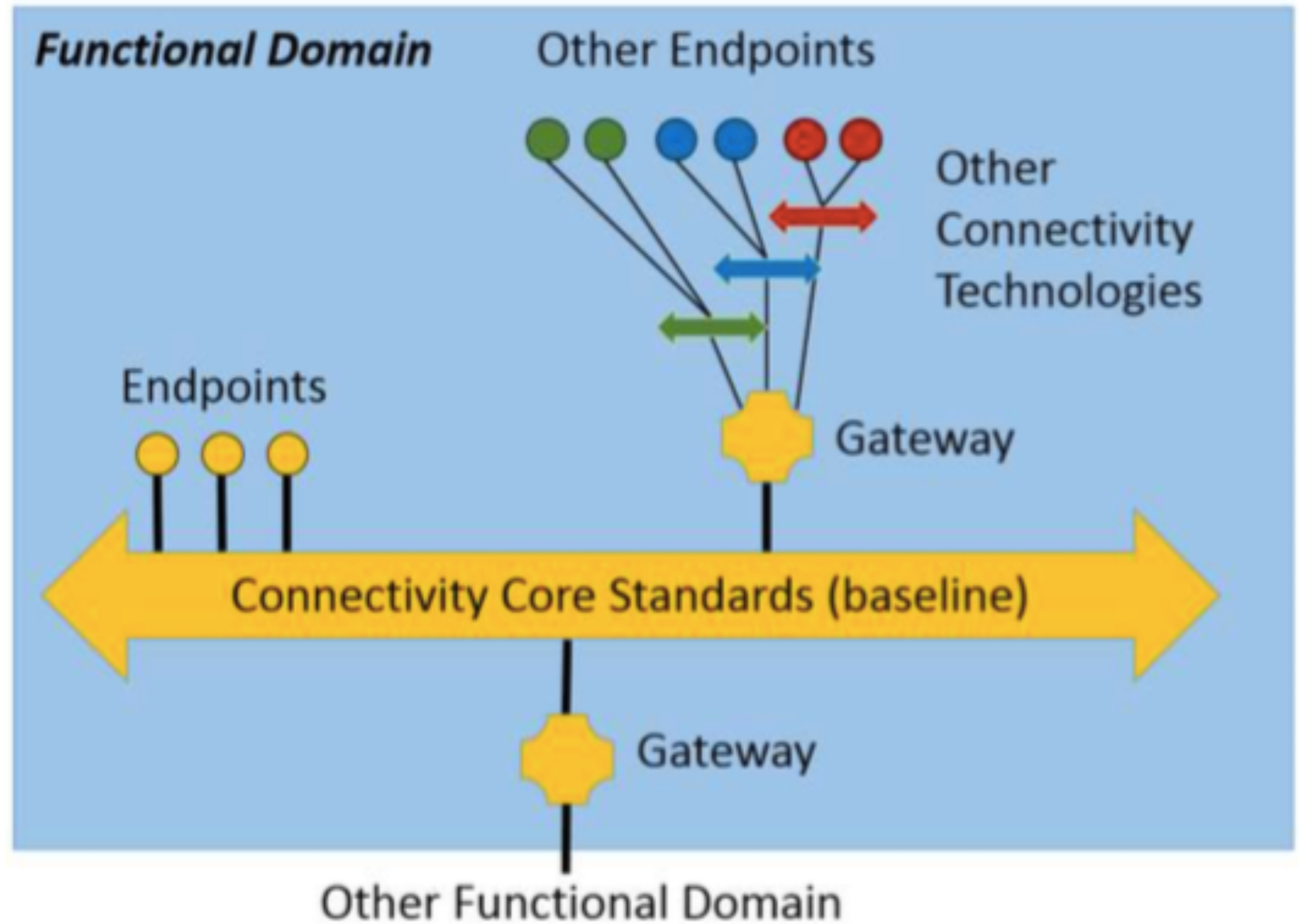


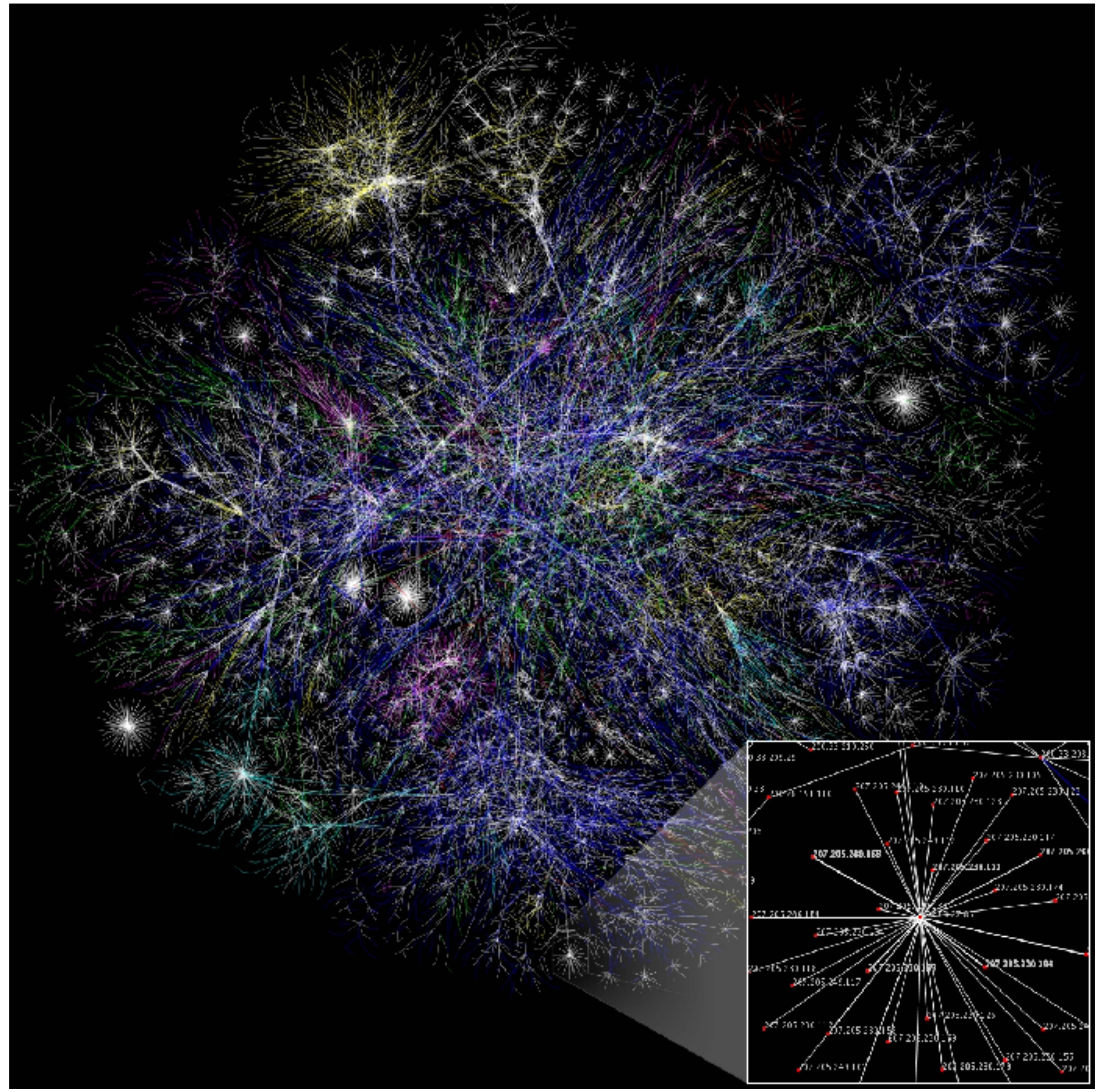
Image from: "Industrial Internet Reference Architecture v1.7"

RAMI & IIRA

IIRA/I4.0 RELATIONSHIP

Architectural Challenges

SCALE



IoT systems tend to fall in the category of Ultra-Large Scale Systems.

These systems whose connectivity tend to follow a power-law, tend to be characterised by emergent behaviours

Proper care should be taken in the design of algorithm for these systems to ensure self-stabilisation properties

HETHEROGENEITY

IoT systems are characterised by an extreme heterogeneity in computational power of their nodes as well as characteristics of the interconnect.

This poses major challenges in ensuring that system remain stable and don't diverge or oscillate due to asymmetry

SECURITY

Security is key in IoT but often under-estimated.

The right set of technologies for addressing security, exist. The gap is often in the security expertise

PRIVACY

Privacy will be major issue in IoT.

Today people are willing to easily give away their data… But eventually will realise that this is a key value.

Technologies like Homomorphic Encryption can help addressing this problem.

SUMMARY

The IoT can be classified in CIoT and IIoT

IIoT is characterised by more stringent needs

Reference architectures have focused to a great extent on IIoT

RAMI4.0 and IIRA are two example of IIoT Reference Architectures

Data is the key asset that creates value in IoT in