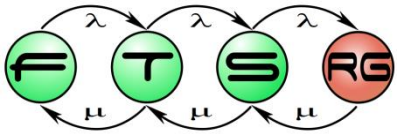
OpenFog Reference Architecture for Fog Computing

http://www.openfogconsortium.org/

February 2017

Budapest University of Technology and Economics
Fault Tolerant Systems Research Group

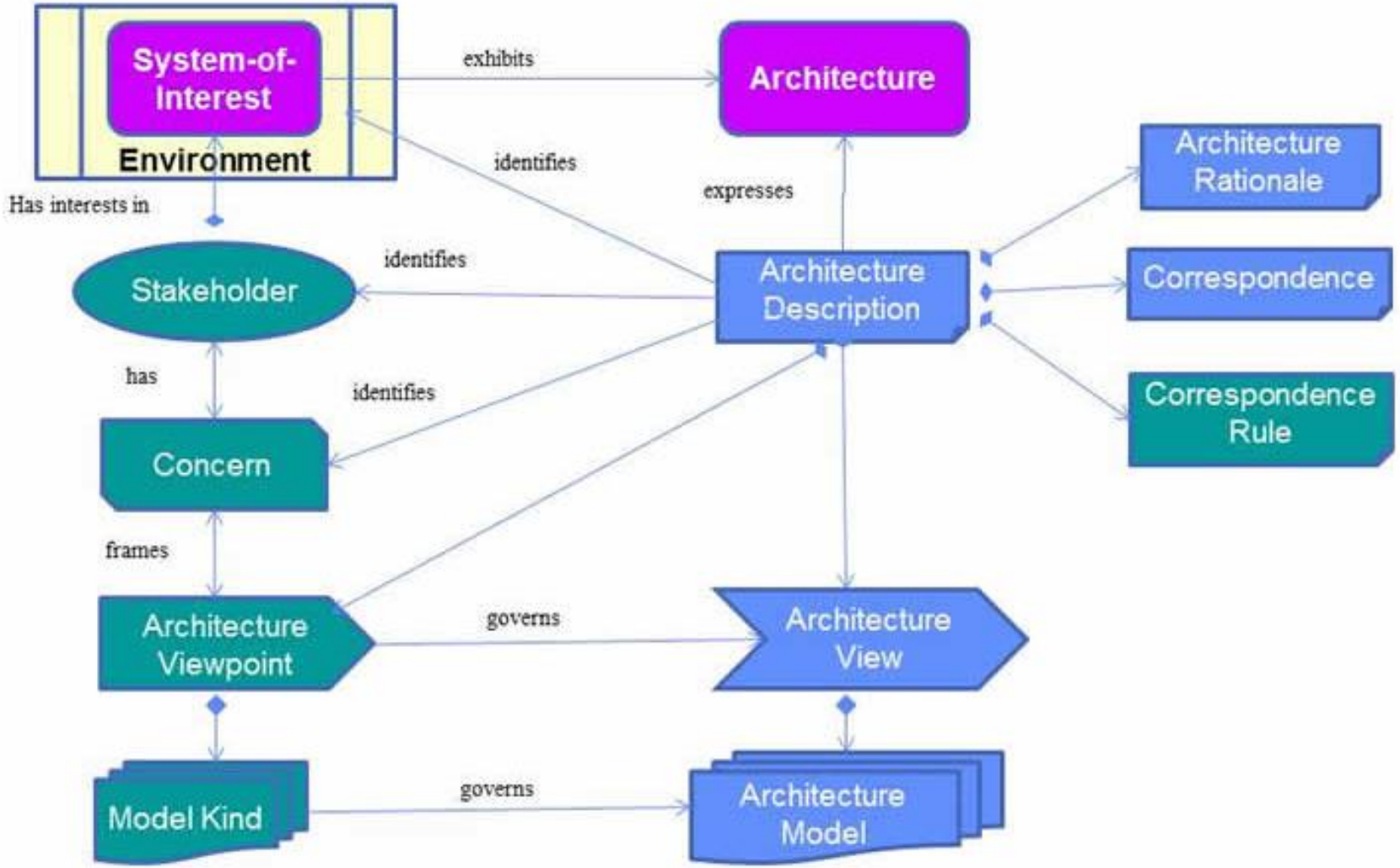


REFERENCE ARCHITECTURES

ISO/IEC/IEEE 42010

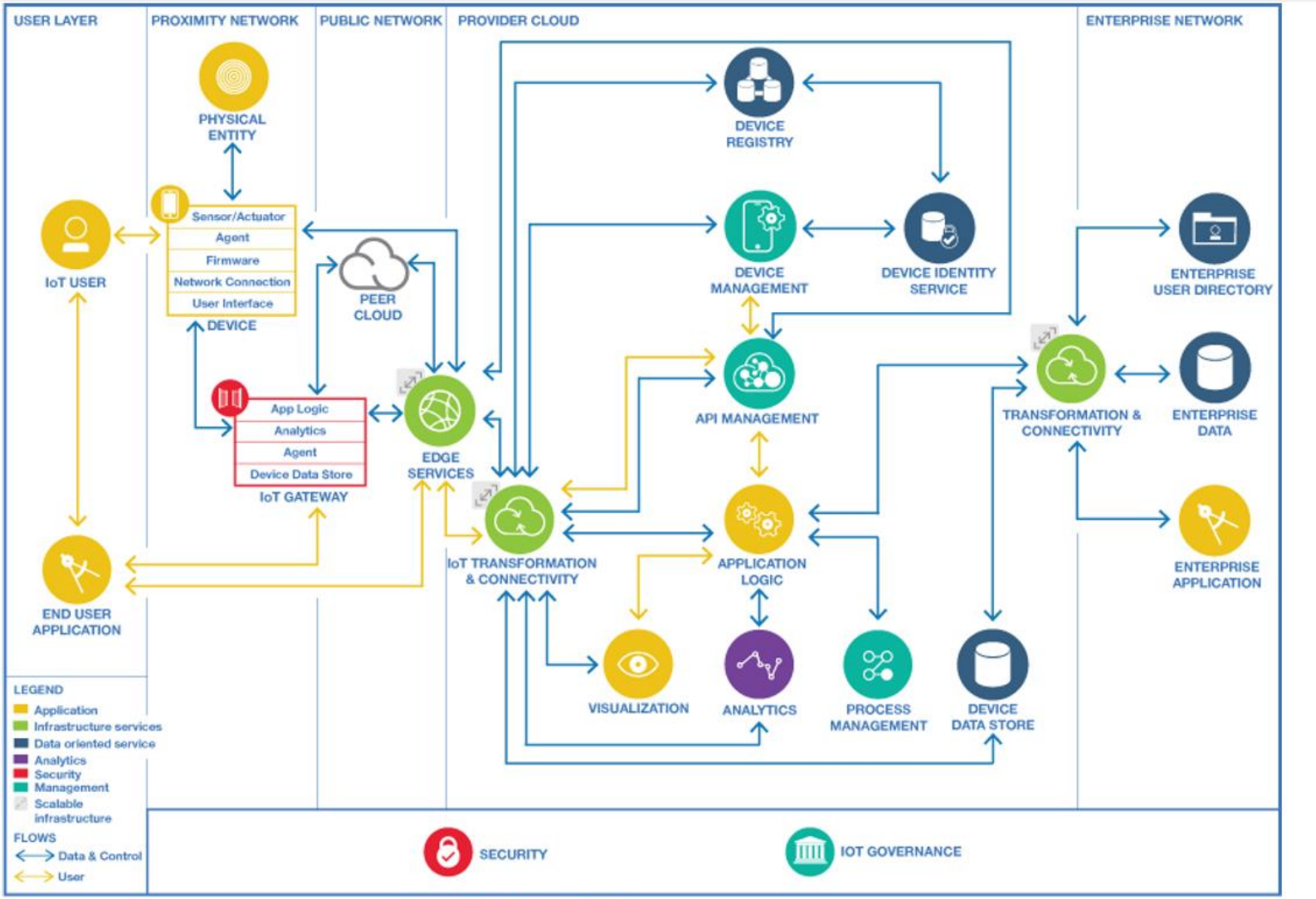
Systems and software engineering — Architecture description

ISO/IEC/IEEE 42010 Concepts

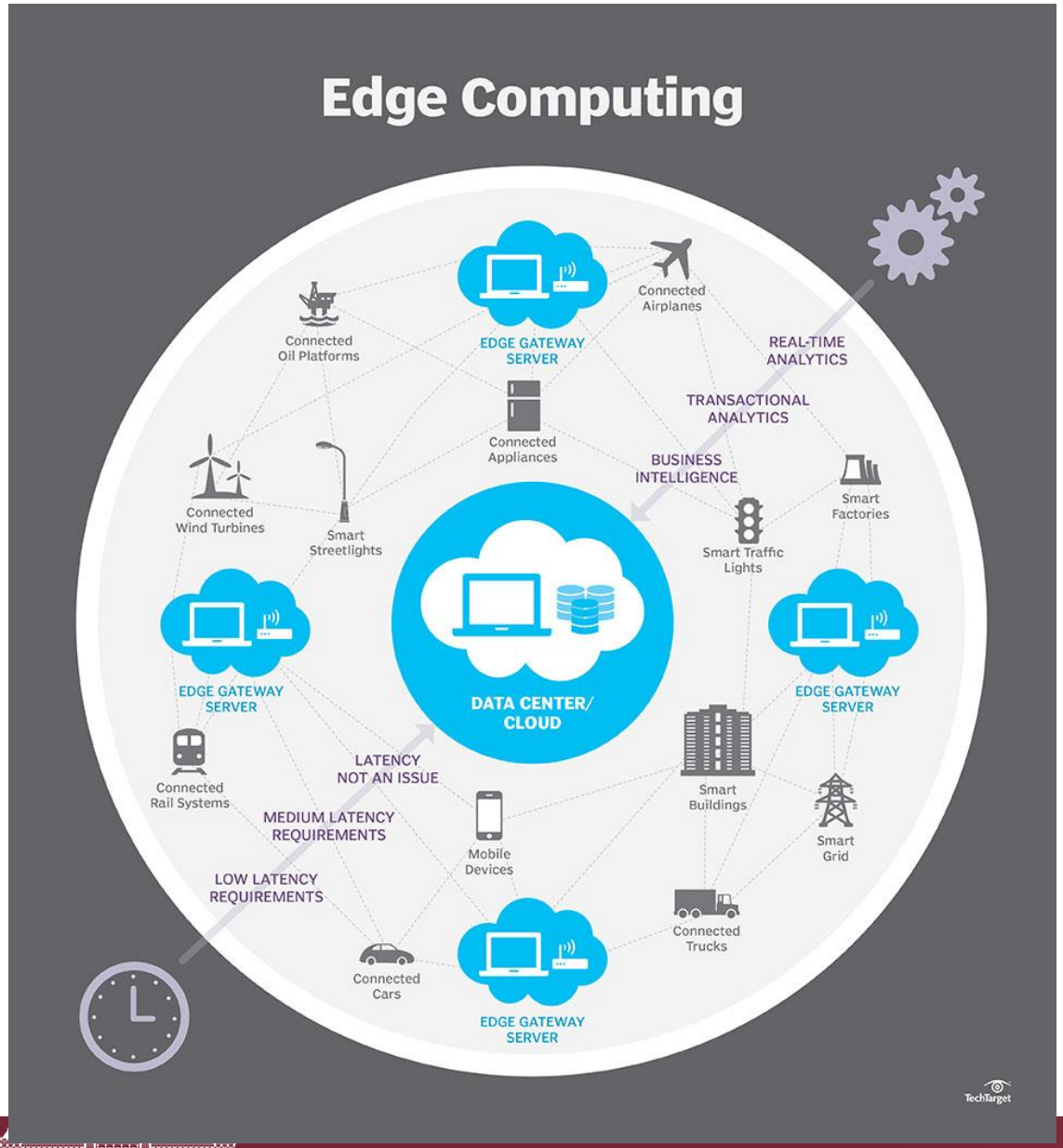


Cloud Customer Architecture for IoT

- http://www.cloud-council.org/deliverables/CSCC-Cloud-Customer-Architecture-for-IoT.pdf

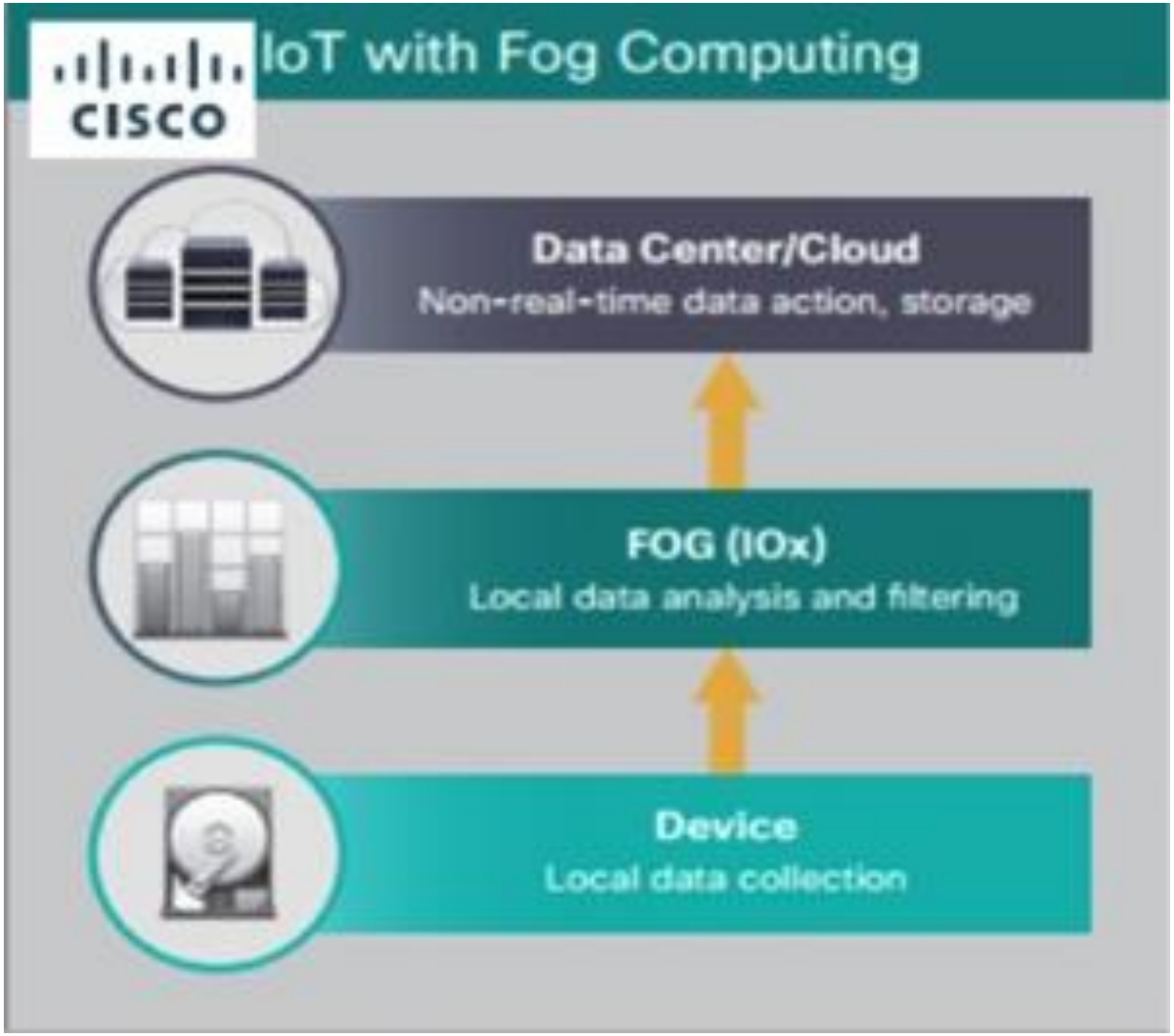


Edge computing

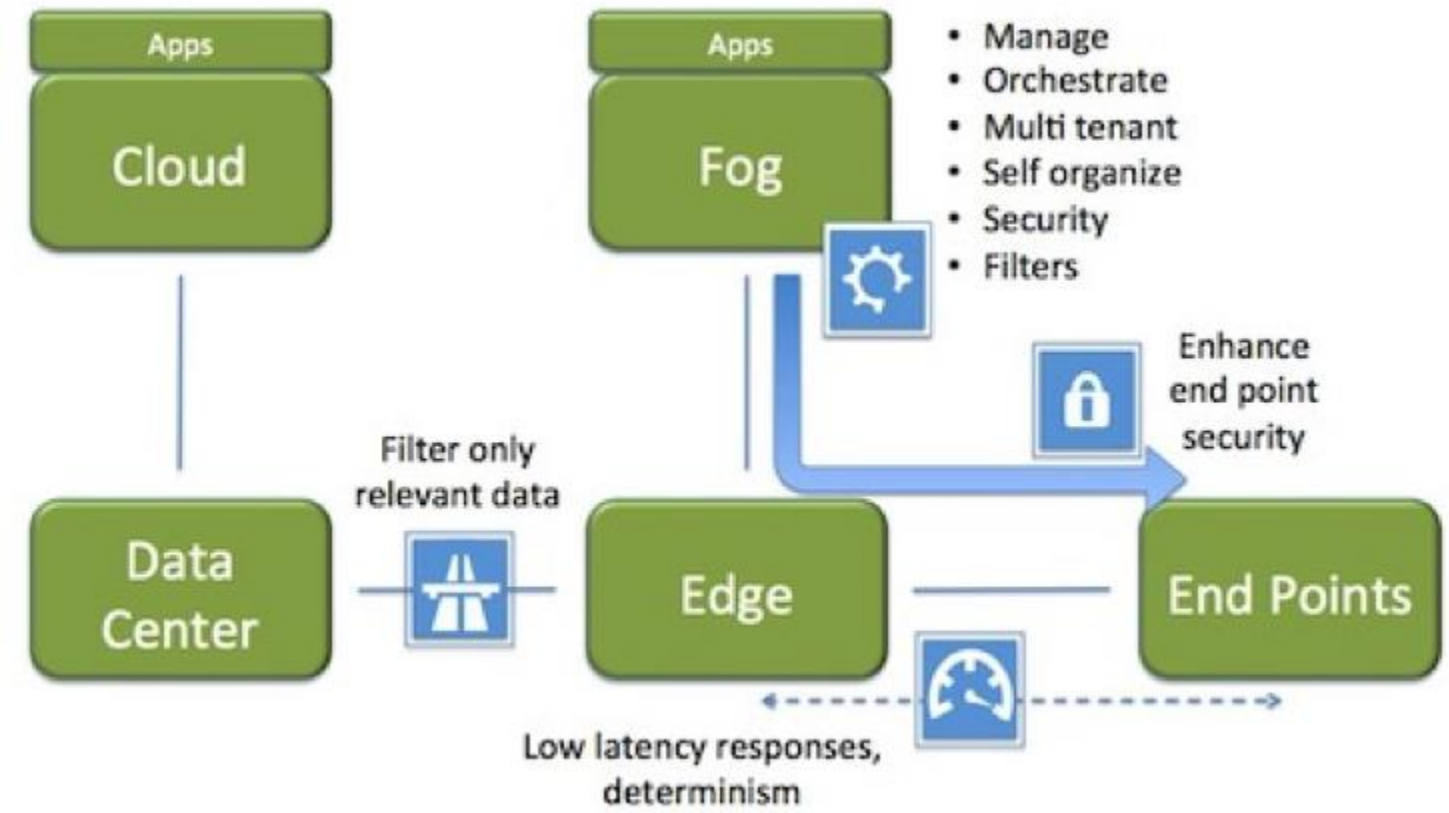


- Techtarget: Edge computing [definition]

Fog computing



Edge and fog computing



Objective

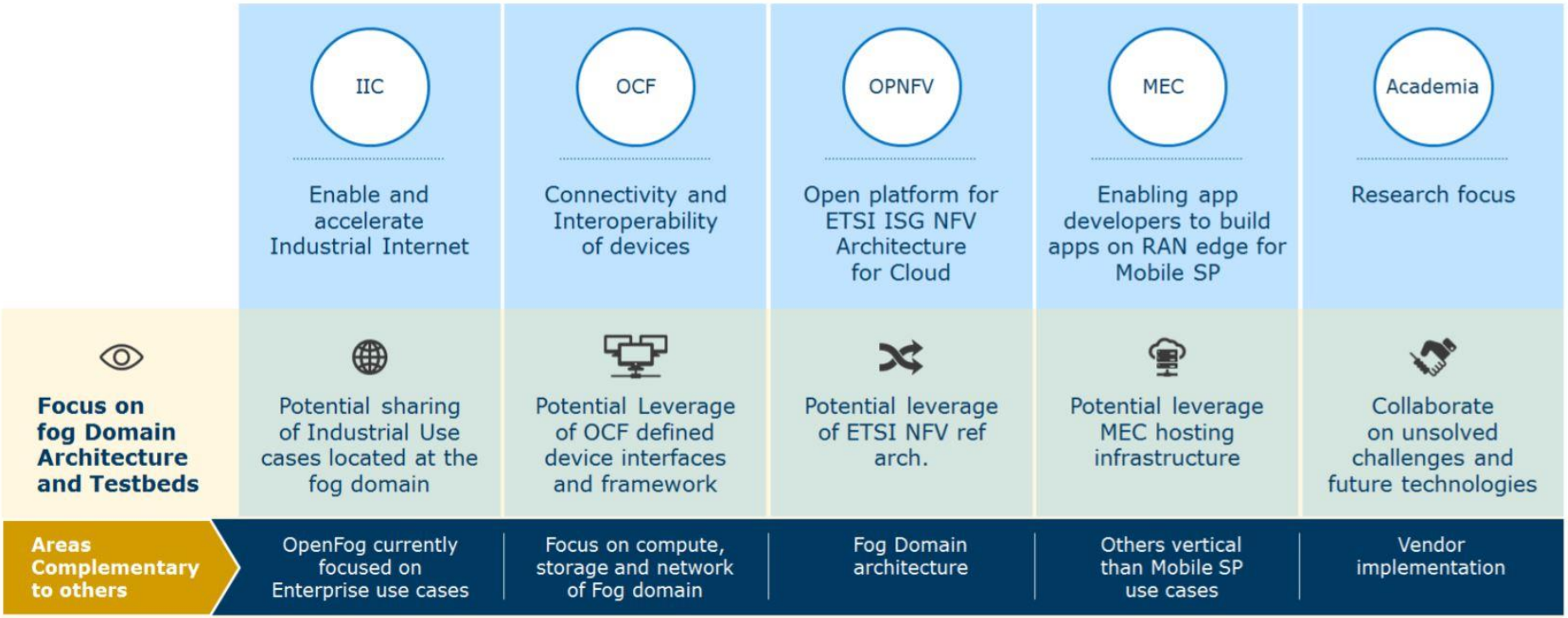
- Cloud cannot cope with all data
- 2016: 1.1 zettabytes (or 89 exabytes) per year
- 2020: 2.3 zettabytes (or 1[illegible] exabytes) per year
  - Internet of Things (IoT),
  - Artificial Intelligence…
- **Fog computing:**
  A horizontal, system-level architecture
  - distributes computing, storage, control and networking
  - closer to the users along a cloud-to-thing continuum.

a unit of information equal to one sextillion (10^{21}) or, strictly, 2^{70} bytes.

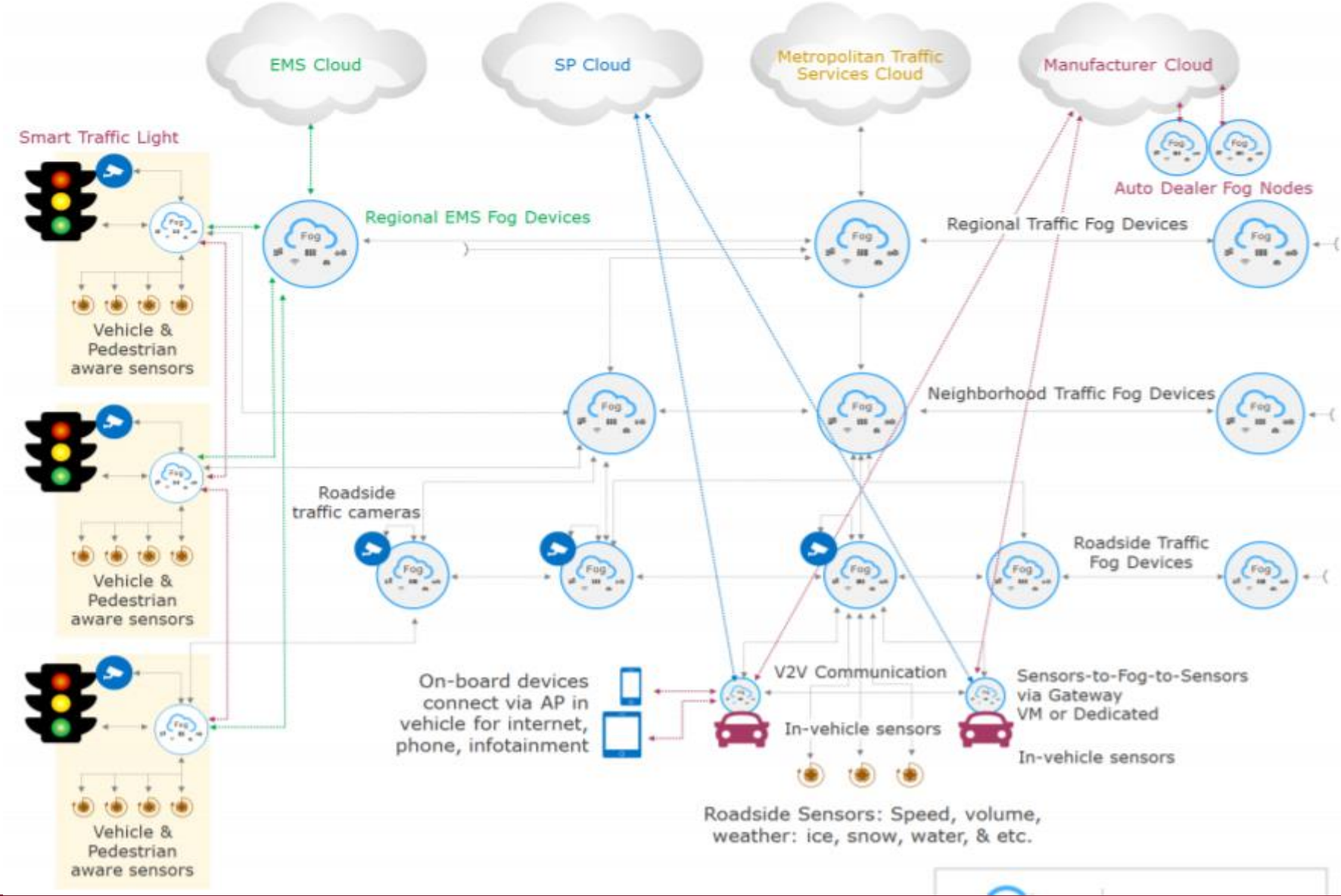
Fog computing vs other architectures

- Extension of the traditional cloud-based computing model
  - implementations in multiple layers of a network's topology.
- Benefits of cloud preserved
  - Containerization, virtualization, orchestration, efficiency.
- Pillars:
  - security,
  - scalability,
  - Openness,
  - Autonomy,
  - RAS (reliability, availability and serviceability),
  - Agility,
  - hierarchy,
  - programmability. In
- Fog computing <> edge computing
  - Fog works with the cloud, <> edge :exclusion of cloud. F
  - Fog hierarchical, <> edge : a small number of layers. I
  - Fog also addresses networking, storage, control and acceleration.

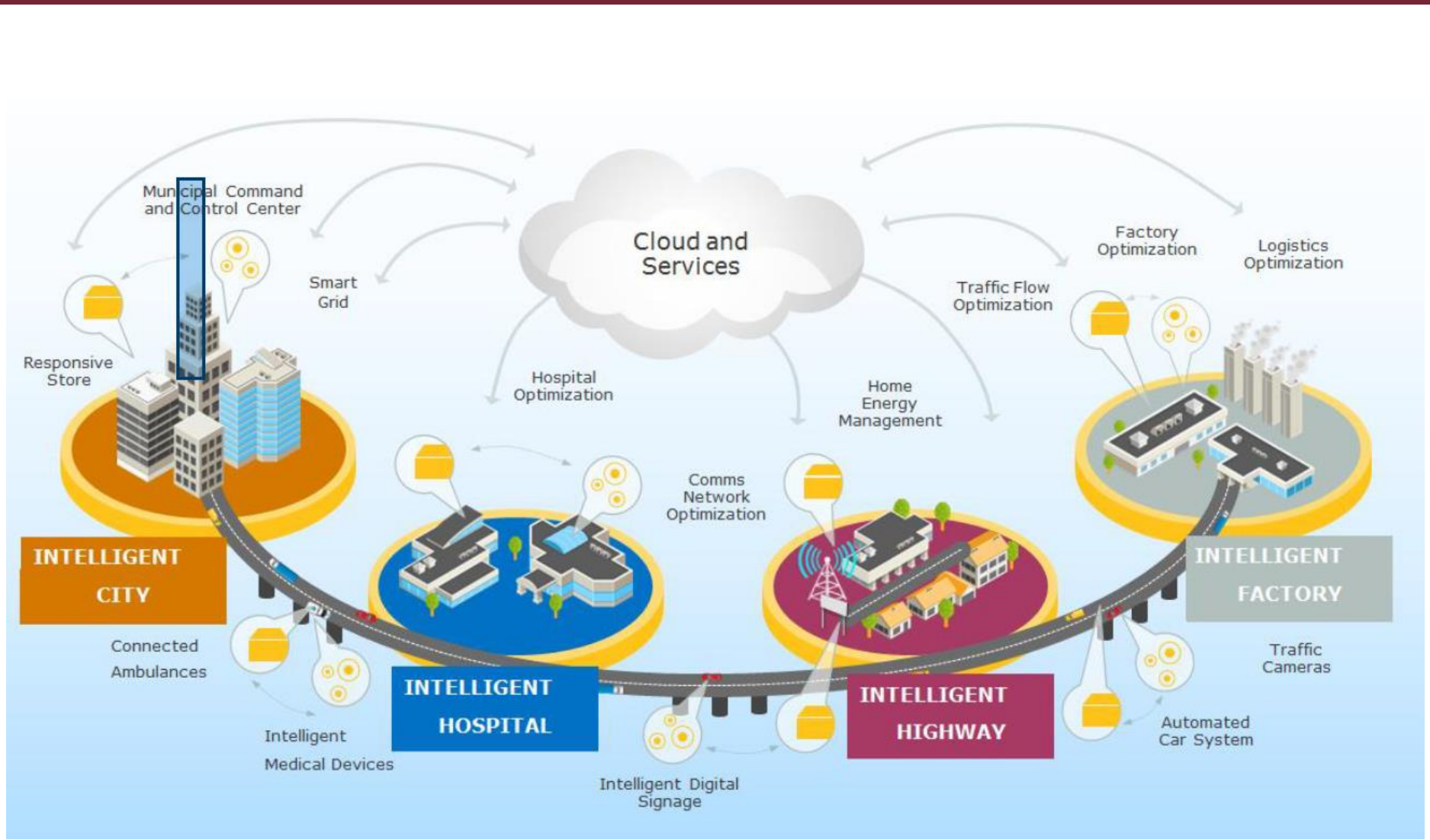
OpenFog Consortium and Other Consortia



Smart Car and Traffic Control System

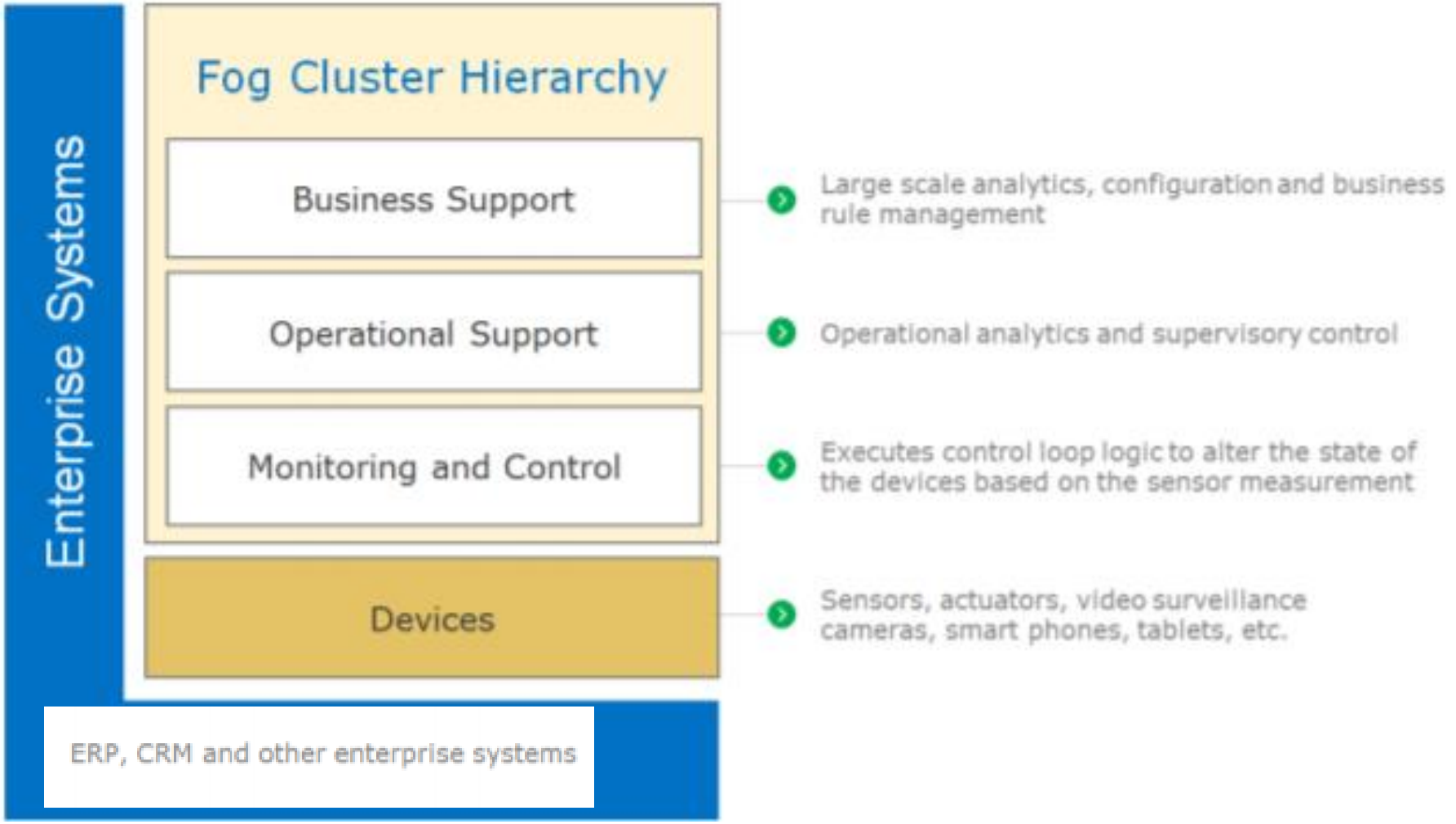


Opportunities for Smart Cities

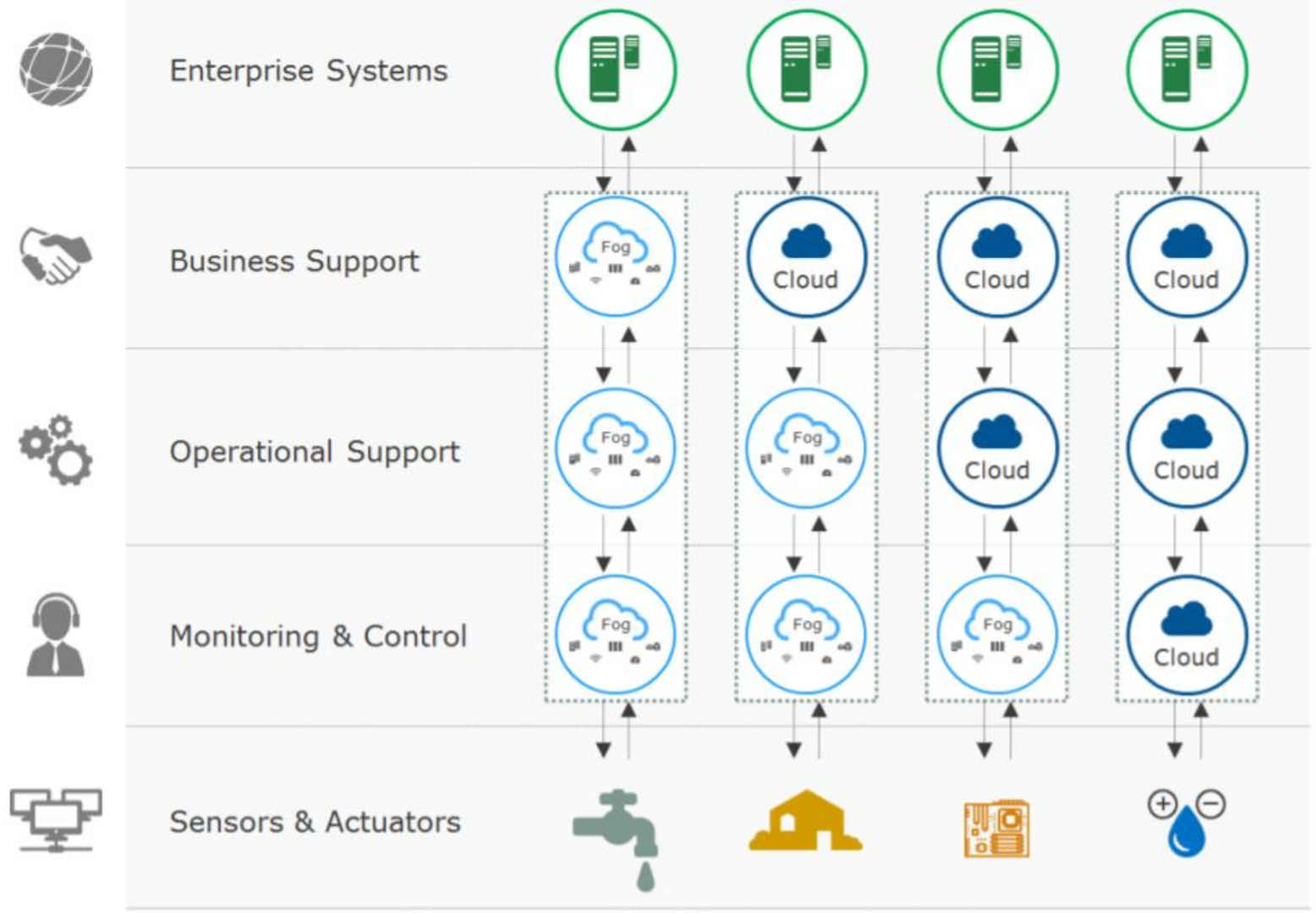


Pillars of OpenFog

Layered Architecture View of an IoT System



IoT System Deployment Models



Cloud-independent Deployment

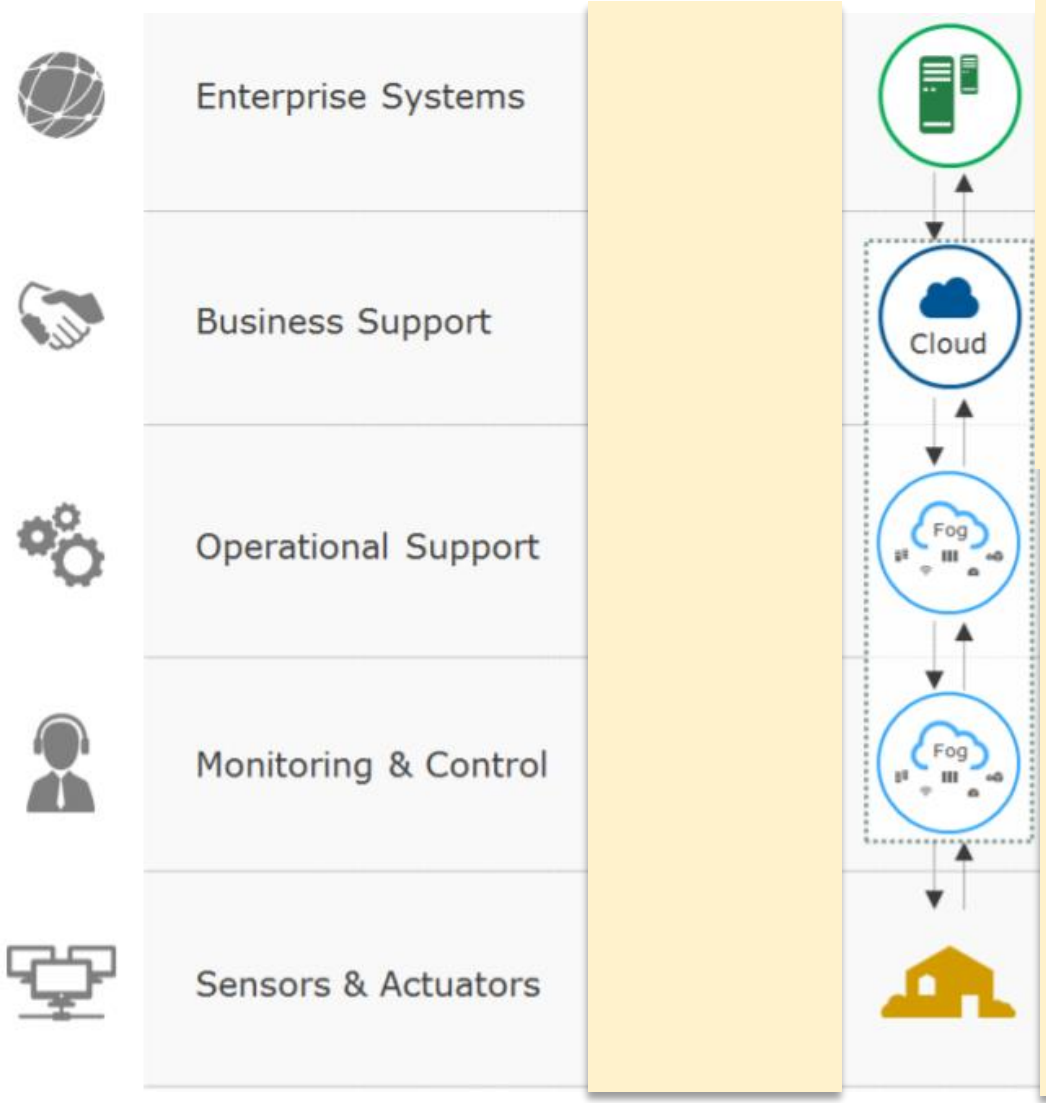
No use of cloud :

- low event to reaction time window,
- regulatory compliance,
- military grade security
- privacy,
- unavailability of a cloud

Examples:

- combat systems,
- drone operations,
- some healthcare systems

Cloud for decision preparation



Event-to-action time window hours …days …months.

- Operation-centric processing fog

Use cases:

- Building management,
- Solar panel monitoring,
- Retail

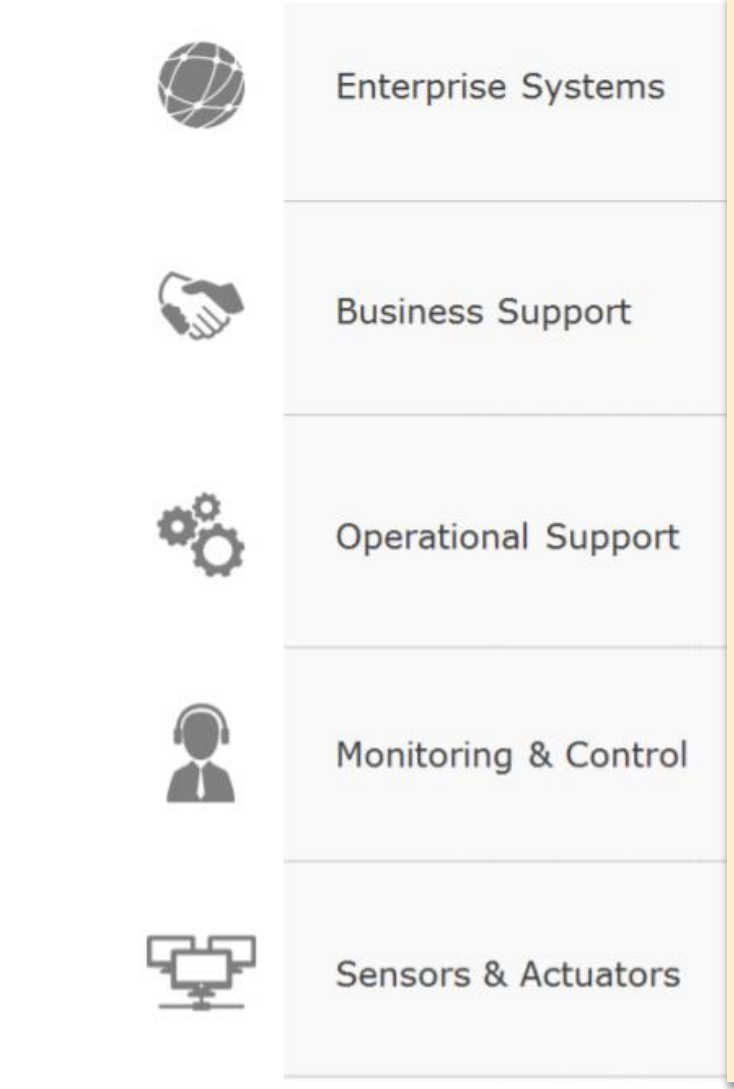
Cloud-fog separation by timeliness

- **Local fog:** time-sensitive computation
- **Cloud:** balance of operational and business-related processing

Use cases :

- UPS device monitoring,
- Mobile network acceleration,
- Content delivery networks (CDNs) for Internet acceleration. .

Cloud-integrated devices

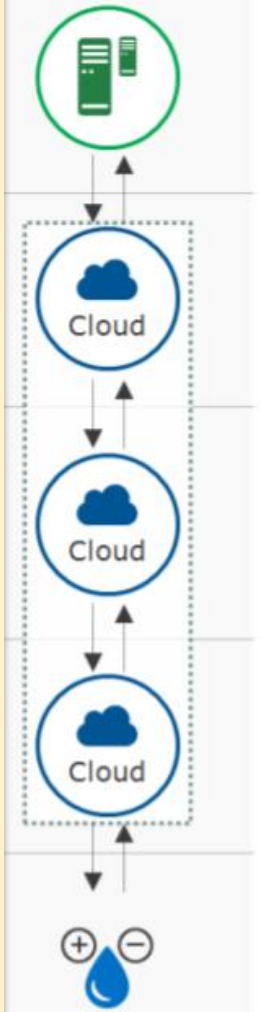


Cloud for the entire stack

- Constrained environments
- Fog nodes at the device layer

Use cases

- agriculture,
- connected cars,
- remote weather stations



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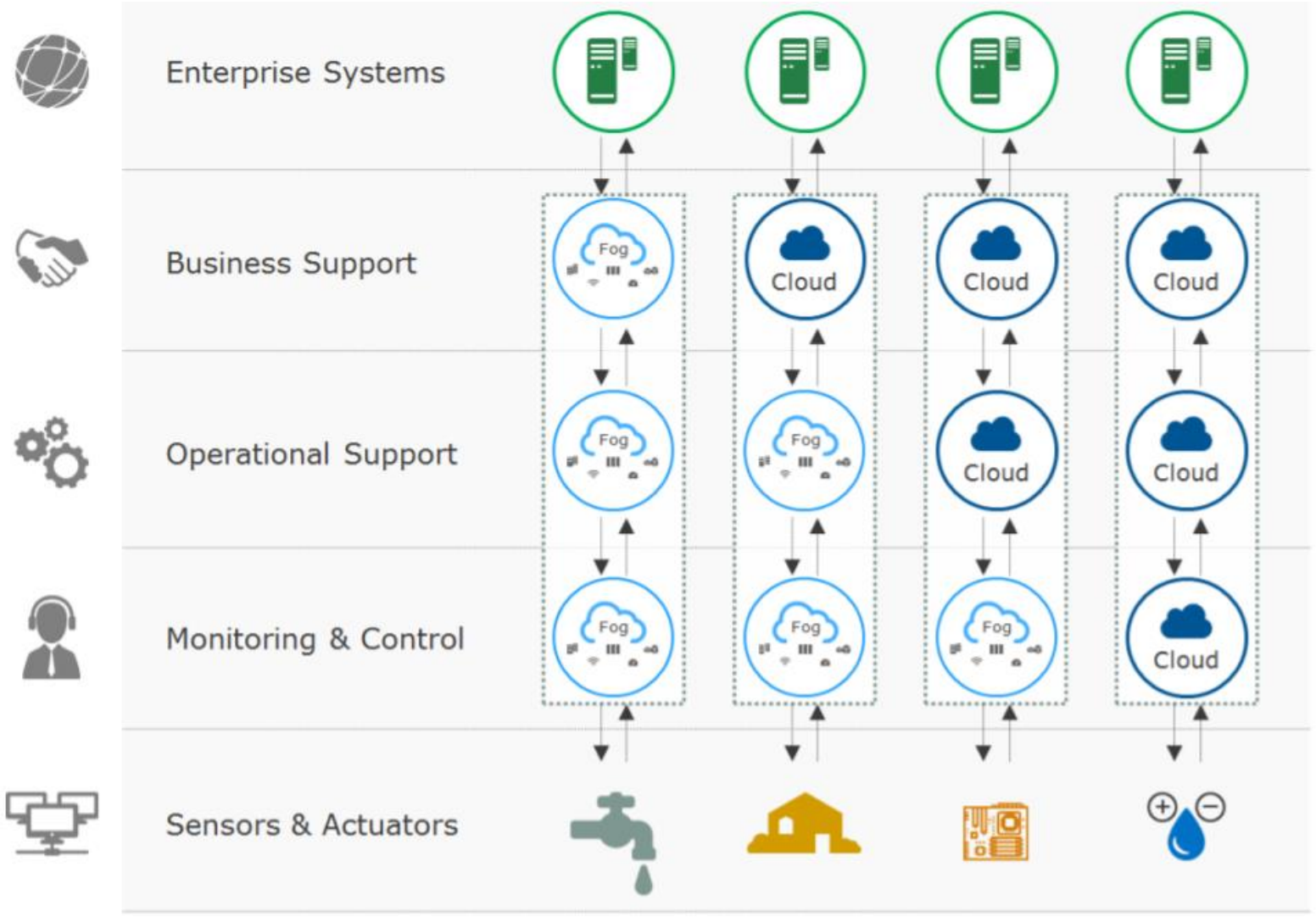
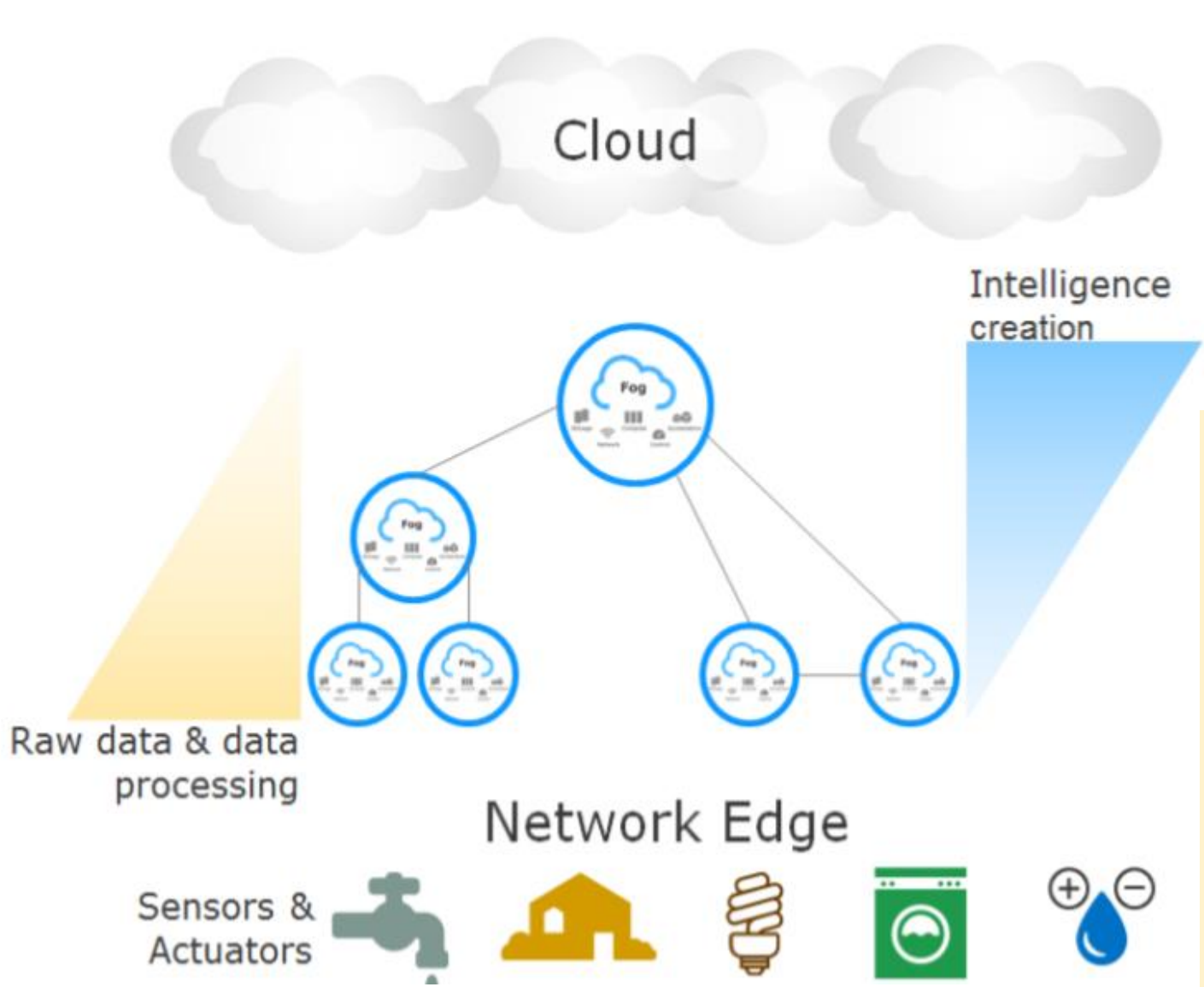


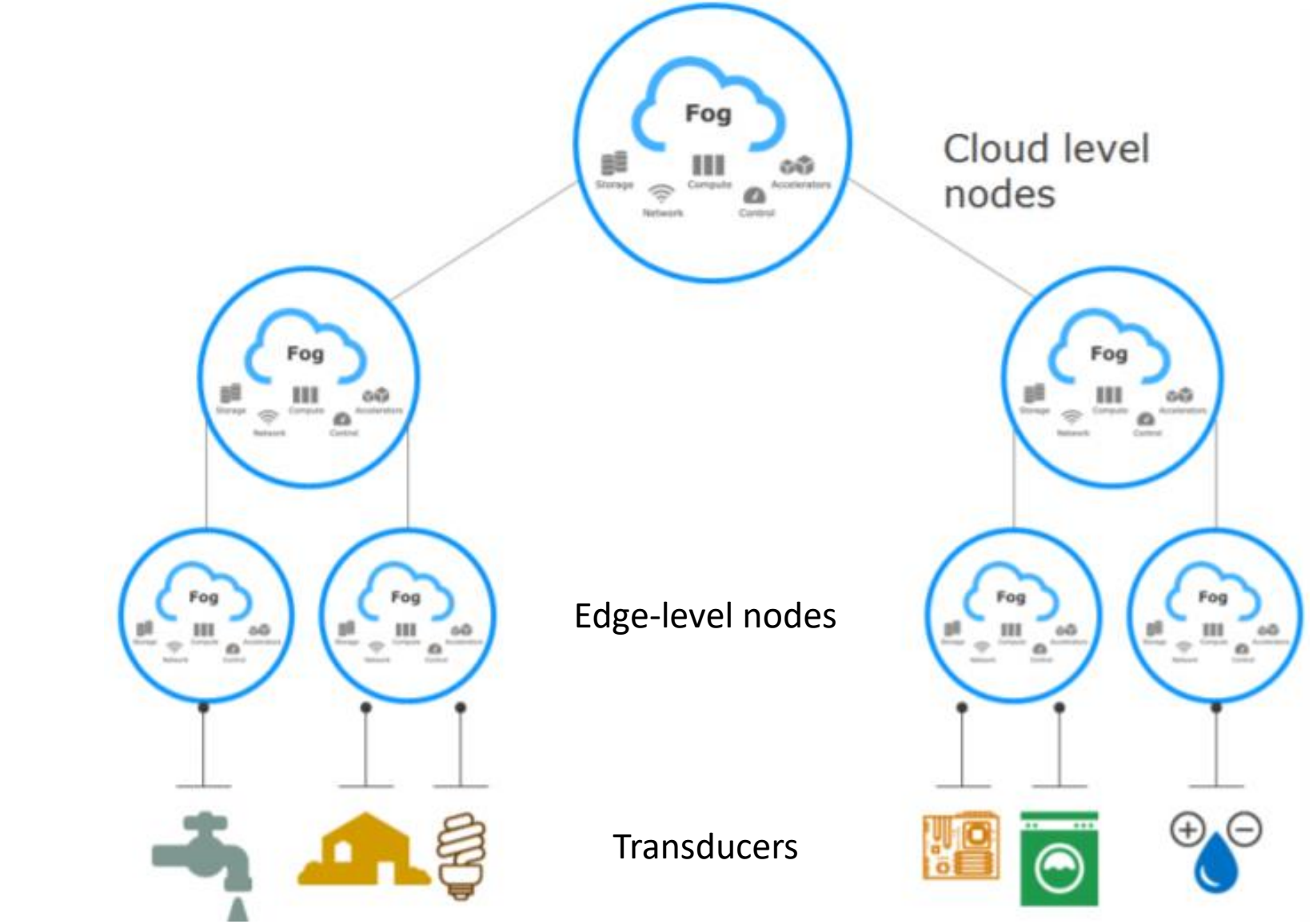
Intelligence from data

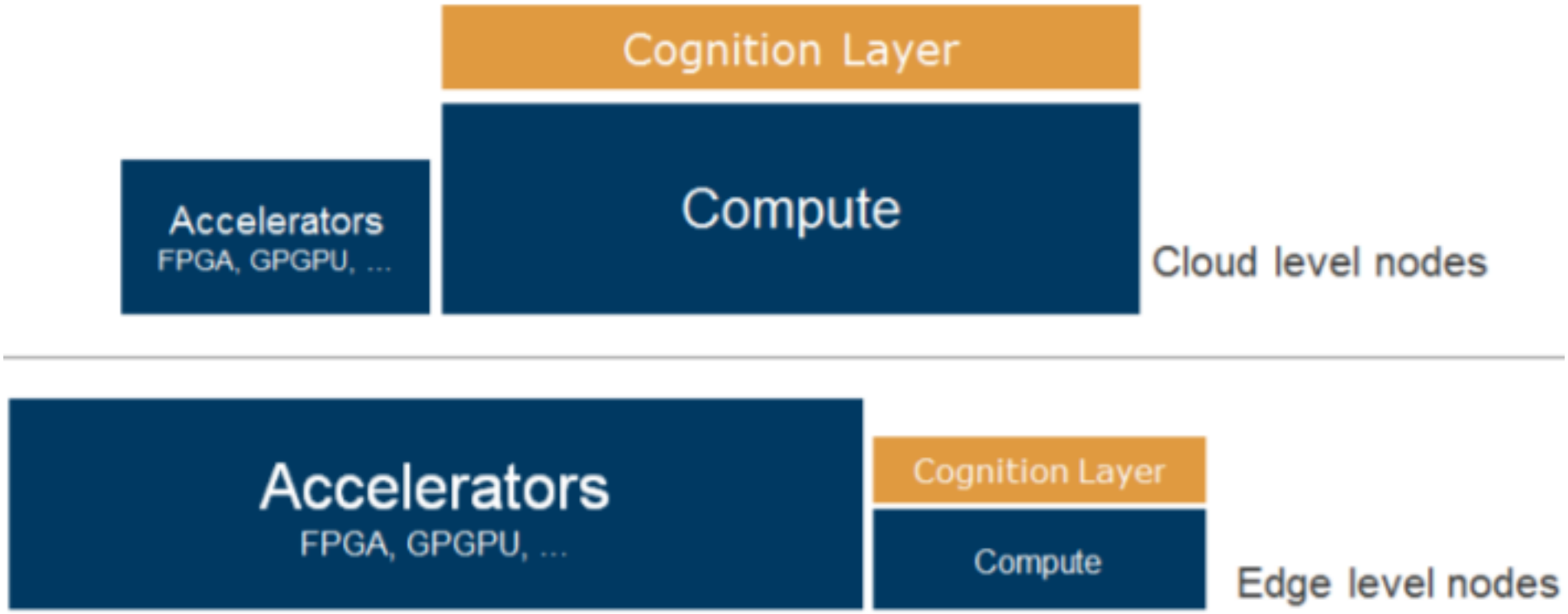


Number of tiers:
← requirements

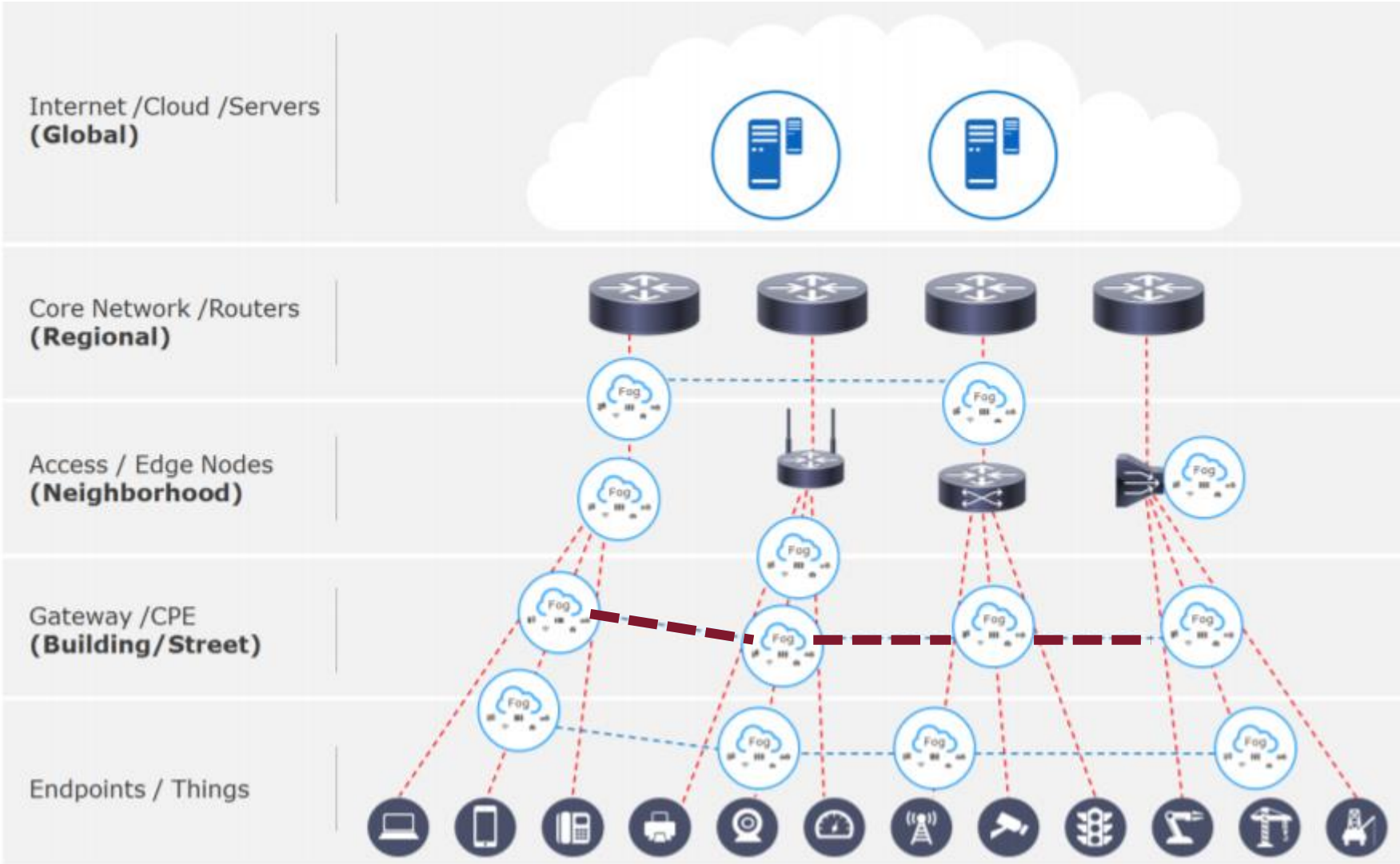
- Amount of work
- Number of sensors
- Capabilities of the nodes
- Latency
  - internode
  - Inter-transducer
- Reliability availability of nodes

Hierarchical deployment

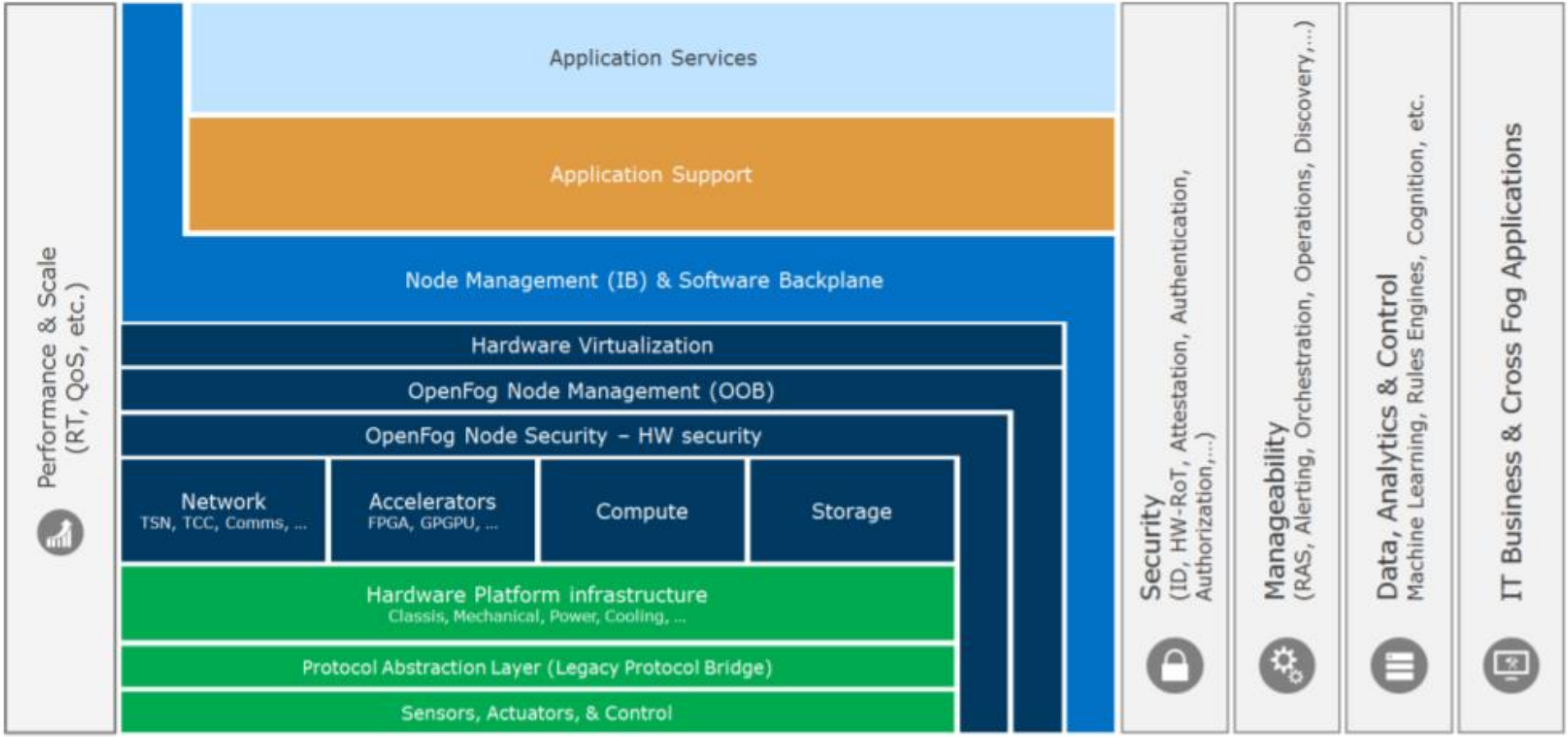



Cognition Layer
Accelerators
FPGA, GPGPU, ...
Compute
Cloud level nodes
Accelerators
FPGA, GPGPU, ...
Cognition Layer
Compute
Edge level nodes

Local communication

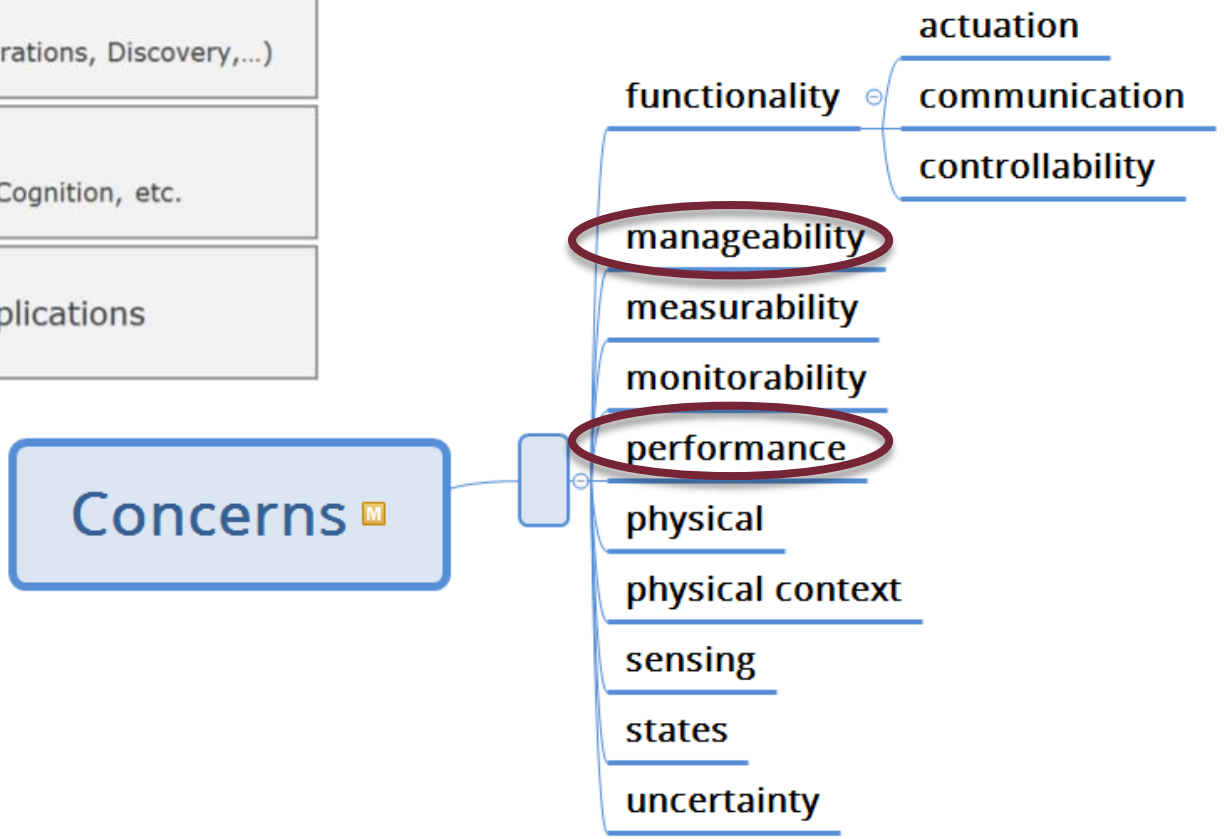


Architecture Description with Perspectives



OpenFog Architecture Perspectives

- Performance & Scale
  (RT, QoS, etc.)
- Security
  (ID, HW-RoT, Attestation, Authentication, Authorization,…)
- Manageability
  (RAS, Alerting, Orchestration, Operations, Discovery,…)
- Data, Analytics & Control
  Machine Learning, Rules Engines, Cognition, etc.
- IT Business & Cross Fog Applications



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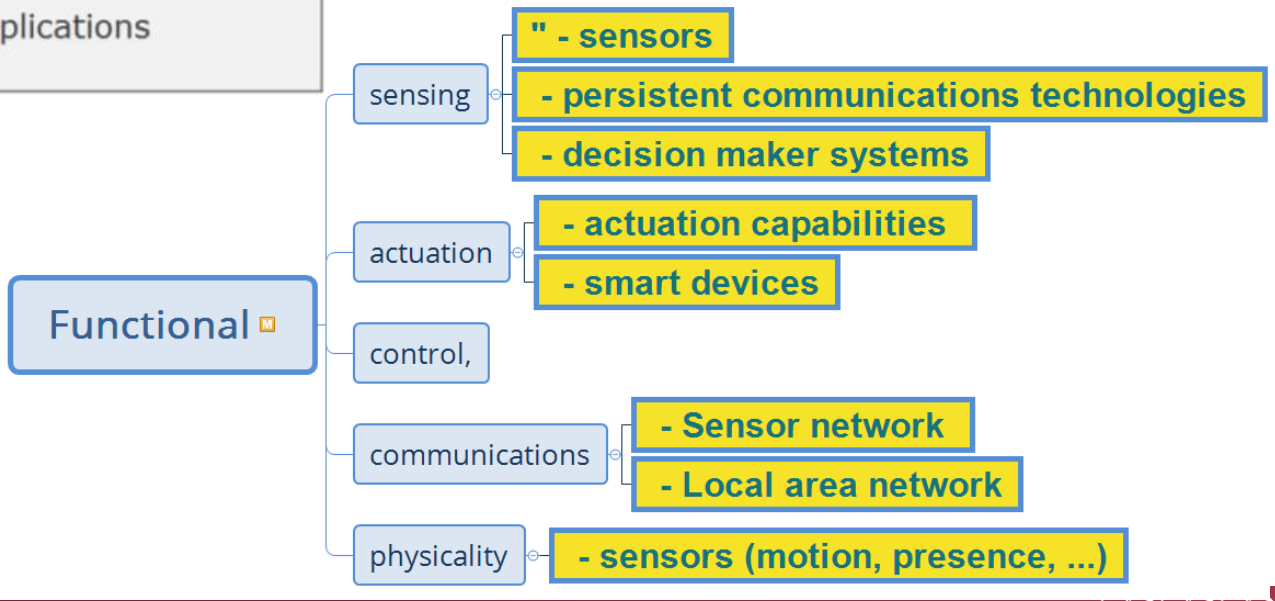

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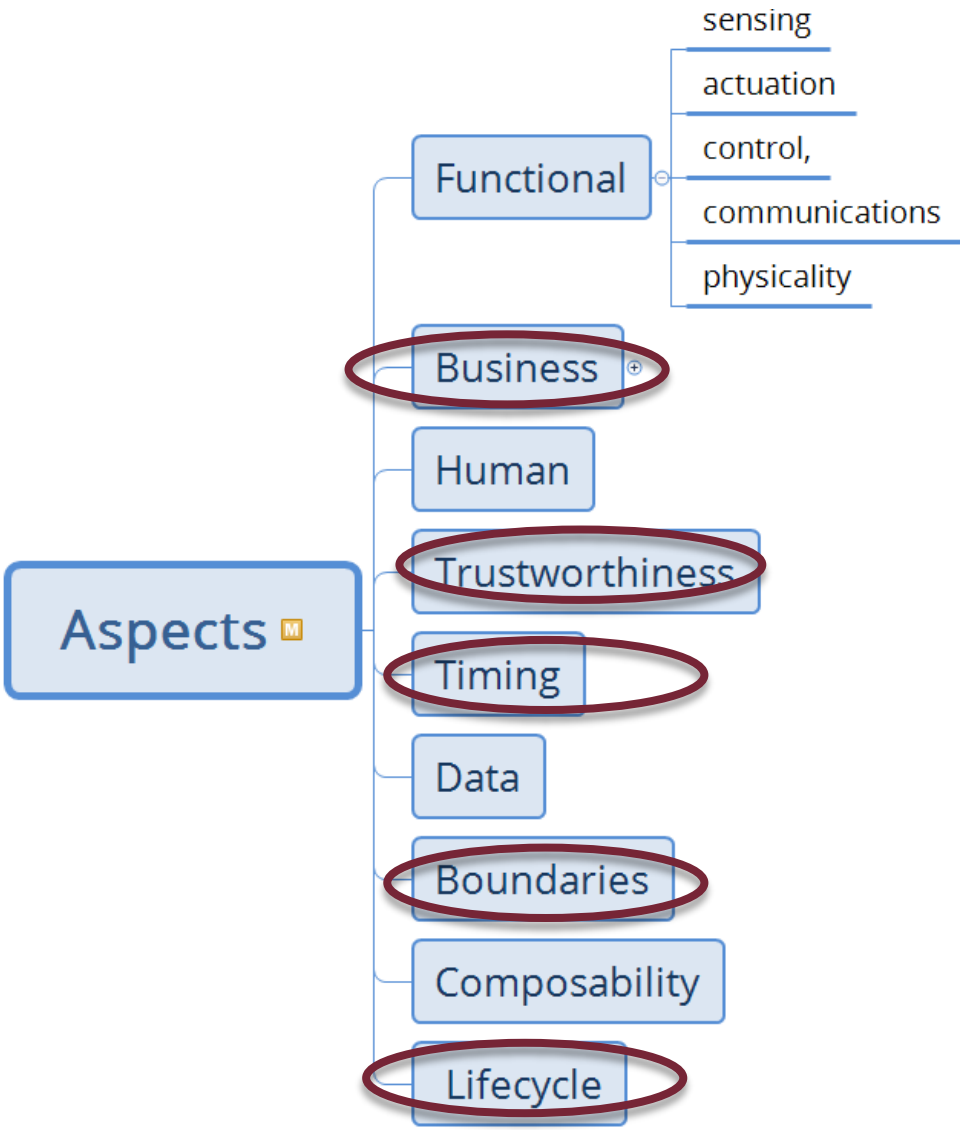
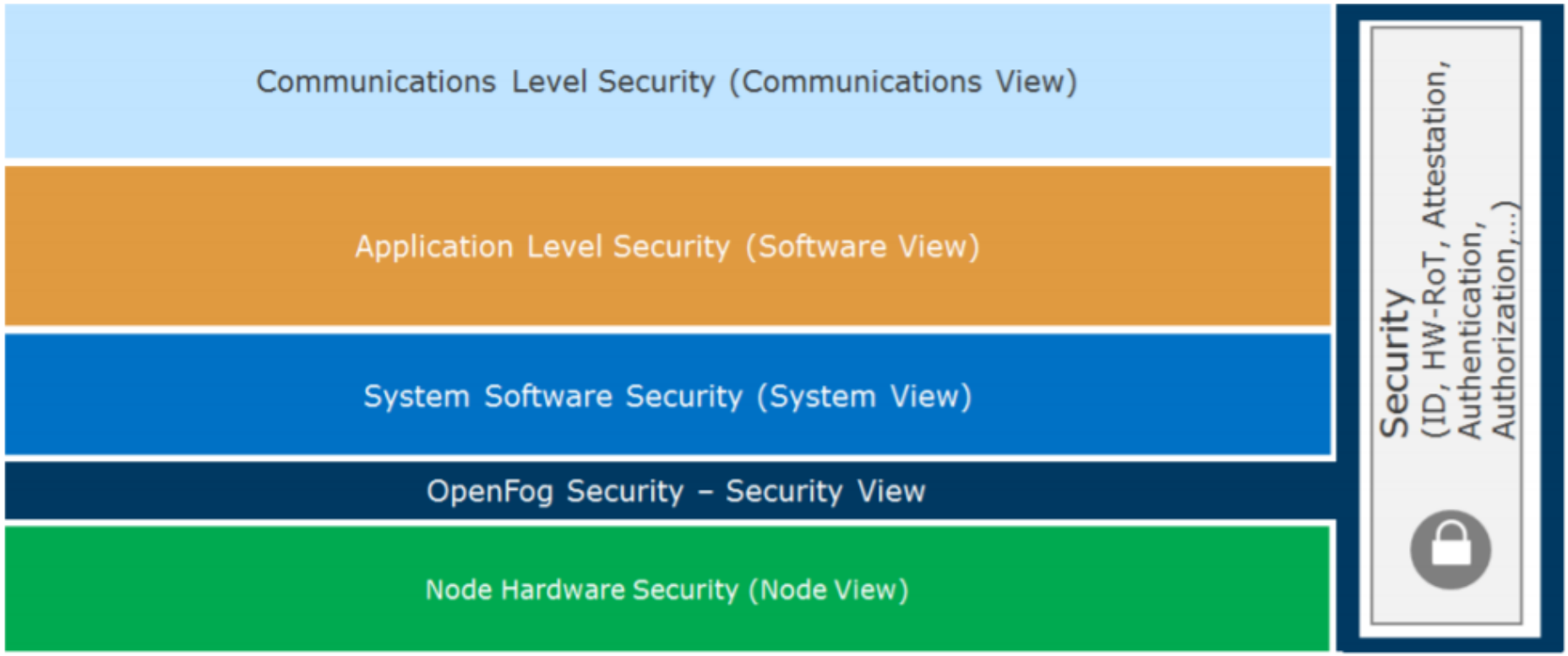


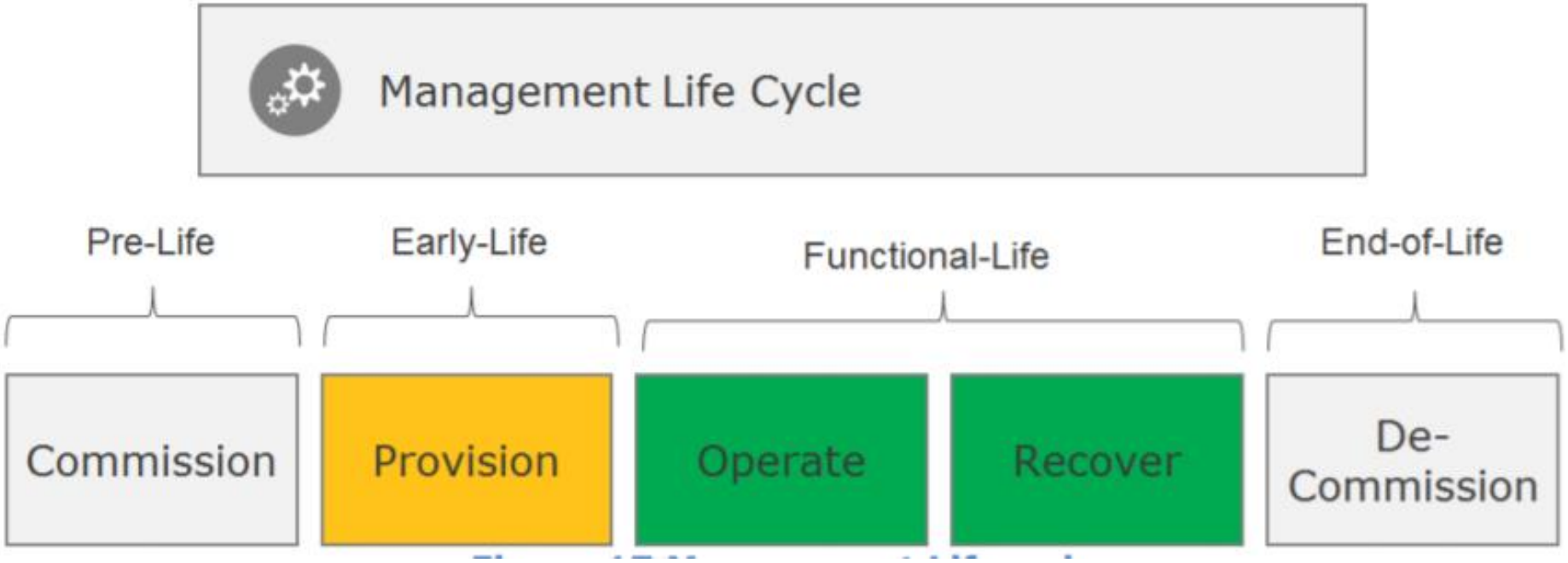
Security


Communications Level Security (Communications View)
Application Level Security (Software View)
System Software Security (System View)
OpenFog Security – Security View
Node Hardware Security (Node View)
Security
(ID, HW-RoT, Attestation, Authentication, Authorization,...)

Example Threats and Attacks

Threat Categories (Intents / Attack Venues)	Confidentiality Violation	Integrity Violation	Authentication Violation	Availability Violation	Privacy Violation
	Leaking information through overt/covert channels	Modifying data/code without proper authorization	Masquerading one entity as another entity	Rendering resources unreachable /unavailable	Leaking sensitive information of an entity (incl. identity)
Insider Attacks	Data Leaks	Data Alteration	Identity/Password / Key Leaks	Equipment Sabotage	Data/Identity Leaks
Hardware Attacks	Hardware Trojans, Side Channel Attacks	Hardware Trojans	Hardware Trojans	Radio Jamming, Bandwidth Exhaustion	Hardware Trojans, Side Channel Attacks
Software Attacks	Malware	Malware	Malware	DoS/DDoS, Resource Depletion	Malware, Social Network Analyses
Network Based Attacks	Eavesdropping	Message / Transaction Replay	Spoofing, Man-in-Middle Attacks	DoS/DDoS, Subnet Flooding	Traffic Pattern Analyses

Management Lifecycle



Business Intelligence

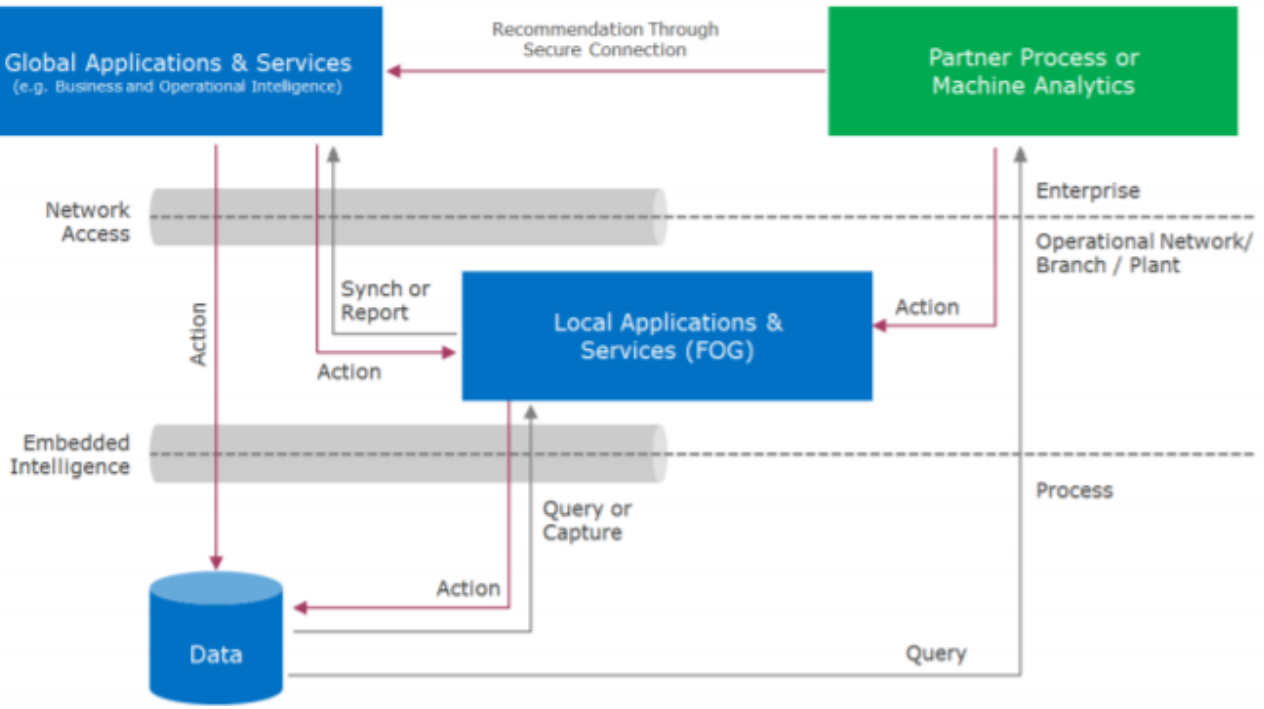
Global Application and Services:
Cloud-Based Business Intelligence, Global Operational Efficiencies, Market Conditions Affecting production, etc.

Secure Access To Network and Data:
Controlled Access to Data Granted to Enterprise Application and to Partners/ Suppliers

Local Services and Applications:
Analyze Operations, Request More Data Based on Thresholds, and Adjust Operations. Report & Dashboards

Network-Embedded Intelligence:
"process" Data is Reported to Local Services or Captures by the Network (e.g. Deep Packet Inspection - DPI)

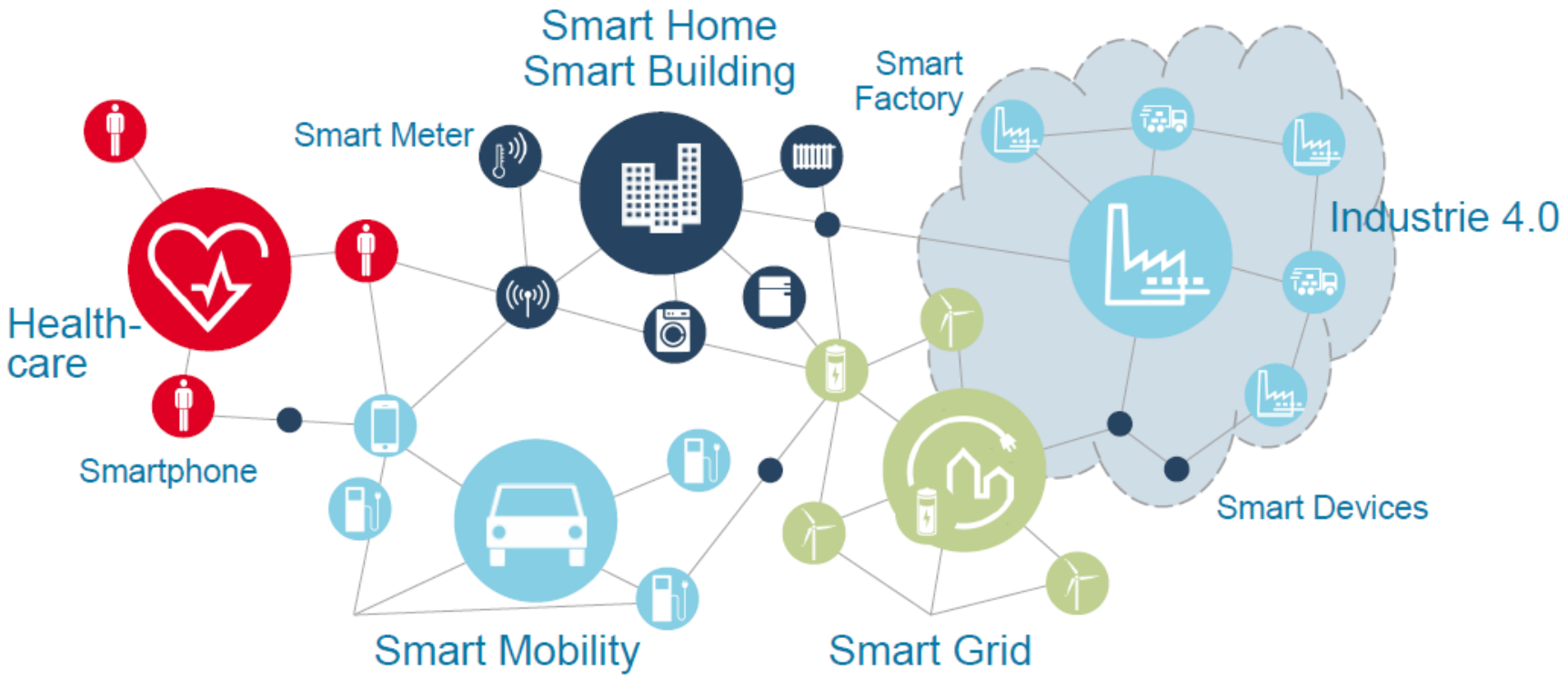
Data Generated from Process:
Status Logs, Temperature, Pressure, Levels, Yield, Energy Consumption, etc.



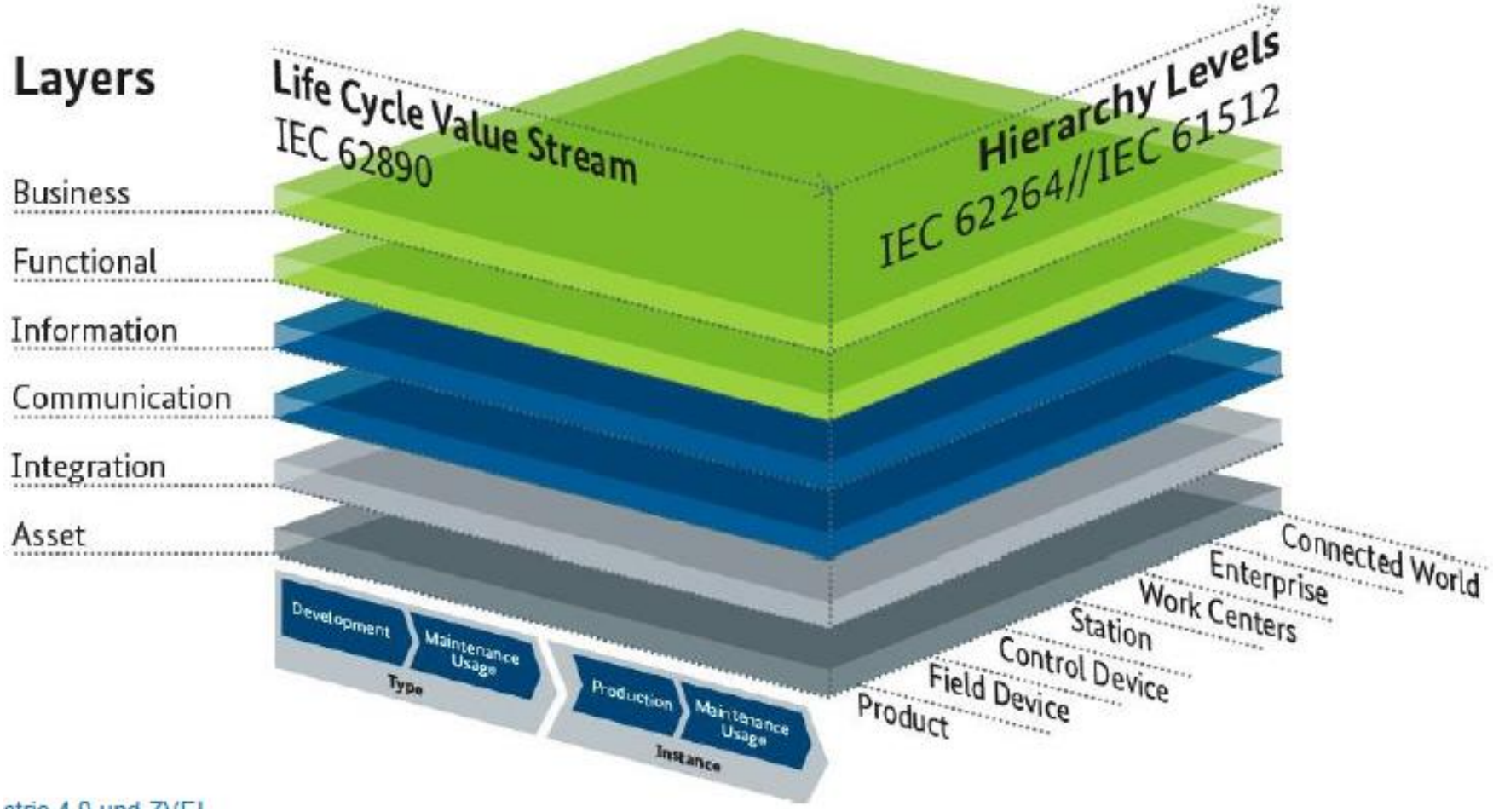
THE CHANGING WORLD

Evolving need: flexibility to match evolving demands

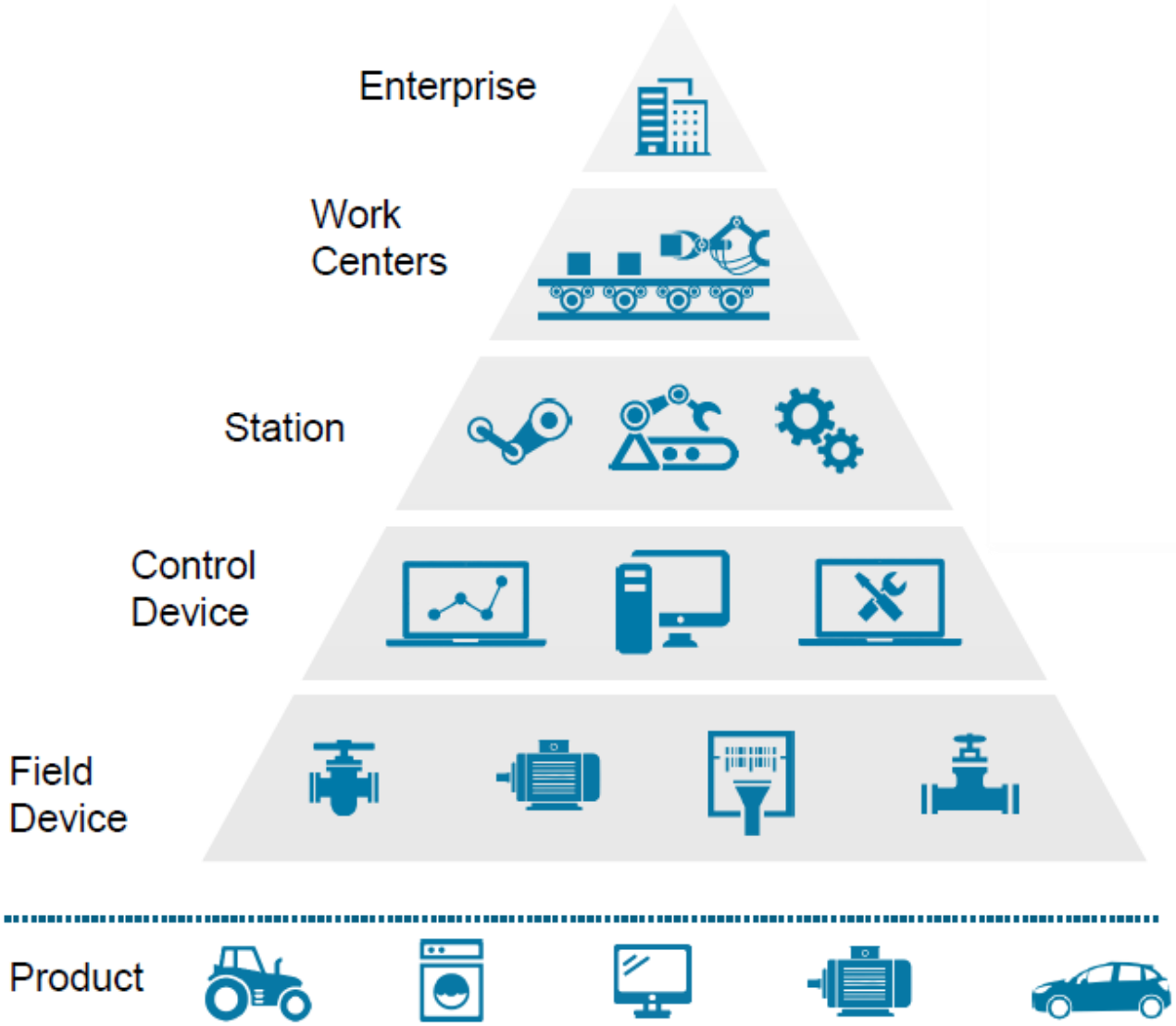
Industry 4.0 vision



RAMI 4.0


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

Industry 3.0


Enterprise
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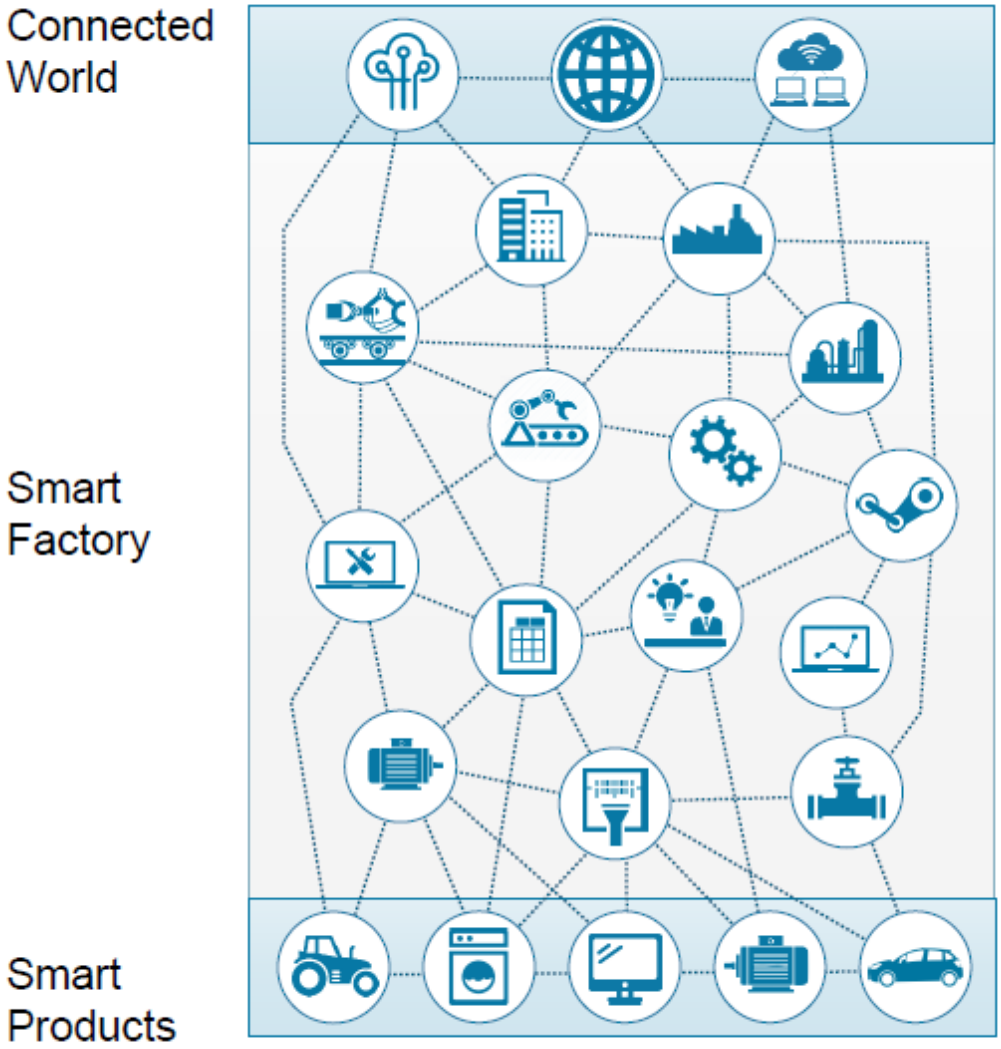
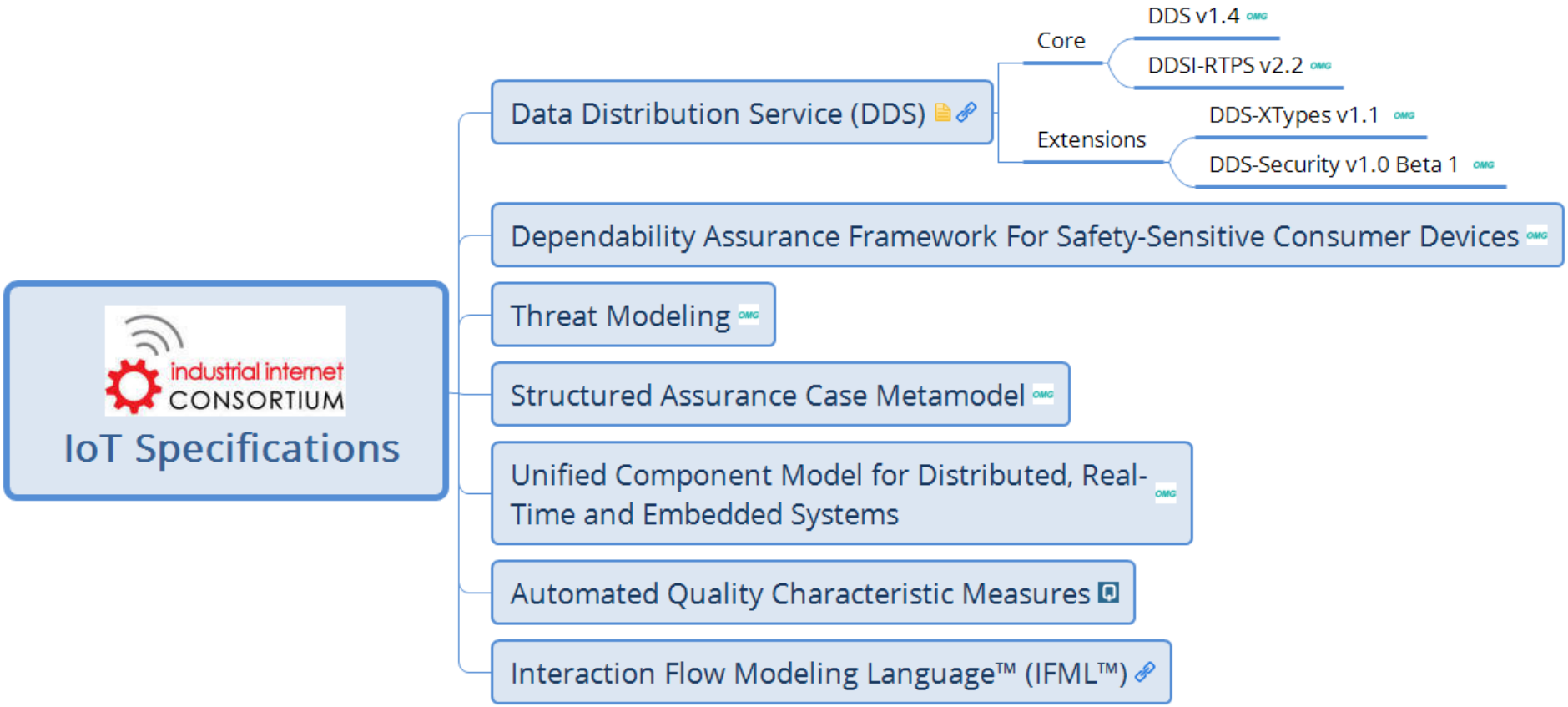
Industry 4.0



VIRTUAL ARCHITECTURES

Need for simple, on-demand configurable systems

“Overlay architectures”



FOUNDING & CONTRIBUTING MEMBERS

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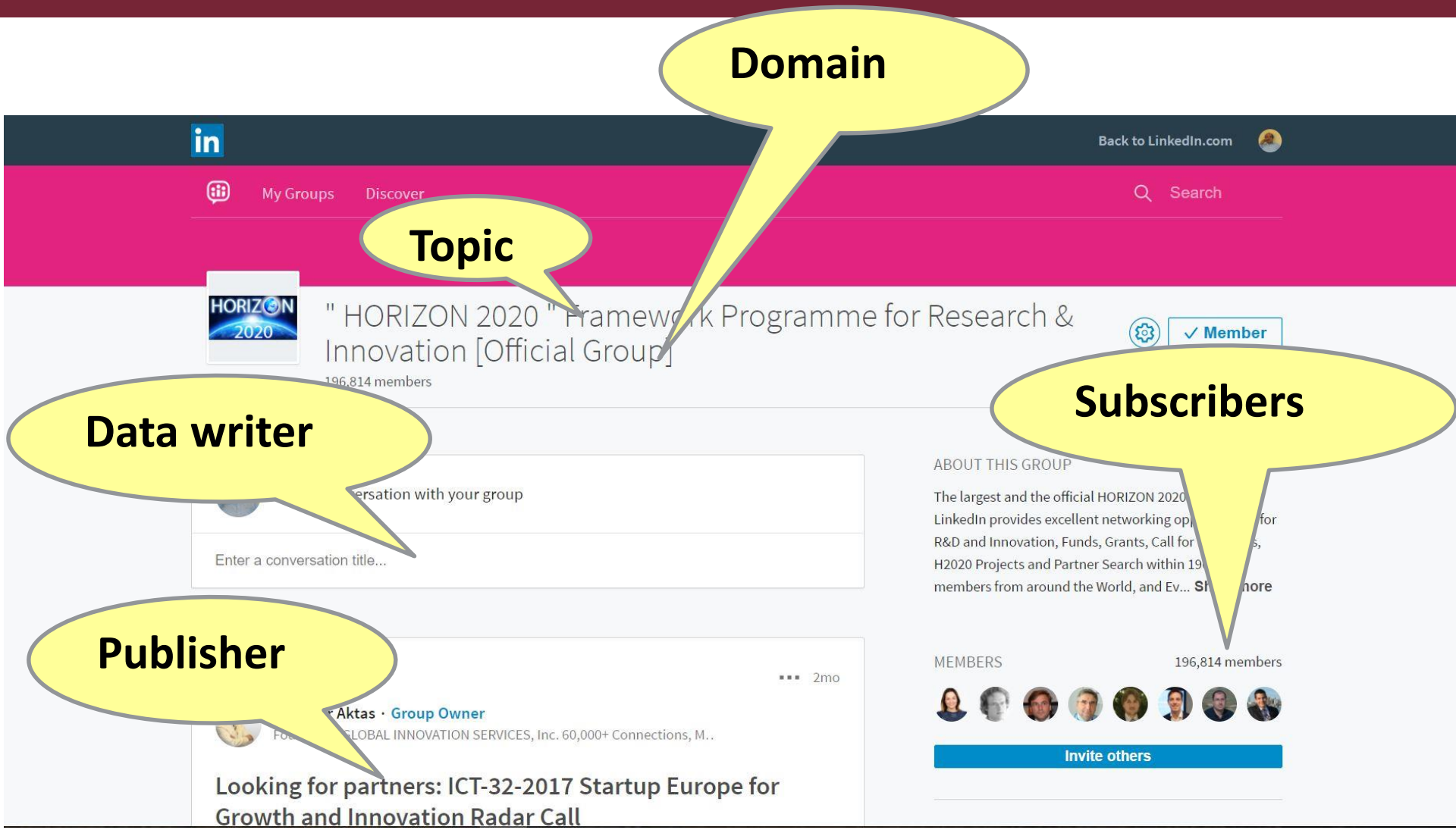
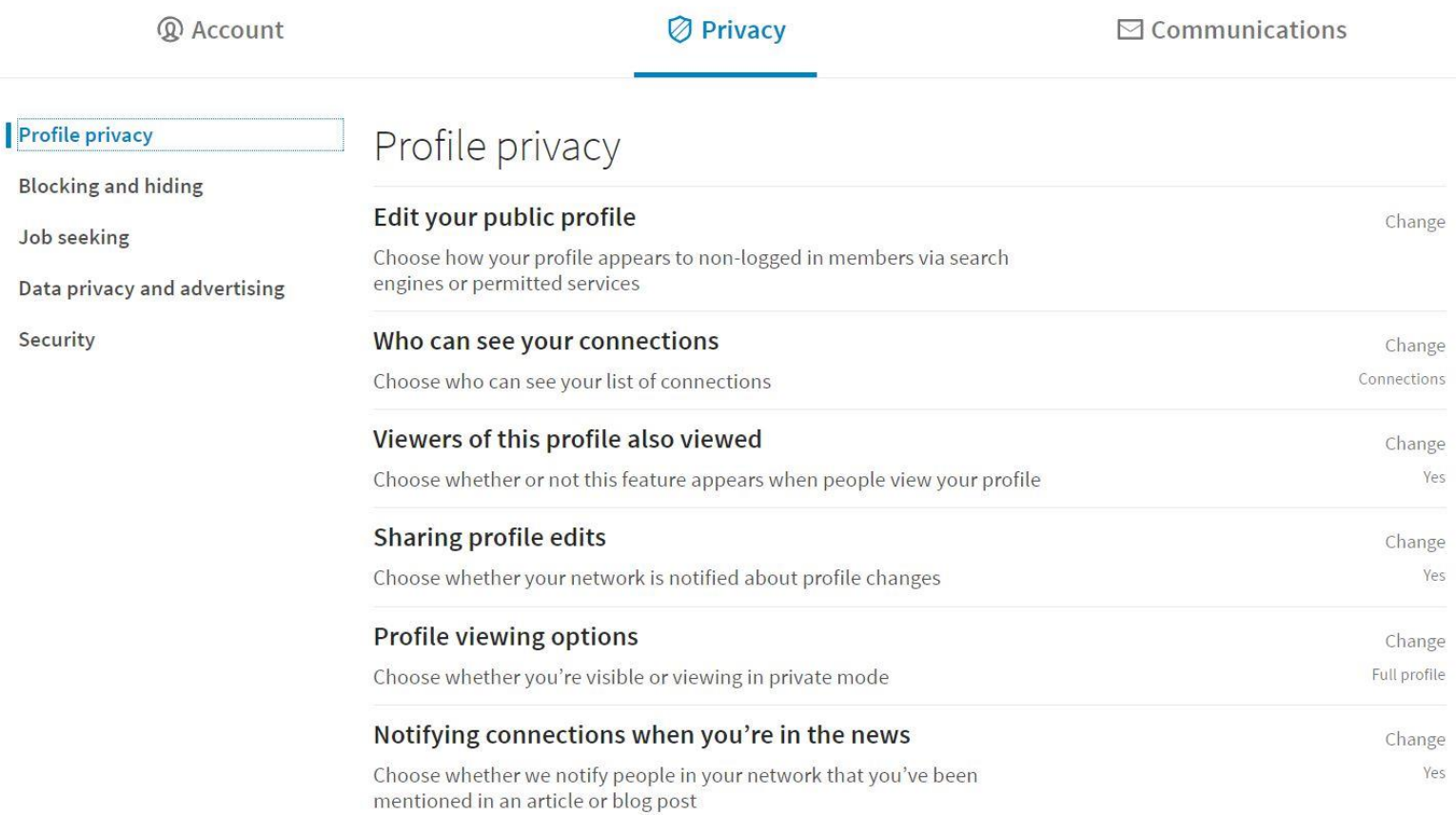


Control layer



OMG DDS Core notions