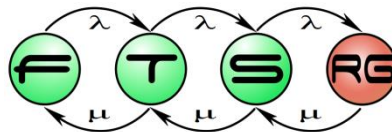


OpenFog Reference Architecture for Fog Computing

<http://www.openfogconsortium.org/>

February 2017

Budapest University of Technology and Economics
Fault Tolerant Systems Research Group

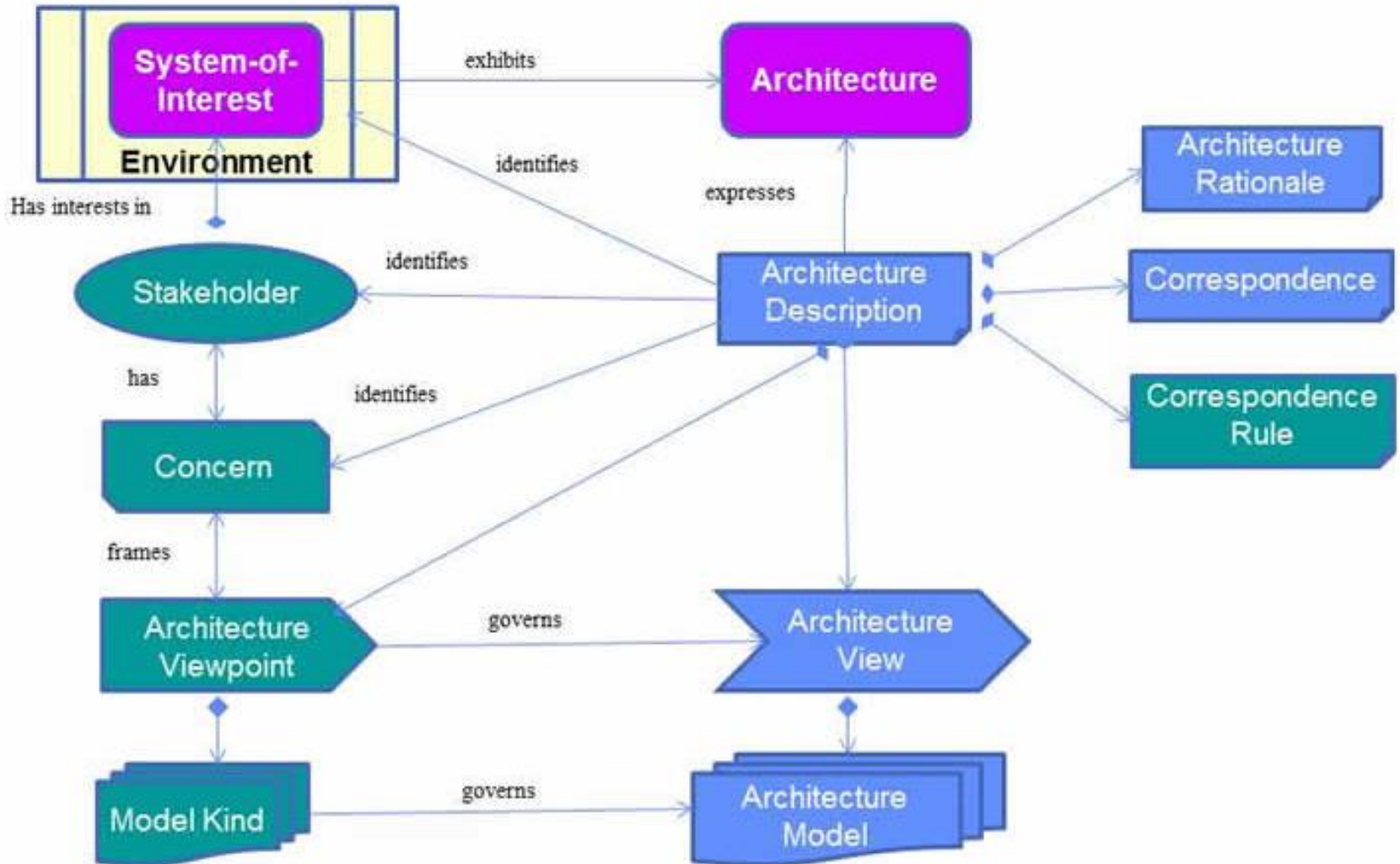


REFERENCE ARCHITECTURES

ISO/IEC/IEEE 42010

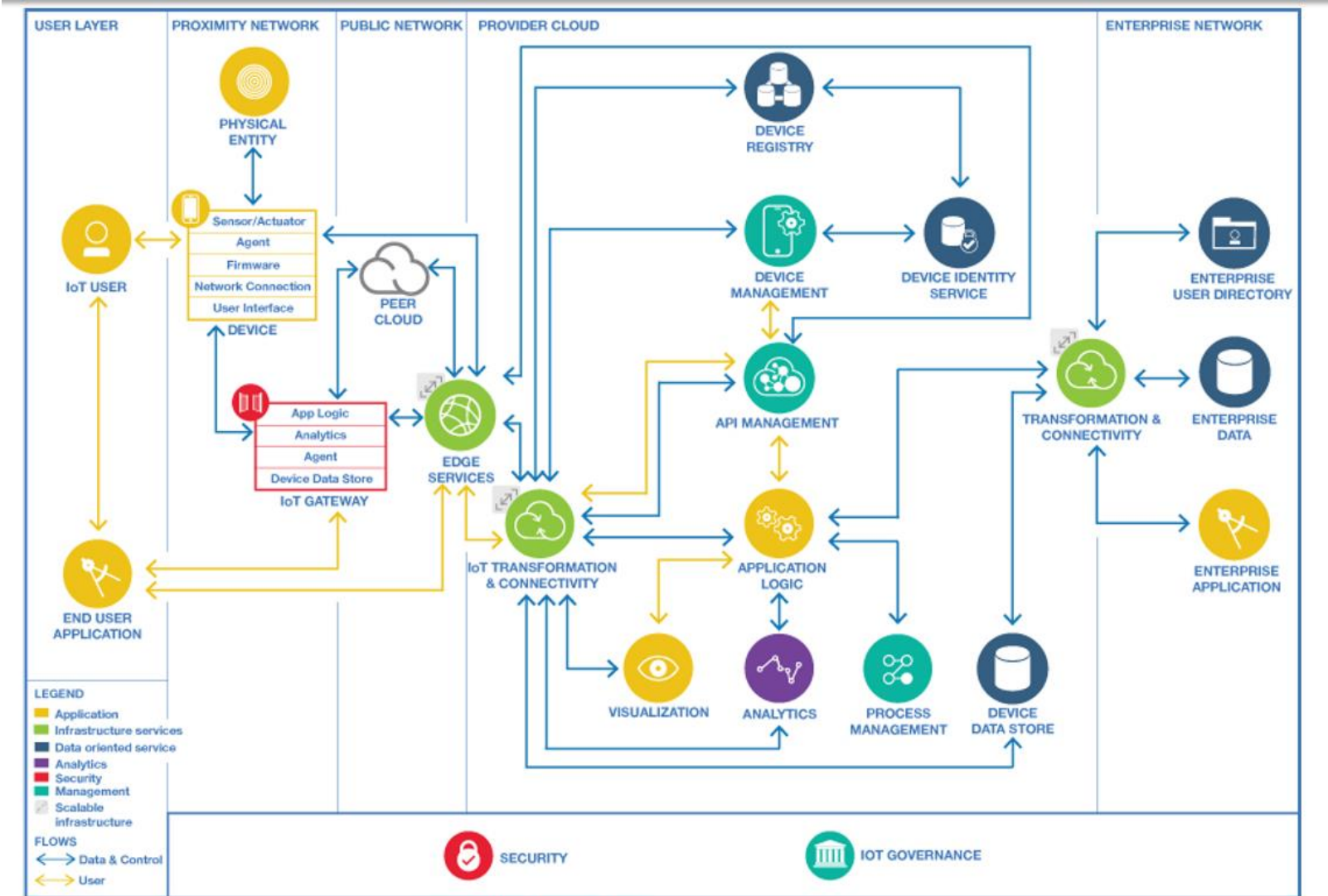
Systems and software engineering — Architecture description

ISO/IEC/IEEE 42010 Concepts



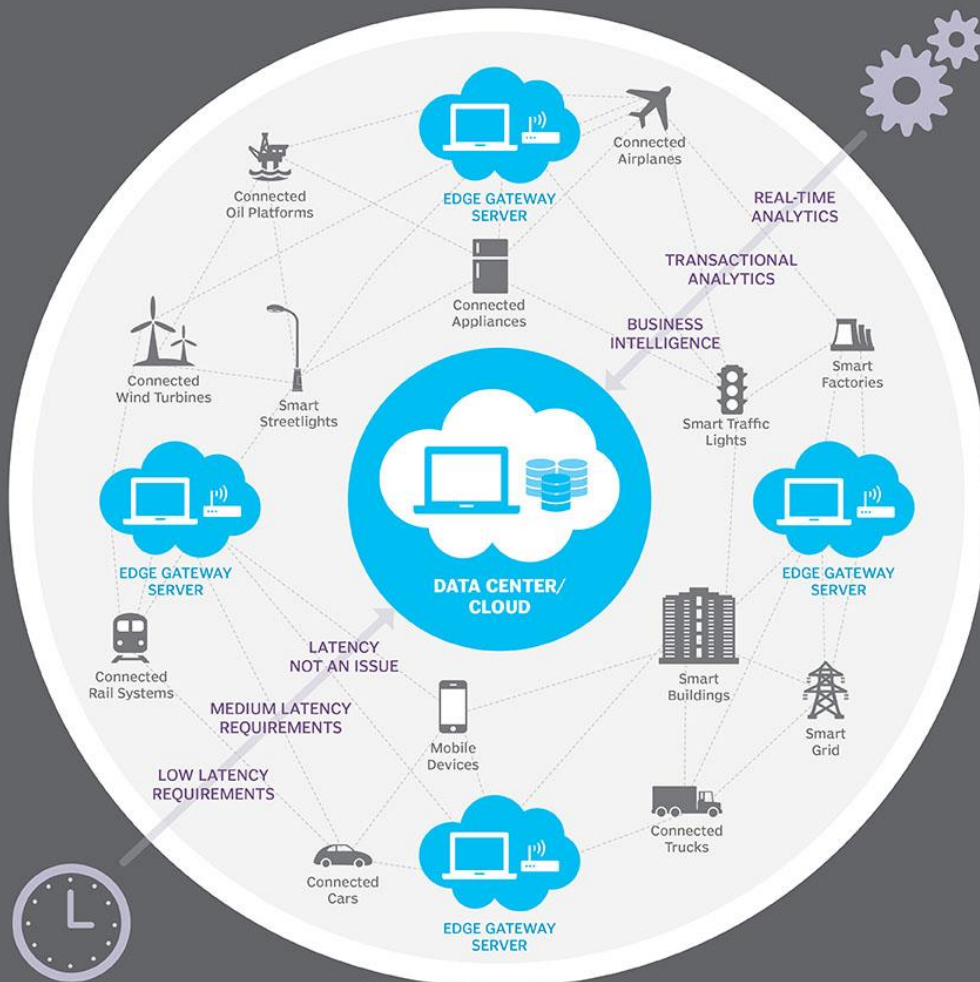
Cloud Customer Architecture for IoT

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



Edge computing

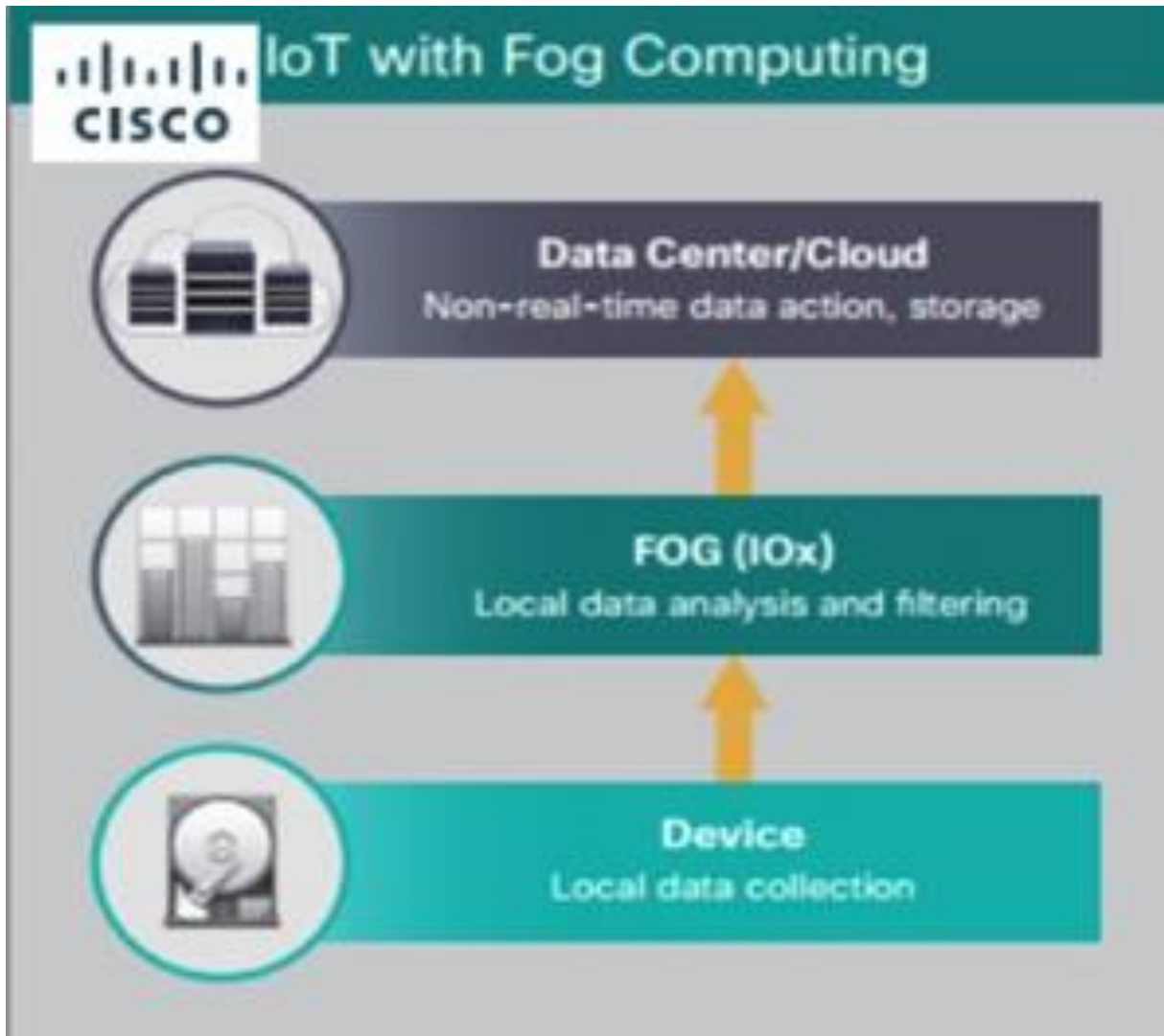
Edge Computing



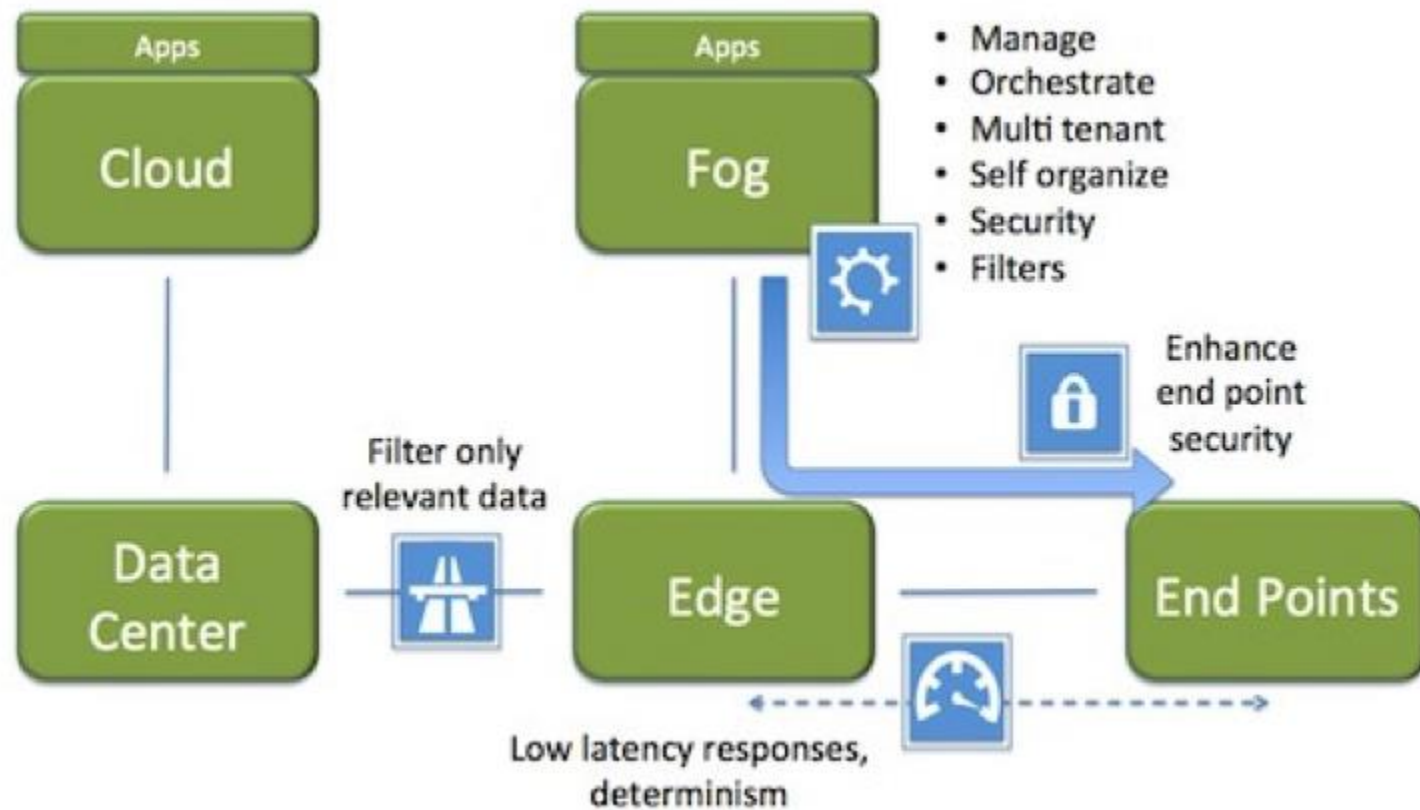
TechTarget

- 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 194 exabytes) per year
 - Internet of Things (IoT),
 - Artificial Intelligence...

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

- **Fog computing:**

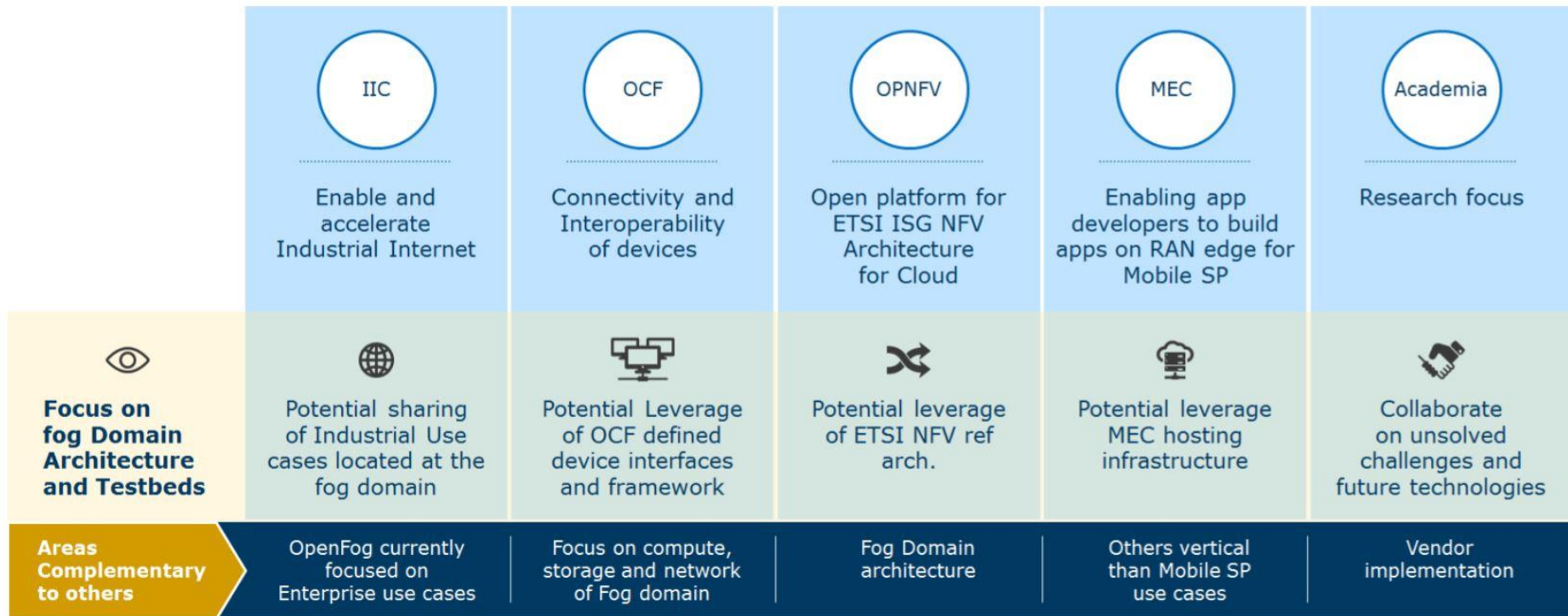
A horizontal, system-level architecture

- distributes computing, storage, control and networking
- closer to the users along a cloud-to-thing continuum.

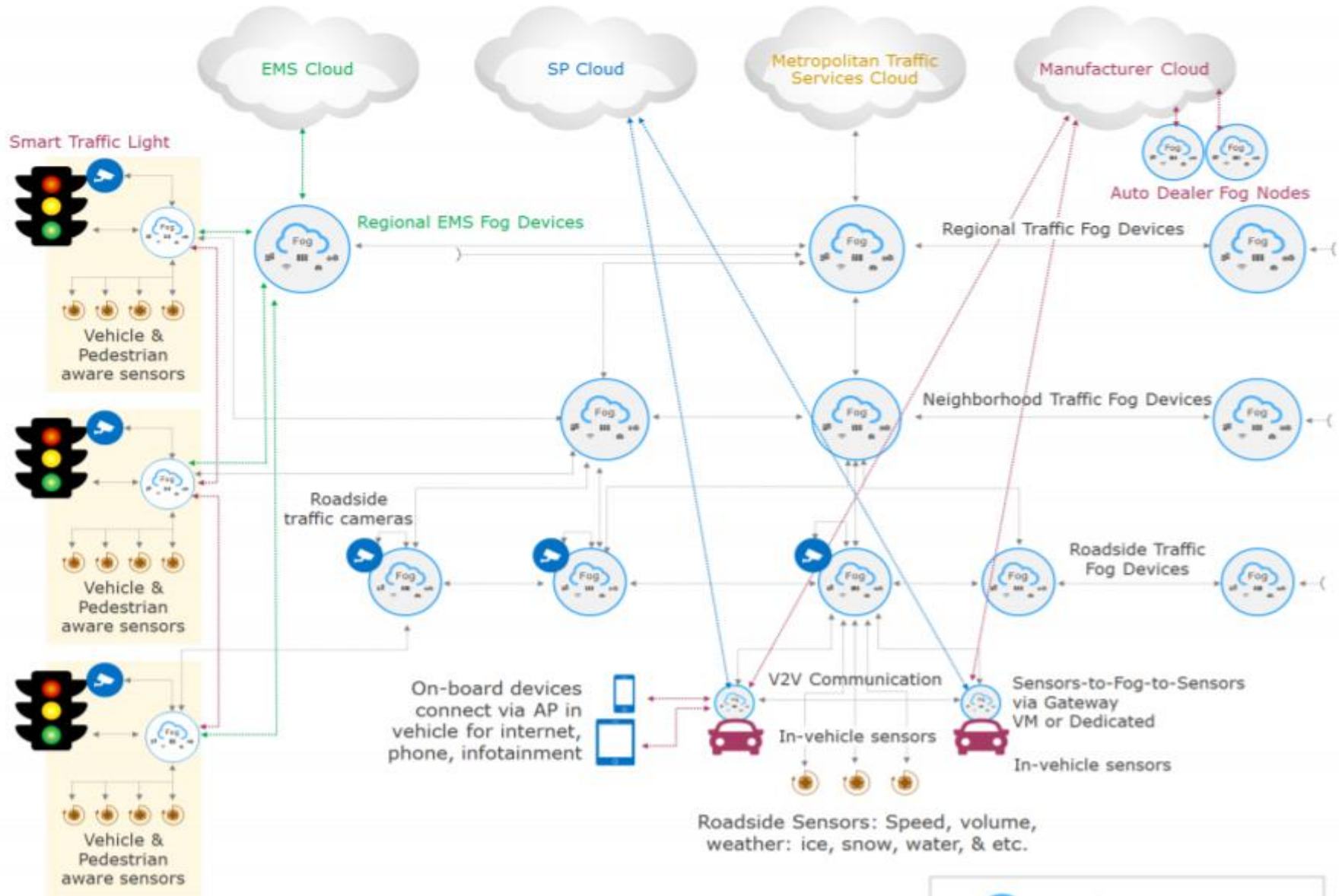
Fog computing vs other architectures

- 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.

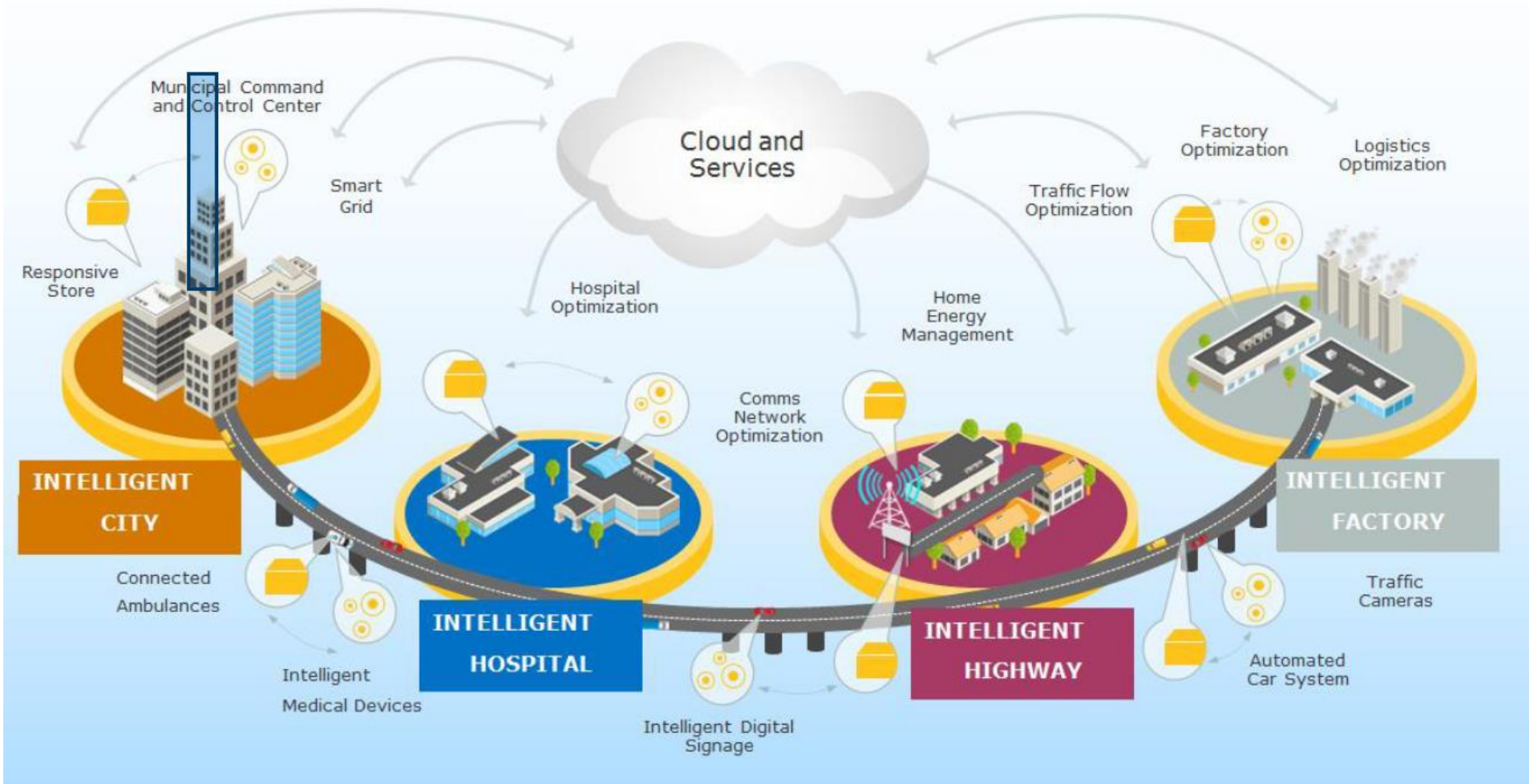
OpenFog Consortium and Other Consortia



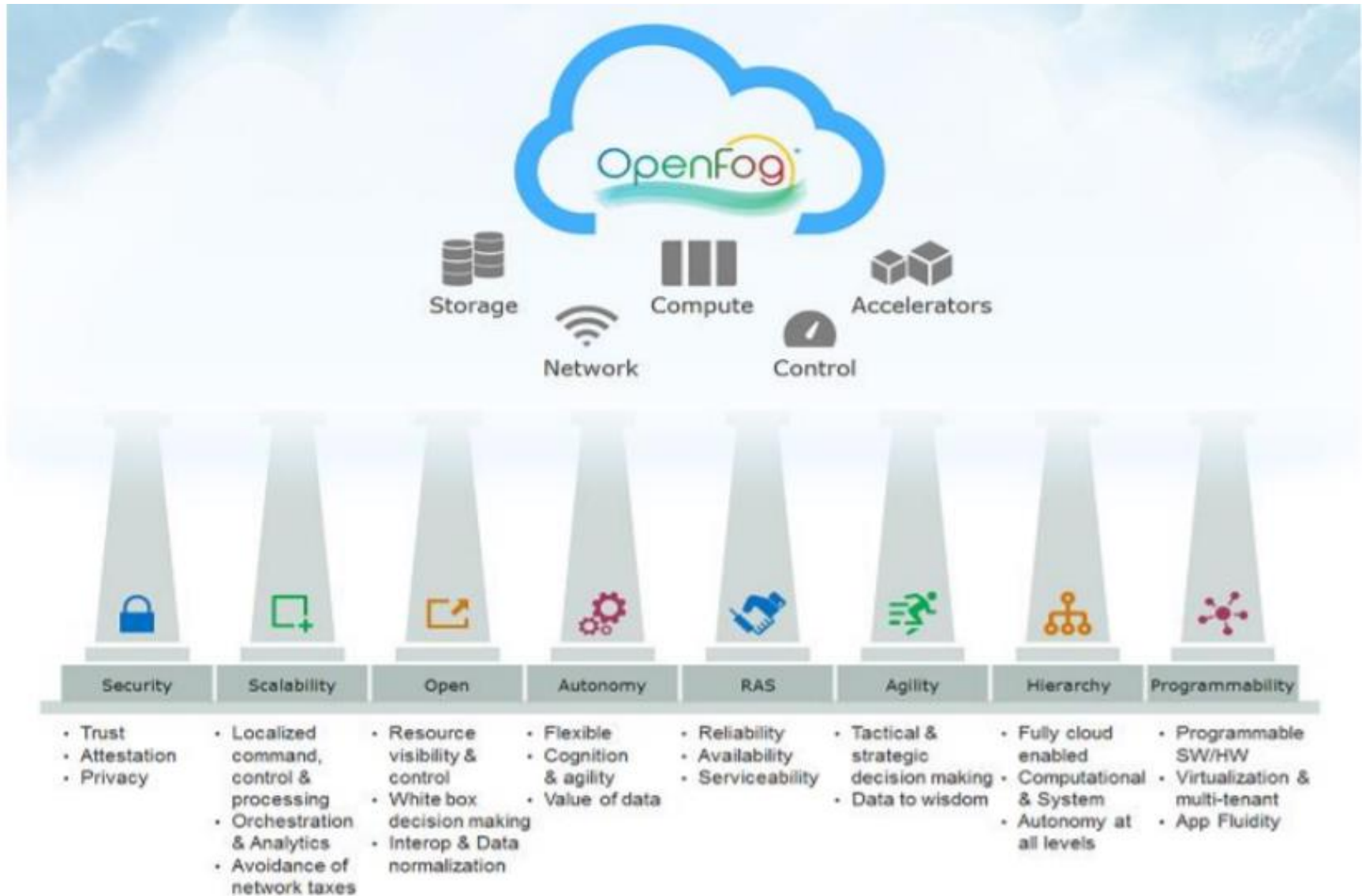
Smart Car and Traffic Control System



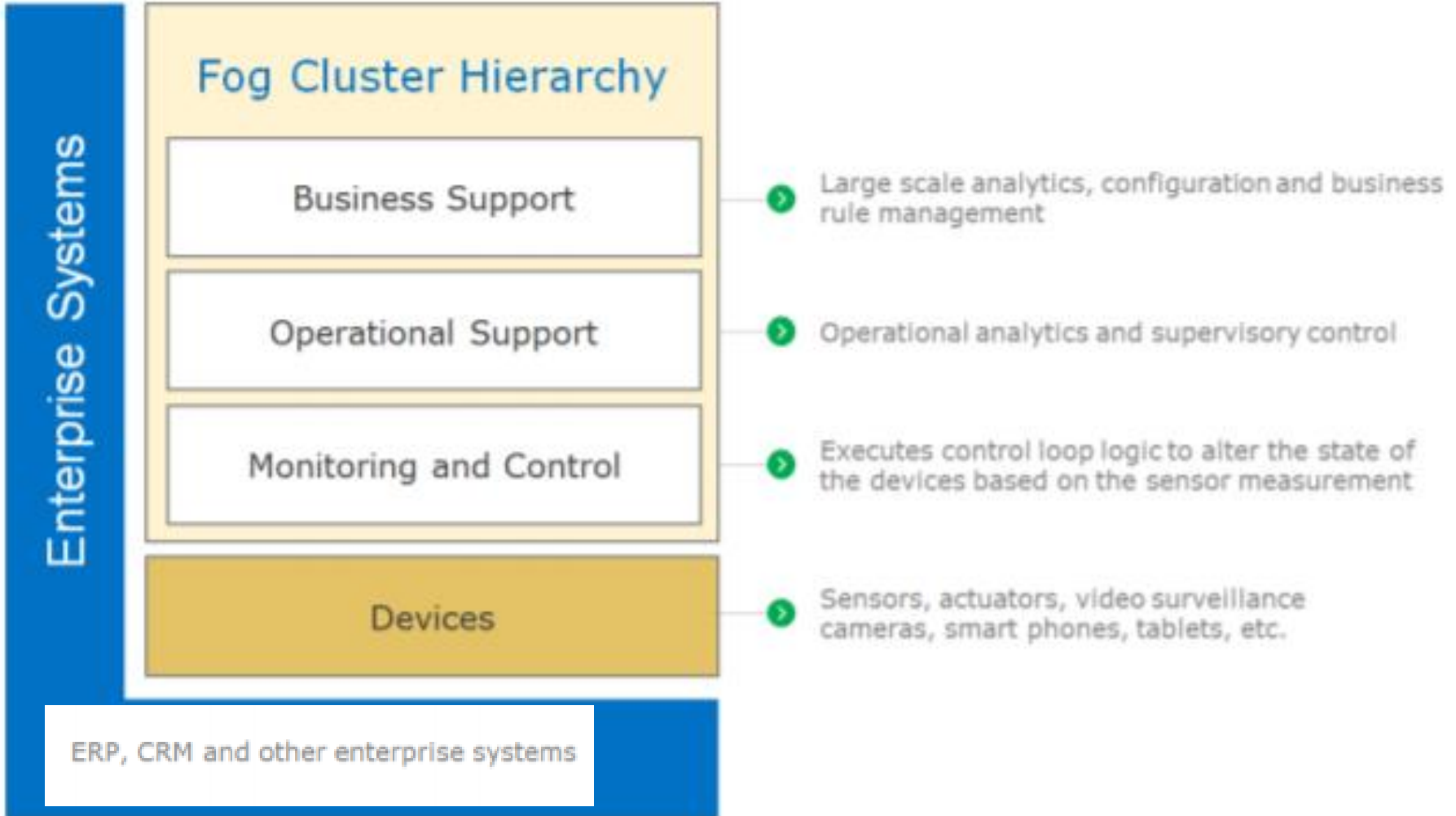
Opportunities for Smart Cities



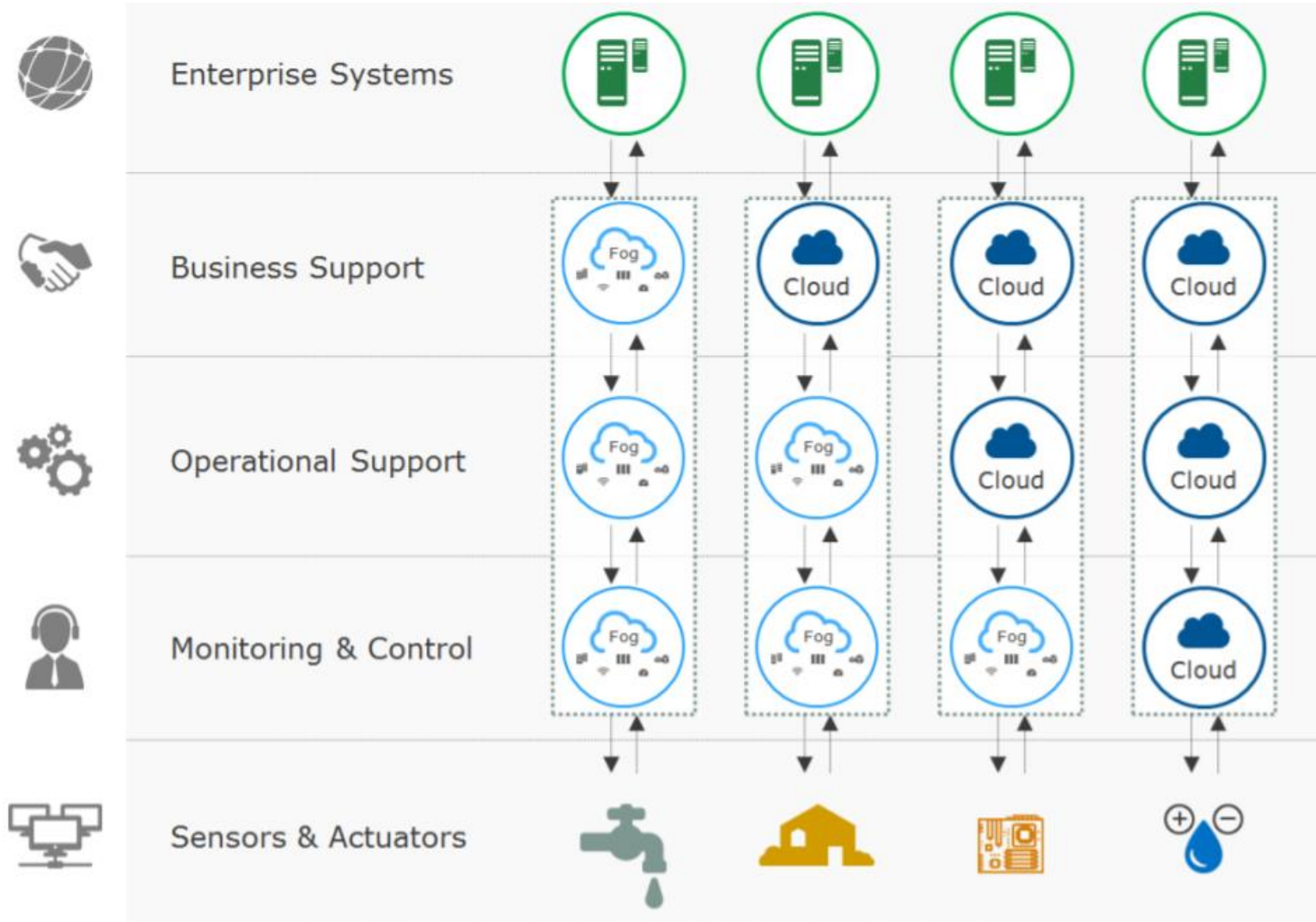
Pillars of OpenFog



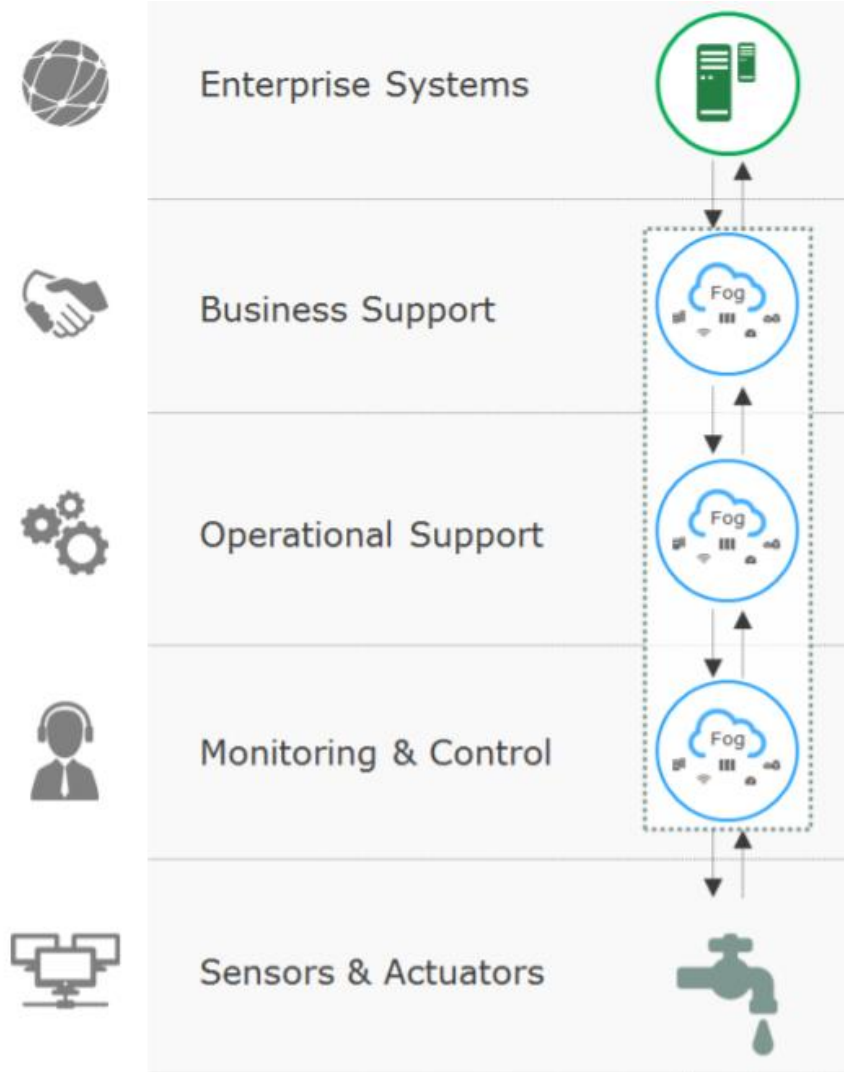
Layered Architecture View of an IoT System



IoT System Deployment Models



Cloud-independent Deployment



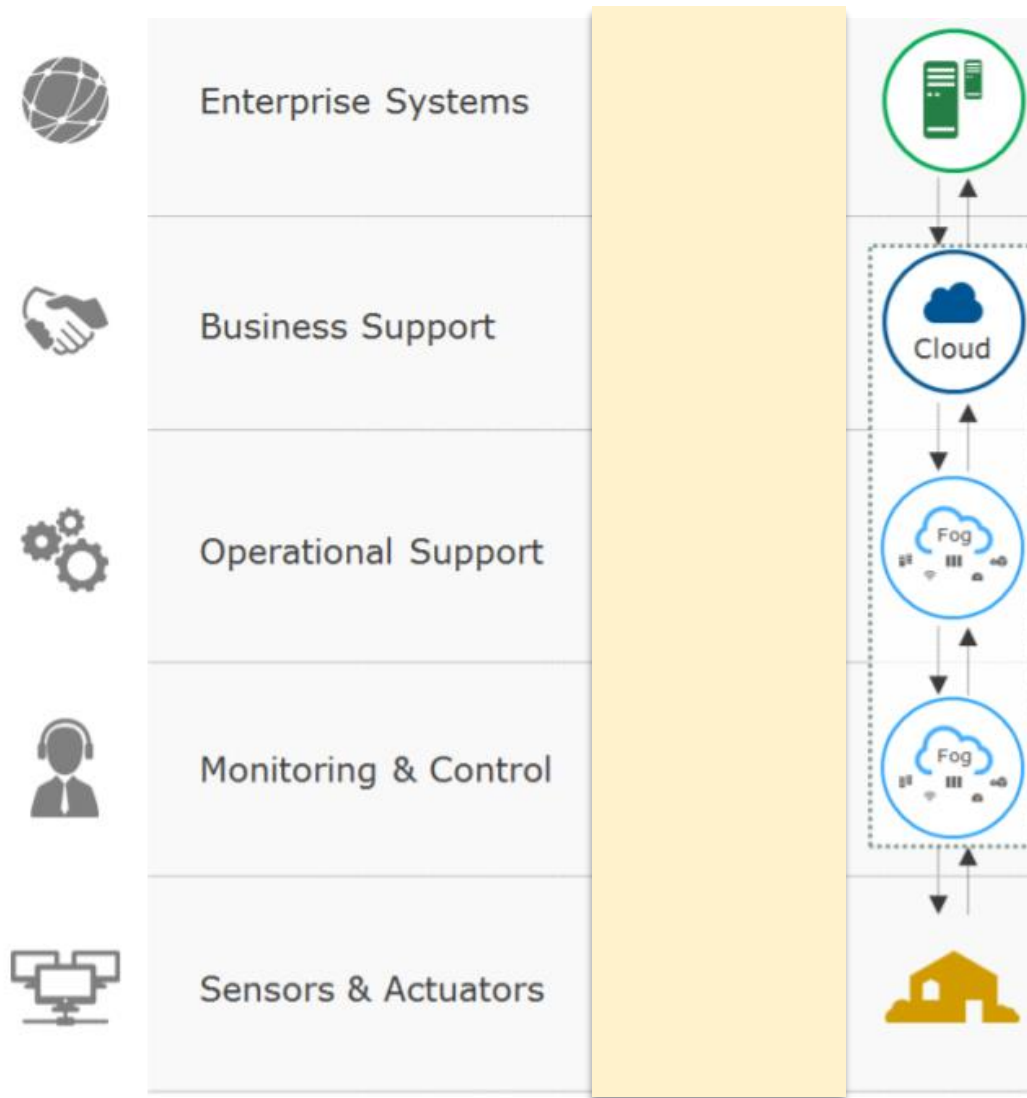
No use of cloud :

- 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



Enterprise Systems



Business Support



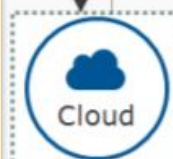
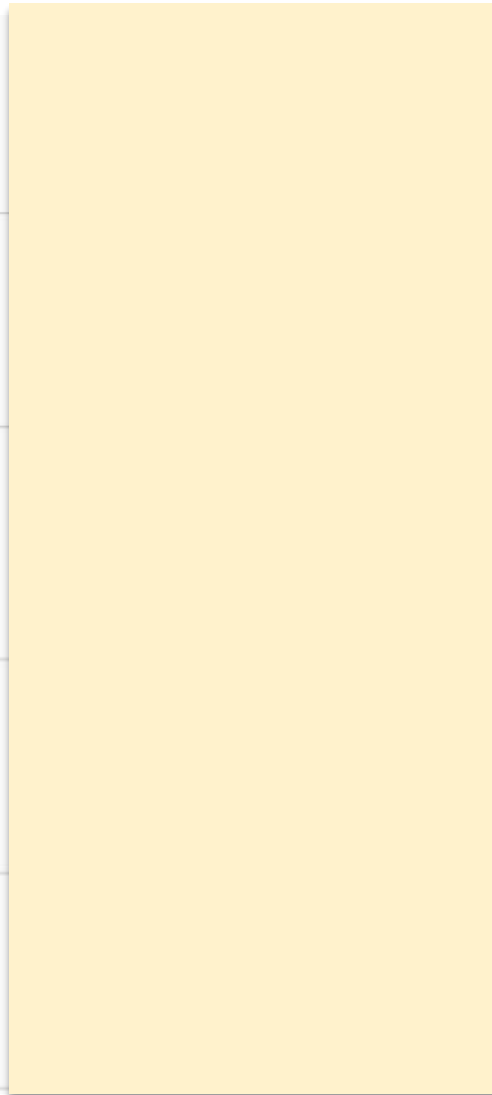
Operational Support



Monitoring & Control



Sensors & Actuators



- **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



Enterprise Systems



Business Support



Operational Support



Monitoring & Control



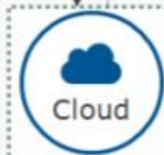
Sensors & Actuators

Cloud for the entire stack

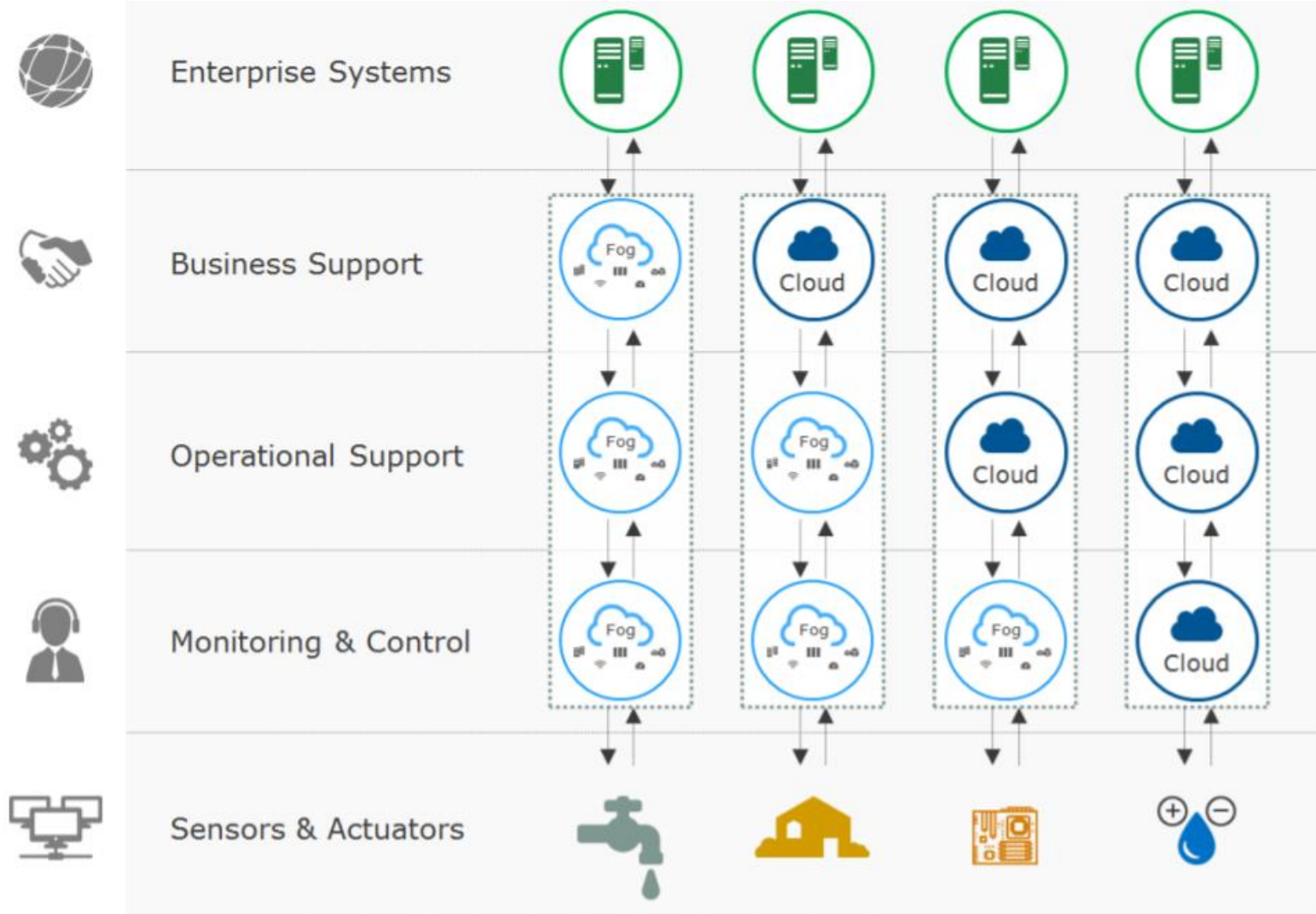
- Constrained environments
- Fog nodes at the device layer

Use cases

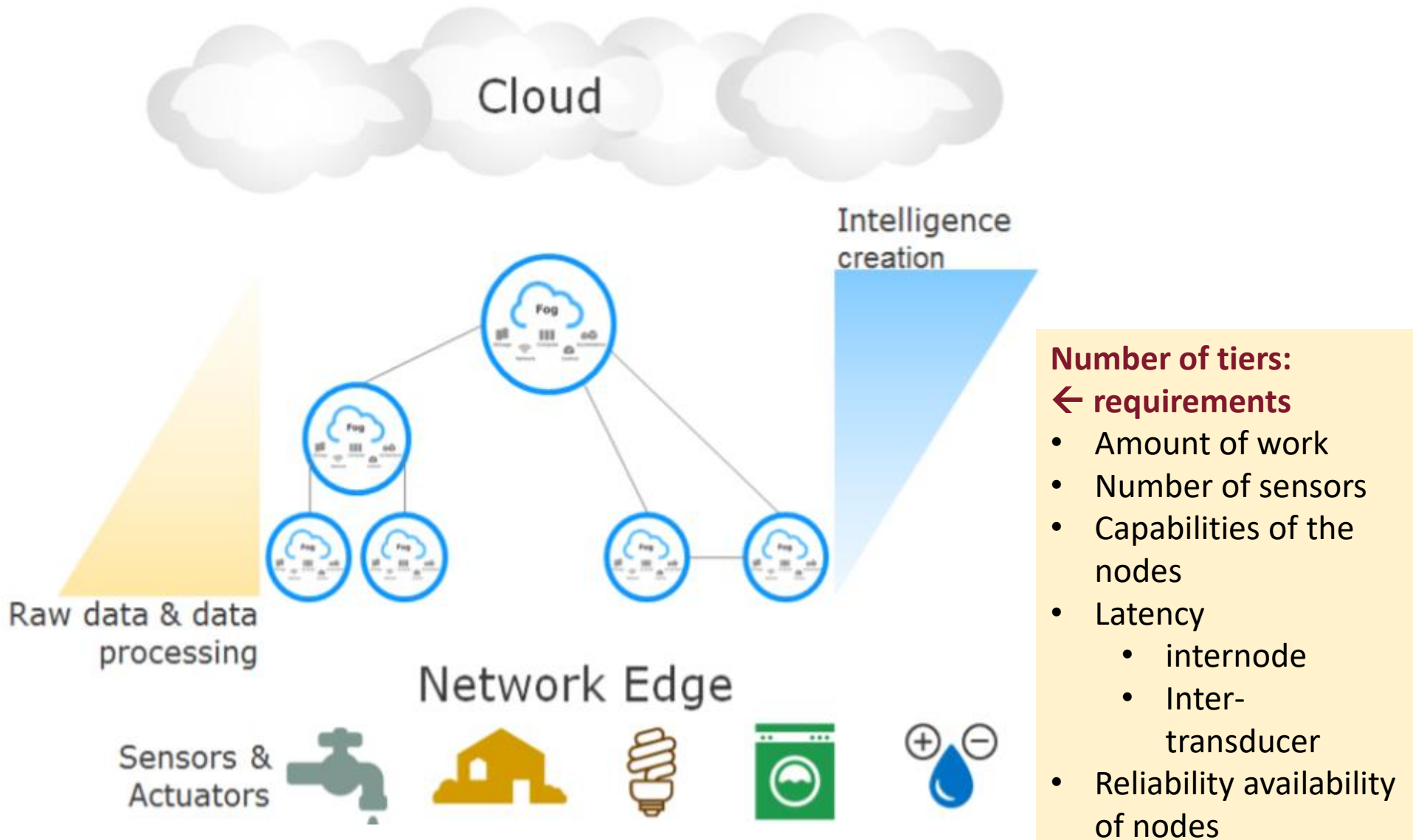
- agriculture,
- connected cars,
- remote weather stations



IoT System Deployment Models



Intelligence from data

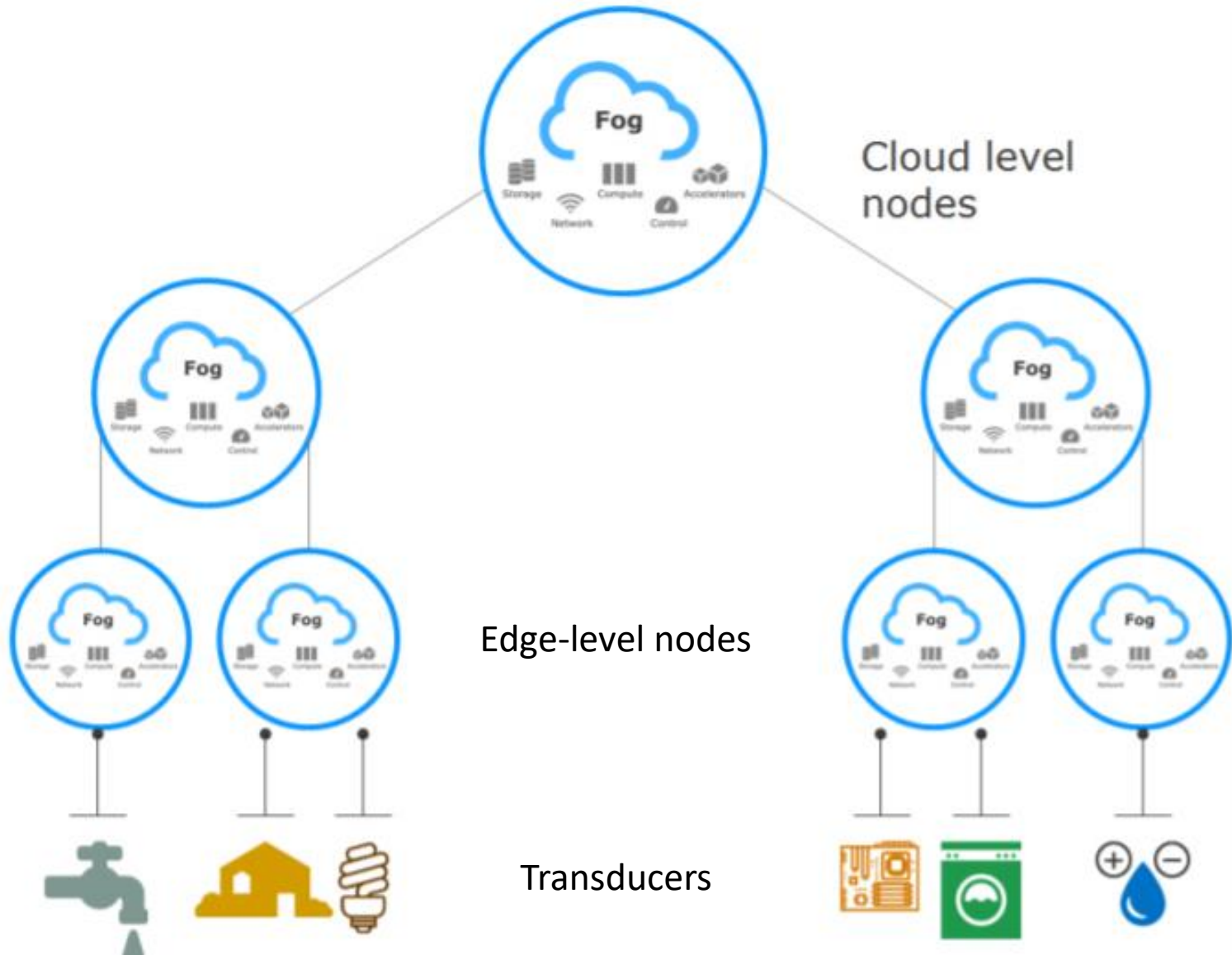


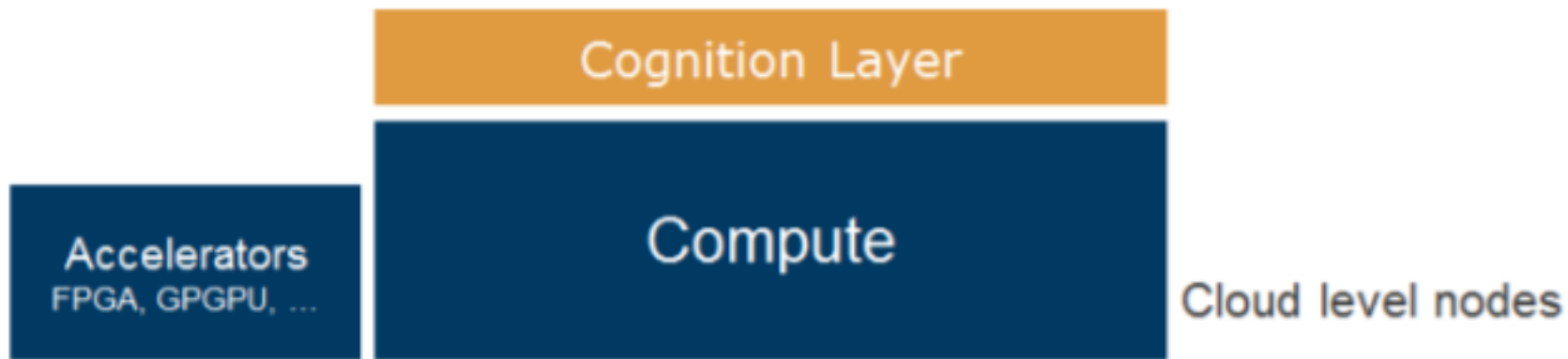
Number of tiers:

← requirements

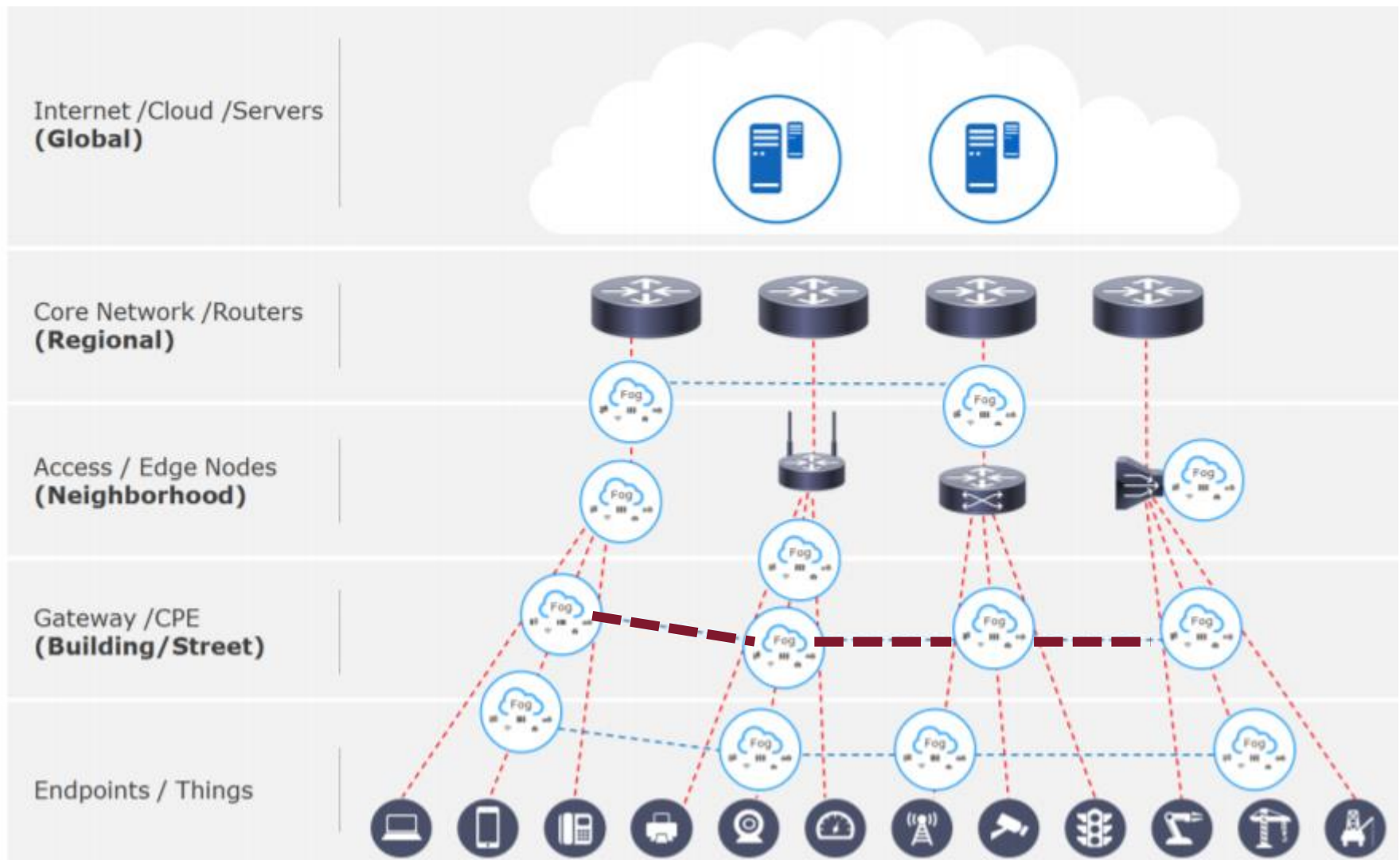
- Amount of work
- Number of sensors
- Capabilities of the nodes
- Latency
 - internode
 - Inter-transducer
- Reliability availability of nodes

Hierarchical deployment

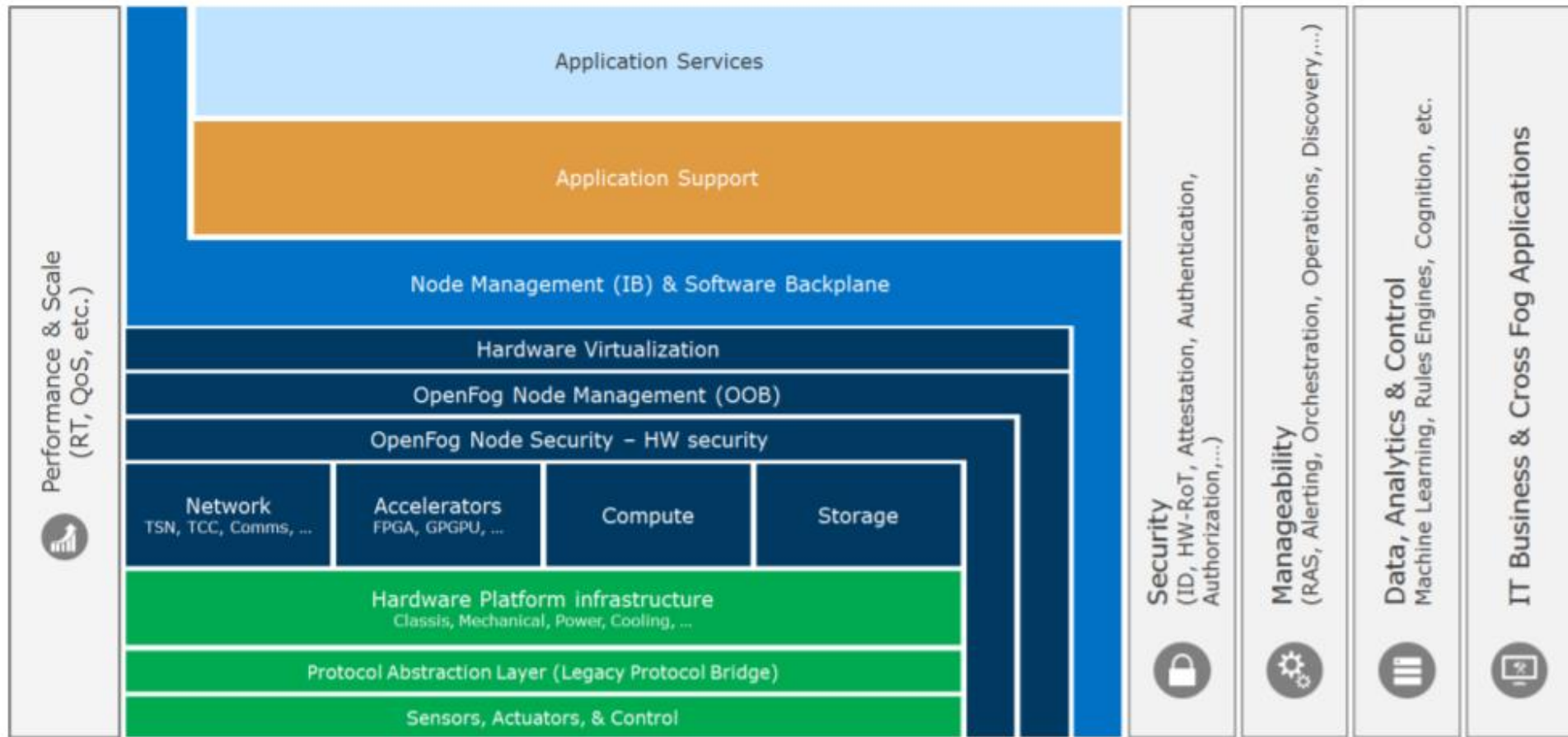




Local communication



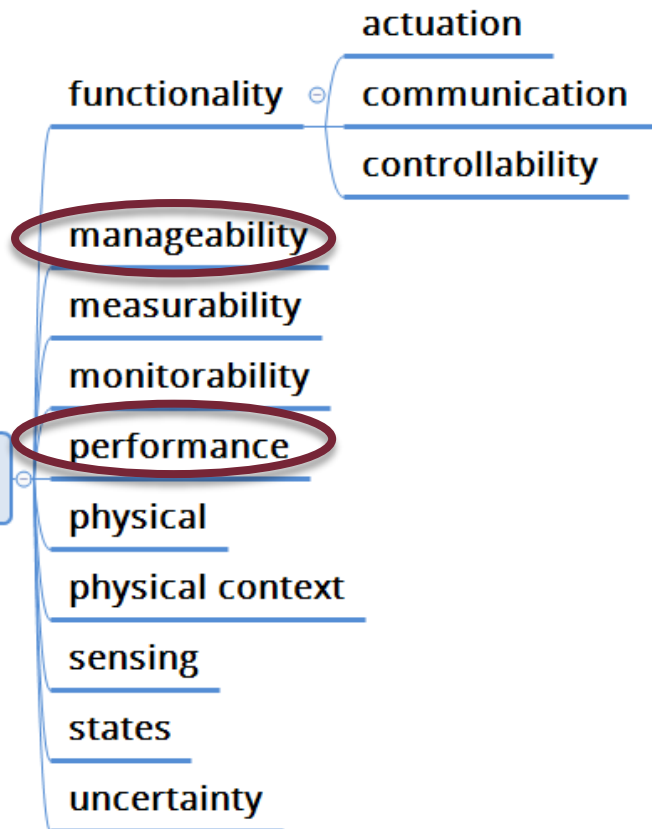
Architecture Description with Perspectives



OpenFog Architecture Perspectives

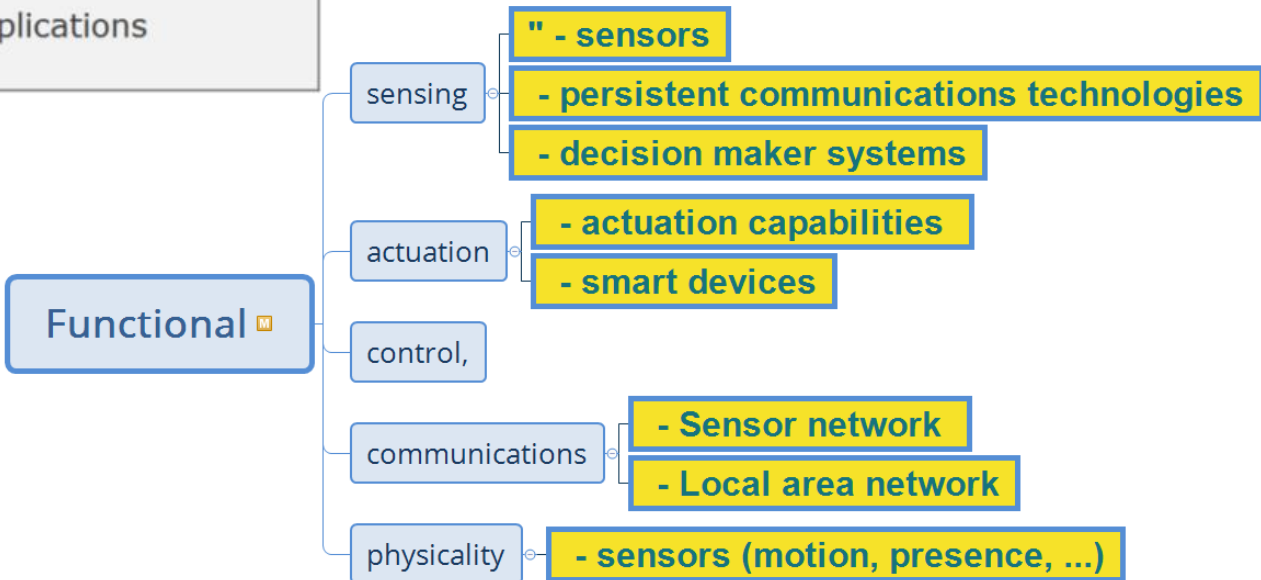


Concerns



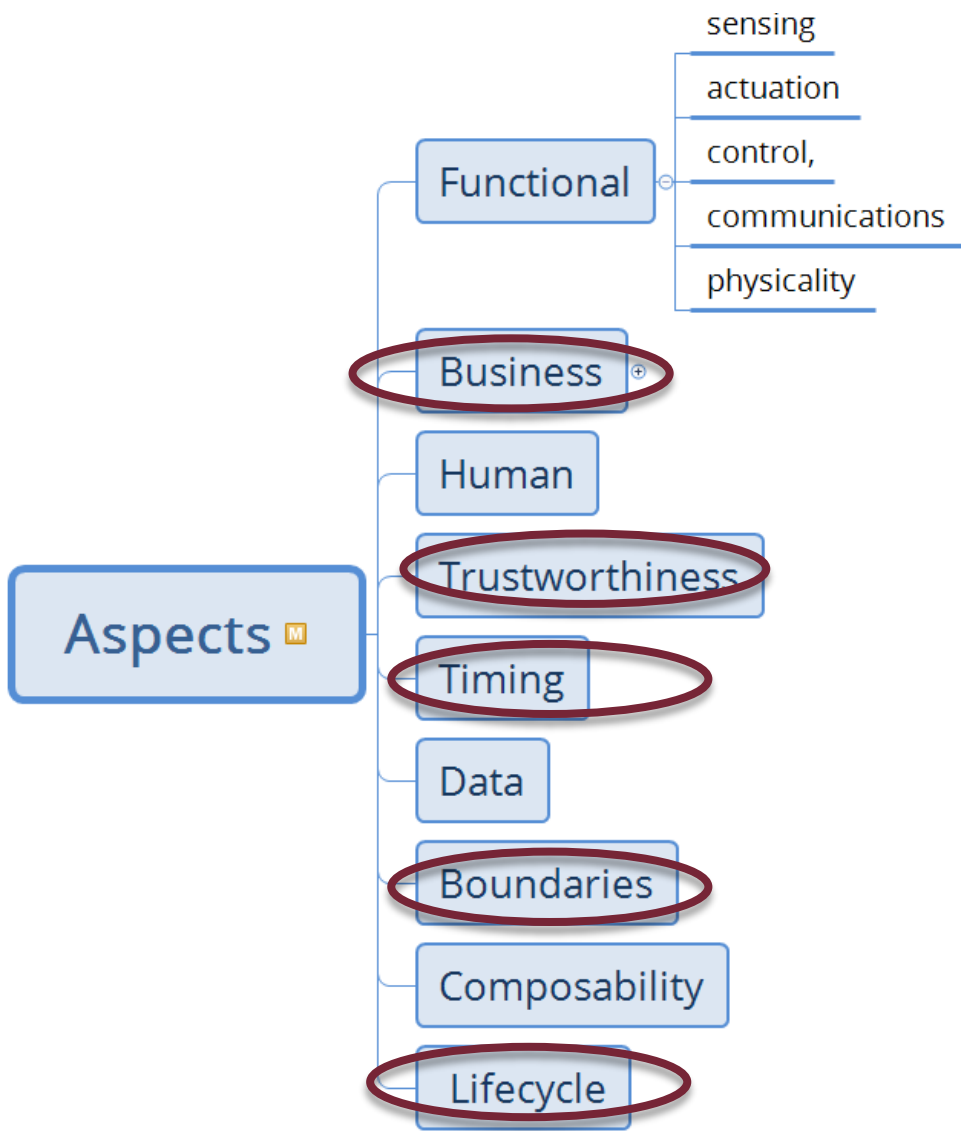
OpenFog Architecture Perspectives

-  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



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



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)

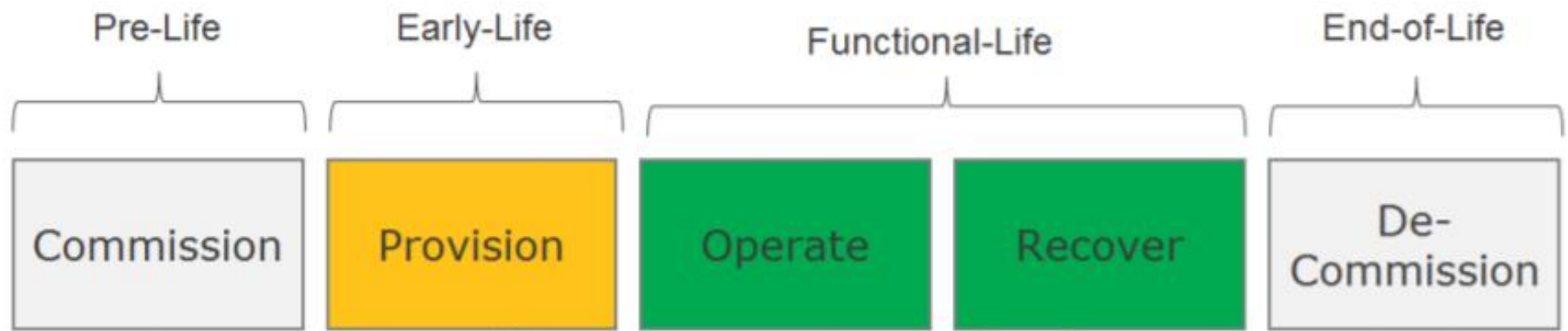
Security
(ID, HW-RoT, Attestation,
Authentication,
Authorization,...)



Example Threats and Attacks

Threat Categories	Confidentiality Violation	Integrity Violation	Authentication Violation	Availability Violation	Privacy Violation
<div style="background-color: #f4a460; padding: 5px; text-align: center;">Intents</div> <div style="background-color: #4f81bd; color: white; padding: 5px; text-align: center;">Attack Venues</div>	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.

Global Applications & Services
(e.g. Business and Operational Intelligence)

Recommendation Through
Secure Connection

**Partner Process or
Machine Analytics**

Network
Access

Enterprise

Operational Network/
Branch / Plant

Action

Synch or
Report
Action

**Local Applications &
Services (FOG)**

Action

Embedded
Intelligence

Process

Query or
Capture

Action

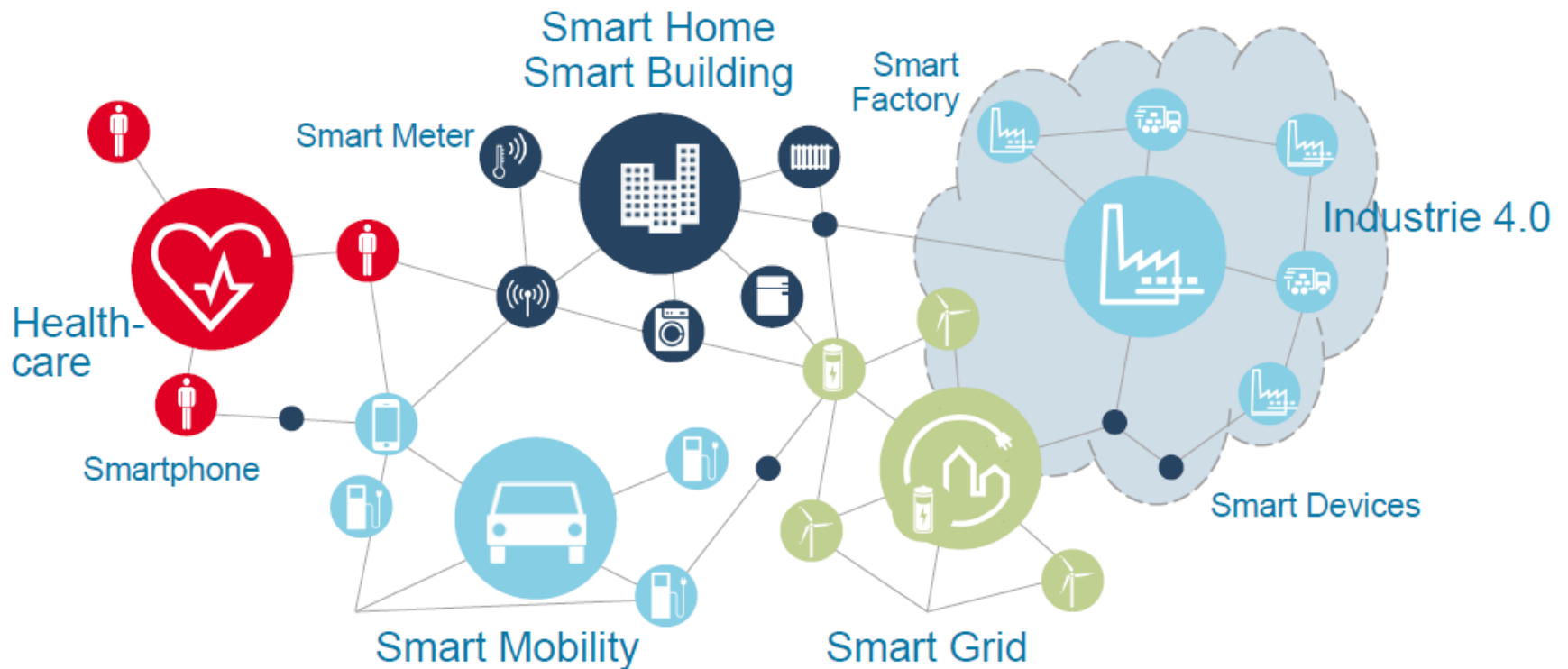
Data

Query

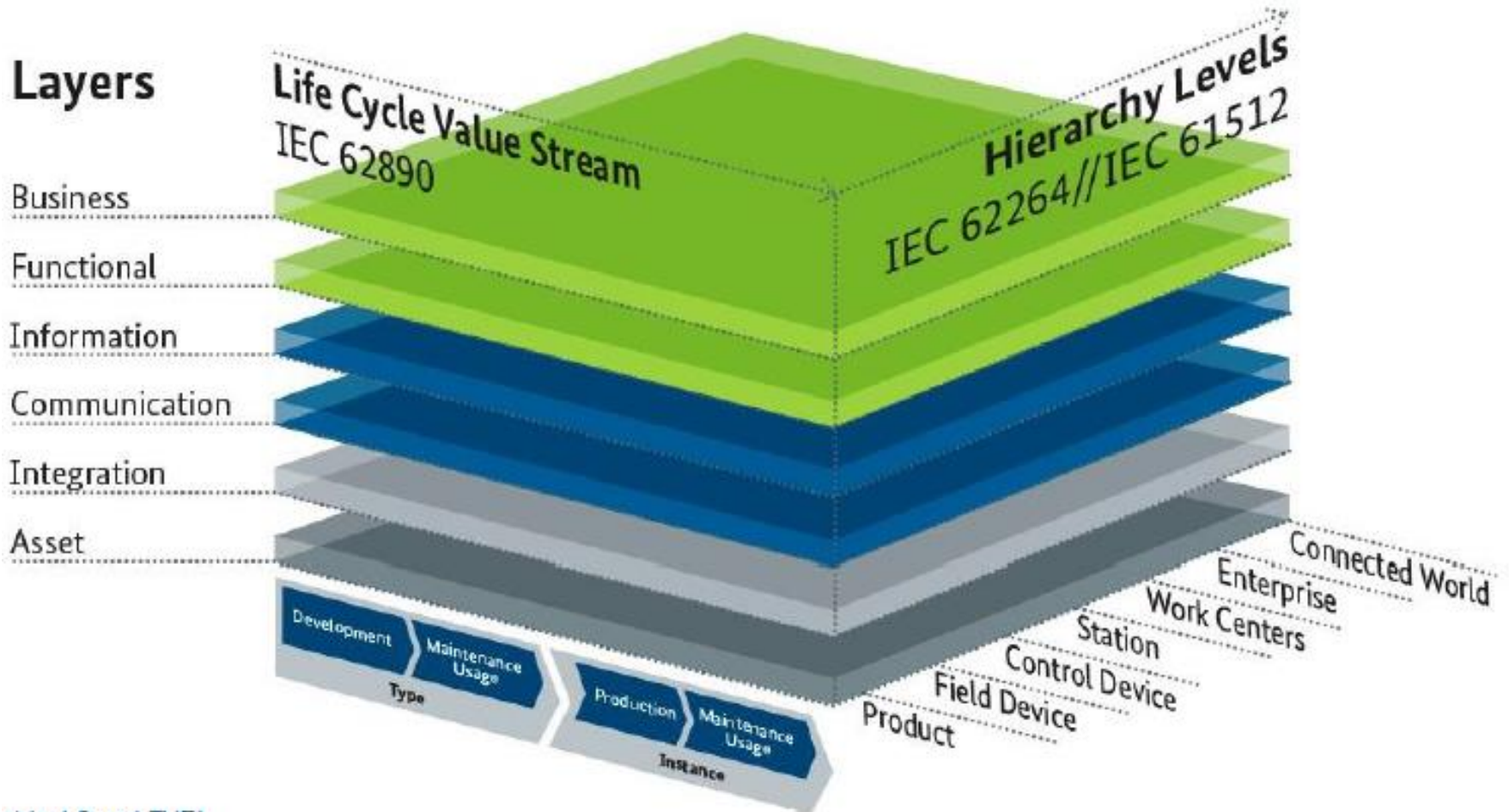
THE CHANGING WORLD

Evolving need: flexibility to match evolving demands

Industry 4.0 vision

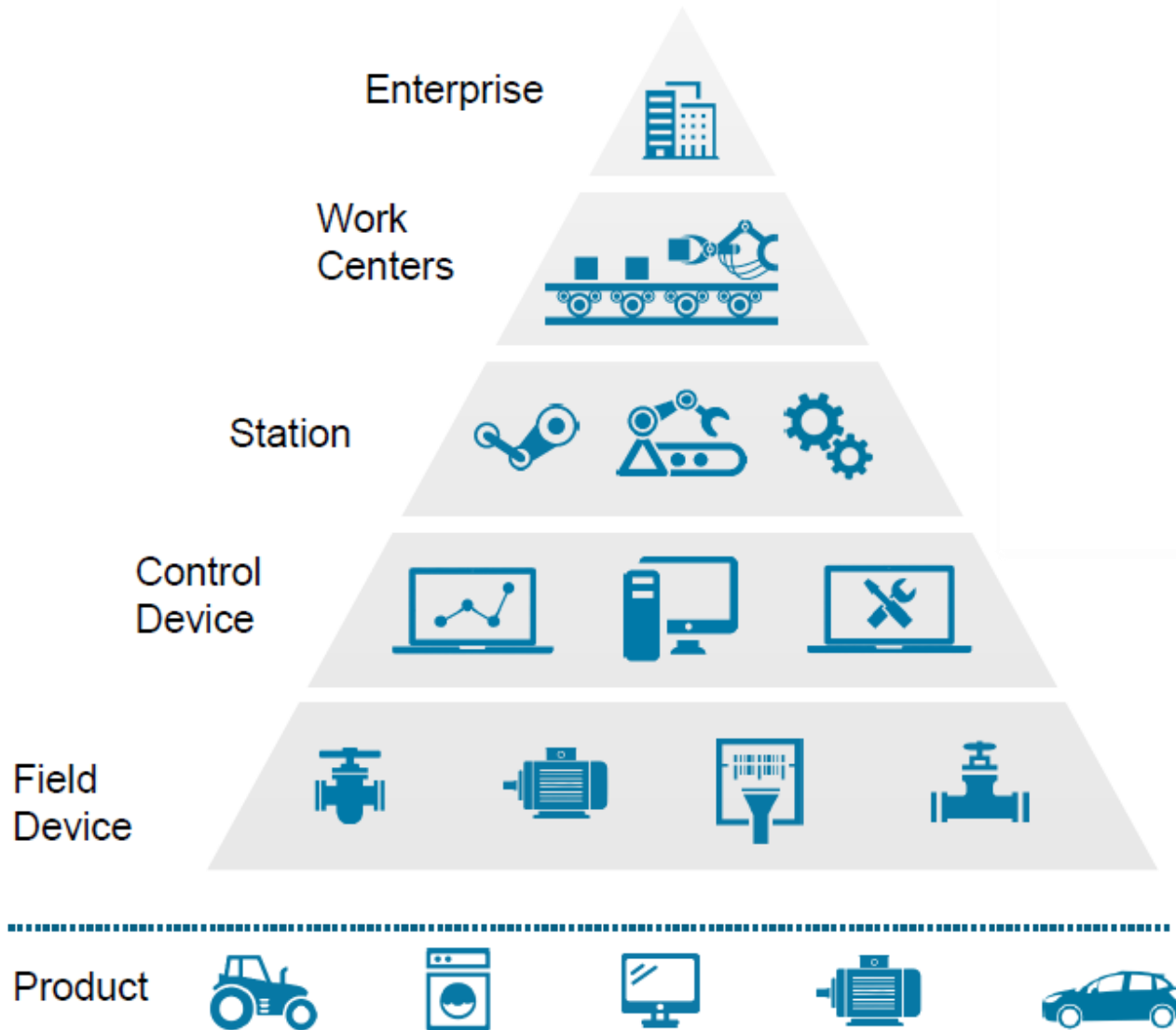


RAMI 4.0

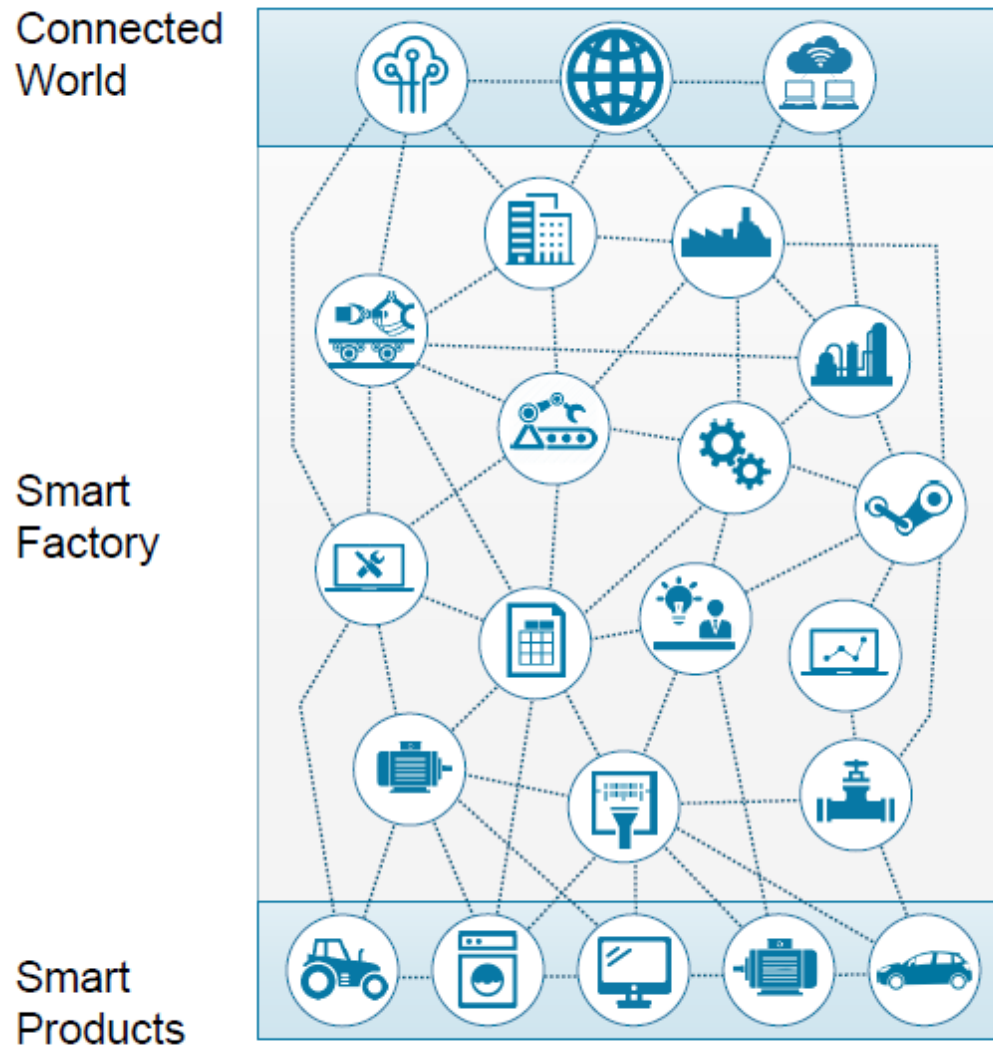


RAMI 4.0 und ZVEI

Industry 3.0



Industry 4.0



VIRTUAL ARCHITECTURES

Need for simple, on-demand configurable systems
“Overlay architectures”



IoT Specifications

Data Distribution Service (DDS) 

Core

DDS v1.4 OMG

DDSI-RTPS v2.2 OMG

Extensions

DDS-XTypes v1.1 OMG


DDS-Security v1.0 Beta 1 OMG


Dependability Assurance Framework For Safety-Sensitive Consumer Devices OMG

Threat Modeling OMG

Structured Assurance Case Metamodel OMG

Unified Component Model for Distributed, Real-Time and Embedded Systems OMG

Automated Quality Characteristic Measures 

Interaction Flow Modeling Language™ (IFML™) 

FOUNDING & CONTRIBUTING MEMBERS



BOSCH
Invented for life

EMC²



HUAWEI



IBM

SAP

Schneider
Electric



Publish-subscribe

Domain

Topic

Data writer

Publisher

Subscribers

The image shows a screenshot of a LinkedIn group page for "HORIZON 2020". The page features a dark blue header with the LinkedIn logo and navigation options like "My Groups" and "Discover". A search bar is visible in the top right. The main content area displays the group's name, a "Member" button, and a description. A post by "Aktas" is visible at the bottom. Yellow callout boxes are overlaid on the image, pointing to specific elements: "Domain" points to the group name, "Topic" points to the group description, "Data writer" points to the conversation input field, "Publisher" points to the user profile of the group owner, and "Subscribers" points to the members list.

Control layer

 Account

 Privacy

 Communications

Profile privacy

Blocking and hiding

Job seeking

Data privacy and advertising

Security

Profile privacy

Edit your public profile

Change

Choose how your profile appears to non-logged in members via search engines or permitted services

Who can see your connections

Change

Choose who can see your list of connections

Connections

Viewers of this profile also viewed

Change

Choose whether or not this feature appears when people view your profile

Yes

Sharing profile edits

Change

Choose whether your network is notified about profile changes

Yes

Profile viewing options

Change

Choose whether you're visible or viewing in private mode

Full profile

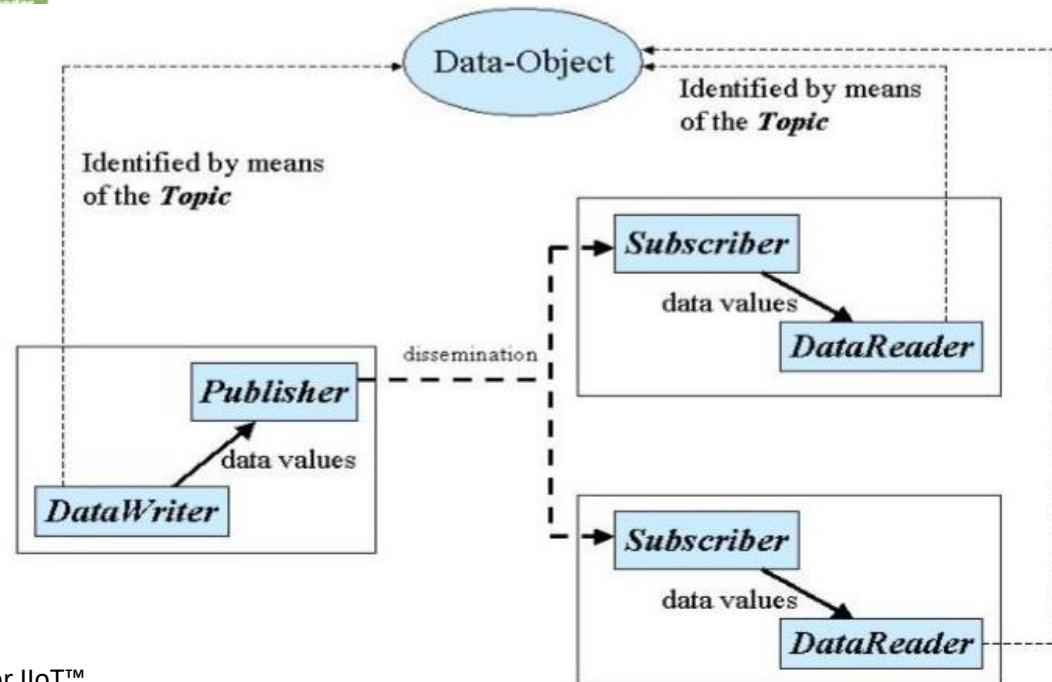
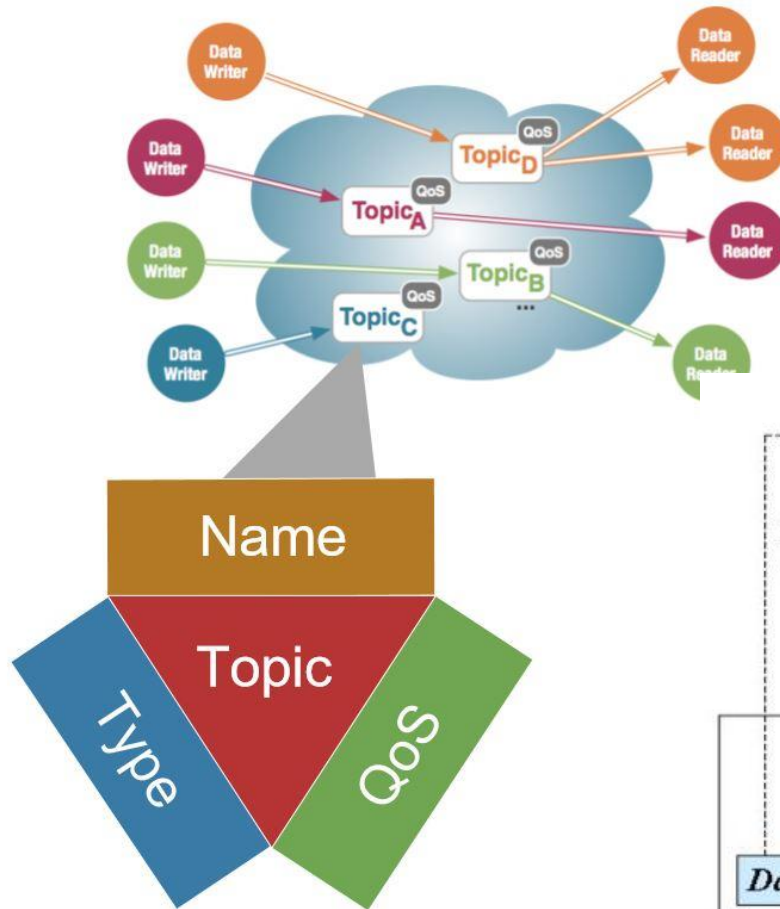
Notifying connections when you're in the news

Change

Choose whether we notify people in your network that you've been mentioned in an article or blog post

Yes

OMG DDS Core notions



Introducing DDS DDS™ – The Proven Data Cconnectivity Standard for IIoT™