Evolving IoT with Smart Objects

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Phases of IoT Development

Monolithic IoT applications (2005-2010)

Application at the centre of a static "star network" of passive IoT devices (sensors, actuators)

Example: Industrial monitoring & control applications running on private networks

Challenges: P*rotocol interoperability, data confidentiality*.

IoT (cloud) platforms (2011-today)

Applications interact with (mostly) passive IoT devices as network services by means of some cloud middleware

Introduction of d*evice discovery* and *plug-and-play* concerns, *access control, user privacy etc.*

Single-Vendor-Interoperability Concerns

Smart Objects (Emerging)

Objects with semi-autonomous behavior interacting with the cloud infrastructure and passive objects

Challenges: Distribution of application logic, security mechanisms etc.

Expanded use of robots, cyber-physical systems etc.

State-of-the-art: IoT & Cloud Convergence

- Convergence of IoT and Cloud Computing
- Allow IoT applications to leverage the benefits of the Cloud
- Challenge
  - Conflicting properties of IoT (e.g., WSN) and Cloud

Performance

Capacity

IoT in the Cloud

Elasticity

Utility-Driven

IoT/Sensors	Cloud Computing
• Location specific • Resource constrained • Expensive (development/ deployment cost) • Generally inflexible (resource access and availability)	• Location independent • Wealth of inexpensive resources • Rapid elasticity • Flexibility

Solutions for IoT-Cloud Convergence

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Heterogeneity	Solution deployment	Production of large volumes of high-velocity data	Application development
Abstraction layers	Adapt existing Cloud models (e.g., IaaS, SaaS, PaaS) to IoT	BigData techniques in the Cloud	Integrated Cloud environments
E.g., Virtual sensors in WSN	Take into account peculiarity of IoT resources	Streaming middleware	Services mashups

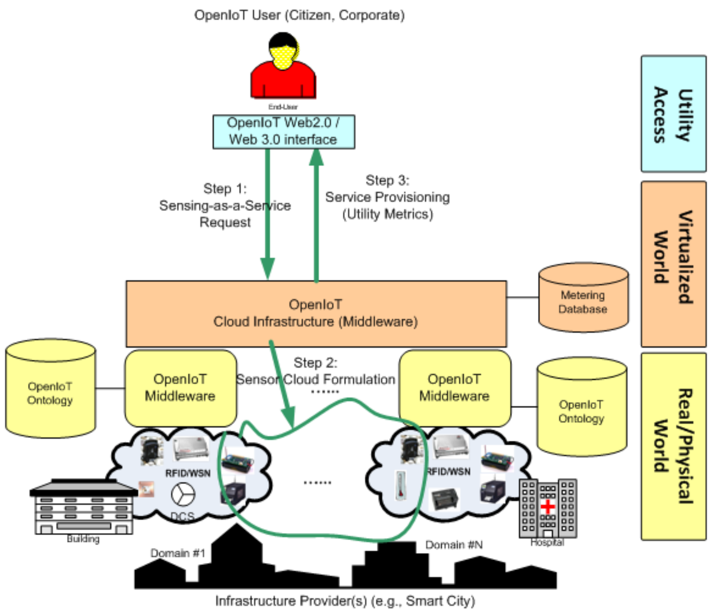
Source: Models for IoT/Cloud Delivery

IaaS
- Cloud of sensors and actuators
- Business Model: Data/Sensor provider
- Access control to resources

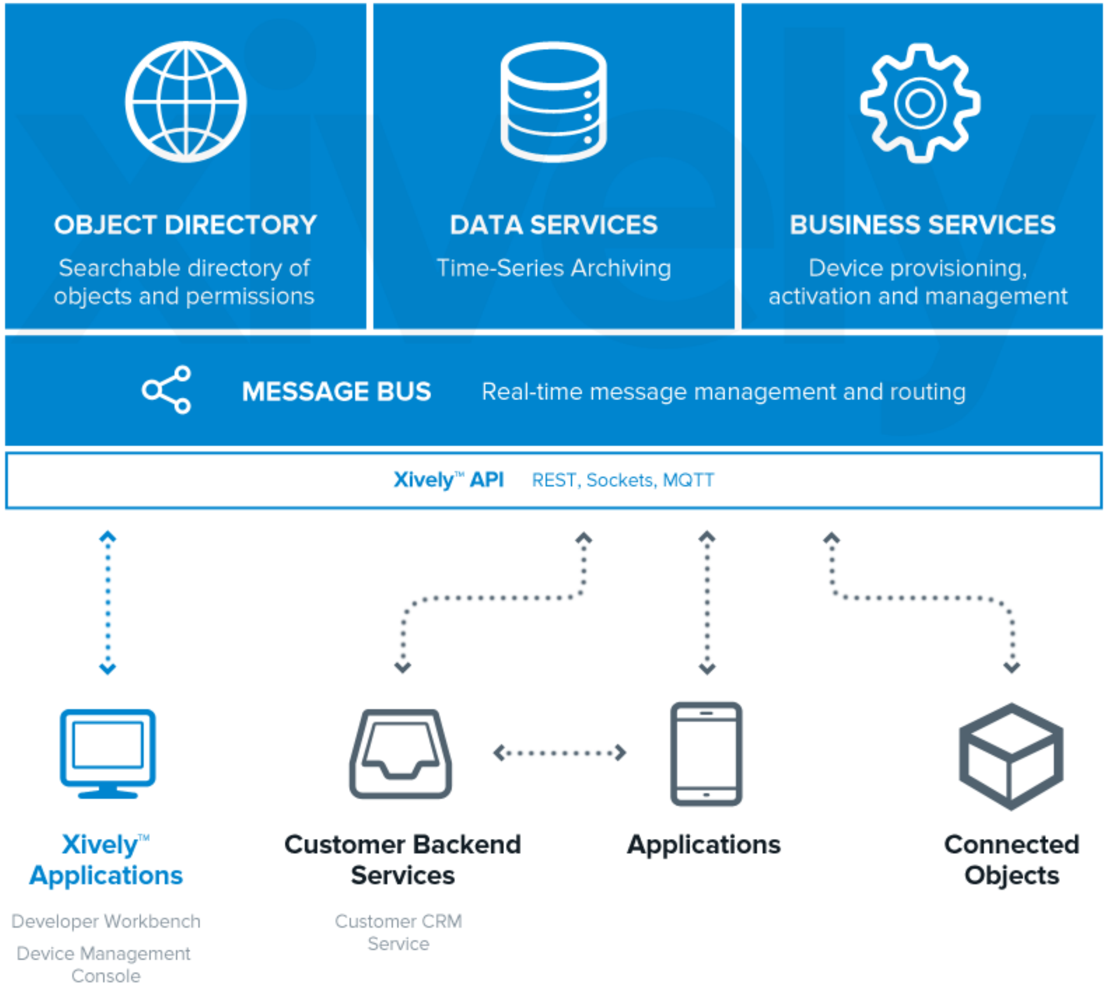
PaaS
- Most widespread nowadays (Public IoT Clouds)
- Access to data, not to hardware
- Tools & facilities for app development

SaaS
- Built over PaaS
- Specific application domains
- Typical utility-based business models

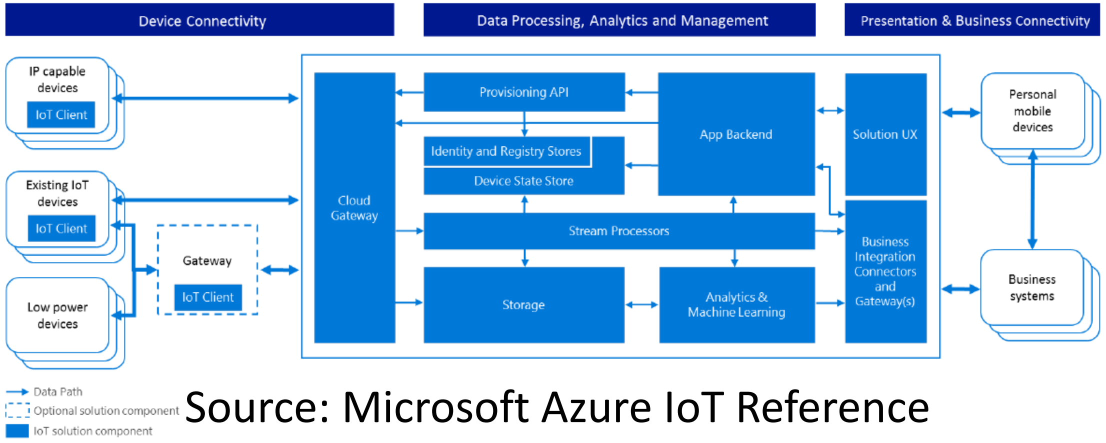
Sensing-as-a-Service



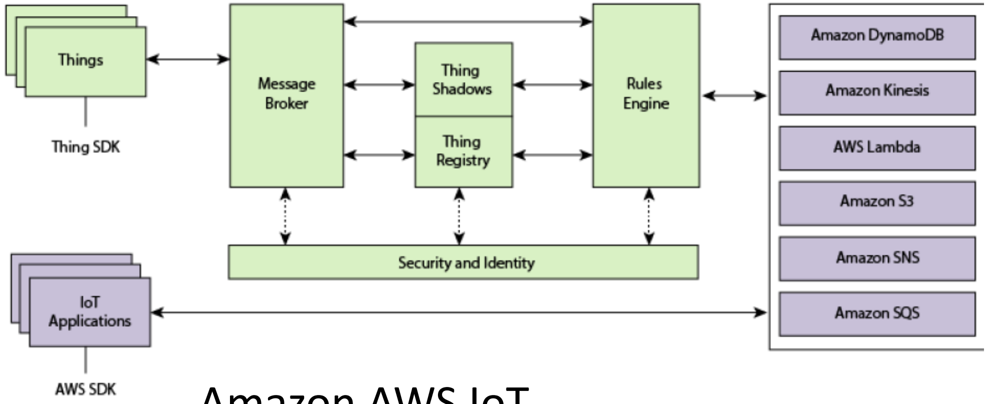
IoT & Cloud Computing Platforms: Examples



Xively.com



Source: Microsoft Azure IoT Reference Architecture (www.microsoft.com)



Amazon AWS IoT

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IoT Platforms Interoperability

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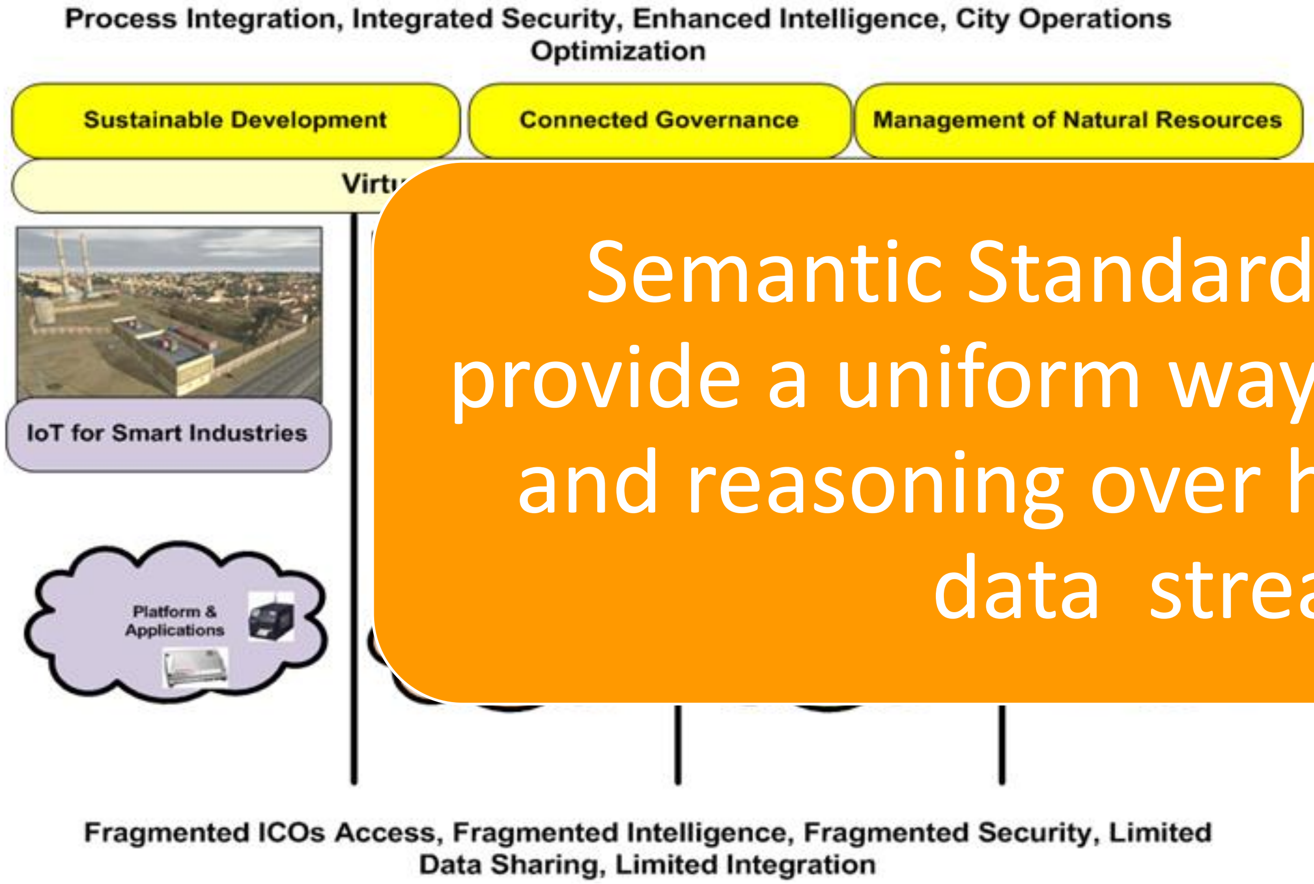
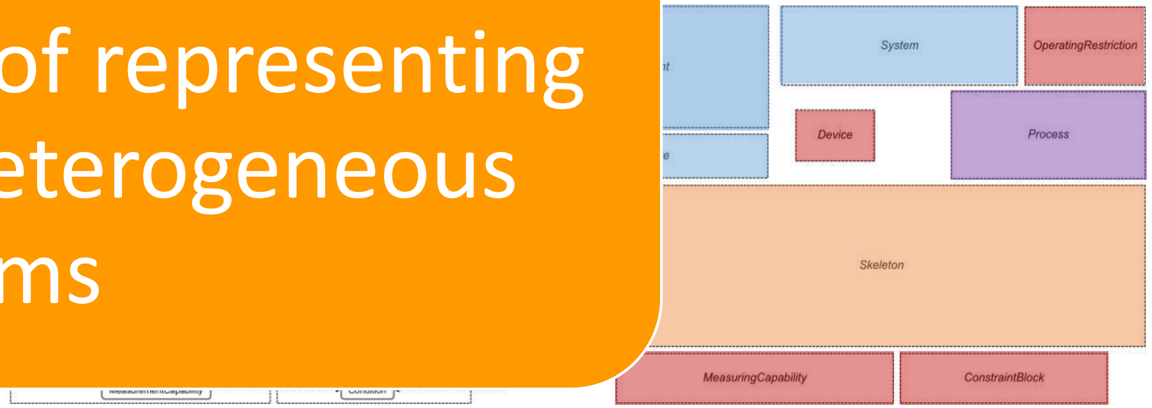


Semantic Interoperability

- Distributed and Heterogeneous Data Sources
- Diverse Data Streams

Reasoning Algorithms

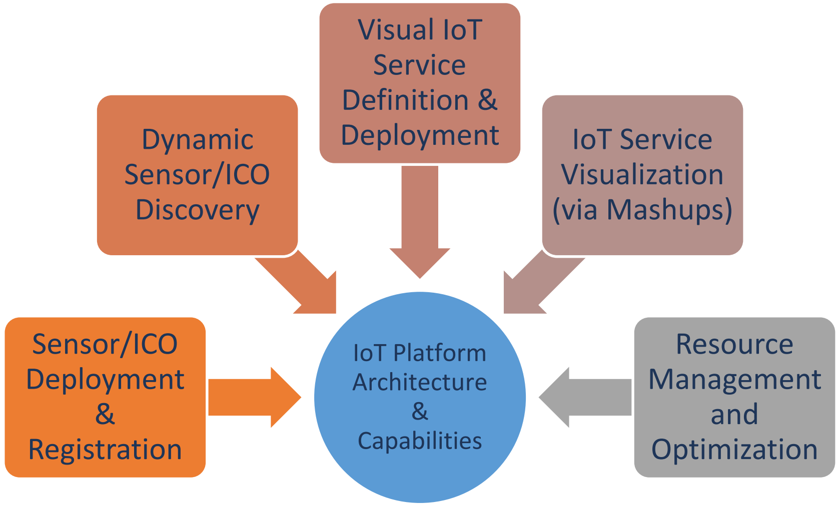
- Intelligent Selection & Filtering of Sensors
- Intelligent Selection & Filtering of Sensor Data
- Use of Reasoners
- /OWL Ontology (W3C SSN + Linked Data)

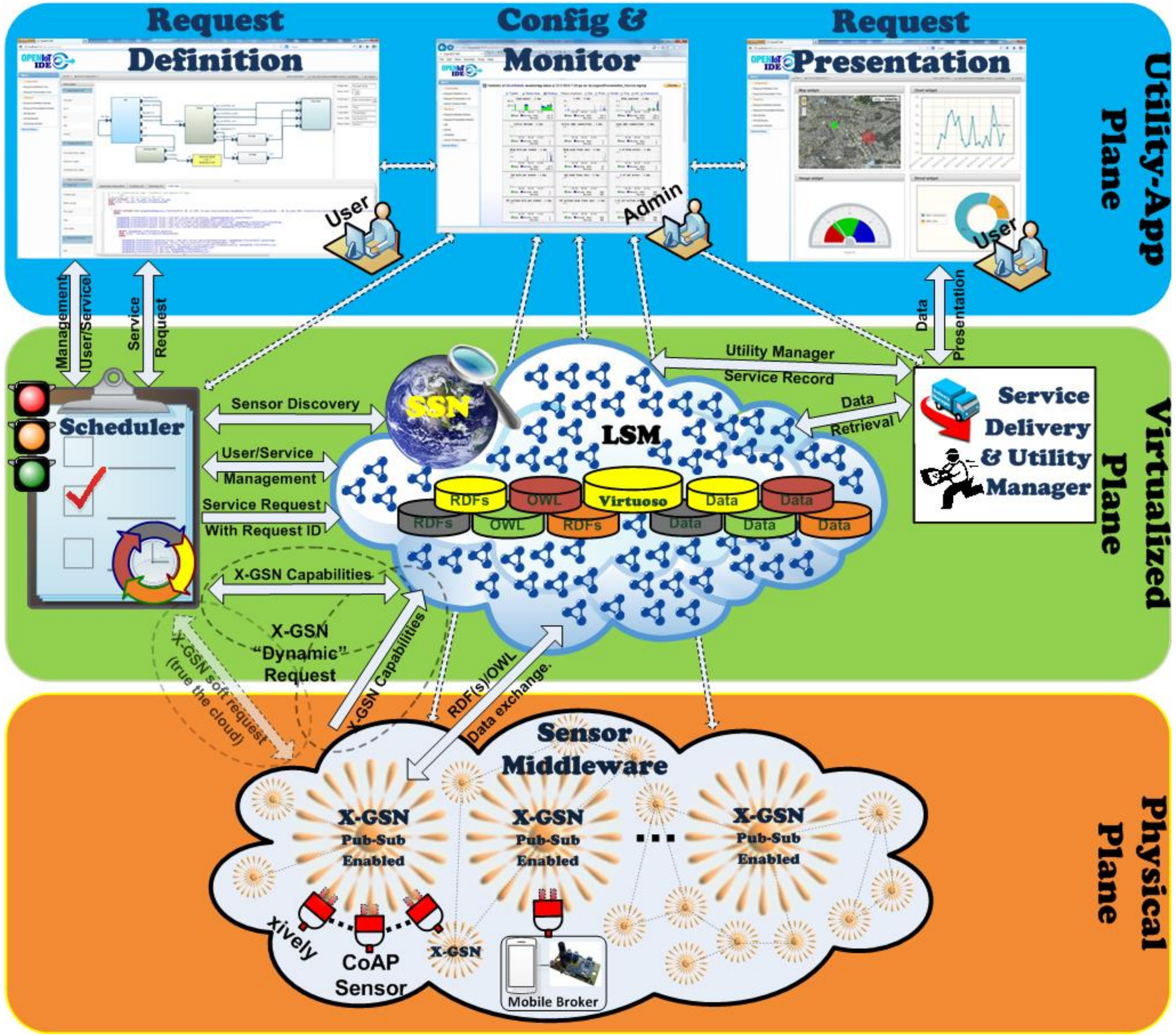


Semantic Standards for sensors provide a uniform way of representing and reasoning over heterogeneous data streams

OpenIoT (openiot.eu) Open source semantic interop

- Open Source IoT project enabling
  - Sensing-as-a-Service & dynamic formulation and deployment of IoT services
  - Semantic unification & interoperability across IoT data streams
  - Available at https://github.com/OpenIotOrg/openiot
- All streams are annotated based on the W3C Semantic Sensor Networks (ontology)





H2020 FIESTA: Testbeds Interoperability www.fiesta-iot.eu

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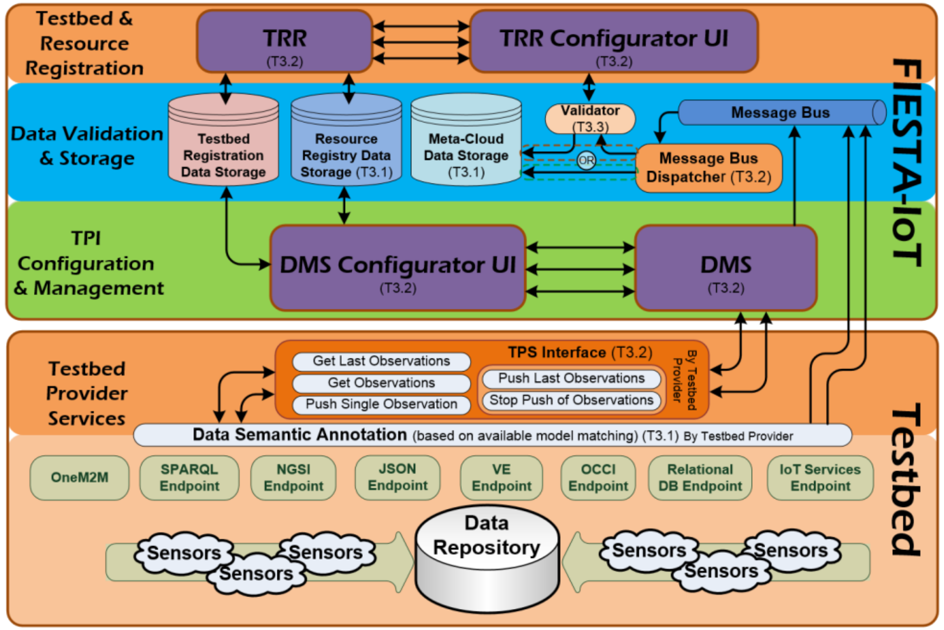
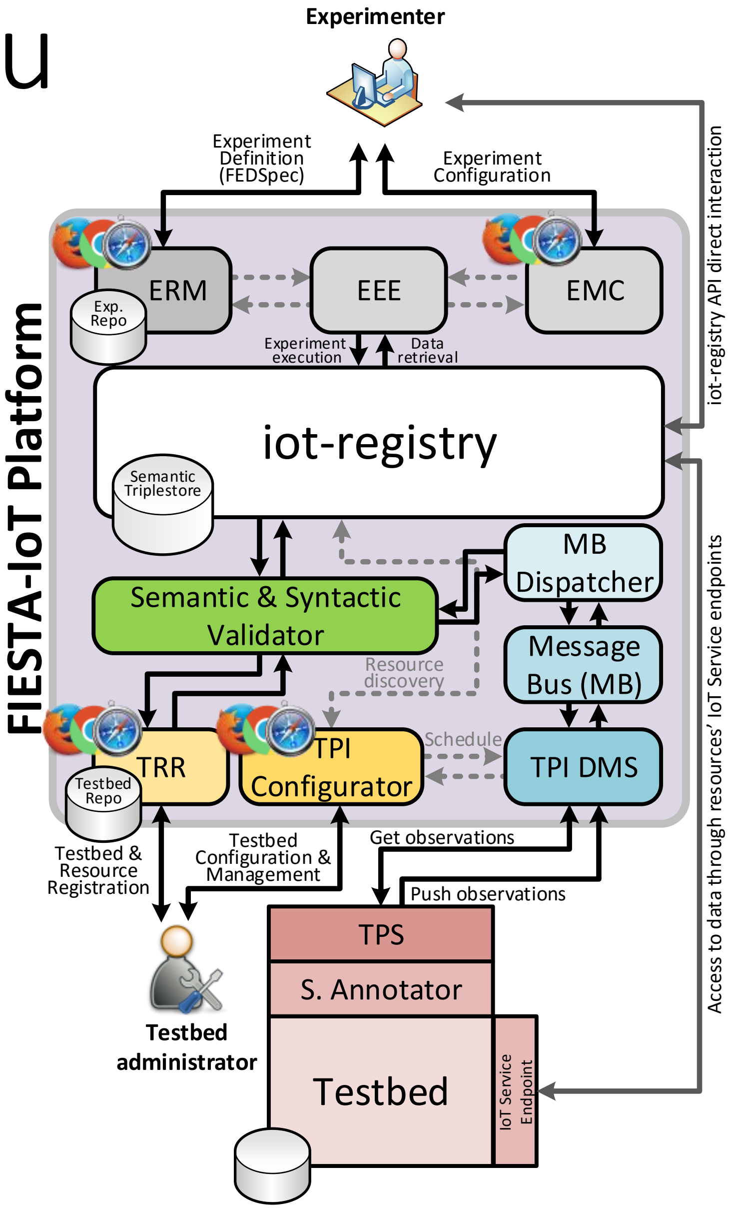
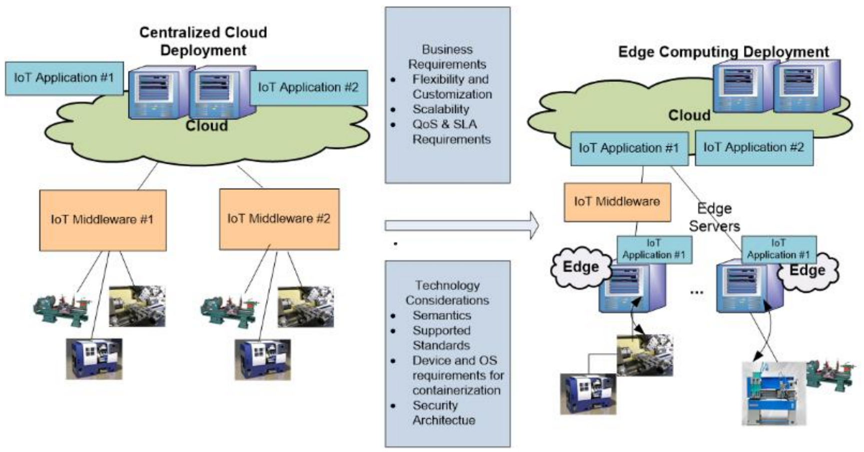




FIESTA Open Calls: http://fiesta-iot.eu/index.php/opencall/

Edge (fog) Computing



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Limitations of Cloud Computing

- Waste of Bandwidth
- Network latency
- Insufficient use of resources
- Limited flexibility in privacy protection

Edge Computing

- Move IoT data processing and actuation to the edge of the network
- Introduce a layer of gateways (Edge Nodes) between the Cloud and the IoT devices

Edge Node Types

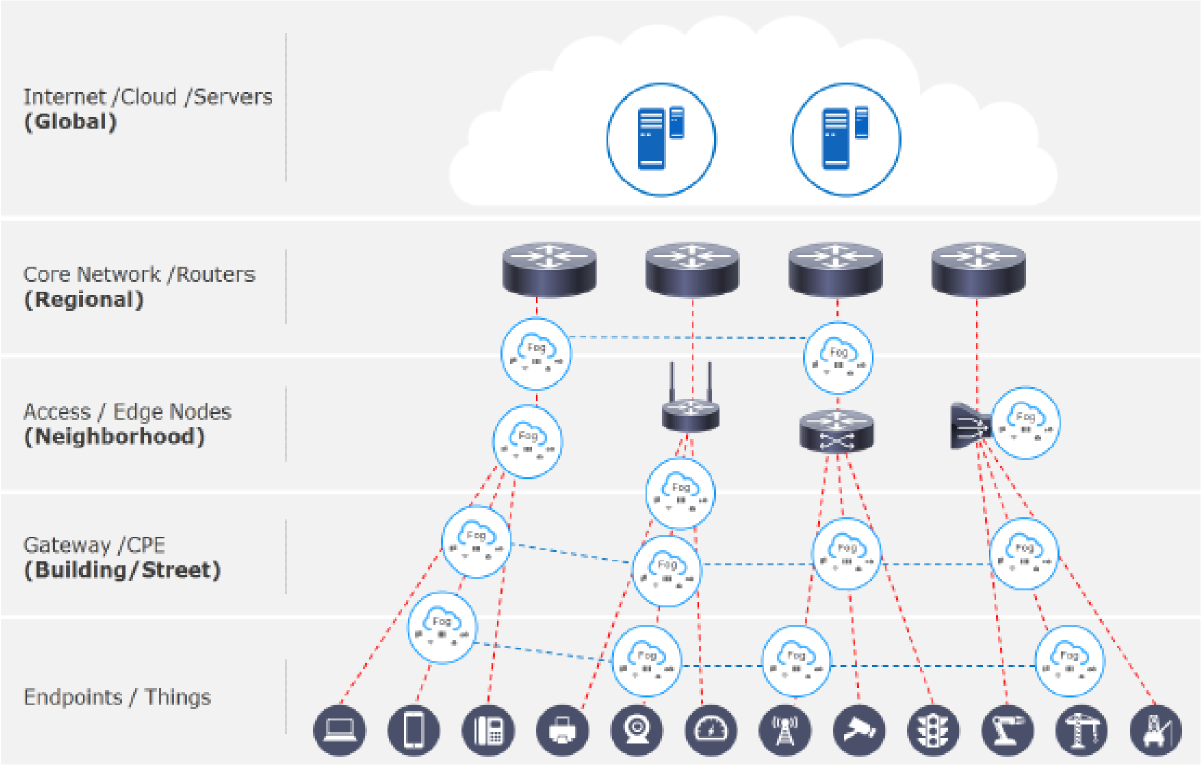
- Depend on the scale and the nature of the deployment
- Embedded controllers or IoT devices with processing capability
- Computers
- Clusters or small-scale data centers

Benefits

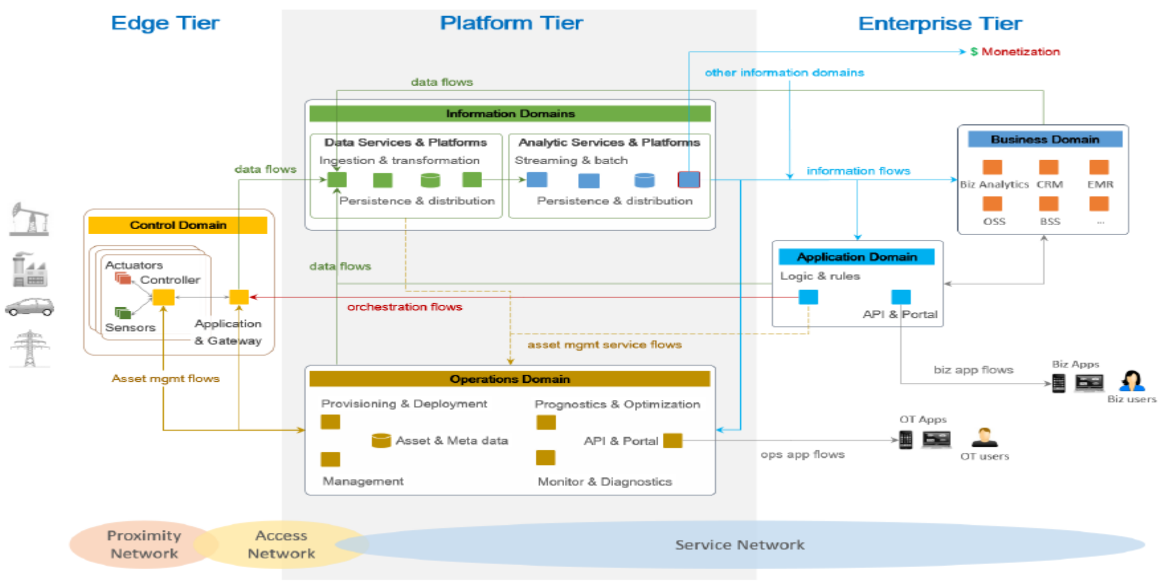
- Reduced latency for real-time applications
- Efficient use of bandwidth and storage resources
- Improved scalability
- Reduction in costs and energy consumption
- Better privacy control

IoT Reference Architectures are Edge-based

OpenFog Reference Architecture (February 2017)

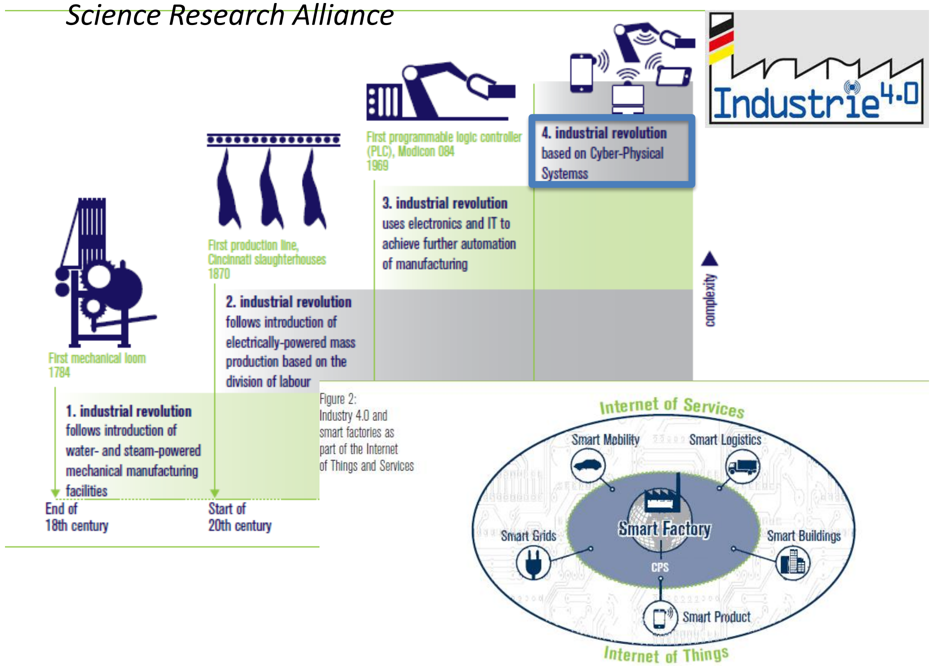


Industrial Internet Consortium Reference Architecture (July 2015)



Rise of Smart Objects in IoT

Source: *Recommendations for implementing the strategic initiative INDUSTRIE 4.0 by The Industry-Science Research Alliance*



Smart Objects

- Objects with semi-autonomous behavior
- Can connect to the internet and IoT/cloud platforms
- Emphasize on Field Actuation & Control
- Examples: Industrial Robots, Socially Assistive Robot, Smart Pumps, Smart Wearables, Drones

Why Smart Objects? – Driving Trends

- Evolution of deep learning & AI
- BigData trends & ability to process arbitrarily large data sets
- Rise of Industry 4.0 and Cyber-Physical Systems
- “Killer” Applications like self-driving vehicles

Challenges of Smart Objects

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Scalability & Reliability

- Single Cloud Registry Challenged in terms of scalability
- Dynamism of Smart Objects (e.g., mobility)
- Need for more decentralized approach

Changes in IoT Architectures

- Changes to Edge Computing & Mobile-Edge Architectures
- Distributed State Management for multiple objects and state sharing

Security

- Dynamic behaviors introduce new security challenges
- Unpredictability & dynamism can be hardly addressed based on static security mechanisms and reactive measures only

Scalability and Reliability for SO: Blockchain

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Blockchain Concepts

- No central authority
- Distributed ledger - a shared record of transactions
- Trust through immutable, time-stamped records
- Keeping track of transactions and preventing “double spending”- A series of blocks of data, chained together cryptographically using “hashes”
- “Proof of work” by “miners” who secure transactions into the chain of blocks by performing difficult computations

Smart Contracts

- Computer algorithms can be written to automatically execute the terms of a contract
- E.g., Company X pay $1,000 to Company Y when shipping company provides proof of delivery of Package A to Company X
- Blockchain distributed ledgers can be used to not only store the proof of delivery record, but instructions on what to do (terms of the contract) and scripts to execute the instructions

Smart Objects Interactions

- Enabling semi-autonomous interactions between smart objects
- Modelling of Interaction as “smart contracts”
- Introduction of Ledger Services to enable the smart contracts between internet connected objects

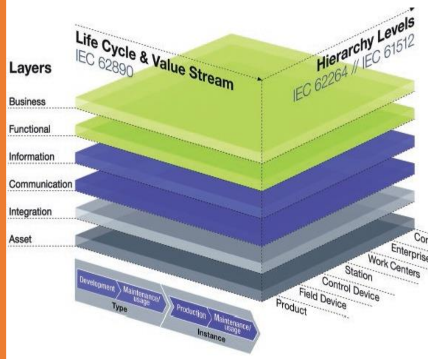
Example: H2020 FAR-EDGE (www.far-edge.eu) – Factory Automation based on Edge Computing & Ledger Services

FAR-EDGE = Joint effort of global leaders in manufacturing and IoT towards adoption of *virtualized* Factory Automation

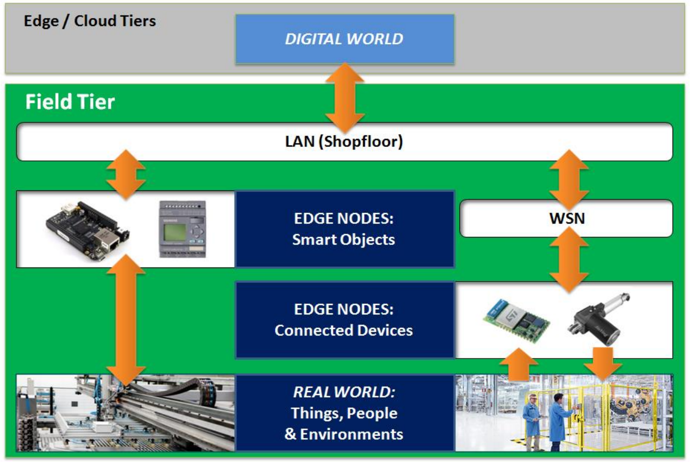
- Cloud and Edge Computing for Manufacturing
- Decentralization of control
- RAMI 4.0 & Industrial Internet standards

Expected Outcomes

- Reduced Time to deploy new automation concepts and technologies (e.g., 3D printers)
- Better Exploitation of Data
- Increase automation in factories
- Improve process agility
- Enable x-factory collaboration
- RAMI Compliant Implementation



FAR-EDGE Aligns to RAMI4.0: Common Language for I4.0 (work-in-progress)



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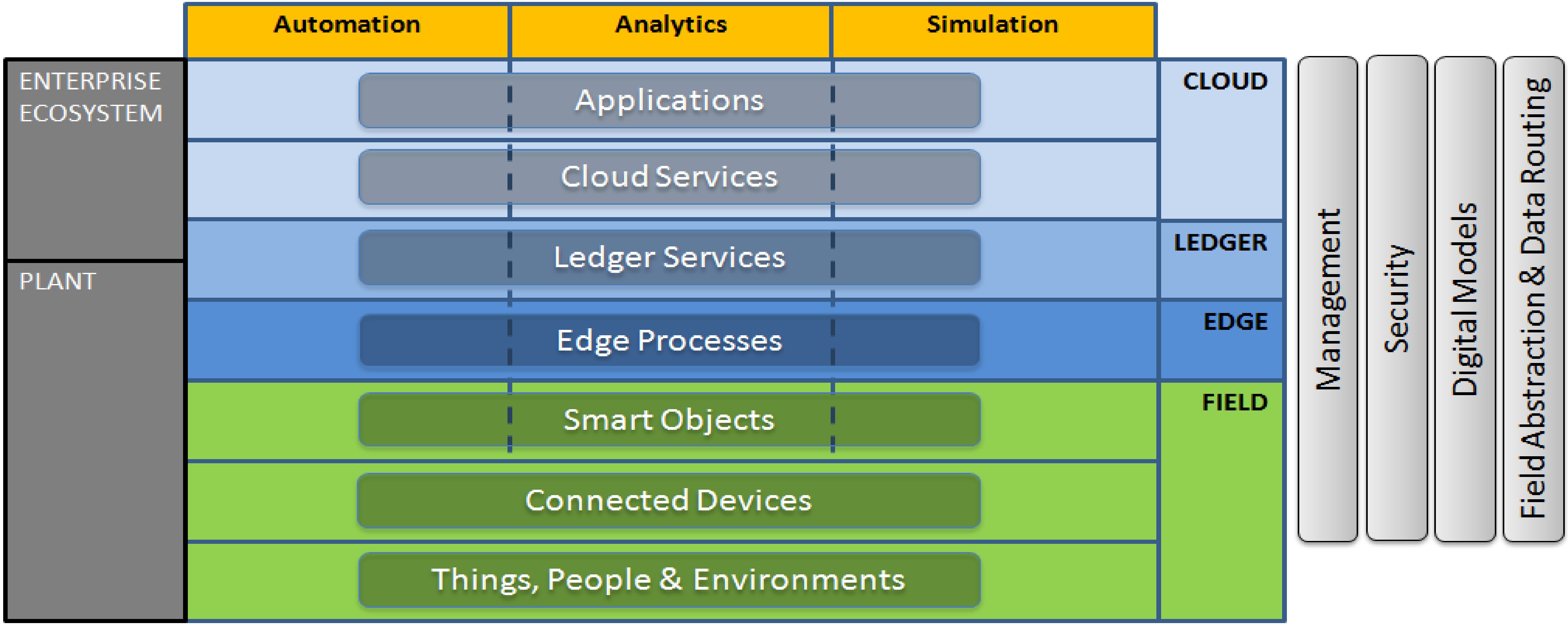
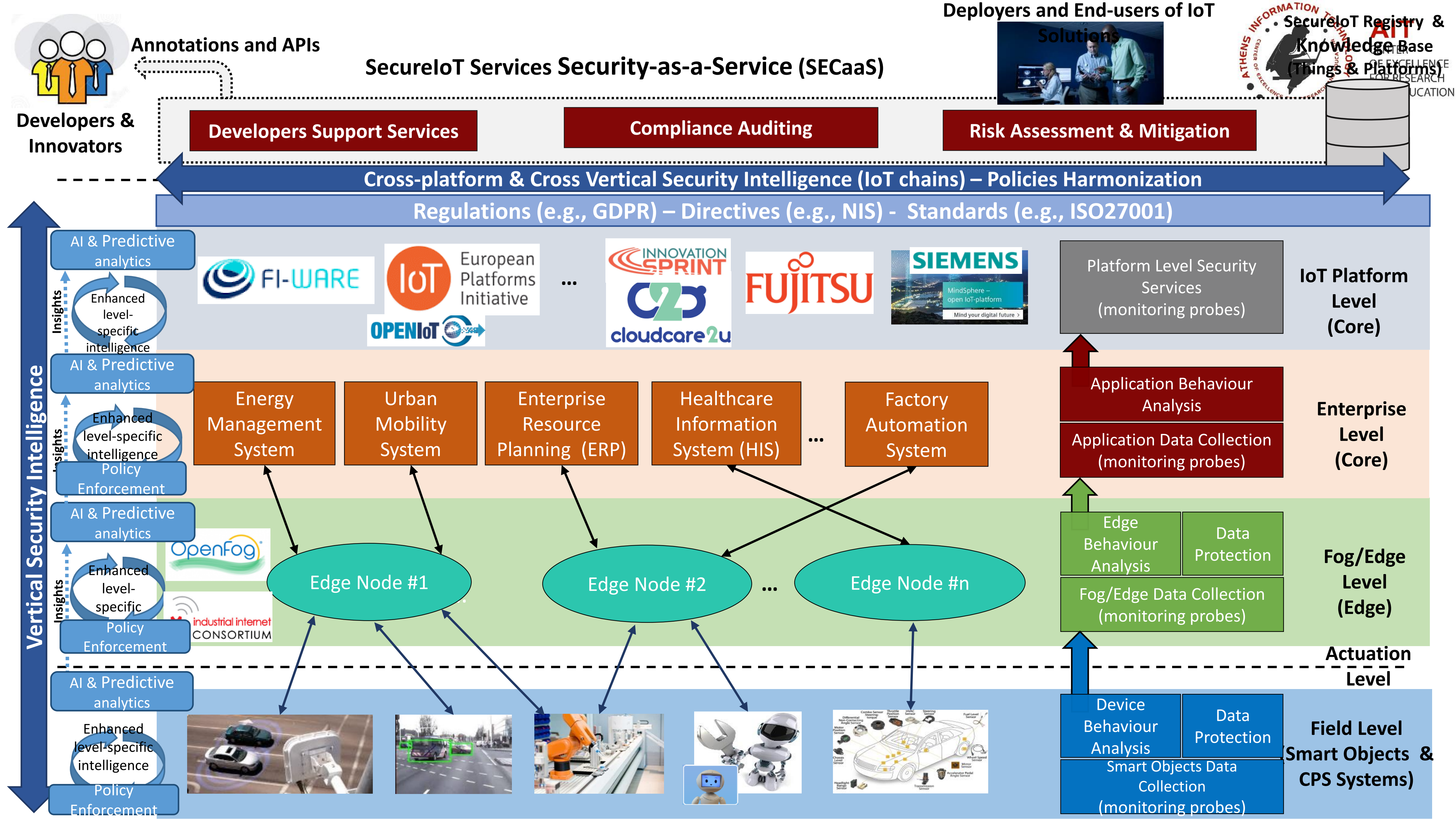
FAR-EDGE Reference Architecture



IoT & Smart Objects Security: H2020 SecureIoT

- Leverage AI techniques (deep learning) towards anticipating security attacks
- Based on data collection at multiple levels (smart object, device, fog/edge, cloud)
- Provide AI-based security applications and measures:
  - Risk assessment
  - Compliance to directives
  - Support for secure IoT programming



Annotations and APIs
Developers & Innovators
SecureIoT Services Security-as-a-Service (SECaaS)
Deployers and End-users of IoT Solutions
SecureIoT Registry & Knowledge Base (Things & Platforms)
Developers Support Services
Compliance Auditing
Risk Assessment & Mitigation
Cross-platform & Cross Vertical Security Intelligence (IoT chains) – Policies Harmonization
Regulations (e.g., GDPR) – Directives (e.g., NIS) - Standards (e.g., ISO27001)
Vertical Security Intelligence
AI & Predictive analytics
Insights
Enhanced level-specific intelligence
Policy Enforcement
FI-WARE
IoT European Platforms Initiative
OPENIoT
INNOVATION SPRINT
cloudcare2u
FUJITSU
SIEMENS
MindSphere – open IoT-platform
Mind your digital future
Platform Level Security Services (monitoring probes)
IoT Platform Level (Core)
Energy Management System
Urban Mobility System
Enterprise Resource Planning (ERP)
Healthcare Information System (HIS)
Factory Automation System
Application Behaviour Analysis
Application Data Collection (monitoring probes)
Enterprise Level (Core)
OpenFog
industrial internet CONSORTIUM
Edge Node #1
Edge Node #2
Edge Node #n
Edge Behaviour Analysis
Data Protection
Fog/Edge Data Collection (monitoring probes)
Fog/Edge Level (Edge)
Actuation Level
Device Behaviour Analysis
Data Protection
Smart Objects Data Collection (monitoring probes)
Field Level (Smart Objects & CPS Systems)