Internet of Things Reference Architectures

trying not to get lost in the jungle

Alessandro Bassi

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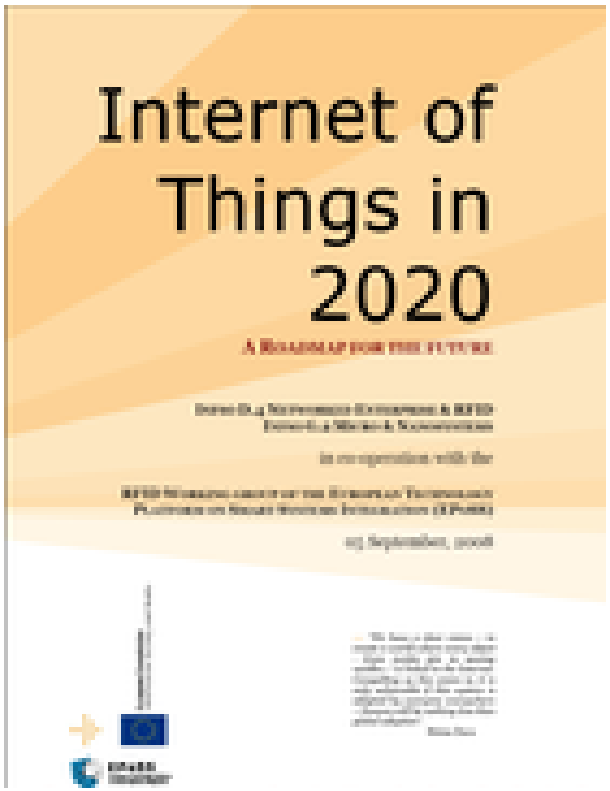
March 17, 2017

Outline

Practical Infos - Who am I? Why am I here?



Beyond RFID: The Internet of Things

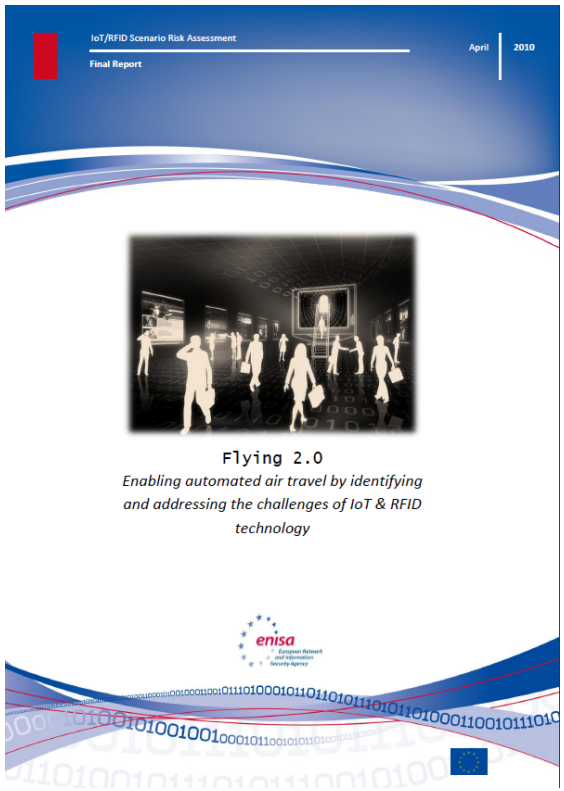
- Joint EU-EPoSS Workshop (held in Feb 2008)
- more than 80 experts discussing for 2 days on 4 areas: People, Vision, Technology, Processes

Practical Infos - Who am I? Why am I here?

Technical Coordinator of ioT-A (lighthouse Project for Objective 1.3 - Internet of Things)

- 18.6 M EUR Budget
- Heavy industrial participation (Siemens, IBM, NEC, Alcatel-Lucent, Telefonica, SAP, ...)
- Main Objective, to realise a Reference Architectural Model for the IoT (from INTRAnets of Things to INTERnet of Things)

Practical Infos - Who am I? Why am I here?



Expert for ENISA on risks related to IoT Technology (Flying 2.0)

- Risks related to adoption of IoT Technologies in different aspects of everyday's life
- Identification of threats, risks and vulnerabilities and suggestions for policymakers

Practical Infos - Who am I? Why am I here?

Official Journal of the European Union

COMMISSION DECISION

of 10 August 2010

setting up the Expert Group on the Internet of Things

(2010/C 217/08)

Expert for the EU Commission on IoT

- Helping policymakers at EU Parliament
- First topics Privacy/Security and Governance of IoT

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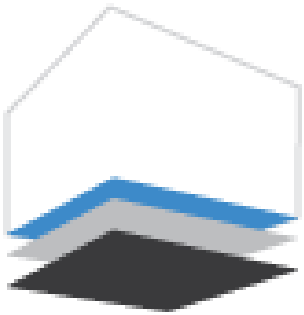
What is the "Internet of Things"?



Postscapes™

Tracking the Internet of Things

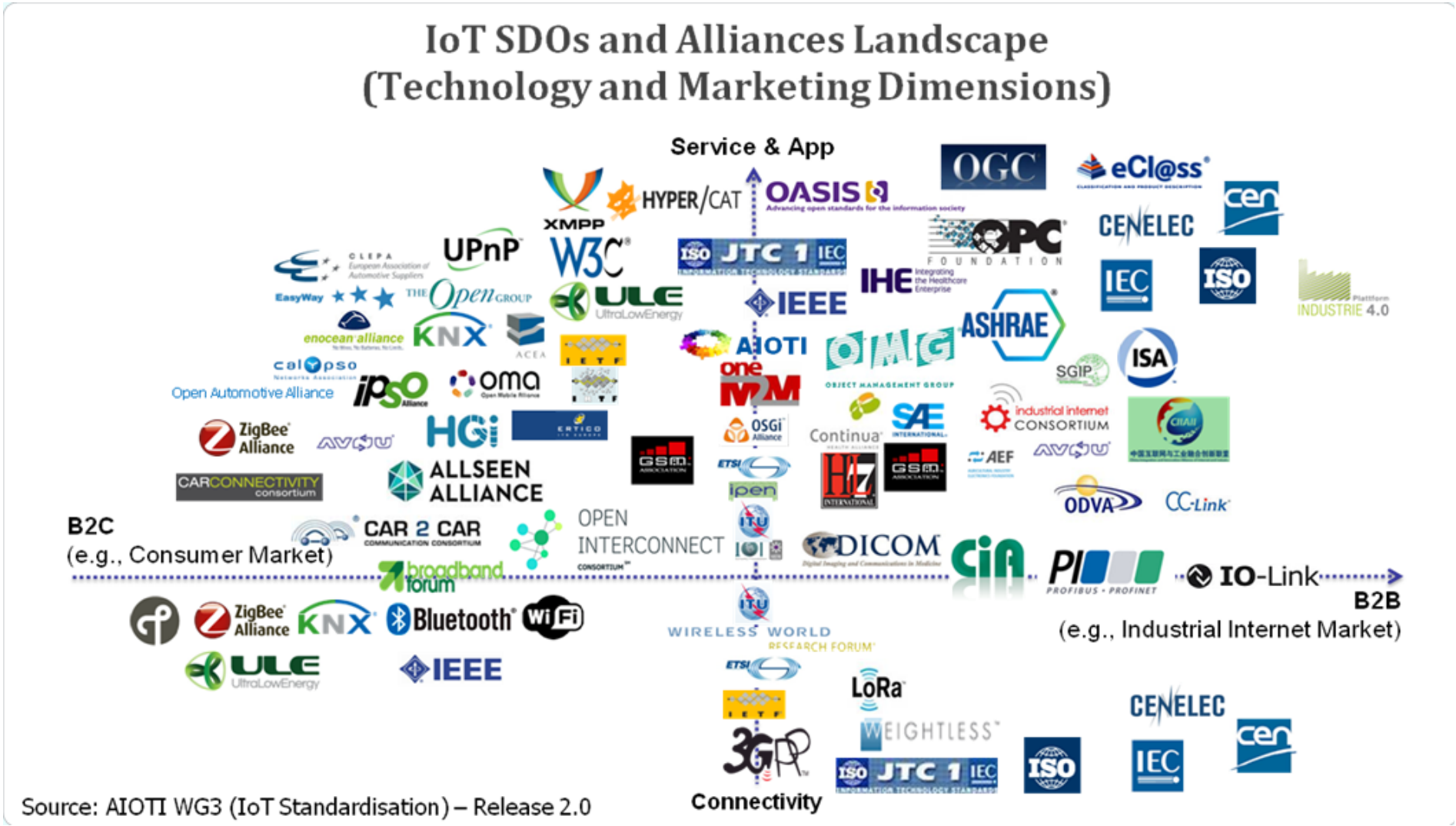
40+ definitions ....

Pick your own definition is ...

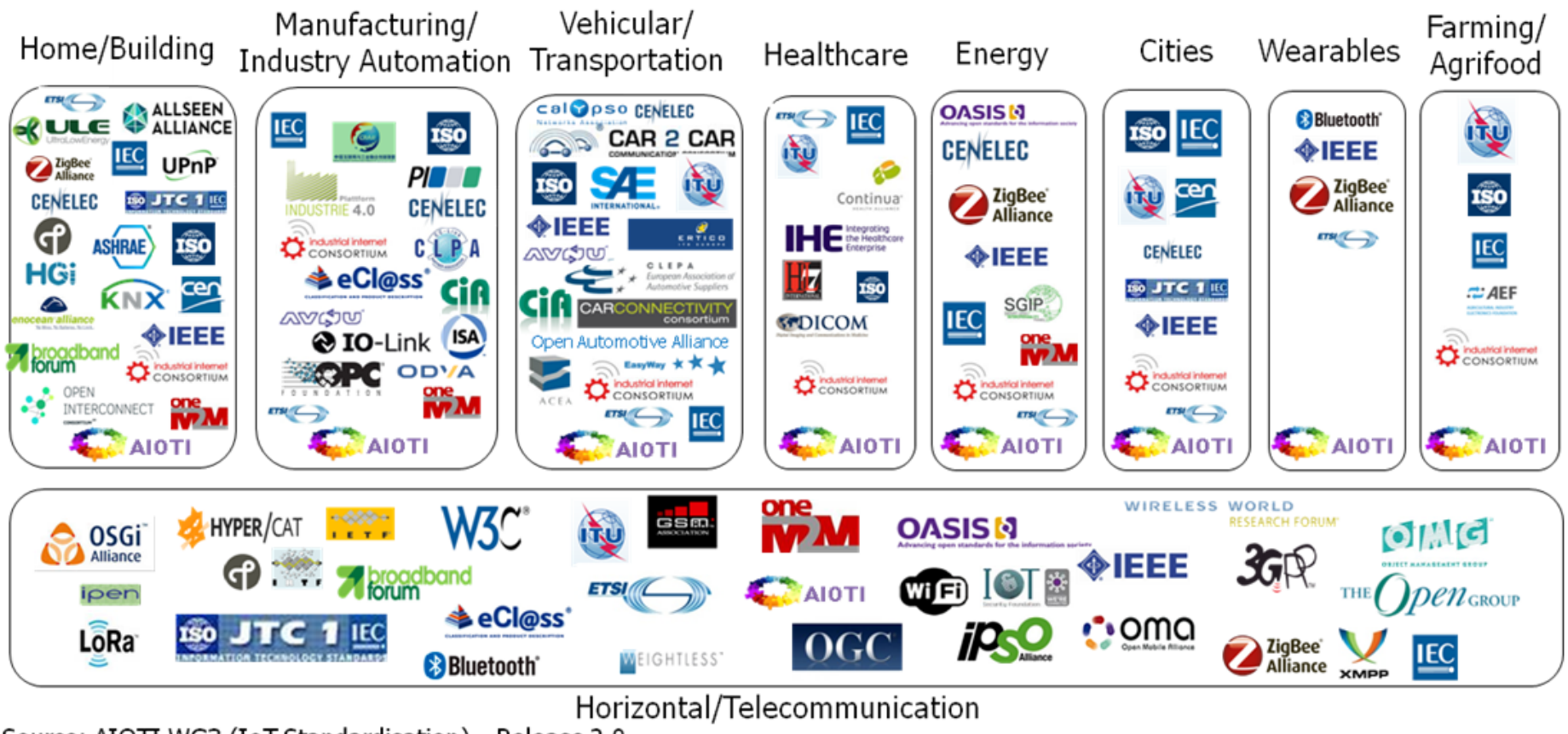
1. 2 pots of yogurt talking with each other
2. Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental and user contexts
3. Combination of item identification (RFID), detection (sensors) and interaction (nanoactuators) of environmental changes
4. The IoT is the superset of all objects that are uniquely identifiable and for which is possible to specify a semantic and a behaviour
5. etc etc ....

Outline

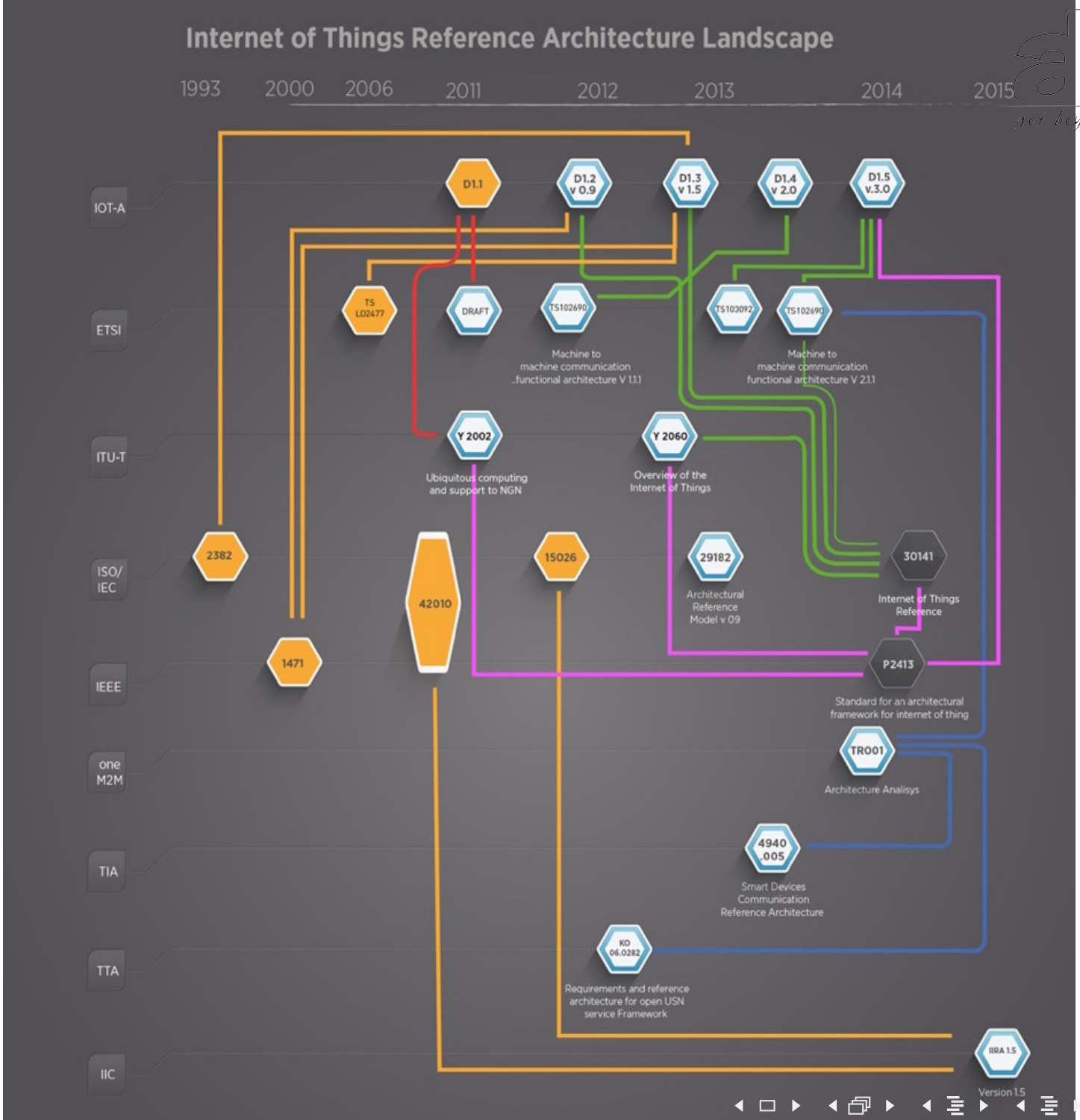
AIOTI WG3 IoT standardization landscape



Many related vertical and horizontal activities



Source: AIOTI WG3 (IoT Standardisation) – Release 2.0


Internet of Things Reference Architecture Landscape
1993
2000
2006
2011
2012
2013
2014
2015
IOT-A
ETSI
ITU-T
ISO/ IEC
IEEE
one M2M
TIA
TTA
IIC
D1.1
D1.2 v 0.9
D1.3 v 1.5
D1.4 v 2.0
D1.5 v.3.0
TS L02477
DRAFT
TS102690
Machine to machine communication ..functional architecture V 1.1.1
TS103092
TS102690
Machine to machine communication functional architecture V 2.1.1
Y 2002
Ubiquitous computing and support to NGN
Y 2060
Overview of the Internet of Things
2382
42010
15026
29182
Architectural Reference Model v 09
30141
Internet of Things Reference
1471
P2413
Standard for an architectural framework for internet of thing
TR001
Architecture Analisys
4940 .005
Smart Devices Communication Reference Architecture
KO 06.0282
Requirements and reference architecture for open USN service Framework
IIRA 1.5
Version 1.5

Outline

IoT-A Fact Sheet

- Flagship FP7 IP project,call 5, Objective 1.3
- Total Budget 18.6 M EUR
- 17 Partners from 8 EU countries
- Coordinator: Gunter Kuelzhammer
- Technical Coordinator: Alessandro Bassi
- Start Date: Sept 1st, 2010
- Duration: 39 months.

IoT Domain - 2010 status

Vertical silos

- Fragmented architectures, no coherent unifying concepts, solutions exist only for specific application silos.
- No coherent approaches to implement the IoT have been proposed, yet.
- Many island solutions do exist (RFID, Sensor nets, etc.).
- Little cross-sectorial re-use of technology and exchange of knowledge.
- The development is geared towards **Intranets** of Things.

Introducing the IoT-A tree:

- a generic Reference Model, derived from Business considerations, application-based requirements and current technologies,
- able to generate different Reference architectures depending on domain-specific requirements,
- to be used as a blueprint for concrete architecture design.

Definitions

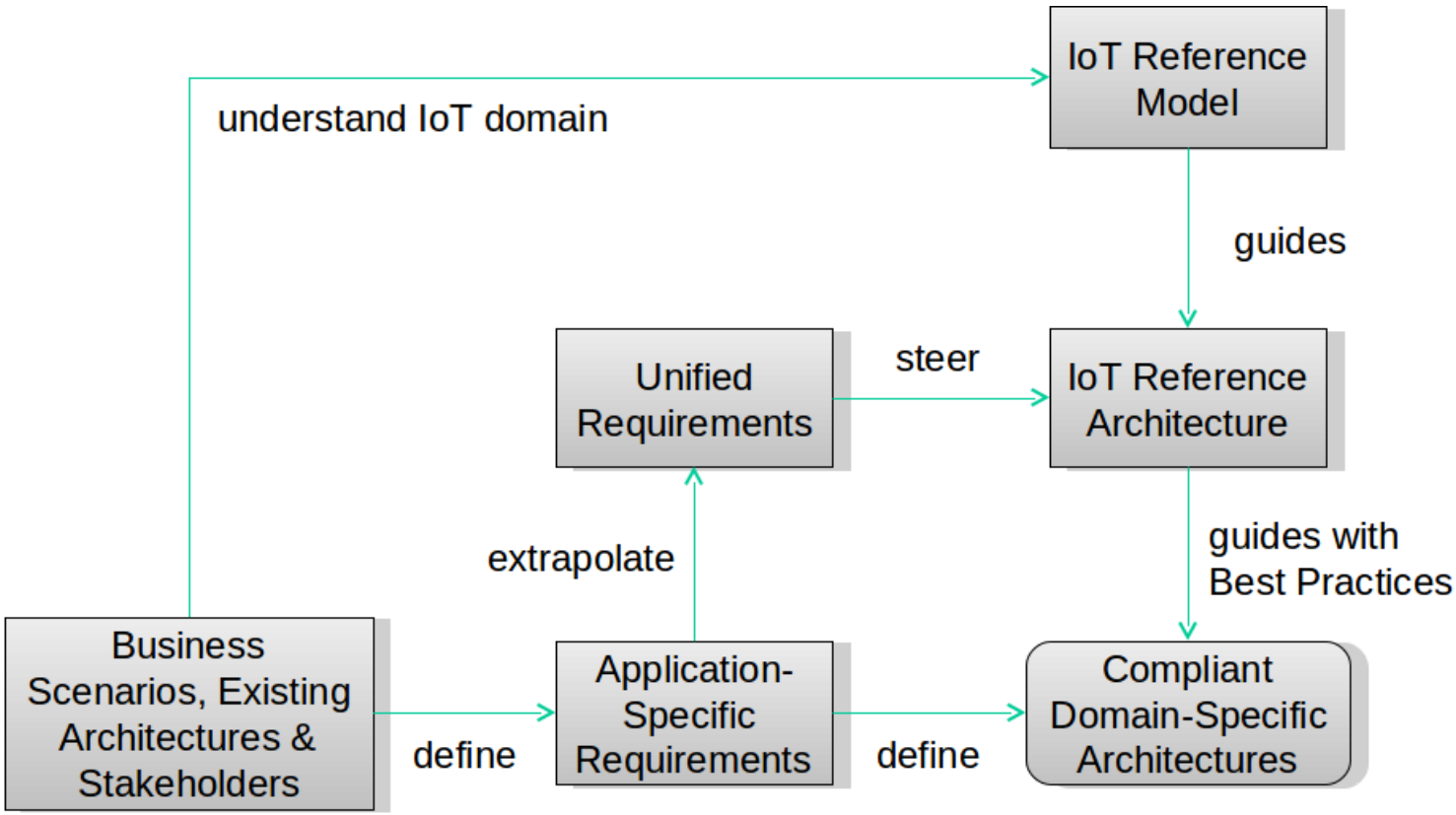
Reference Model

A Reference Model is an **abstract framework** for **understanding significant relationships** among the entities of some environment. It **enables the development of specific reference architectures**. A Reference Model consists of a **minimal set of unifying concepts, axioms and relationships**

Reference Architecture

A Reference Architecture is an **architectural design pattern** that indicates how an abstract set of relationships realises a set of requirements. The **main purpose** of a RA is to **provide guidance** for the development of concrete architectures. More reference architectures may be derived from a common reference model.

Architectural Reference Model



Alessandro Bassi · Martin Bauer · Martin Fiedler · Thorsten Kramp · Rob van Kranenburg
Sebastian Lange · Stefan Meissner *Editors*

Enabling Things to Talk

Designing IoT solutions with the IoT Architectural Reference Model

The Internet of Things (IoT) is an emerging network superstructure that will connect physical resources and actual users. It will support an ecosystem of smart applications and services bringing hyper-connectivity to our society by using augmented and rich interfaces. Whereas in the beginning IoT referred to the advent of barcodes and Radio Frequency Identification (RFID), which helped to automate inventory, tracking and basic identification, today IoT is characterized by a dynamic trend toward connecting smart sensors, objects, devices, data and applications. The next step will be "cognitive IoT," facilitating object and data re-use across application domains and leveraging hyperconnectivity, interoperability solutions and semantically enriched information distribution.

The Architectural Reference Model (ARM), presented in this book by the members of the IoT-A project team driving this harmonization effort, makes it possible to connect vertically closed systems, architectures and application areas so as to create open interoperable systems and integrated environments and platforms. It constitutes a foundation from which software companies can capitalize on the benefits of developing consumer-oriented platforms including hardware, software and services.

The material is structured in two parts. Part A introduces the general concepts developed for and applied in the ARM. It is aimed at end users who want to use IoT technologies, managers interested in understanding the opportunities generated by these novel technologies, and system architects who are interested in an overview of the underlying basic models. It also includes several case studies to illustrate how the ARM has been used in real-life scenarios. Part B then addresses the topic at a more detailed technical level and is targeted at readers with a more scientific or technical background. It provides in-depth guidance on the ARM, including a detailed description of a process for generating concrete architectures, as well as reference manuals with guidelines on how to use the various models and perspectives presented to create a concrete architecture. Furthermore, best practices and tips on how system engineers can use the ARM to develop specific IoT architectures for dedicated IoT solutions are illustrated and exemplified in reverse mapping exercises of existing standards and platforms.

Computer Science

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Bassi · Bauer · Fiedler
Kramp · van Kranenburg
Lange · Meissner *Eds.*

Enabling Things to Talk

abc
get beyond formulæ

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Editors

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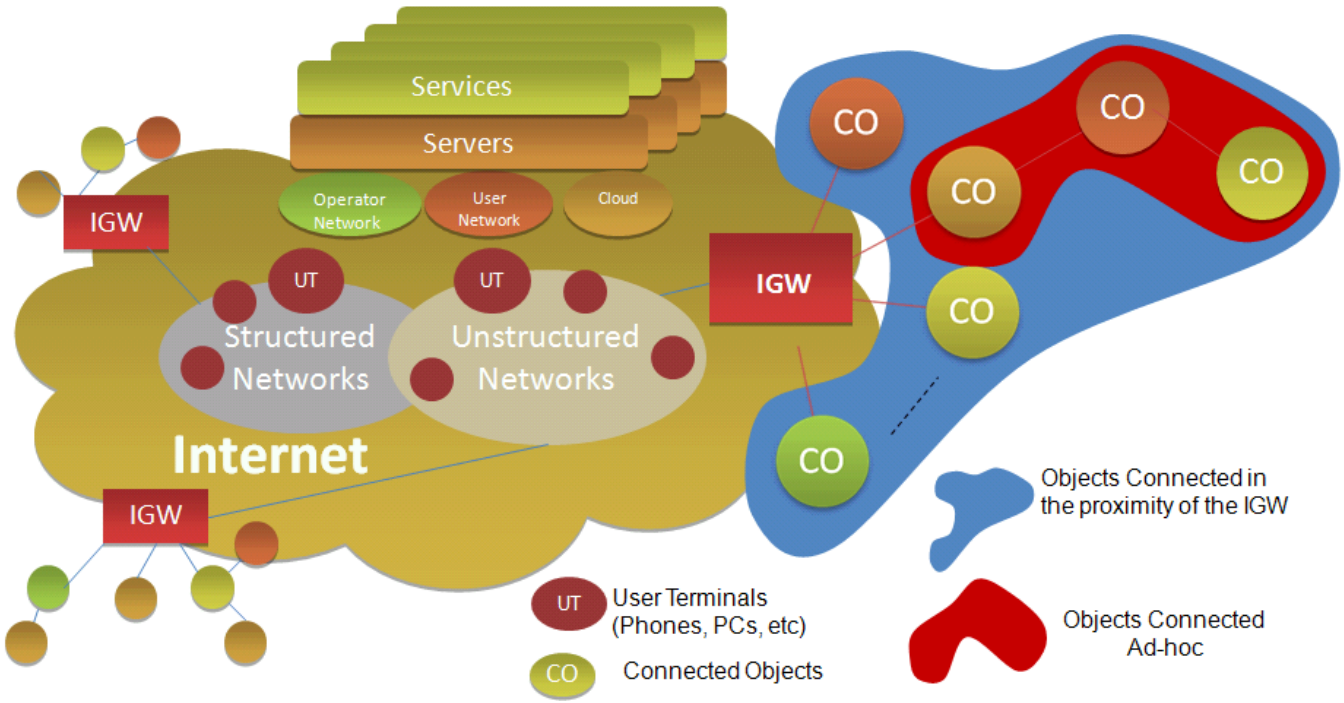
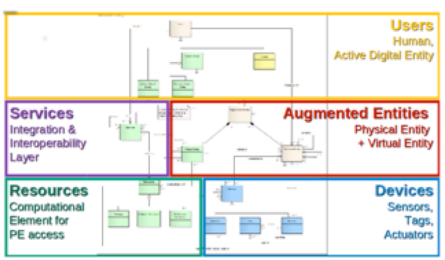
IoT-A
Internet of Things - Architecture

Springer Open

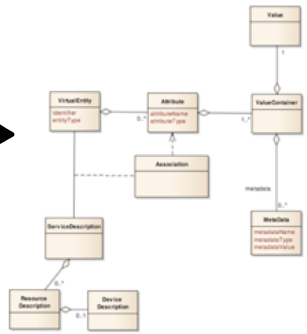
Heterogeneous Architectures



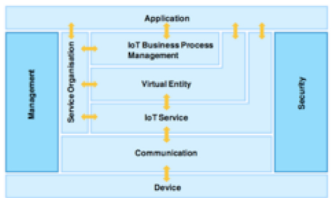
IoT-A reference model



Domain Model



Information Model

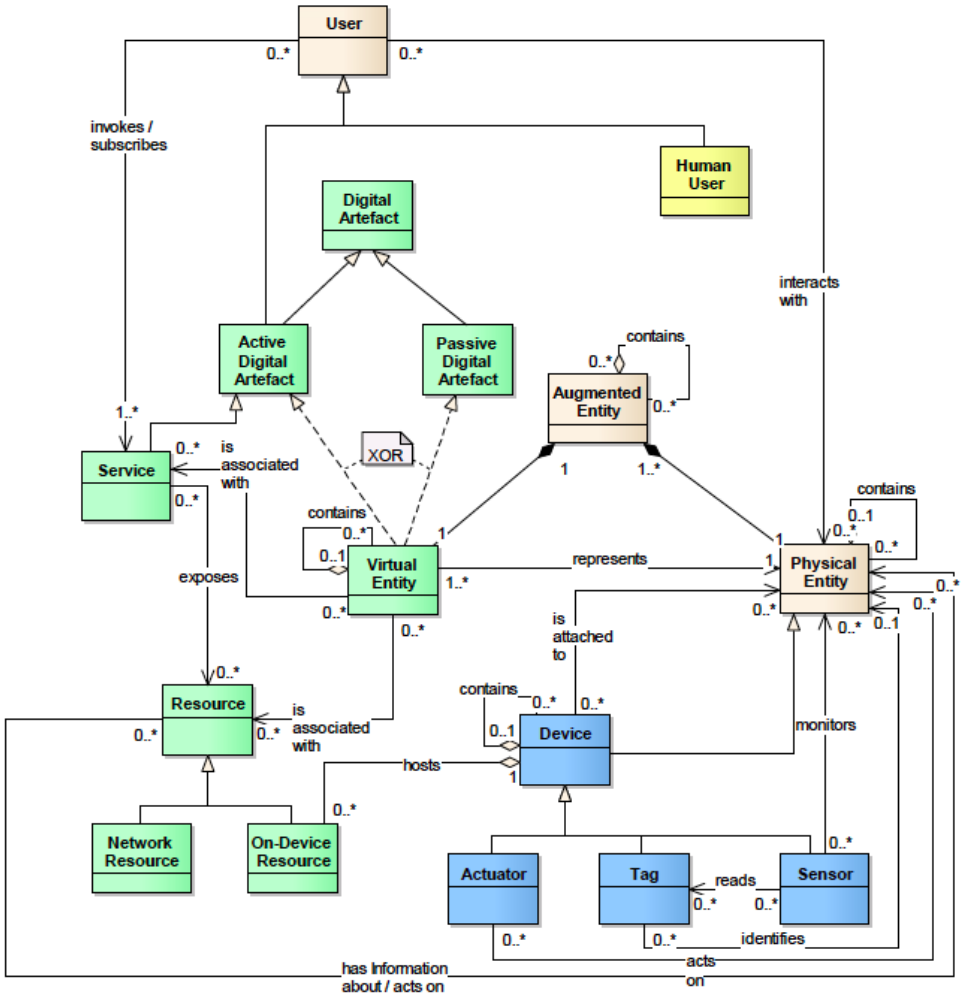


Functional Model

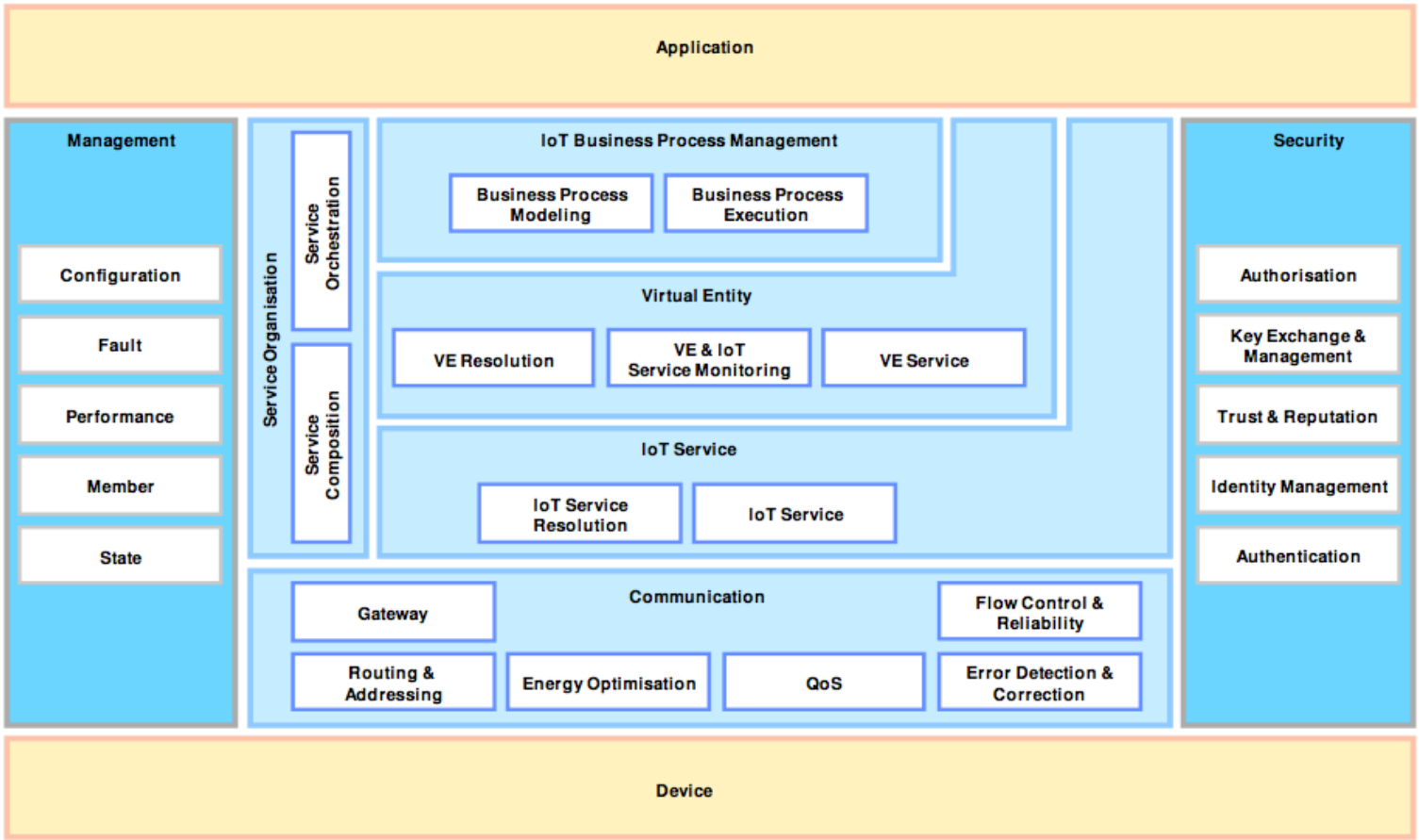
Communication Model

Security Model

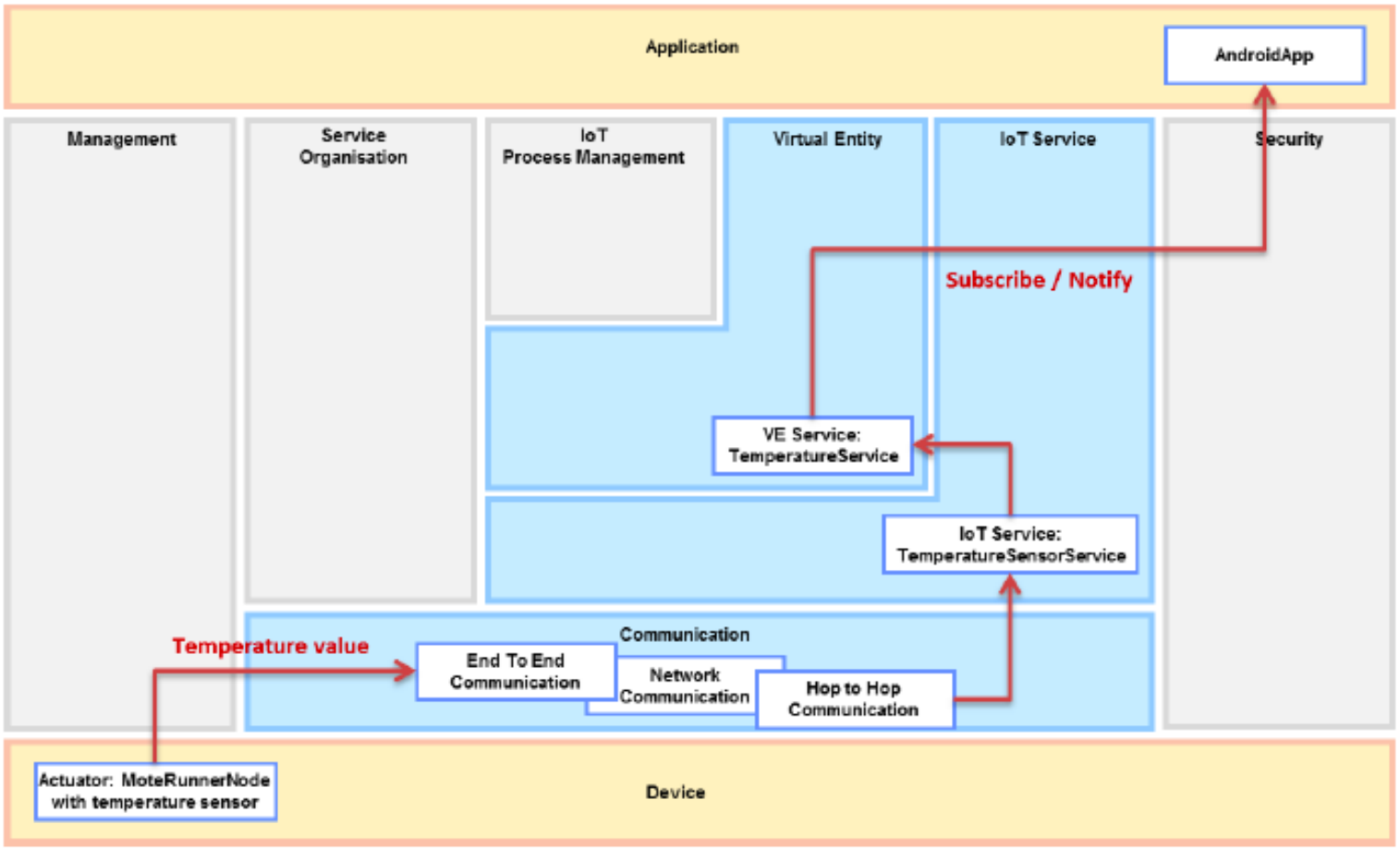
Domain Model



Functional Model



Functional Model

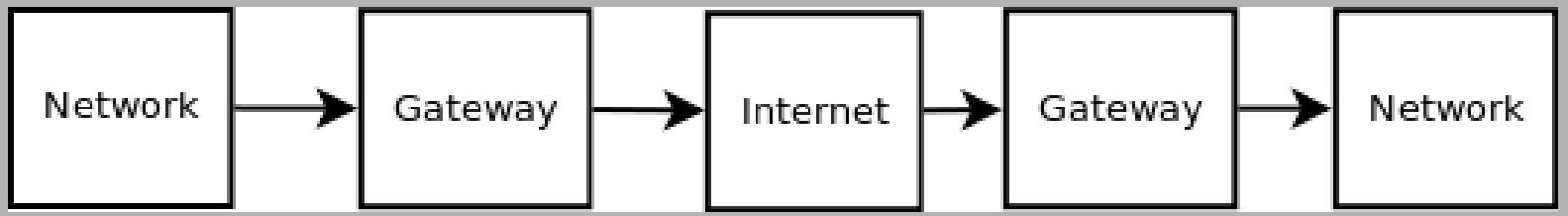


Matching views and perspectives

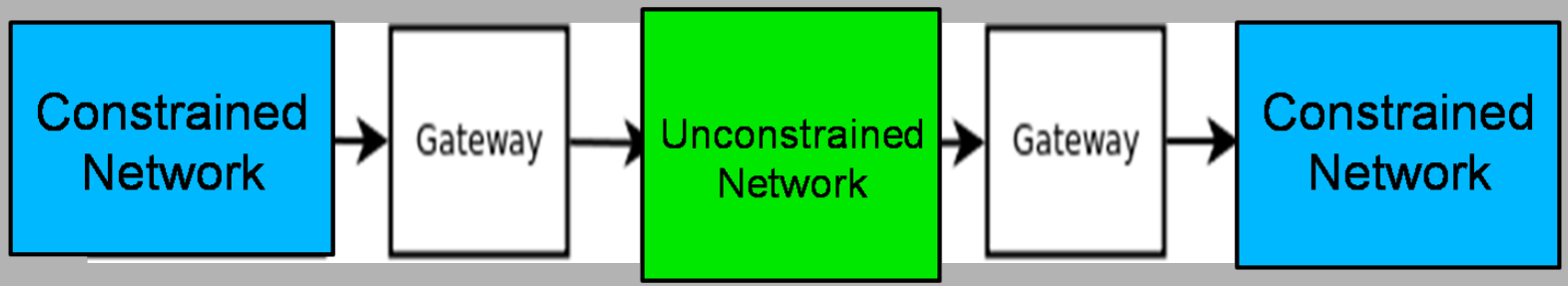
Topic	Design Choice	Impact on: Trust, Security & Privacy	Performance & Scalability	Availability & Resilience	Evolution & Interoperability
IoT Business Process Management / Application support	DC1.1 Business Process Modelling according to BPMN 2.0	+/-	+	+	+
	DC1.2 Business Process Execution by BPMN 2.0 execution engine	+/-	+	+	+
Service Organisation	DC2.1 Service Orchestration with mandatory security	+/-	0	+	0
	DC2.2 Service Orchestration with optional security	-	0	-	0
VE Resolution	DC3.1 VE Resolution with mandatory security	+/-	0	+	0
	DC3.2 VE Resolution with optional security	-	0	-	0
	DC3.3 VE Resolution with QoS	0	0	+	0
	DC3.4 VE Resolution domain-oriented	+	+	+	+
	DC3.5 VE Resolution location-oriented	-	+	+/-	+/-
	DC3.6 Resolution Semantic Web-oriented	0	0	+	+/-

Communication Model: Channel Analysis

Standard Internet Model



IoT Model



Outline

oneM2M

oneM2M is a specification for an M2M service layer being standardised by a range of national and regional SDOs in the hope that this will lead to a single global standard (as occurred with 3GPP for cellular). Partner standard organisations include

- ARIB (Japan)
- ATIS (America)
- CCSA (China)
- ETSI (Europe)
- TIA (America)
- TTA (Korea)
- TTC (Japan)

oneM2M, current Specifications

Published Specifications

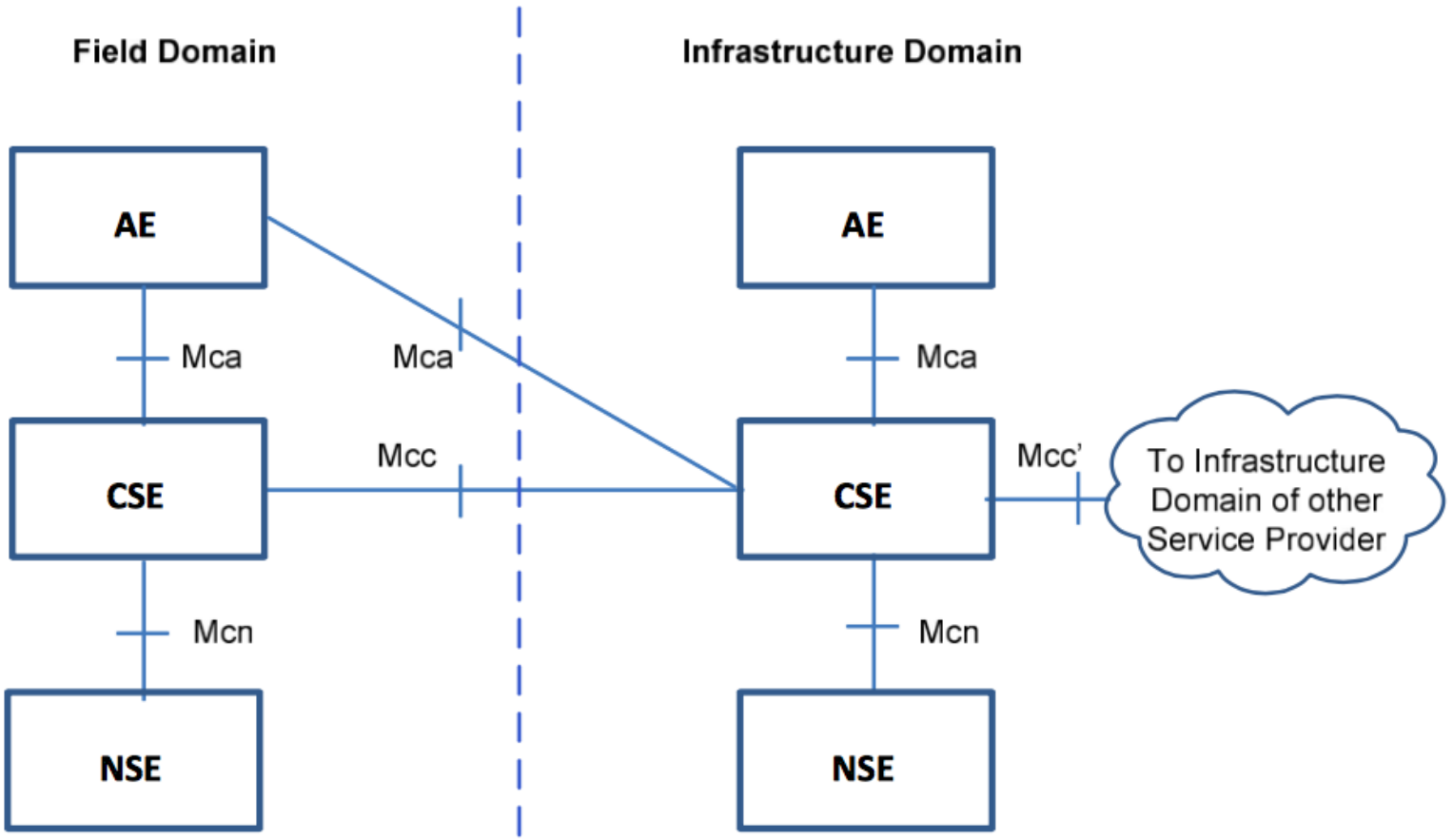
As we publish new specifications, they will appear here or on release-specific pages.

Print

oneM2M Release 2 specifications

Latest	Reference	Version	Title	Date	ARIB	ATIS	CCSA	ETSI	TIA	TSDSI	TTA	TTC
★	TS 0001	2.10.0	Functional Architecture	08/2016				TS 118 101 V.2.10.0				TS-M2M-0001v2.10.0
★	TS 0002	2.7.1	Requirements	08/2016				TS 118 102 V2.7.1				TS-M2M-0002v2.7.1
★	TS 0003	2.4.1	Security Solutions	08/2016				TS 118 103 V2.4.1				TS-M2M-0003v2.4.1
★	TS 0004	2.7.1	Service Layer Core Protocol	08/2016				TS 118 104 V2.7.1				TS-M2M-0004v2.7.1
★	TS 0005	2.0.0	Management Enablement (OMA)	08/2016				TS 118 105 V2.0.0				TS-M2M-0005v2.0.0
★	TS 0006	2.0.1	Management Enablement (BBF)	08/2016				TS 118 106 V2.0.1				TS-M2M-0006v2.0.1
★	TS 0007	2.0.0	Service Components	08/2016								TS-M2M-0007v2.0.0
★	TS 0009	2.6.1	HTTP Protocol Binding	08/2016				TS 118 109 V2.6.1				TS-M2M-0009v2.6.1
★	TS 0010	2.4.1	MQTT Protocol Binding	08/2016				TS 118 110 V2.4.1				TS-M2M-0010v2.4.1
★	TS 0011	2.4.1	Common Terminology	08/2016				TS 118 111 V2.4.1				TS-M2M-0011v2.4.1
★	TS 0012	2.0.0	oneM2M Base Ontology	08/2016				TS 118 112 V2.0.0				TS-M2M-0012v2.0.0
★	TS 0014	2.0.0	LWM2M Interworking	08/2016				TS 118 114 V2.0.0				TS-M2M-0014v2.0.0

oneM2M, functional Architecture



oneM2M Functional Architecture

Application Entity (AE)

- Application Entity provides Application logic for the end-to-end M2M solutions.
- Examples of the Application Entities can be fleet tracking application, remote blood sugar monitoring application, or remote power metering and controlling application.

oneM2M Functional Architecture

Common Services Entity (CSE)

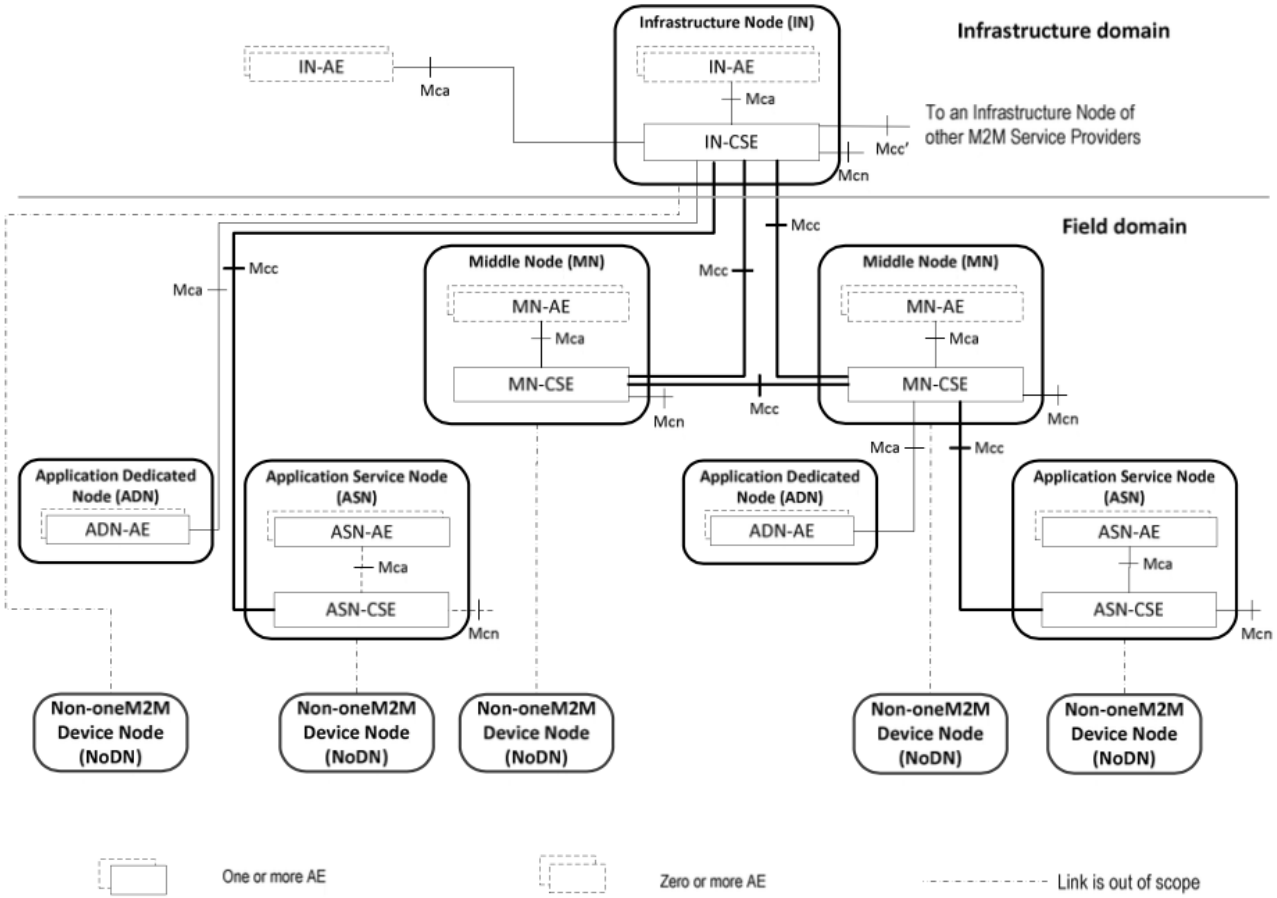
- A Common Services Entity comprises the set of ”service functions” common to the M2M environments.
- Such service functions are exposed to other entities through Reference Points Mca and Mcc. Reference point Mcn is used for accessing Underlying Network Service Entities.
- Examples of service functions offered by CSE are: Data Management, Device Management, M2M Subscription Management, Location Services etc. Such "sub-functions" offered by a CSE may be logically apprehended as Common Services Functions (CSFs). Inside a CSE, some of the CSFs can be mandatory and others can be optional.

oneM2M Functional Architecture

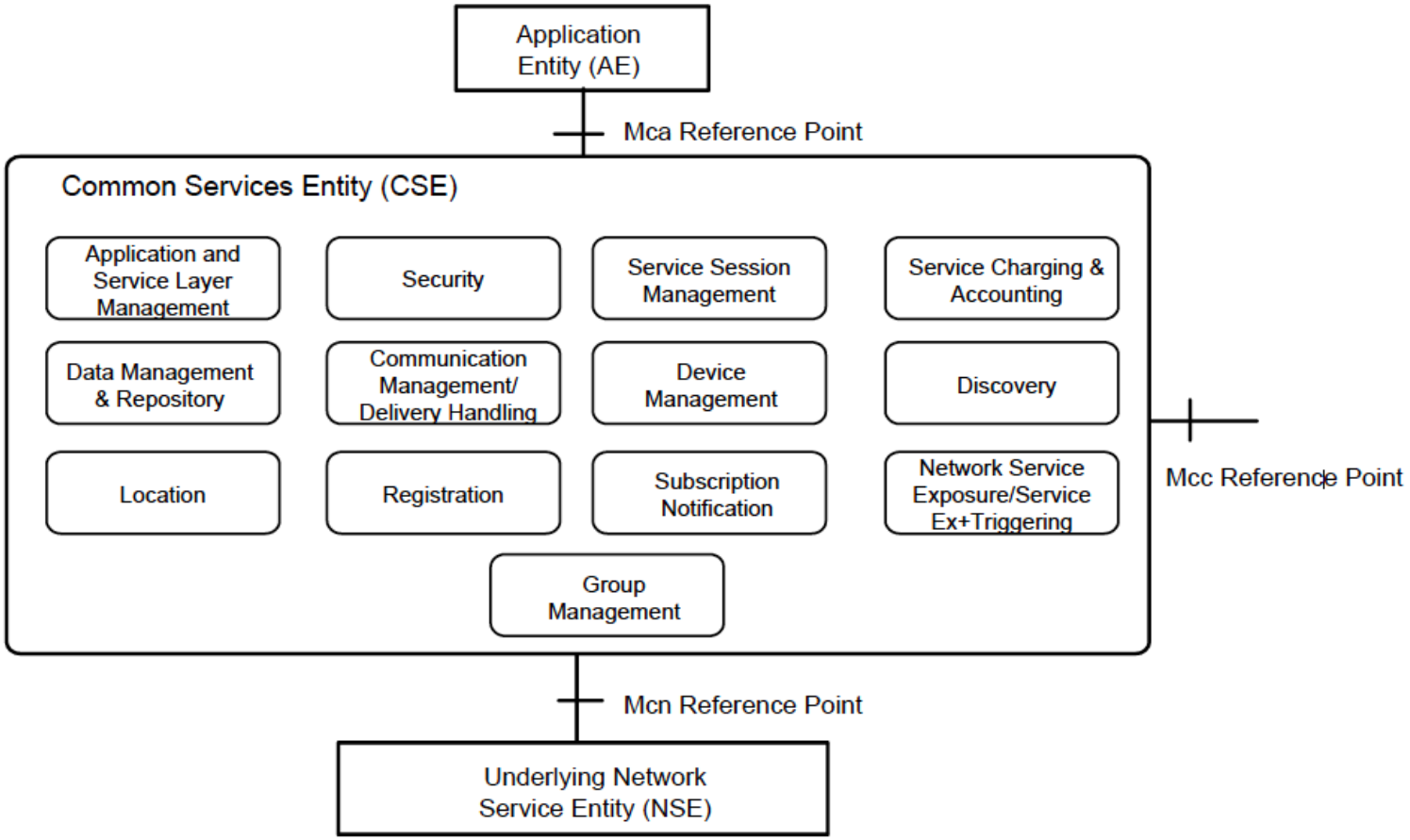
Underlying Network Services Entity (NSE)

- An Underlying Network Services Entity provides services to the CSEs. Examples of such services include device management, location services and device triggering. No particular organization of the NSEs is assumed.

Configurations supported by oneM2M Architecture

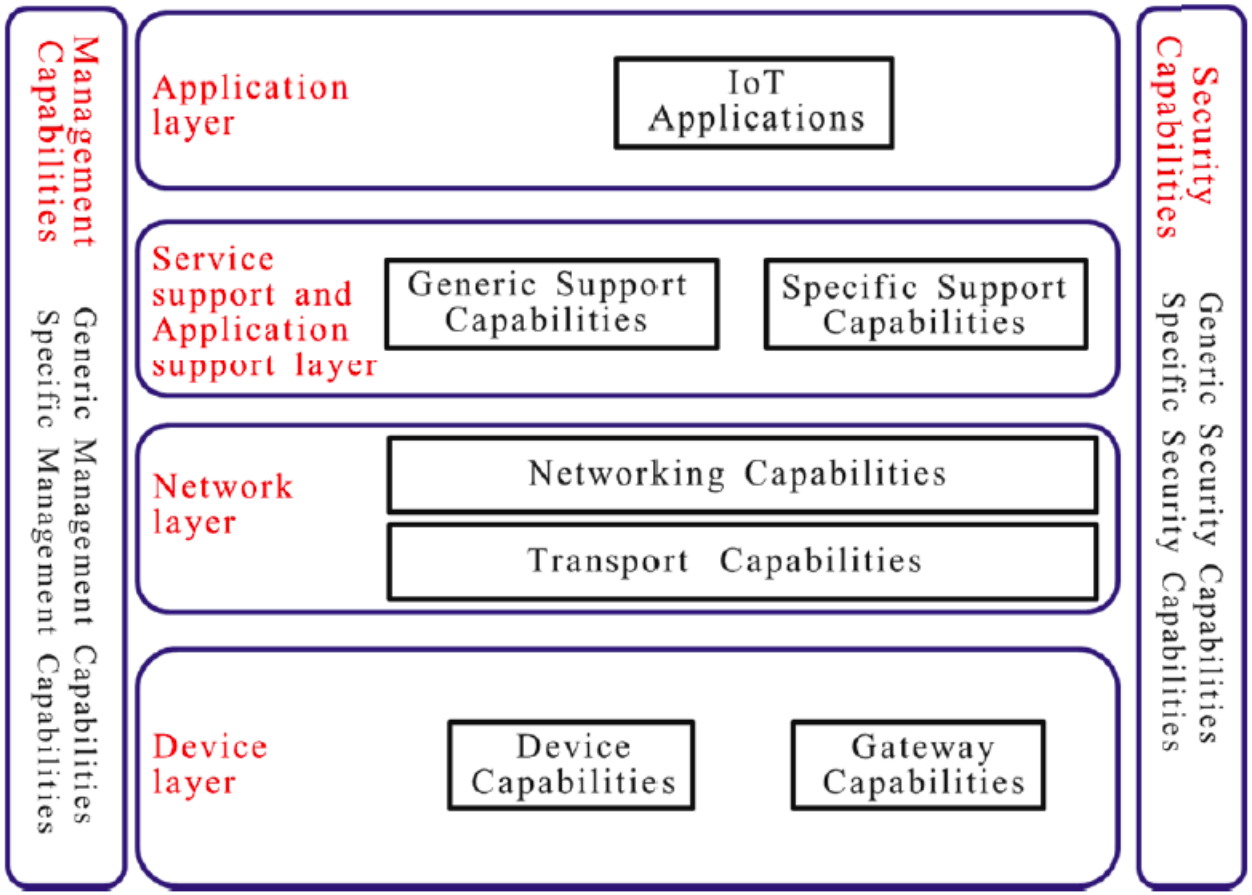


oneM2M, Common Service Functions



Outline

ITU-T Reference Model

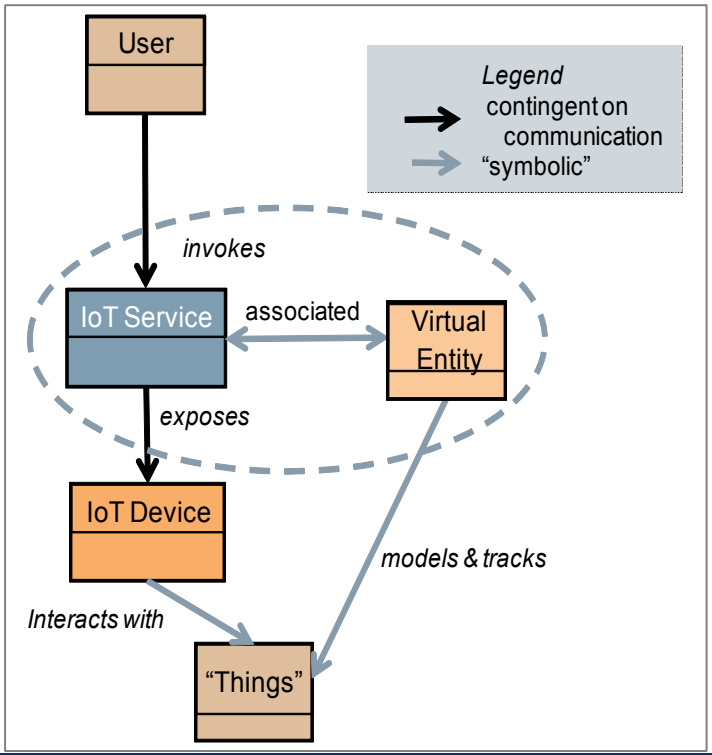


Outline

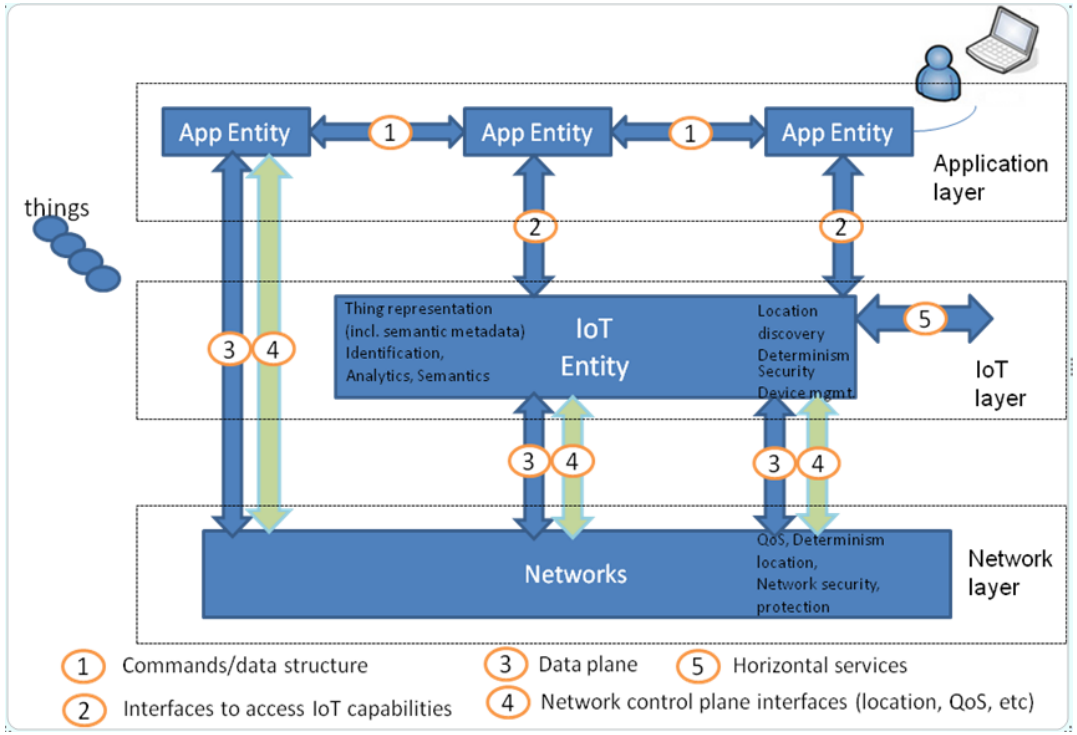
A consolidated high level IoT Reference Architecture

- AIOTI WG03 IoT Reference Architecture
  - Consolidation of IoT reference architecture from many sources, i.e. IoT-A, IEEE P2413, OneM2M, ITU-T, ISO/IEC JTC1
  - Architectural views based on ISO/IEC/IEEE 42010

❑ Domain model:



❑ Functional model:

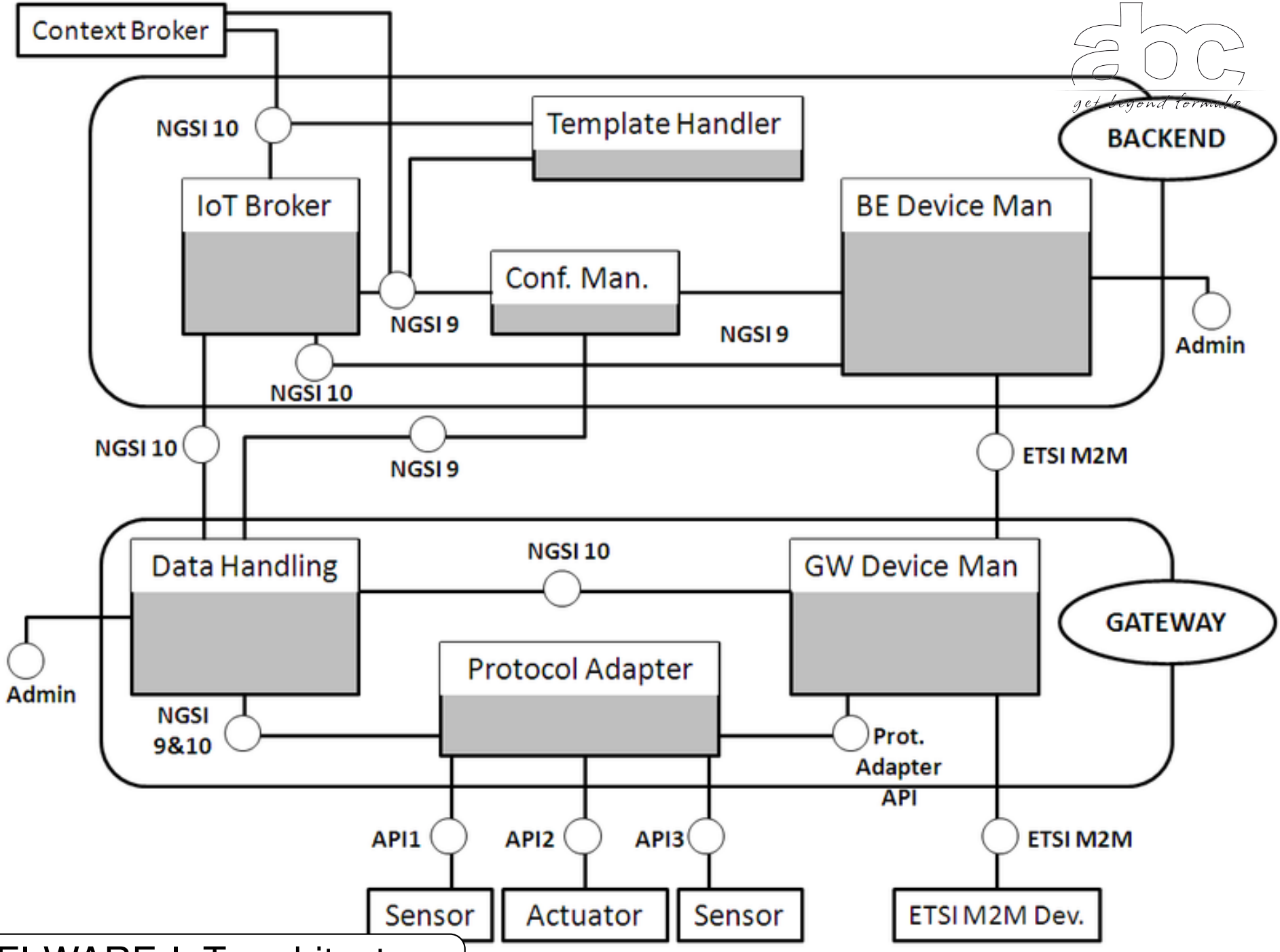


Outline

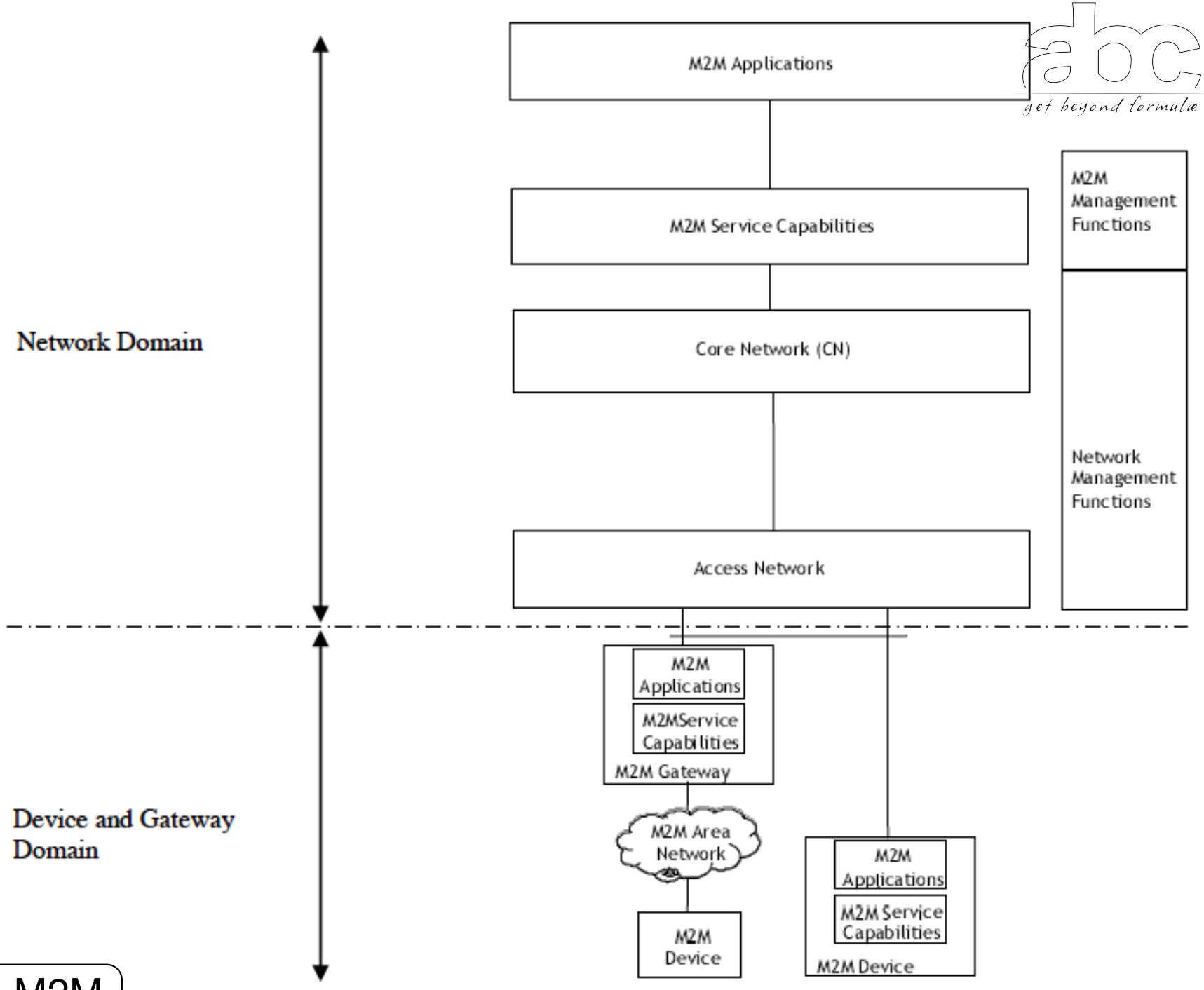
FI-WARE

Main Concepts

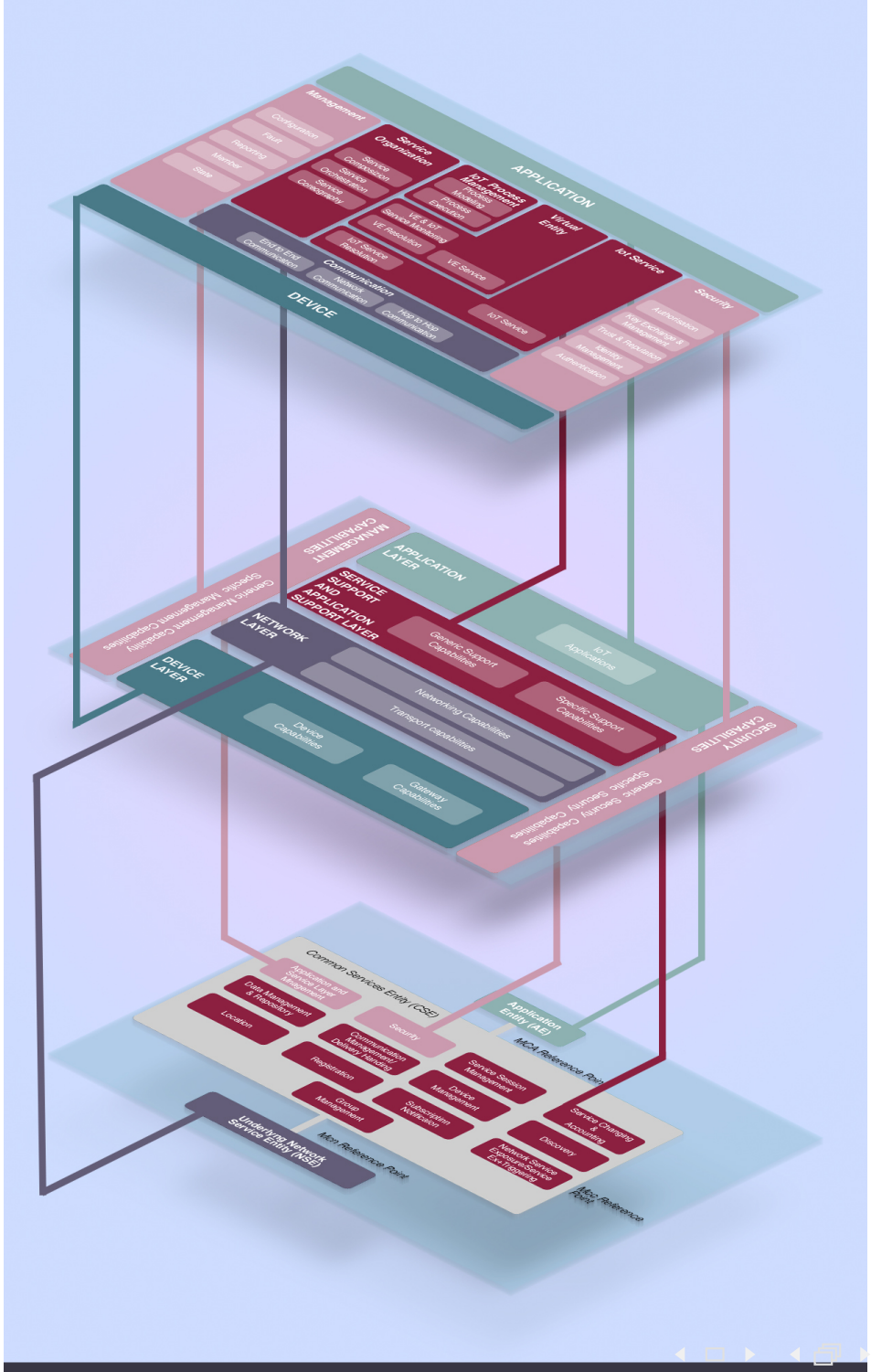
- FI-WARE identifies Generic Enablers (GE) as "common bricks" on top of which each sector can develop specific technologies.
- A FI-WARE Instance is an implementation of needed GE.
- A version with all FI-WARE instances, called ”FI-WARE Testbed” allows Use Case projects and third parties to run and test Future Internet Applications based on FI-WARE Generic Enablers.



FI-WARE IoT architecture


M2M Applications
M2M Service Capabilities
Core Network (CN)
Access Network
M2M Management Functions
Network Management Functions
Network Domain
Device and Gateway Domain
M2M Applications
M2MService Capabilities
M2M Gateway
M2M Area Network
M2M Device
M2M Applications
M2M Service Capabilities
M2M Device

ETSI M2M


APPLICATION
Management
Configuration
Fault
Reporting
Monitor
State
Service Organization
Service Commission
Service Orchestration
Service Consignment
IoT Process Management
Process Modeling
Process Execution
Virtual Entity
VE & IoT Service Modeling
VE Resolution
IoT Service Resolution
VE Service
IoT Service
Security
Authorization
Key Exchange & Management
Trust & Revocation
Identity Management
Authentication
DEVICE
End to End Communication
Communication
Network Communication
Hop-to-Hop Communication
MANAGEMENT CAPABILITIES
Generic Management Capability
Specific Management Capabilities
APPLICATION LAYER
SERVICE SUPPORT AND APPLICATION SUPPORT LAYER
NETWORK LAYER
DEVICE LAYER
Generic Support Capabilities
Specific Support Capabilities
IoT Applications
Networking Capabilities
Transport Capabilities
Device Capabilities
Gateway Capabilities
SECURITY CAPABILITIES
Generic Security Capabilities
Specific Security Capabilities
Common Services Entity (CSE)
Application and Service Logic Management
Data Management & Repository
Location
Security
Application Entity (AE)
MCA Reference Point
Communication Management / Delivery Handling
Registration
Group Management
Service Session Management
Device Management
Subscription Notification
Service Charging & Accounting
Discovery
Network Service Exposure/Service Ext Triggering
Mcc Reference Point
Underlying Network Service Entity (NSE)
Mcn Reference Point

OpenFog

Security:
- Trust
- Attestation
- Privacy

Scalability:
- Localized cmd, ctrl, & processing
- Orchestration & Analytics
- Avoidance of network taxes

Open:
- Resource visibility & control
- White box decision making
- Interop & Data normalization

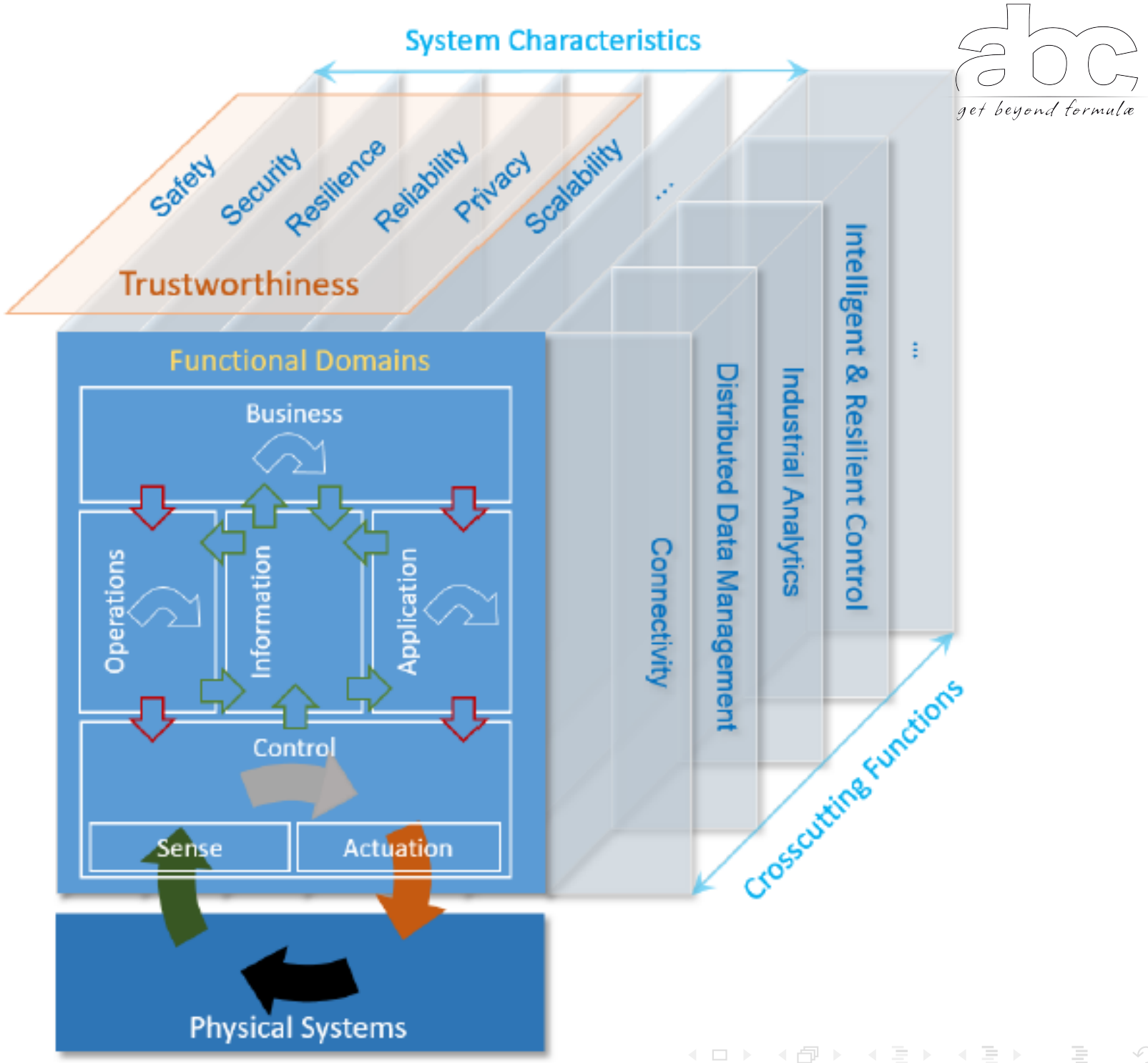
Autonomy:
- Flexible
- Cognition & agility
- Value of data

RAS:
- Reliability
- Availability
- Serviceability

Agility:
- Tactical & strategic decision making
- Data to wisdom

Hierarchy:
- Fully cloud enabled
- Computational & System
- Autonomy at all levels

Programmability:
- Programmable SW/HW
- Virtualization & multi-tenant
- App Fluidity


System Characteristics
Safety
Security
Resilience
Reliability
Privacy
Scalability
...
Trustworthiness
Functional Domains
Business
Operations
Information
Application
Control
Sense
Actuation
Physical Systems
Connectivity
Distributed Data Management
Industrial Analytics
Intelligent & Resilient Control
...
Crosscutting Functions

Thank you for your attention