Connected objects,
IoT, M2M, architecture, protocols, ...

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Agenda

Part I

IoT Definition
Statistical data
Cyberdependance
IoT Market
Global architecture
IoT Architecture
System Architecture

Part II

M2M System - Definition
M2M System - Global architecture
M2M System - Communication example
M2M System - Standards
M2M Open platform
Lightweight M2M
M2M impact for IoT
Big data
IoT and digital hub

Part III

Concept of IoT data model
Use case and automatic generation
Developing an IoT

IoT Definition

The internet of things (IoT) is the network of physical devices, vehicles, buildings and other items embedded with electronics, software, sensor, actuators, and network connectivity that enable these objects to collect and exchange data.

- Mobile devices
- Smart meters and objects
- Wearable devices including clothing, health care implants, smartwatches, and fitness devices
- Internet-connected automobiles
- Home automation systems, including thermostats, lighting, and home security
- Other measuring sensors for weather, traffic, ocean tides, road signals, and more

Part I

IoT Definition

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IoT and market segmentation

Global architecture

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System Architecture

Sondage IFOP du 1er décembre 2015 N°37742

Intérêt de l'IoT

- Les Français se montrent très familiers avec le principe des objets connectés : près de 6 Français sur 10 (57%) déclarent savoir précisément ce dont il s'agit.

- Les plus au fait sont les populations les plus jeunes (76% des moins de 25 ans déclarent savoir exactement ce que c'est), les CSP+ (66 %) et les hommes (63 %) . Seuls 3% des Français n'ont jamais entendu parler des objets connectés.

CSP+: catégories socio-professionnelles favorisées - https://fr.wikipedia.org/wiki/CSP%2B

Statistical data

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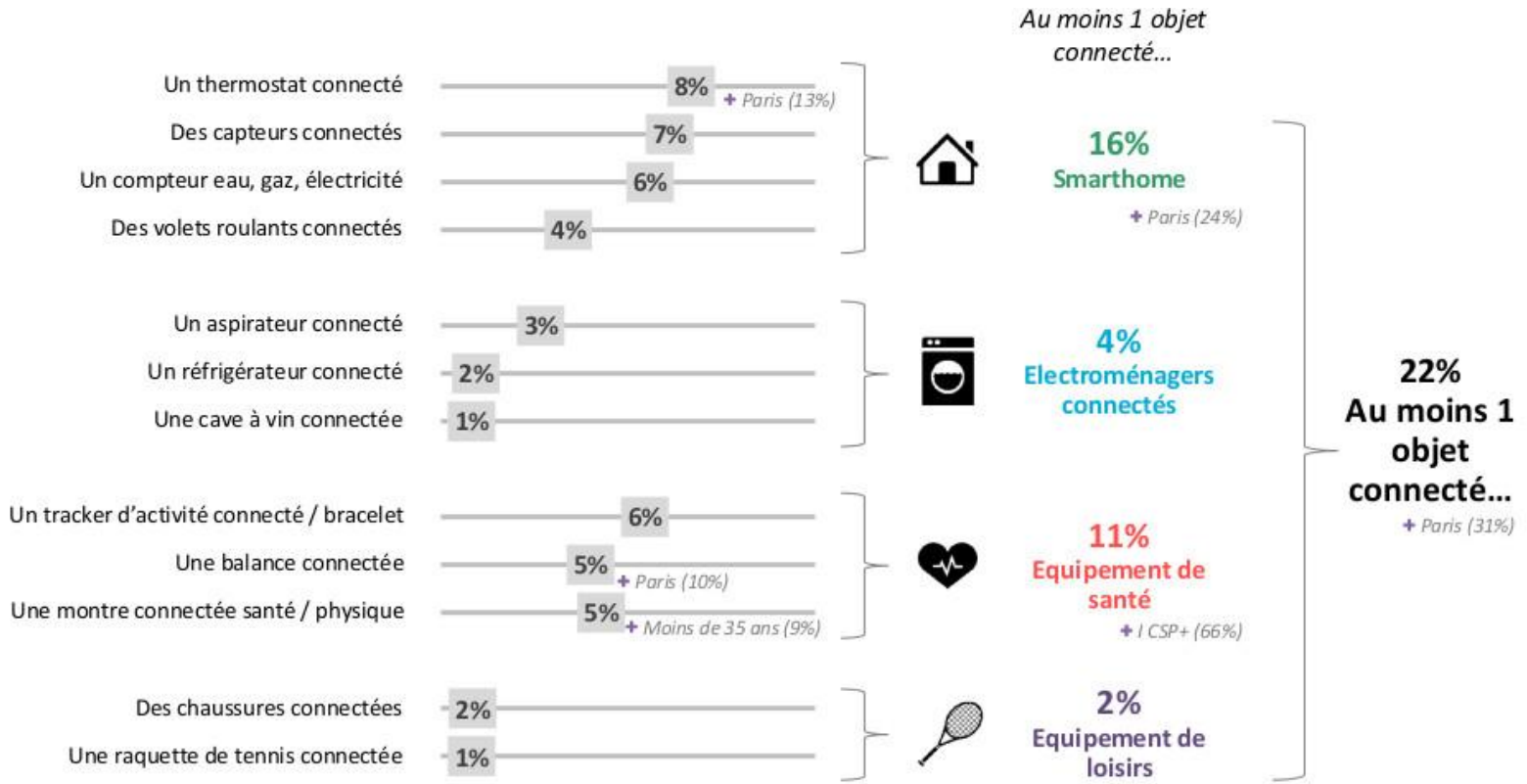
Equipement en objets connectés



Statistical data

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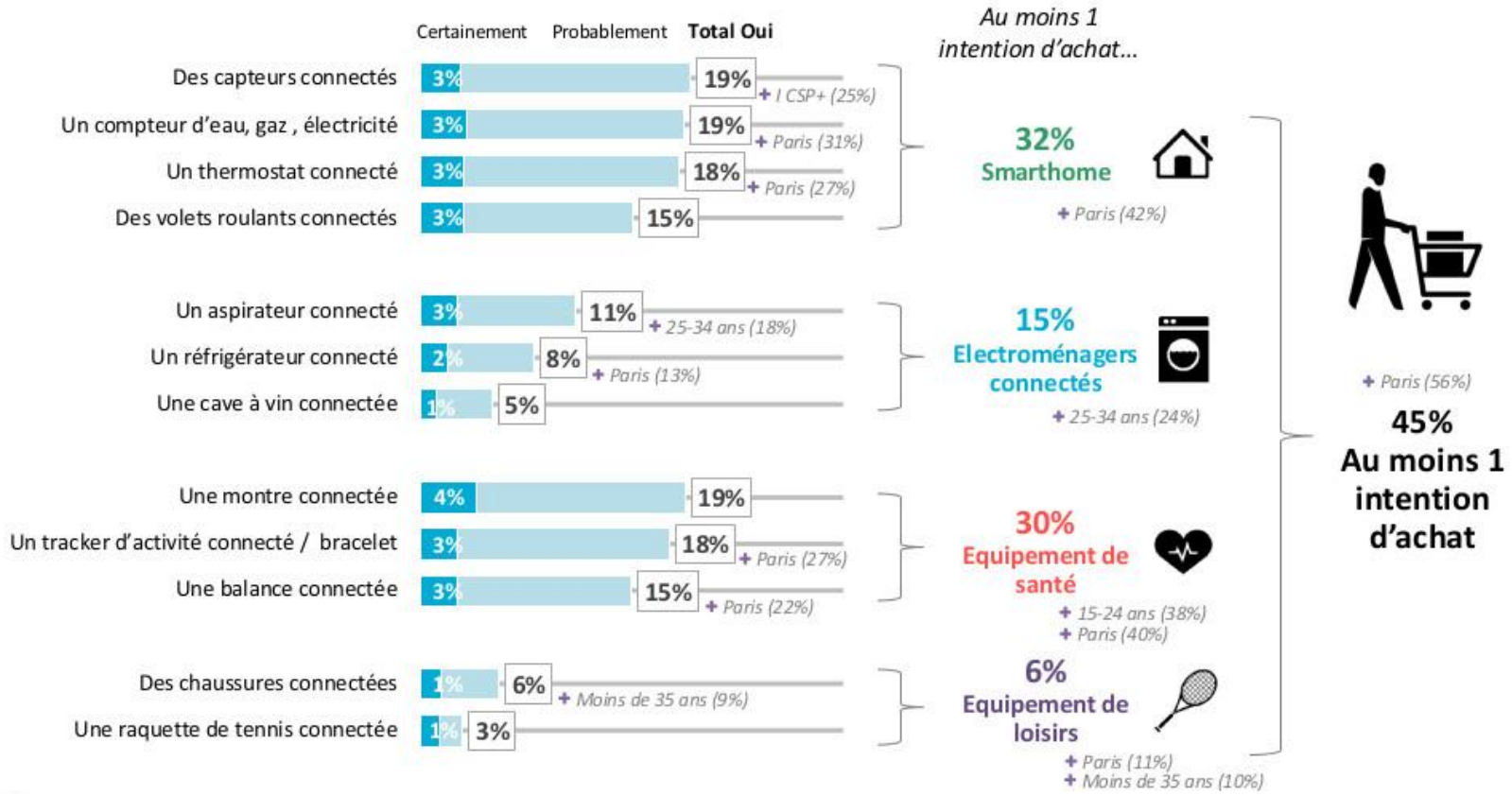
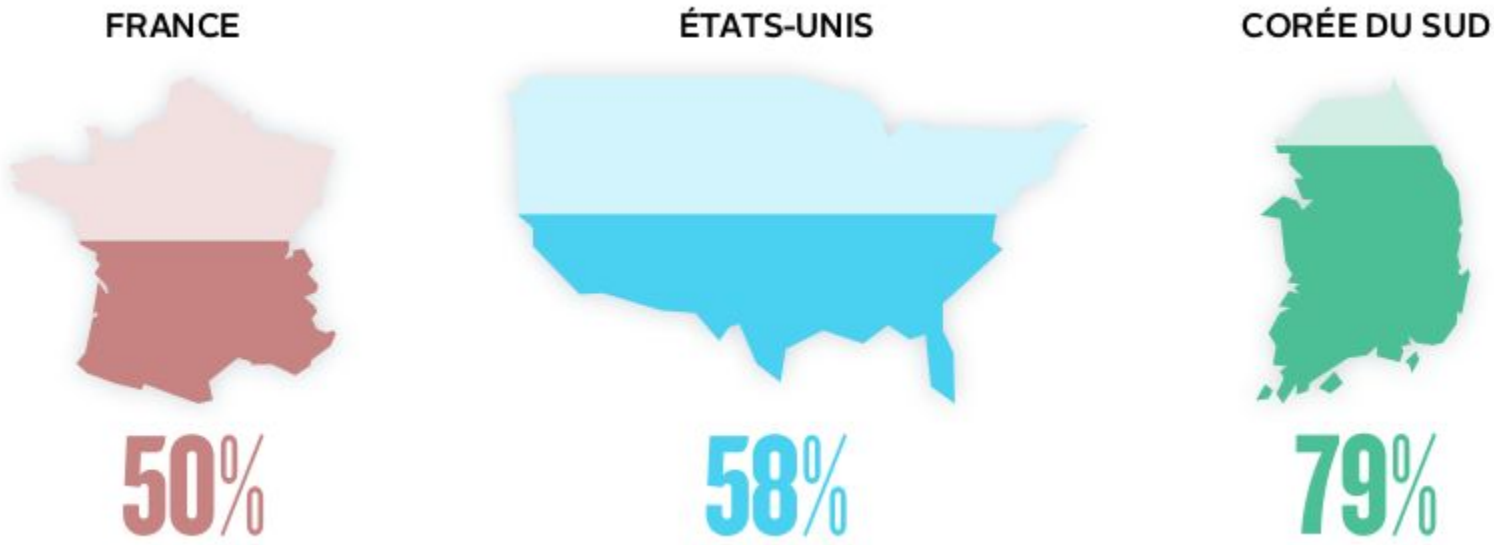
Intention d'achat d'un objet connecté



Statistical data

OBSERVATOIRE 2015 DES OBJETS CONNECTÉS DE L'IFOP

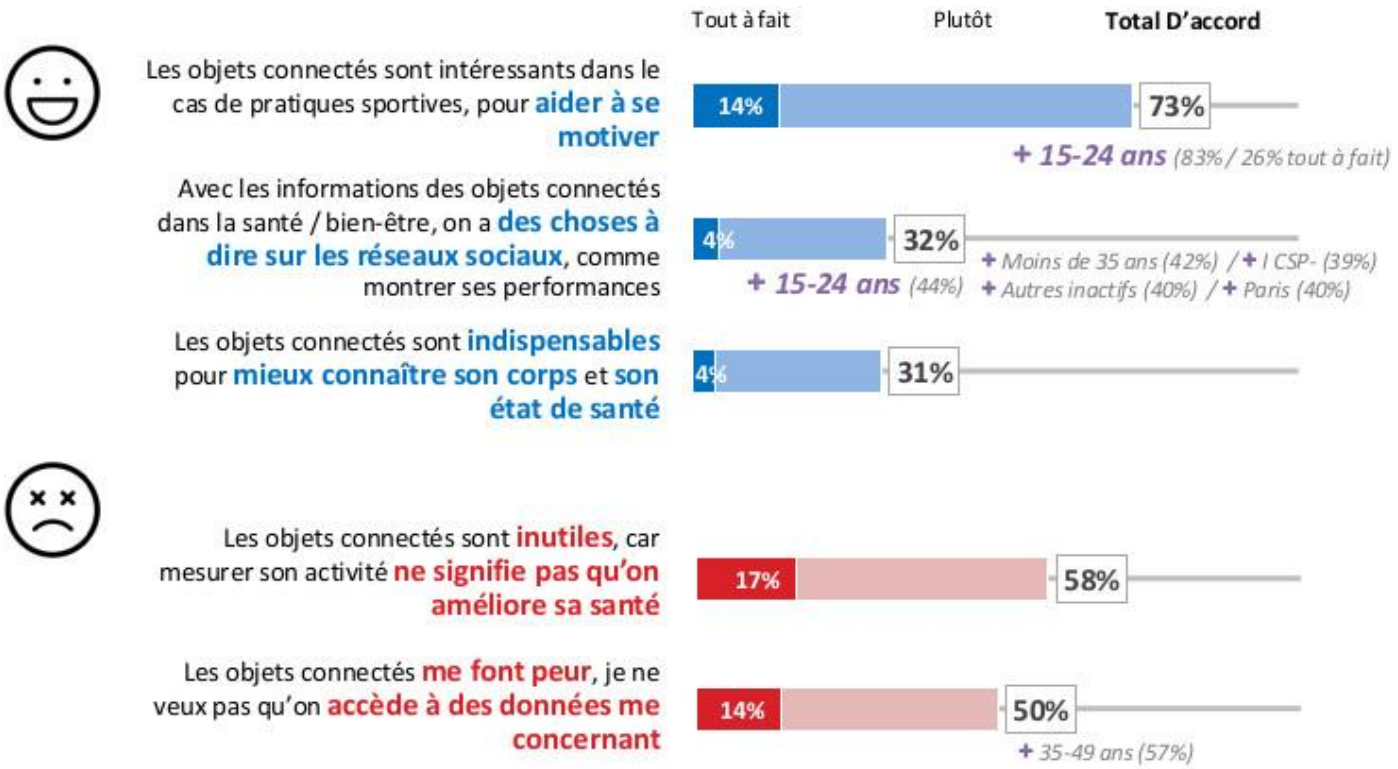
Intention d'achat



Statistical data

Sondage IFOP du 1er décembre 2015 N°37742

Opinions concernant les objets connectés



Cabinet GfK / Cabinet XERFI

Dynamique du marché

Cabinet GfK:

En 2015, leurs ventes auraient atteint 700 000 unités soit 120 millions d'euros.

Près de **2 milliards d'objets connectés** pourraient se vendre entre **2015 et 2020** : chaque foyer posséderait alors en moyenne 30 objets connectés.

Cabinet XERFI

Une progression régulière des dépenses qui pourraient atteindre **500 millions d'euros en 2016.**

IFOP / Harris Interactive

Les freins à l'achat

- Parmi les individus qui ne prévoient pas d'acquérir un objet connecté, les freins sont le prix (59%), le manque d'utilité (45%), les risques liés à l'utilisation des données personnes (15%) (Source : Ifop).

- Les intentions d'achat resteraient cependant modestes, freinées par les craintes liées à:
  - la sécurité des données personnelles (68%),
  - le risque de dépendance (65%),
  - le prix (63%). (Source : Harris Interactive).

Statistical data

Sondage IFOP du 1er décembre 2015 N°37742

Impression sur la sécurité

- Le fait que les objets connectés produisent de la data est un principe plutôt clair dans les esprits (seuls 10 % des Français n'en avaient pas du tout conscience).

- Les Français semblent porter un regard inquiet sur les risques qui y sont associés : la moitié d'entre eux se dit effrayée par le risque de fuite des données personnelles, et les deux tiers (68 %) considèrent que les données sont mal protégées .

- Ce sentiment est largement partagé dans la population française, y compris auprès des "early adopters" , déjà équipés d'un ou plusieurs objets connectés.

Sondage IFOP du 1er décembre 2015 N°37742

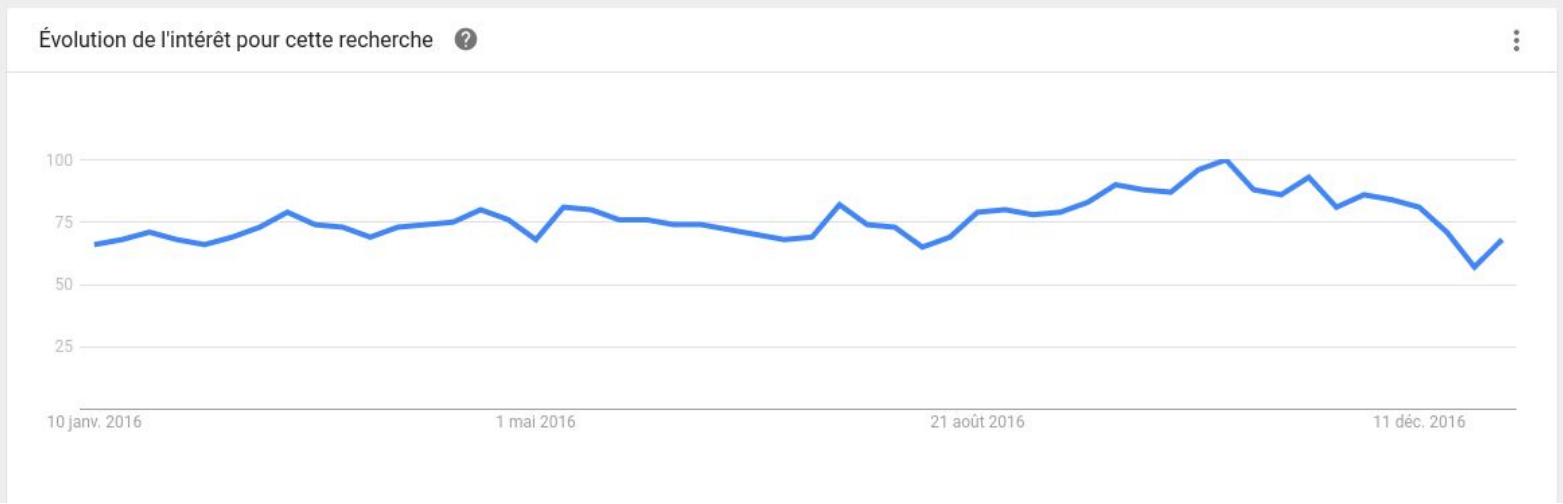
Utilisation des données produites

- Les français ont en outre un **t**rès large doute sur le devenir des données produites et sur leur possesseur.
- Seul un quart des Français pense que les données appartiennent à son émetteur (18 % les attribuent à l'OS du smartphone, et 39 % ne savent pas).
- Les avis sont très partagés sur la possibilité de vendre les données produites par les objets connectés à des fins commerciales
- Seuls 16 % des Français se disent prêts à partager leurs données, mais à condition d'en tirer un avantage (assurance …).

Statistical data

Analyse **Google Trends** en janvier 2017

Recherche sur mot clés “Internet des objets” sur 2016



Corée du Sud (100)
Taïwan (64)
Singapour (60)
Japon Inde (52) …
France (11)

Sondage IFOP du 1er décembre 2015 N°37742

Pour résumer 1/2

- Un secteur en croissance,
- L'IoT est connu du public: plus de la moitié de la population connaît bien, (public plutôt jeune et CSP+),
- Des inquiétudes pour la sécurité d'utilisation,

Sondage IFOP du 1er décembre 2015 N°37742

Pour résumer 2/2

- Des questionnements sur l'utilisation des données,
- L'utilité est un facteur essentiel, phénomène de "gadgetisation",
- Le prix reste un facteur de blocage non négligeable,
- Le manque d'interopérabilité est un frein important.

Part I

IoT Definition

Statistical data

Cyberdependance

IoT Market

Global architecture

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System Architecture

Cyberdependance

Symptômes physiologiques (Nayebi, 2007)

- Syndrome du canal carpien,
- Sécheresse des yeux,
- Négligence de l'hygiène personnelle,
- Alimentation irrégulière, repas sautés et de mauvaise qualité,
- Insomnies ou modifications dans le cycle du sommeil.

Cyberdependance

Symptômes psychologiques (Nayebi, 2007; Young, 2004)

- Sentiment de bien-être, soulagement ou euphorie pendant l'utilisation d'Internet et/ou objets connectés,

- Sentiment de vide, dépression, anxiété, irritabilité hors ligne ou quand l'accès à Internet ou au objets connectés est impossible,

- Sentiment de culpabilité ou honte face à l'utilisation d'Internet,

- Incapacité à cesser ou à diminuer l'usage d'Internet ou besoin d'augmenter le temps de connexion.

Cyberdependance

Symptômes psychologiques (Nayebi, 2007; Young, 2004)

- Diminution de l'intérêt ou du temps consacré aux autres activités «hors ligne,

- Altération du niveau de fonctionnement (difficultés relationnelles (familiales, amoureuses, professionnelles, etc.), pertes d'emploi, isolement social, etc.),

- Mensonges à propos de l'utilisation d'Internet (durée, activités en ligne, etc.)

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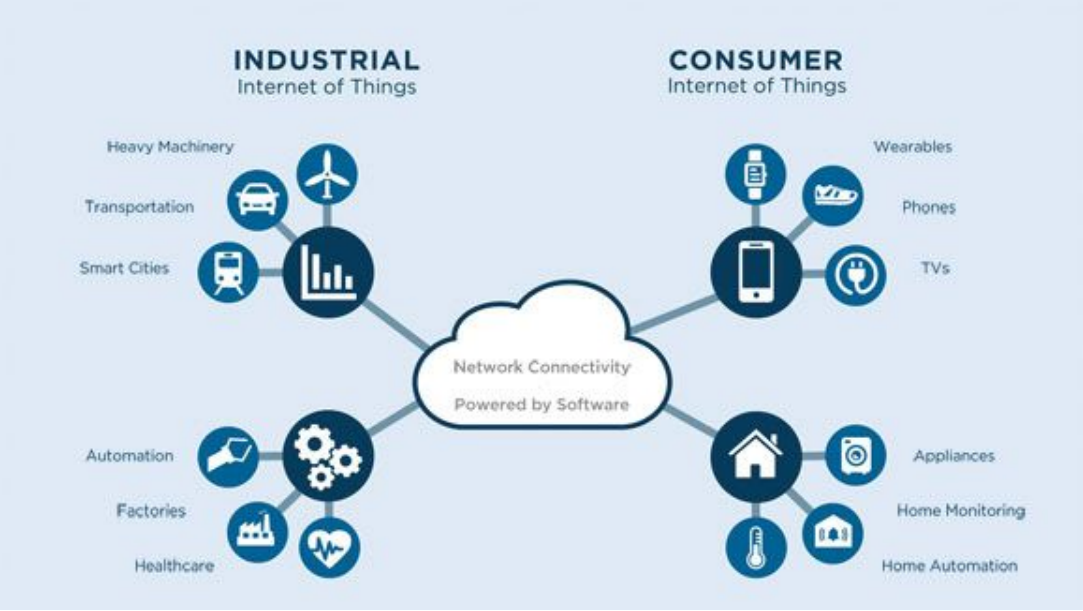
IoT Market

Market segmentation



A market strongly oriented to software that plays a vital role.

IoT Market

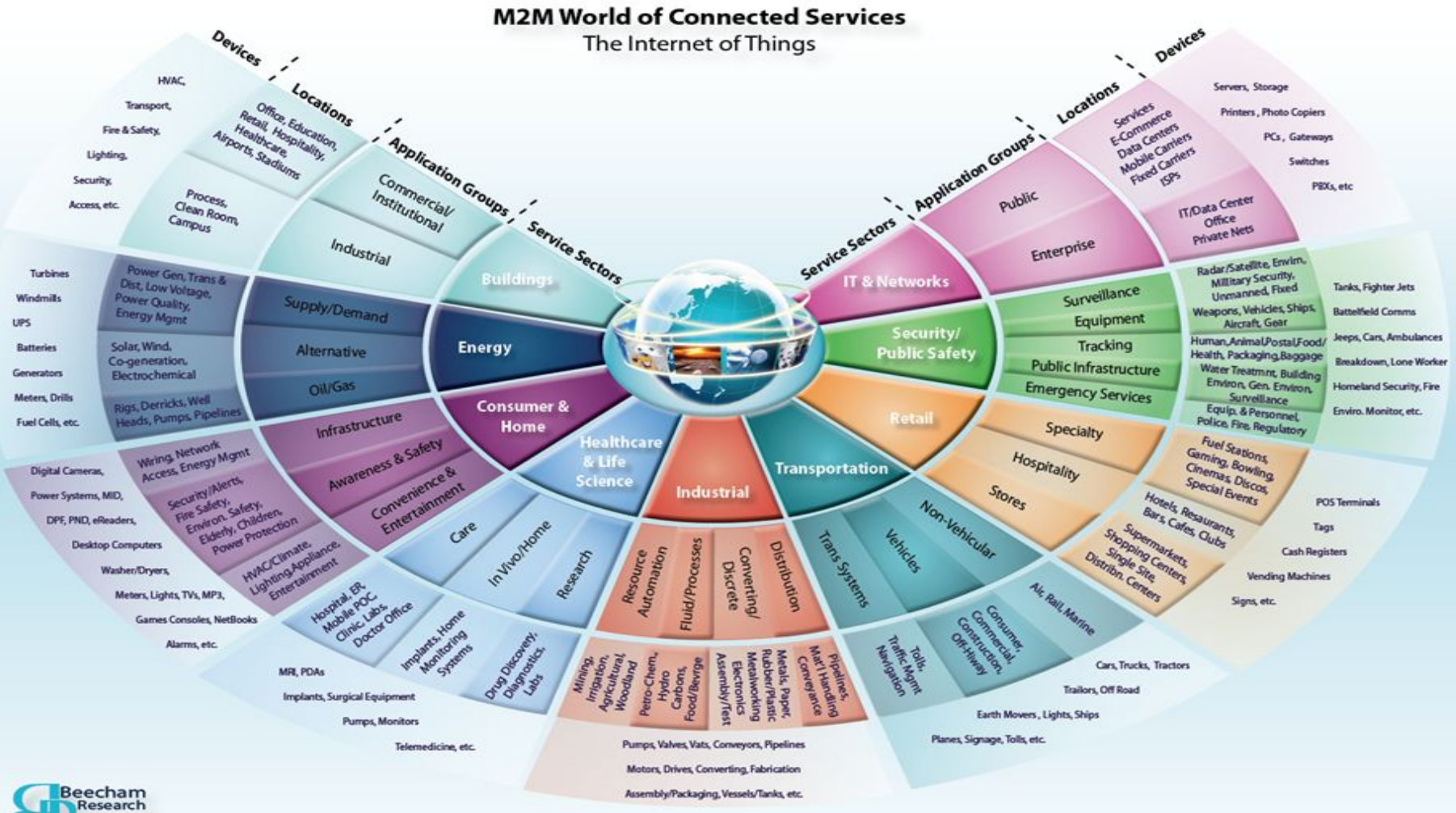
Market segmentation

Le marché est segmenté avec des IoT aux propriétés très diverses:

- Des produits différents (industriel, consommateur …),
- Une mise en oeuvre plus ou moins complexe,
- Un niveau d'intégration très différent (embarqué réduit ou pas),
- Des niveaux de fiabilité important ou inexistant,
- Des systèmes de communication plus ou moins élaborés,
- Des infrastructures à très grande échelle ou une architecture Ad hoc ...

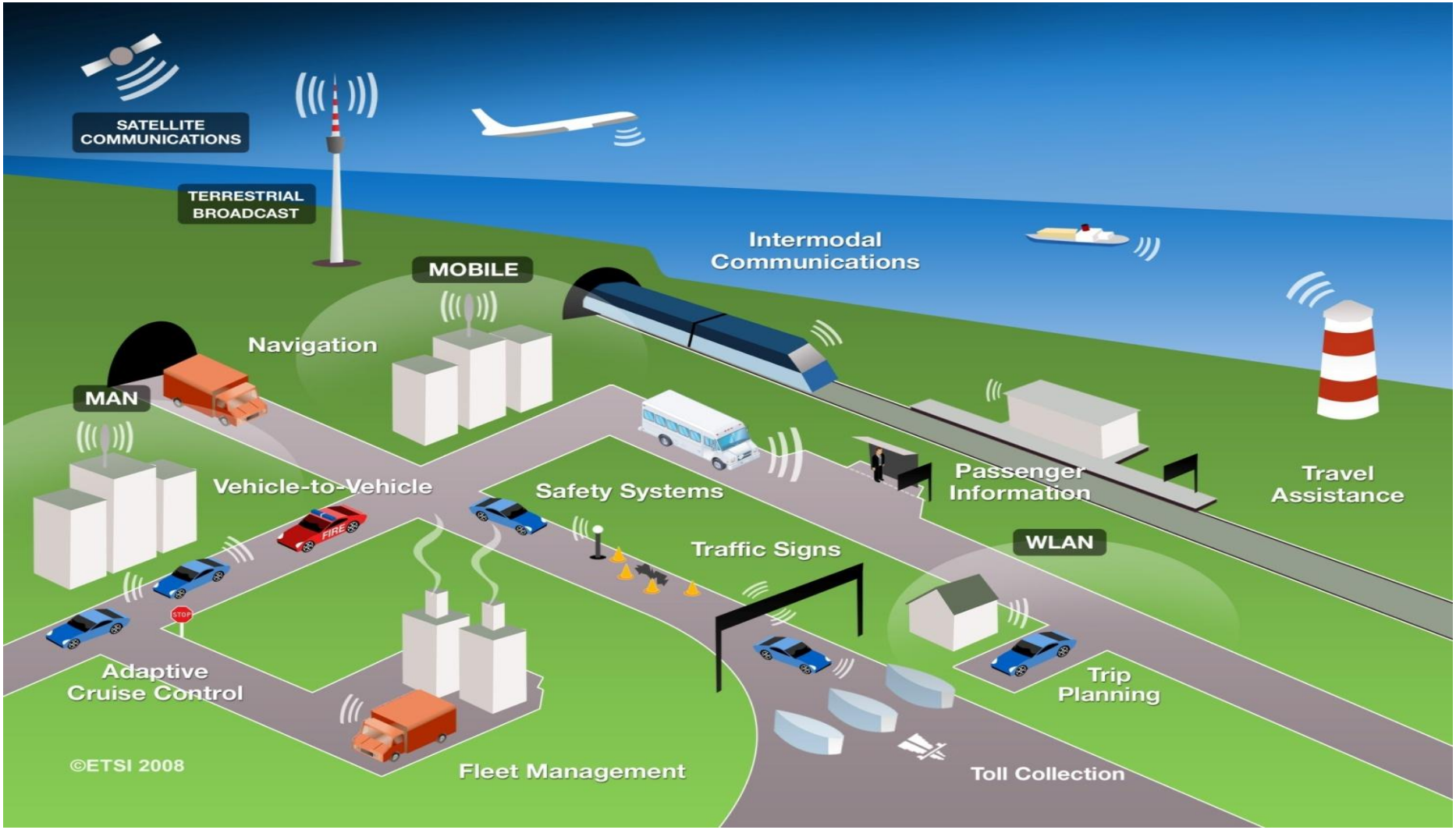
IoT Market

Market segmentation



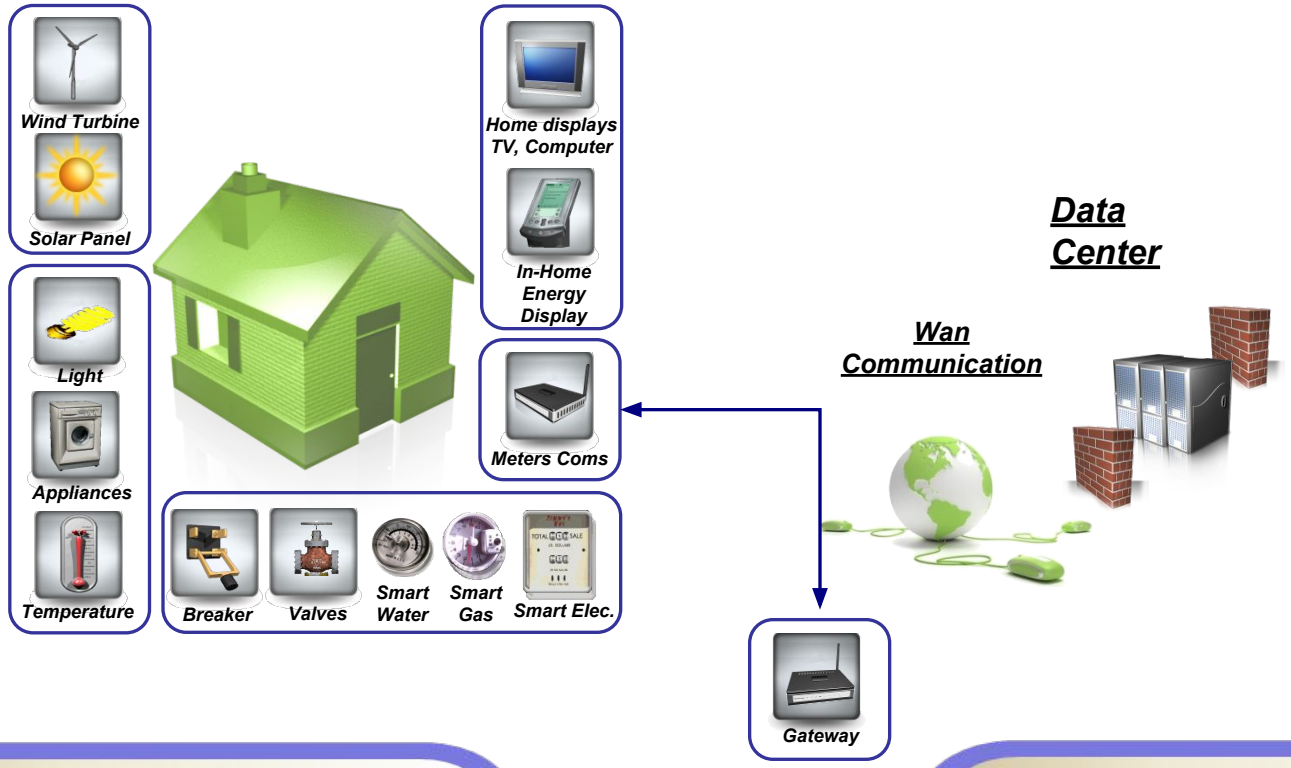
IoT Market

Market segmentation: transport



IoT Market

Market segmentation : Smart meter



- Consumption info
- Fault details
- Threshold management

- Remote Meter reading
- Consumption management
- Pricing info

IoT Market

Market segmentation : e-Health

Disease management

Ageing independently

Personal fitness

Remote monitoring

Health Check

On-line health records

Scheduling appointments

Lifestyle and dietary advice

Part I

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System Architecture

Global architecture - Cyber-Physical Systems

http://www.designworldonline.com/big-future-for-cyber-physical-manufacturing-systems/
https://en.wikipedia.org/wiki/Internet_of_things

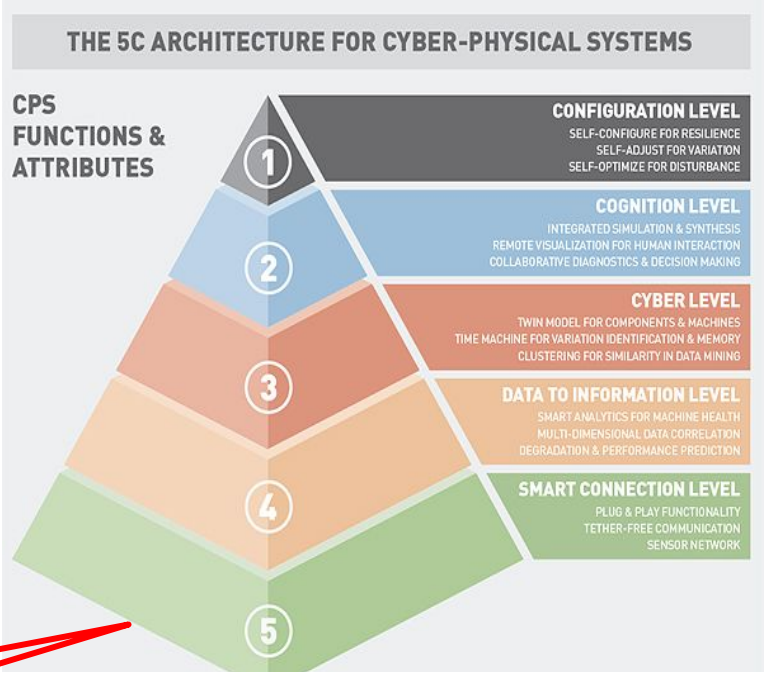
1- **Configuration**: A machine able to track its own health can detect failures early on and send health monitoring information to the operation level.

2- **Cognition**: In cognition level, the machine itself should take advantage of online monitoring to diagnose its own potential failures and become aware.

3- **Cyber**: This level acts as the hub for information and performs complex analytics.

4- **Conversion**: This level converts data to information using algorithms that are based on the application.

5- **Connection**: In the connection level, the data generated by connected machines.



M2M architecture, IoT, network sensor.

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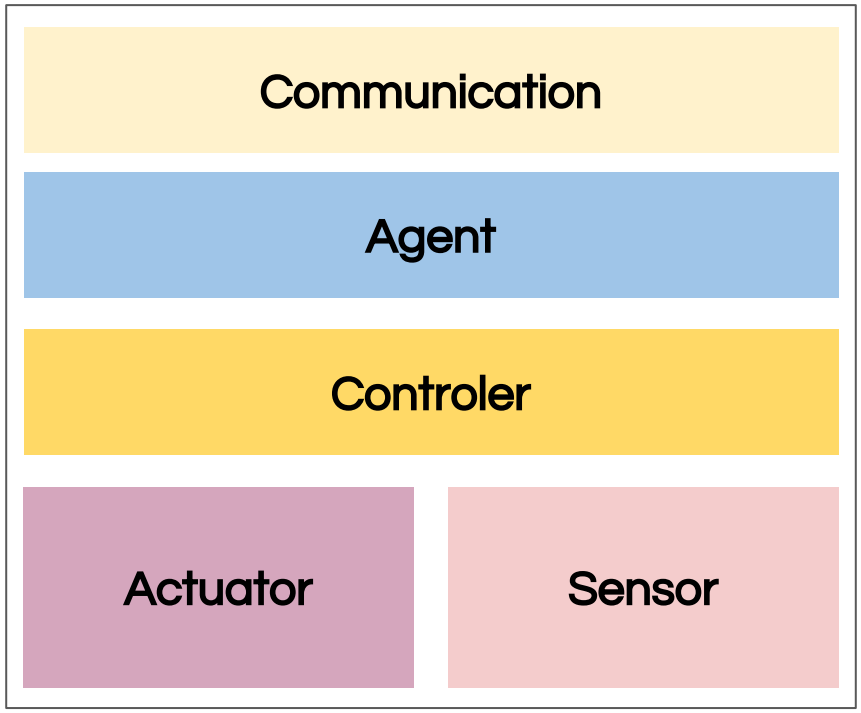
IoT Architecture

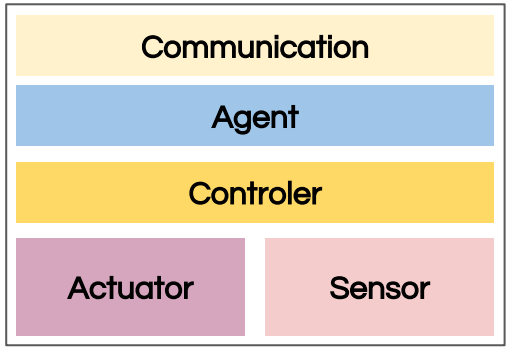
Abstract Architecture Model



An IoT “Thing” anatomy

IoT Architecture

Abstract Architecture Model

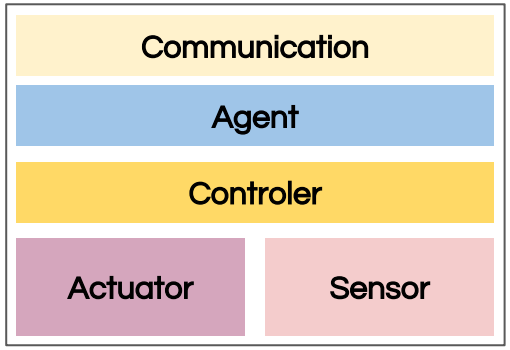


Communication layer

- Short-haul media: Wifi, Bluetooth, NFC …
- Long-haul media: wired Ethernet, 3G, 4G, LoRa, SigFox, NB-IoT…
- Protocol: TCP/UDP/IP, HTTP, CoAP (Constrained Application Protocol) …

IoT Architecture

Abstract Architecture Model



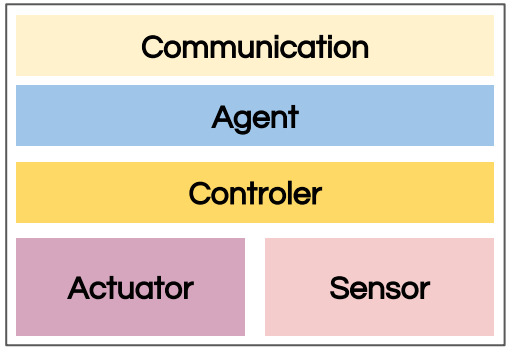
Agent

Agent is an embedded program that :

- Runs on the IoT device,
- Reports the status of an asset or environment,
- Acts as a bridge between the controller and the cloud,
- Deciding what data to send and when to send it…
- Intelligent Algorithms are located in Agent.

IoT Architecture

Abstract Architecture Model



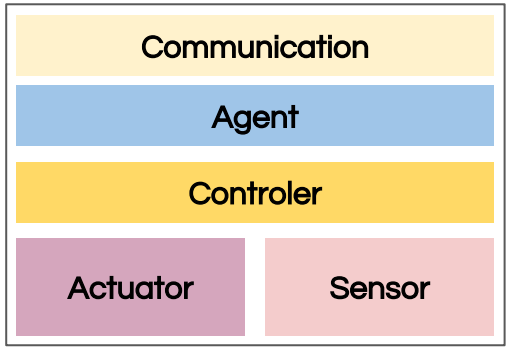
Controler

A hardware or software component that interacts electrically or logically with sensors and actuators.

For example, a *controler* may be a simple circuit that reads an analog signal from a temperature sensor and digitizes the signal into discrete transmissions.

IoT Architecture

Abstract Architecture Model



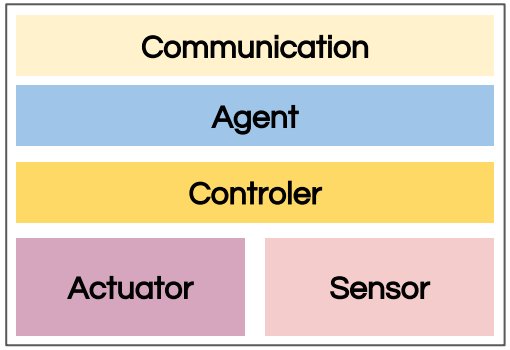
Sensors

- Sensors read and report on the real-world status of connected products, machines, and local environments.

- They are the eyes and ears of the system, monitoring environmental elements like:
  - Temperature sensors,
  - Light sensors,
  - Moisture sensors,
  - GPS receivers,
  - Vehicle on-board diagnostics,
  - Files,
  - Product-specific data,
  - Inertial sensor,
  - **New!** composite sensor on Android ...

IoT Architecture

Abstract Architecture Model

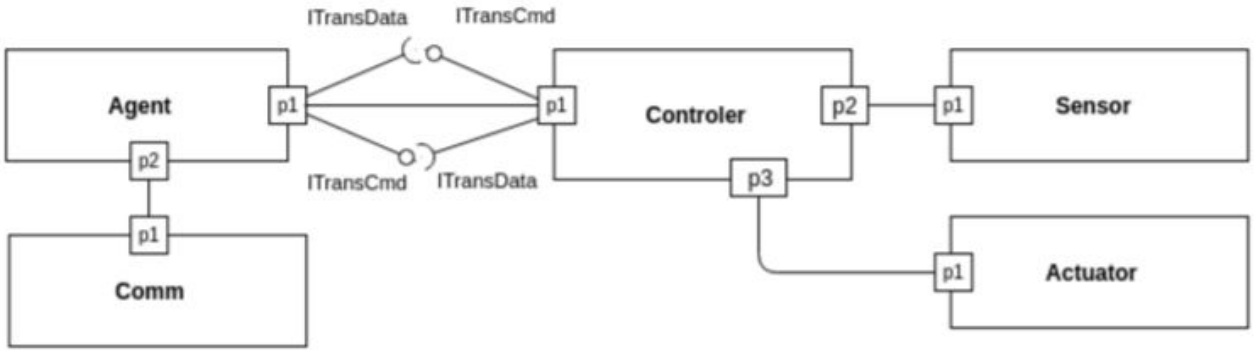


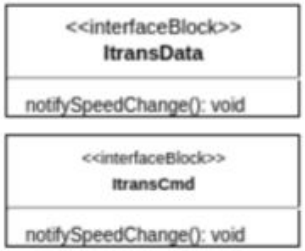
Actuators

- Actuators affect the electromechanical or logical state of a product or environment.

- They are the system's hands and feet:
  - Lights
  - Valves
  - Motors
  - Commands ("soft" actions, file distribution, firmware updates) ...

Composite Structure





Design Pattern (software + hardware)

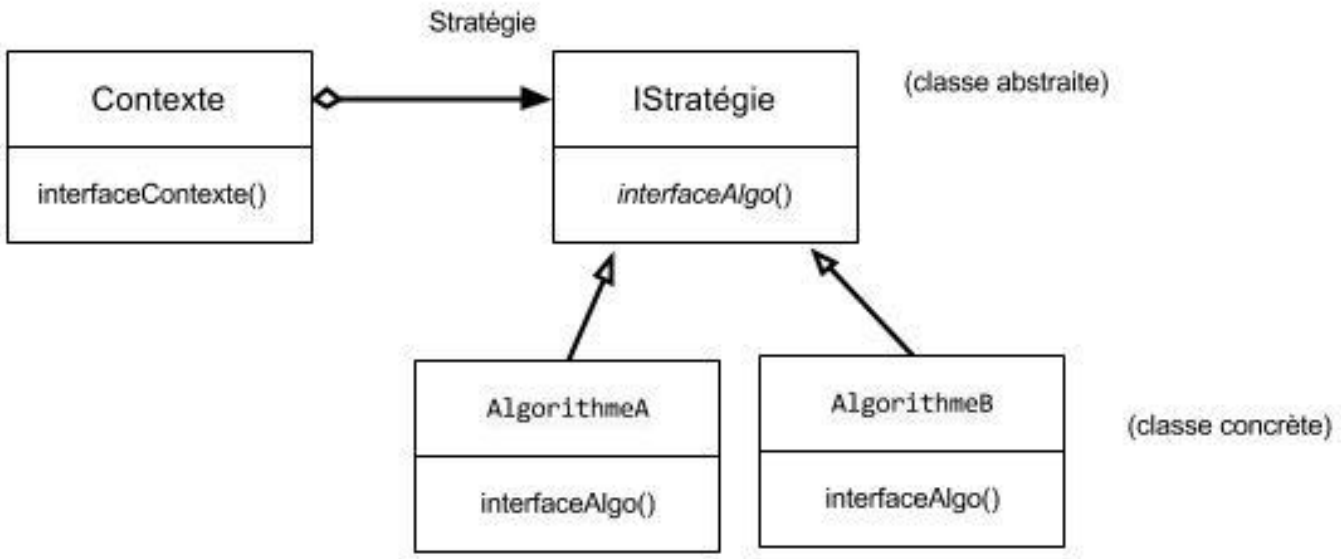
- Solve design problems commonly encountered,
- Best practices and standards,
- Design Patterns are building blocks of architecture,
- Build an end to end solution in well specified ways,
- Provide an understanding of the use of different components of the system in a system context.

Design Pattern standard (GoF...)

Patterns de comportement	Patterns de création	Patterns de structure
- command, - interpreter, - iterator, - mediator, - memento, - observer, - state, - strategy, - visitor.	- abstract factory, - builder, - factory method, - prototype, - singleton.	- adapter, - bridge, - composite, - decorator, - façade, - flyweight, - proxy.

Example: Design Pattern standard (GoF) / Strategy

The Strategy pattern can be implemented in the context of a range of products where identical functionality is found but in a different execution context.

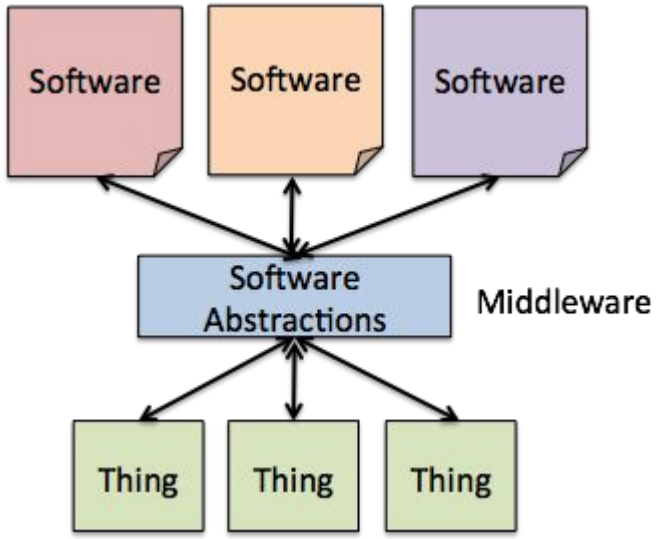


IoT Architecture

Design Pattern

Virtualization through middleware:

- Allows many applications to interact with things.
- Middleware can cache the state of the thing and minimize network traffic and power drain ...



IoT Architecture

Design Pattern

Design patterns for IoT / Use Case:

- Devices talk to other devices peer-to-peer: local network connectivity enables proximal ad-hoc networking, service federation and chaining, media stream continuity.

- Personal tracking device uses smartphone as gateway: common pattern for bluetooth and WiFi connectivity.

- Smarthome local application controller and gateway: application gateway pattern ...

Design patterns for IoT:

For information models

- *Structured data*: XML documents, JSON objects,
- *Web Objects*: multiple resources at a URI endpoint, object encapsulation ...

For Interaction

- *REST*,
- *Event-driven architecture,*
- *Asynchronous Events*: State updates propagate through the system as they occur,
- State Machine,
- State Externalization ...

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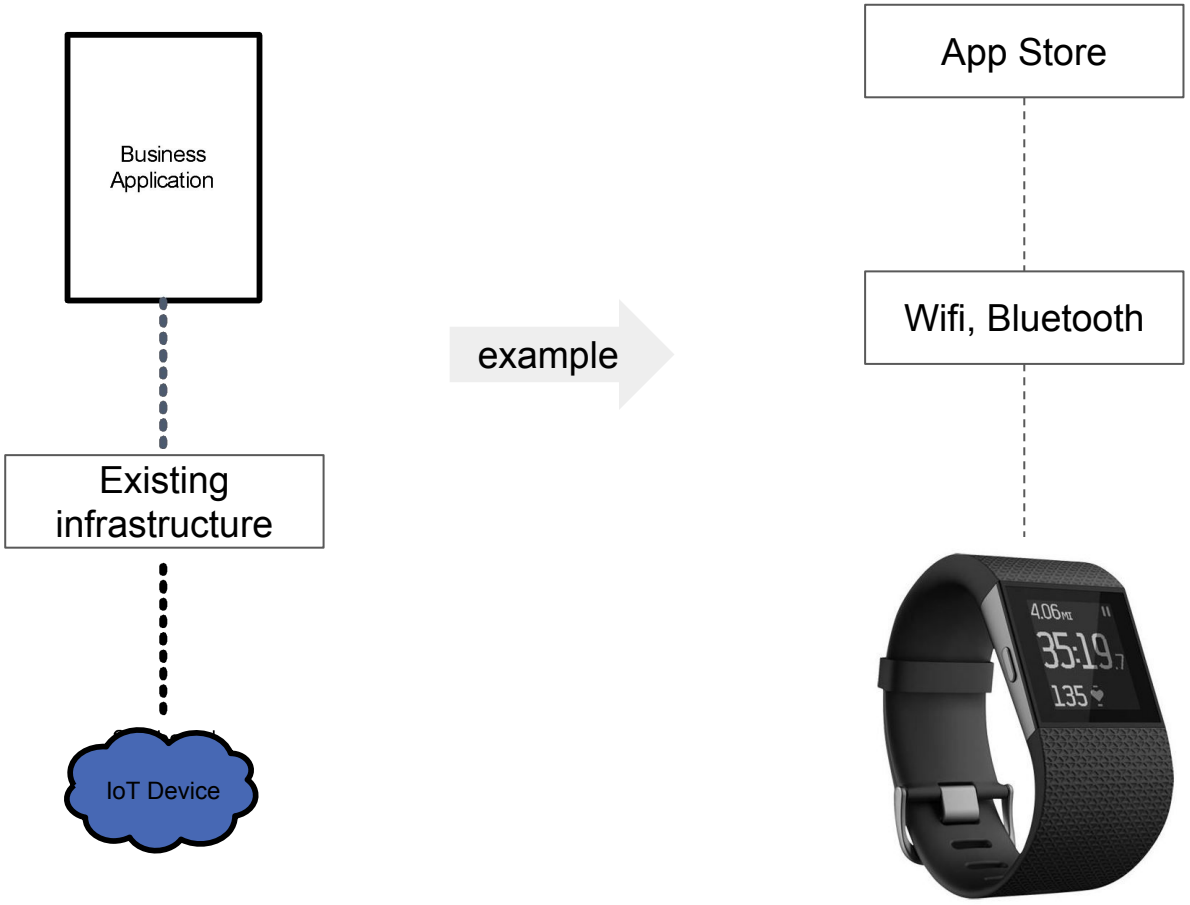
System Architecture

Vertical applications

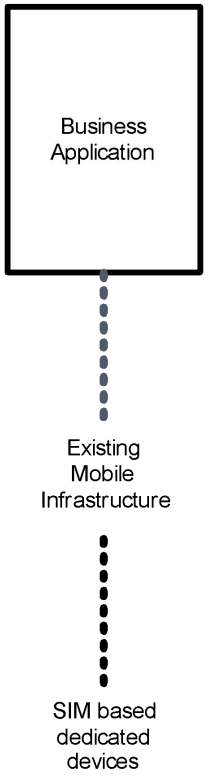
Architecture of vertical applications…



System Architecture

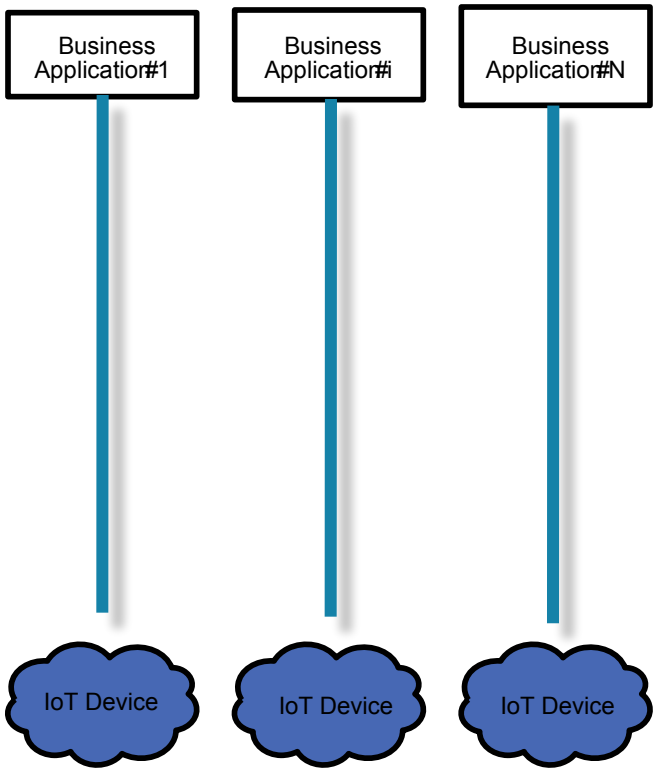
vertical applications

Vertical applications…



example

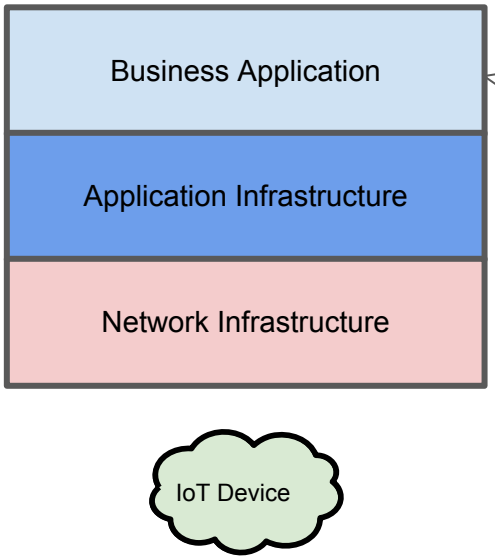
Applications don't share common infrastructure, environments and network elements



With permission of HP

System Architecture

vertical applications



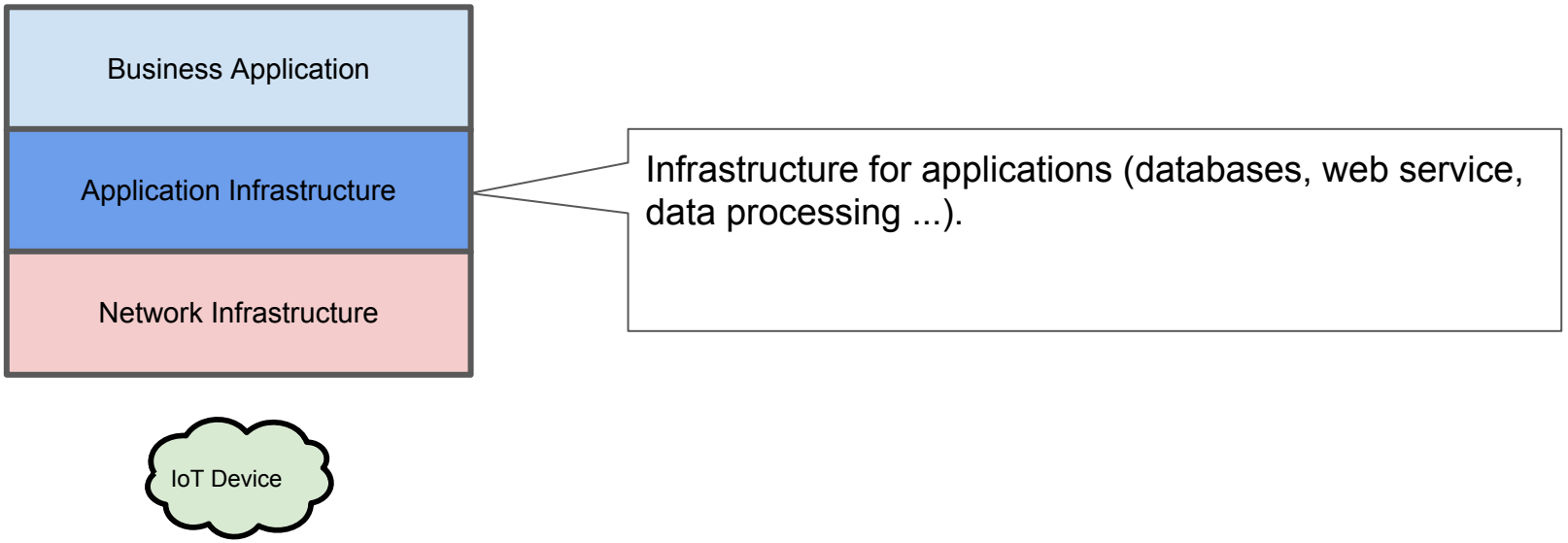
End-user application. It uses data from IoT systems. It also uses data analysis systems.

Complex decision-making algorithms are often at this level for the following reasons:

- Lack of computing capacity,
- The IoT can not have an overview ...
- The decision-making infrastructure is centralized,
- Energy consumption ...

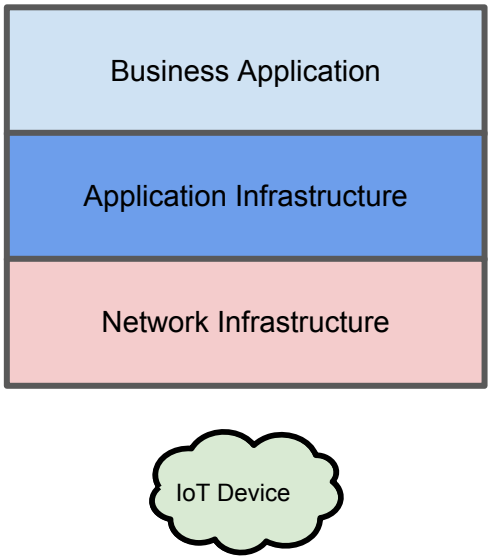
System Architecture

vertical applications



System Architecture

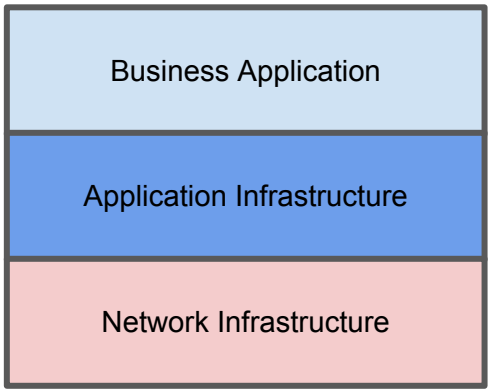
vertical applications

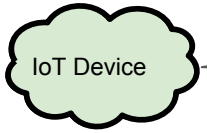


Physical interconnection (radio, wired ...), one uses several media with standard protocol IP, one calls this "IP unified".

System Architecture

vertical applications



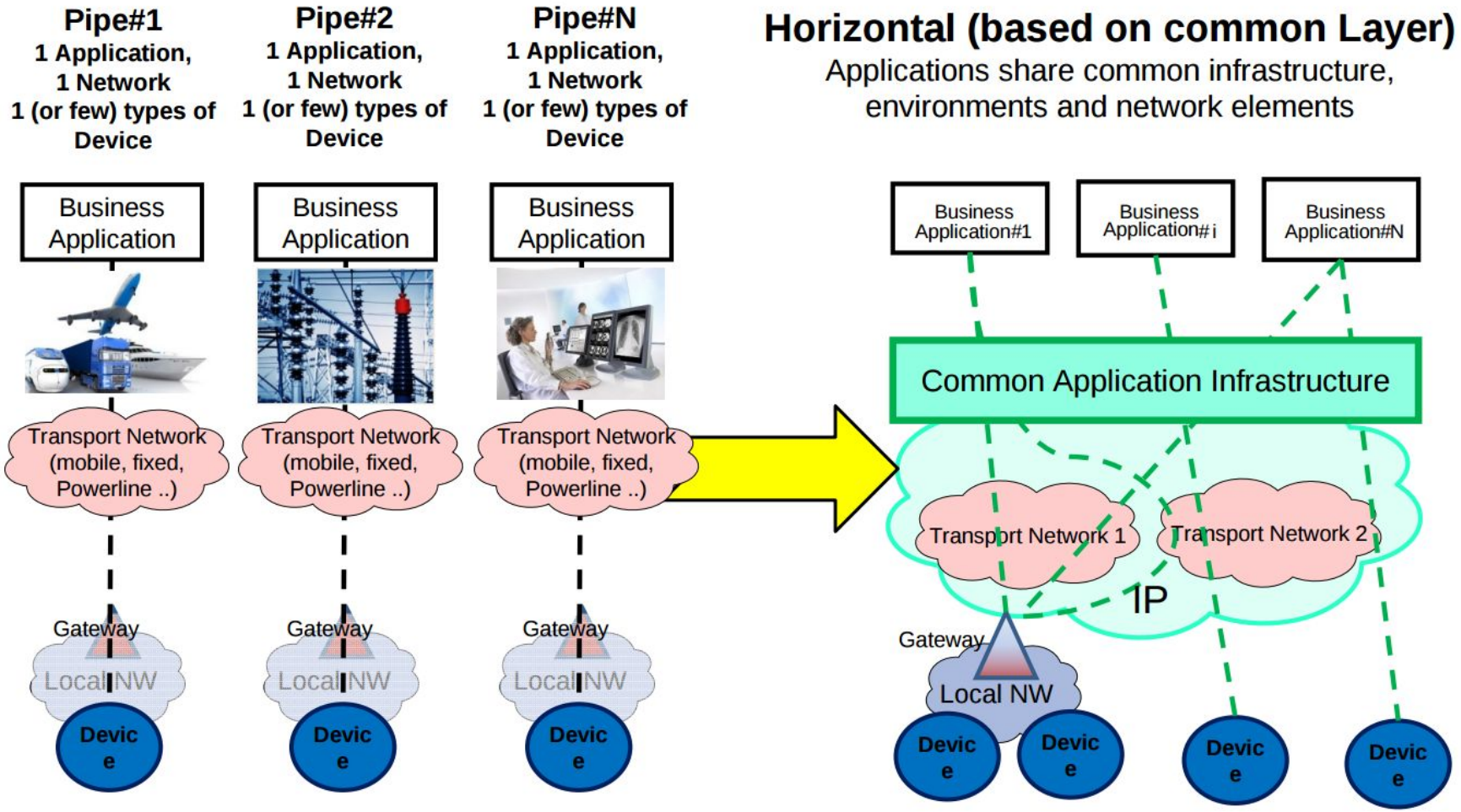


The IoT produces data and sends it to servers, local storage is possible. It also has actuators (ON / OFF system, PWM ...).

System Architecture

Horizontal applications

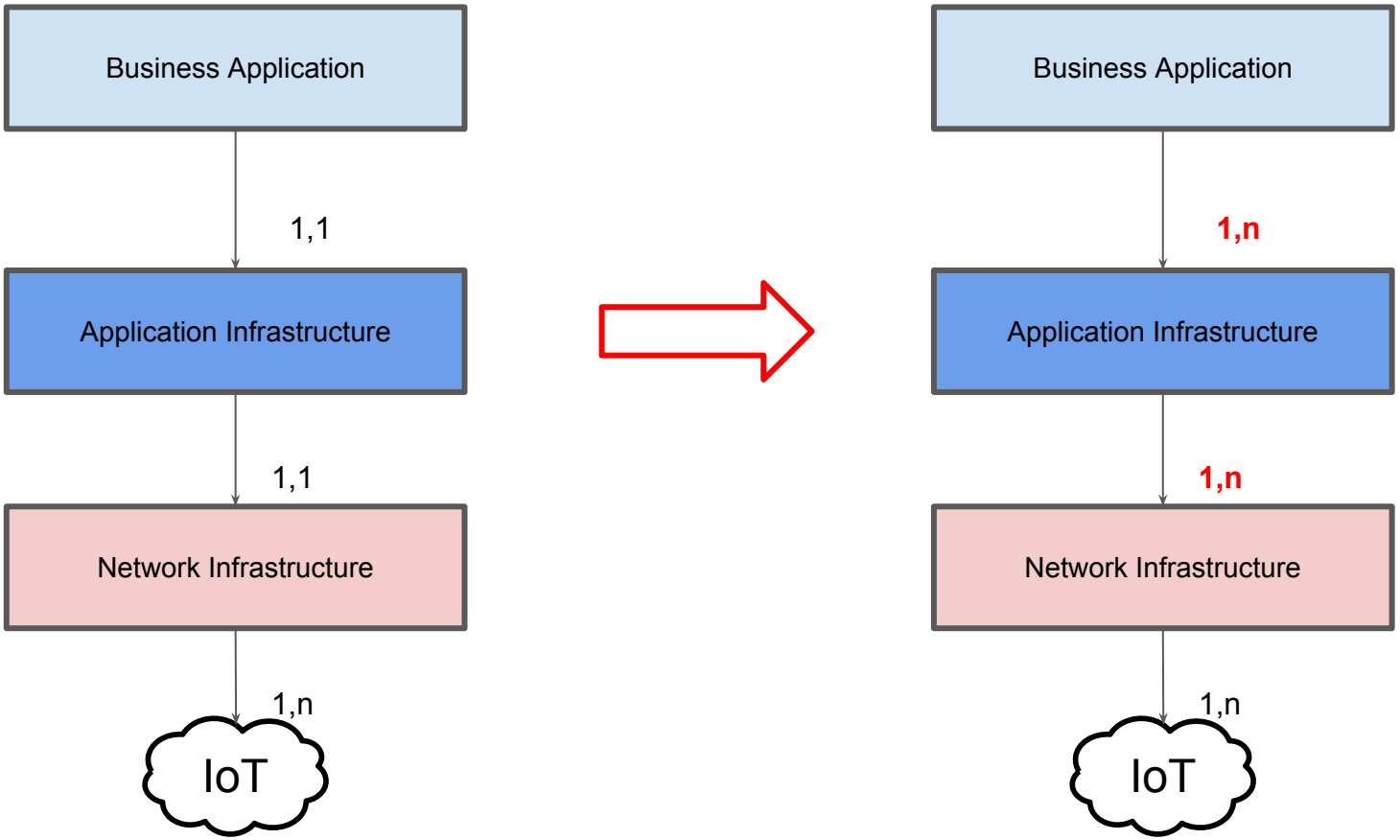
www.etsi.org



System Architecture

Horizontal applications

Reversing the trend



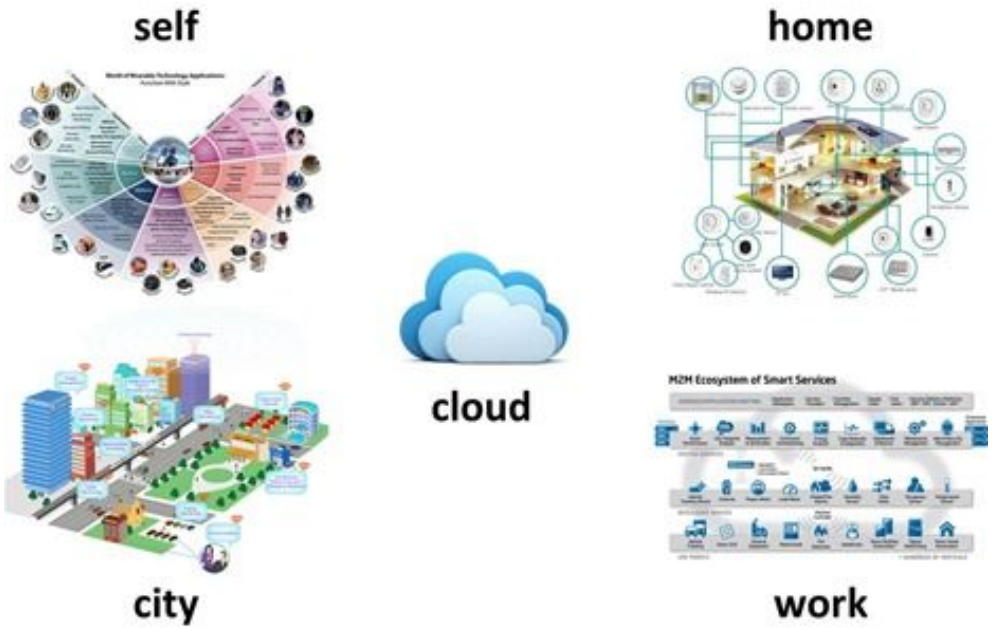
System Architecture

Classical architectures

The most classical architectures:

- It has what one carries on oneself: self
- That one has at home: home.
- What is in the city or in business.

The immaterial part of the cloud is at the crossroads of the four categories.

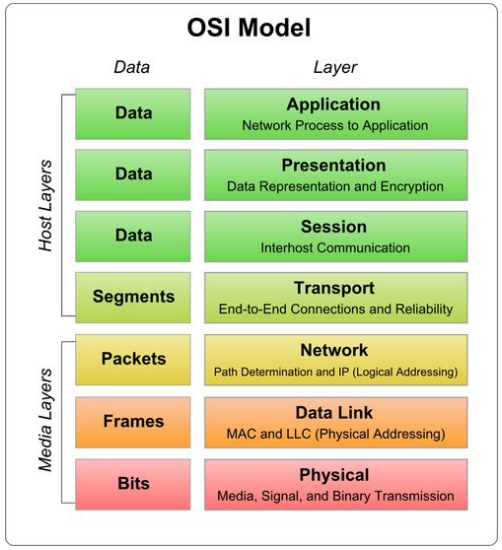


System Architecture

Network support

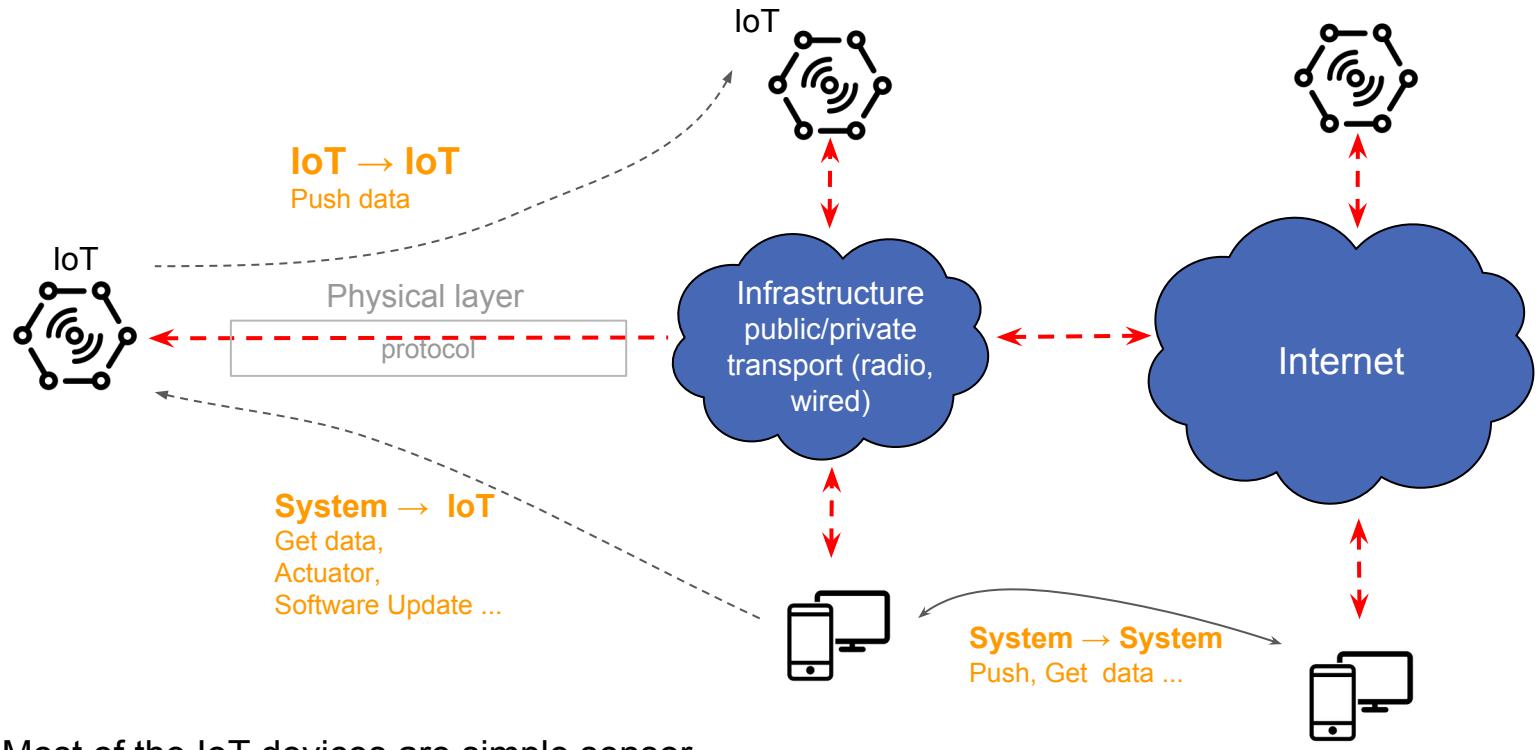
The iot takes as support OSI system with sometimes adaptation in order to solve problems specific to the IoT:

- management of the cost of communication,
- size of data,
- local area network,
- wireless system,
- special branch of industry ...



System Architecture

Network flows



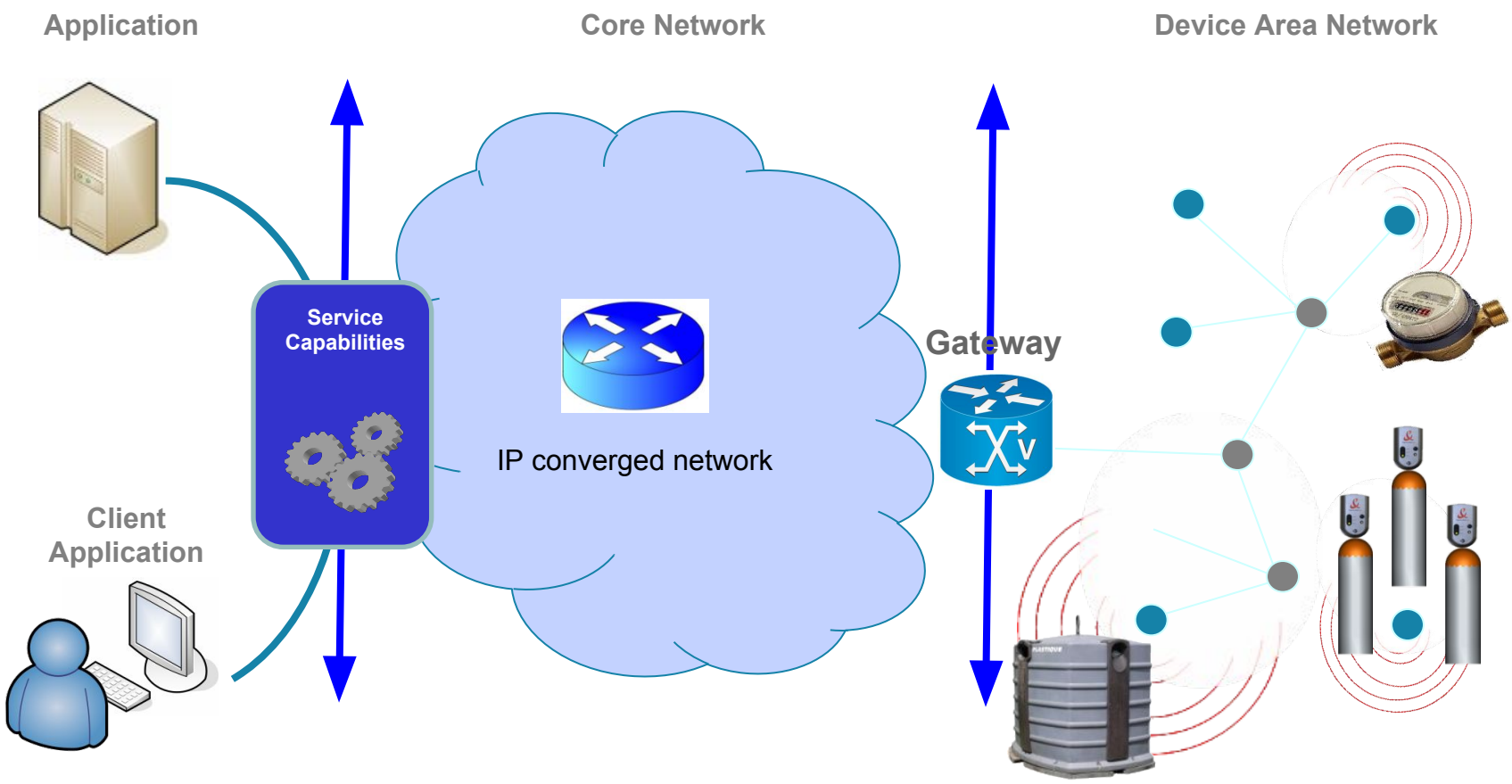
- Most of the IoT devices are simple sensor
  – Payload between 10 to 50 bytes, a few times per day
  – Traffic is therefore largely dominated by the uplink

http://www.societe-informatique-de-france.fr/wp-content/uploads/2015/12/IOT-Pr%C3%A9sentation-Orange.pdf

System Architecture

Common Architecture

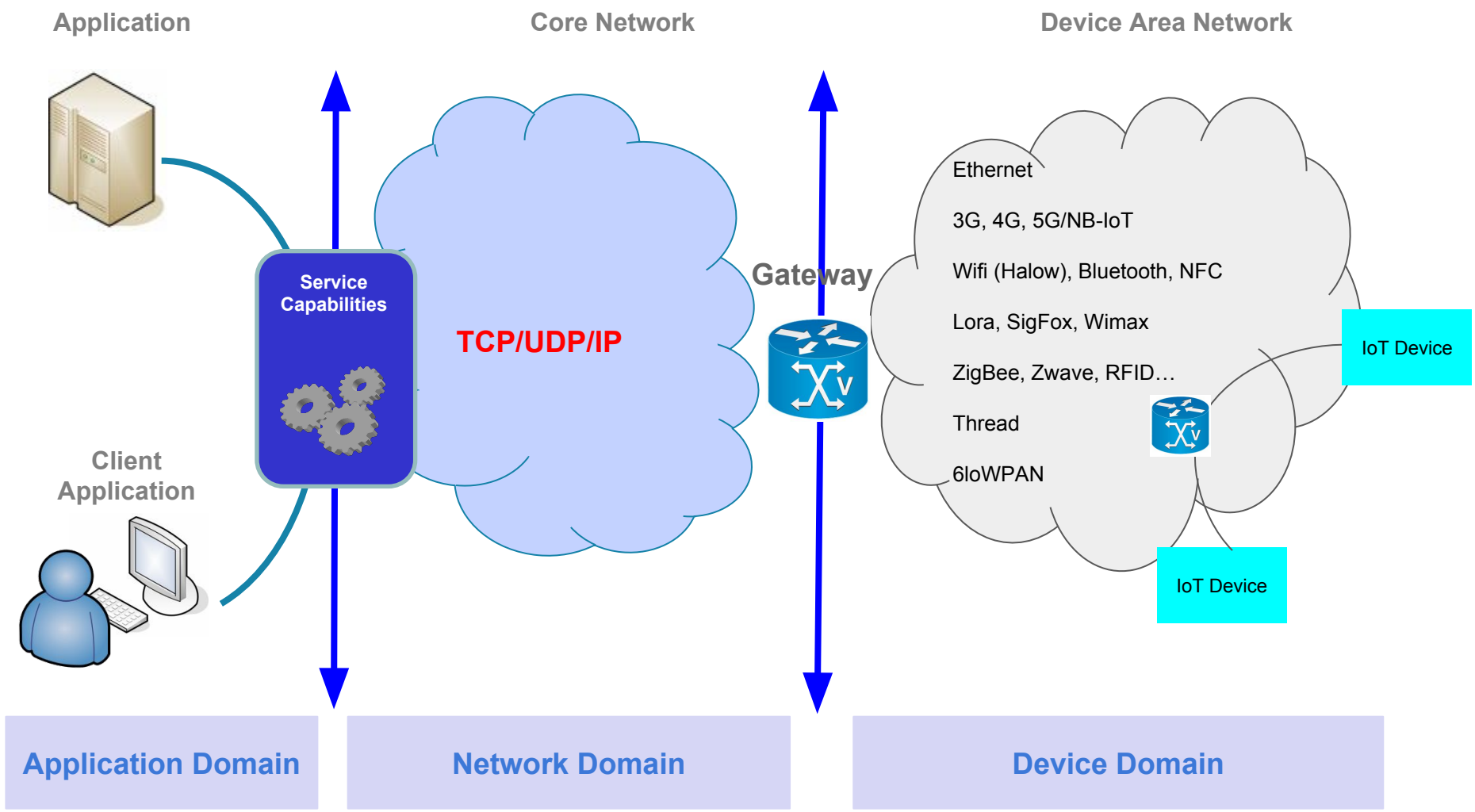
http://www.etsi.org/



System Architecture

Transport protocols: Home, City

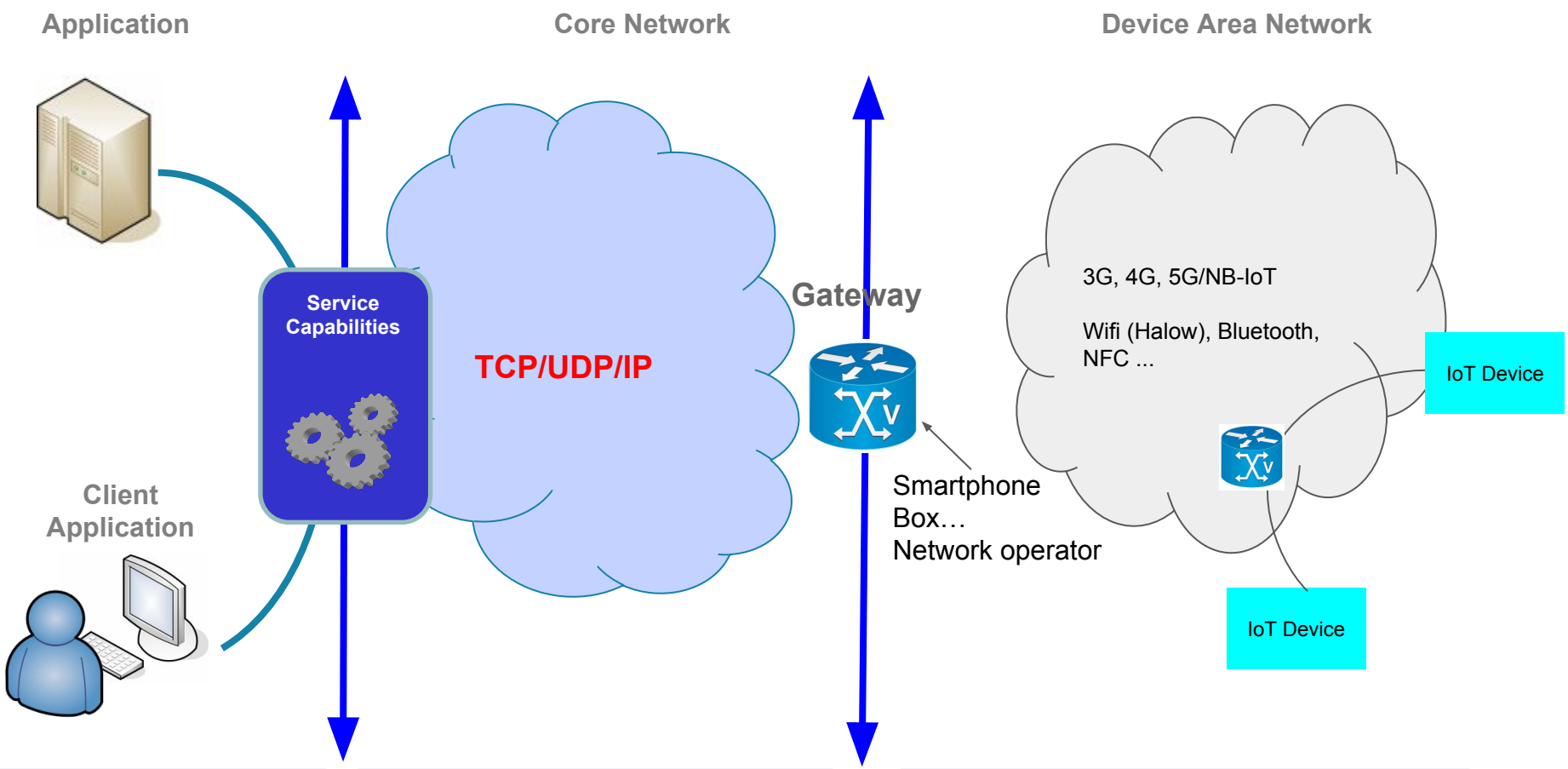
http://www.etsi.org/



System Architecture

Transport protocols: Self

http://www.etsi.org/



System Architecture

Gateway

- A gateway manages traffic between networks that use different protocols.
- A gateway is responsible for protocol translation and other interoperability tasks.
- An IoT gateway device is employed because some devices don't contain the network stack required for Internet connectivity, a gateway device acts as a proxy, receiving data from devices and packaging it for transmission over TCP/IP.

System Architecture

Application Domain

- End-user application,
- Ready-to-use catalog application, just a few fit for customization,
- The application uses all the capacity of the system: from the sensor to the big data:
  - Decision making,
  - Analysis,
  - Interaction with the natural environment...

System Architecture

Network Domain

- Independent of transport technologies,
- Whole IP convergence technology,
- Use of gateway system or direct access to the M2M platform,

System Architecture

Device Domain

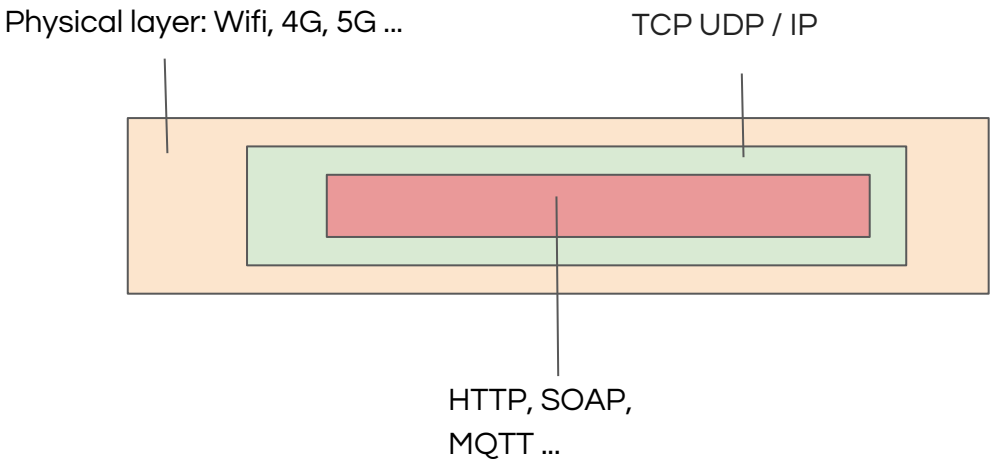
- Sensor and actuator system,
- Communication system,
- Performs a requested task.

System Architecture

Data Protocols for IoT - 1/2

There are several scenarios for payload transport:

- Use of TCP UDP (layer 4) and IP (layer 3) + application level (layer 7): HTTP, SOAP, MQTT, BACnet, Modbus,

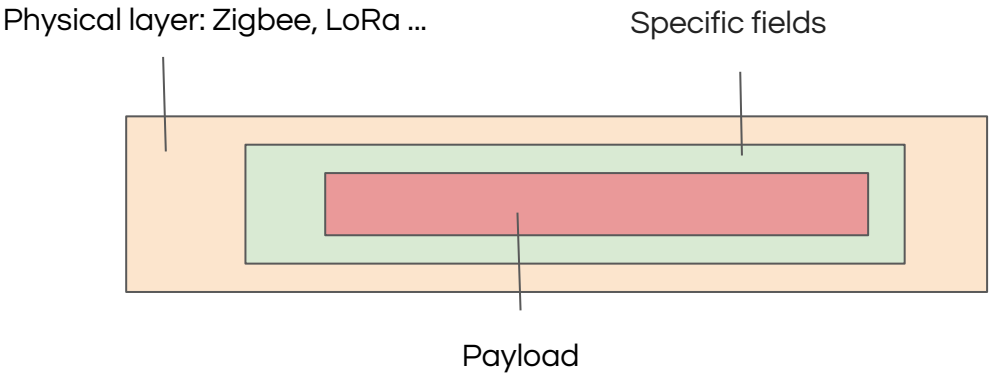


System Architecture

Data Protocols for IoT - 2/2

There are several scenarios for payload transport:

- The technology provides an end-to-end transport protocol:
  - ZigBee, LoRa, Sigfox, Bluetooth, NFC …
- M2M / IP gateway is mandatory



System Architecture

Transport protocols - Products

http://www.societe-informatique-de-france.fr/

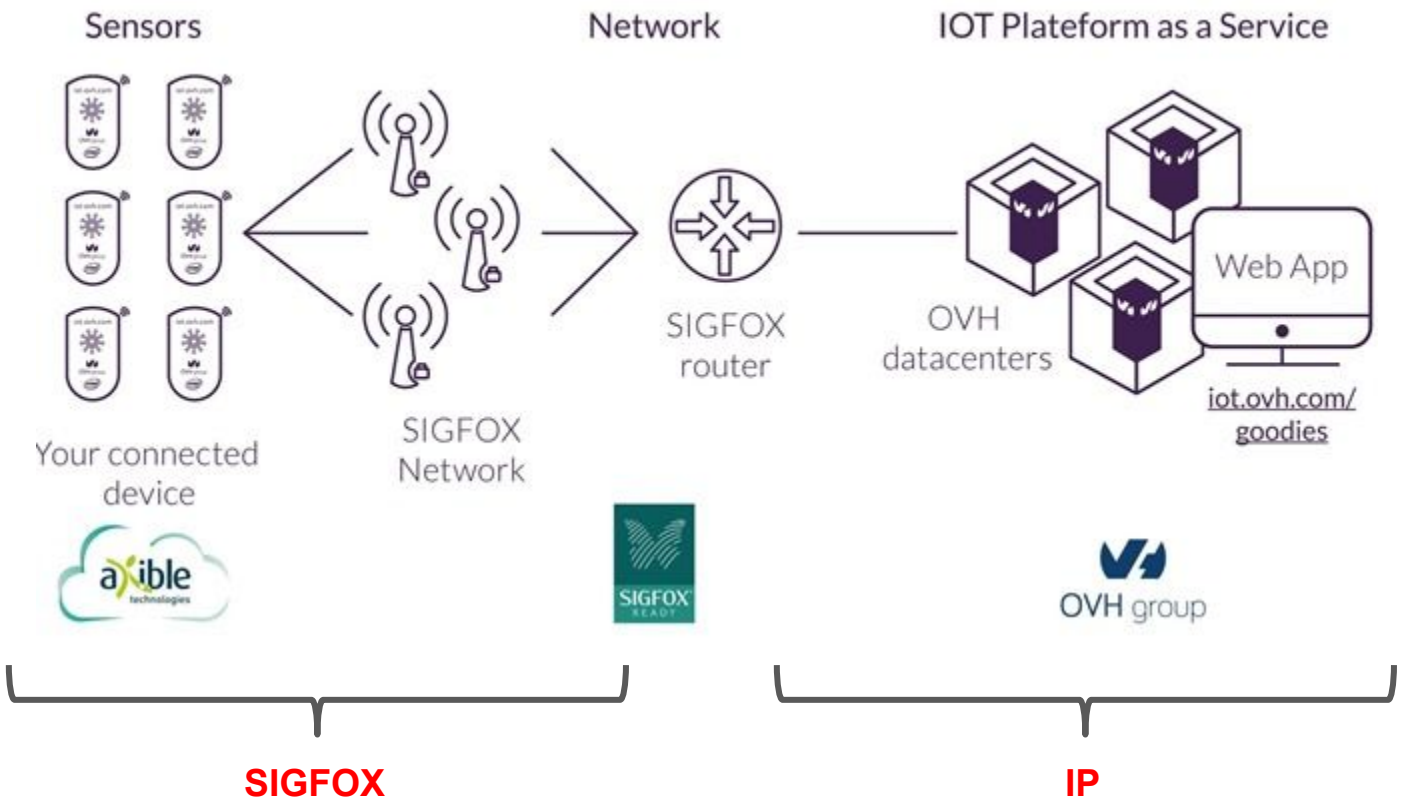
A myriad of radio communication solutions are already used to address IoT services:

- Unlicensed Band,
- Standard, other are proprietary solutions ...

System Architecture

Transport protocols - Long range communication

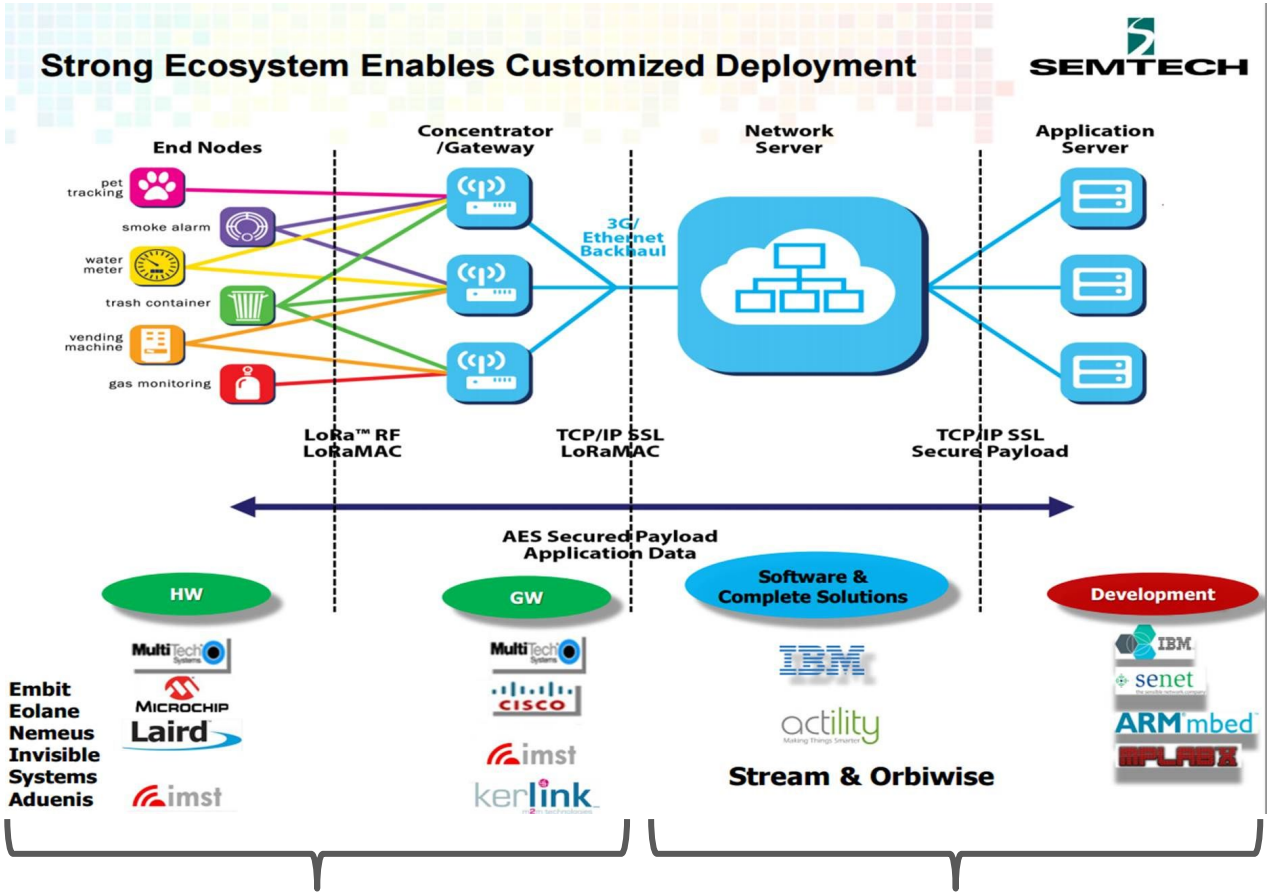
Sigfox



System Architecture

Transport protocols - Long range communication

LoRa



System Architecture

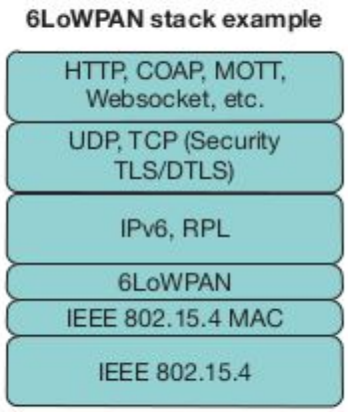
Transport protocols - mesh - 6loWPAN - Principle

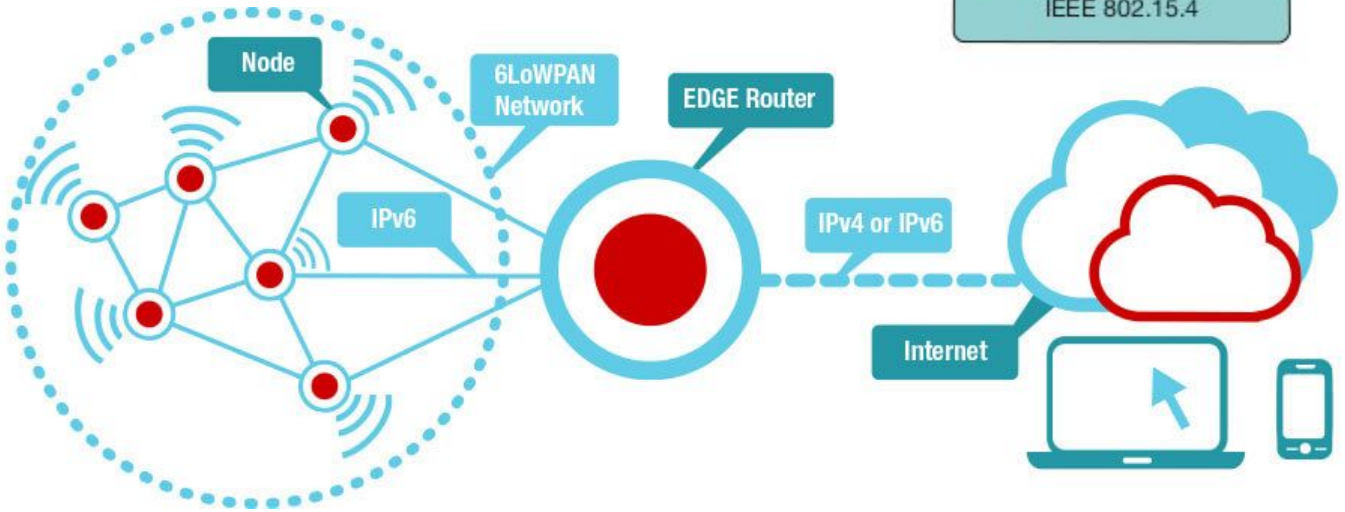
https://tools.ietf.org/html/rfc6282
https://en.wikipedia.org/wiki/IEEE_802.15.4

6LoWPAN - IETF RFC 6282

("IPv6 over Low-Power Wireless Personal Area Networks")

- IEEE 802.15.4 in the 2.4-GHz band,
- Ethernet, Wi-Fi,
- Low-power wireless mesh network.





System Architecture

Transport protocols - mesh - 6loWPAN - Limitation

https://tools.ietf.org/html/rfc6282
https://en.wikipedia.org/wiki/IEEE_802.15.4

- Limited throughput network (up to 250 kbit/s),
- IPv6 only (due to IPv6 compression),
- Limited payload size (33 bytes over UDP, 21 bytes over TCP),
- The packet size constraints imposed by IPv6 and 802.15.4 result in an excessive fragmentation / reassembly problem.

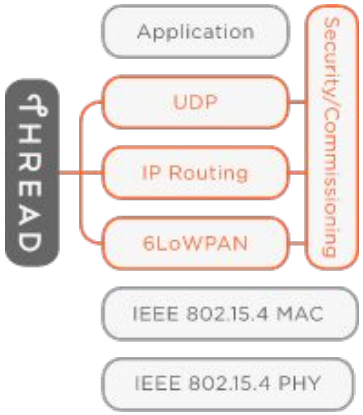
System Architecture

Transport protocols - mesh - Thread

http://threadgroup.org
https://en.wikipedia.org/wiki/Thread_(network_protocol)

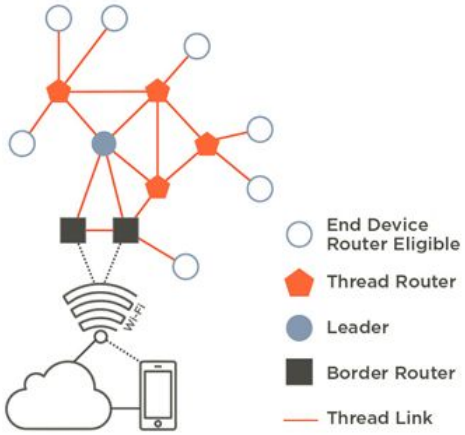
Thread - Closed-documentation

- Use existing infrastructure with a software update,
- Based on IEEE802.15.4 and 6LowPAN,
- Up to 250 nodes with high levels of authentication and encryption,
- IPv6-based, UPD + DTLS,
- Designed for very low power.



OpenThread - BSD license (allowing anyone to reuse, modify or redistribute it in source or binary form)

- https://github.com/openthread/openthread)
- https://github.com/ARMmbed/nanostack-border-router



(thread Leader is a device responsible for managing router ID assignment)

System Architecture

Transport protocols - mesh - Zwave

z-wavealliance.org
https://en.wikipedia.org/wiki/Z-Wave

Z-Wave Alliance ZAD12837 / ITU-T G.9959 - open protocol / proprietary technology

- Receipt acknowledgment,
- Each component is both receiver and transmitter,
- Z-Wave gateway for Ip an Internet access,
- The throughput is 9.6/40/100kbit/s ,
- Enabling control of up to 232 devices,
- The only maker of chips is Sigma Designs,

Contrôleur Z-Wave Plus dongle USB - 40€

Open source: http://www.openzwave.com/ - to incorporate Z-Wave functionality into applications.

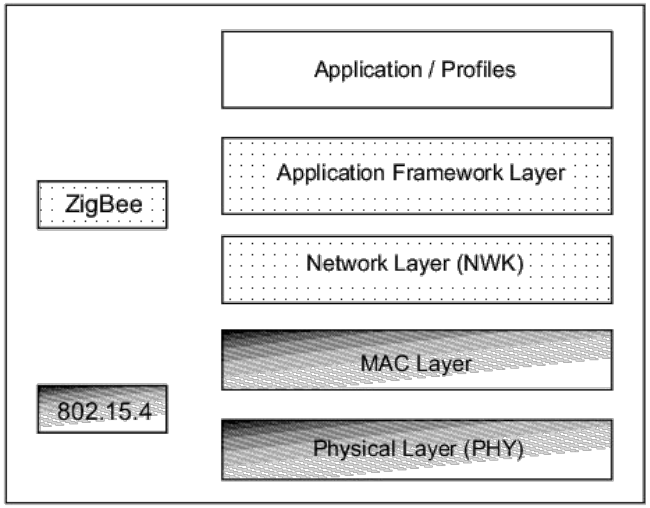
System Architecture

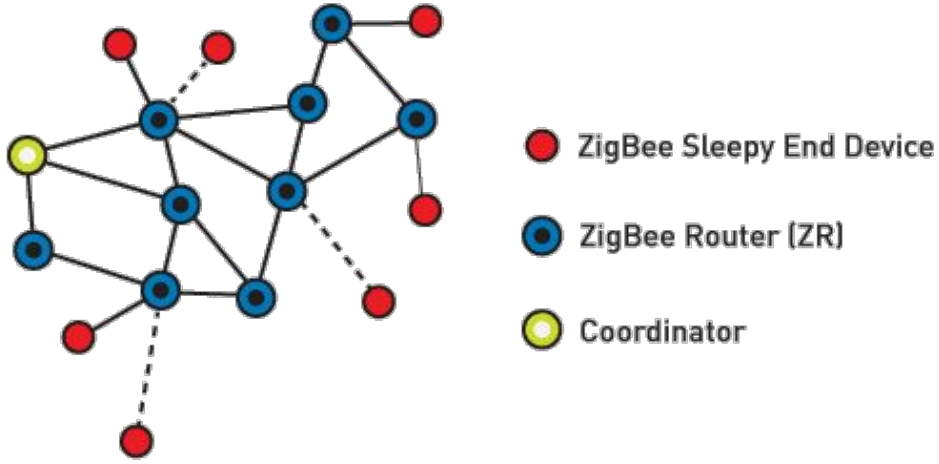
Transport protocols - mesh - ZigBee

http://www.zigbee.org
https://en.wikipedia.org/wiki/ZigBee

ZigBee - IEEE 802.15.4-2003 - ZigBee Alliance

- The nodes are designed to work for several months (up to ten years for the less consuming),
- Data rate : 250 Kb/s (up to),
- Ready Profile: Home Automation , Personal Home & Hospital Care, Smart Energy ...





System Architecture

Transport protocols - EnoCean

https://www.enocean.com
https://en.wikipedia.org/wiki/EnOcean

EnoCean - ISO/IEC 14543-3-10

- Ultra low power radio applications,
- Batteryless wireless communications with piezo generators,
- AES algorithm with a 128-bit key,
- 125 kilobits per second, 50 µWs for a single telegram,
- 868 MHz for Europe,
- Unique 32-bit identification number (ID),
- Gateway: WiFi, Ethernet/IP, KNX, BACnet,
- Raspberry Pi board with the EnOcean Developer Kit.

IP gateway

System Architecture

Transport protocols - 5G/NB-IoT

http://www.3gpp.org/
https://en.wikipedia.org/wiki/NarrowBand_IOT
http://www.3gpp.org/news-events/3gpp-news/1785-nb_iot_complete

Narrow Band* **IoT** (NB-IoT) - 3GPP Release 13

- LTE (Long Term Evolution),
- Ubiquitous coverage,
- Low Power Wide Area Network (LPWAN),
- Low range communication,
- Low cost, long battery life,
- **Managed quality of service** (QoS),
- End-to-end security,
- Availability 2017.

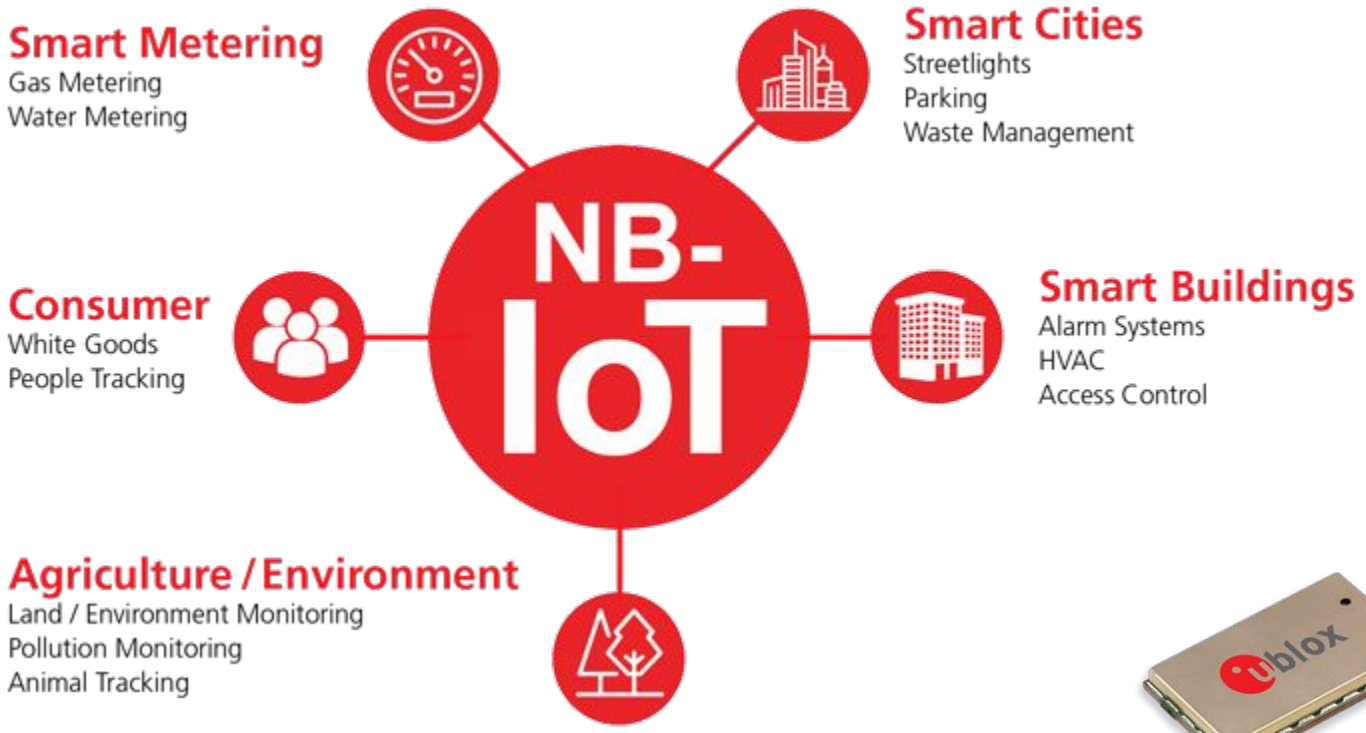
- **Specification**:
  - Downlink Peak Rate: 250 kbps,
  - Uplink Peak Rate: 250 kbps (multi-tone), 20 kbps (single-tone),
  - Duplex Mode : Half Duplex,
  - Device Transmit Power: 23 dBm or 20 dBm

*NarrowBand: bande étroite, https://en.wikipedia.org/wiki/Narrowband

System Architecture

Transport protocols - 5G/NB-IoT

http://www.3gpp.org/
https://en.wikipedia.org/wiki/NarrowBand_IOT
http://www.3gpp.org/news-events/3gpp-news/1785-nb_iot_complete



https://www.u-blox.com/en/product/sara-n2-series

System Architecture

Transport protocols- Wifi Halow

http://standards.ieee.org/findstds/standard/802.11ah-2016.html
https://en.wikipedia.org/wiki/IEEE_802.11ah

Wifi Halow - IEEE 802.11ah (2016)

- Spectrum of 900 MHz without a license (863 MHz - 868 MHz in Europe), today 2.4 GHz or 5 GHz,
- Devices operating on batteries,
- Data rates up to 347 Mbit/s,
- Signal is less attenuate when it goes through objects (wall, ground) , the equipment does not consume as much power,
- **Double the range** of wifi current standards,
- A standby mode.

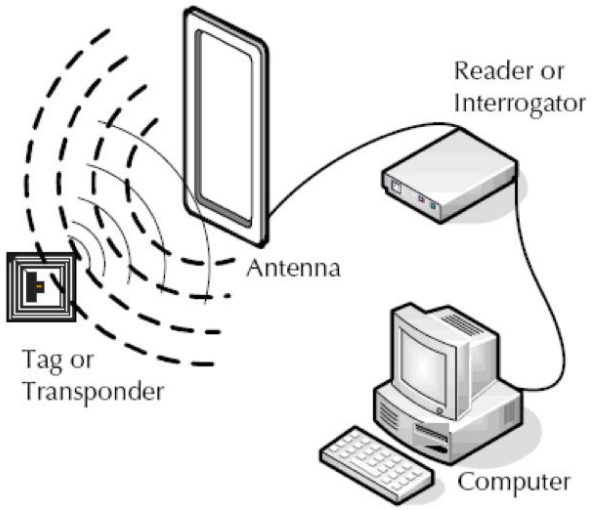
System Architecture

Transport protocols - RFID

http://standards.ieee.org/findstds/standard/802.11ah-2016.html
https://en.wikipedia.org/wiki/IEEE_802.11ah

RFID - Radio-frequency identification

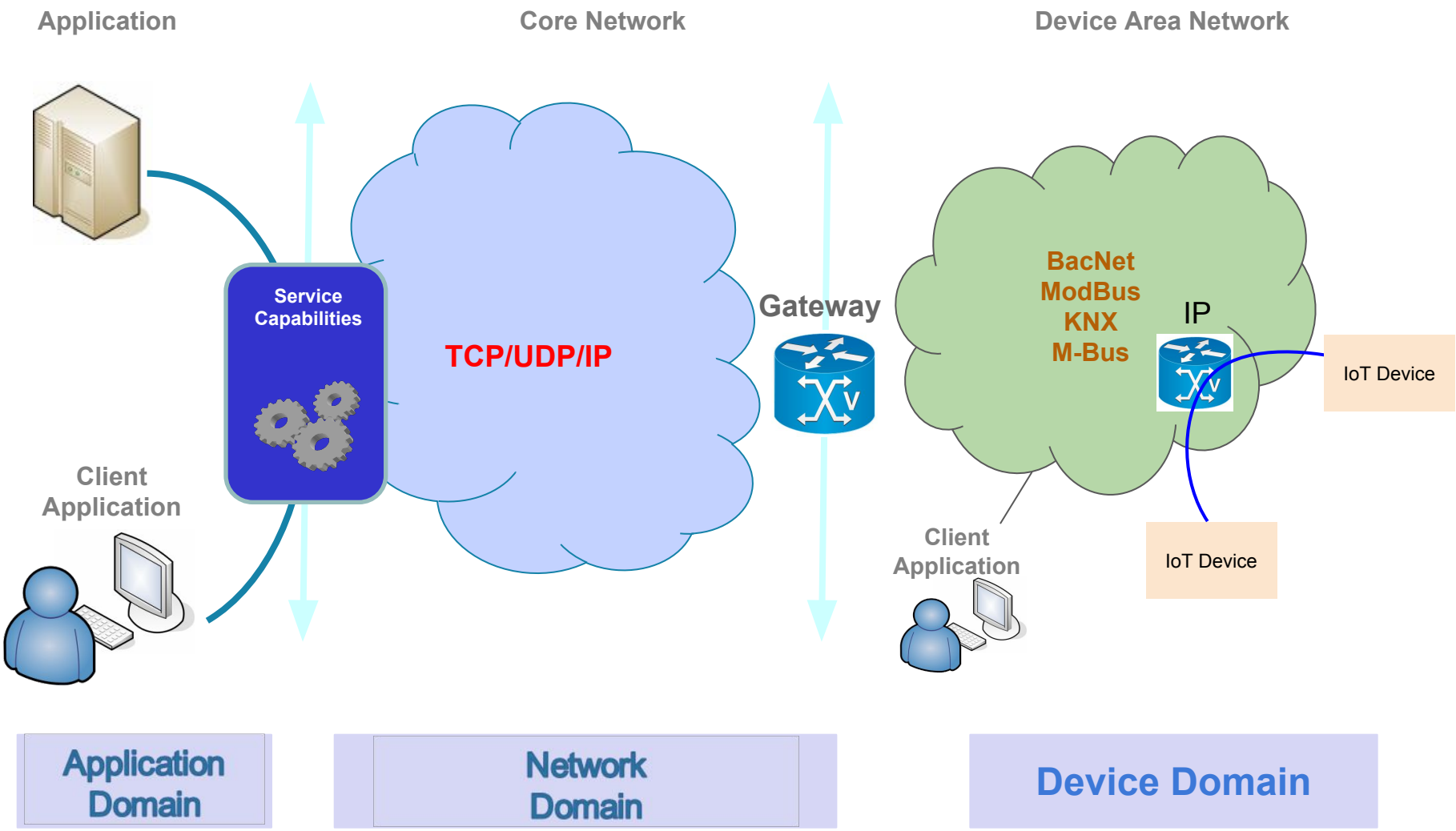
- Invented in 1948 by Harry Stockman
- Identification of objects
- Dedicated for short range communication
- Data: read, write
- Tag**:**
  - Active: internal battery (2 → 4 years), greater range, higher date trans. rates
  - Passive: without battery, unlimited life,
- Component:
  - Tag: chip , antenna
  - Reader: RF module, antenna
  - Host computer : middleware



System Architecture

Transport protocols: Work, City

http://www.etsi.org/



System Architecture

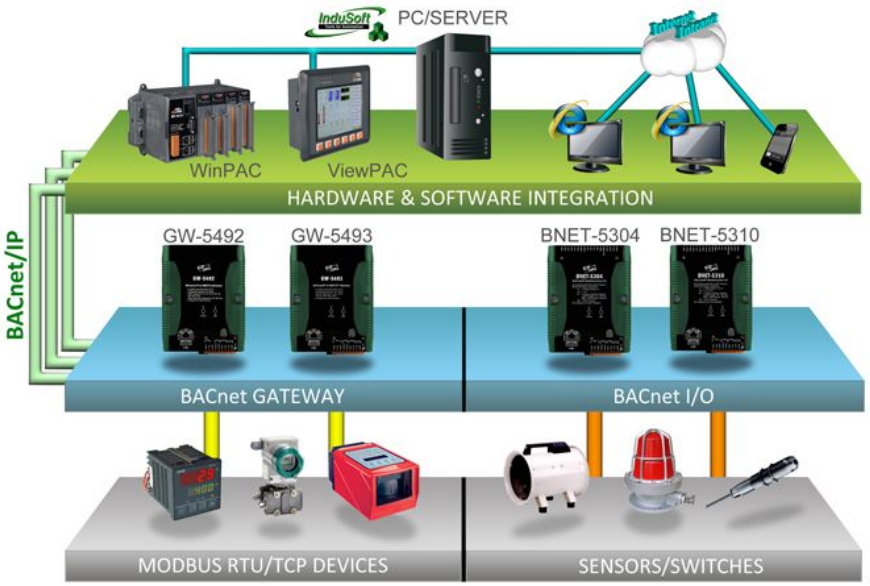
Protocol BACnet: City, Building

http://www.iso.org/iso/fr/catalogue_detail?csnumber=63753
https://en.wikipedia.org/wiki/BACnet

BACnet is a communications protocol for Building Automation and Control (BAC) networks. It is an ASHRAE, ANSI, and ISO 16484-5 standard protocol.

- Control systems for applications such as heating, ventilating, and air-conditioning control (HVAC), lighting control, access control, and fire detection systems and their associated equipment.

http://www.icpdas.com/root/product/solutions/industrial_communication/fieldbus/bacnet_ip/bacnet_ip_intro.html



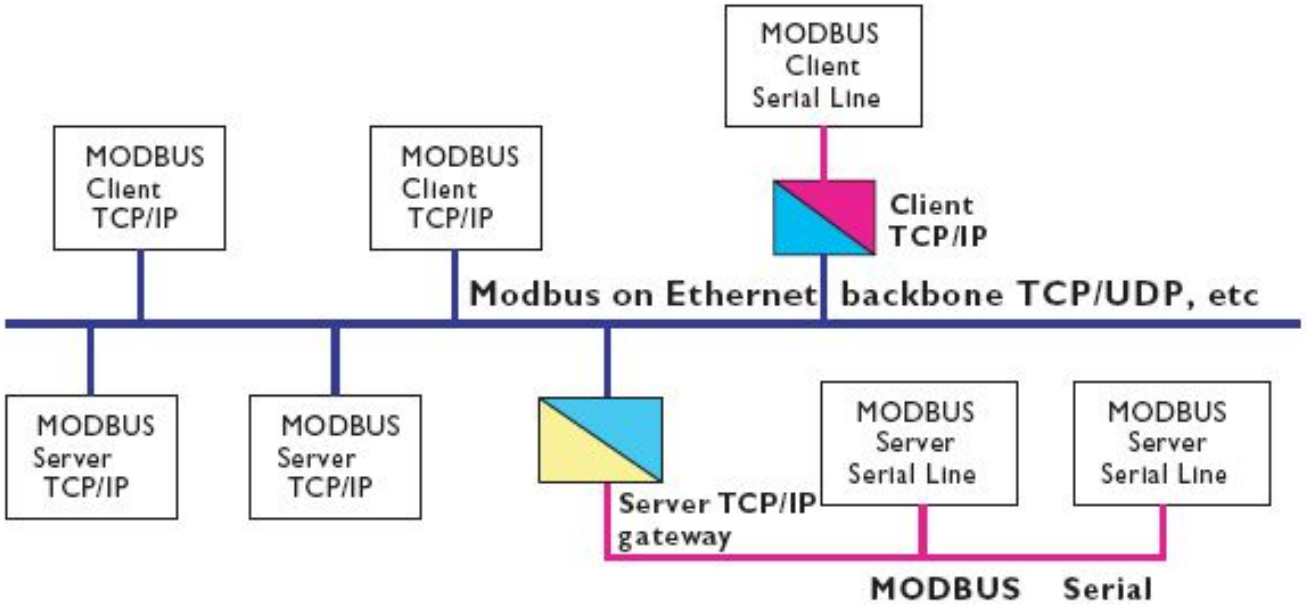
System Architecture

Protocol ModBus: City

http://www.modbus.org/
https://en.wikipedia.org/wiki/Modbus

ModBus is a serial communications protocol originally published by Schneider Electric.

- For use with its programmable logic controllers (PLCs).
- De facto standard communication protocol.



System Architecture

Protocol ModBus - Open source library

http://www.modbus.org/

http://libmodbus.org/ - Linux

- LGPL v2.1+
- Library is written in C
- Supports RTU (serial) and TCP (Ethernet) communications.

http://jamod.sourceforge.net/

- Library is written in Java

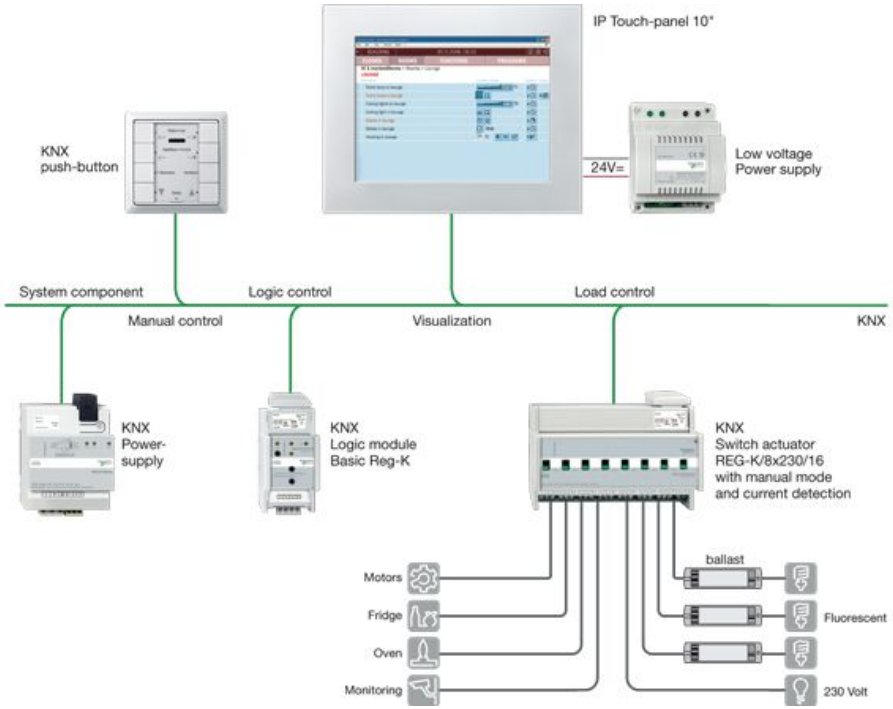
....

System Architecture

Protocol KNX: City, Home

http://www.knx.fr
http://www.iso.org/iso/fr/catalogue_detail.htm?csnumber=59865
https://en.wikipedia.org/wiki/KNX_(standard)

KNX is a standardized (EN 50090, ISO/IEC 14543), OSI-based network communications protocol for building automation. KNX is the successor to, and convergence of, three previous standards: the European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB or Instabus). The KNX standard is administered by the KNX Association



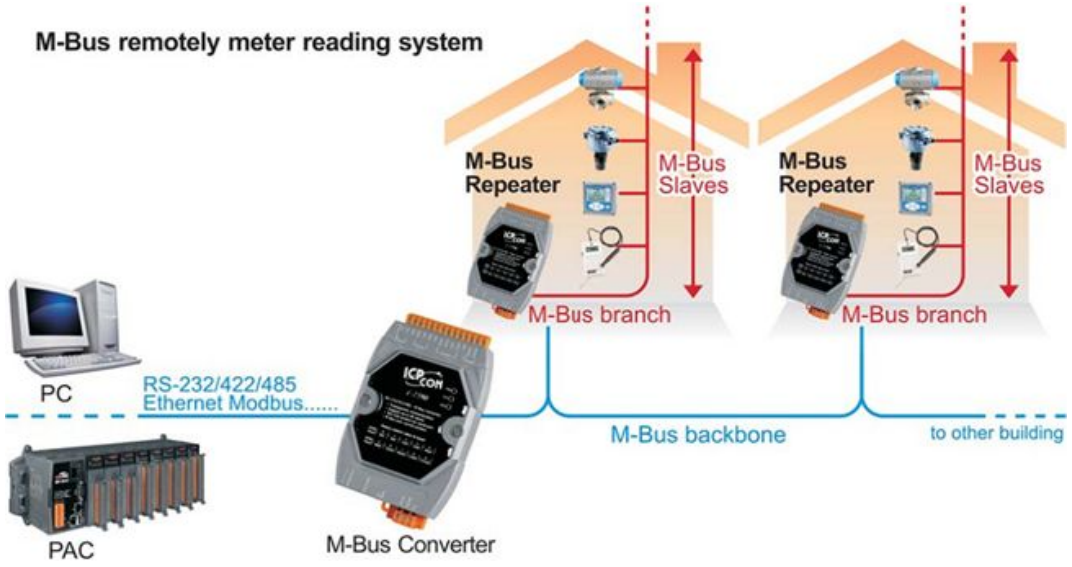
System Architecture

Protocol M-Bus: City

http://oms-group.org/en/standard-sources/
https://en.wikipedia.org/wiki/Meter-Bus

M-Bus (Meter-Bus) is a European standard (EN 13757-2 physical and link layer, EN 13757-3 application layer).

- For the remote reading of gas or electricity meters,
- For communication on two wires, making it very cost effective.
- A radio variant of M-Bus (Wireless M-Bus) is also specified in EN 13757-4.



System Architecture

Data Protocols for IoT - REST

https://www.w3.org/2001/sw/wiki/REST
https://en.wikipedia.org/wiki/Representational_state_transfer

REST (Representational state transfer)

- Providing interoperability between computer systems on the Internet,
- Predefined set of stateless operations,
  - Each request contains necessary to service the request,
  - No client context being stored on the server between requests.
- The message inside: elicits a response that may be in XML, HTML, JSON or some other defined format,
- WWW REST protocol: HTTP verbs GET, POST, PUT, DELETE.

System Architecture

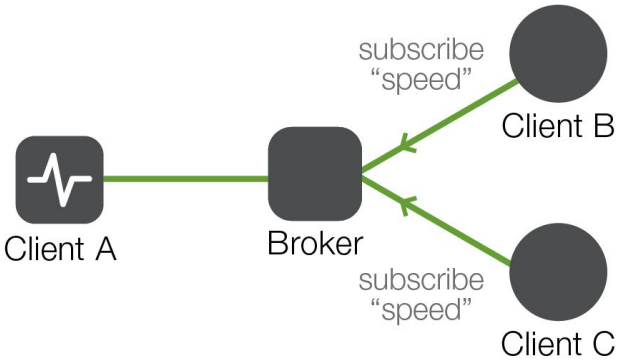
Data Protocols for IoT - “subscribe and publish” - MQTT

http://www.iso.org/iso/catalogue_detail.htm?csnumber=69466
https://en.wikipedia.org/wiki/MQTT

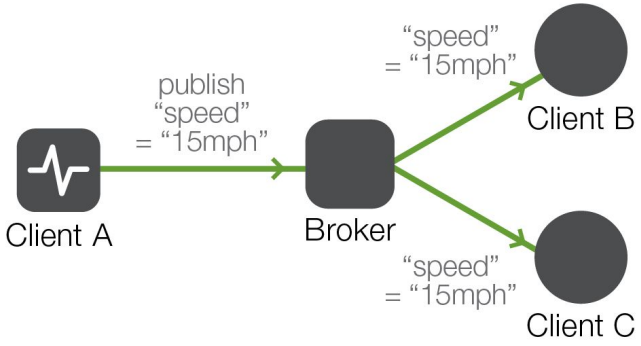
MQTT (Message Queuing TelemetryTransport) - ISO/IEC PRF 20922 :

- Designed for lightweight machine-to-machine communications.
- The message inside: JSON, HTML, CSV, or even a proprietary binary format.

All three clients open TCP connections with the broker. Clients B and C subscribe to the topic speed.



At a later time, Client A publishes a value of 15mph for topic speed. The broker forwards the message to all subscribed clients.



System Architecture

Data Protocols for IoT - “subscribe and publish” - XMPP

https://tools.ietf.org/html/rfc6120
http://xmpp.org
https://en.wikipedia.org/wiki/XMPP

XMPP (Extensible Messaging and Presence Protocol) - IETF 6120, 3920, 3921

- Communication between machines in many different scenarios:
  - Request/Response, Asynchronous Messaging, and Publish/Subscribe
- Standard bi-directional socket connections,
- Presence (broadcast, probes, directed …),
- The message inside: XML over Http/WebSocket, binary data must be first base64,
- Extension for “Provisioning*” (XEP-0324) and “Discovery” (XEP-347),
- XMPP provisioning server,
- XMPP provides “Global Identities,” which helps identify an unlimited number of devices by their unique XMPP addresses …

XEPs: XMPP extension for IoT

*Provisioning: enables IoT devices to delegate trust to more capable servers, defines how provisioning, the management of access privileges, etc., can be efficiently and easily implemented.

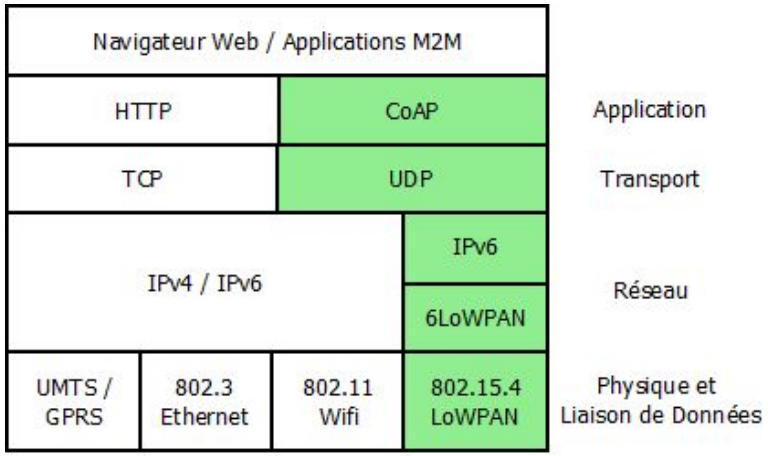
System Architecture

Data Protocols for IoT - “subscribe and publish” - CoAP

https://tools.ietf.org/html/rfc7252
https://en.wikipedia.org/wiki/Constrained_Application_Protocol

CoAP (Constrained Application Protocol) - IETF RFC 7252

- REST architecture,
- Use UDP/IP (with loss recover mechanism),
- Observation mechanism (like subscribe and publish),
- Coap Resource Directory,
- The message inside: text, binary.



System Architecture

Data Protocols for IoT - Websocket

https://tools.ietf.org/html/rfc6455
https://en.wikipedia.org/wiki/WebSocket

Websocket - IETF RFC 6455 - W3C

- Bidirectional communication technology for web browsers and web servers,
- Browser-side: JavaScript interface in HTML 5,
- Use TCP/HTTP (http for protocol handshake),
- Transport Layer Security (TLS),
- The message inside: plain text messages, binary data or images,
- Web Socket transport layer: XMPP, STOMP, AMQP ...

System Architecture

Data Protocols for IoT - AMQP

http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=64955
https://en.wikipedia.org/wiki/Advanced_Message_Queuing_Protocol

AMQP (Advanced Message Queuing Protocol) - ISO/IEC 19464:2014

- Connecting different systems to talks to each other (client , broker*),
- Create cross-platform messaging applications,
- **Avoids using gateway** between evolving systems,
- Message acknowledgements,
- The message inside: the payload of messages are not defined by the AMQP,
- Uses TCP/IP.

*Broker (Server): An application - implementing the AMQP model - that accepts connections from clients for message routing, queuing etc

System Architecture

IoT discovery - mDNS

https://tools.ietf.org/html/rfc6762
https://en.wikipedia.org/wiki/Multicast_DNS

mDNS (multicast Domain Name System) - IETF RFC 6762

- Name resolution without a server (MDNS records are stored locally on each machine),
- MDNS is based on the principle of multicast (IPv4 224.0.0.251, IPv6 FF02::FB),
- UDP port 5353.

System Architecture

IoT identification

https://en.wikipedia.org/wiki/Electronic_Product_Code
https://en.wikipedia.org/wiki/Ucode_system

Hardware:

- Maxim DS1990A (1-Wire®): Unique Factory-Lasered 64-Bit Registration,
- Processor Unique ID,

  → http://www.mouser.fr/Search/Refine.aspx?Keyword=Serial+number+ic

Software:

- **EPC** (Electronic Product Code)
- **uCode**: Structure and Resolution mechanism (ucode resolution server and ucode information server …)

System Architecture

IoT management - TR-069

https://www.broadband-forum.org/
https://en.wikipedia.org/wiki/TR-069

TR-069 CWMP - Broadband Forum

- Addresses modems, routers, gateways, as well as end-user devices,
- The TR-069 standard was developed for automatic configuration and management,
- As a bidirectional SOAP/HTTP-based protocol,
- Security and authentication mechanism, data model ...

EasyCwmp: a GPLv2 open source implementation of the TR069

System Architecture

IoT management - OMA-DM

http://www.openmobilealliance.org/
https://en.wikipedia.org/wiki/OMA_LWM2M

OMA-DM - Open Mobile Alliance

- **Provisioning**: Configuration of the device, enabling and disabling features,
- **Device Configuration:** Allow changes to settings and parameters of the device,
- **Software Upgrades** ,
- **Fault Management** – Report errors from the device,
- OMA DM protocol uses XML for data exchange,
- Transport : USB, RS-232, wireless media:GSM, CDMA, IrDA, or Bluetooth),
- Transport layers: WSP (WAP), HTTP, or OBEX or similar transports.

System Architecture

Data Protocols for IoT - Synthesis

Infrastructure (ex: 6LowPAN, IPv4/IPv6)

Identification (ex: EPC, uCode, IPv6, URIs)

Comms / Transport (ex: Wifi, Bluetooth, LPWAN)

Discovery (ex: Physical Web, mDNS, DNS-SD)

Data Protocols (ex: MQTT, CoAP, AMQP, Websocket)

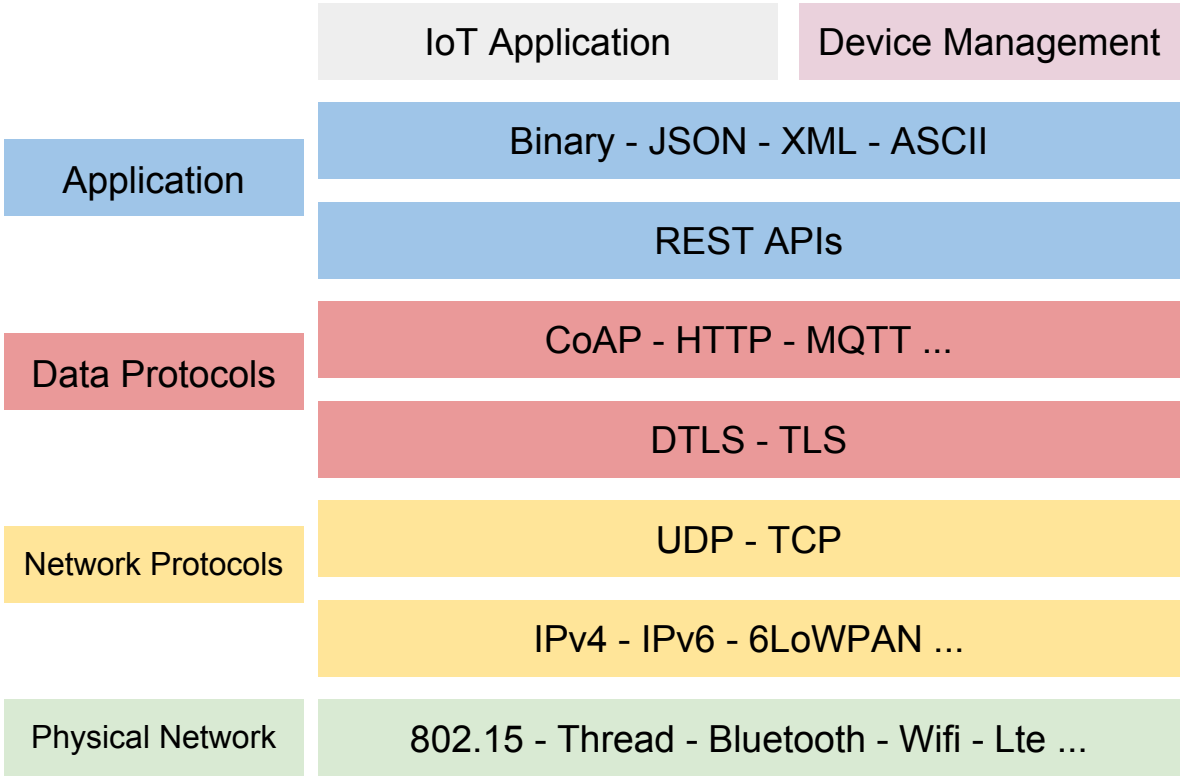
Device Management (ex: TR-069, OMA-DM)

Semantic (ex: JSON, Web Thing Model)

next → Multi-layer Frameworks (ex: OneM2M, Fiware, Alljoyn, IoTivity, Weave, Homekit)

System Architecture

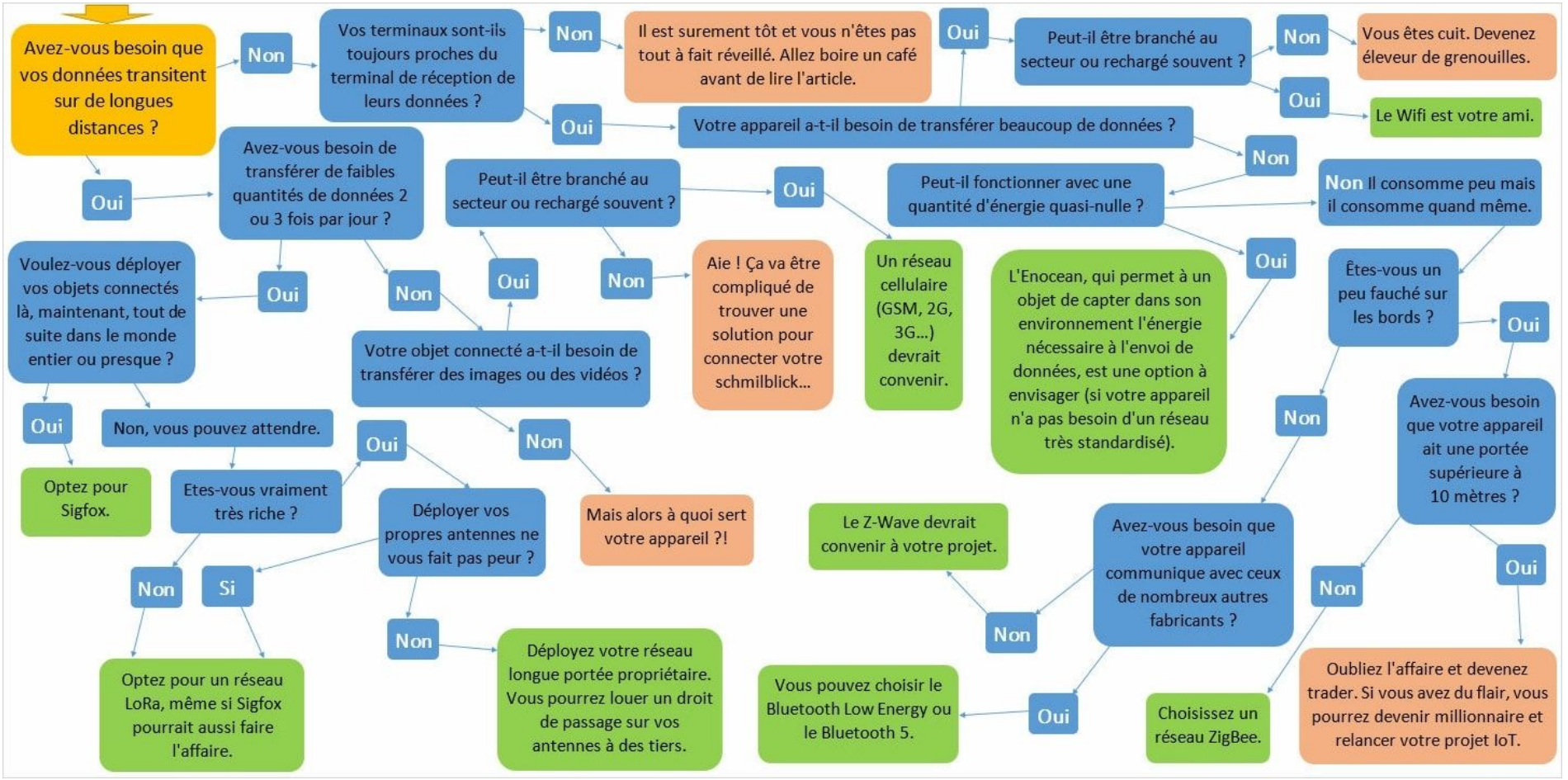
Data Protocols for IoT - Synthesis for IP layered



System Architecture

Architecture and Protocols

http://www.journaldunet.com/ebusiness/telecoms-fai/1181267-les-reseaux-iot/



System Architecture

Architecture and Protocols: Cost effective ?

IoT cost is negligible (?):

- Communication systems,
- Infrastructure (Data storage, web service ...),
- Service (Maintenance, upgrade, troubleshooting ...),
- ...

Part II

M2M System - Definition

M2M System - Global architecture

M2M System - Communication example

M2M System - Standards

M2M Open platform

Lightweight M2M

M2M impact for IoT

Big data

IoT and digital hub

Motivation 1:

- Enabling **interoperability** of systems,
- Machine-to-machine **communication without human** intervention,
- Since systems are increasingly complex, many use cases can not be adapted or require **complex logistics** that could be **dedicated directly to IoTs**,
- Providing large and small-scale **Integration Infrastructure**.

Motivation 2:

- Standardization of data access,
- Define standard infrastructures,
- Defining Development Patterns ..

Motivation 3:

- Enabling application developers to focus on functionality (not lower task : routing, authentication …),
- Enabling any application to read or control any sensor, under control of a horizontal security framework,
- Providing network-based service, such as data publication and subscription.

Motivation 4:

- Reliability by
  - Robustness and fault tolerance
  - Redundancy

- Platform-independence,

- Internet and firewalls,

- Security and access control ...

M2M System

Definition 1/3

https://fr.wikipedia.org/wiki/Machine_to_machine

M2M (Machine To Machine)

"Le Machine to Machine ou M2M est la combinaison des technologies de l'information et de la communication (TIC), avec des objets intelligents et communicants, permettant à ces derniers d'interagir entre eux sans intervention humaine"

- Uses telecommunications and computing to enable communication between machines (without human),
- A communication from a machine or network of machines to a server,
- Requests for data contained in device or capable of transmitting data ...

M2M System

Definition 2/3

https://fr.wikipedia.org/wiki/Machine_to_machine

M2M (Machine To Machine)

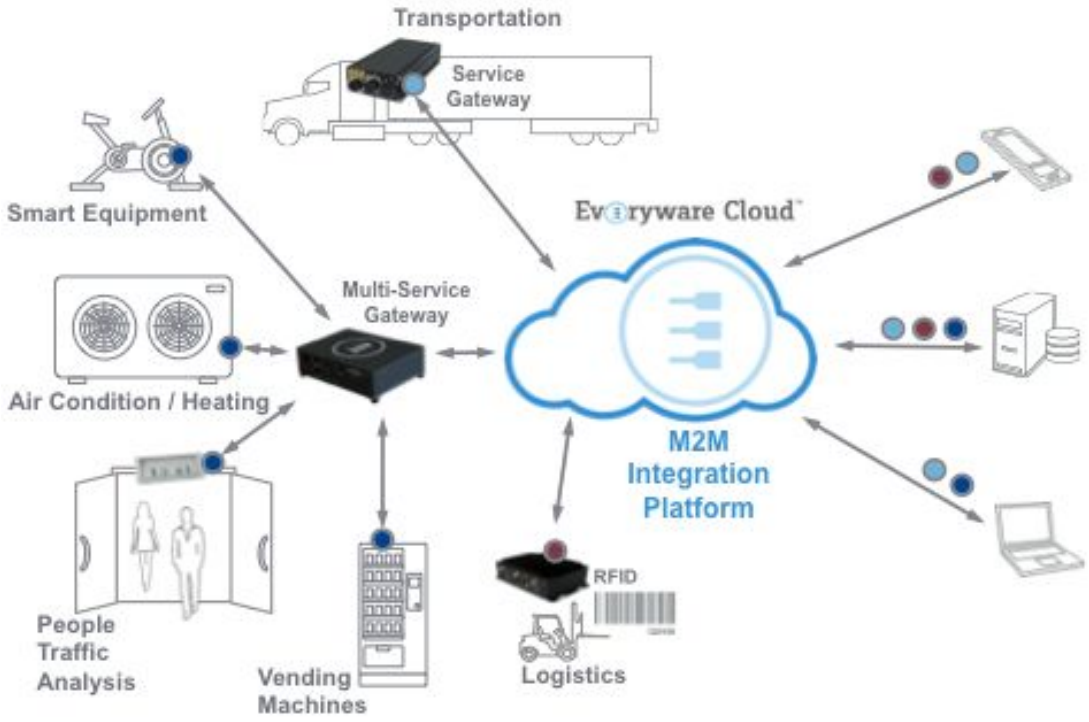
- The data can be updated, deleted inside IoT…
- Discovery System,
- Registers the system status …

M2M System

Definition 3/3

M2M platform act as a concentrator of many technologies.

→ M2M is a support for IoT as a **low level layer**,
→ IoT platform can use M2M support.



Part II

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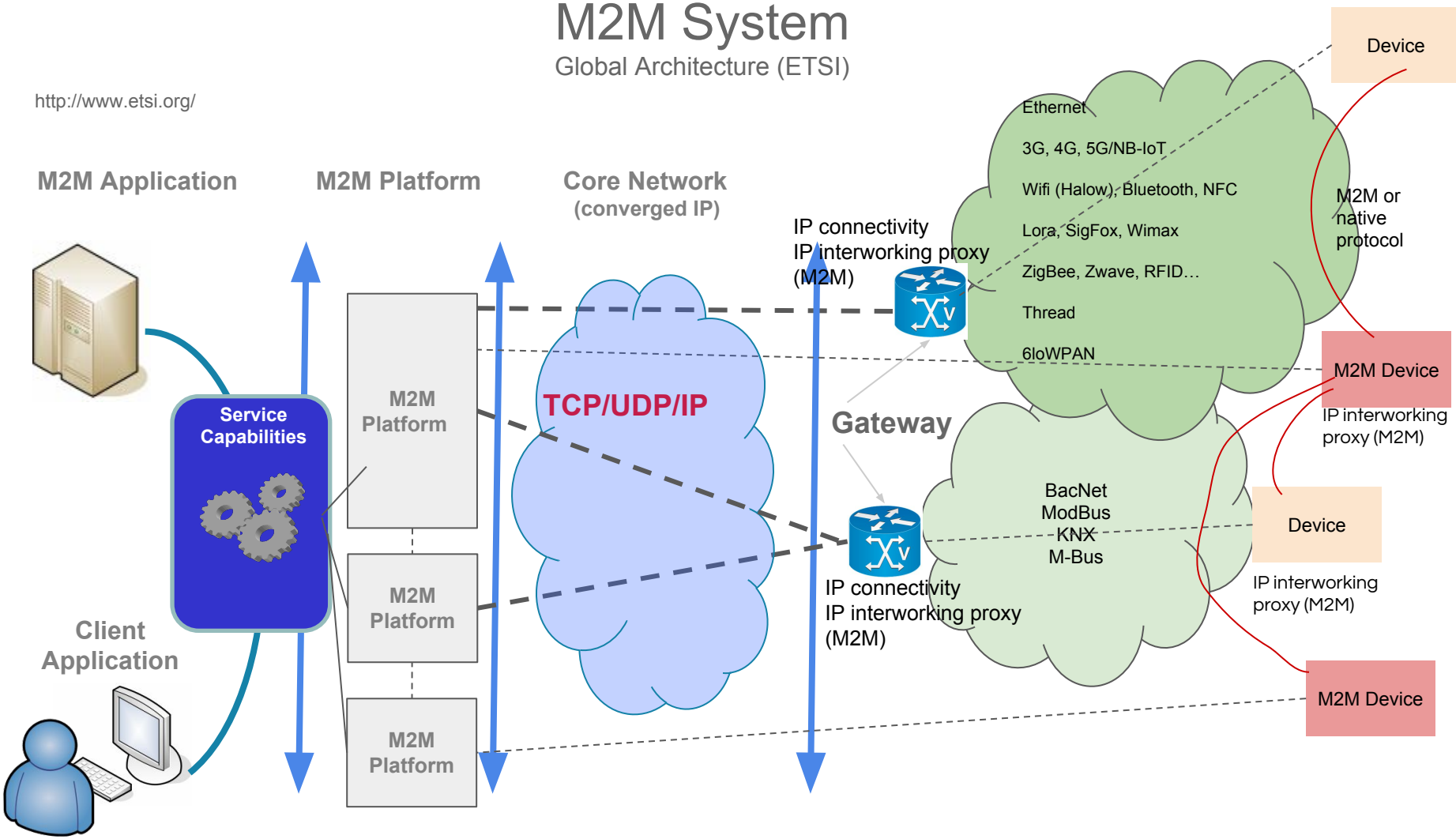
M2M System

Global Architecture (ETSI)

http://www.etsi.org/

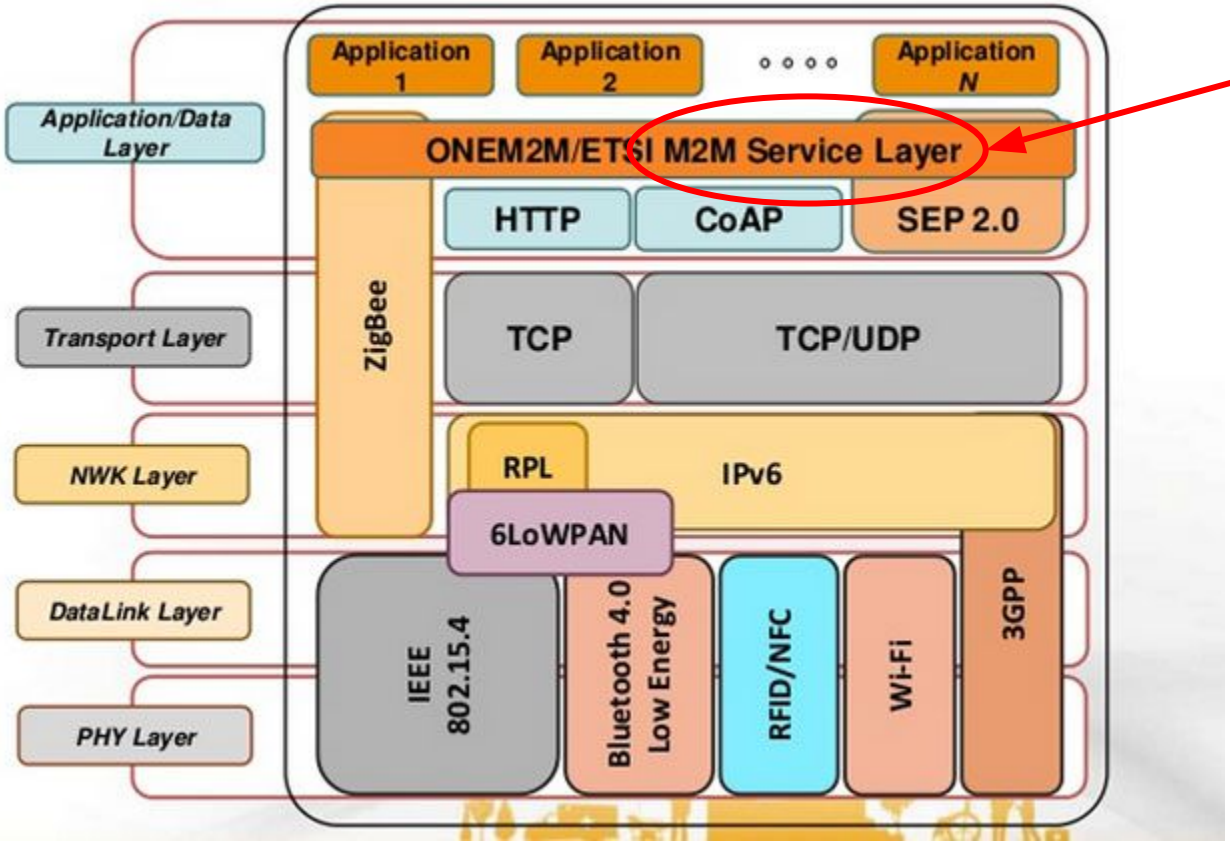


Application Domain | **Network Domain** | **Device Domain**

M2M System

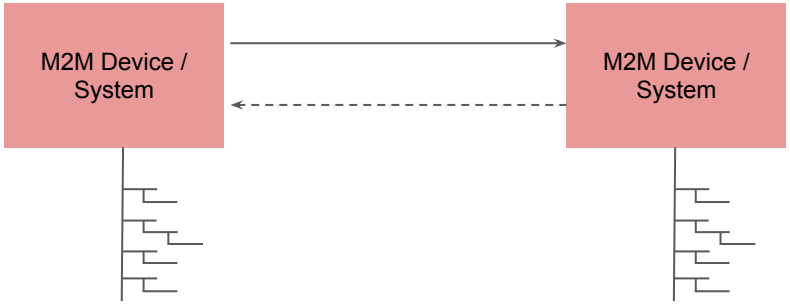
Global Architecture (ETSI)

Graphic: Sensinode: Zach Shelby:
http://www.slideshare.net/zdshelby/standards-drive-the-internet-of-things



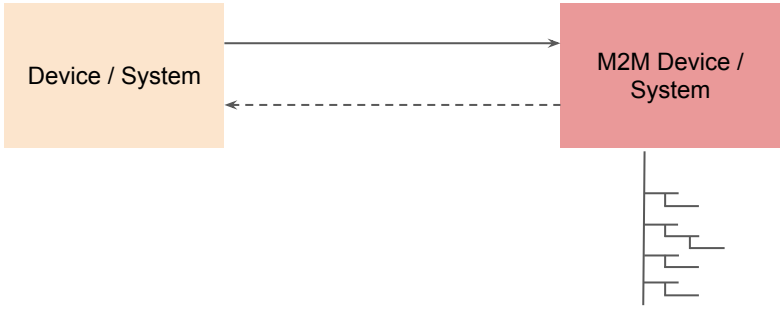
Configuration 1

M2M exchange protocol between M2M enable equipment.



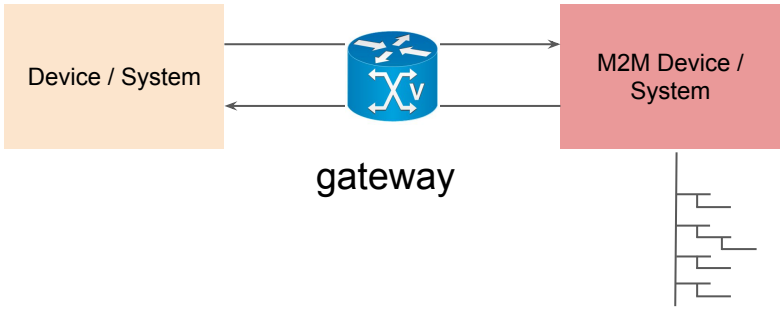
Configuration 2

Recover system information and configuration from standard device to M2M device. This configuration allows limited communication to retrieve basic information.



Configuration 3

M2M exchange between equipment through a gateway, because the device/system is not M2M enable.

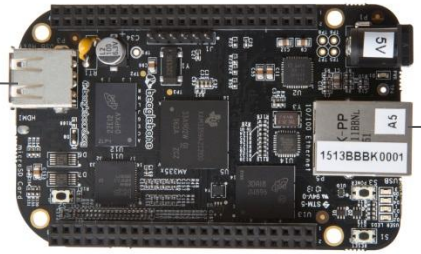


Configuration 3 - Example

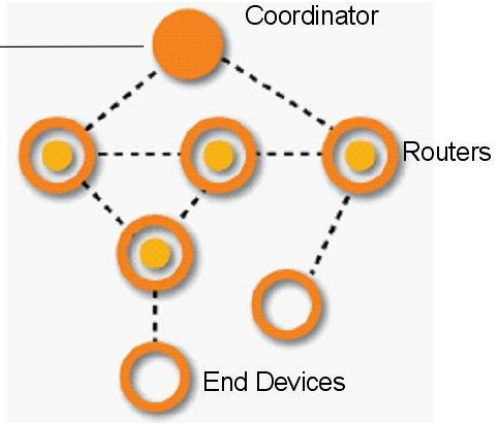
M2M application

Réseau IP

M2M Gateway Zigbee/IP



USB



Part II

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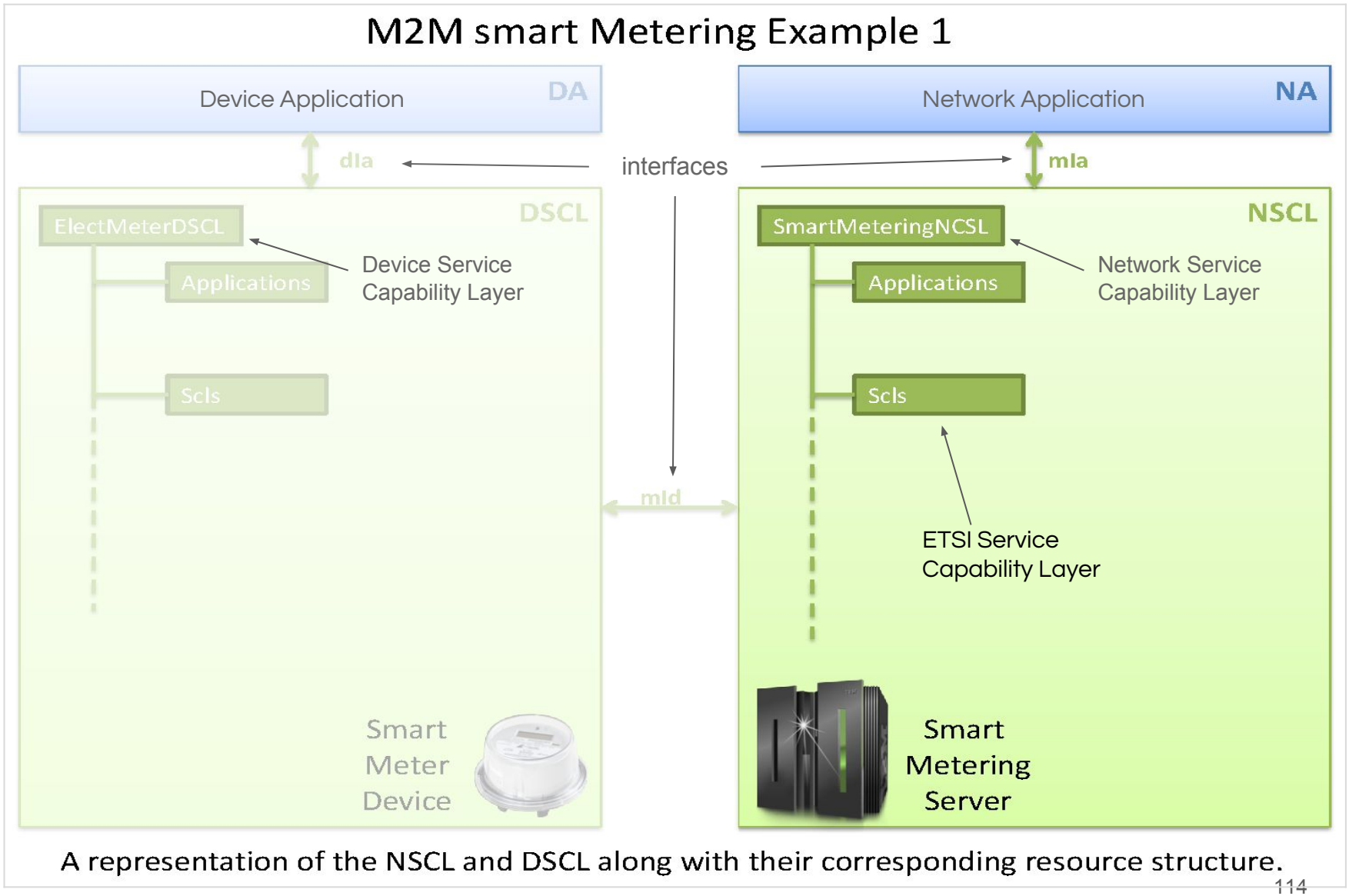
System Architecture

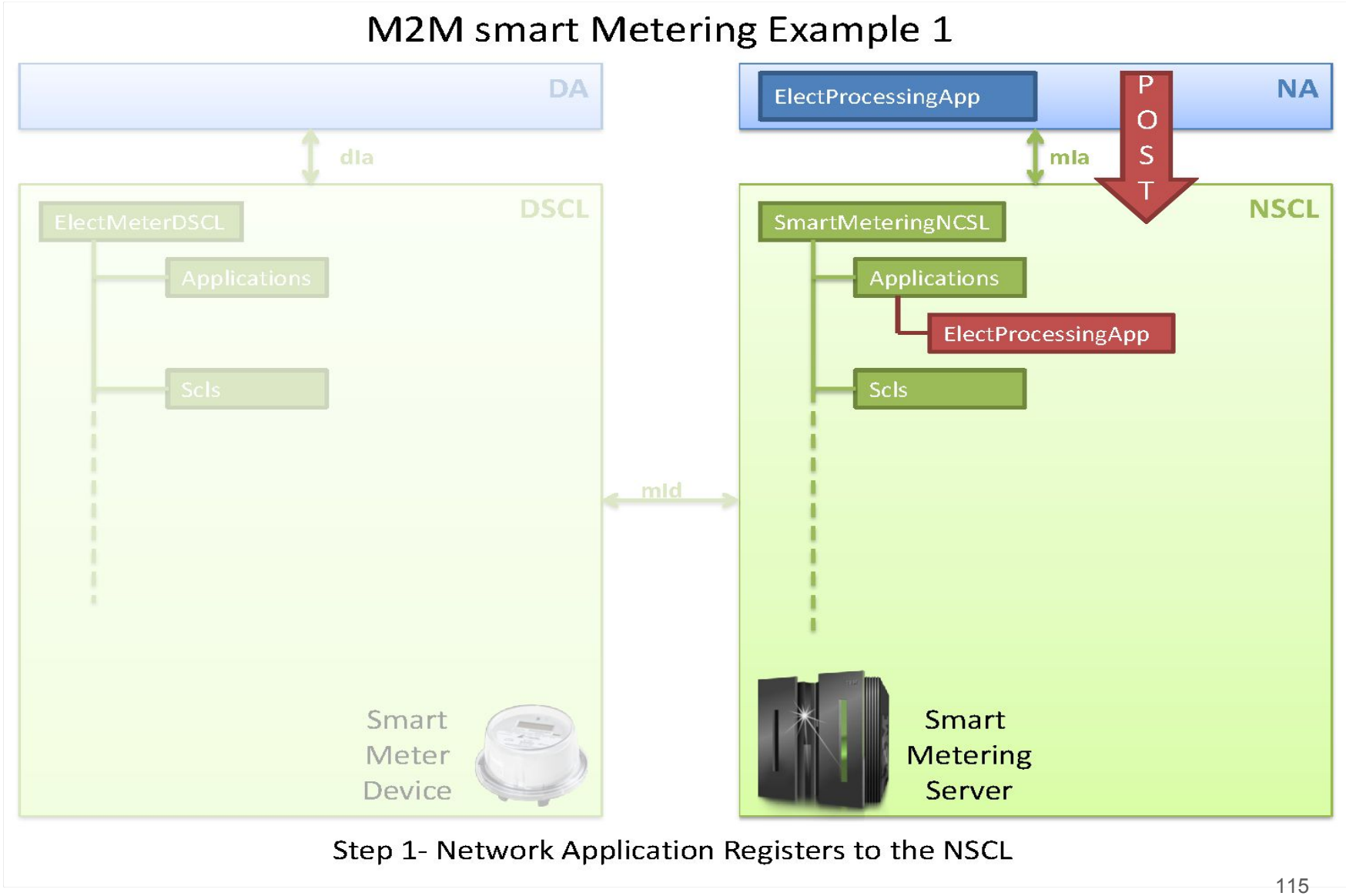
ETSI M2M communication example



A representation of the NSCL and DSCL along with their corresponding resource structure.

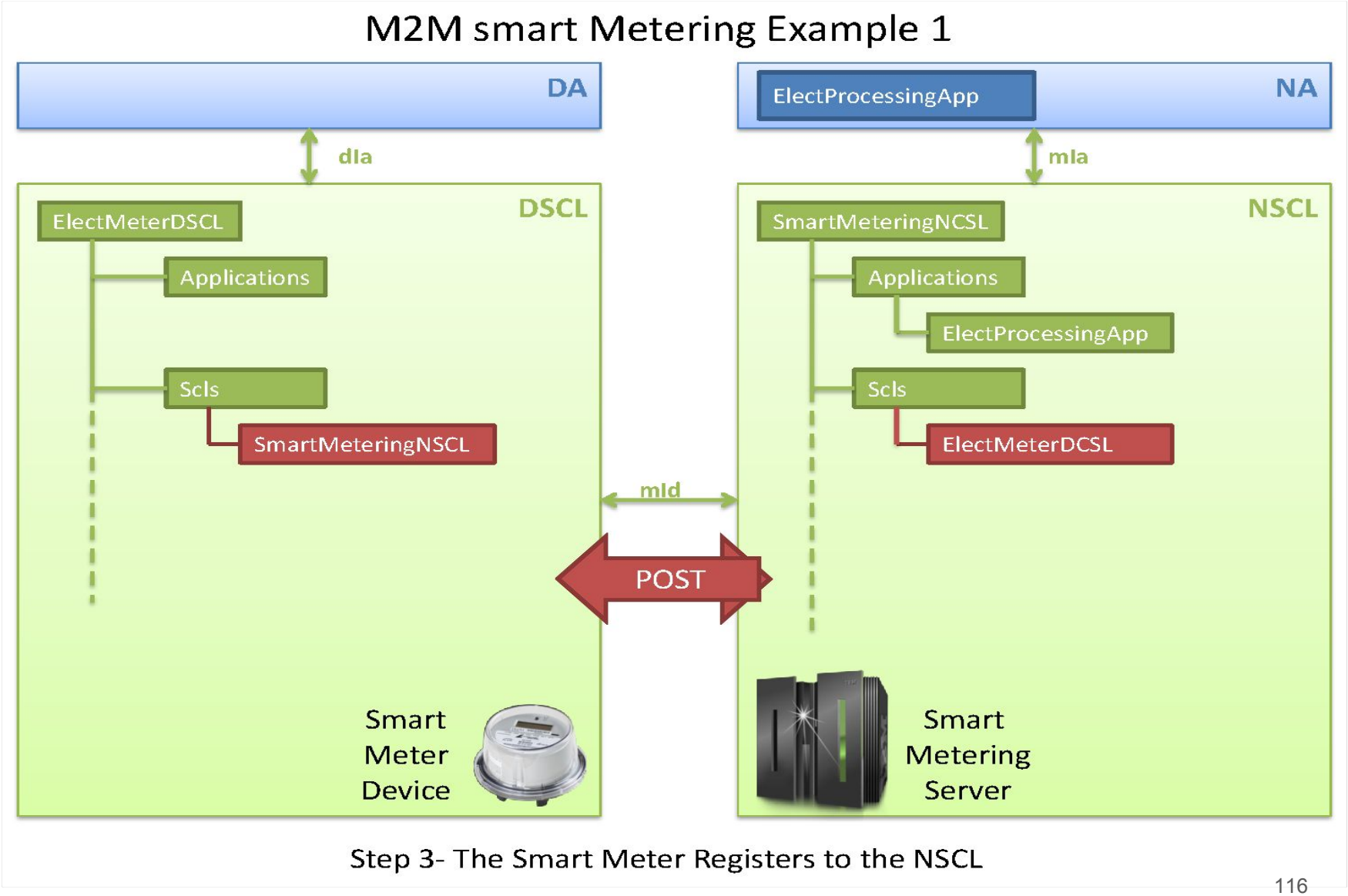
System Architecture

ETSI M2M communication example



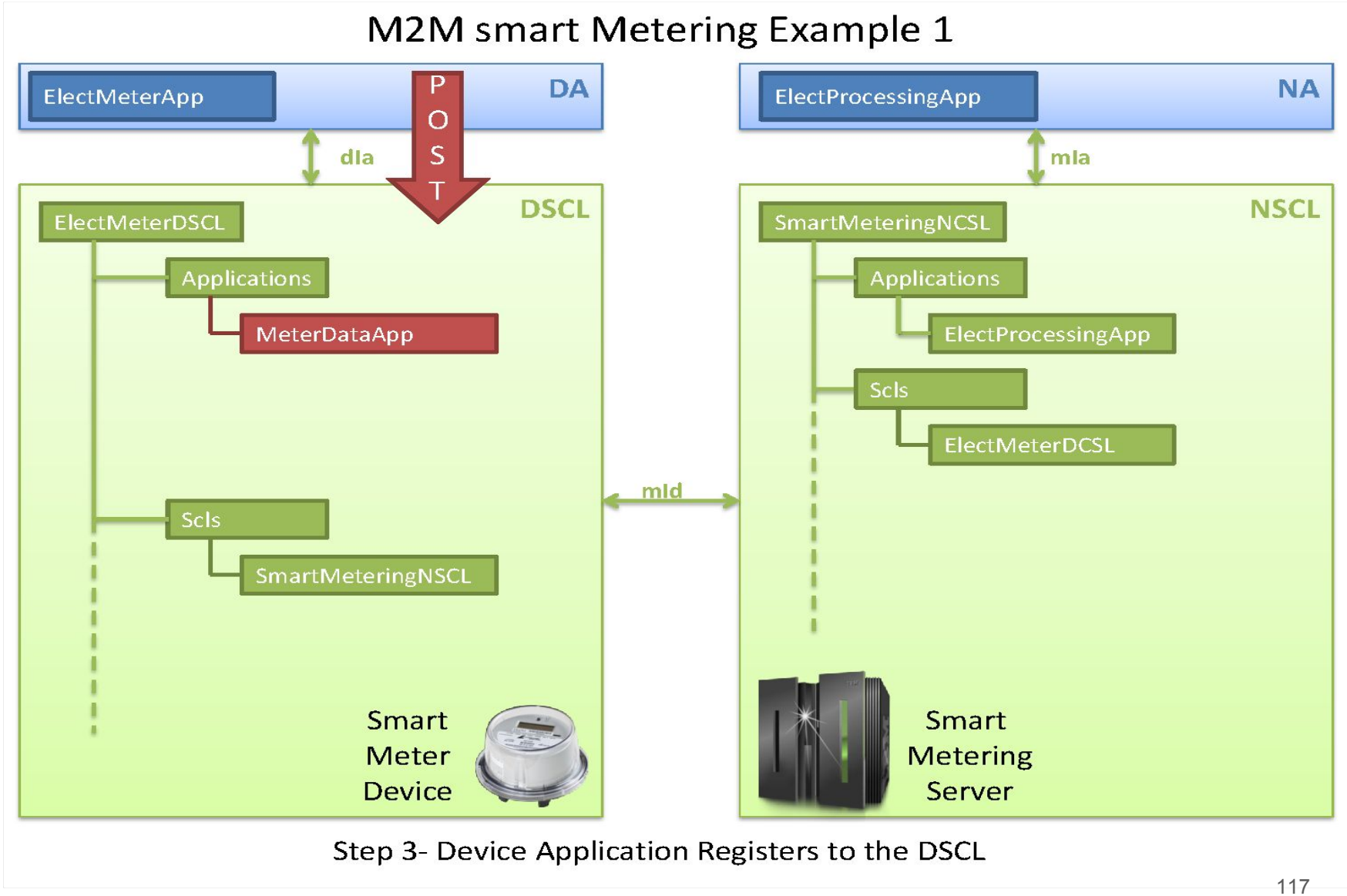
System Architecture

ETSI M2M communication example



System Architecture

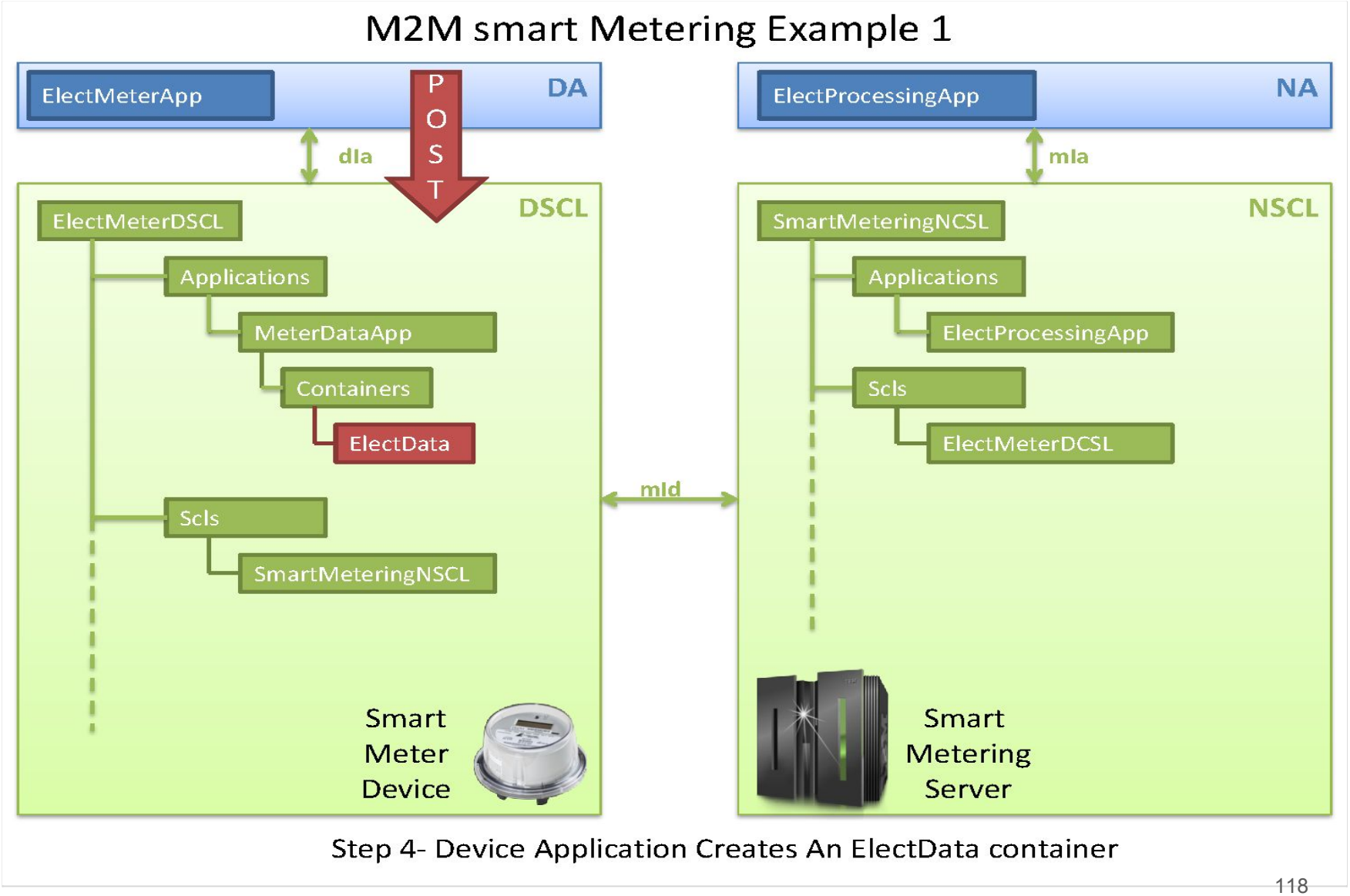
ETSI M2M communication example



Step 3- Device Application Registers to the DSCL

System Architecture

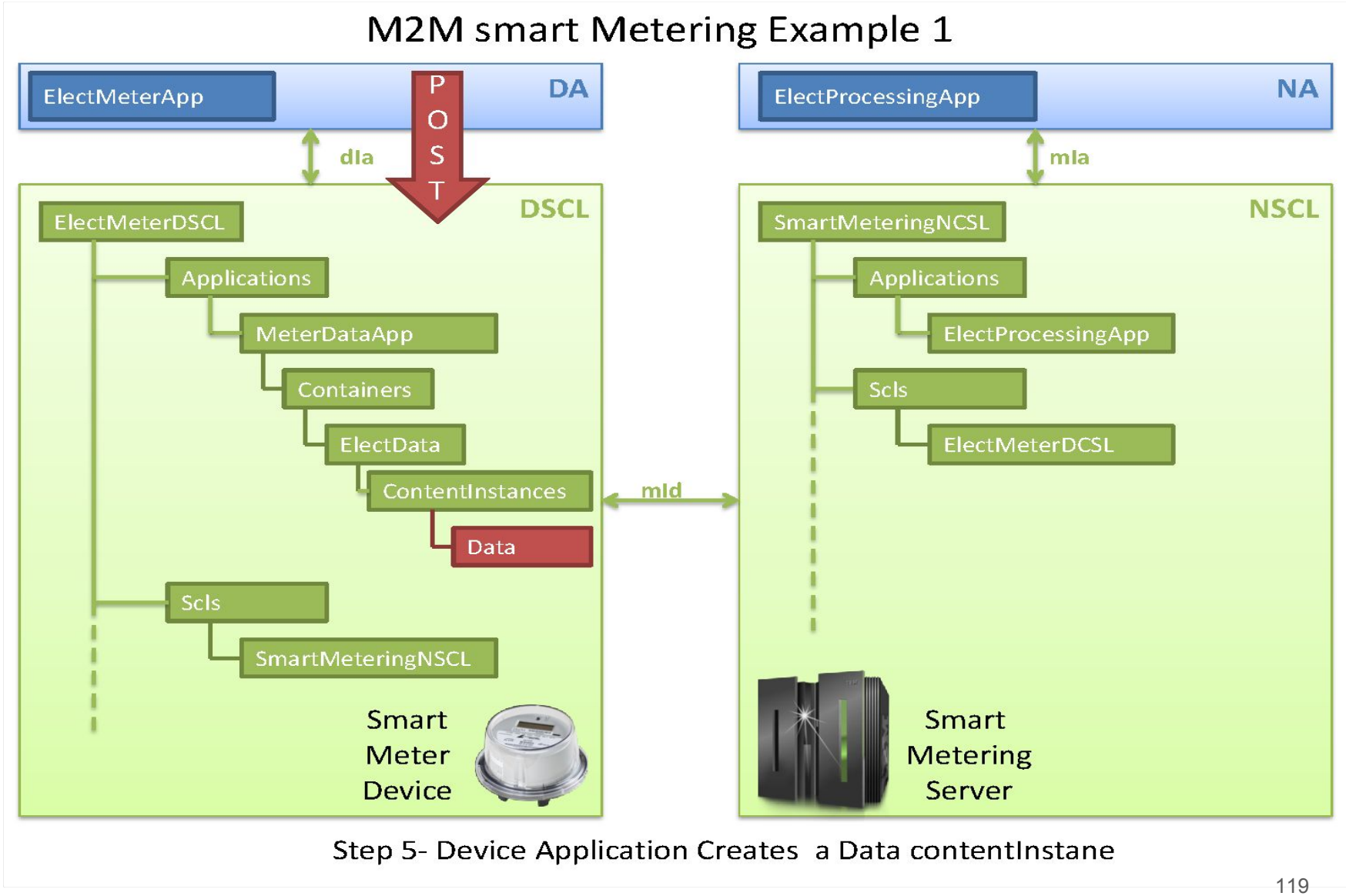
ETSI M2M communication example



Step 4- Device Application Creates An ElectData container

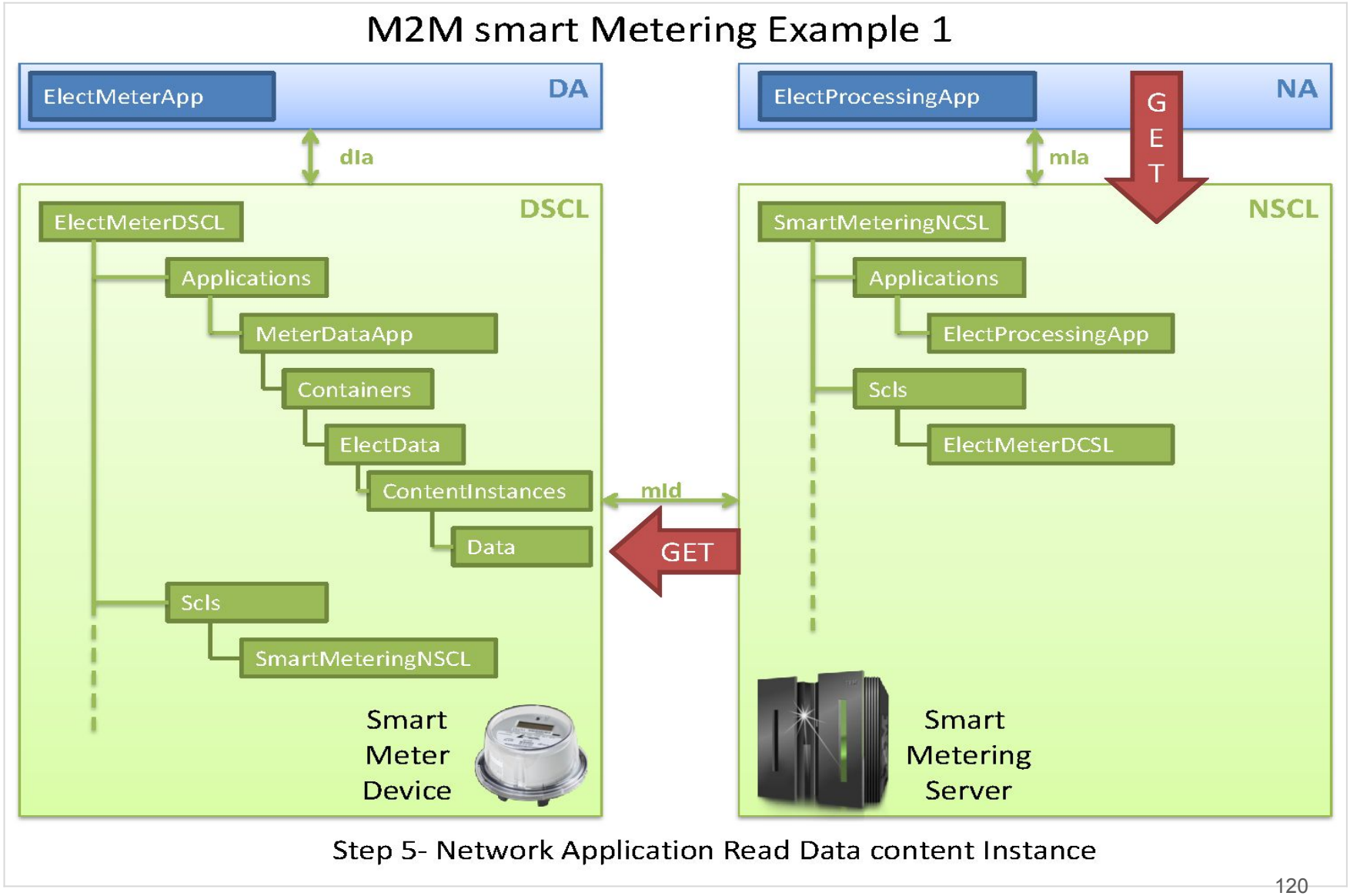
System Architecture

ETSI M2M communication example



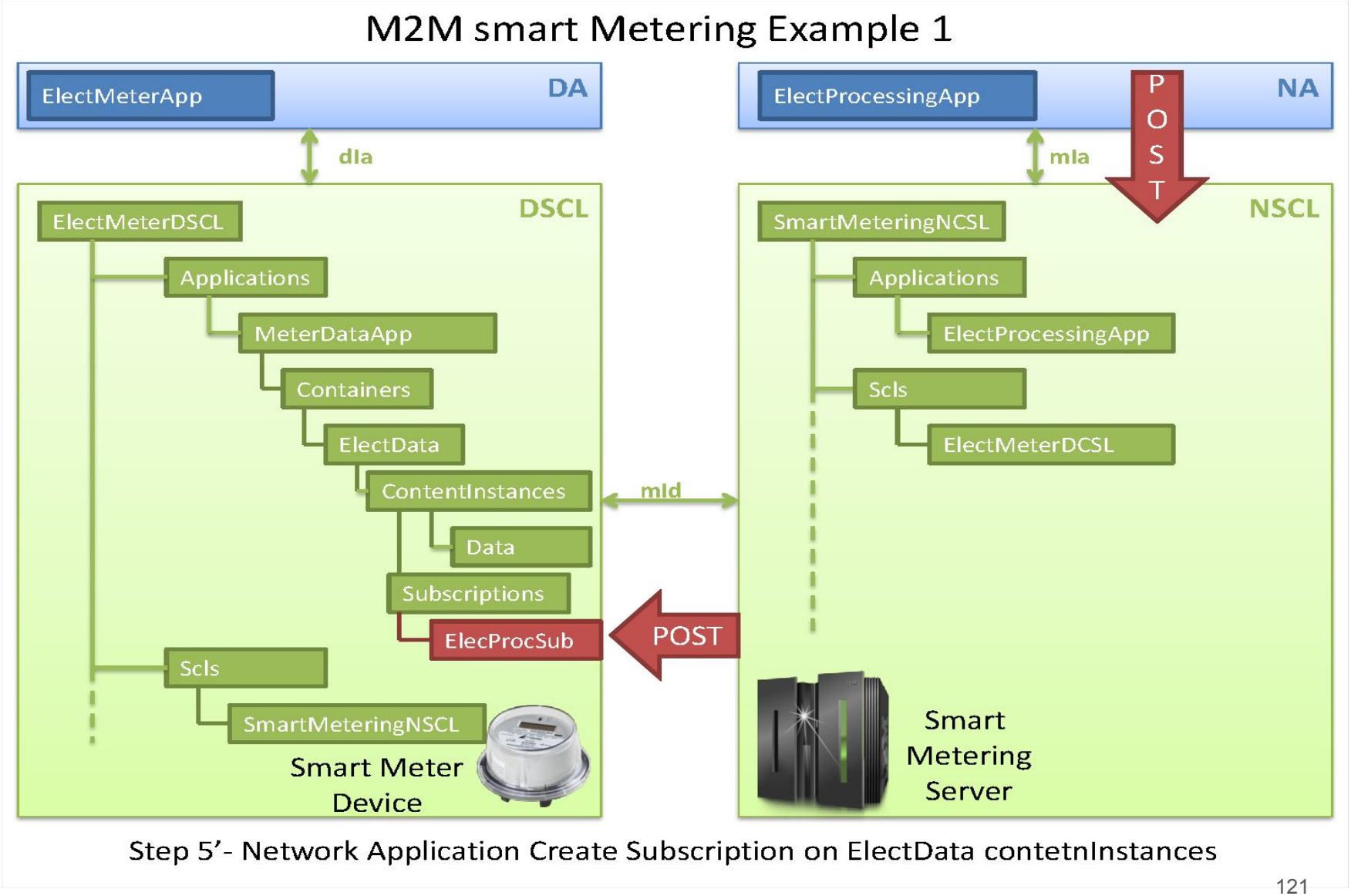
System Architecture

ETSI M2M communication example



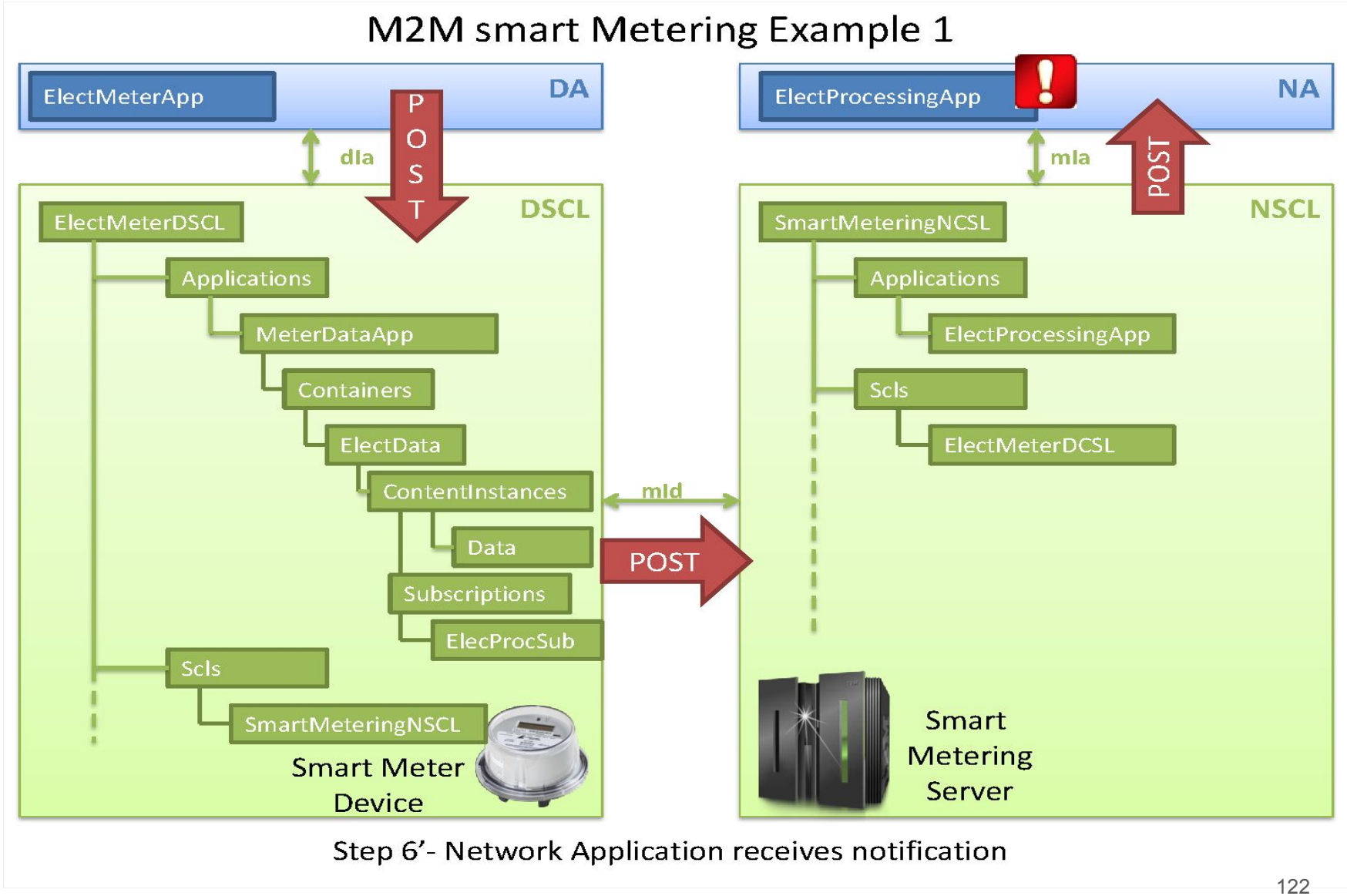
System Architecture

ETSI M2M communication example



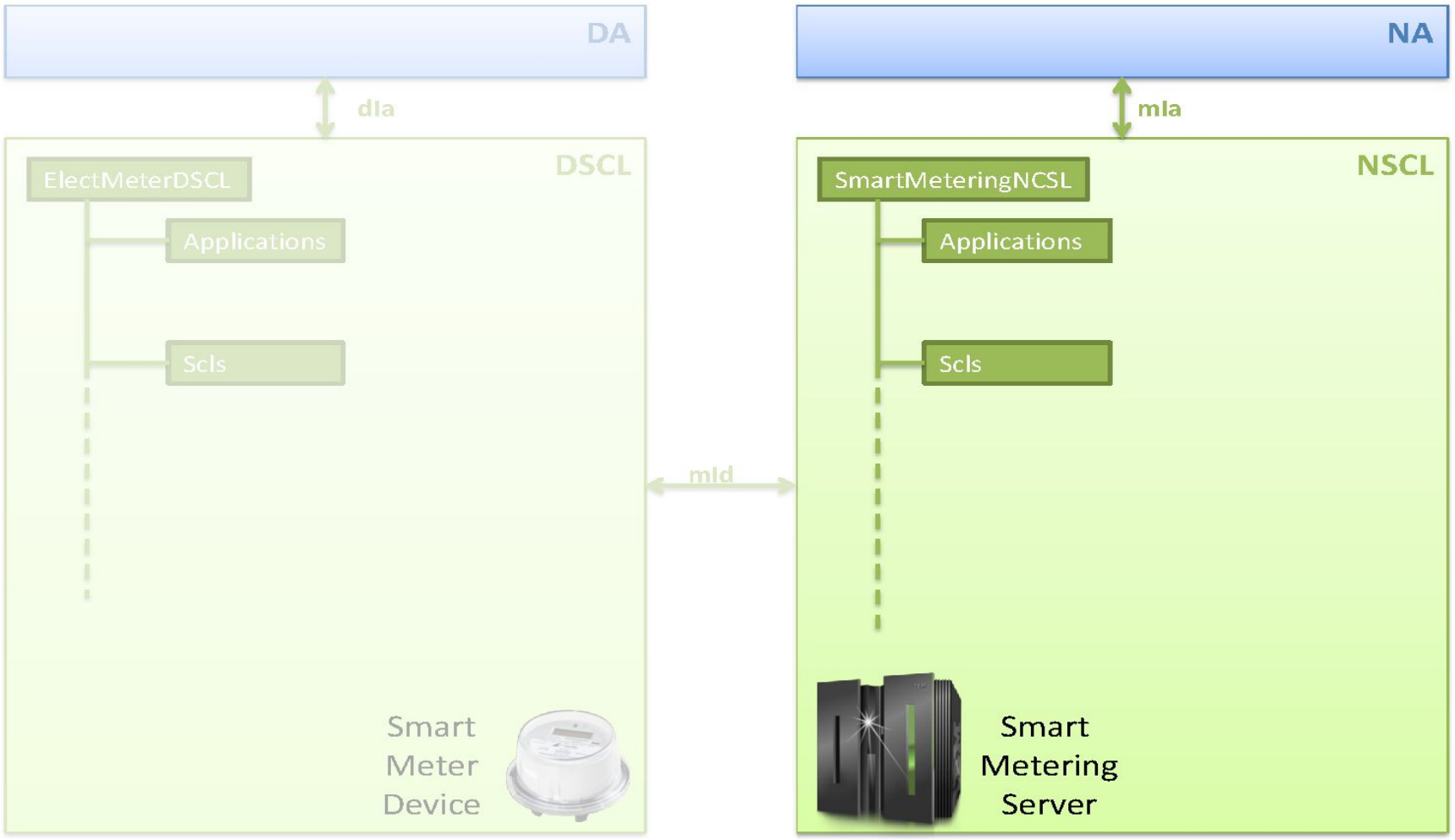
System Architecture

ETSI M2M communication example



System Architecture

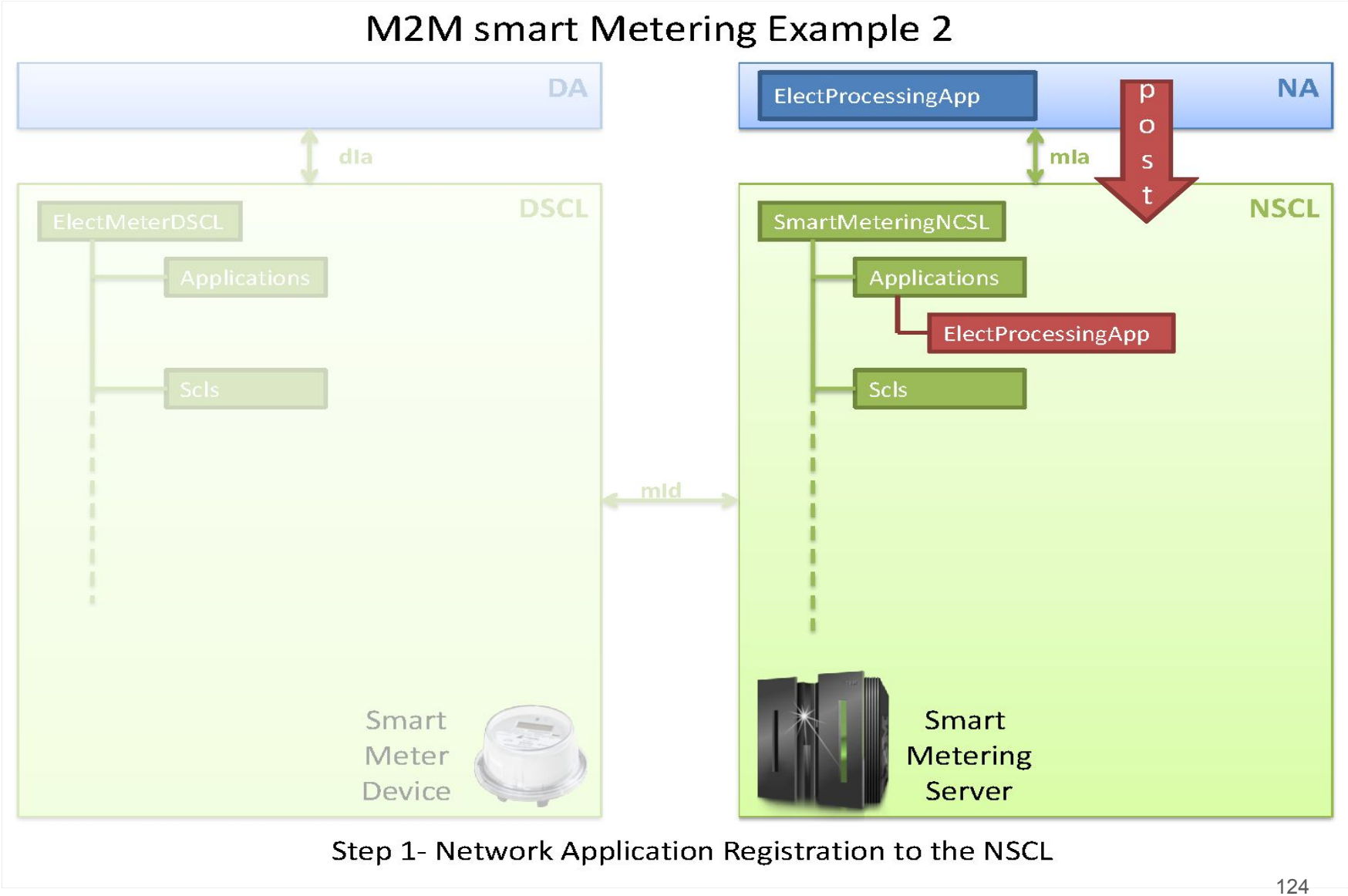
ETSI M2M communication example



A representation of the NSCL and DSCL along with their corresponding resource structure.

System Architecture

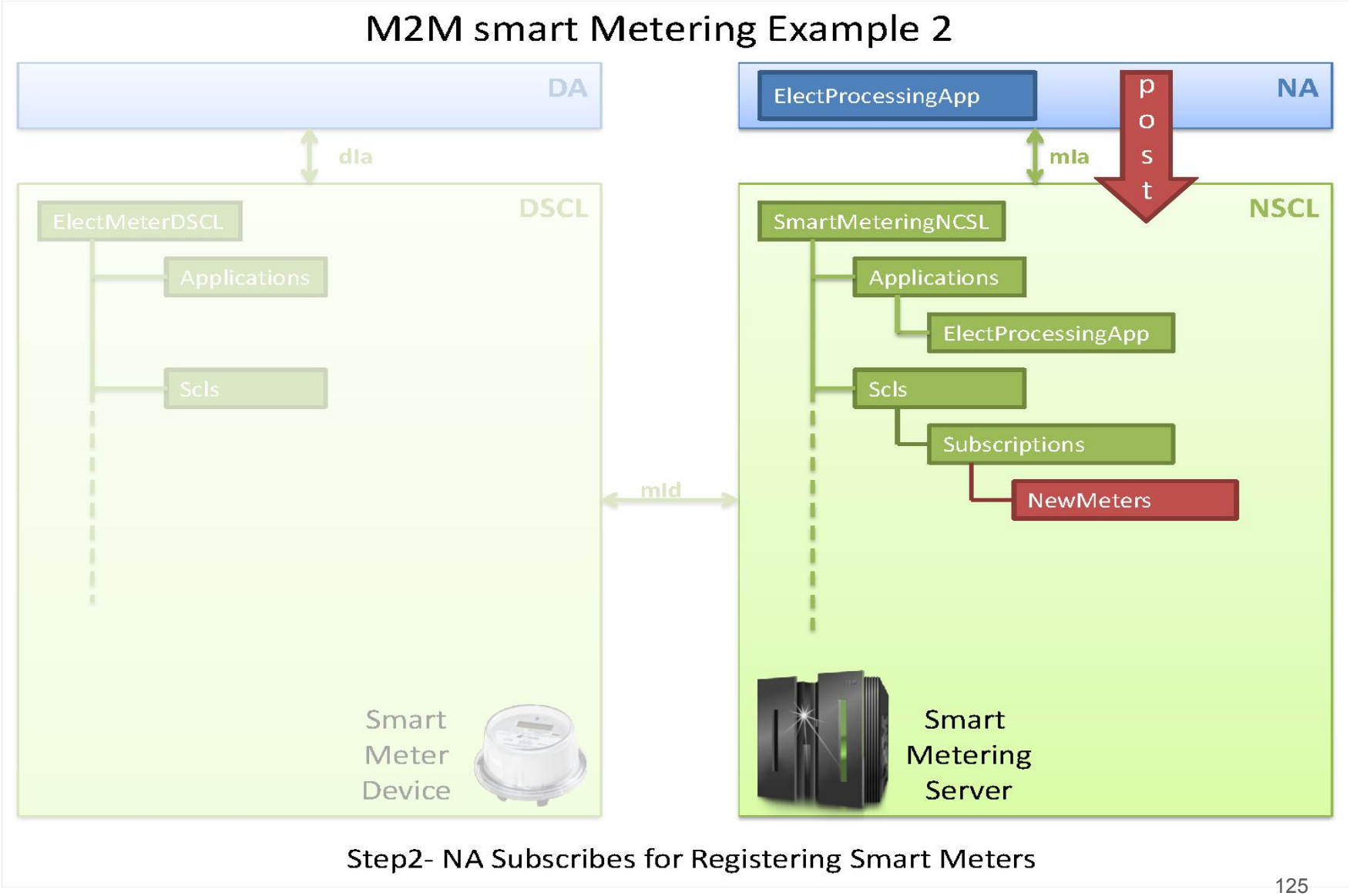
ETSI M2M communication example



Step 1- Network Application Registration to the NSCL

System Architecture

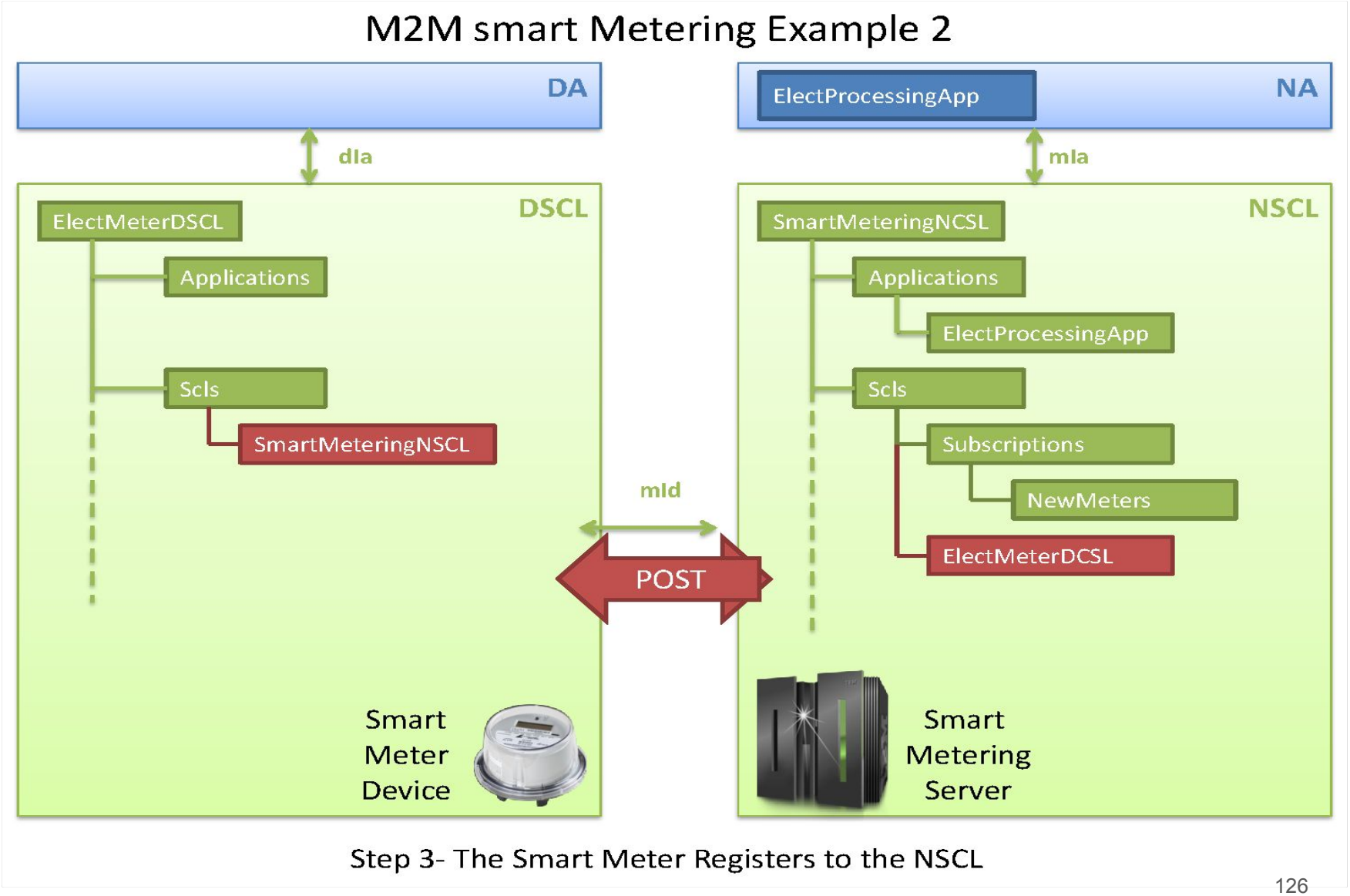
ETSI M2M communication example



Step2- NA Subscribes for Registering Smart Meters

System Architecture

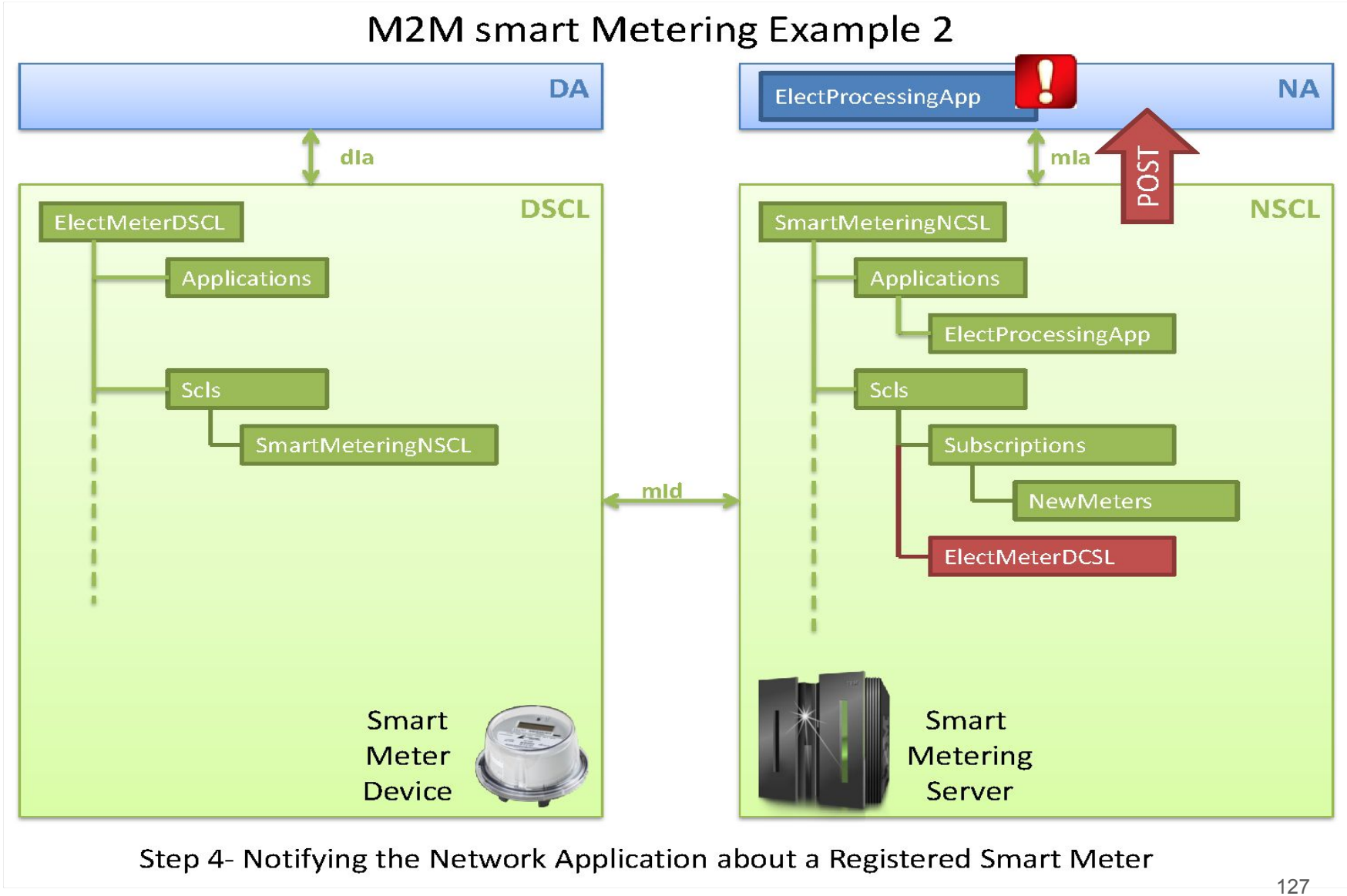
ETSI M2M communication example



Step 3- The Smart Meter Registers to the NSCL

System Architecture

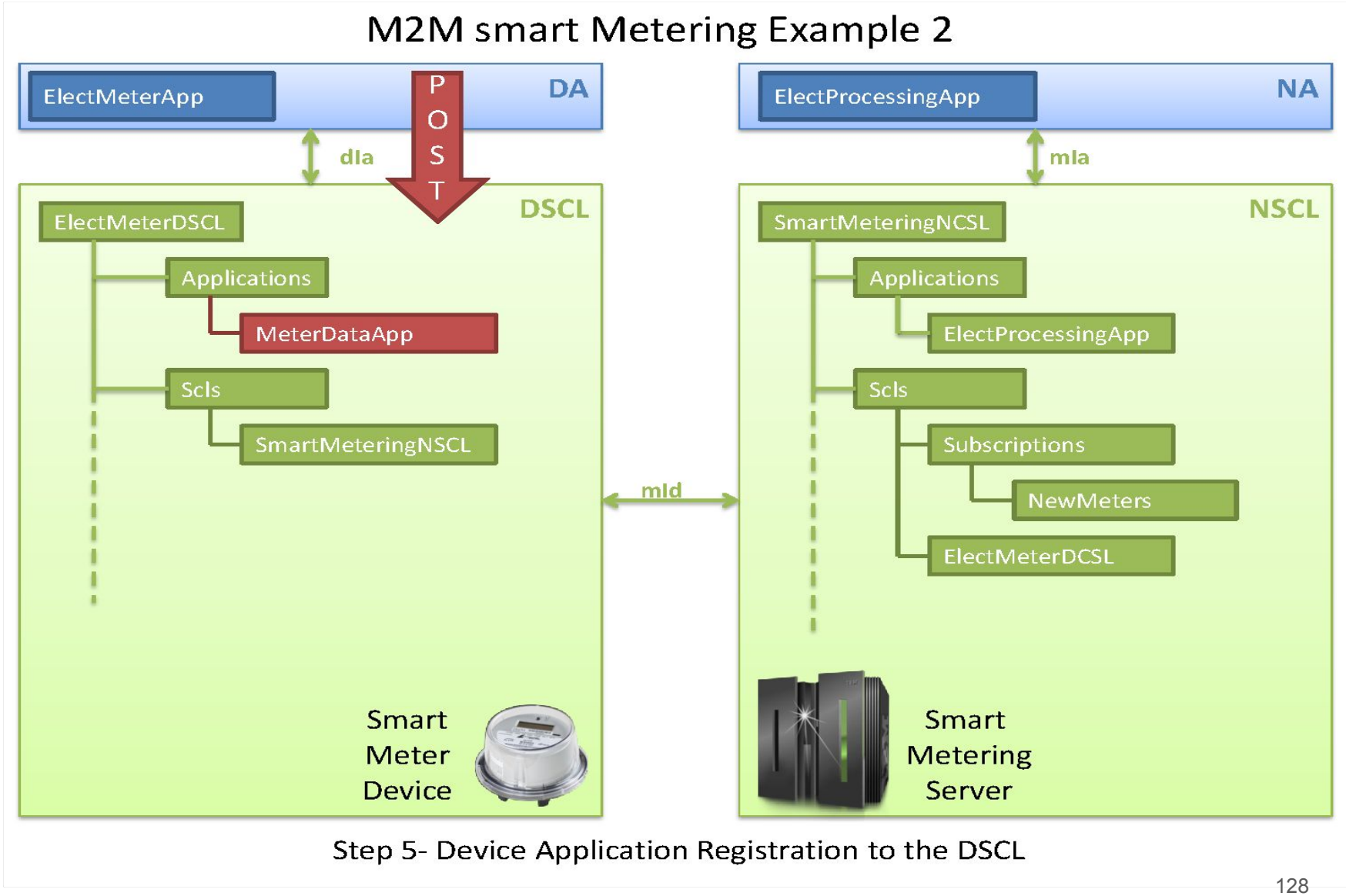
ETSI M2M communication example



Step 4- Notifying the Network Application about a Registered Smart Meter

System Architecture

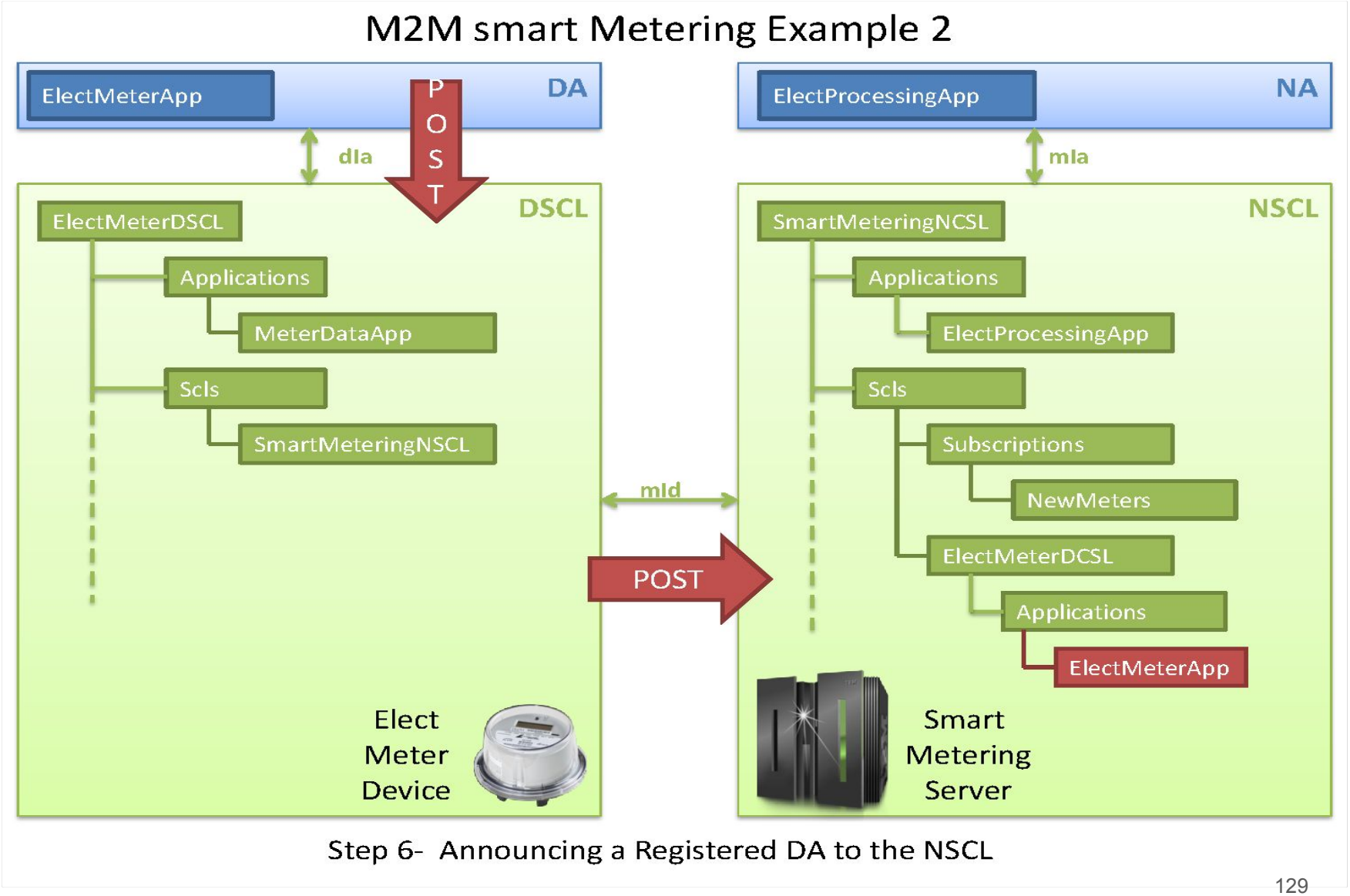
ETSI M2M communication example



Step 5- Device Application Registration to the DSCL

System Architecture

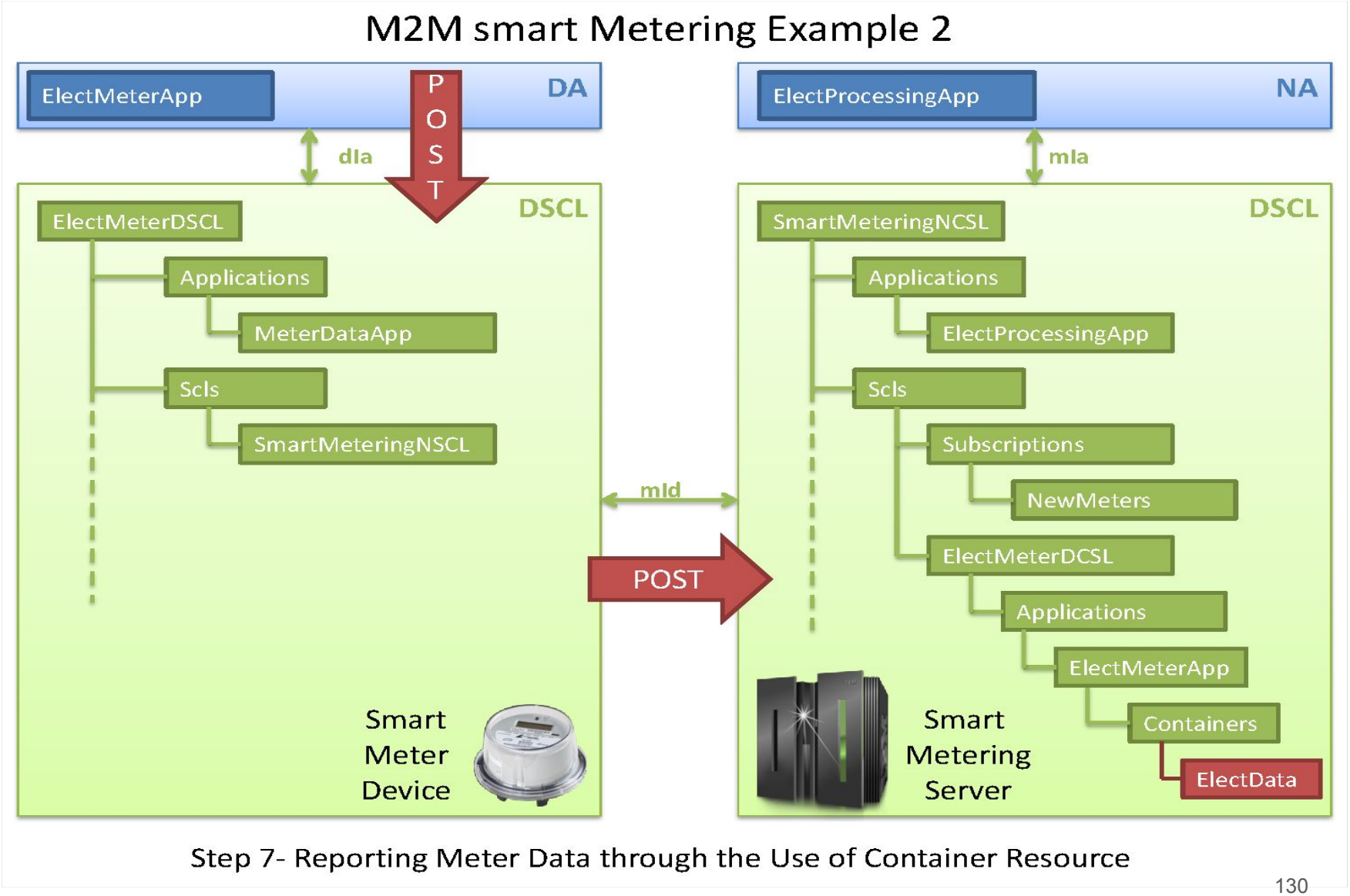
ETSI M2M communication example



Step 6- Announcing a Registered DA to the NSCL

System Architecture

ETSI M2M communication example



Step 7- Reporting Meter Data through the Use of Container Resource

Part II

M2M System - Definition

M2M System - Global architecture

M2M System - Communication example

M2M System - Standards

M2M Open platform

Lightweight M2M

M2M impact for IoT

Big data

IoT and digital hub

M2M System

M2M Standards

https://en.wikipedia.org/wiki/Standards_organization

How are M2M standards organized?

- **De facto** standard (Google, Yahoo, others industrials …): no compatibility with other systems,
- **SDO** (Standard Development Organisation: ETSI, ANSI …,): Standard but no implementation,
- **Open Source** Projects: many projects with little standardization, sometimes absorbed by the SDO,
- **Alliance** (industrials + SDO): Participation of manufacturers in the development and implementation of standards.

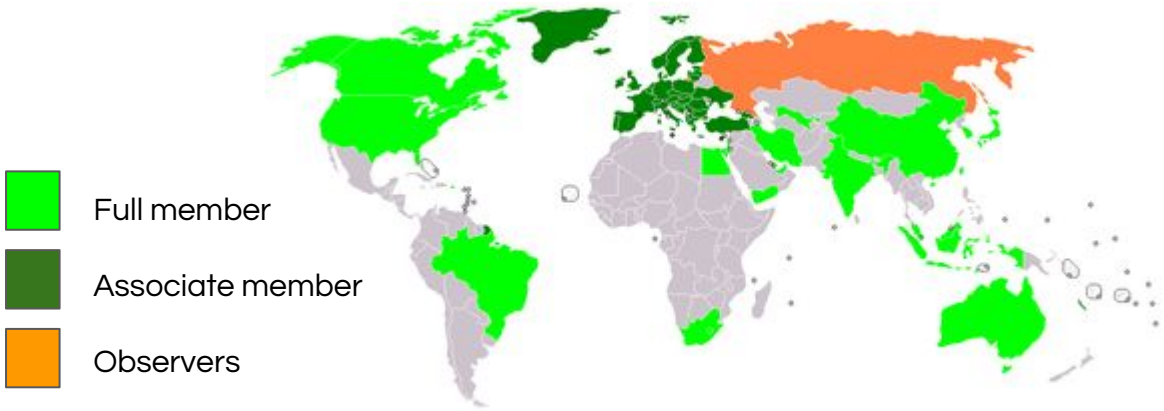
M2M System

M2M Standards - ETSI

http://www.etsi.org
https://en.wikipedia.org/wiki/ETSI

European Telecommunications Standards Institute (ETSI)

- Independent, not-for-profit, standardization organization in the telecommunications industry,
- Headquartered in Sophia-Antipolis, France,
- ETSI inspired the creation of OneM2M with 3GPP.



M2M System

M2M Standards - 3GPP “Organizational Partners” - OneM2M

(http://www.3gpp.org/)
http://www.3gpp.org/images/presentations/2016_11_3gpp_Standards_for_IoT.pdf

The **3rd Generation Partnership Project** (3GPP) unites telecommunications standard development organizations acts as an “Organizational Partners”, example for OneM2M :

- **ARIB**: Association of Radio Industries and Businesses, Japan
- **ATIS**: Alliance for Telecommunications Industry Solutions, US
- **CCSA**: China Communications Standards Association
- **ETSI**: European Telecommunications Standards Institute
- **TSDSI**: Telecommunications Standards Development Society, India
- **TTA**: Telecommunications Technology Association (TTA), Korea
- **TTC**: Telecommunication Technology Committee, Japan

M2M System

M2M Standards - SDO

Alliance: industrial + SDO*

- Participation of manufacturers in the development and implementation of standards,
- **Very active structures** that develop operational products for the industry (compatibility testing, …),
- Permanent Industrial lobbying.

*(Standard Development Organisation)

M2M System

M2M Standards - M2M - OneM2M

Today OneM2M is the most representative standard.

M2M / ETSI:

- Initiates Advanced Specifications for M2M Systems,
- Proposes with the 3GPP a merger of the international M2M specifications to guarantee the interoperability of M2M systems worldwide.

OneM2M / 3GPP:

- Participation of SDOs from several countries to propose an international standard for M2M systems,
- The impact of the standard M2M ETSI is very important because far ahead of other sdo.

M2M System

M2M Standards - M2M - OneM2M

Today OneM2M is the most representative standard.

(http://www.3gpp.org/)

The oneM2M standardization work is split in 5 **W**ork **G**roup:

- **WG1:** Requirements,
- **WG2:** Architecture,
- **WG3:** Protocols,
- **WG4:** Security,
- **WG5:** Management, Abstraction and Semantics.

What M2M standard does not offer ?

- M2M standard are not always compatible with each other, but can offer gateways (data representation, architecture ...),
- All the transport protocols are not all taken into account, it depends on the implementation,
- A standard can have several different implementations with more or less successful integration levels,
- There are implementations specific to certain environments (industrial electronics, real time ...) ...

M2M System

M2M Standards

M2M System

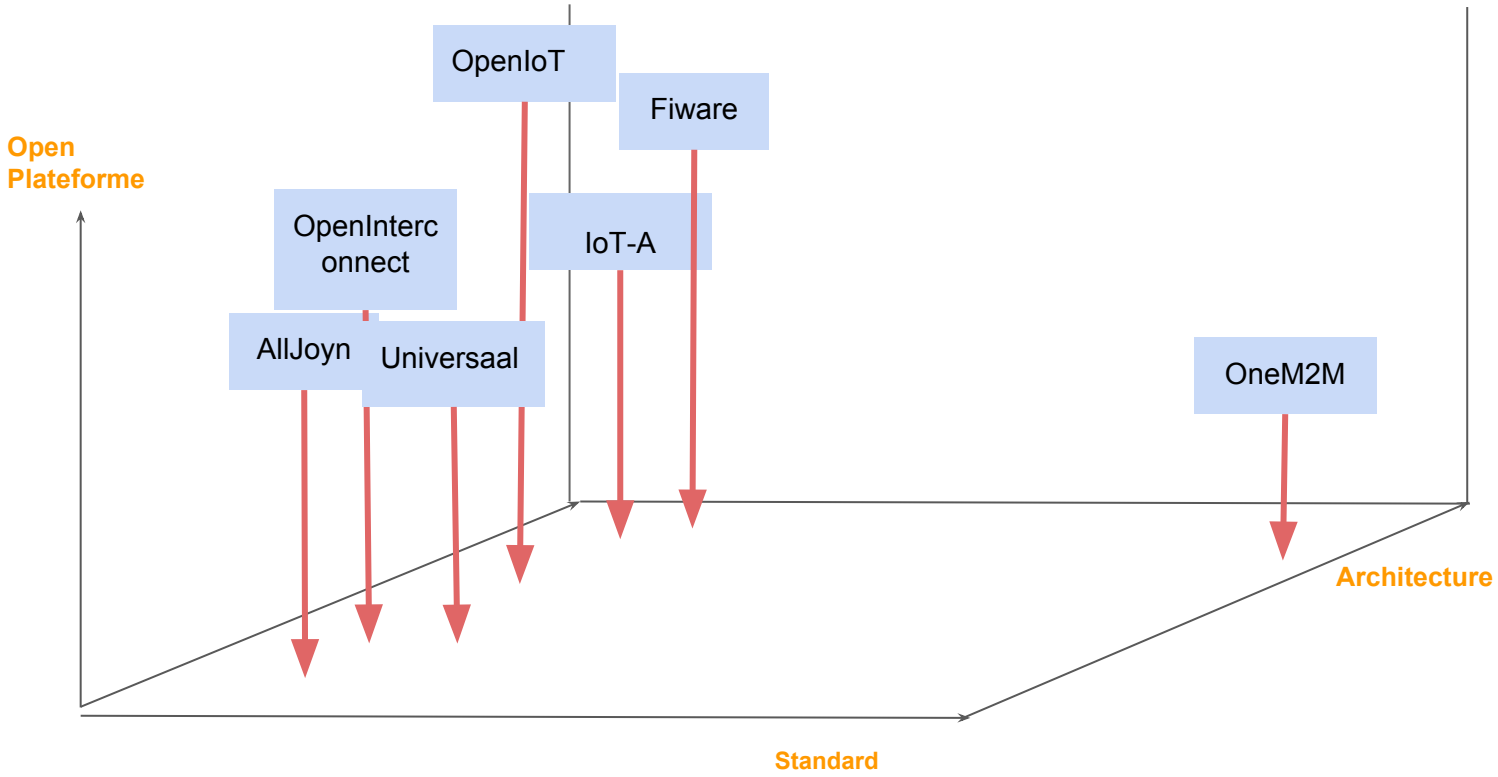
M2M Standards - Main criteria

Main criterias for choosing an M2M system:

- Standard (Europe, USA, Asia …),
- M2M interoperability,
- Scalability,
- Security,
- Small memory footprint for embedded systems,
- Open platform: turnkey infrastructure, which does not follow standard but offers plugin.
- Data mining ...

M2M System

M2M Standards - Platform



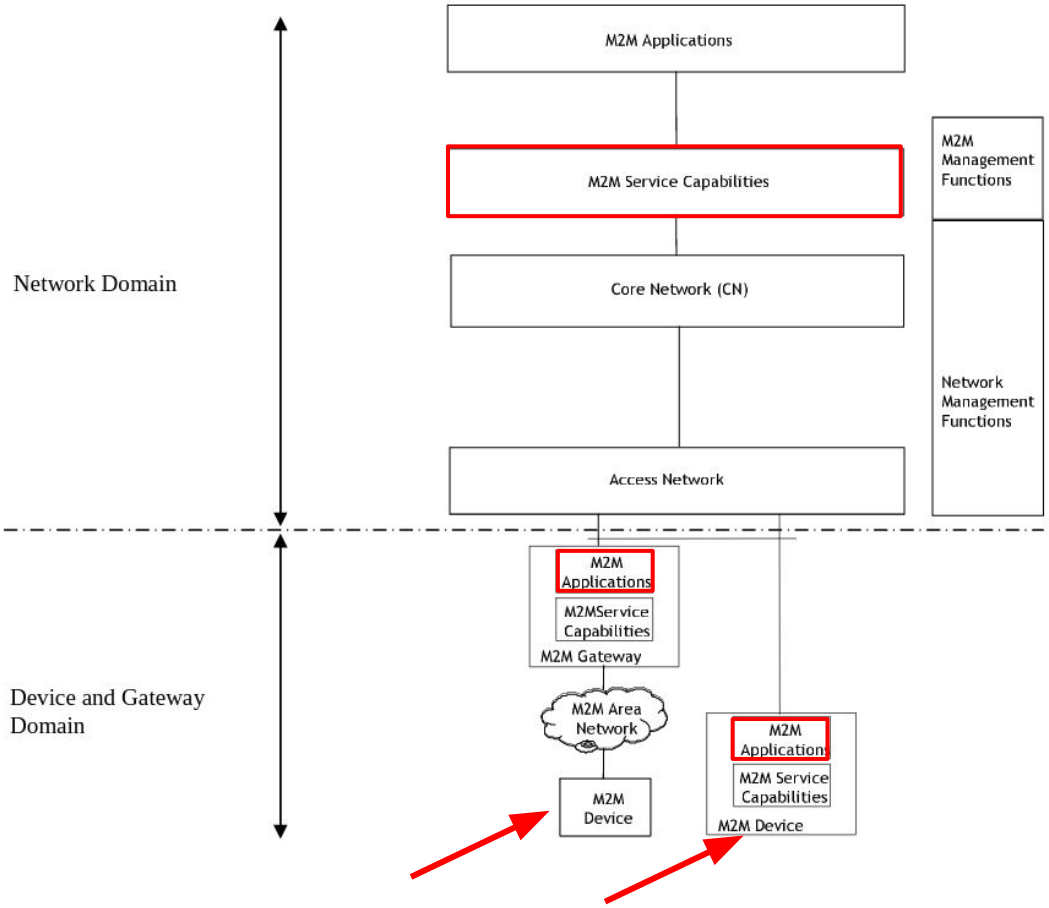
KAA Mango Nimbits Butler ...

M2M System

M2M Standards - ETSI M2M specification

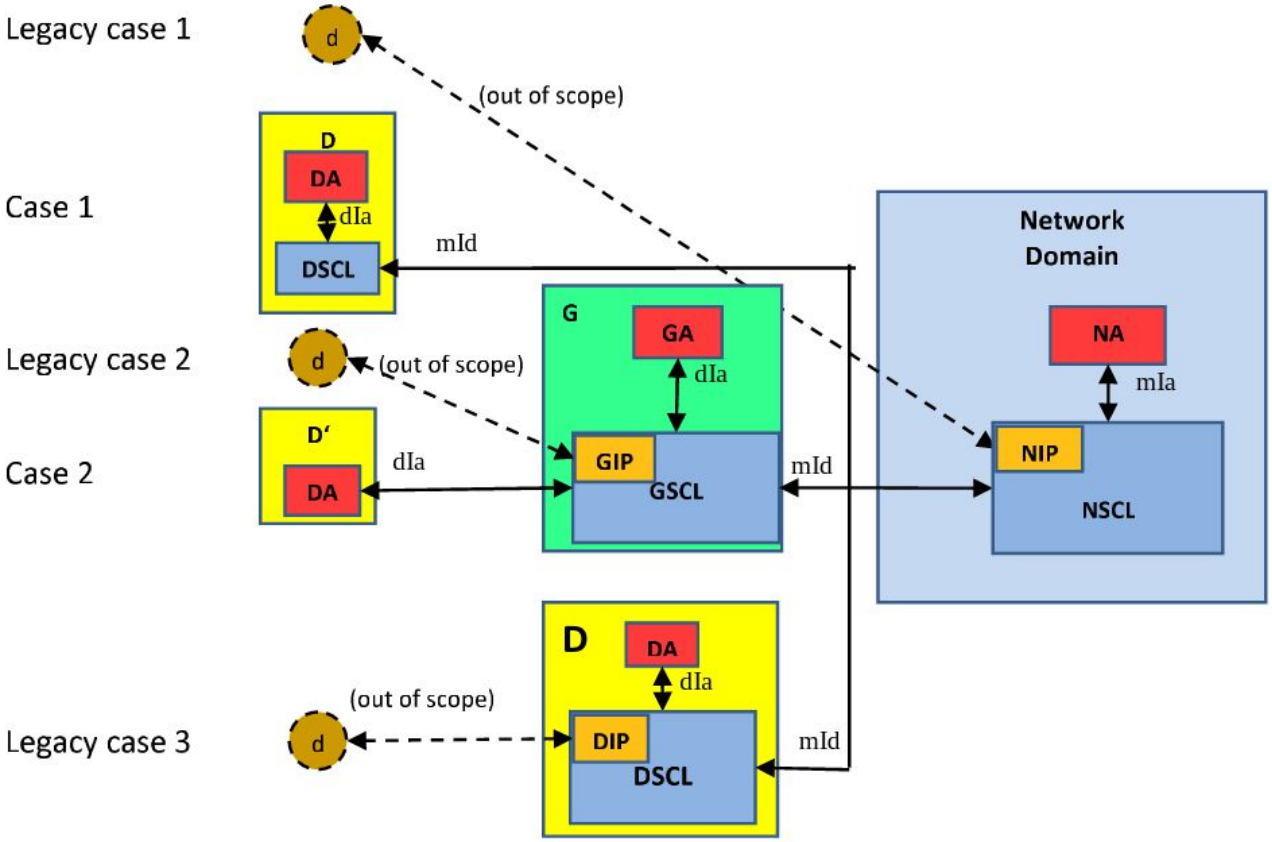
http://www.etsi.org/technologies-clusters/technologies/internet-of-things

Machine-to-Machine communications: **Functional architecture**: ETSI TS 102 690 V1.1.1 (2011-10)



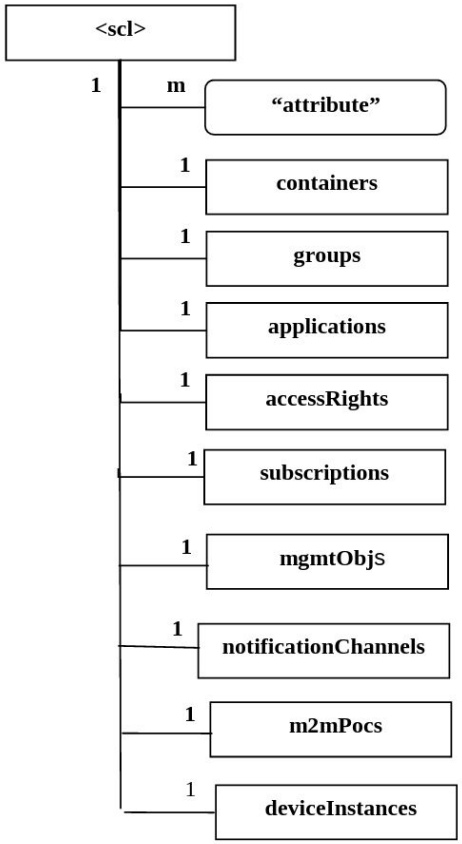
The M2M Service Capabilities are both at **network level** (M2M Service Capabilities in the Network Domain) and at **local level** (M2M Service Capabilities in the **M2M Gateway** and in the M2M Device).

Reference points



ETSI TS 102 690 V1.1.1 (2011-10) - P79

Data <scl>



"An <scl> resource shall represent a remote SCL that is registered to the containing <sclBase> . This means that each remote SCL that is registered with the <sclBase> shall be represented by an <scl> resource in that <sclBase> (the registered remote SCL). "

M2M System

M2M Standards - OneM2M (ETSI implementation)

http://www.onem2m.org/technical/developers-corner/tools/open-source-projects

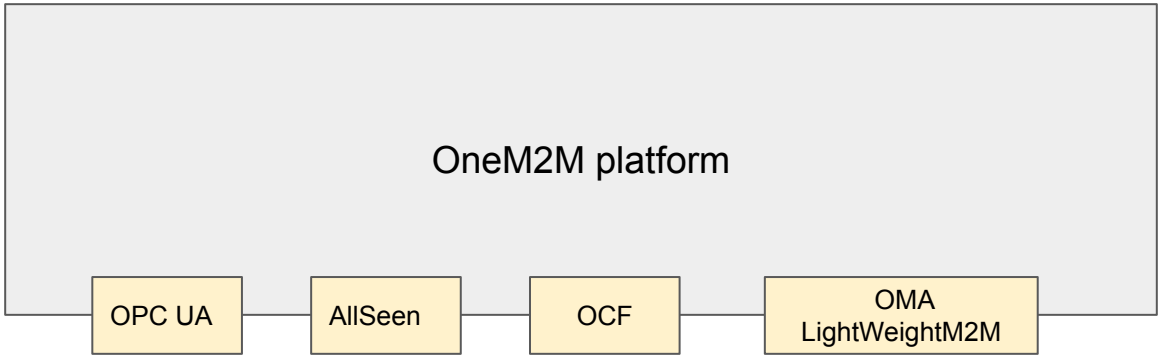
- OCEAN, open alliance for IoT standard,
- IOTDM,
- **OM2M**, hosted by the Eclipse Foundation (LAAS/CNRS),
- ATIS,
- OASIS SI...

M2M System

M2M Standards - OneM2M interoperability

http://www.onem2m.org/technical/published-documents

oneM2M enable interconnection across devices and applications:



IEEE P2413 : http://grouper.ieee.org/groups/2413/
http://grouper.ieee.org/groups/2413/Intro-to-IEEE-P2413.pdf

IEEE P2413

"This standard defines an architectural framework for the Internet of Things (IoT), including descriptions of various IoT domains, definitions of IoT domain abstractions, and identification of commonalities between different IoT domains."

Part II

M2M System - Definition

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M2M System - Communication example

M2M System - Standards

M2M Open platform

Lightweight M2M

M2M impact for IoT

Big data

IoT and digital hub

M2M System

Open platform

- Open platforms are open source projects,
- Can use M2M standards or not,
- Open platforms can be installed as public, private,
- Open platforms can offer a vertical architecture and M2M behaviour,

M2M System

Open platform - Service and implementation

- Open platforms offer more integrated services (data analysis, data storage, security ...),
- Most open platforms are not true standards (depending on the implementation),
- Open platforms can provide gateways to other M2M systems.

M2M System

Open platform - Fiware

https://www.fiware.org/

European project Fiware:

- M2M or simple IoT with transport protocol,
- Integrated services (big data, data analysis),
- Uses Docker components,
- Private or public platform ...
- Plugin to other M2M systems such as OneM2M,
- Easy to use for testing...

M2M System

Open platform - Fiware

Orion Context Broker allows you to model, manage and gather context information at large scale enabling context-aware applications.

Real time processing of Context Events

Publication of Context Information as Open Data

Creating Application Dashboards

Real time processing of Media Streams

Hosting your Application on a FIWARE Cloud

M2M System

Open platform - Fiware

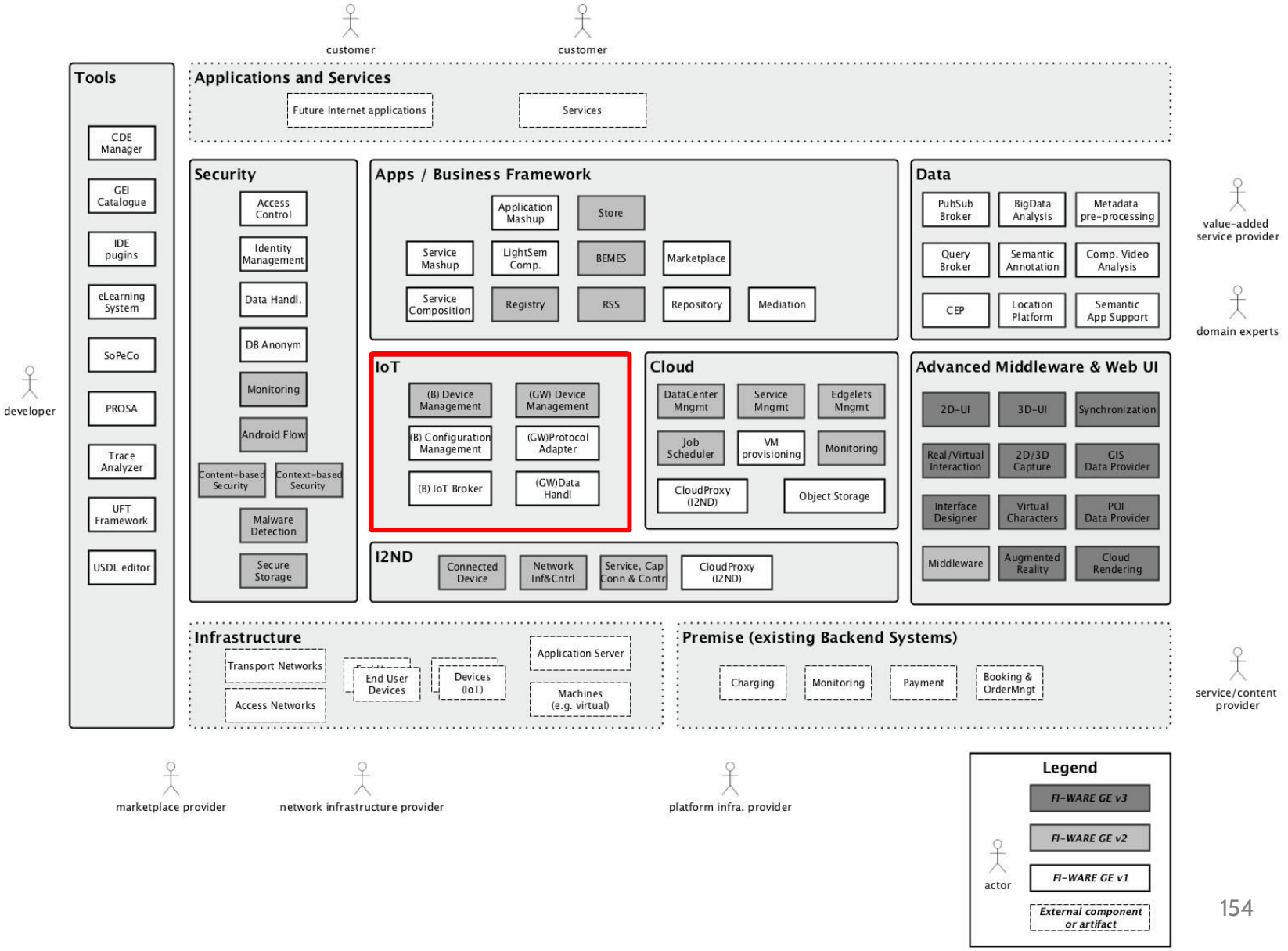
Big Data Analysis of Historic Context Information

Connection to the Internet of Things

Handling Authorization & Access Control to APIS

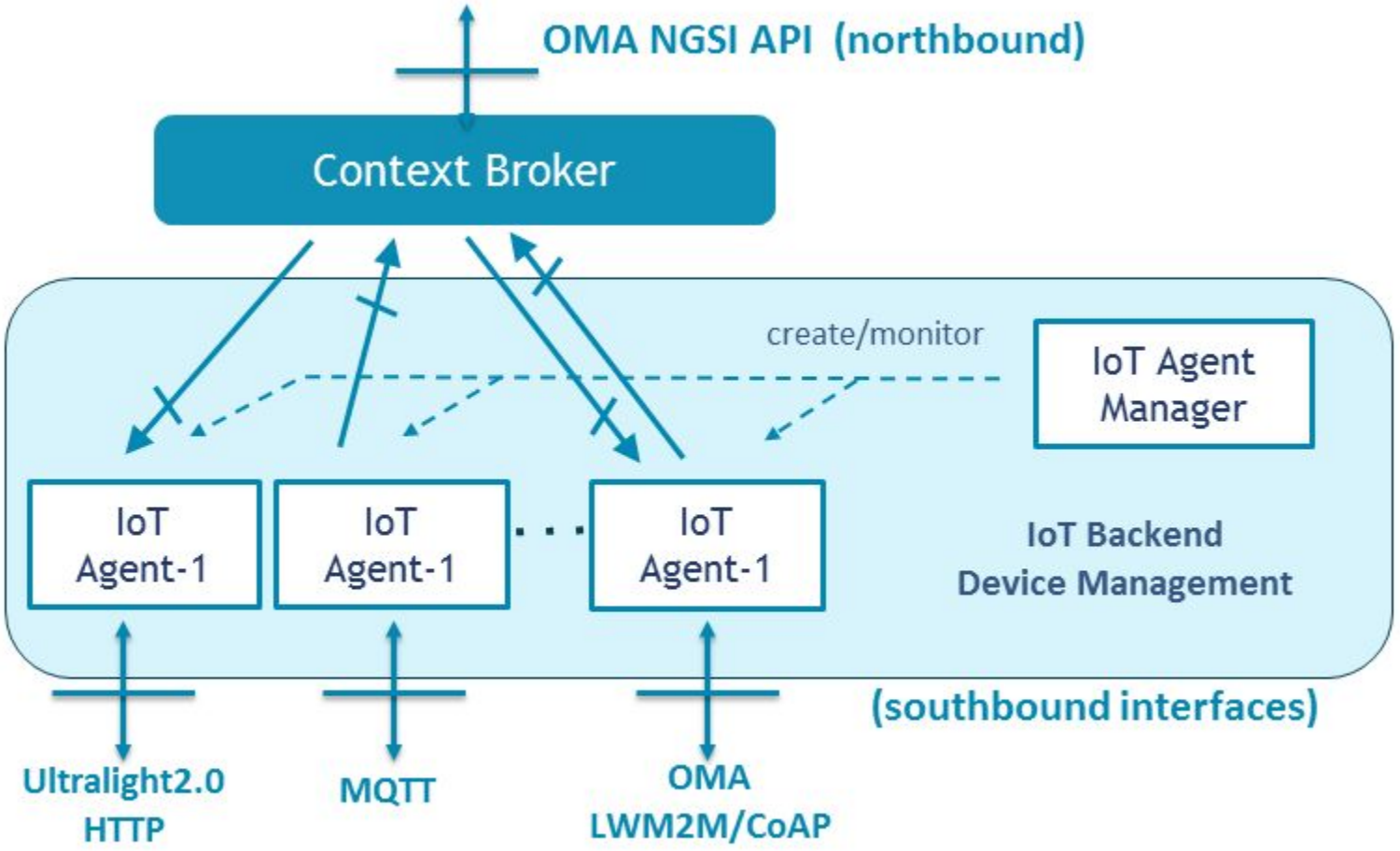
M2M System

Open platform - Fiware



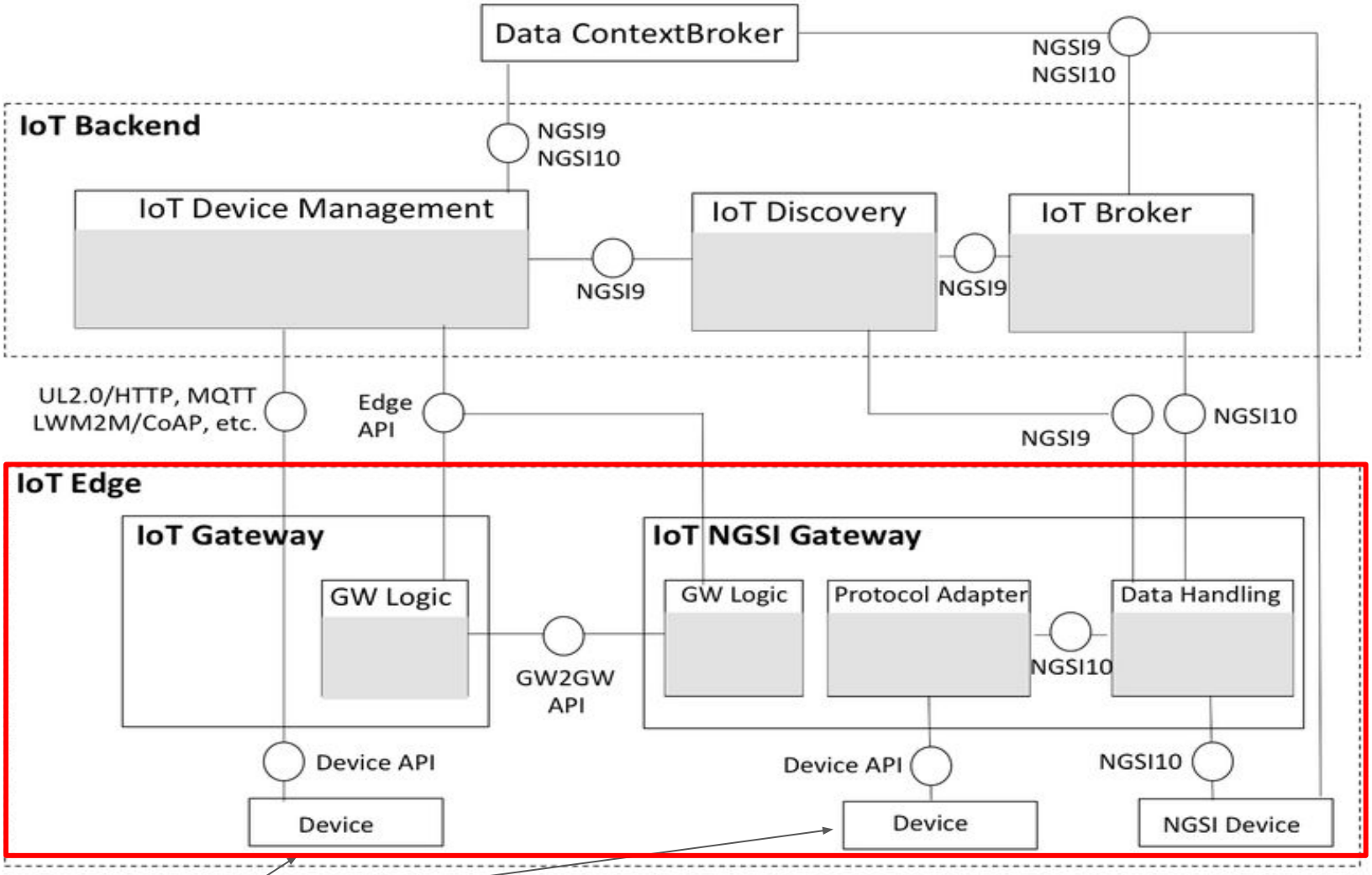
M2M System

Open platform - Fiware



M2M System

Open platform - Fiware



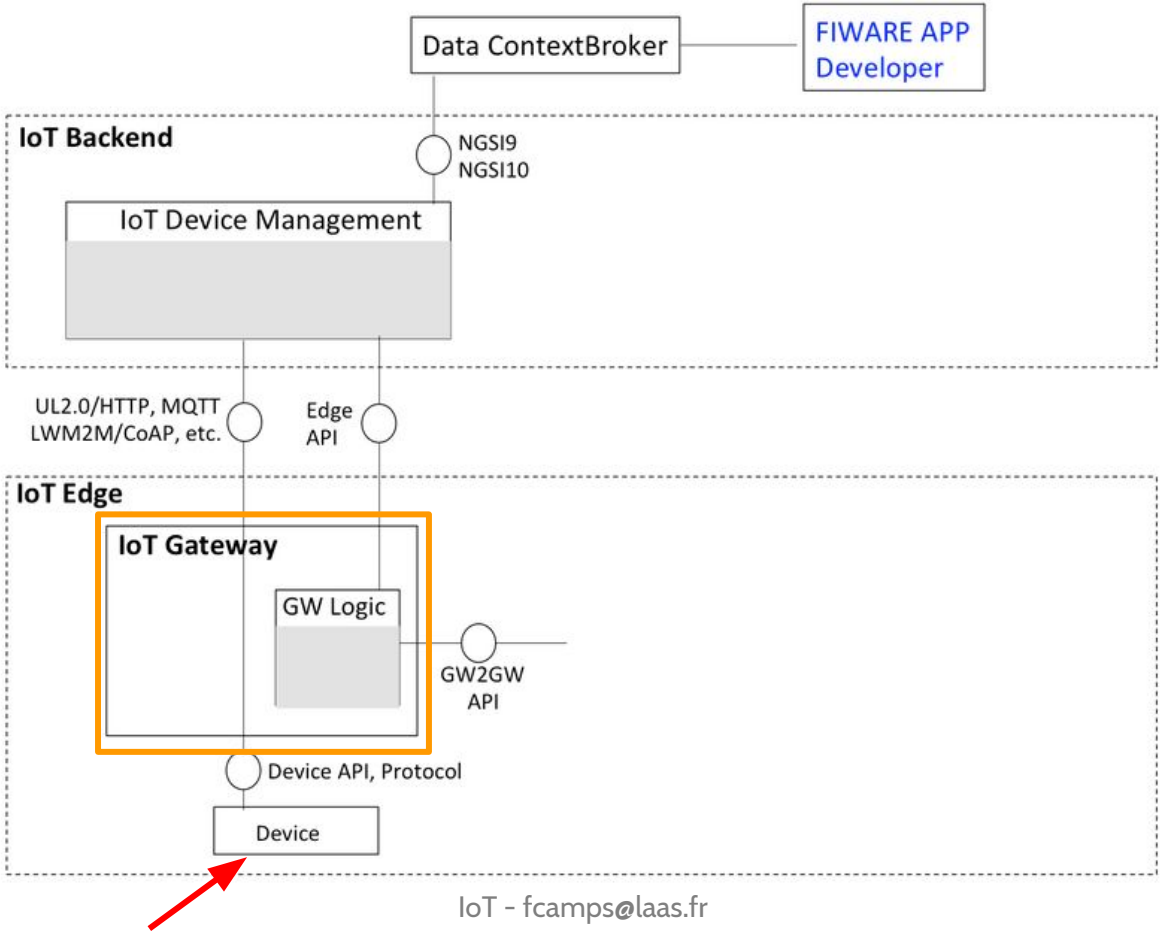
sensor/actuator

M2M System

Open platform - Fiware

https://forge.fiware.org/

This scenario stands for a simple integration of IoT devices into the Data chapter ContextBroker.

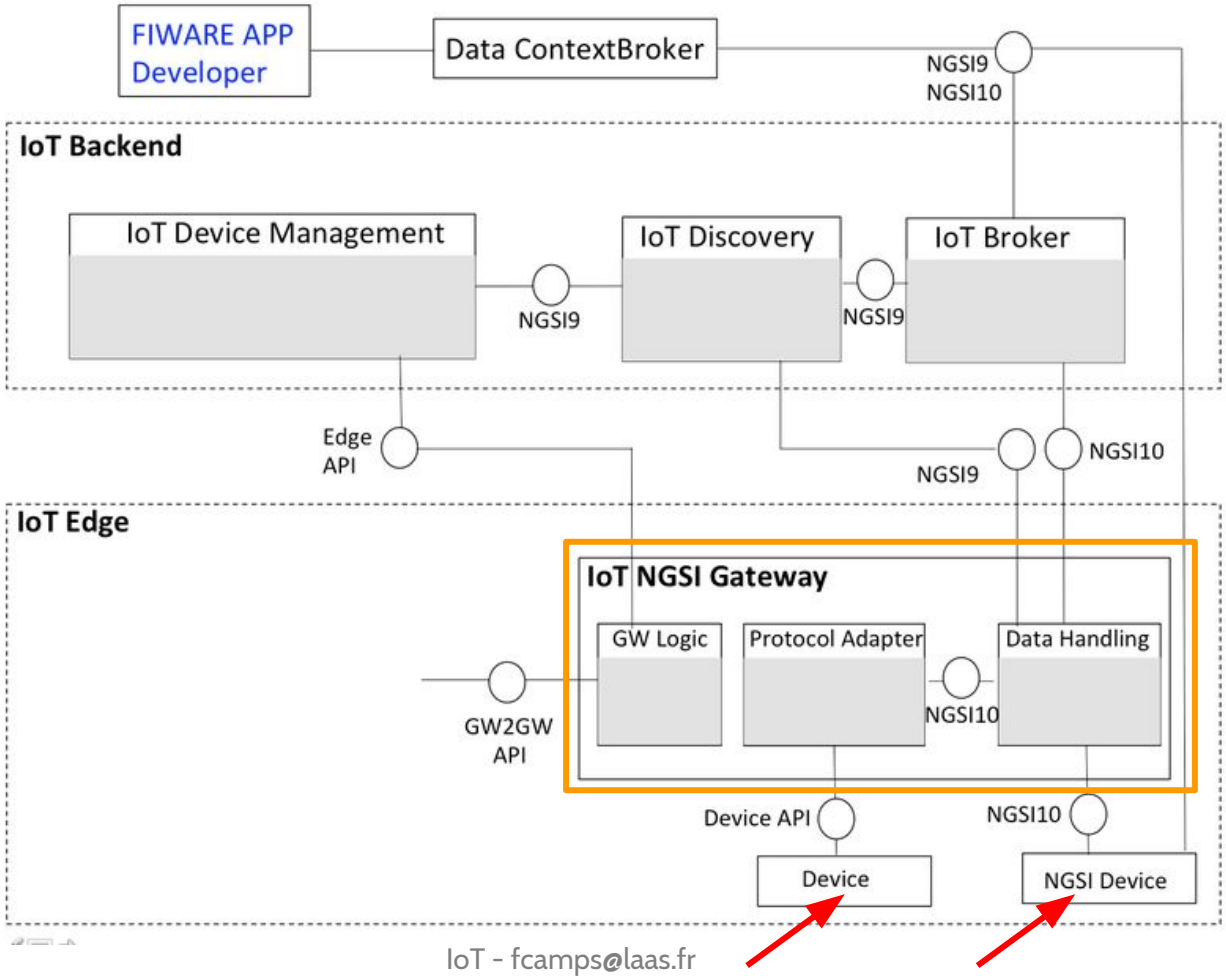


M2M System

Open platform - Fiware

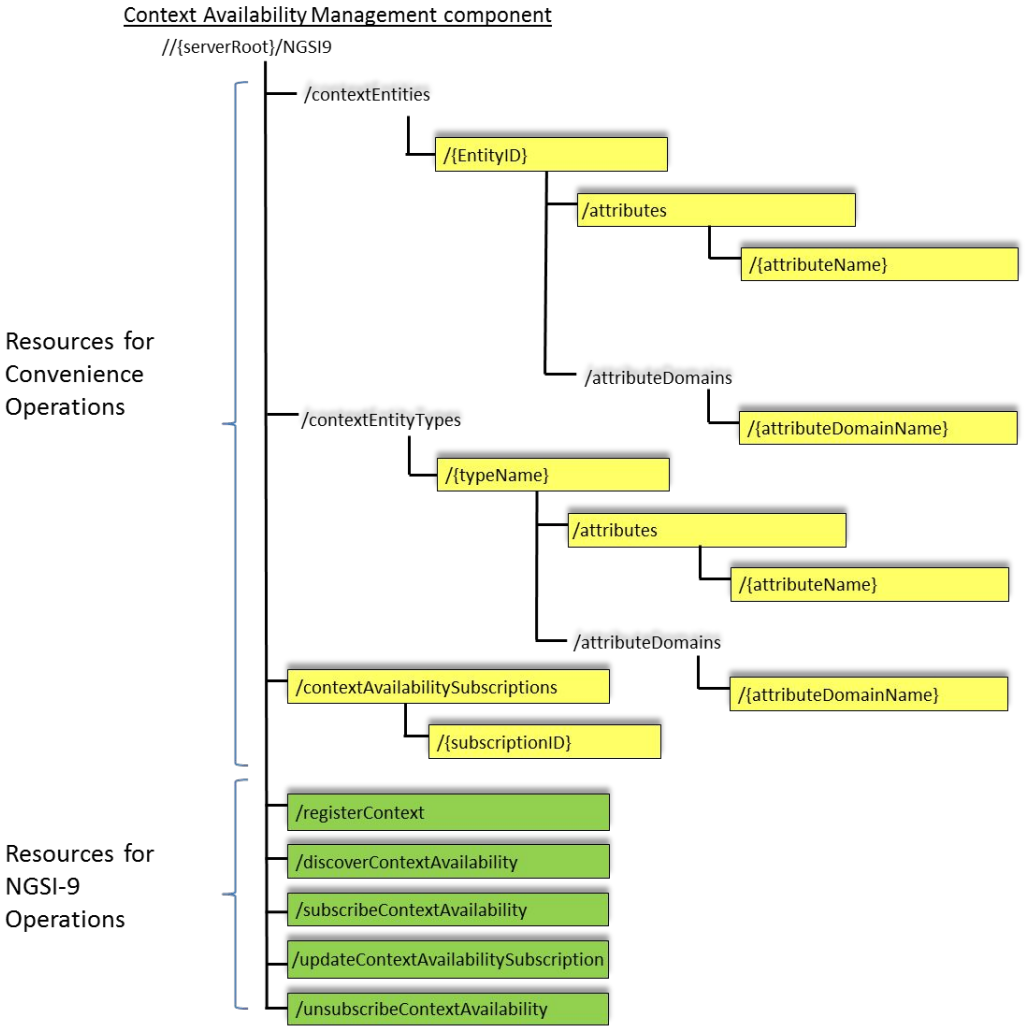
https://forge.fiware.org/

This scenario describes a use case where IoT end nodes or at least intermnediate Gateways implement the NGSI protocol.



M2M System

Open platform - Fiware



The intelligent IoT embeds an API that makes the object "smarter". **The object has a database** that allows to store data and to restore them, to discover other services ...

https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/FI-WARE_NGSI-9_Open_RESTful_API_Specification

https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php/FI-WARE_NGSI-10_Open_RESTful_API_Specification

M2M System

Open platform - Fiware

http://fiwaretourguide.readthedocs.io/en/latest/connection-to-the-internet-of-things/how-to-read-measures-captured-from-iot-devices/

Step 1 : Create an “IDAS” Service

Step 2: Register your IoT device

Step 3: Send Observations related to your IoT device

Step 4: Reading measurements sent by your IoT device

Step 1:

```
POST http://130.206.80.40:5371/iot/services

Headers:

{
  'Content-Type':       'application/json',
  'X-Auth-Token' :      '[TOKEN]',
  'Fiware-Service':     'openiot',
  'Fiware-ServicePath': '/'
}

Payload:

{
  "services": [
    {
      "apikey":      "4jggokgpepnvsb2uv4s40d59ov",
      "cbroker":     "http://0.0.0.0:1026",
      "entity_type": "thing",
      "resource":    "/iot/d"
    }
  ]
}
```

M2M System

Open platform - **High level App**

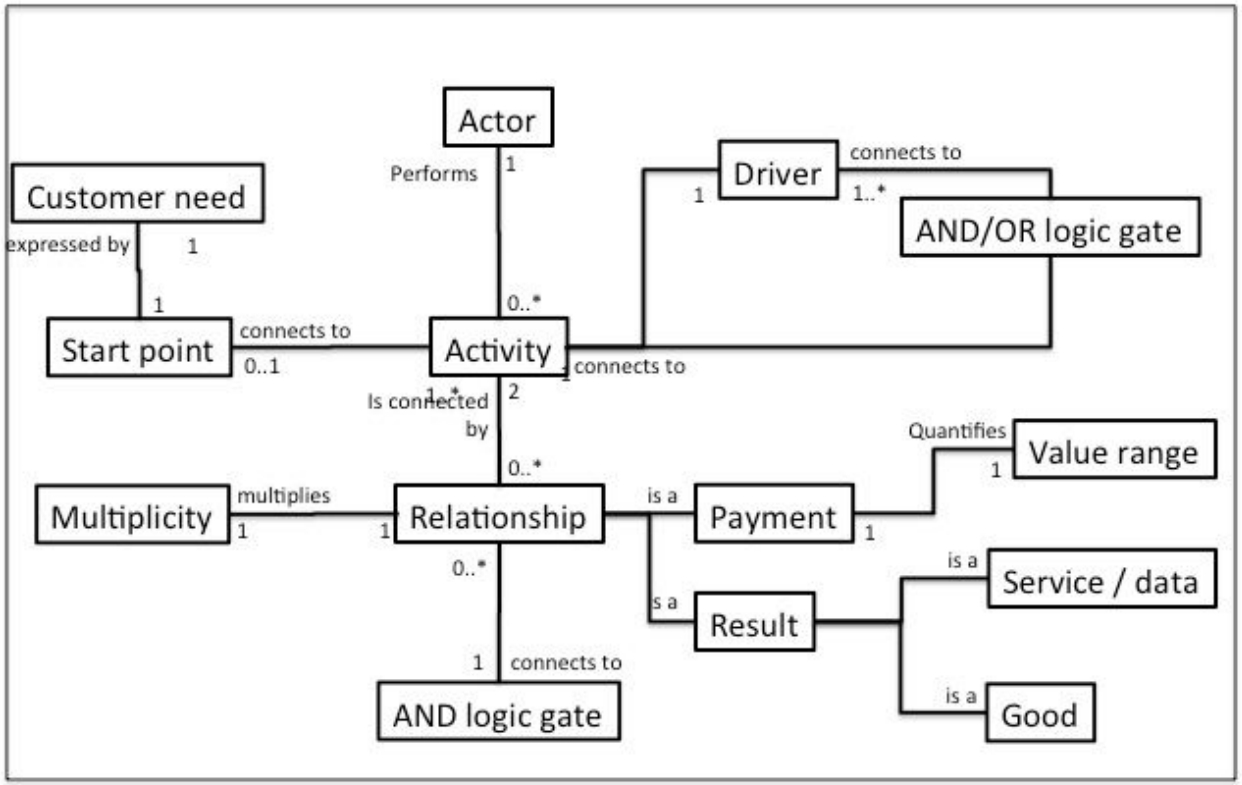
https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php
/FIWARE.ArchitectureDescription.Apps.BusinessModeller

- Future Internet business = models to calculate revenue and cost,
- Future Internet Applications run on top of platform,
- Business Model based on ontology,
- Business Modeler = page web application created in HTML5, CSS3 and JavaScript,
- Ontology = XMI and UML metadata languages to describe a business model,

M2M System

Open platform - High level App - Ontology

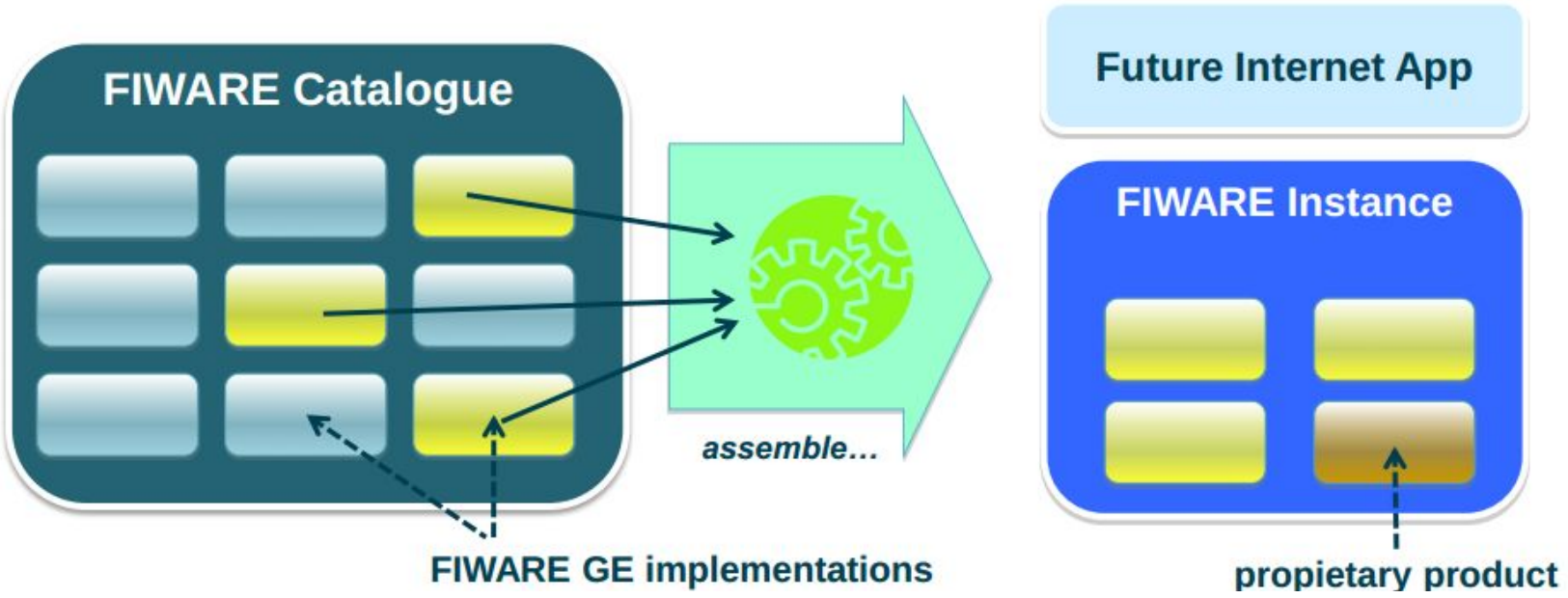
https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php
/FIWARE.ArchitectureDescription.Apps.BusinessModeller



M2M System

Open platform - Fiware - high level App catalogue

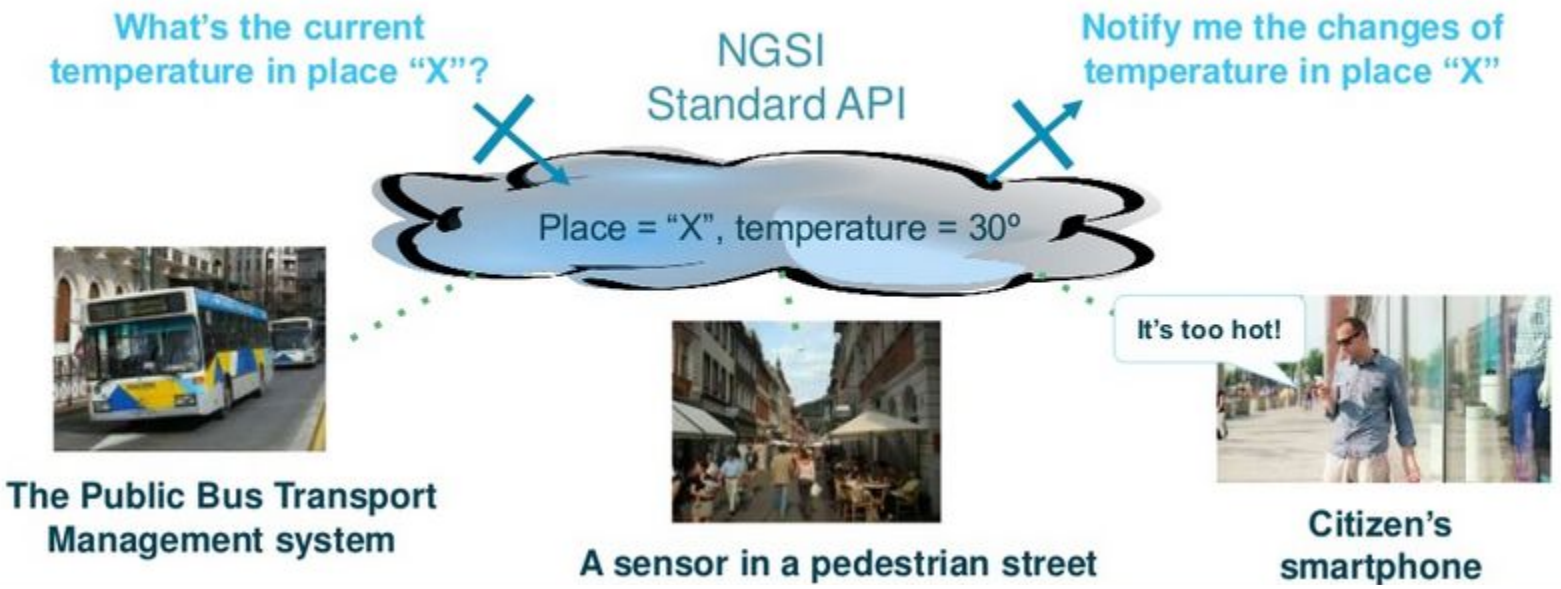
http://www.businessoulu.com/media/tiedostot/fiche/fi-ware-presentation.pdf



M2M System

Open platform - Fiware - high level App - City model

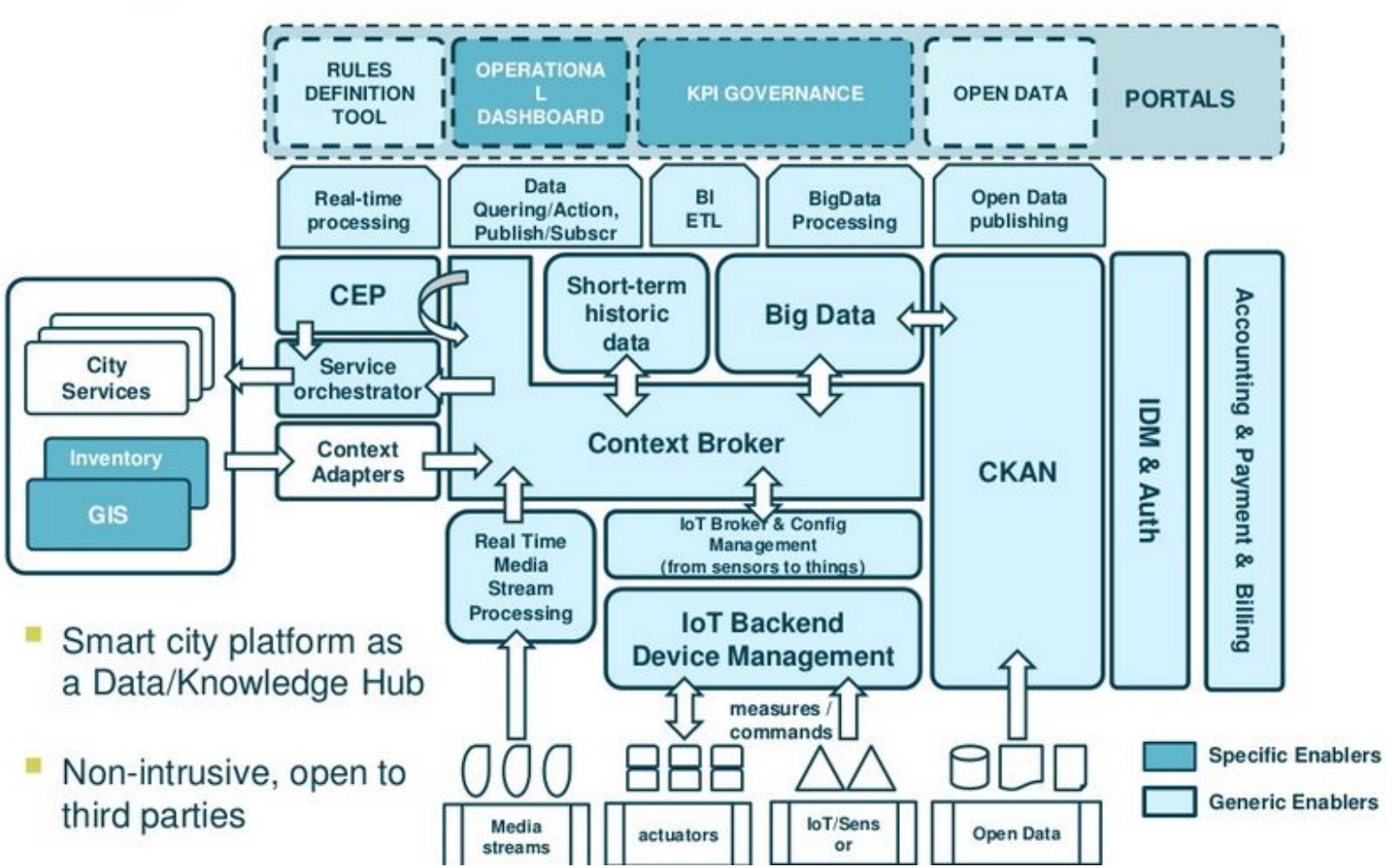
http://smartcityapphack.com/fiware/



M2M System

Open platform - Fiware - high level App - City model

http://smartcityapphack.com/fiware/

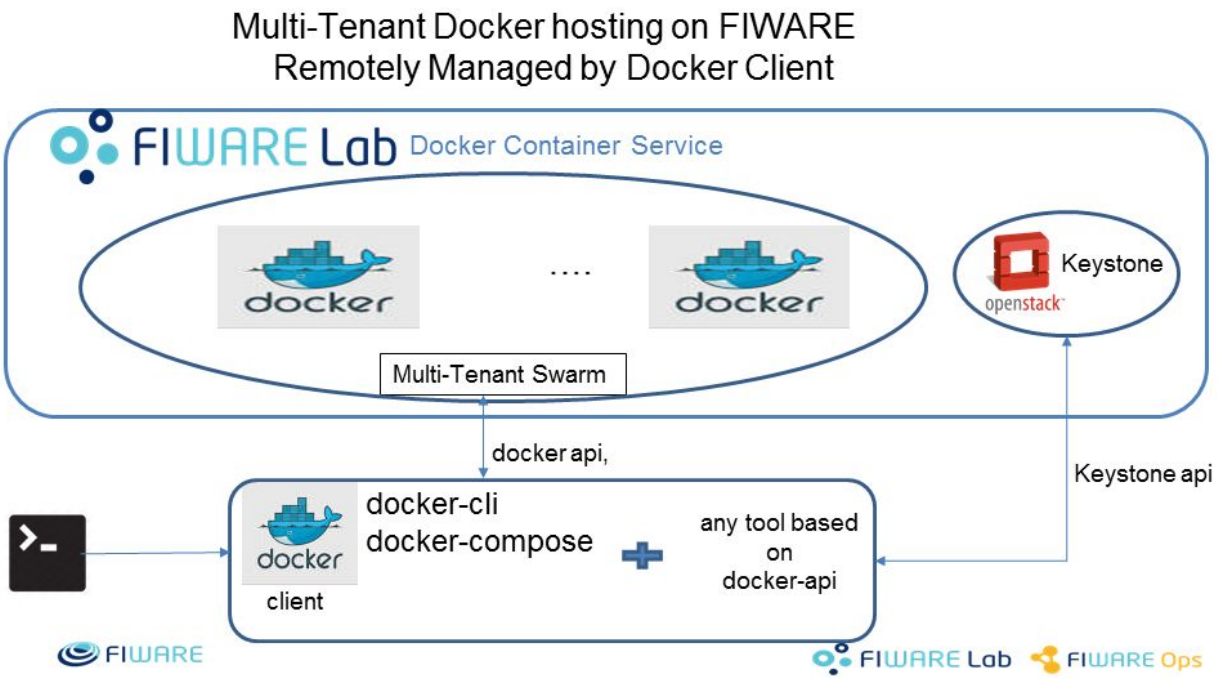


- Smart city platform as a Data/Knowledge Hub
- Non-intrusive, open to third parties

M2M System

Open platform - Fiware - docker

https://forge.fiware.org/plugins/mediawiki/wiki/fiware/index.php
/FIWARE.OpenSpecification.Cloud.Docker



M2M System

Open platform - IoTivity (US)

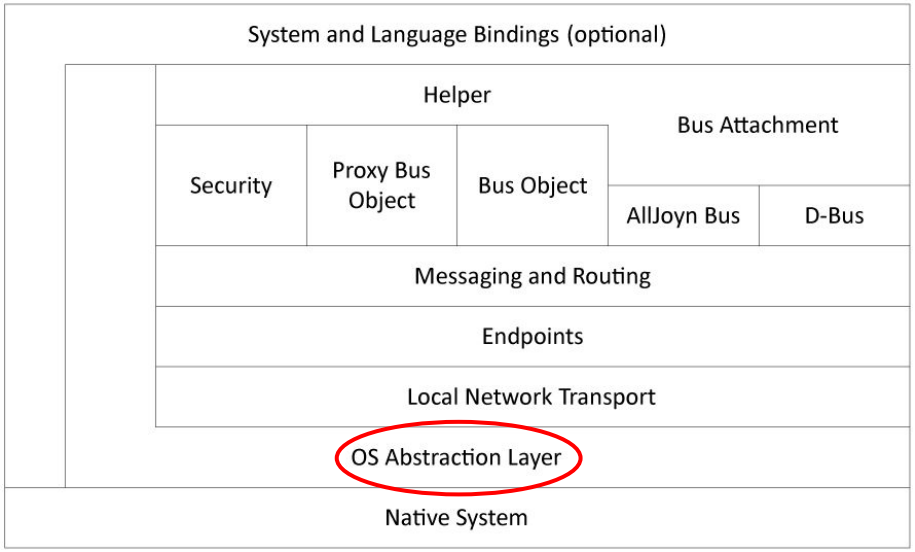
https://allseenalliance.org/
https://www.iotivity.org/

- A collaborative open source software framework (AllJoyn + Linux Fondation),
- Apache 2.0 license,
- Sponsored by the Open Connectivity Foundation (OCF), a group of industry leaders,
- Development in C, C++ and Java,
- Android, Tizen, Ubuntu (Linux), and Windows.

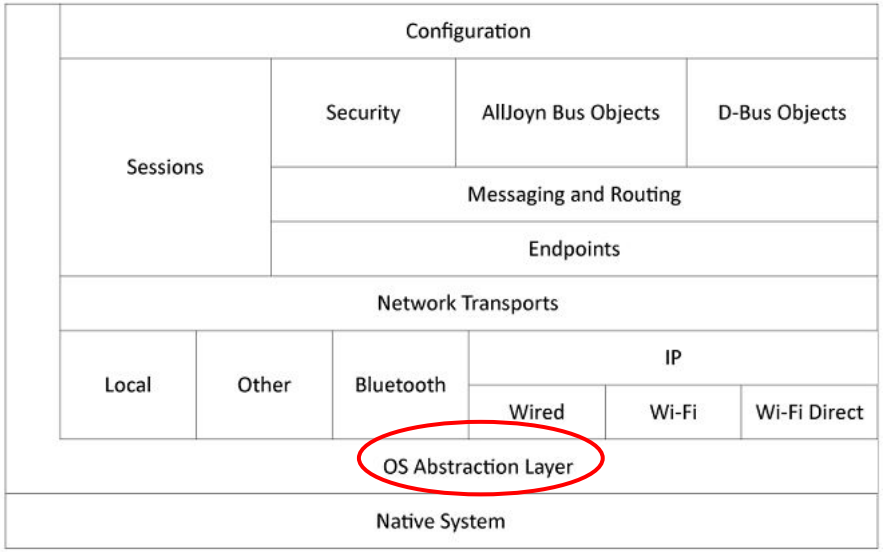
M2M System

Open platform - AllSeen (US)

https://allseenalliance.org/
https://allseenalliance.org/framework/documentation/learn/core/standard-core



Basic client, service, or peer architecture



Basic router architecture

M2M System

Open platform - Deployment and adoption announcements

http://www.onem2m.org/news-events/onem2m-deployment-announcements

http://www.nec.com/en/press/201412/global_20141215_02.html

- NEC is the first company in the world to deploy the new oneM2M service layer standard in a live smart city control center deployment

- Fiware + OneM2M plugin

Partie II

M2M System - Definition

M2M System - Global architecture

M2M System - Communication example

M2M System - Standards

M2M Open platform

Lightweight M2M

M2M impact for IoT

Big data

IoT and digital hub

M2M System

Lightweight M2M

- The above solutions are possible on large systems,
- Some industrial equipment requires **very light M2M** system,
- Lightweight M2M behavior should be similar to the large systems,
- Interoperability with other M2M systems.

M2M System

Lightweight M2M - OPC-UA

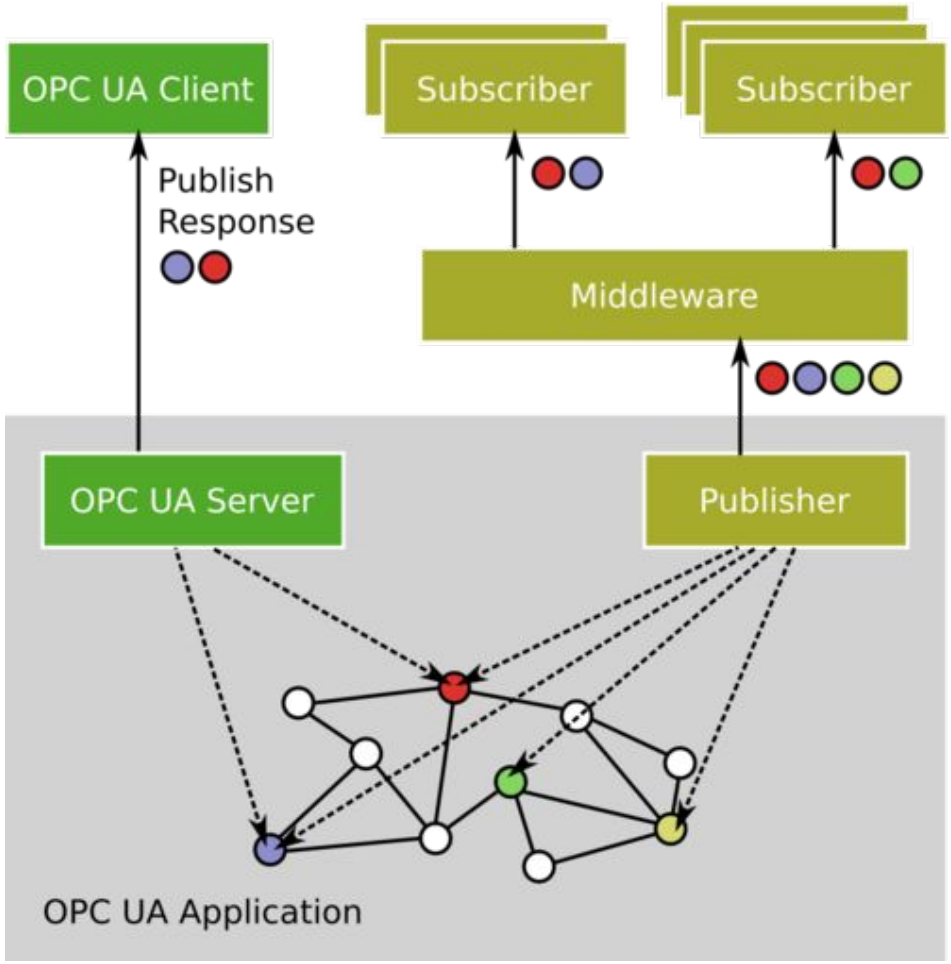
https://opcfoundation.org/about/what-is-opc/
https://www.unified-automation.com/
http://open62541.org/

- OPC is an interoperability standard industrial automation,
- Standardized in the IEC 6254,
- Asynchronous protocol built upon TCP, HTTP or SOAP,
- Its purpose was to abstract specific protocols (such as Modbus, Profibus, etc.).

M2M System

Lightweight M2M - OPC-UA - Structure

https://opcfoundation.org/about/what-is-opc/
https://www.unified-automation.com/
http://open62541.org/



M2M System

Lightweight M2M - OPC-UA - M2M Functions

https://opcfoundation.org/about/what-is-opc/
https://www.unified-automation.com/
http://open62541.org/

- **Discovery**: find the availability of OPC Servers on local PCs and/or networks,
- **Address space**: all data is represented hierarchically,
- **On-demand**: read and write data/information based on access-permissions,
- **Subscriptions**: monitor data/information and report-by-exception when values change based on a client's criteria,
- **Events**: notify important information based on client's criteria,
- **Methods**: clients can execute programs, etc. based on methods defined on the server.

M2M System

Lightweight M2M - OPC-UA - Platform Independence

https://opcfoundation.org/about/what-is-opc/
https://www.unified-automation.com/
http://open62541.org/

- **Hardware platforms**: traditional PC hardware, cloud-based servers, PLCs, micro-controllers (ARM etc.)

- **Operating Systems**: Microsoft Windows, Apple OSX, Android, or any distribution of Linux, etc.

M2M System

Lightweight M2M - OPC-UA - Implementation

https://opcfoundation.org/about/what-is-opc/
https://www.unified-automation.com/
http://open62541.org/

- Open62541 (http://open62541.org) - LGPL : C
- Unified-automation.com : Java, .NET, C++, ANSI C
- https://github.com/FreeOpcUa/freeopcua : C++

M2M System

Lightweight M2M - OPC-UA - Implementation open62541 (server)

http://open62541.org/doc/current/tutorial_server_firstSteps.html

```
#include <signal.h>
#include "open62541.h"

UA_Boolean running = true;
static void stopHandler(int sig) {
    running = false;
}

int main(void) {
    signal(SIGINT,  stopHandler);
    signal(SIGTERM, stopHandler);

    UA_ServerConfig config = UA_ServerConfig_standard;
    UA_ServerNetworkLayer nl;
    nl = UA_ServerNetworkLayerTCP(UA_ConnectionConfig_standard, 16664);
    config.networkLayers = &nl;
    config.networkLayersSize = 1;
    UA_Server *server = UA_Server_new(config);

    UA_Server_run(server, &running);
    UA_Server_delete(server);
    nl.deleteMembers(&nl);
    return 0;
}
```

M2M System

Lightweight M2M - OMA - Implementation

http://openmobilealliance.org
https://en.wikipedia.org/wiki/OMA_LWM2M

- OMA Lightweight M2M is a protocol from the Open Mobile Alliance for M2M or IoT,
- Communication protocol between a LWM2M Server / Client,
- Architectural design based on REST,
- Simple Object based resource model:
  - Resource operations of creation/retrieval/update/deletion/configuration of attribute,
  - Resource observation/notification,
  - TLV/JSON/Plain Text/Opaque data format support.

M2M System

Lightweight M2M - OMA - Implementation

http://openmobilealliance.org

the ARM mbed platform,

Microsoft's Azure platform,

Nokia's IMPACT IoT Platform,

Ericsson's Device Connection Platform,

IoTerop's IOWA LwM2M commercial stack,

Sierra Wireless' modules,

gateways and IoT platform ...

Part II

M2M System - Definition

M2M System - Global architecture

M2M System - Communication example

M2M System - Standards

M2M Open platform

Lightweight M2M

M2M impact for IoT

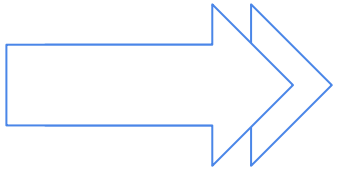
Big data

IoT and digital hub

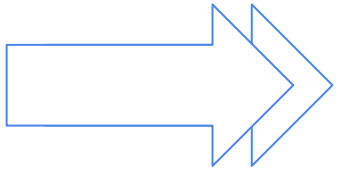
M2M System

Impact on IoT

- M2M behavior:
  - Gateway
  - IoT only
- Platform (Linux, Android …)
- Data structure,
- M2M compatibility,
- Remote setup,
- New protocol,
- Update procedure.



- Memory
- CPU
- Communication medium



- Fleet management

Part II

M2M System - Definition

M2M System - Global architecture

M2M System - Communication example

M2M System - Standards

M2M Open platform

Lightweight M2M

M2M impact for IoT

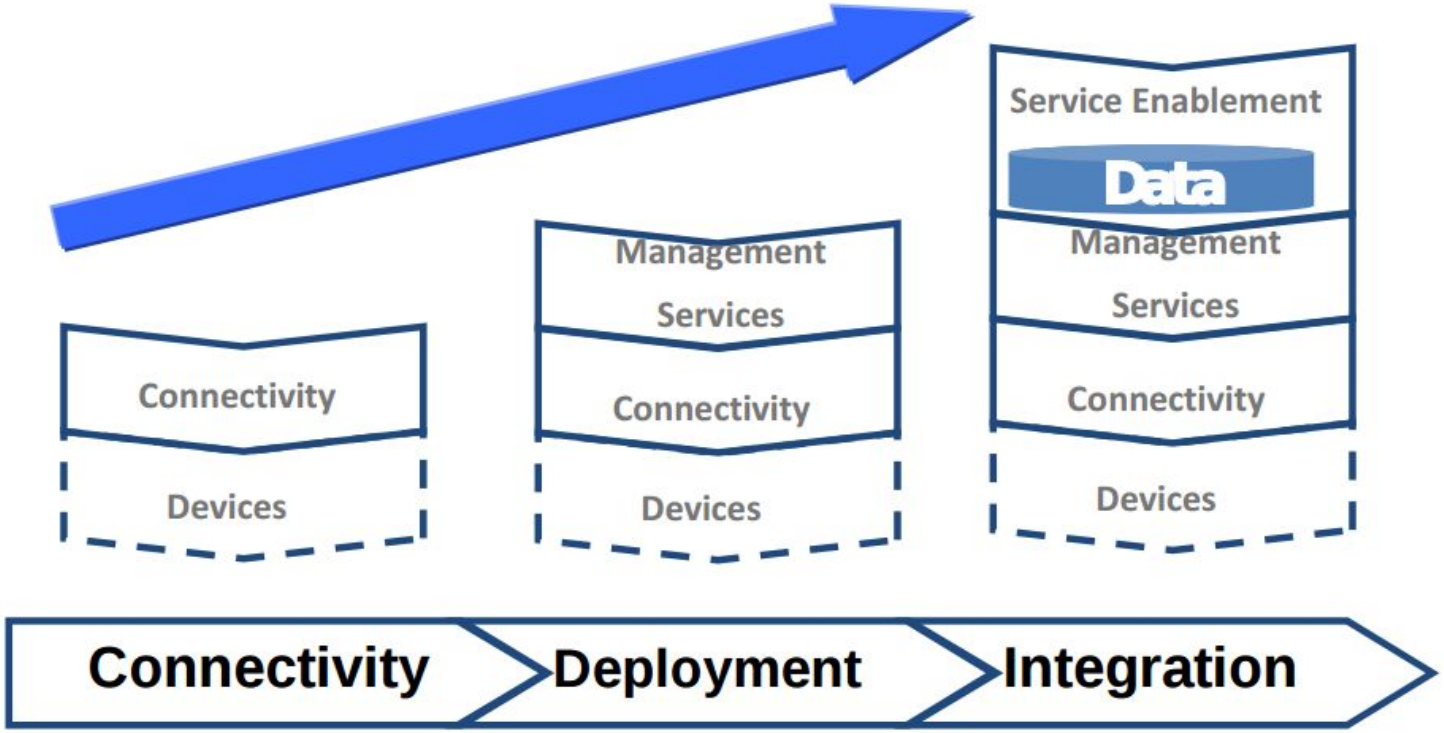
Big data

IoT and digital hub

M2M System

Big data - Sharing the data

http://www.etsi.org/images/files/Events/2014/201405_DGCONNECT_SmartM2MAppliances/ETSI_M2M_introduction_main.pdf



M2M is based on a "Store and Share" paradigm

- The data may be made available in the platform to the other applications, interested application are notified by means of subscription
- Privacy is ensured by a strict Access Rights Management...

M2M System

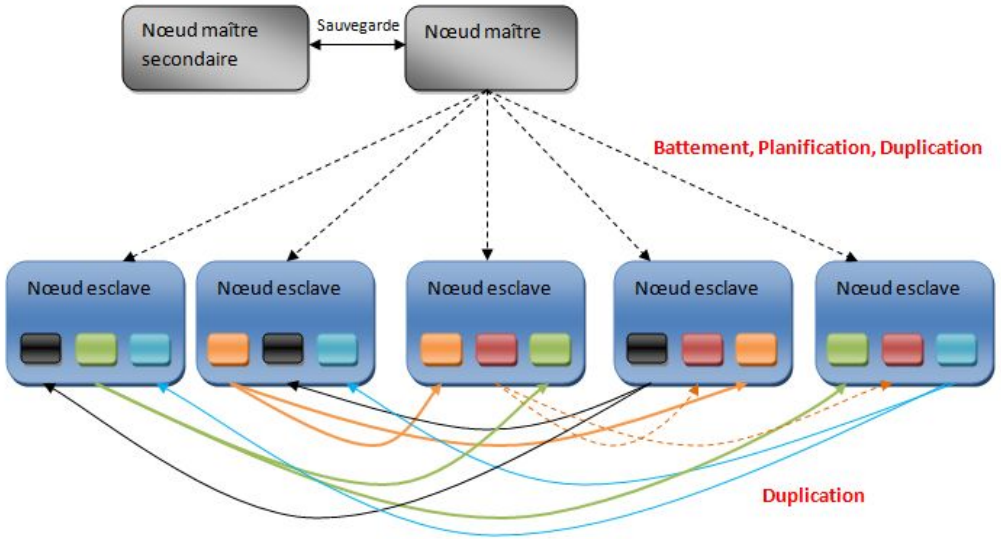
Big data - Sharing the data

http://hadoop.apache.org/
https://fr.wikipedia.org/wiki/Hadoop
http://fr.slideshare.net/welkaim/big-data-architecture-part-1

- Taming the data deluge,

- Challenges:
  - Data storage and management,
  - De-centralized/multi-server architectures,
  - Performance bottlenecks,
  - Increasing hardware requirements.

- Example: Hadoop project



M2M System

Big data - Sharing the data

http://www.fromdev.com/2015/03/hadoop-alternatives.html

"Hadoop dans les nuages"

- Hadoop can be deployed in a data center (Microsoft, Amazon, IBM et Google) ,

- Alternative:
  - Disco project: http://discoproject.org/
  - Misco
  - Cloud MapReduce
  - ...

Part II

M2M System - Definition

M2M System - Global architecture

M2M System - Communication example

M2M System - Standards

M2M Open platform

Lightweight M2M

M2M impact for IoT

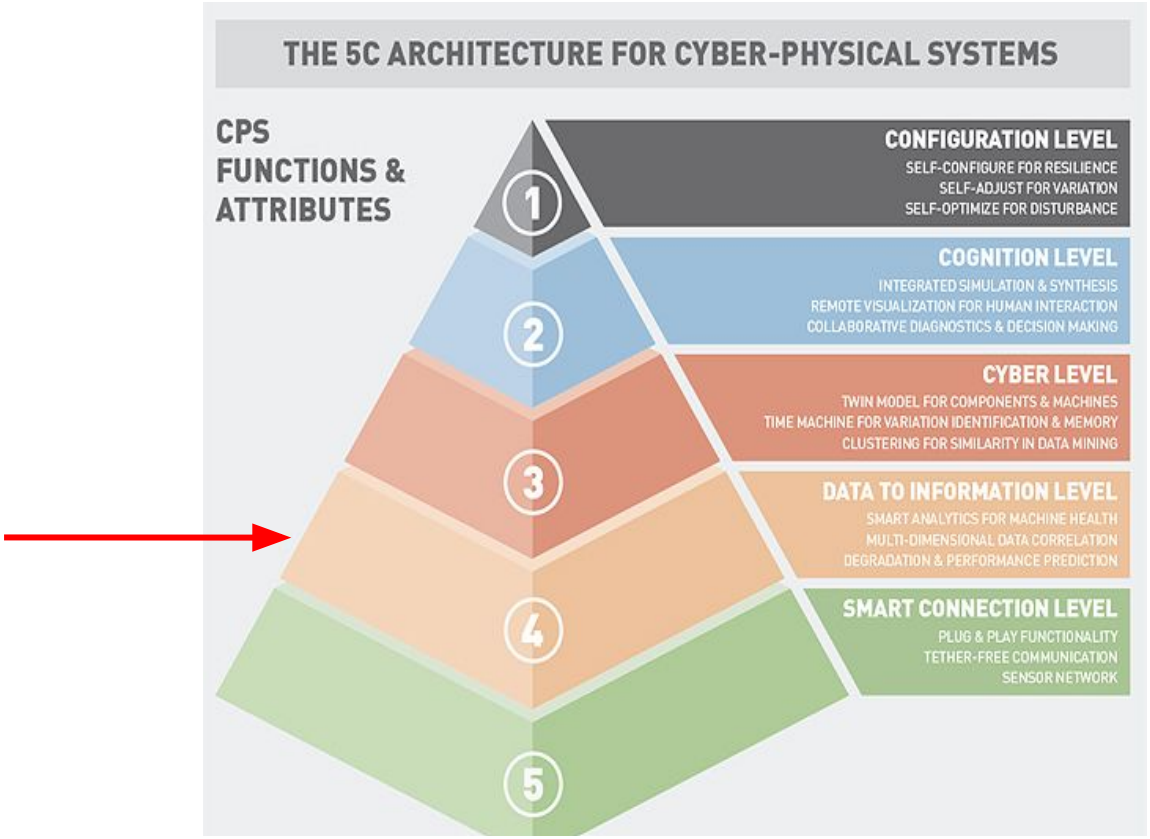
Big data

IoT and digital hub

IoT hub

IoT and digital hub - Cyber-Physical Systems

http://www.designworldonline.com/big-future-for-cyber-physical-manufacturing-systems/
https://en.wikipedia.org/wiki/Internet_of_things



IoT hub

IoT and digital hub

- Offer an all-in-one product to manufacturers and developers of connected objects
- Use a virtualized platform with standard (s) and protocols,
- Pay an overall cost,
- Trust the provider ...

Example: http://www.hubnumeriquedelaposte.fr/
http://www.ibm.com/internet-of-things/

IoT hub

IoT and digital hub

Example:

Amazone, ThingSpeak, dweet.io, open.sen.se, SMQ IoT LED Control , Kaa , Beebotte ...

IoT hub

IoT and digital hub

https://iot-analytics.com/5-things-know-about-iot-platform/

A modern IoT platform architecture consists of 8 elements:

1- **Connectivity and standardization**: brings different protocols and different data formats into a single "software" interface ensuring accurate data transmission and interaction with all devices.

2- **Device management**: ensures that the connected "objects" work correctly, allows to distribute patches and updates for software and applications running on systems and gateways.

3- **Database**: Scalable data storage provides requirements for databases in the cloud.

IoT hub

IoT and digital hub

https://iot-analytics.com/5-things-know-about-iot-platform/

A modern IoT platform architecture consists of 8 elements:

4- **Management Processing & Action**: Dynamic data analysis triggers events and gives meaning to mass storage.

5- **Analytical processing**: more complex analysis of data and learning systems. The analysis becomes predictive and makes it possible to extract the useful data from the mass of the data.

6- **Visualization**: Reading by humans analysis of data, graphic, dashboard.

https://iot-analytics.com/5-things-know-about-iot-platform/

A modern IoT platform architecture consists of 8 elements:

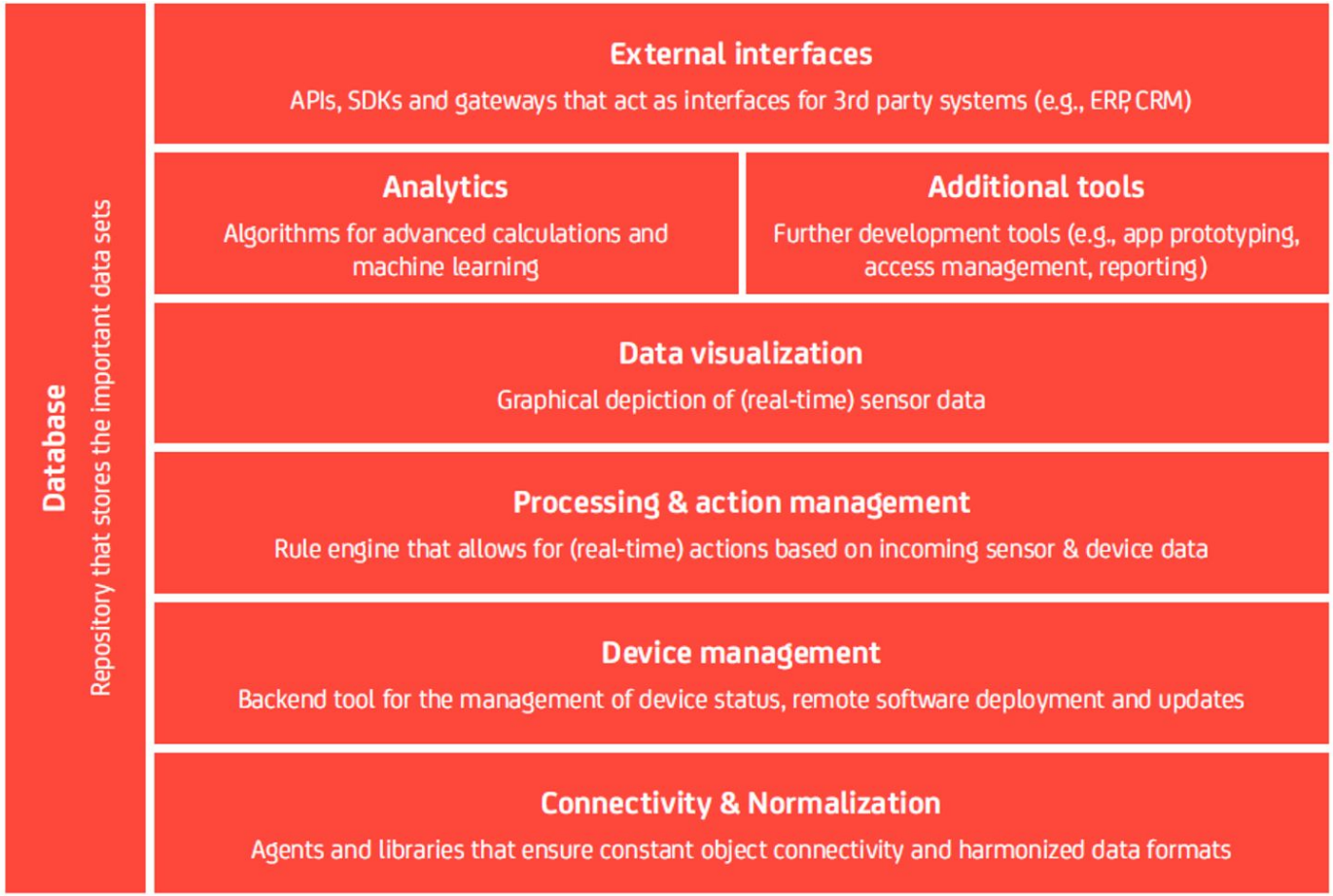
7- **Additional tools**: Enable prototyping, testing, ecosystem creation, IoT management and control.

8- **External interface**: Provide development APIs, Software Developments Kits (SDKs), gateways between different technologies.

IoT hub

IoT and digital hub

https://iot-analytics.com/5-things-know-about-iot-platform/

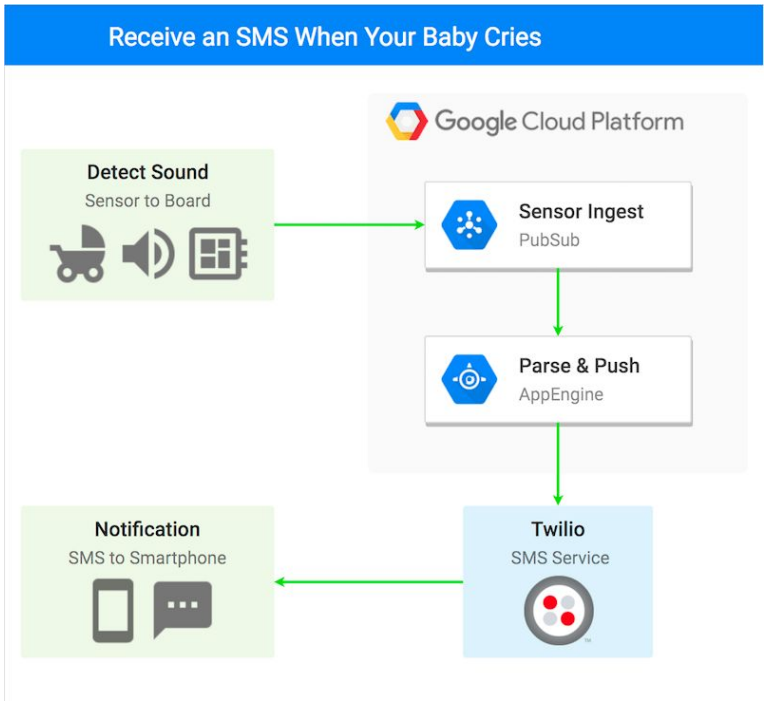


IoT hub

IoT and digital hub - Example: Google

https://developers.google.com/weave/guides/overview/what-is-weave
https://cloud.google.com/
https://cloud.google.com/speech/

- Convert audio to text by applying powerful neural network models,
- Recognizes over 80 languages and variants,
- Context-aware recognition …
- Batch prediction services ...

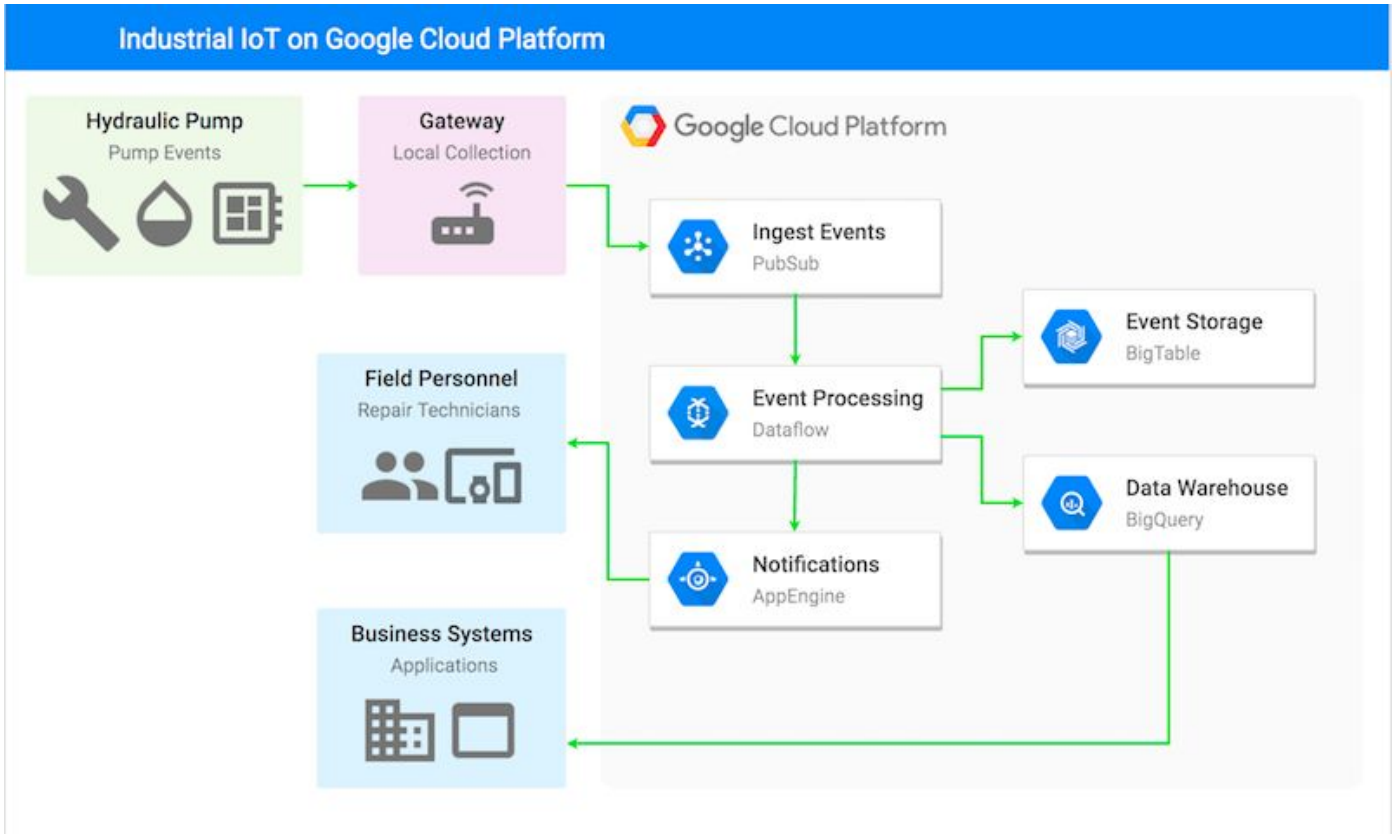


IoT hub

IoT and digital hub - Example: Google

https://developers.google.com/weave/guides/overview/what-is-weave
https://cloud.google.com/

Weave



Partie III

Concept of IoT data model

Use case and automatic generation

Developing an IoT

M2M System

Concept of IoT data model

http://www.eclipse.org/vorto/news/index.html

Objectives:

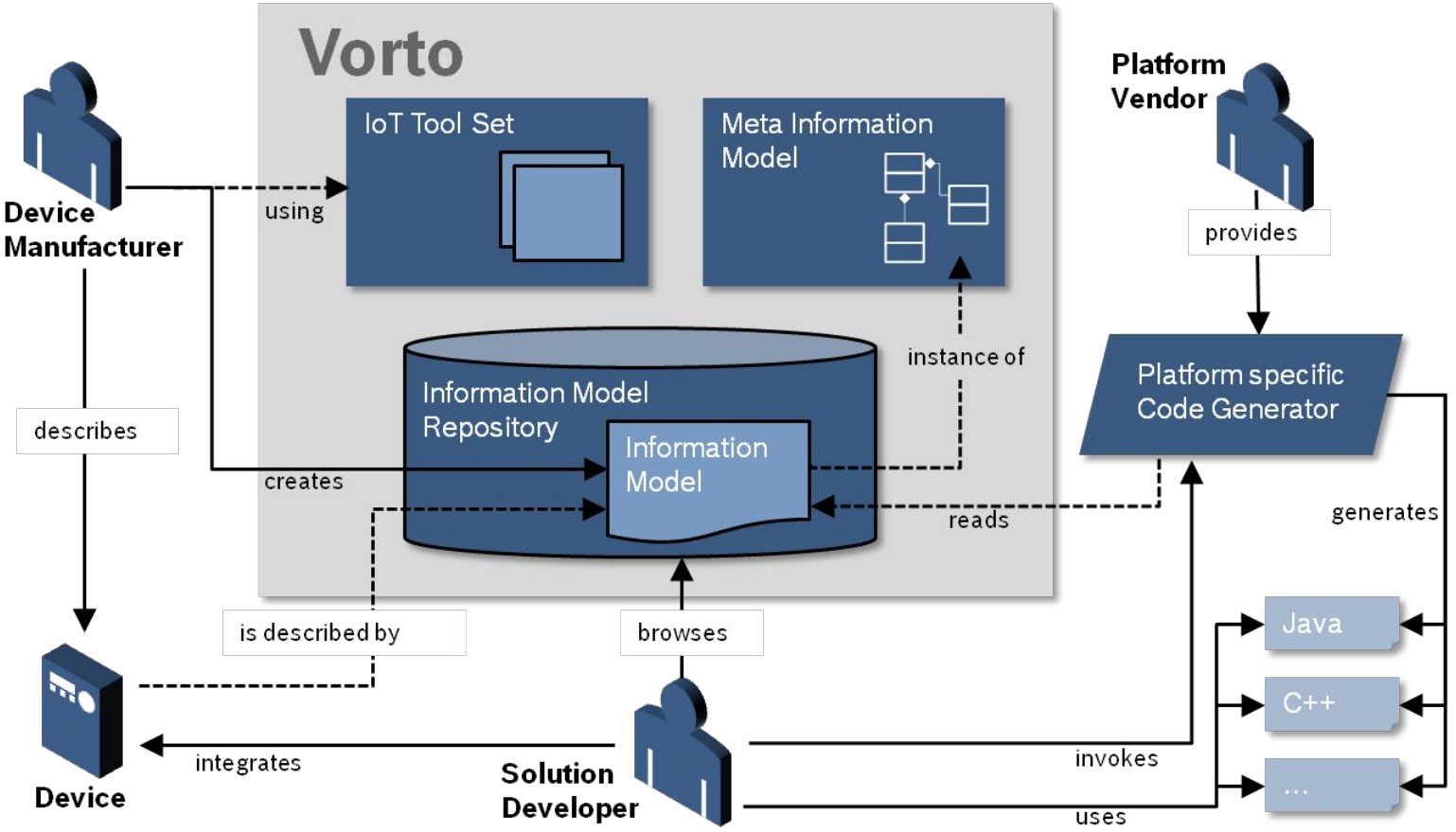
- Accelerate the integration of IoT into the platform,
- Search device characteristics and device functionality,
- Use a code generator for devices ...

Example: Bosch M2M with the ThingWorx® IoT platform.

M2M System

Concept of IoT data model

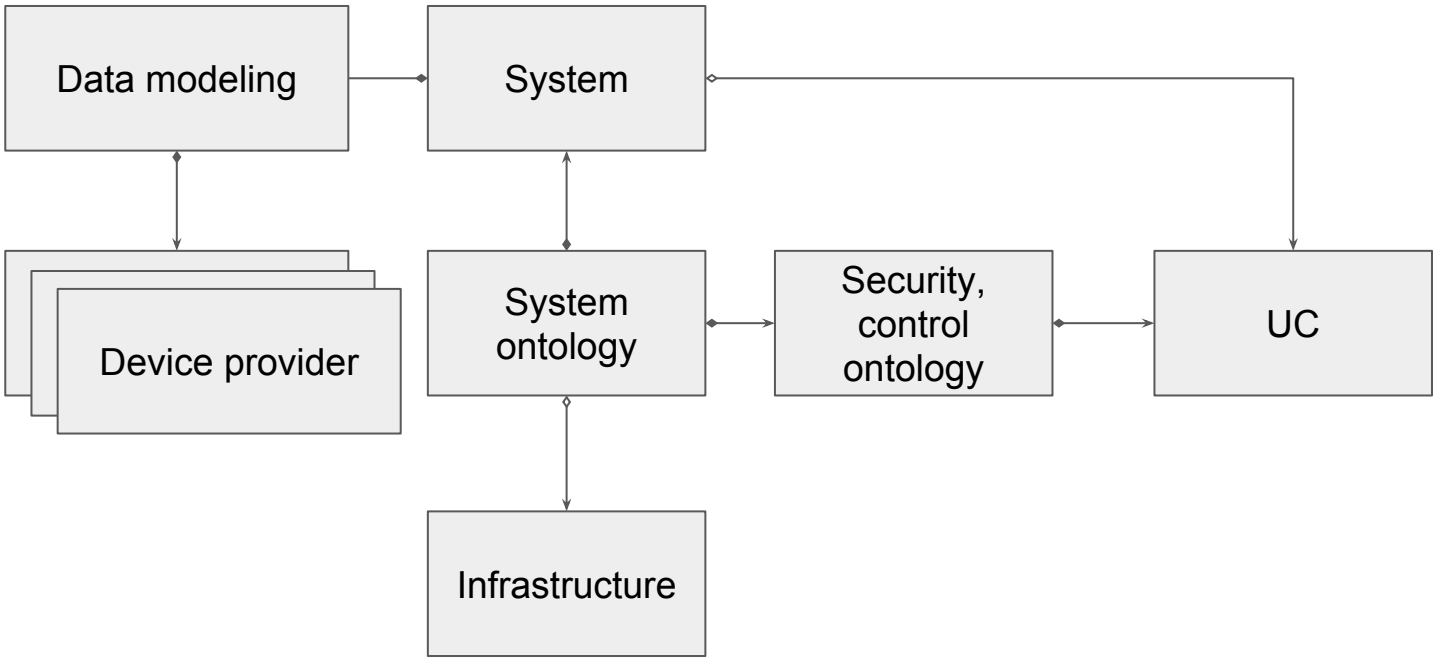
http://www.eclipse.org/vorto/documentation/overview/introduction.html



M2M System

Concept of IoT data model

- The system describes itself,
- The system describes its own UCs and disseminates them under control,
- The system executes the UCs.



M2M System

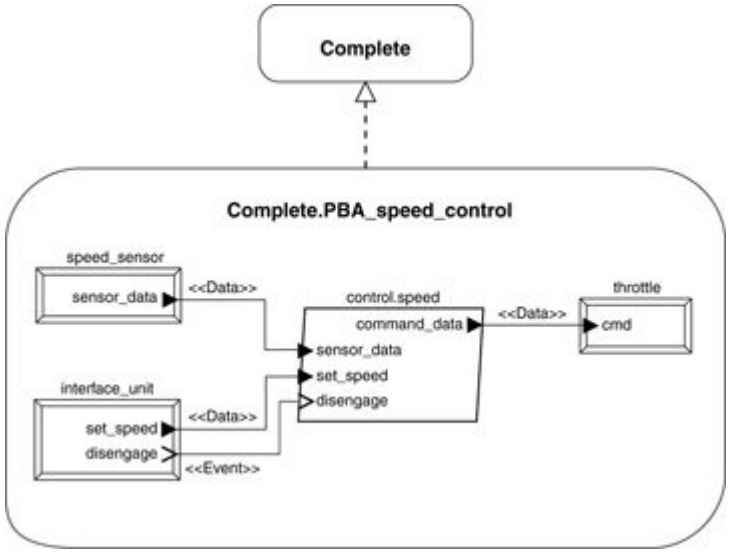
Concept of IoT data model - Language design

http://standards.sae.org/as5506b/
https://en.wikipedia.org/wiki/Architecture_Analysis_%26_Design_Language
Example: http://www.informit.com/articles/article.aspx?p=1959953

- AADL: The Architecture Analysis & Design Language
- AADL is used to model the software and hardware architecture of an embedded

```
system Complete
end Complete;

system implementation Complete.PBA_speed_control
  subcomponents
    speed_sensor: device sensor.speed;
    throttle: device actuator.speed;
    speed_control: process control.speed;
    interface_unit: device interface.pilot;
  connections
    DC1: port speed_sensor.sensor_data ->
         speed_control.sensor_data;
    DC2: port speed_control.command_data -> throttle.cmd;
    DC3: port interface_unit.set_speed ->
         speed_control.set_speed;
    EC4: port interface_unit.disengage ->
         speed_control.disengage;
end Complete.PBA_speed_control;
```



Part III

Concept of IoT data model

Use case and automatic generation

Developing an IoT

Constat:

- L'équipement est aujourd'hui relativement bas coût car cela permet une grande diffusion, c'est l'objectif de l'IoT !

- La valeur ajoutée "apparente" pour le client se situe plus dans les services offerts par le système, le matériel est complètement abstrait.

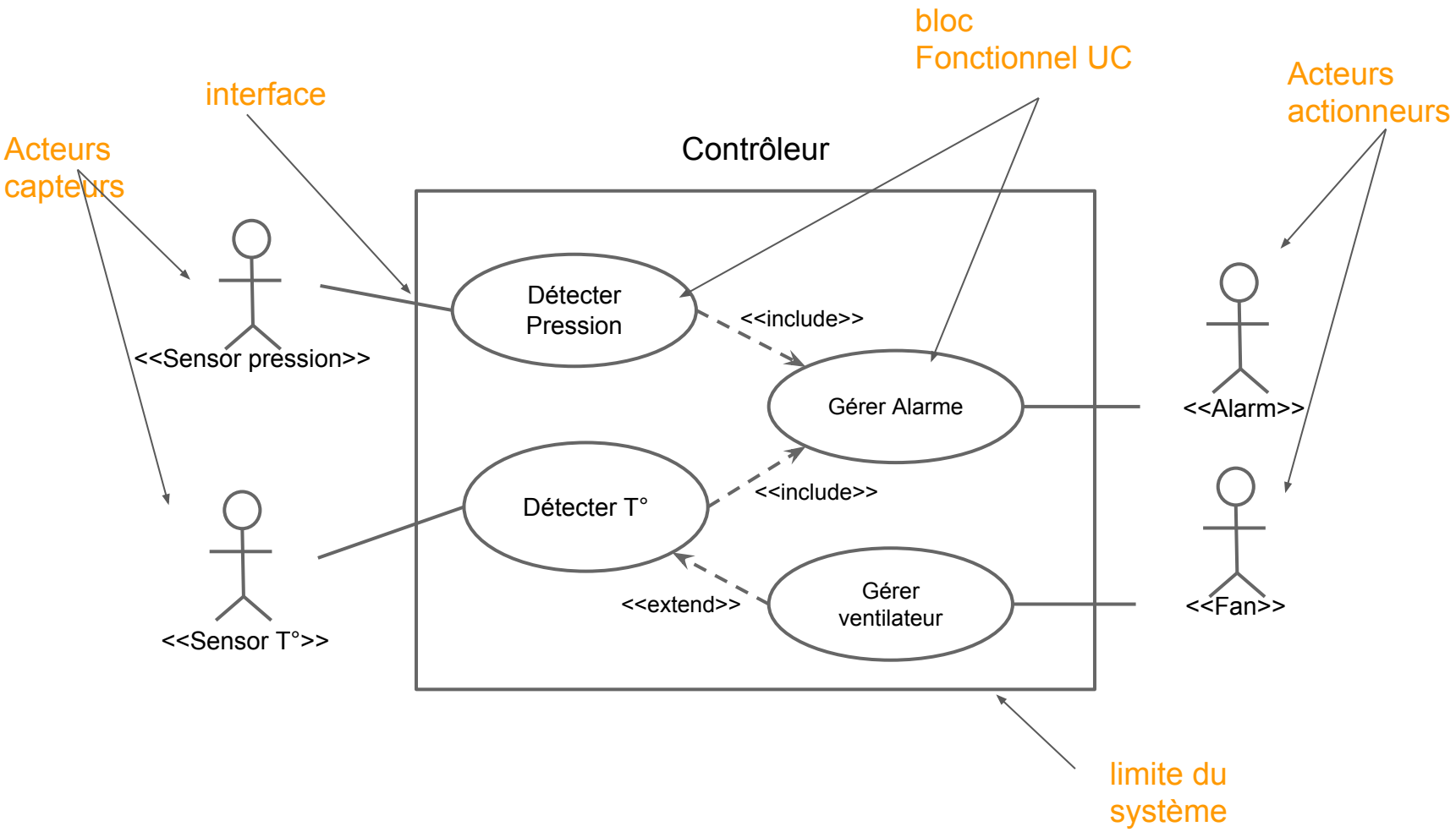
- Les cas d'utilisation ou Use Case permettent de démontrer une utilisation particulière d'un système:

    - gestion de la température,
    - alarme
    - ...

Qu'est ce qu'un USE CASE ?:

- Caractériser l'utilisation d'un système dans un contexte donné,
- Mettre en évidence les aspects fonctionnels (quels sont les fonctions/services que l'utilisateur pourra mettre en oeuvre),
- Décrire les aspects fonctionnels optionnels ou non,
- Présenter les interactions entre les acteurs humains et non humains,
- Mettre en évidence un fonctionnement nominal et non nominal.

Comment représenter USE CASE ?

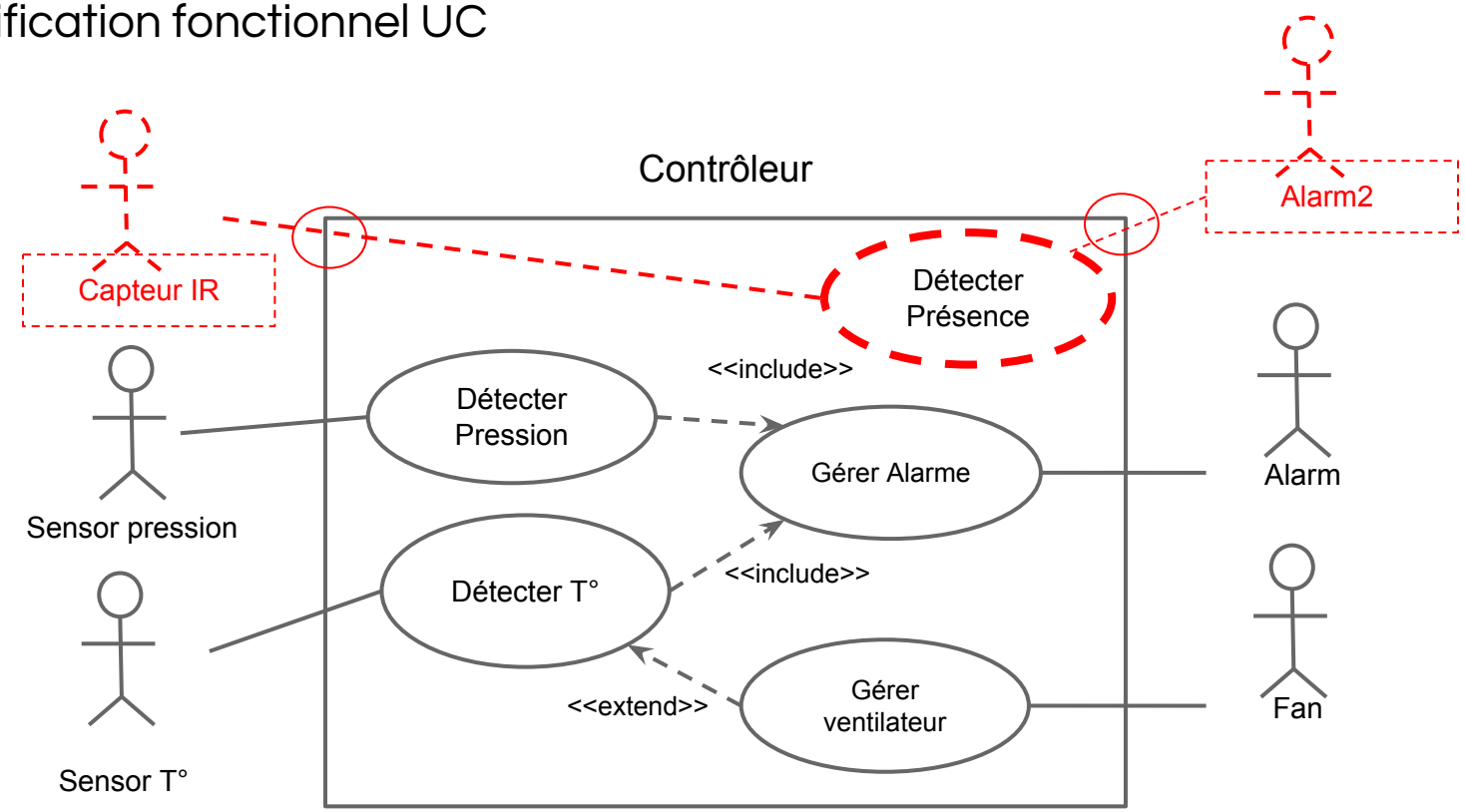


Création d'un UC

- En principe les équipements sont livrés dans un contexte de Use Case qui permet d'utiliser le système avec des paramètres de configurations modifiables, mais on reste dans le cadre du Use Case:
    - Un système d'alarme reste un système d'alarme,
    - Un système de gestion de température sera toujours utilisé pour gérer des températures.

  On voit bien ici que le système est figé dans son utilisation et qu'il n'y a pas de possibilité de modifier le cadre du UC !

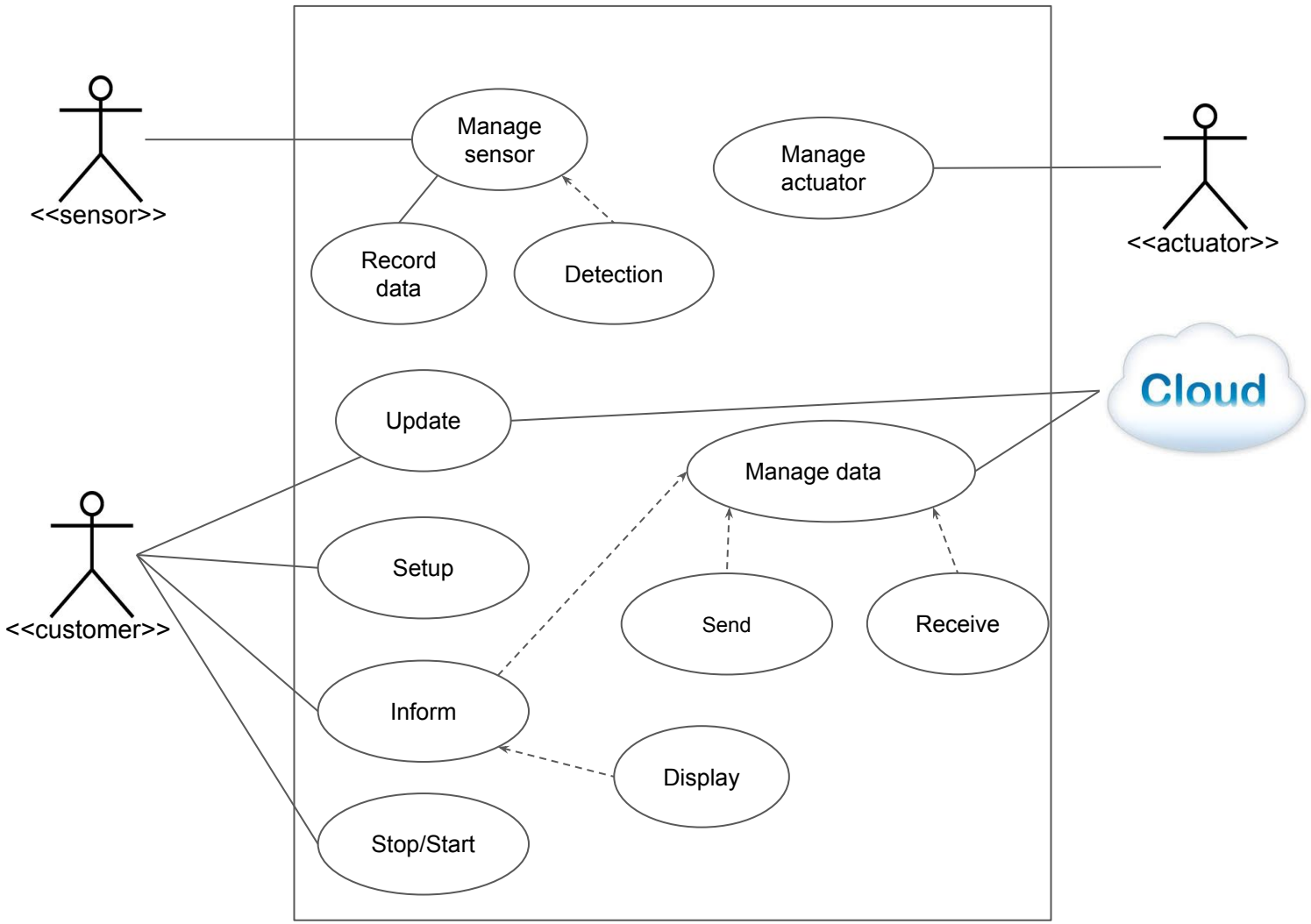
Modification fonctionnel UC



Une modification fonctionnelle implique ici un capteur IR + une alarme. Il faut prévoir deux interfaces supplémentaires, les traitements associés … il faut réaliser une fusion des modèles (éventuellement à partir d'une banque de modèle) ...

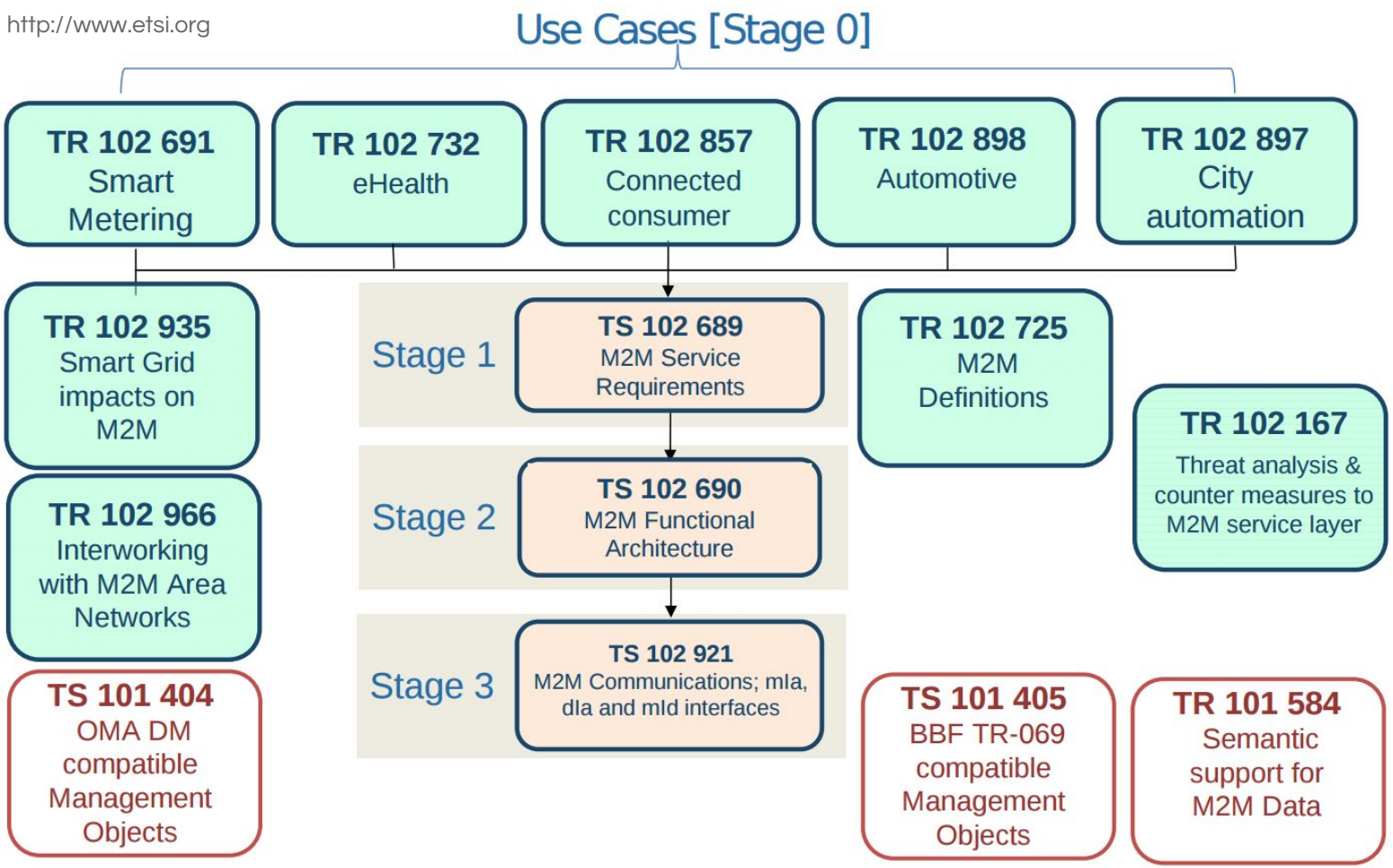
IoT

Use Case


<<sensor>>
Manage sensor
Record data
Detection
Manage actuator
<<actuator>>
Cloud
Update
Manage data
<<customer>>
Setup
Send
Receive
Inform
Display
Stop/Start

IoT

Use Case


http://www.etsi.org
Use Cases [Stage 0]
TR 102 691 Smart Metering
TR 102 732 eHealth
TR 102 857 Connected consumer
TR 102 898 Automotive
TR 102 897 City automation
TR 102 935 Smart Grid impacts on M2M
TR 102 966 Interworking with M2M Area Networks
TS 101 404 OMA DM compatible Management Objects
Stage 1
TS 102 689 M2M Service Requirements
Stage 2
TS 102 690 M2M Functional Architecture
Stage 3
TS 102 921 M2M Communications; mIa, dIa and mId interfaces
TR 102 725 M2M Definitions
TR 102 167 Threat analysis & counter measures to M2M service layer
TS 101 405 BBF TR-069 compatible Management Objects
TR 101 584 Semantic support for M2M Data

Les uses case complexes:

- Utilisation du cloud,
- Fusion de modèle (Use case …),
- Définition de Use Case en fonction du hub numérique (plateforme IoT),
- Intelligence artificielle (capacité à raisonner …),
- Ontologie (description du système),

Les uses case complexes:

- Machine learning, auto apprentissage (deep learning),
- Autonomic (self-Configuration, self-Healing …)
- Gestion des écosystèmes urbains et non urbains,
- Gestion des systèmes de systèmes (SoS) …

- Many use case are listed:
  - Health,
  - Transportation,
  - Energy management,
  - Security …

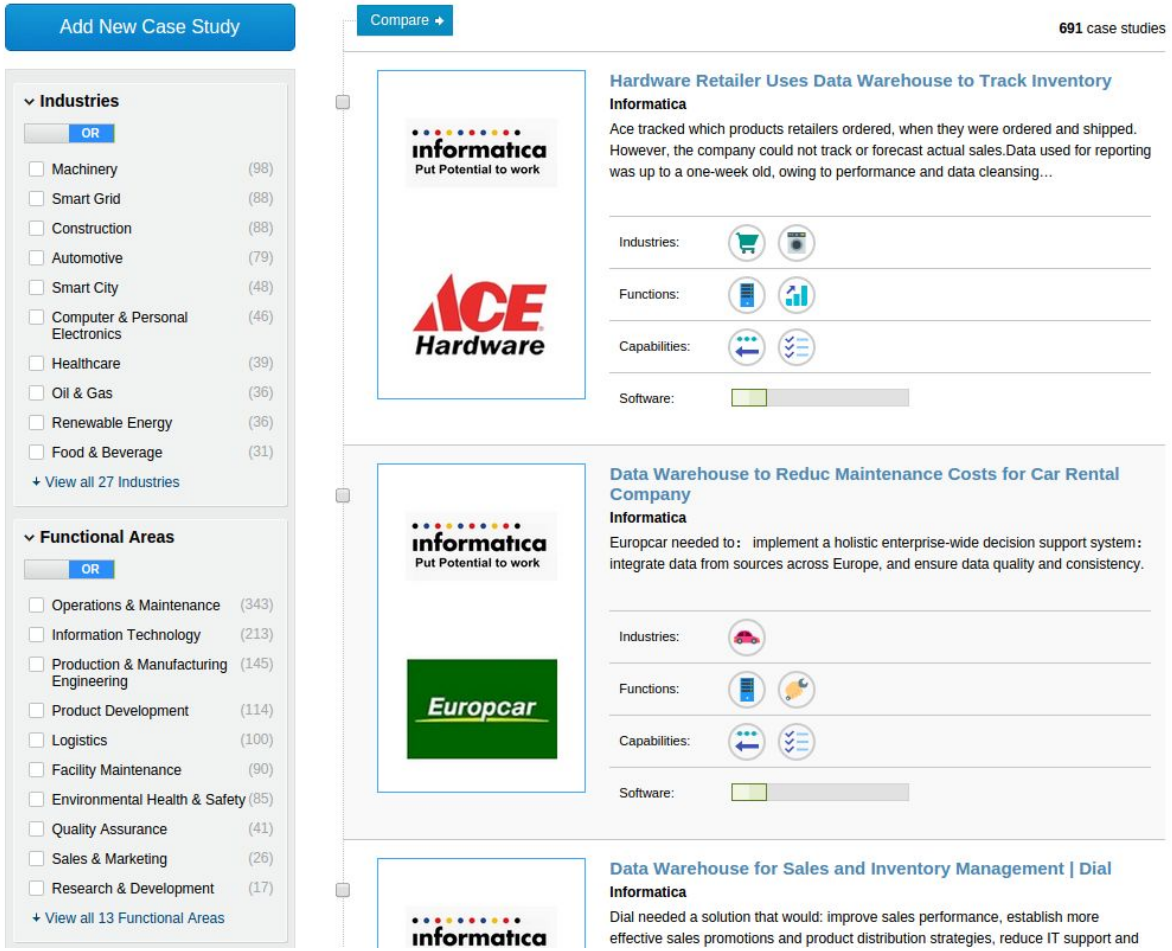
- These use cases are described very precisely
  - Actor,
  - Sensor,
  - Architecture (software, hardware),
  - Limits …

- These Use Case can be purchased …

IoT

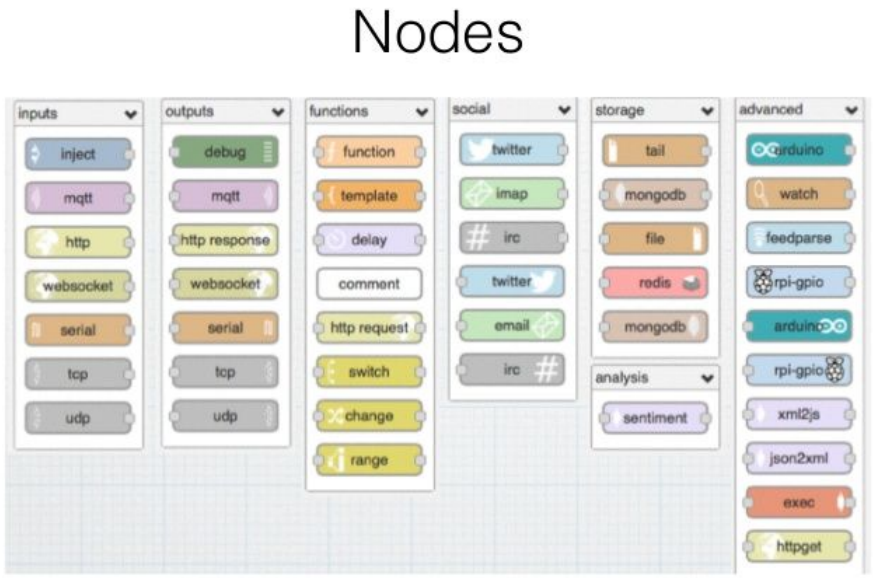
IoT Use Case - Use Case bank

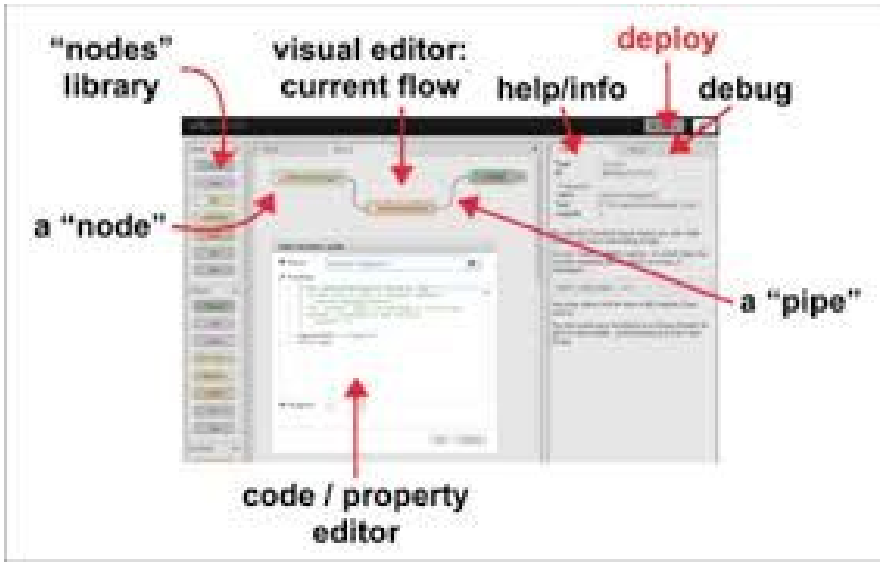
http://www.iotone.com/usecases



https://nodered.org

- “visual tool for wiring the Internet of Things”





Part III

Concept of IoT data model

Use case and automatic generation

Developing an IoT

Developing an IoT

New Concept ?

Nouvelle approche (?):

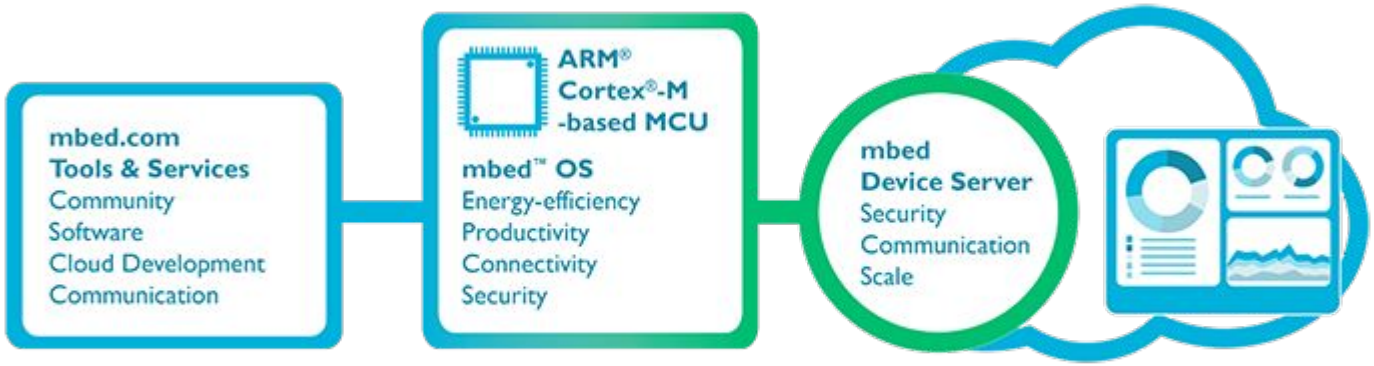
- IoT très basse consommation,
- Sans OS ou micro OS, RT OS,
- Intégration d'une/plusieurs architectures d'intégration,
- Niveau de sécurité élevé,
- Comportement générique du système,
- OS clé en main ...

Developing an IoT

New Concept ?

OS spécialisé “clé en main”

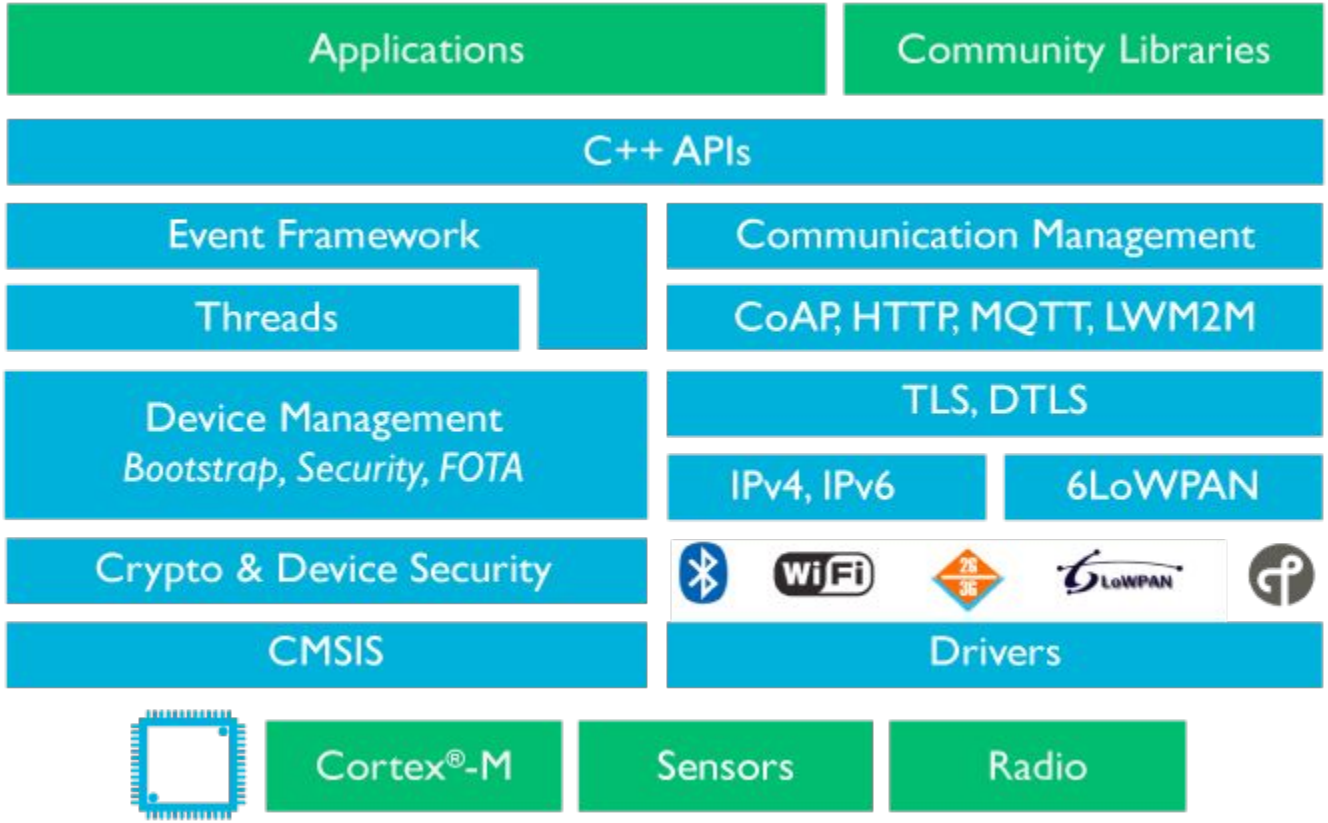
- mbed IoT
  - compilateur en ligne,
  - grand choix de carte, composant …
  - mini OS, très léger ...



Developing an IoT

New Concept ?

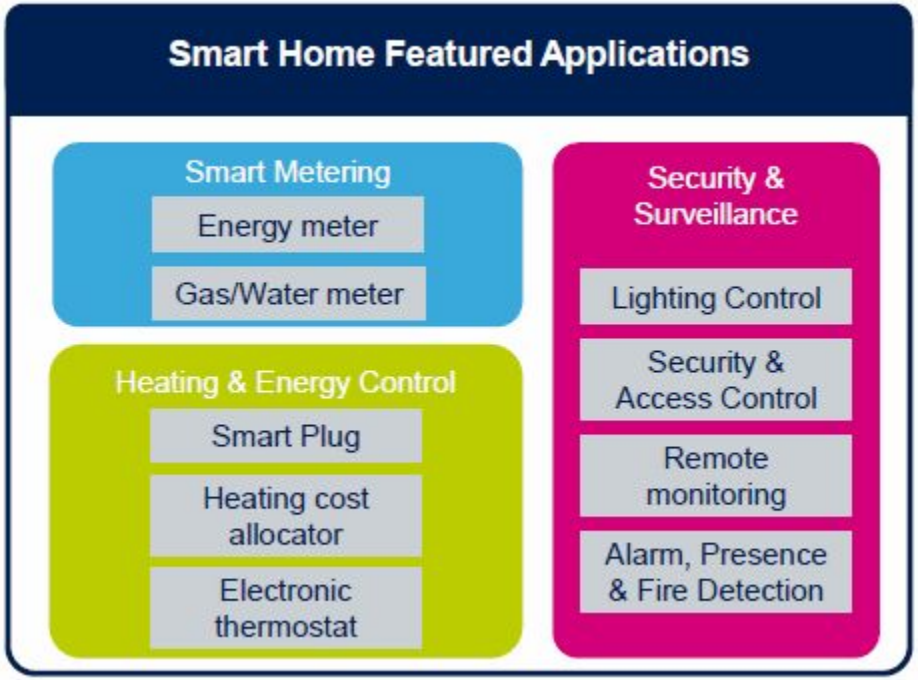
mbed ⇒ OS spécialisé “clé en main” + API



Developing an IoT

New Concept ?

Featured applications



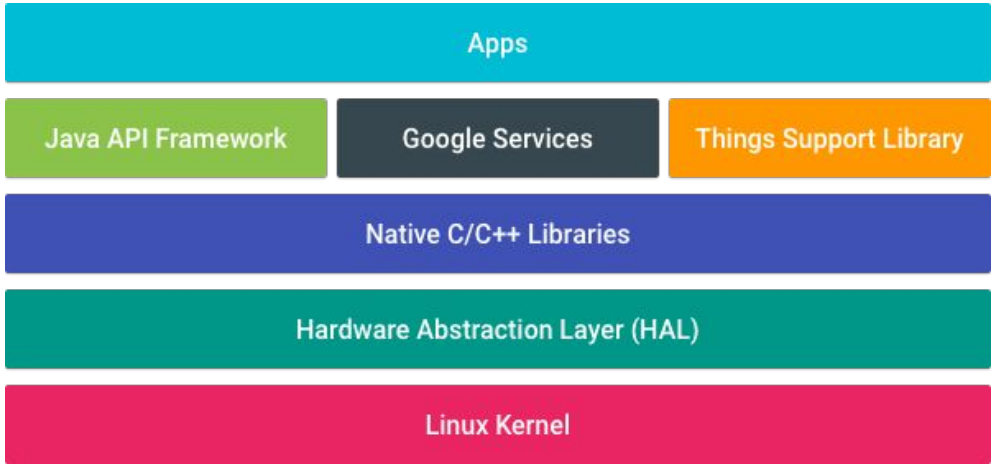
Developing an IoT

New Concept ?

https://developer.android.com/things/index.html
https://developer.android.com/things/hardware/index.html

androidthings

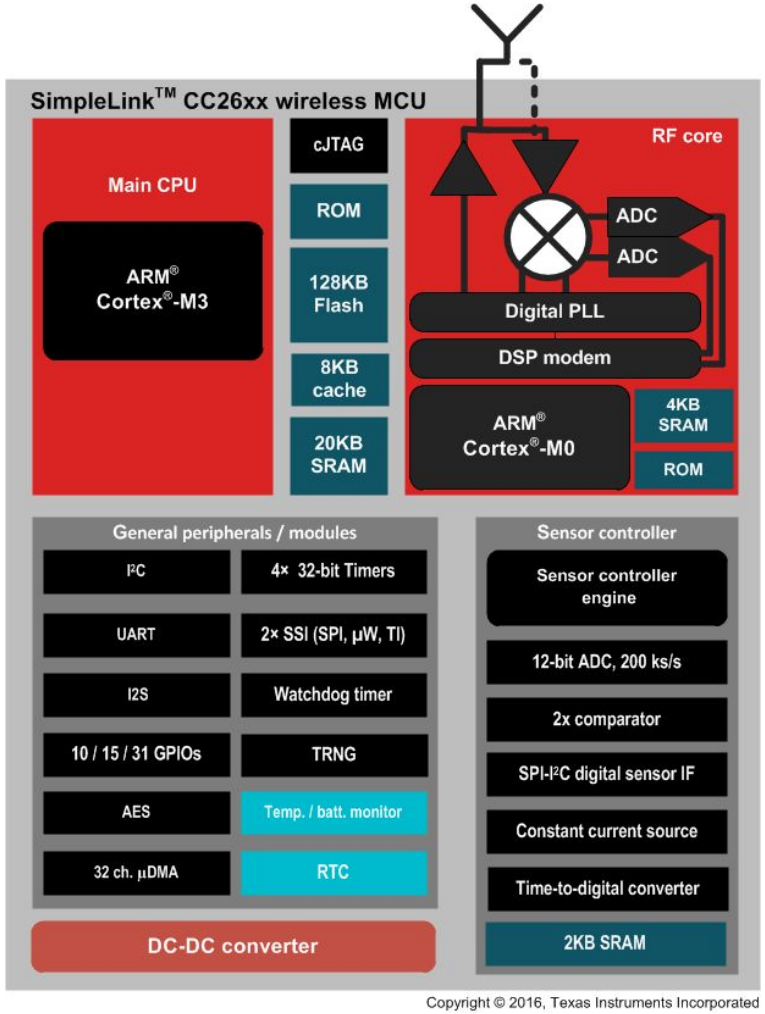
- Android Things (formerly known as Brillo),
- Android and certified hardware,
- Android APIs, Google services, and Android developer tools,
- Google BSP: The Board Support Package (BSP) is managed by Google ...



Developing an IoT

New Concept ? - Module multi-standard

http://www.ti.com/lsds/ti/wireless-connectivity/multi-standard/products.page



Éléments clés pour le développement IOT

Quels sont les comportements et besoins des utilisateurs ?

Où sont les manques des solutions existantes ?

Quels sont les potentiels technologiques à exploiter ?

Quels sont les standards à utiliser ?

Comment rendre une solution innovante simple à mettre en œuvre et à utiliser ?

Éléments clés pour le développement IOT

Comment utiliser un maximum de capteur, de système de réseau ?

Quelle valeur ajoutée propose le produit (action cognitive et impact sur l'humain) ?

Quelle interaction cognitive (type de valeur ajoutée) ?

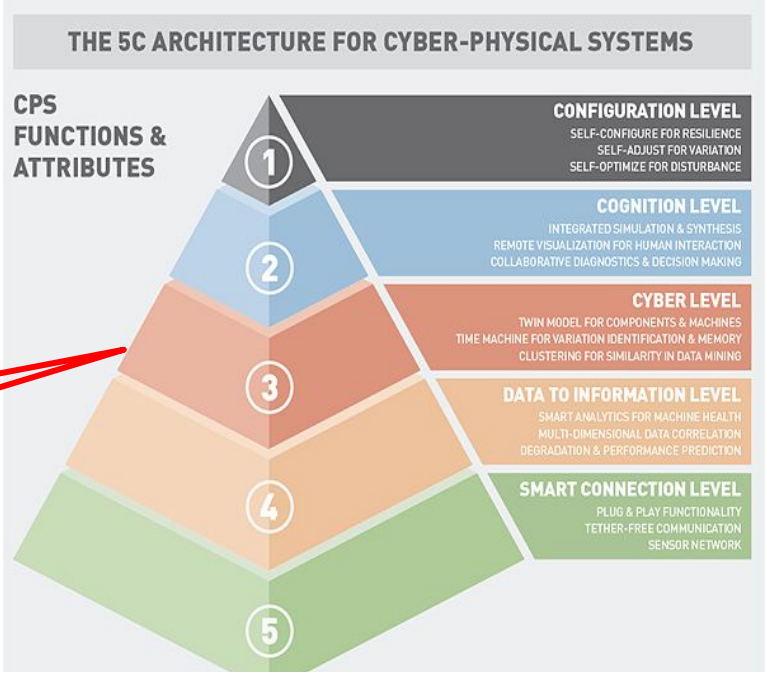
Quel est l'écosystème du produit ?

Puissance de la plateforme qui analyse les données (lien producteur < == > consommateur via une plateforme) ?

System Architecture

Global architecture - Cyber-Physical Systems

http://www.designworldonline.com/big-future-for-cyber-physical-manufacturing-systems/
https://en.wikipedia.org/wiki/Internet_of_things



Niveau de la création de la valeur ajoutée

System Architecture

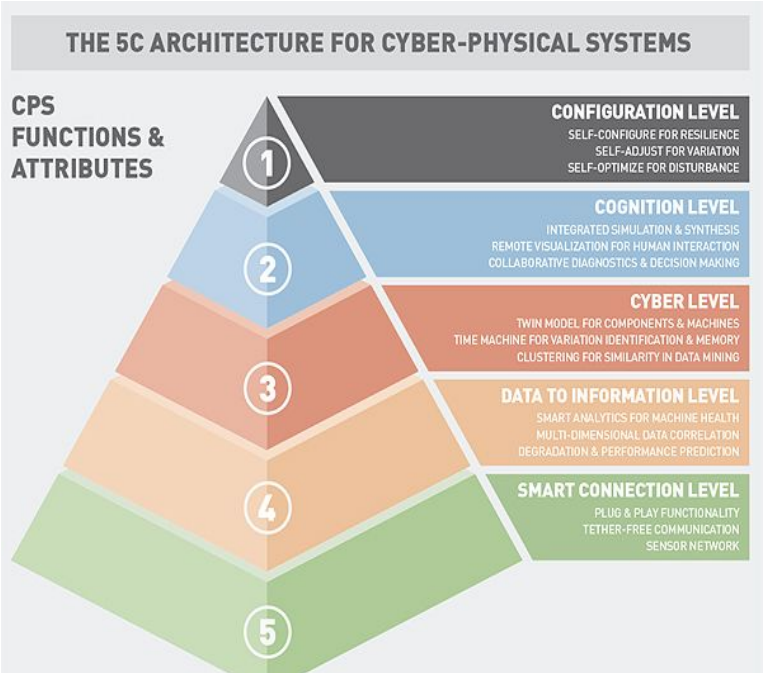
Global architecture - Cyber-Physical Systems

https://en.wikipedia.org/wiki/Minimum_viable_product

Analyse en sens inverse pour trouver la véritable valeur ajoutée du produit MVP (Minimal Viable Product). On définit la cognition utile puis on trouve le produit associé !

Ici on oublie l'approche "capteur" …

L'industrie du digital (GAFA) permet de donner de l'intelligence aux objets !



Developing an IoT

Pattern Development

Développeurs

Qui construit le système: ingénieur, designer, client ?

Qui réalise la veille technologique ? Quels sont vos axes stratégiques ?

Clients

Qui achètent la solution, et qui l'utilisent ?

Produit, service, cycle de vie ?

Est ce que la solution est un produit et/ou un service ? Est-ce que le cycle est long, court ?

Rythme

Savoir le concevoir, prototyper et fabriquer rapidement !

Savoir développer du logiciel et maîtriser une chaîne de valeur (du capteur au cloud)

A éviter pour le développement IoT

- Mono-usage,
- Mono-fonction,
- Mono-logiciel,
- Mono-support (utiliser le smartphone et le Web …)
- Technologie complètement banalisée,
- Aucune mise à jour,
- Système vertical,
- Manque de sécurité, trop de sécurité,
- Peu de visibilité sur les données (production et traitement) …
- Système sans diagnostique …

Références

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