From M2M to Virtual Continuum

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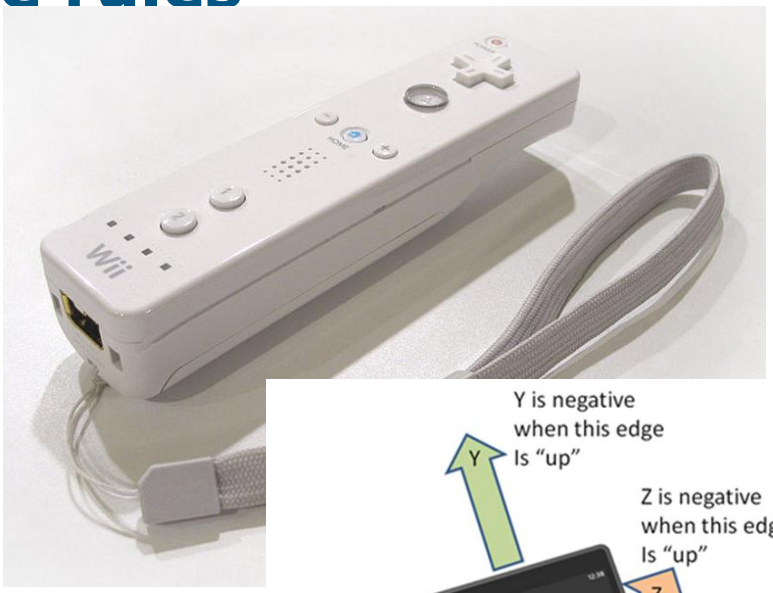
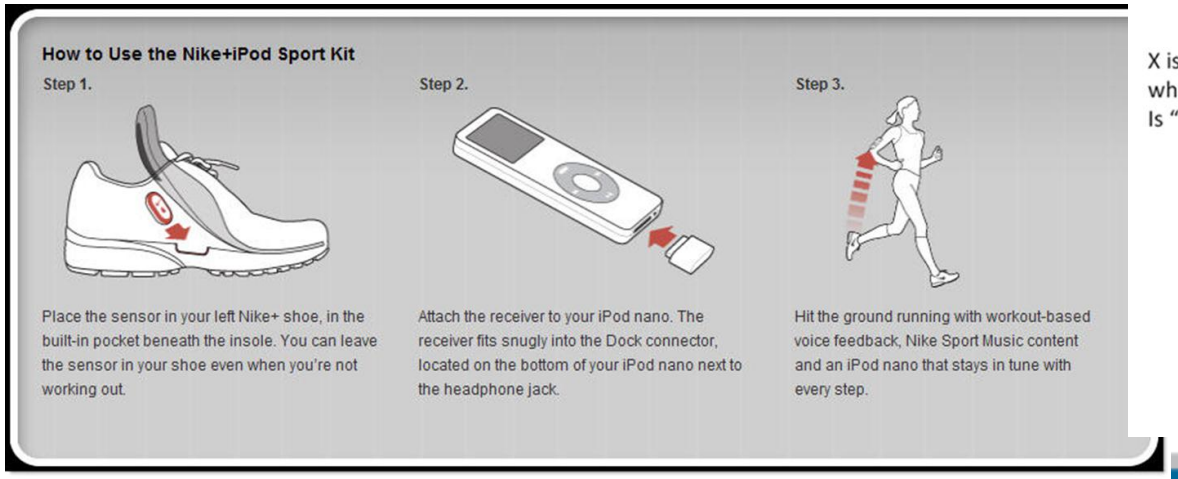
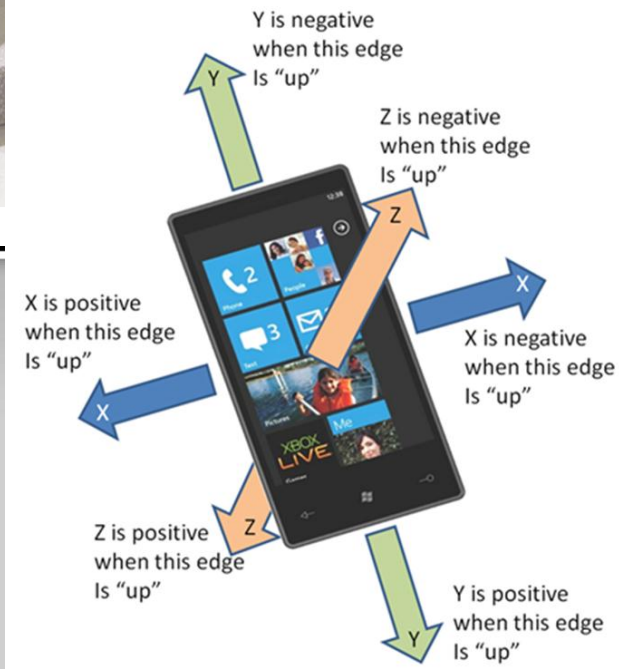
IEEE Internet of Things

PUT A SENSOR IN IT – How Sensors can change the game rules







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Agenda

- Simple definition(s) of Internet of Things
- IoT Challenges
- A Path towards the Virtual Continuum

A Definition of IoT

A set of documents to soon appear in iot.ieee.org

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What is Internet of Things ?

Internet of Things is a Buzzy phrase

It has to be interpreted according to the needs and assets of the proponents

- "Machine-to-Machine (M2M) communications is the communication between two or more entities that do not necessarily need any direct human intervention. M2M services intend to automate decision and communication processes." - ETSI oneM2M
- IoT as "A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies" – ITU
- "Internet of things" as: "A network of items—each embedded with sensors—which are connected to the Internet." IEEE Institute. March 2014
- "The basic idea is that IoT will connect objects around us (electronic, electrical, non-electrical) to provide seamless communication and contextual services provided by them. Development of RFID tags, sensors, actuators, mobile phones make it possible to materialize IoT which interact and co-operate each other to make the service better and accessible anytime, from anywhere." – IETF
- "Cyber-physical systems (CPS) – sometimes referred to as the Internet of Things (IoT) – involves connecting smart devices and systems in diverse sectors like transportation, energy, manufacturing and healthcare in fundamentally new ways. Smart Cities/Communities are increasingly adopting CPS/IoT technologies to enhance the efficiency and sustainability of their operation and improve the quality of life." – NIST
- "A global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object-identification, sensor and connection capability as the basis for the development of independent cooperative services and applications. These will be characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability." - CASAGRAS

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These definitions and many more are available in the Document " What Internet of Things is" to be released by the IEEE IoT Initiative

IoT Definition

A few features of IoT (that we are stressing out in IoT Initiative)

- The Internet of Things (IoT) envisions a self-configuring and adaptive complex system made out of networks of sensors and smart objects whose purpose is to interconnect “all” things, including every day and industrial objects in such a way to make them intelligent, programmable and more capable of interacting with humans.

- Smart Objects and Sensors
- Network of Things
- Self-organizing systems

- Intelligence at the edge
- Massive Data
- New communication paradigms
- Servitization
- Virtual Continuum

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(the many) IoT Challenges

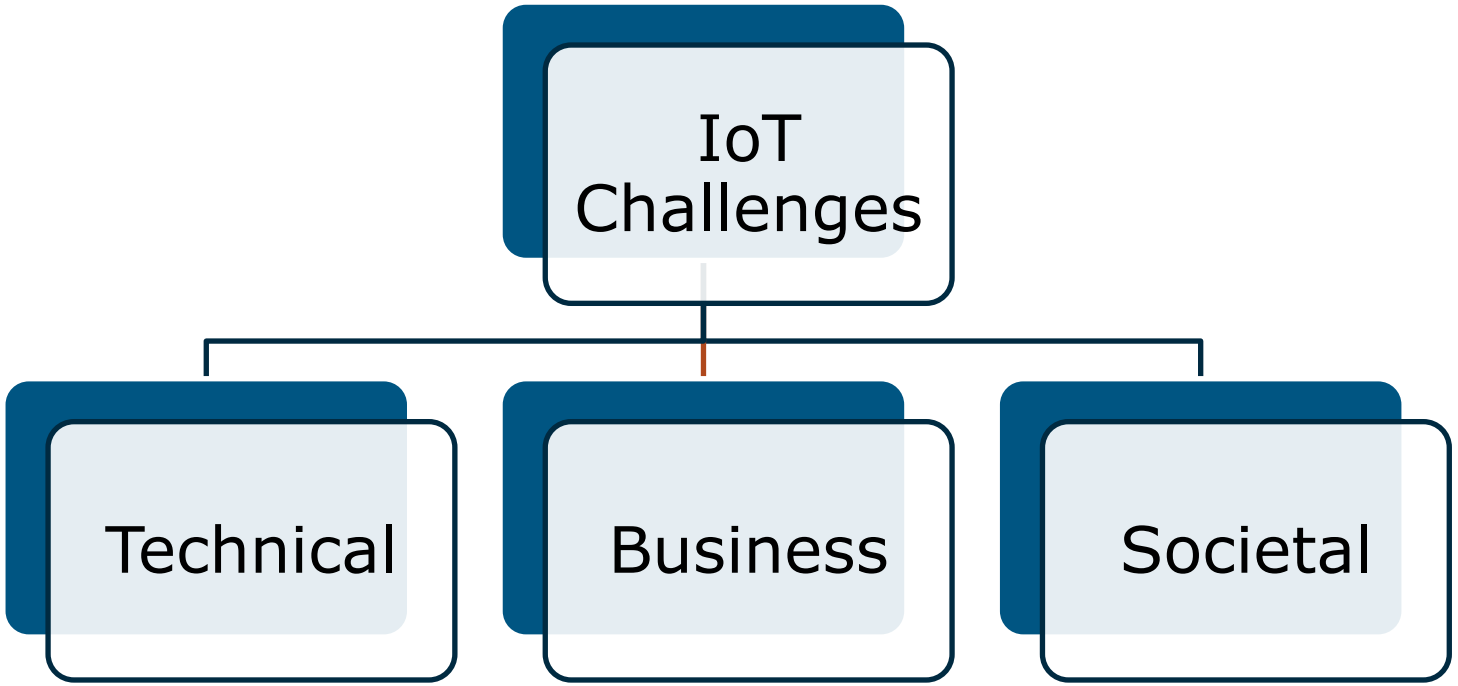
IoT Challenges (1)

Also the Challenges are pretty related to assets and specific views

- 5 Challenges The IoT Presents To Manufacturers – Forbes
  - http://www.forbes.com/sites/ptc/2014/09/10/5-challenges-the-iot-presents-to-manufacturers/
- IoT Challenges - Rob van Kranenburg and Alex Bassi
  - http://www.muxjournal.com/content/1/1/9
- Five challenges for the Internet of Things (IoT) - Rolph Haspers
  - http://blog.leaseweb.com/2014/07/17/five-challenges-internet-things-iot/
- IoT Challenges – Texas Instruments
  - http://www.ti.com/ww/en/internet_of_things/challenges.html
- Opportunities: Back To The Future – IoT & Smart Systems Evolution Challenges – Harbor Research
  - http://harborresearch.com/iot-evolution-challenges/
- 5 Challenges of Internet of Things Connectivity – PubNub
  - http://www.pubnub.com/blog/5-challenges-of-internet-of-things-connectivity/

IoT Challenges (2)

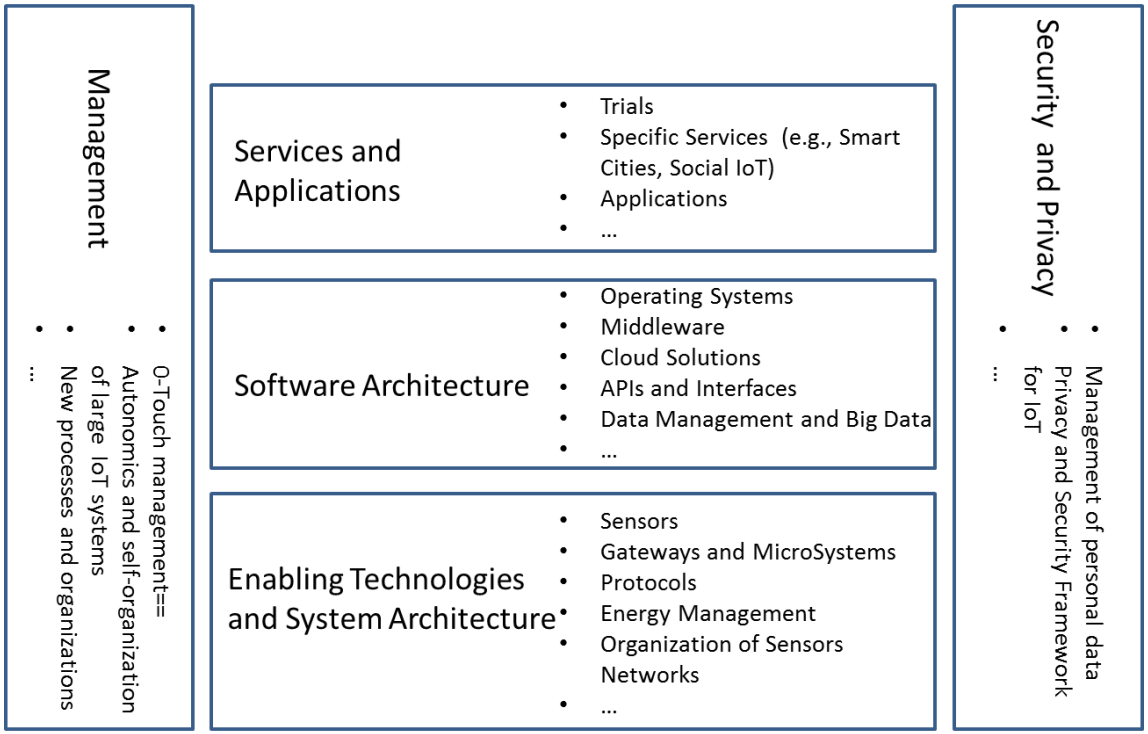
Trying to frame the challenges in macro categories



Technical Challenges

(Some) Technical Challenges

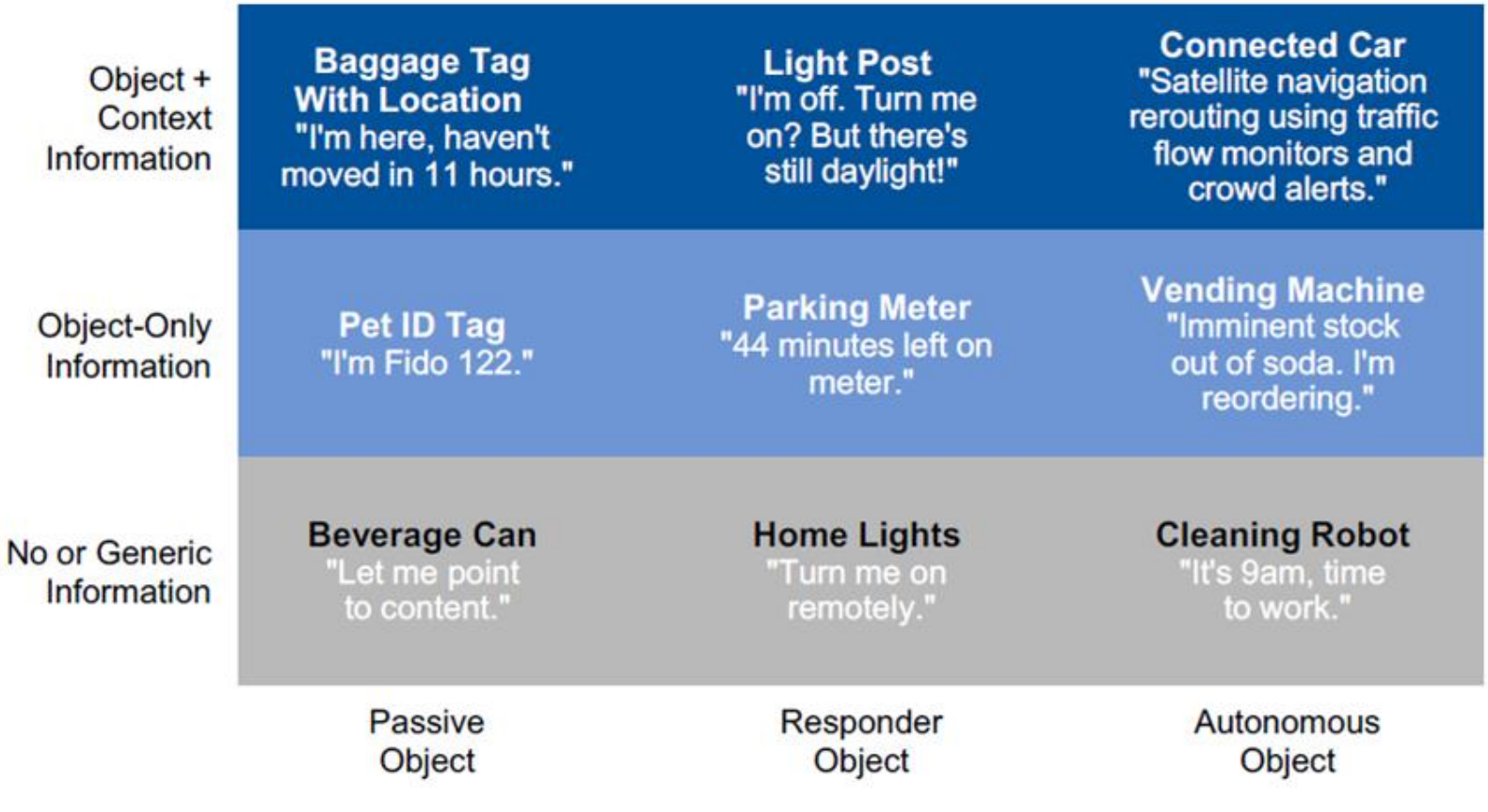
Trying to identify the major challenges within each category



- Platform
- Security
- Signaling and Protocols
- Data Management
- Cloud
- Large System Management (autonomics)
- Power Consumption
- Connectivity
- Programmability
- Complexity
- Standardization
- Virtualization
- Smart Objects
- Communication Paradigms (cooperation and gossiping)
- ...

What are Internet-Connected Things? Active/passive, with/without information

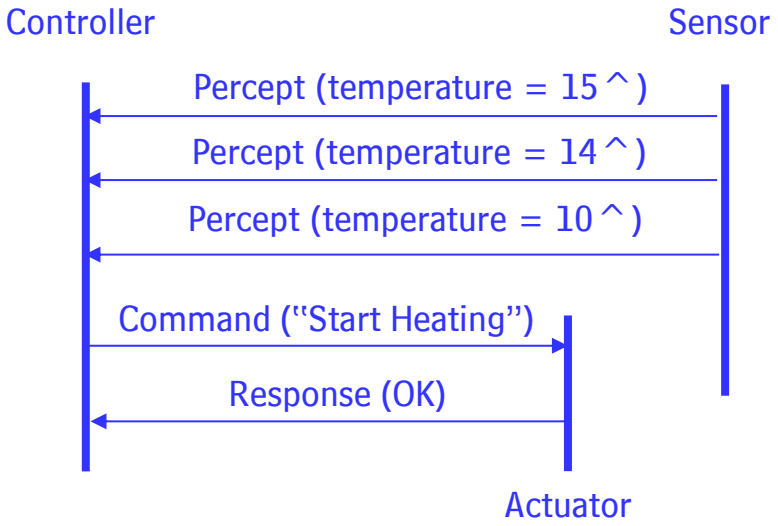
Objects bring information: some can be used stand-alone some just make data available to the outside world. Information can be contextualized, and objects can even act autonomously on that basis.



Interactions with sensors

Ideally:

- **Few Primitives**
  - **Percept**
  - **Command**
  - **Response**
  - **Exception**
  - **Property**
- **Simple Control: Events and Commands**
- **Simple Semantic**



Many protocols are currently used such as SensorML, COAP, MQTT, … each one adhering to a communication paradigm. Another Protocol Battle ?

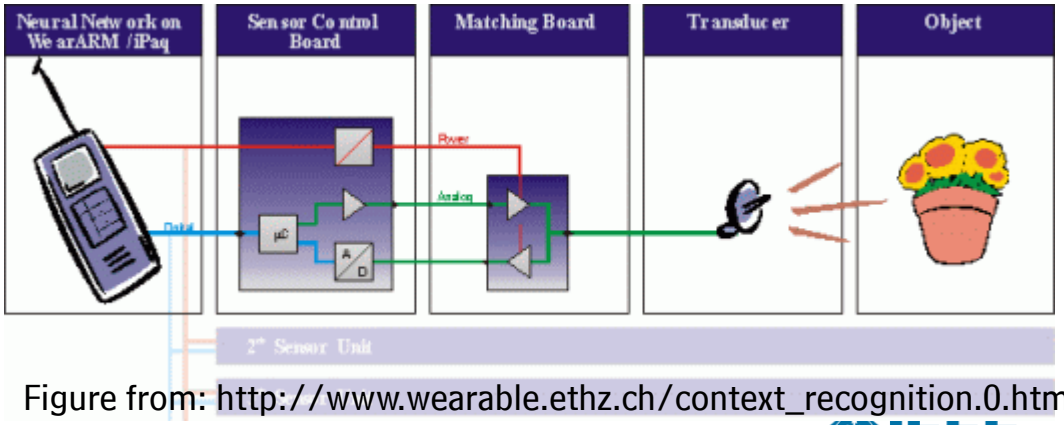


Figure from: http://www.wearable.ethz.ch/context_recognition.0.htm

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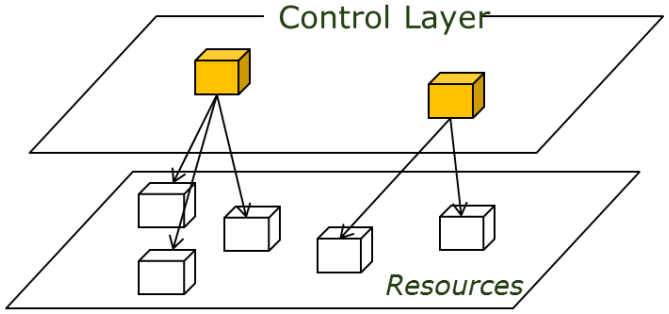
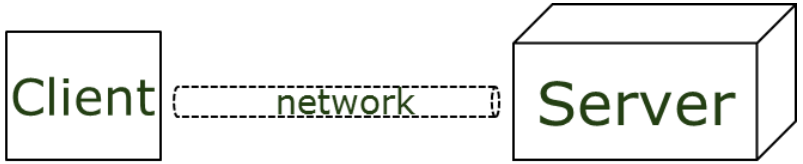
How Smart Objects will communicate



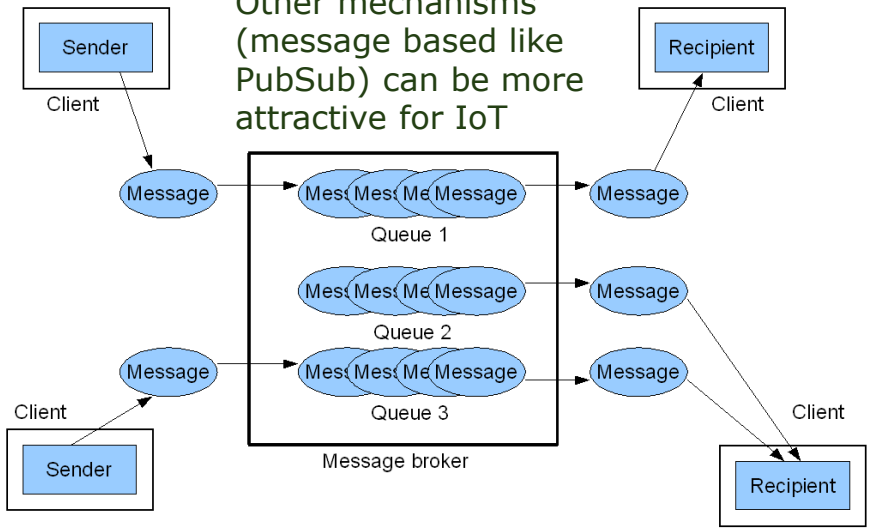
Physical Layer

Network Intelligence (e.g., IMS) is a hierarchical model based on the assumption that control has to be exerted by a few specialized control nodes



Client – Server model disregards the network aspects and can lead to a tragedy of commons (misuse of common networking resources)

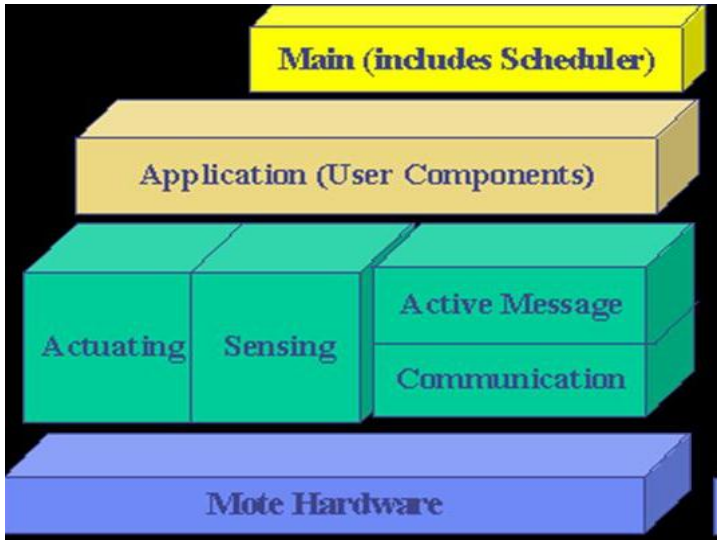
Other mechanisms (message based like PubSub) can be more attractive for IoT



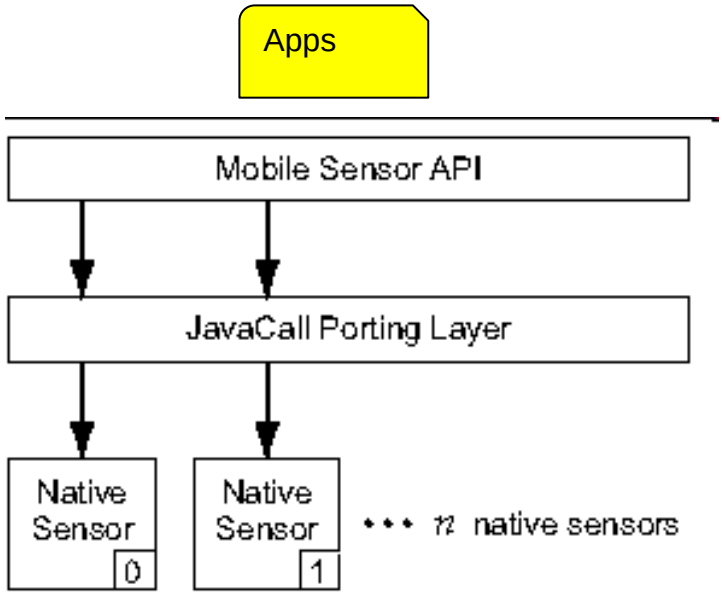
This is a reason for different IoT protocols COAP, MQTT-S …
Is it there a better communication paradigm for IoT ?

Software for Wireless Sensor Networks (What Middleware?)

A simplified TinyOS architecture



Sensor as a small computer ➔ it needs an Operating System
TinyOS is such a system providing for basic functions



Mobile Sensor API is an example of middleware for Wireless Sensor Networks

Obviously there are many OSes for IoT (e.g., Contiki, …)

http://www.cs.kookmin.ac.kr/project/project_2003/project2003_12/project2003_12.htm

http://java.sun.com/javame/reference/docs/sjwc-2.1/pdf-html/html/porting-users/MobileSensor256.html

What Network - Sensors and Capillary vs Telco network - General view

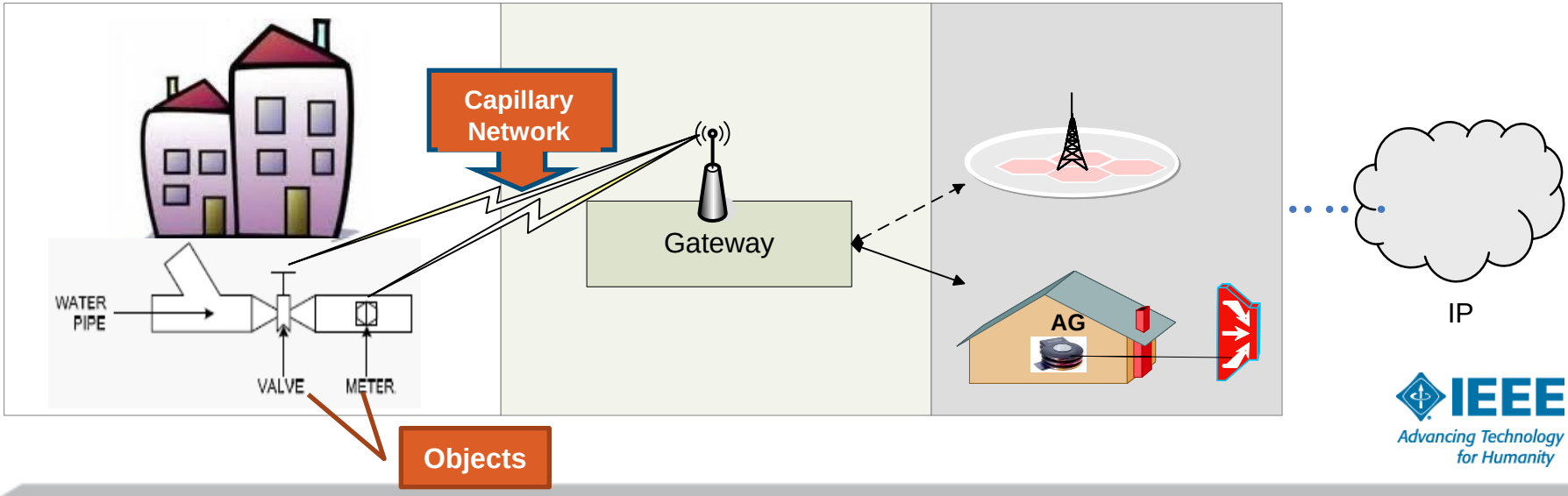
Capillary Network – connecting sensors & actuators to:

- "wired" (cable, xDSL, optical, etc.)
- wireless cellular (GSM, GPRS, EDGE, 3G, LTE-M, WiMAX, etc.)
- wireless "capillary"/short-range (WLAN, ZigBee, IEEE 802.15.4x, WMBUS, etc.)

Gateway – connecting access and backhaul/core networks:

- concentrating
- network address translation
- packet (de)fragmentation; etc.

IoT on Public Networks or on Lower Range/Capillary Networks ?



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Anything will be a node !

- Intel has unveiled a WiFi sliver of silicon that can be part of a normal microprocessor chip.
- As of today, WiFi chips were separate from the microprocessor because of specific needs of the radio part.
- This is the first time that someone (Intel) has come up with an industrial manufactured chip embedding radio on the chip.
- We can expect that wherever we find a microprocessor (e.g. in over 70% of toys, to name just one area) we will find embedded connectivity.

Roberto Saracco
http://www.blog.telecomfuturecentre.it/

Can we manage this communication, processing and storage challenge all in a single node ?

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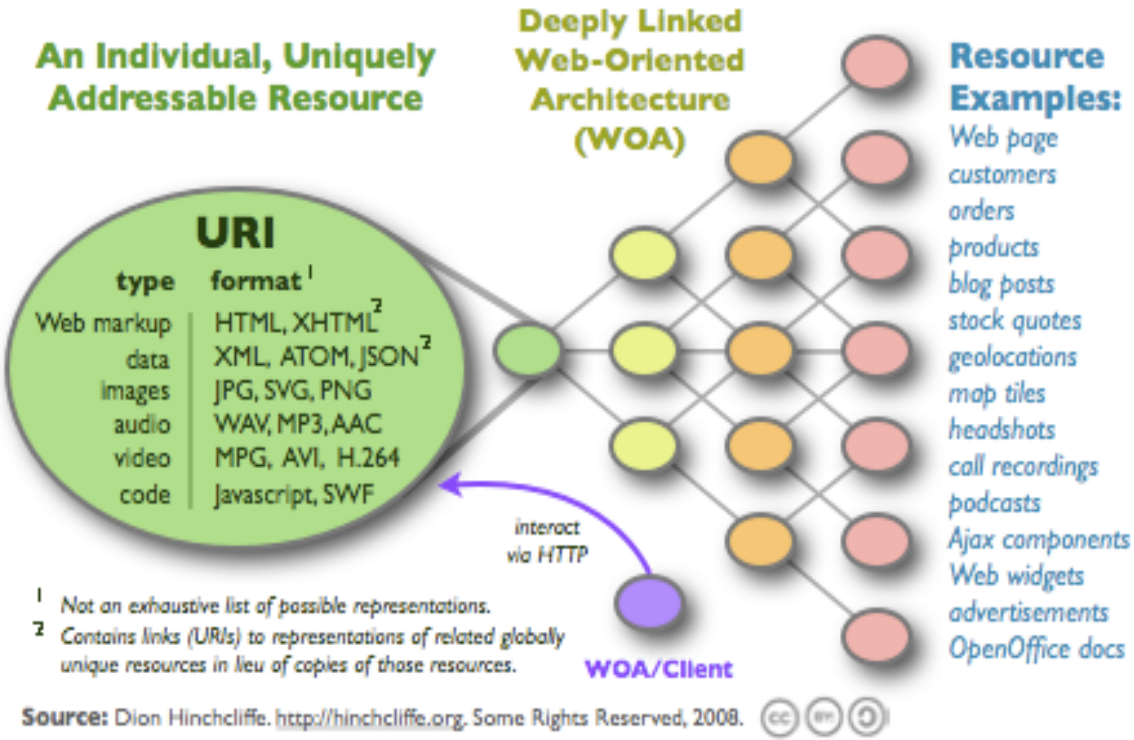
Identity of Things (1)



- Each Resource is addressable
- Each resource is CONNECTED
  - –Connectivity must be guaranteed in a variety of environments
- Each Resource can be associated to a User (Identity)

Identity of objects and their relationships with other objects and other identities (Humans)

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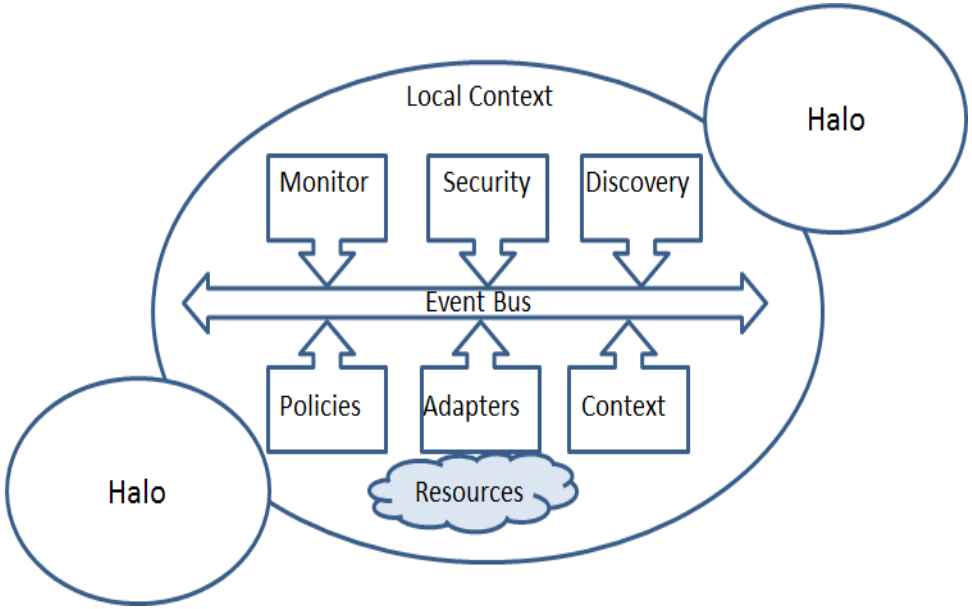
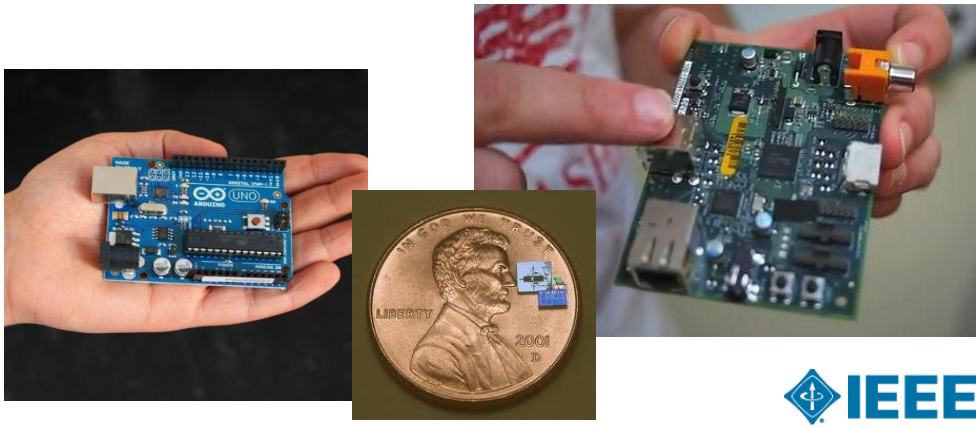
A self-organizing node

- A self-organizing node can be seen as a dynamic system whose states are time-evolving as events occur.
  - –It is sensitive to the context variations and capable of reacting to self-adapt dynamically
- It is like a "self-managed cell" with a set of features, e.g.,
  - –Discovery, Policies, Monitor, Security
- What is needed to build it ?
  - –a smart phone (as Wi-Fi Hot Spot)
  - –cheap, tiny PCs (e.g. Raspberry Pi)
  - –microcontrollers (e.g. Arduino)
  - –Sensors, actuators, etc.





The Self-organization within a node challenge …

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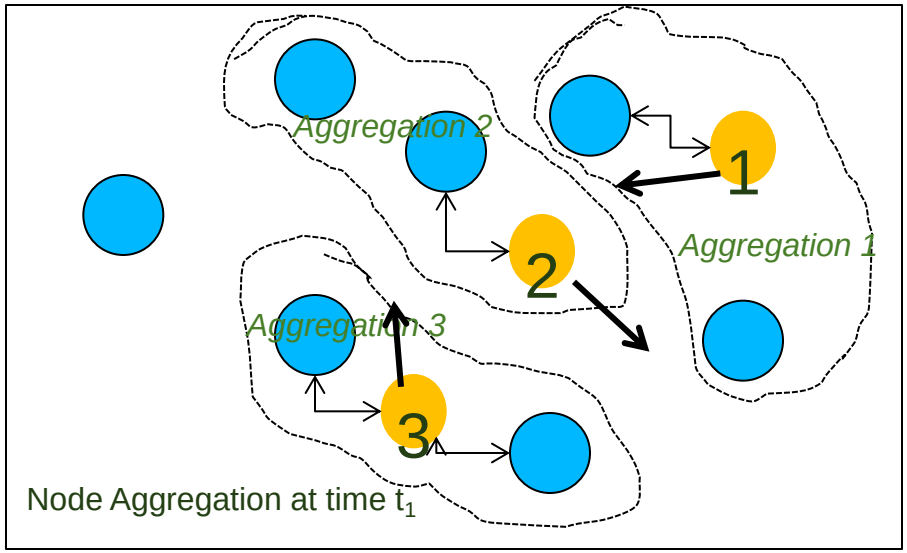
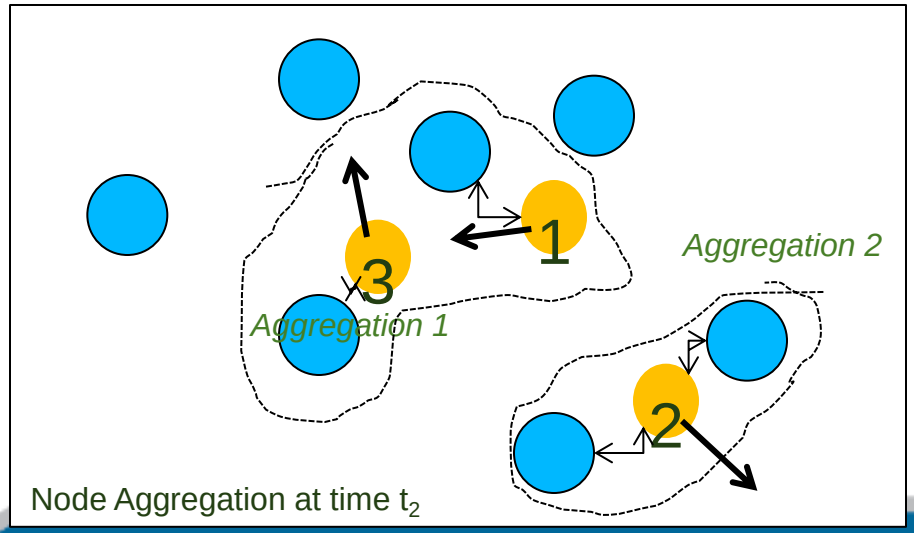
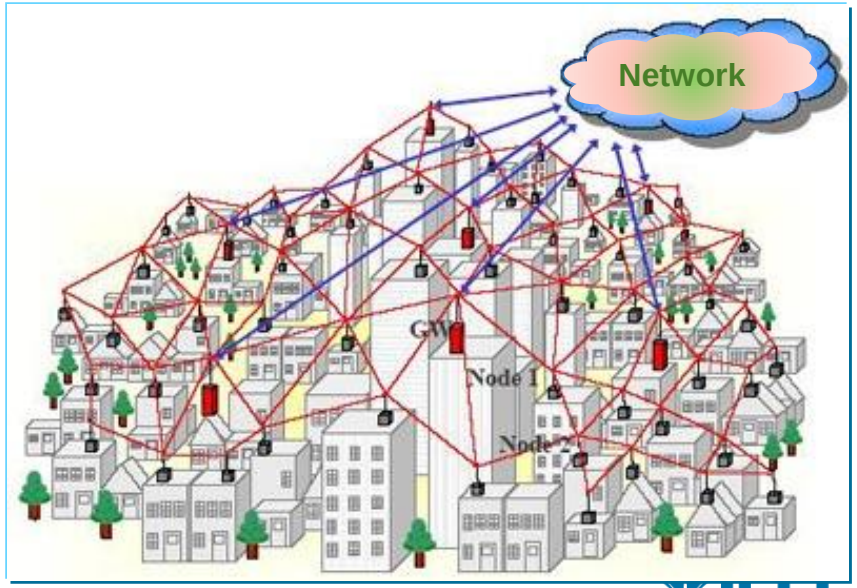
Nodes will connect each other in unpredictable ways



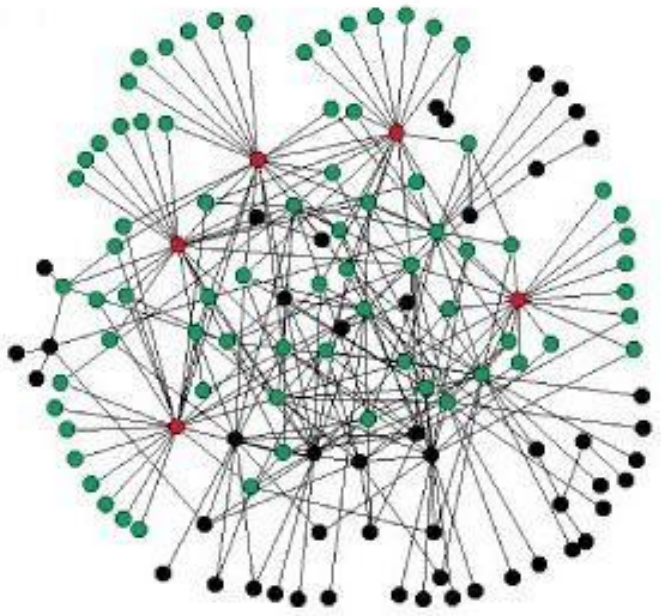


Increasing richness and complexity at the edge of networks



http://muxware.net/sol_mesh.php

Dealing with Complexity at the edge: Self-Organization of Networks



Scale-free

- Management of complex and dynamic "Networks of Networks" will be critical
- No human intervention possible
- Competition on resources

Requires

- Self-organization
- Game theory techniques for highly distributed systems

http://innovation.gsa.gov/blogs/OCIO.nsf/dx/Management-Innovators-Bookshelf-Small-Pieces-Loosely-Joined-A-Unified-Theory-of-the-Web-by-David-Weinberger-2002

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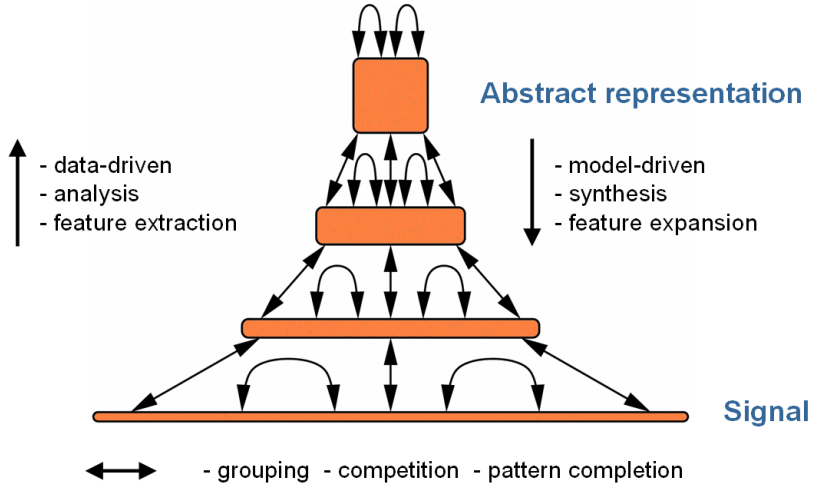
How much Data Mining from IoT ?



http://www.ais.uni-bonn.de/images/Neural_Abstraction_Pyramid.png

http://www.limsi.fr/~jps/enseignement/examsma/2004/BHATTI/index.htm

IoT is instrumental to build Smart Environments. They are smart because they can manipulate plenty of local data including personal data.
Who is the owner of these data ? Who onws the inferred information ?

The Data Management and the Data Ownership Challenges …

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Business Challenges

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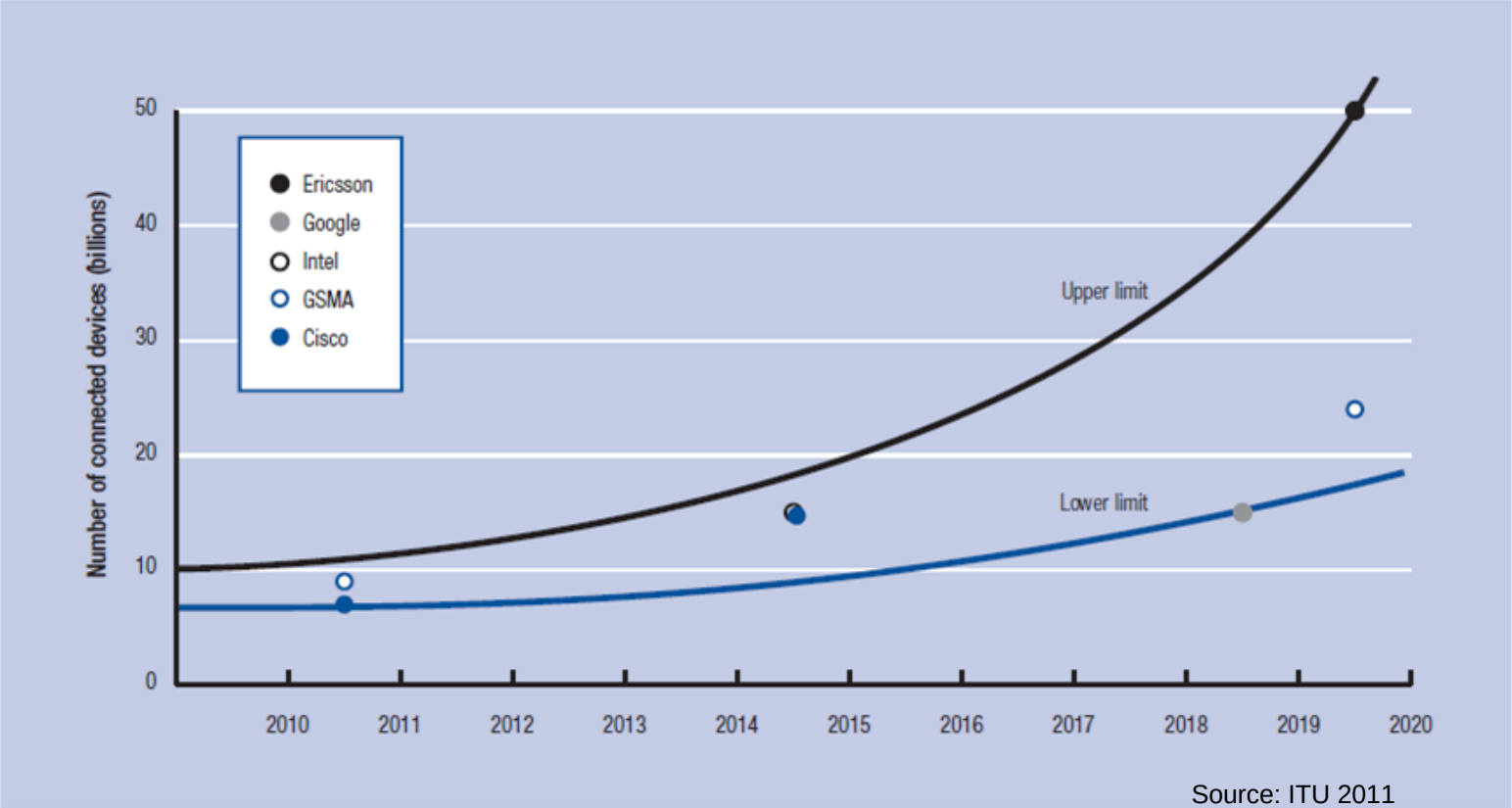
Connected Devices: WW forecast

According to HP, at the end of 2011 some 15 B devices were already connected to a communication network; most of them come from the Consumer Electronics world. Forecasts for the decade are different, but all follows fast growing curves



Source: ITU 2011

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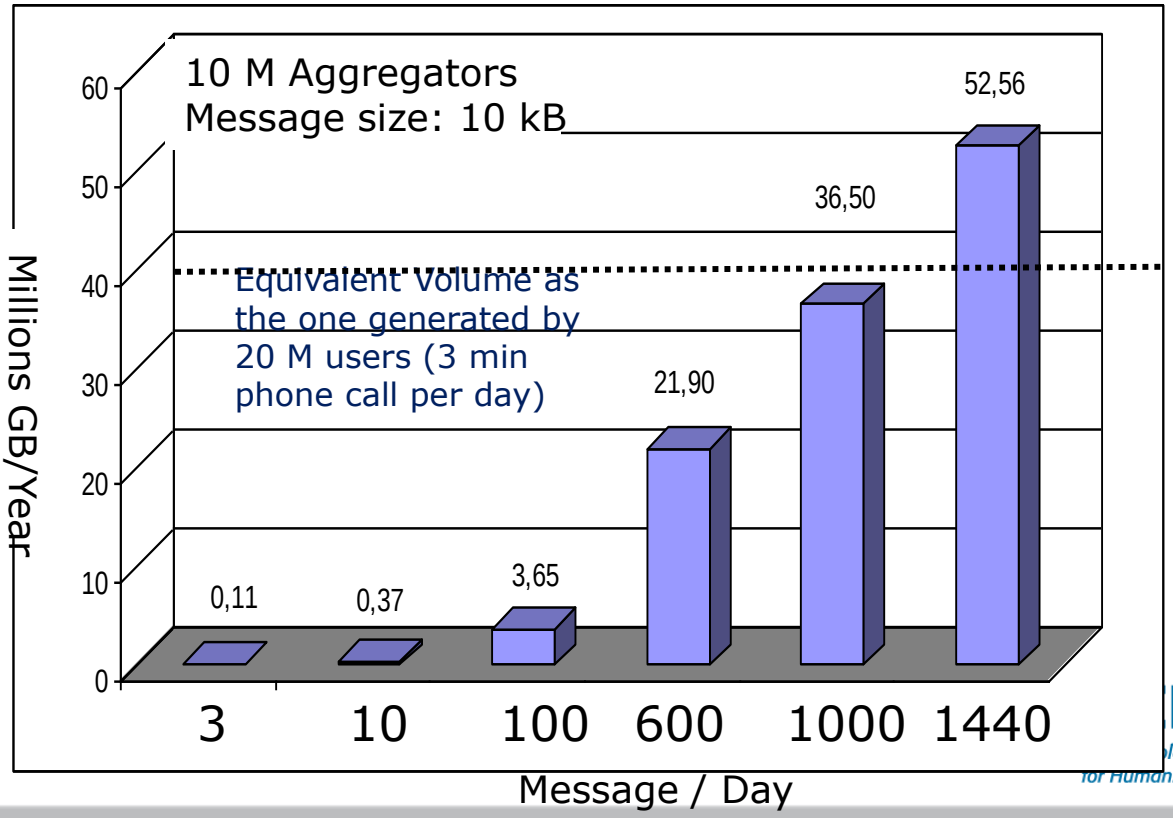
How Many Nodes, How Many Messages, How Much Bandwidth ?

The Bandwidth challenge …

Issue: low average traffic, but highly impulsive traffic (e.g., spikes of messages when containers ships enter in a harbor)

- Gateways/Aggregators will greatly reduce the number of messages forwarded on public networks
- Multimedia (video) will be the major cause for traffic
- Many objects/nodes will come with communications already paid for (i.e., embedded communications)
- Pure bit transport is not a big value for Operators



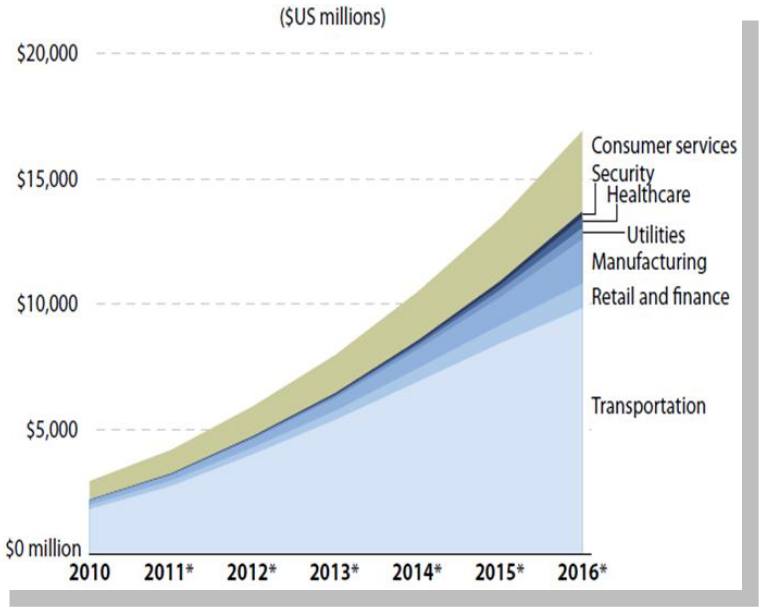
WW connectivity revenues in 2016

The Bandwidth Challenge …

Connectivity revenues are forecasted to be about 10-15% of total revenues

	2010	2011*	2012*	2013*	2014*	2015*	2016*	CAGR 2010 to 2016
Transportation	$1,810	$2,730	$4,010	$5,380	$6,900	$8,430	$9,830	33%
Retail and finance	$170	$220	$280	$360	$540	$730	$990	34%
Manufacturing	$170	$230	$340	$510	$760	$1,120	$1,760	48%
Utilities	$20	$30	$60	$100	$170	$280	$460	72%
Healthcare	$10	$10	$30	$50	$100	$210	$420	95%
Security	$20	$20	$40	$560	$90	$160	$250	60%
Consumer services	$740	$940	$1,200	$1,520	$1,950	$2,500	$3,220	28%
Total	**$2,930**	**$4,180**	**$5,940**	**$7,980**	**$10,500**	**$13,410**	**$16,910**	**34%**

WW connectivity revenues in Millio



Source:Forrester

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«Per devices» effect

The Revenue Challenge …

Average revenue per devices changes very much according to applicative area

Categories	Average monthly connectivity revenue per device
Transportation/fleet management	$3.00-$10.00
Retail and finance/ kiosk applications	$1.00-$6.00
Manufacturing/ asset management	$4.00-$7.00
Utilities/energy demand management	$0.50-$1.00
Healthcare/health monitoring	$5.00-$8.00
Security/video surveillance	$5.00-$11.00
Consumer services/ appliance control	$0.50-$2.00

Source: Forrester

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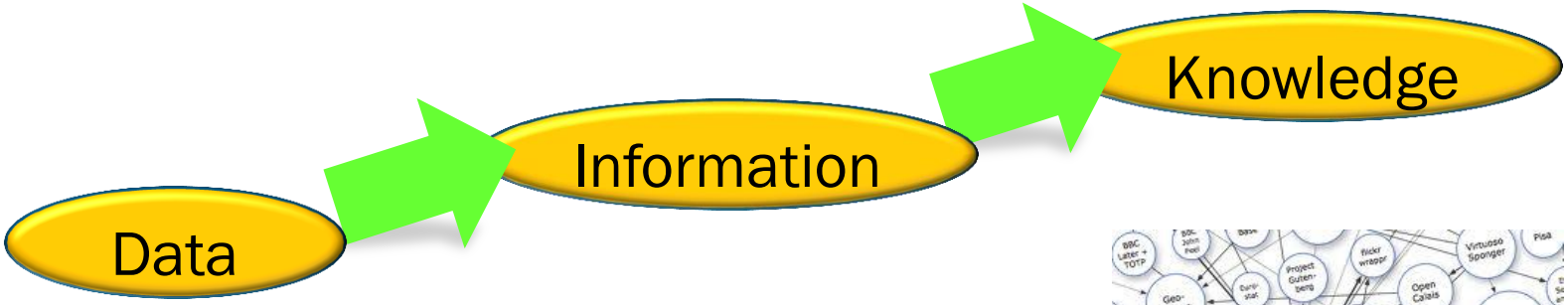
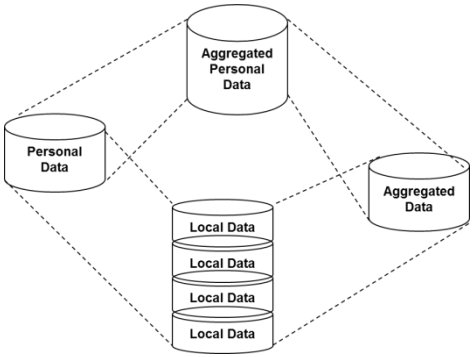
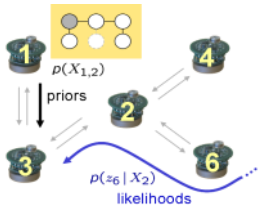
Where is the Value then ?

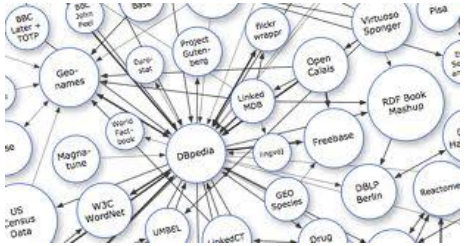




- **Aggregation**
- **Personalization**



- **Inference**



- **Relationships**

The Big Data Challenge …

IoT: Application Domains

The Vertical vs. Horizontal markets challenge …

Source: Beecham Research

Which Business Model For the Internet of Things?

- **Thesis 2: Sensor information should be made available on an open platform to allow everyone to offer higher level services**
- **Thesis 3: Intermediaries are needed as coordinating central structures on the IoT market**

The Biz Model Challenge …

- **Thesis 8: The value of the IoT market grows more than linearly with the number of consumers**
- **Thesis 9: Intermediaries should consider subsidizing micro providers to create an additional incentive for service provisioning and enable the intermediaries' business in the first place**
- **Thesis 14: Incentives will be needed to stimulate participation of a large number of (micro) providers**

Initial Observations on Economics, Pricing, and Penetration of the Internet of Things Market
Jens-Matthias Bohli, Christoph Sorge, and Dirk Westhoff
ACM SIGCOMM Computer Communication Review

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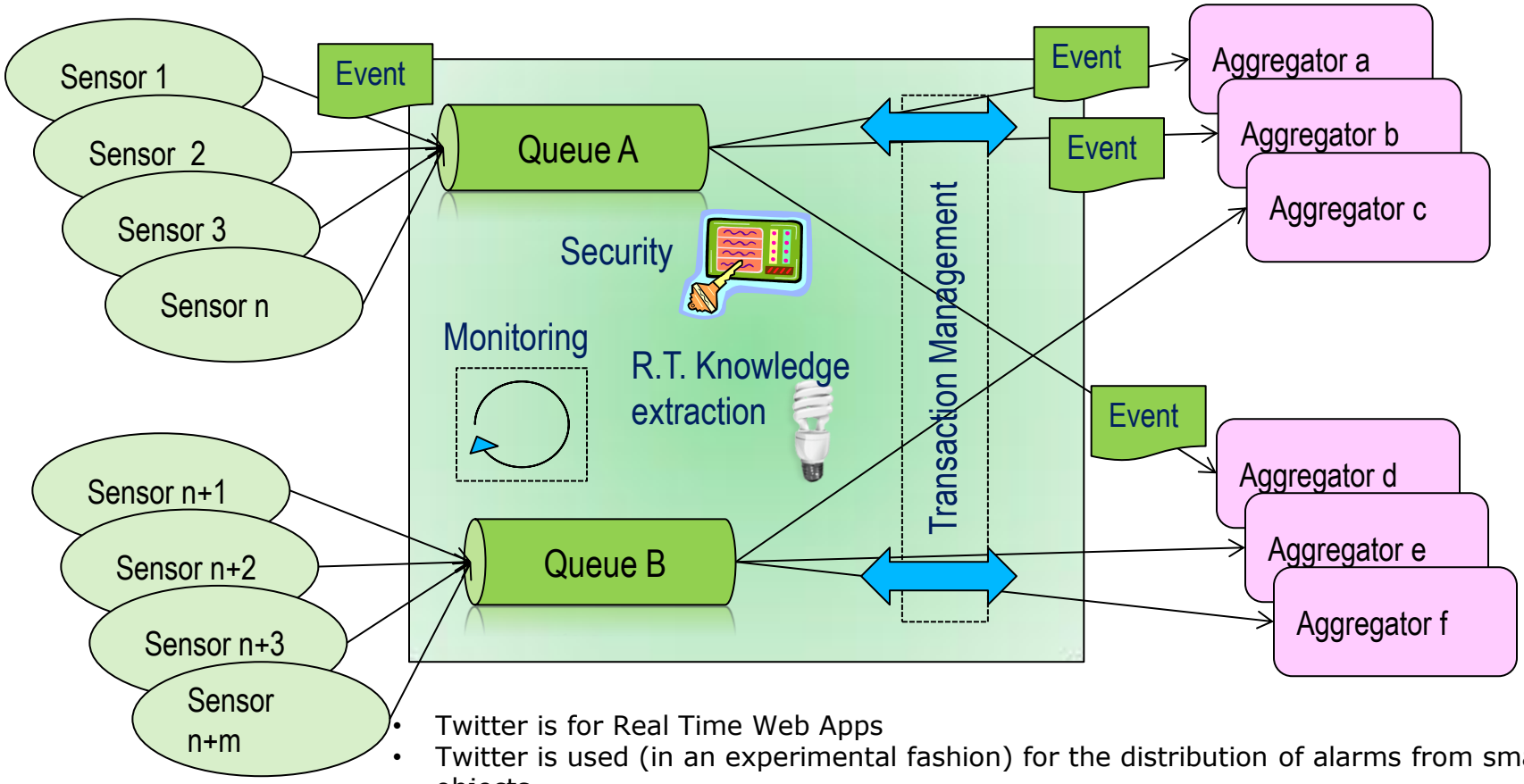
A Twitter of Things: a Transactional Complex Event Processing

The Data Valorization Challenge



- Twitter is for Real Time Web Apps
- Twitter is used (in an experimental fashion) for the distribution of alarms from smart objects
- The real time web (and in particular the PubSub models) could support new classes of services and enabling new platforms and providers:
- The twitter of things enables the Brokering role for info exchanged by smart objects

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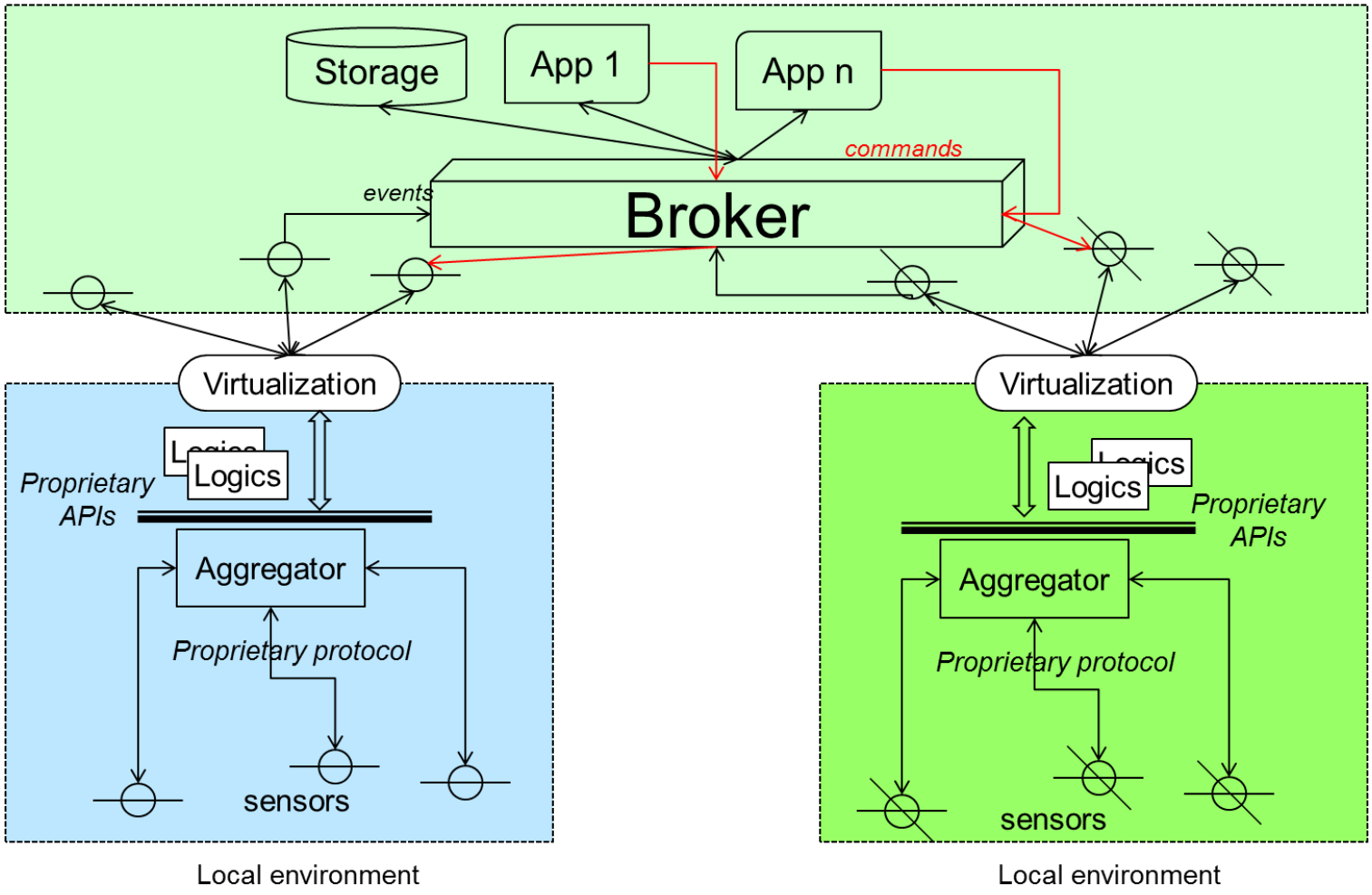
Application and Data Brokering

The Data Valorization Challenge



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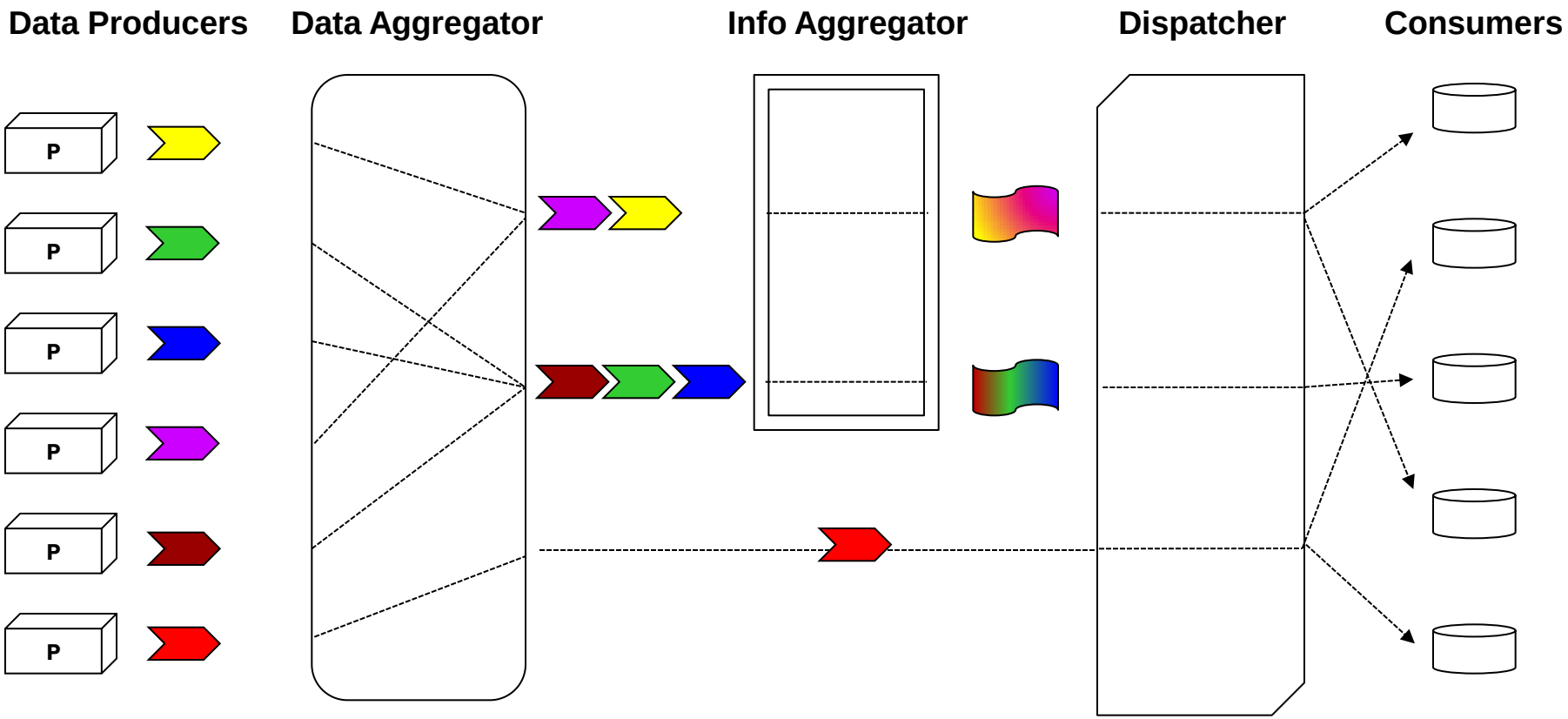
Different Roles for a Distributed Objects Ecosystem



The Value Chain Challenge

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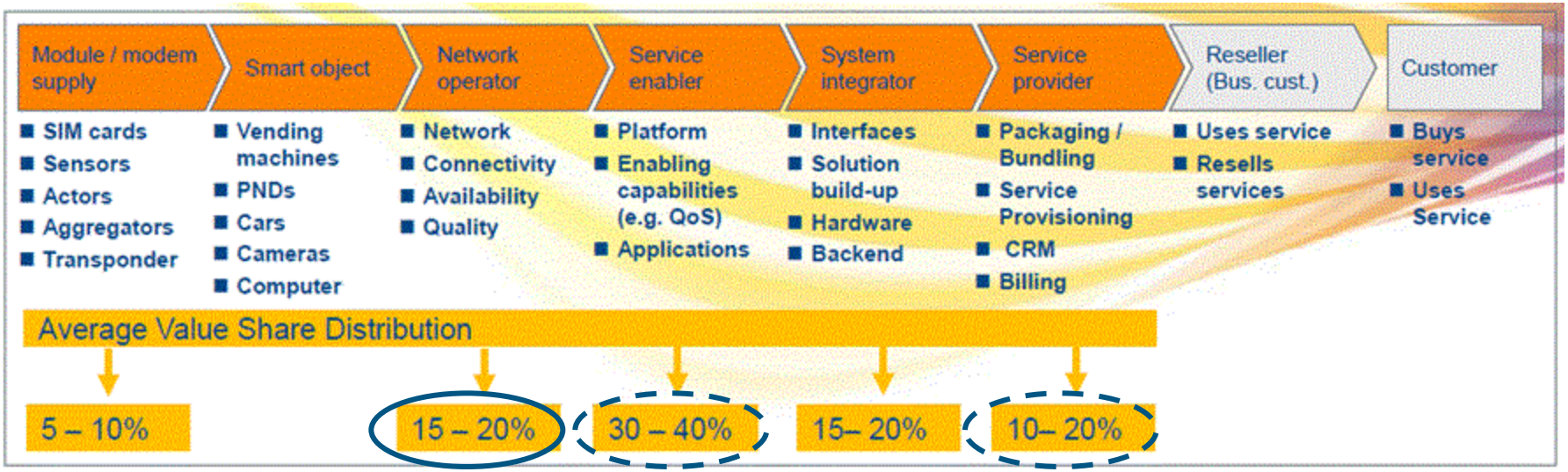
A long value chain opens up opportunities for many Actors

The Ecosystem Challenge



Value highly distributed across the Value Chain – creating the opportunity for a consolidator

Source: Nokia Siemens Networks

Traditional Markets

«New» Markets

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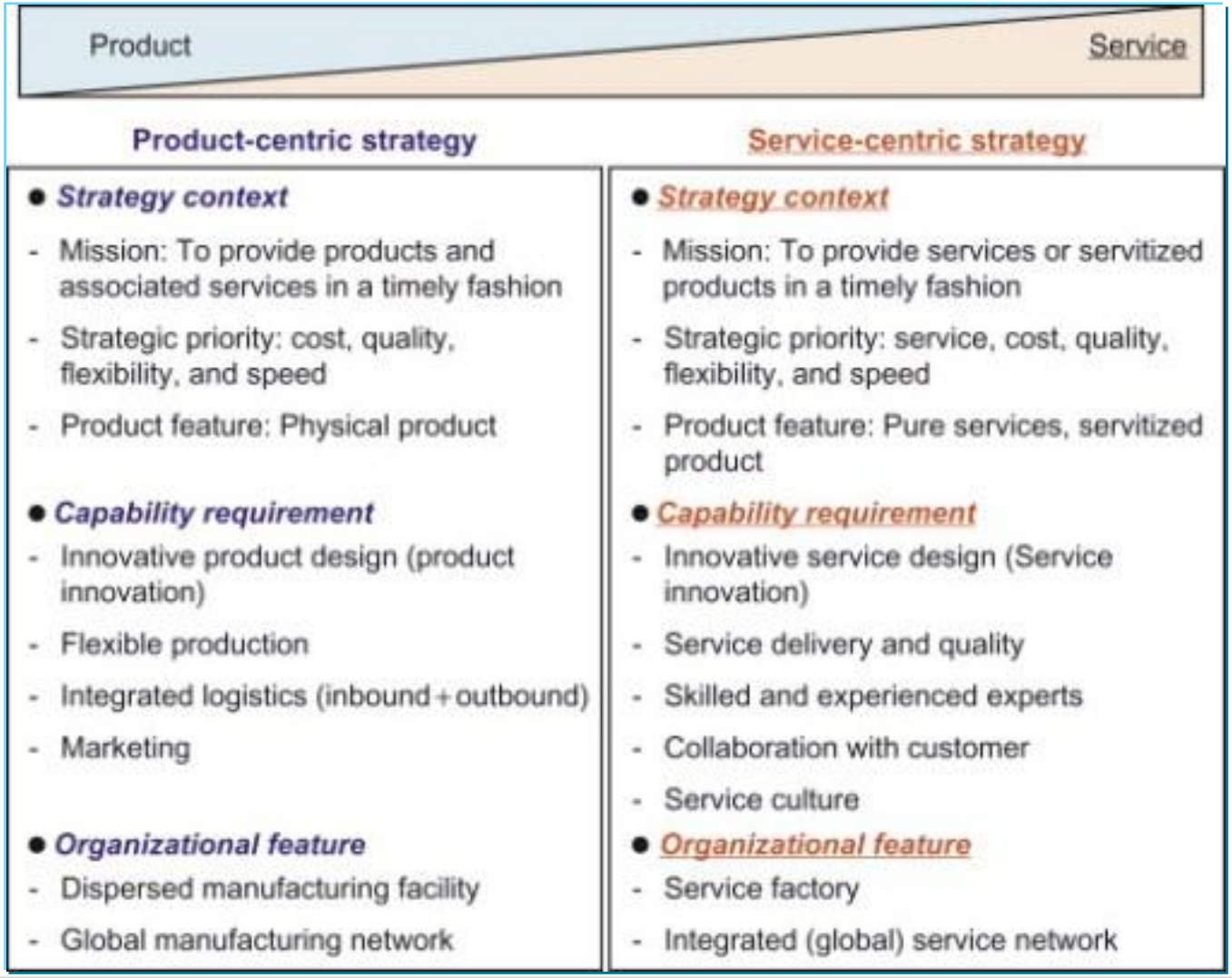
Servitization as a viable Business Model for IoT

The New Biz Models Challenge



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Societal Challenges

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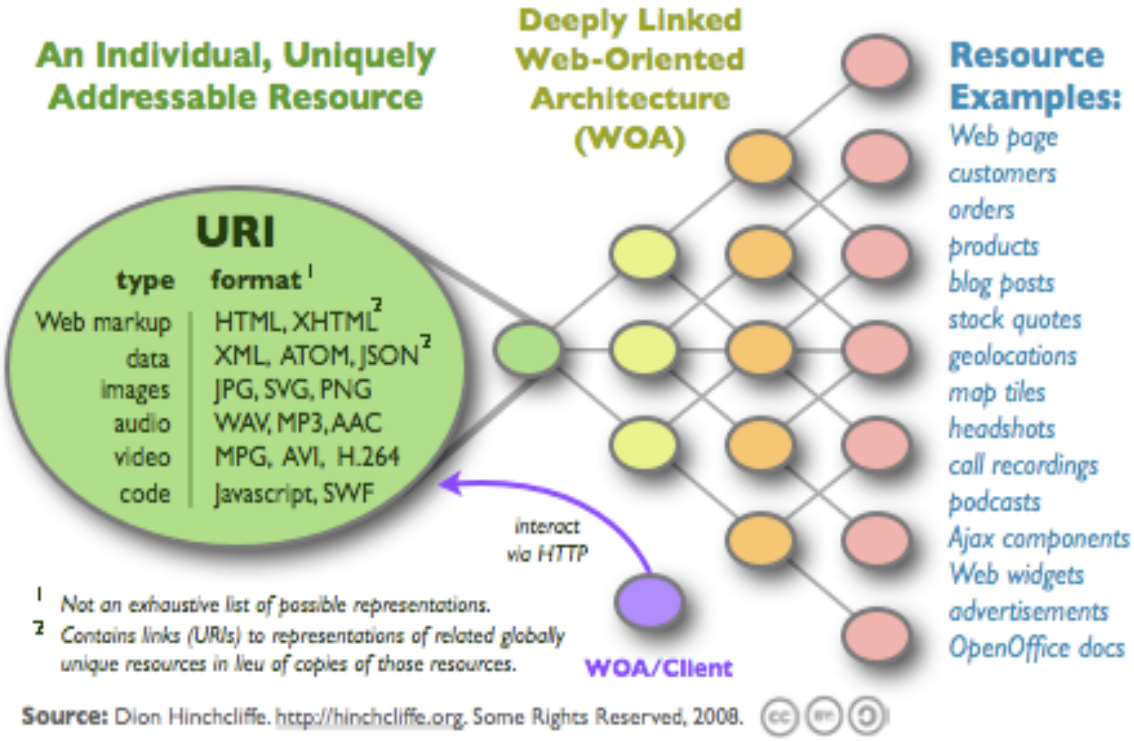
Identity of Things (2)

The Privacy, Trust, and Ownership Challenges



- Each Resource is addressable
- Each resource is CONNECTED
  - –Connectivity must be guaranteed in a variety of environments
  - –Secure Links have to be guaranteed
- Each Resource can be associated to a User (Identity)
  - –Who owns these relations :UserId - Location - ResourceId - data used/generated ?

- Things can collect user related actions and data
- Each Thing can be used for tracking Users
- Owners of Things can collect a lot of data

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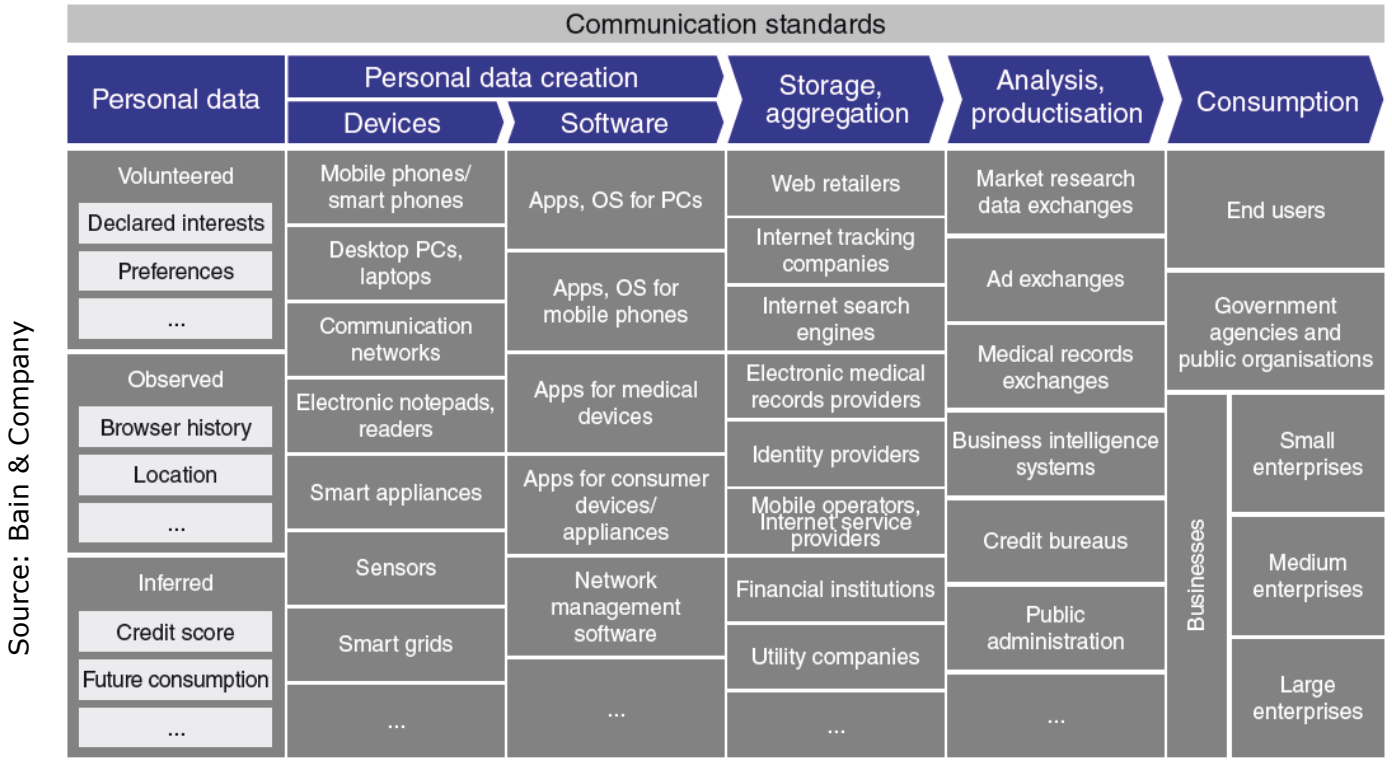
Proper Management of Personal Data



Source: Bain & Company

A "user-centric personal data eco-system" (WEForum)

Excerpt form: "Personal Data - The Emergence of a New Asset Class" (WEF)

Volunteered data: created and explicitly shared by individuals

Observed data: captured by recording the actions of individuals

Inferred data: based on analysis of volunteered or observed information

Personal Data should be properly regulated and managed

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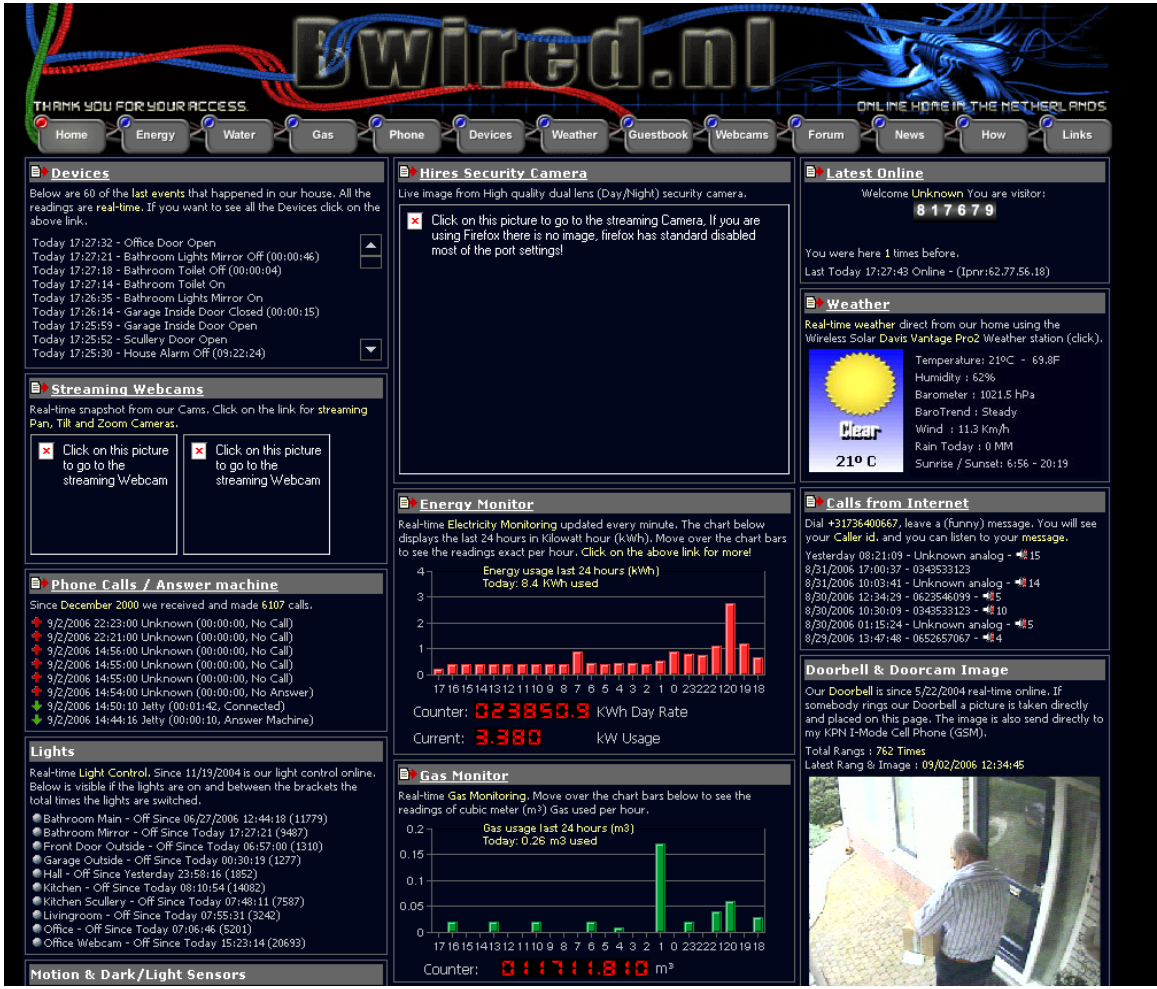
IoT Usability

- How Many Sensors
- What a complicated system
- What Services ?
- How to use them?
- How to deploy them
- How to maintain them?



www.bwired.nl

The Usability and Effectiveness Challenges

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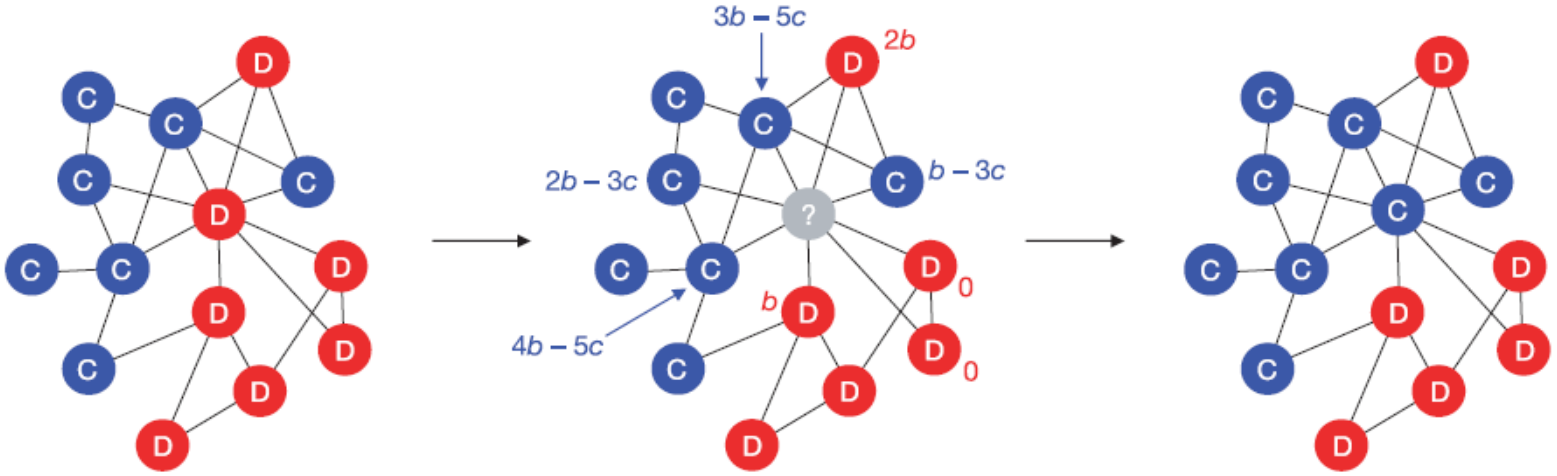
(Social) Cooperation is very important

The Socialization of IoT Challenge

- A fundamental aspect of all adaptive systems is cooperation.
- Natural selection favors cooperation, if the benefit of the altruistic act, b, divided by the cost, c, exceeds the average number of neighbors, k, which means b/c > k.
- It is necessary enforcing altruistic behaviors in IoT networks (social aspects on it)



Hisashi Ohtsuki, “A simple rule for the evolution of cooperation on graphs and social networks”, Nature, Letters, Vol 441|25 May 2006|doi:10.1038/nature04605

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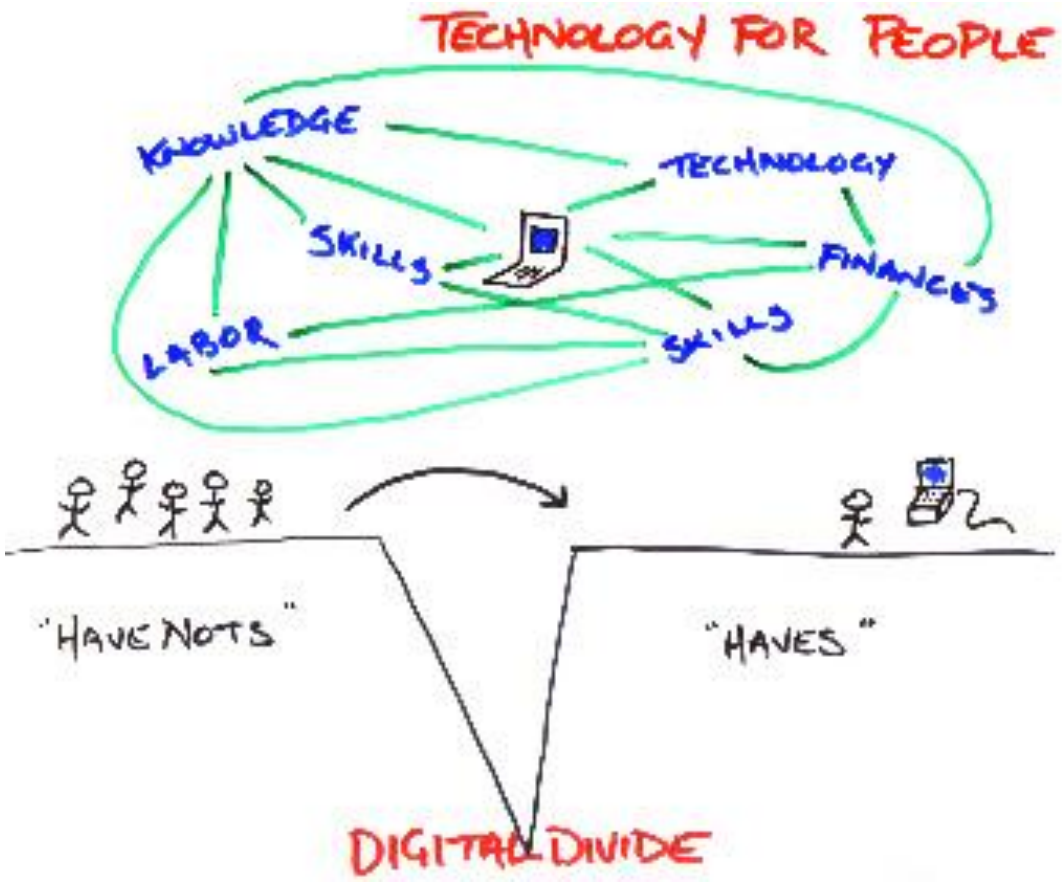
Digital Divide

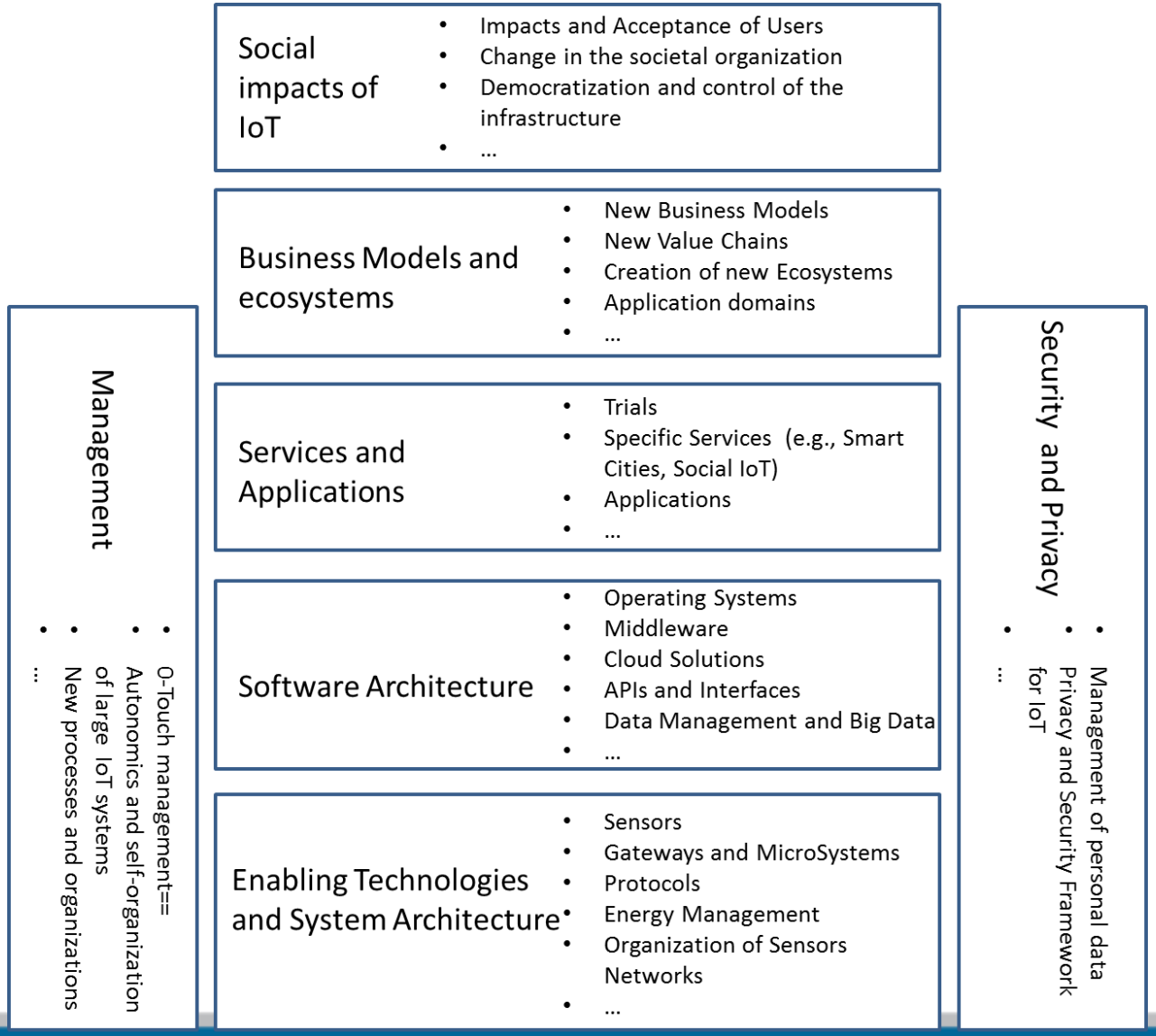


IoT will exacerbate the differences between infrastructured societies and no connected ones

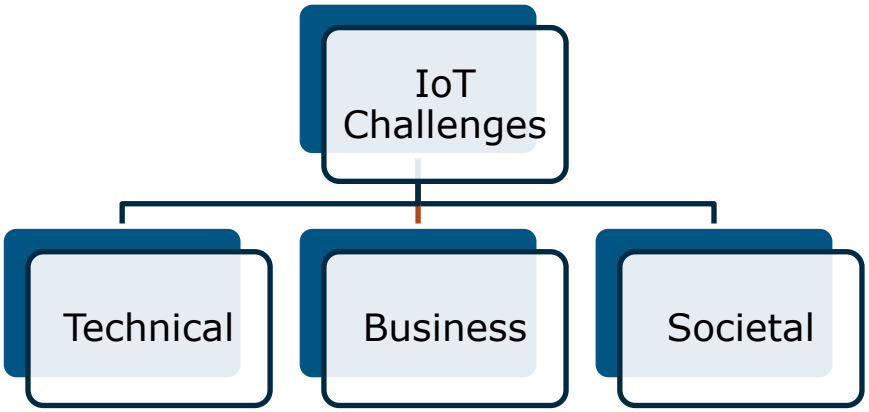
Source: http://ci-journal.net/index.php/ciej/article/view/293/318

Back to IoT Challenges

IoT Challenges (3)



IoT Challenges (4)



- Platform
- Security
- Signaling and Protocols
- Data Management
- Cloud
- Large System Management (autonomics)
- Power Consumption
- Connectivity
- Programmability
- Complexity
- Standardization
- Virtualization
- Smart Objects
- Communication Paradigms (cooperation and gossiping)
- …

- Market Value
- New Business Models
- New Ecosystem
- Applications Domains
- New Business Processes
- User Needs
- Market and solutions fragmentation
- …

- Security
- Privacy
- Trust
- Usability
- Effectiveness
- Social Control
- …

A Major Challenge of IoT Global Cooperation !!!

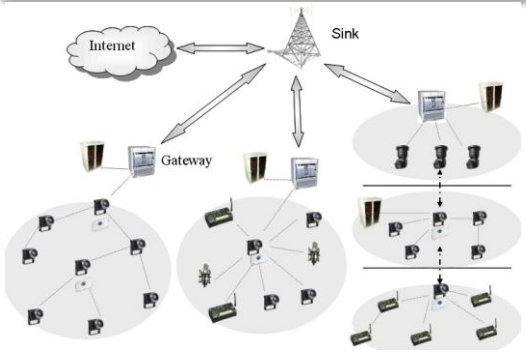
Towards a Virtual Continuum

Evolutionary roadmap for key functional elements

M2M

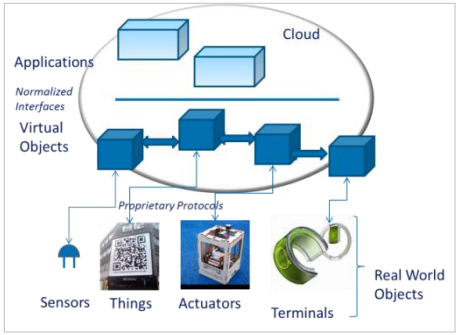
Key elements:
Separated applications
Ad-hoc designed modules
Ubiquitous connectivity
SIM management
International agreements
Embedded SIM

IoT



Key elements:
Low-cost standard sensors
Short range communication
Capillary and macro netw.
Horizontal Services
Data aggregation in cloud
Third party development

Virtual Continuum



Key elements:
"Virtual Objects"
Mirroring Things in cloud
Object Semantics
Data integration, federation and portability
Cloud as developing platf.

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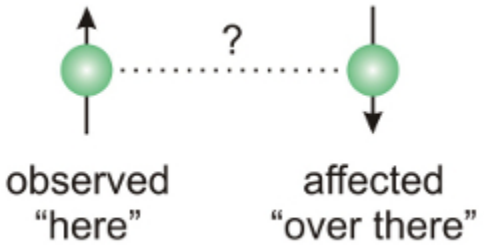
The Virtual Continuum

A virtual environment is a software feature that allows customers to use an entire (virtualized) computational and communication environment tailored to their specific needs.

The Virtual Continuum is the constant entanglement between real objects and their representations in the network. Events, actions, data on a physical object will be represented in the virtual world and vice versa. The Virtual Continuum makes possible the close relation between atoms and bit



Entanglement

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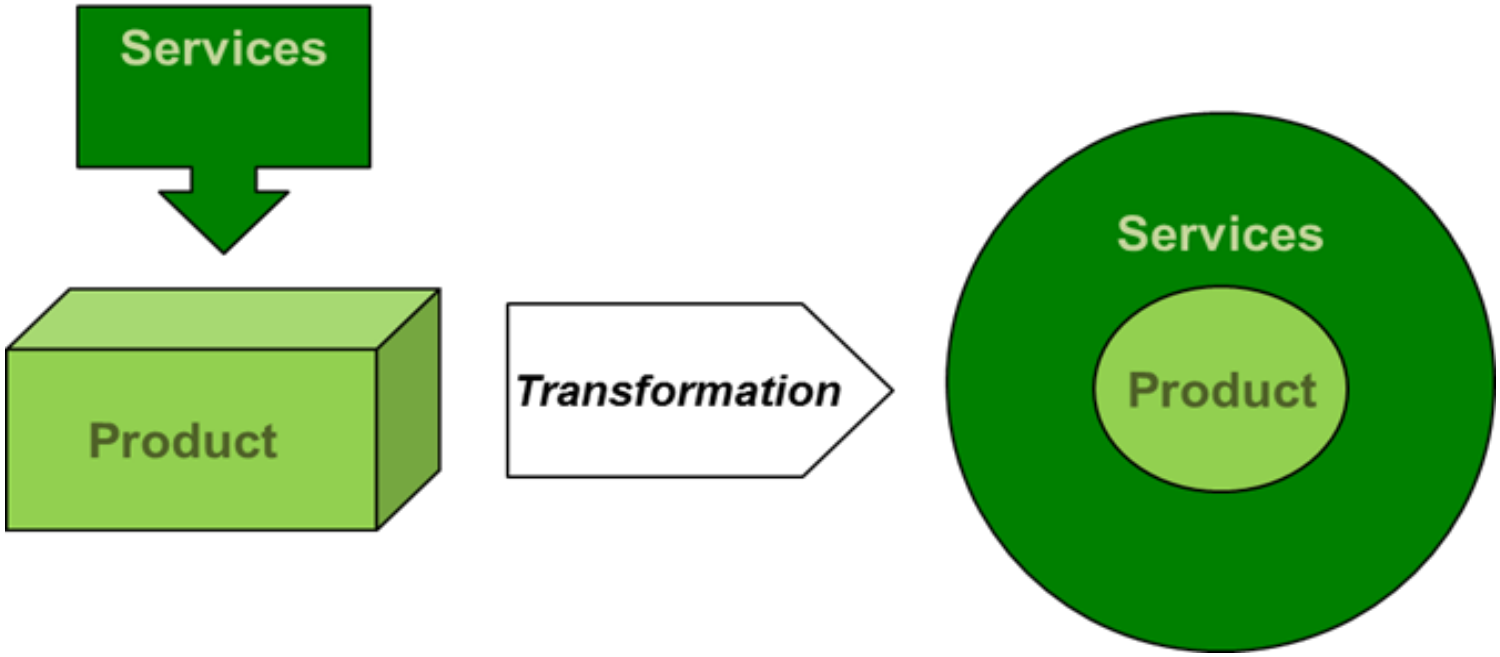
Virtual Continuum is Servitization



Servitization is the capability of creating a link between a (physical) product and a set of services and enriched functionalities that extend, complement, and add value to the product itself

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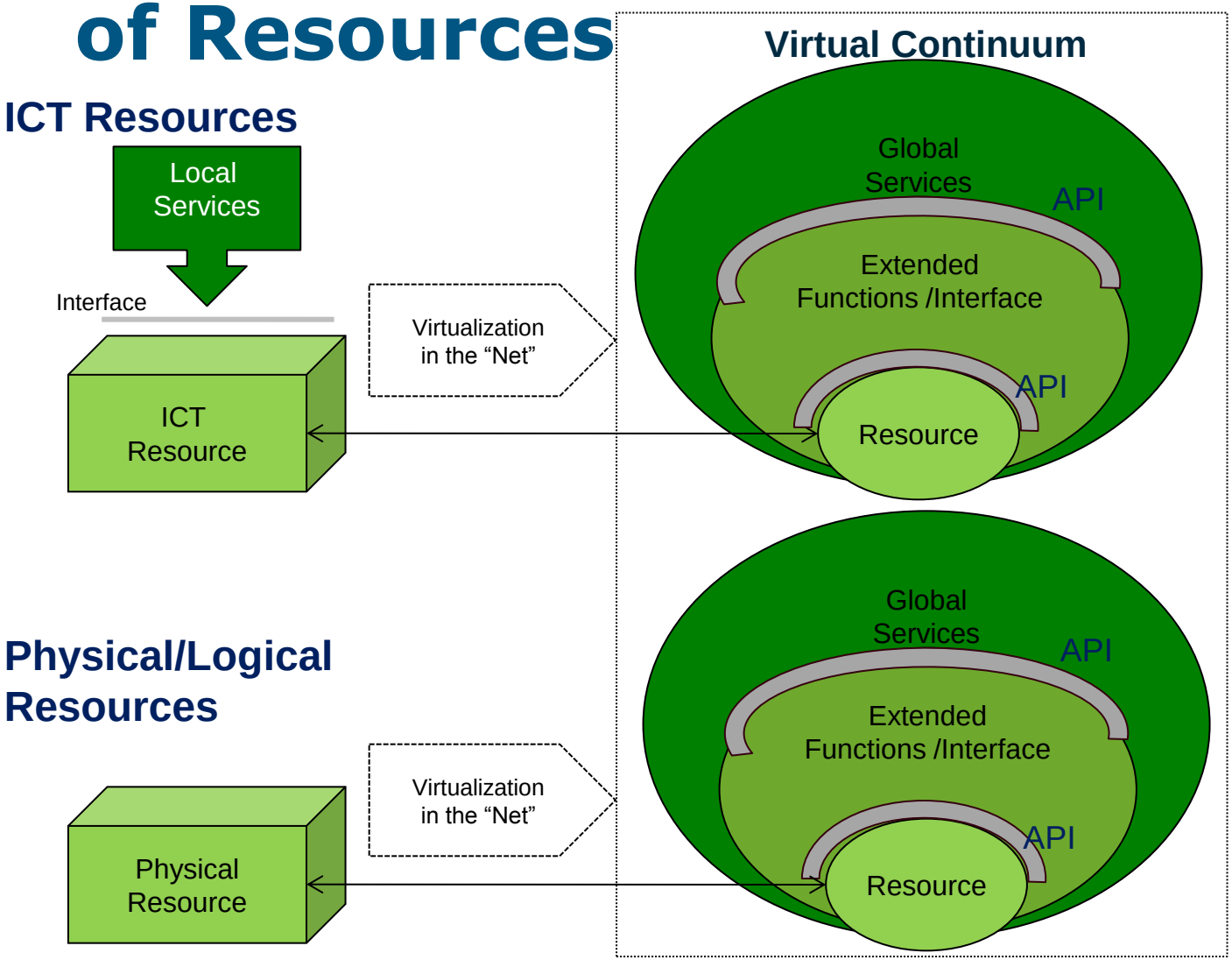
Virtual Continuum is Virtualization of Resources



- **Each Resource is representable**
- **Each resource is programmable**
- **Each Resource can be functionally augmented**

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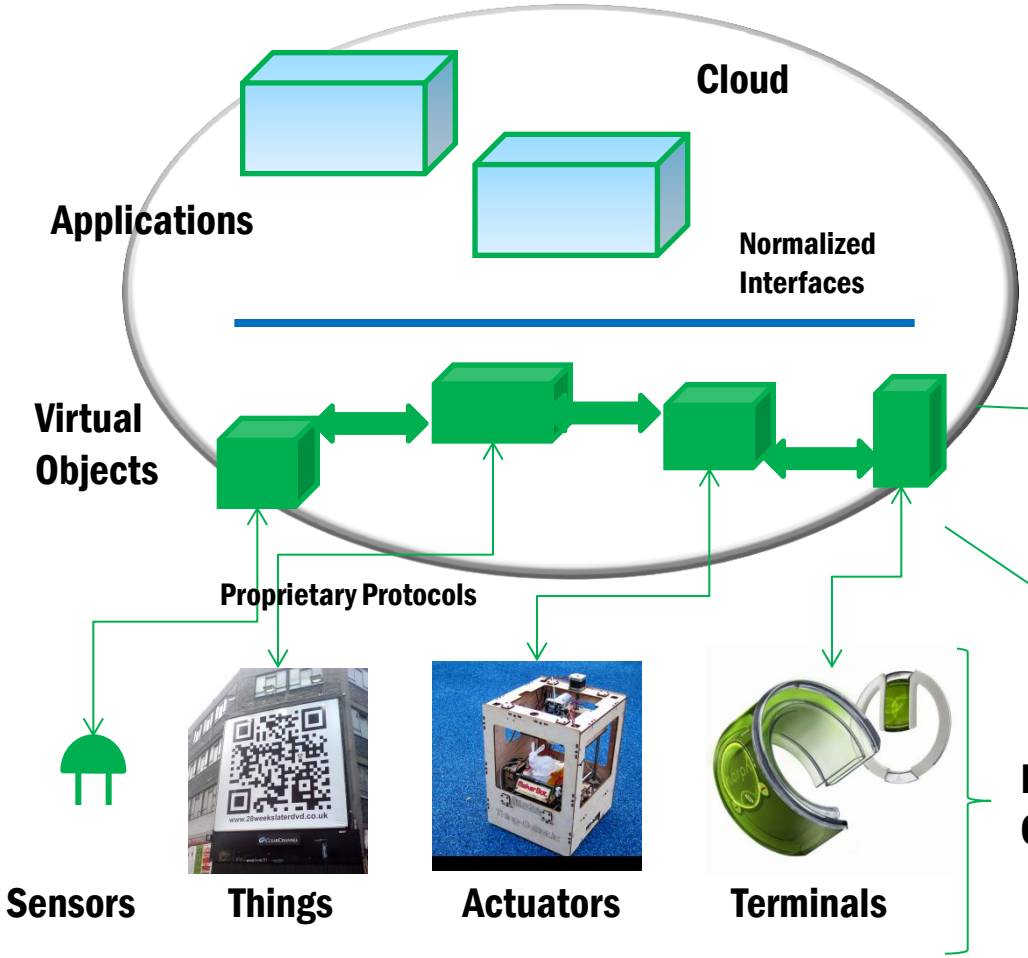
Virtualization and APIs as means to enter into the Virtual Continuum

- **Decoupling of physical objects and virtual ones (Virtual Continuum)**
- **Normalized applications can be built on Virtual Objects (having an impact on Physical Objects)**
- **Servitization**



Each Virtual Object will have:
- A unique identifier
- A contract
- An API
- A communication mechanism (PubSub)

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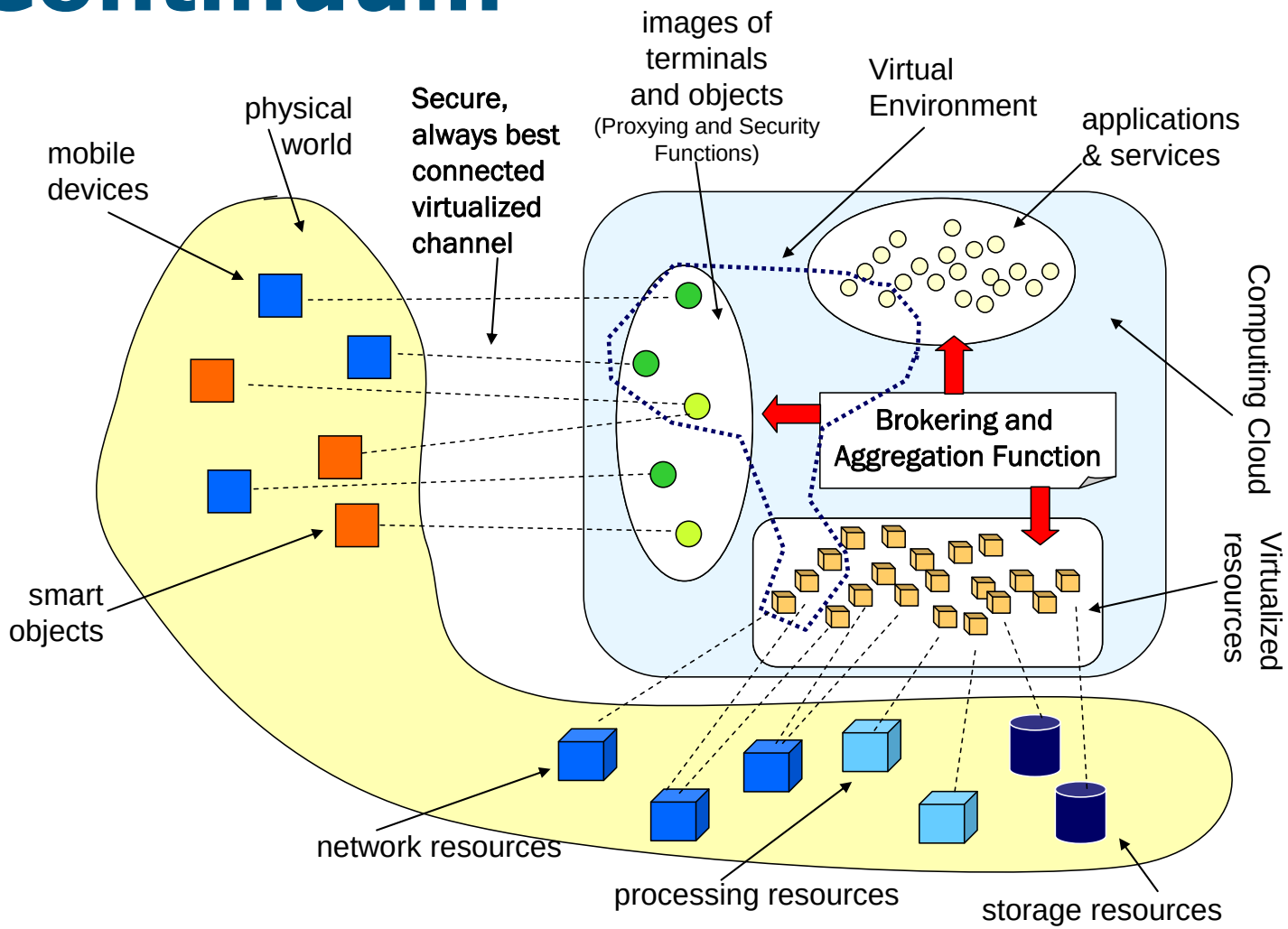
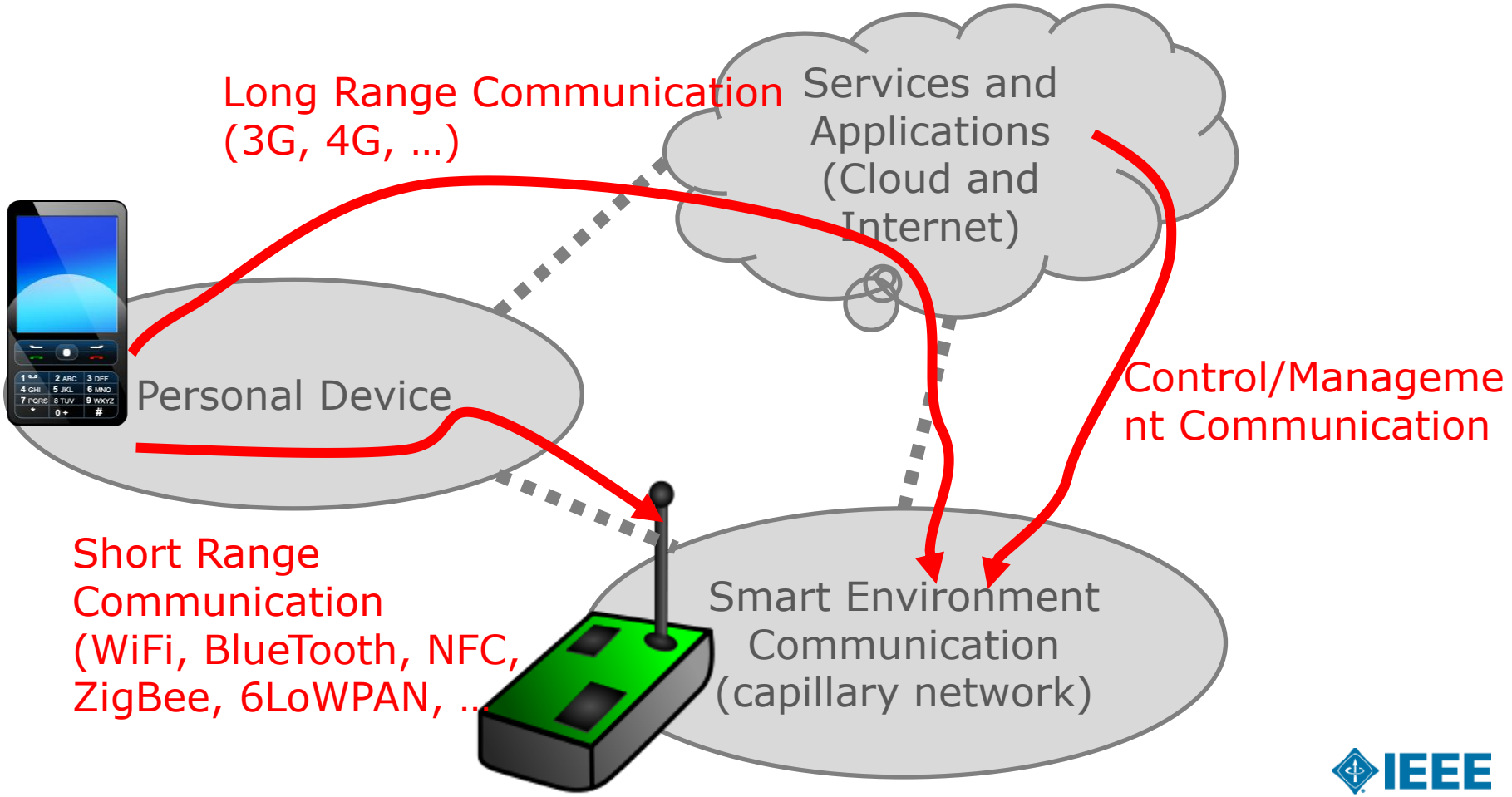
The Context for Virtual Continuum



Three Communication Environments



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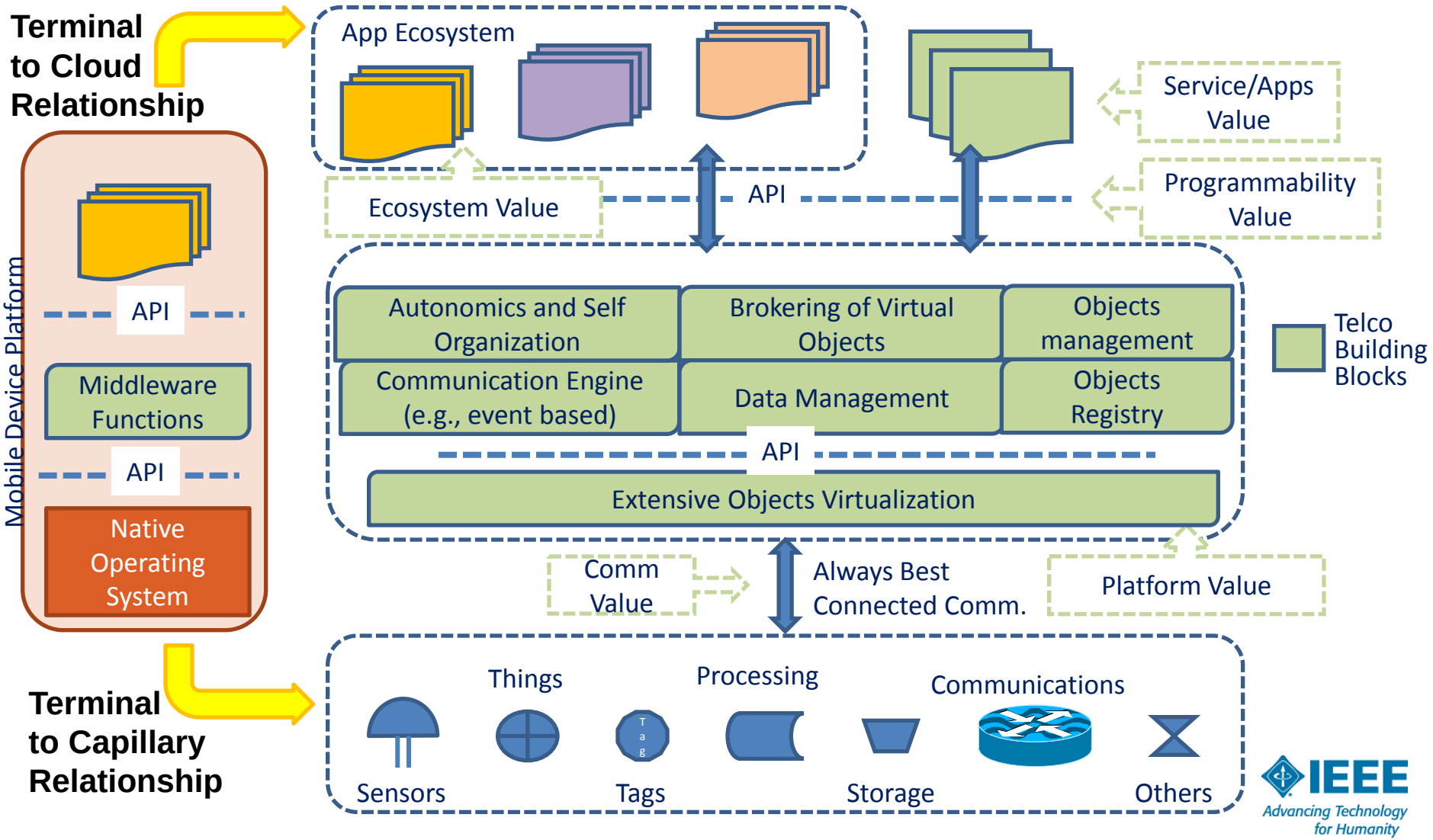
Platform View



A few words about IEEE Initiative on IoT

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An IEEE Initiative on IoT: Goal and Objectives

- IEEE is a cross-disciplinary initiative fostering collaboration and connecting technical & business communities to IEEE experts and resources
- Establish IEEE as a **Thought Leader** and essential to the IoT community
- IEEE to be recognized as the go-to resource for:
  - engineering and technology professionals in industry, academia and government working on IoT;
  - broad education of the public (including consumers) and governmental bodies desiring non-biased and balanced understanding of IoT developments, including its related technologies, products, implementation and its ongoing evolution.
- Develop and promote valued programs, products and services for the IoT community.
- To establish:
  - The IEEE World Forum on IoT as the principal conference devoted to IoT
  - The IEEE IoT Journal as the principal journal devoted to IoT
  - IEEE IoT standards as the principal standards in IoT
  - IEEE's IoT tutorials, review articles, workshops, short courses and similar activities as the principal IoT educational activities.

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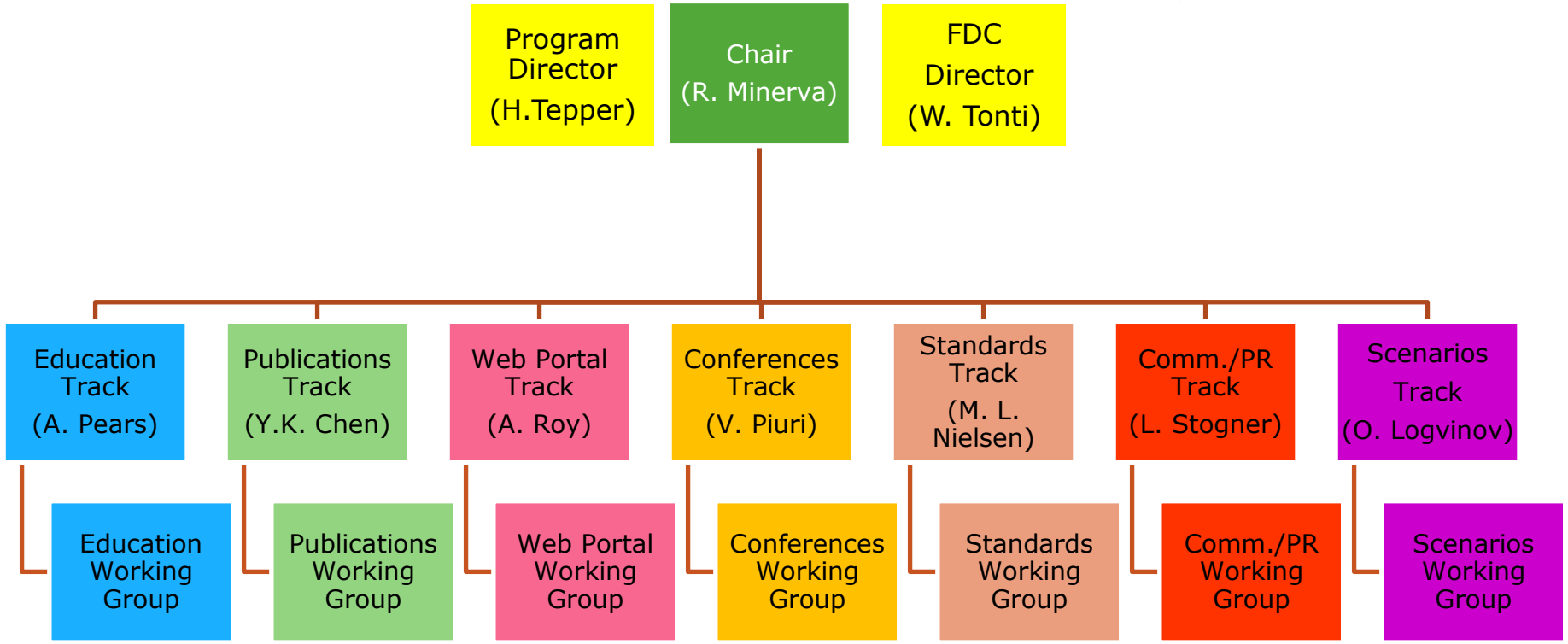
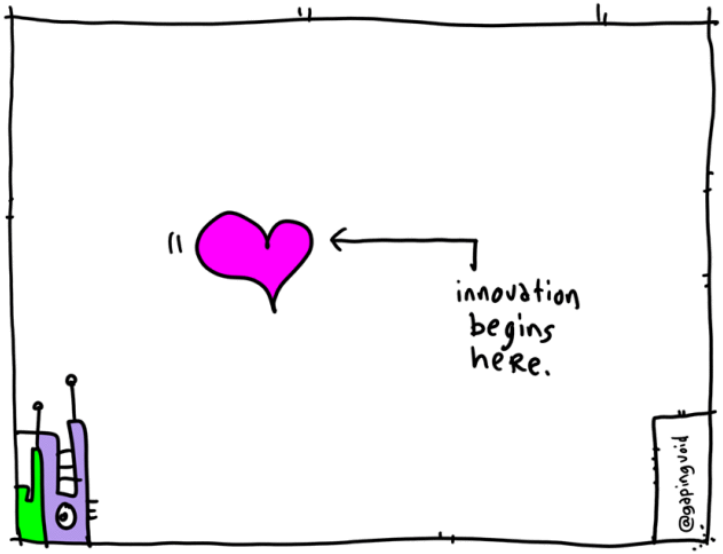
IOT Initiative Organization



Seeking Volunteers for Scenarios, Application Designs, Reference Implementations.
Join the Technical Community at http://iot.ieee.org/



Thank you!

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