POLIMI GRADUATE SCHOOL OF MANAGEMENT

Internet of Things for the Extended Enterprise

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Who am I?

- Professor of Advanced Supply Chain Planning @ Politecnico di Milano

- Senior director at Osservatori.net, 100-people research group on Digital Innovation:
  - Internet of Things / Industry 4.0
  - Artificial Intelligence
  - 5G
  - Smart and Connected Mobility

- Co-founder of the Internet of Things Lab, the applied research lab of Politecnico di Milano on IoT (www.iotlab.polimi.it)
- Co-founder of the AIRIC, the applied research center of Politecnico di Milano on AI (www.airic.polimi.it)

- Co-founder of IqConsulting, academic spin-off, now part of Digital360 (listed)

- More than 100 cooperation projects with leading Italian and International companies

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Agenda

- Foreword
- Technologies for the Extended Enterprise
- Data Architecture
- Benefits Evaluation
- Q&A

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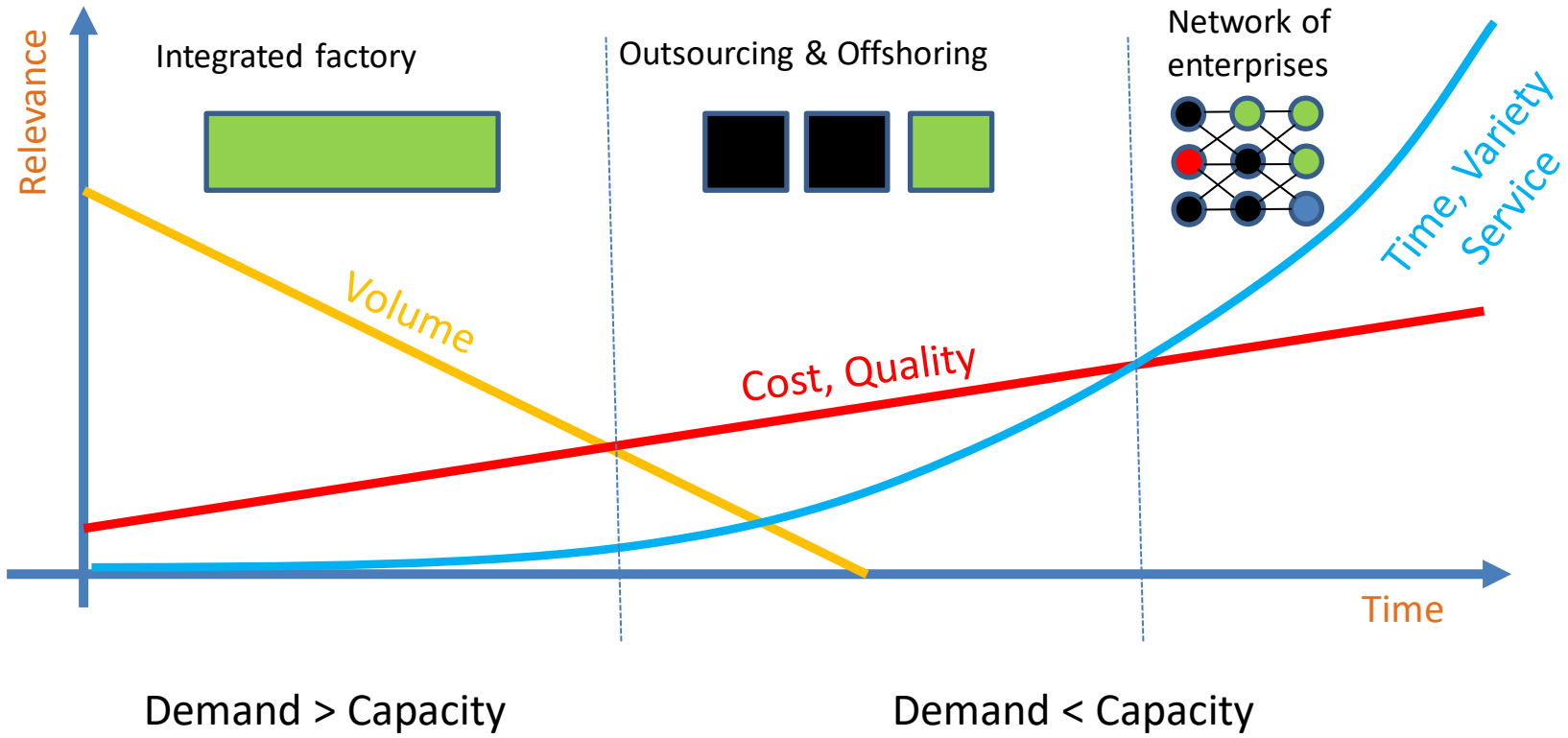
A brief history of competition



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Supply Chain Management

Definition

- The firm is not a stand alone entity but it is part of a network of interconnected firms: optimizing internal processes is no longer enough
- Need to manage processes beyond the boundaries of the single company, because there has been a shift on competition: from "**Company vs Company**" to "**Value Chain vs. Value Chain**"

Network, Processes, Information and Money managed as a whole, in a dynamic environment

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A brief history of competition

Business needs and tech requirement

Evolving business needs	Tech Requirements
Globalization, decentralization, fragmentation	Visibility, business integration, ubiquity, dependability, scalability
Competing on time	Sub-optimal, fast decision making, simulate to promise reliable dates
Competing on variety, with shorter lifecycles	Complex decision support (multiple products, sites, etc.) scenario and uncertainty management
Competing on services	Connected products, knowledge from data

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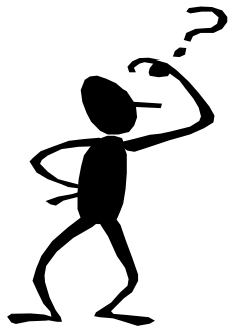
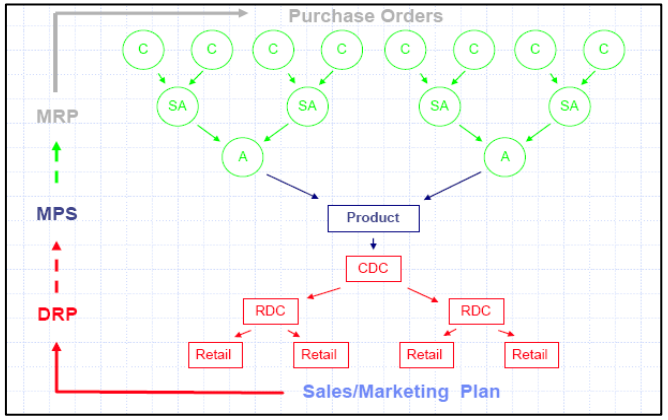
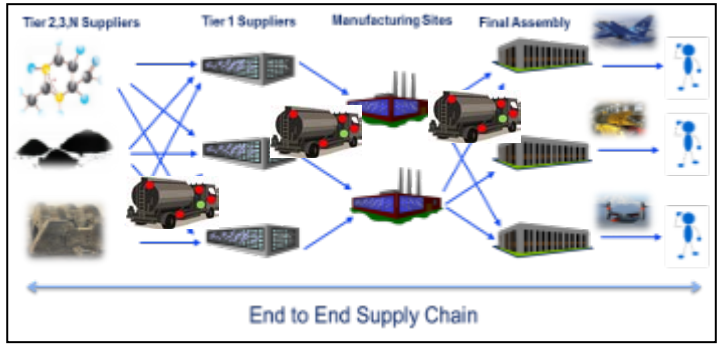
The gap between Information and Operations

IT

OT







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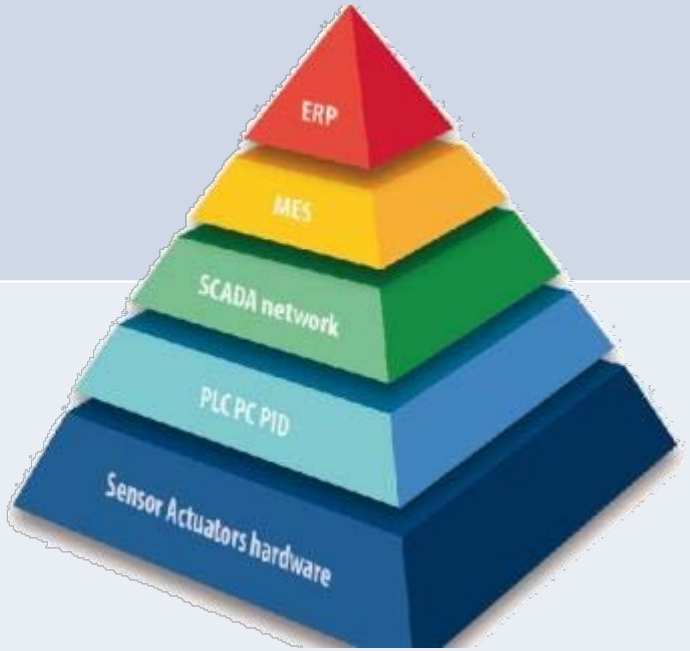
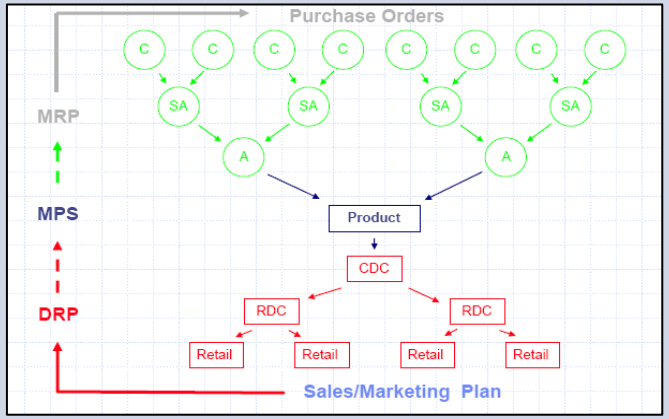
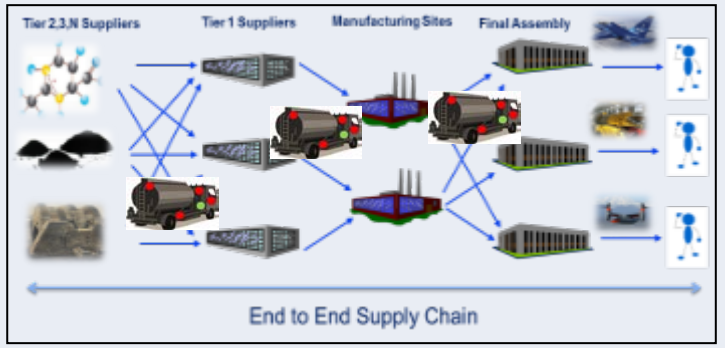
The gap between Information and Operations

	Factory	Supply Chain
IT		
OT		

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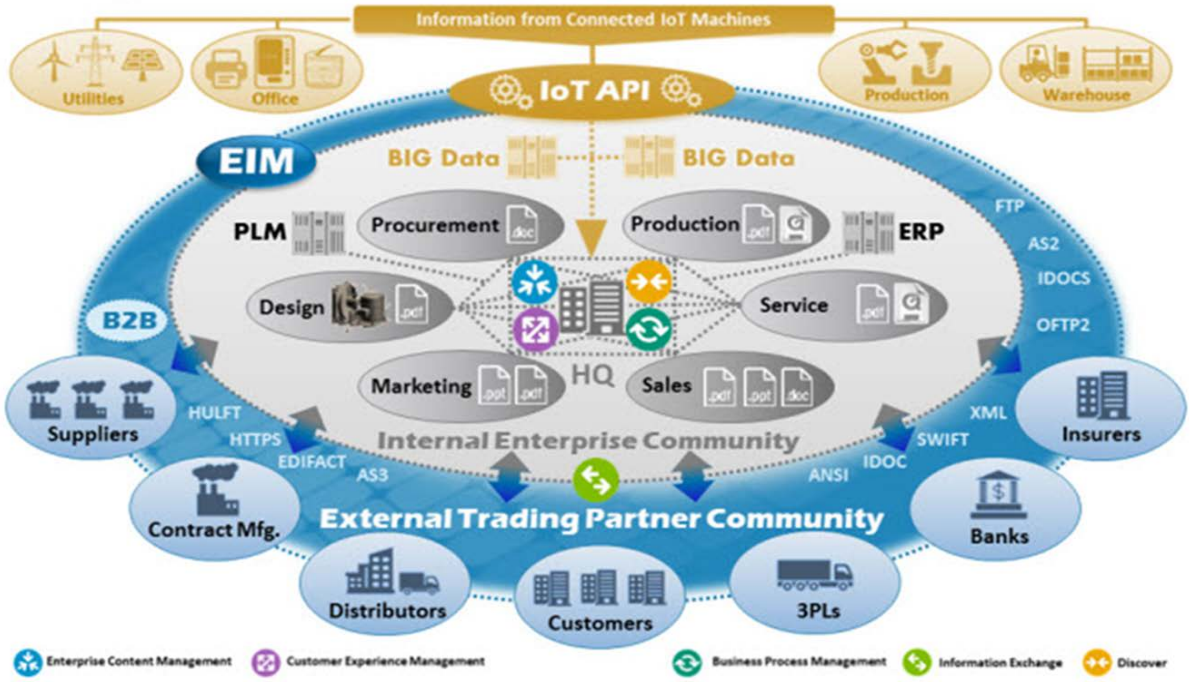
The Extended Enterprise

*"The extended enterprise is the entire set of **collaborating companies**, both upstream and downstream, from raw material to end-use consumption, that **work together** to bring value to the marketplace"*



E.W. Davis, R.E. Spekman, 2004, "Extended Enterprise: gaining competitive advantage through collaborative Supply Chain", Prentice Hall

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The Extended Enterprise… what?

The following slides contain explicit material which should only be viewed by ***consenting adults***

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What is at stake?

- “In January 1999, a car demolition company in Walloon, Belgium, delivered oil from a transformer to a municipal oil recycling plant. That oil contained approximately 1 gram of dioxins.

- The oil ended up in a vegetable oil storage tank, an ingredient for feedstuff. Through the animal feed, the contaminated product entered the human food chain.

- The problem could not be contained since a targeted recall was impossible:
- there were few records on the feedstuff ingredients, the production date or the batch identity;
- it was impossible to ascertain whether other feed factories were involved
- it was impossible to ascertain which farmers had bought the contaminated feedstuff, let alone which food products were contaminated and to which countries these products had been transported.

- Consequently, it was impossible to launch a proper recall, due to a lack of coherent and adequate information. As a result, millions of Euros were wasted on the withdrawal and recall of products that on hindsight were perfectly safe, but that were considered to be a major public health risk at the time.

- Ever since, the concept of the implementation of traceability in the food supply chain has received a great deal of attention. [CIES, 2005]”

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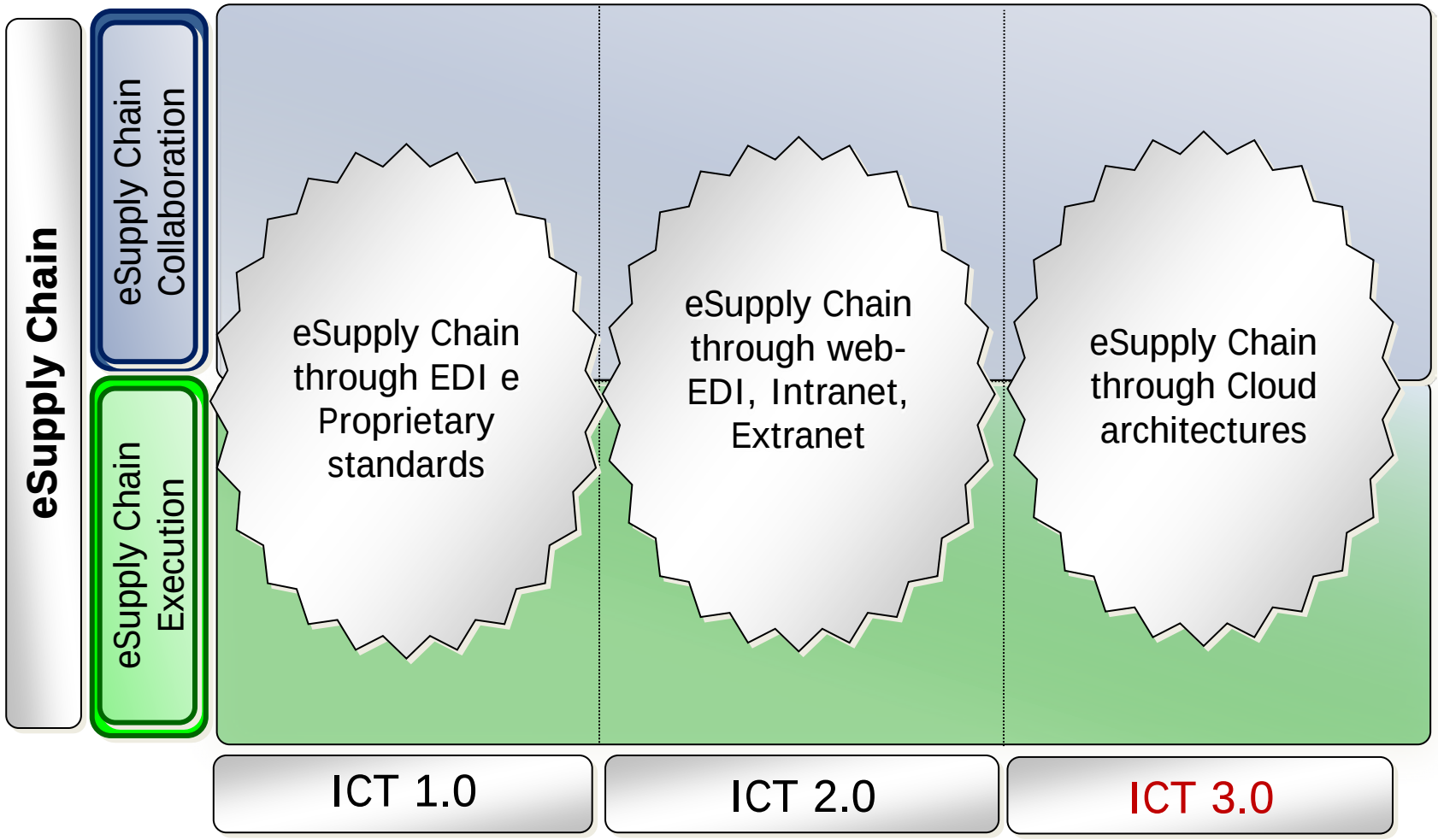
IT view



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Why it is so difficult?

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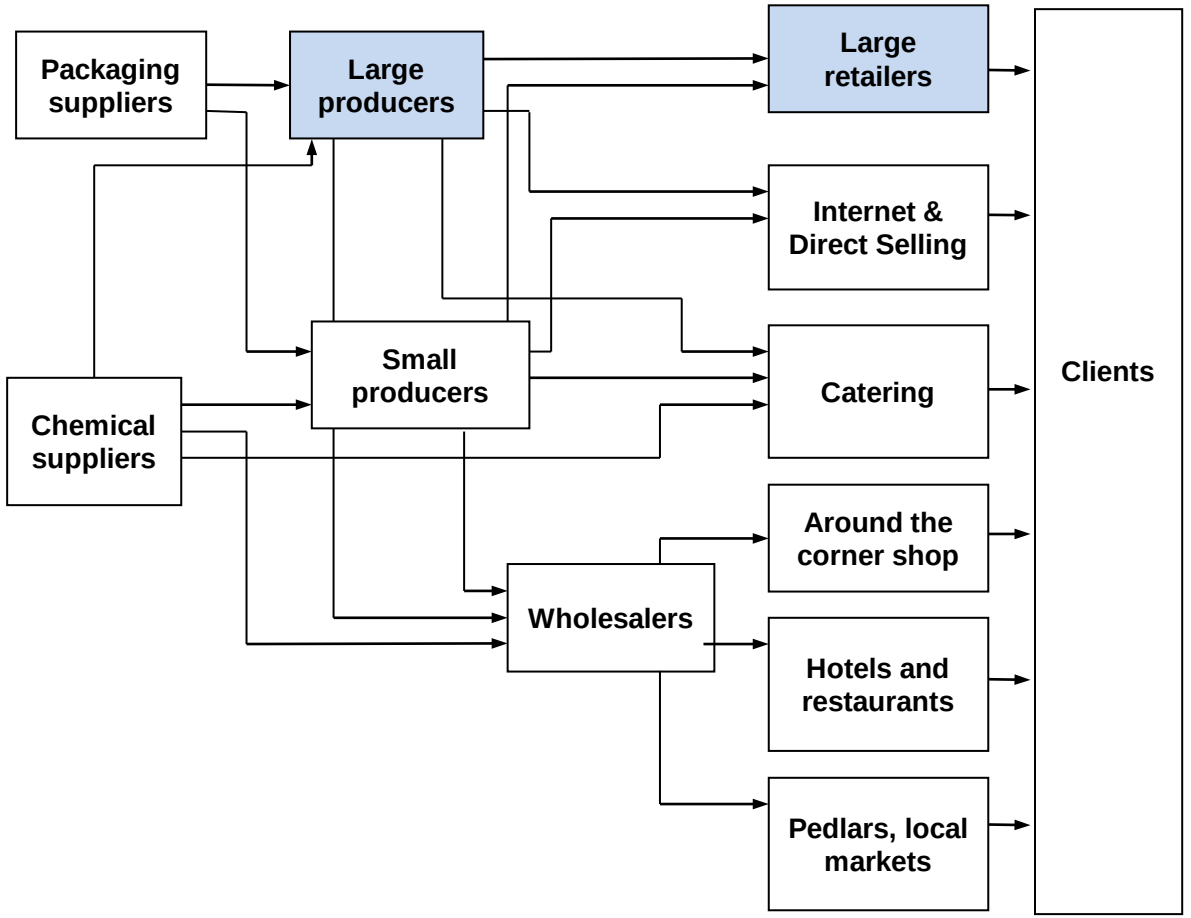

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Why it is so difficult?

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The business drivers

	Food	Pharma	Logistics and transportation	Luxury
Regulations compliancy	+++	++	+ (++)	
Process optimization	++	++	+++	+
Service and Quality	+	++	++	++
Brand protection		++		+++

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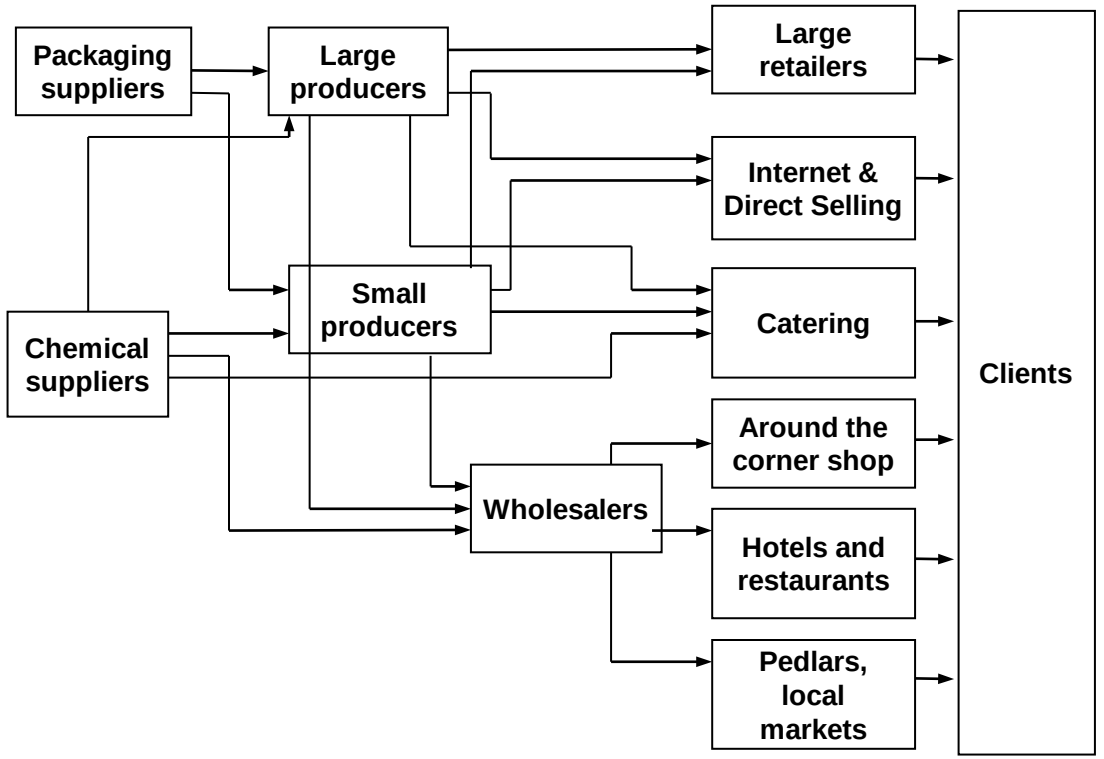
Why it is so difficult?

- Why it is so difficult?
  - The complexity of the process



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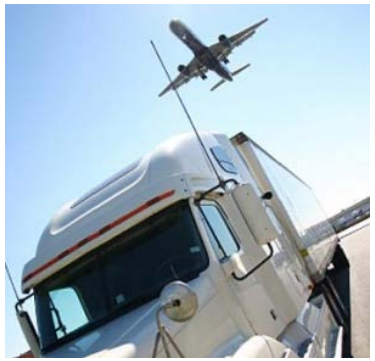
Why it is so difficult?

- Why it is so difficult?
  - The complexity of the process
  - What to record?
  - Who is supposed to record?



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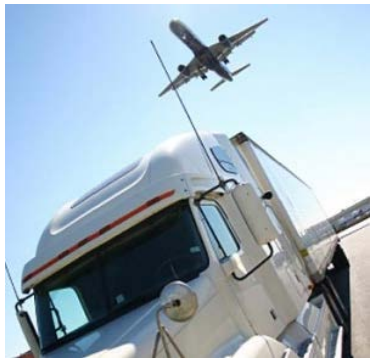
Why it is so difficult?

- Why it is so difficult?
  - The complexity of the process
  - What to record?
  - Who is supposed to record?
  - How is information shared?



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The solution requirements

- We need a new technology to bridge the gap between digital and physical worlds:
  - Give a unique identity to every single object
  - Automatically acquire this identity
  - Effectively bring the data acquired to the digital world
  - Make physical objects talk and work with each others

- … in line with openness and interoperability principles

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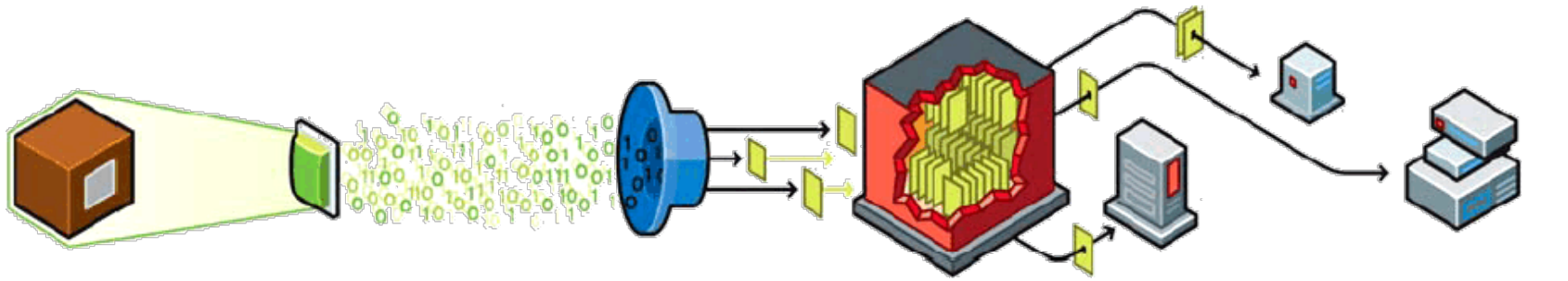
Radio Frequency Identification

Definition

RFId (Radio Frequency Identification) is a technology for the automatic identification of objects, animals or people, the measurement and the communication of the collected data in radiofrequency by using smart tags (autonomous power supply, embedded software)



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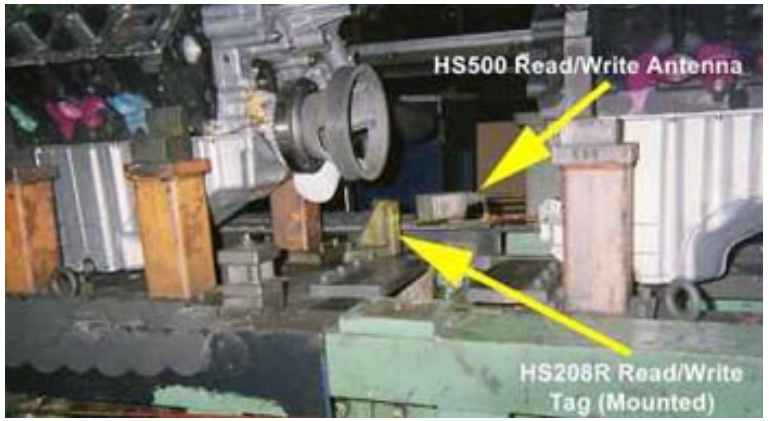
Radio Frequency Identification

History

- RFId applications have more than 50 years…



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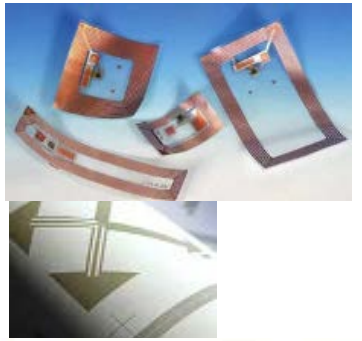
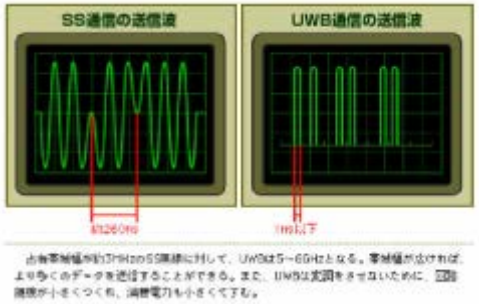
Radio Frequency Identification

What's new?

- Passive technologies



- New materials and processes



- New frequencies

- Computation and networking capabilities

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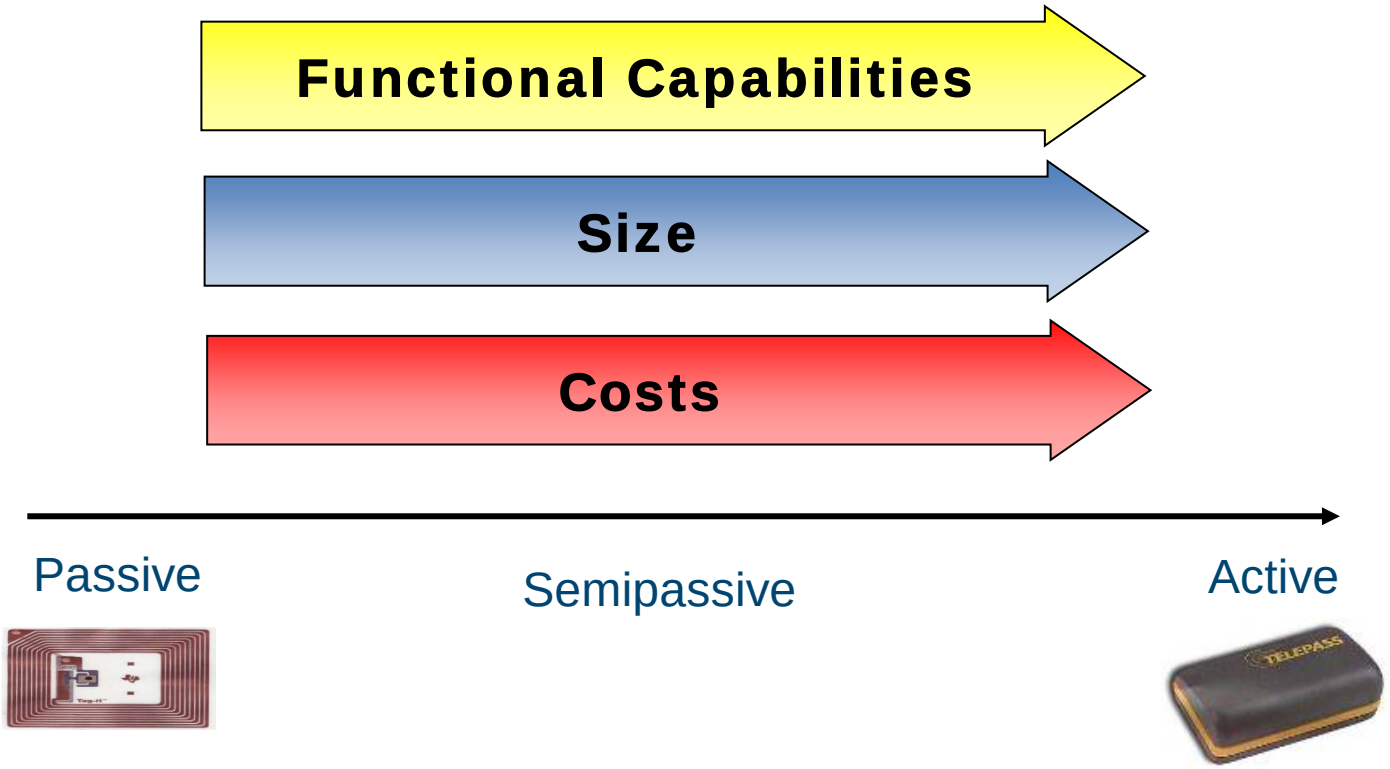
Radio Frequency Identification

A comparison with barcode…



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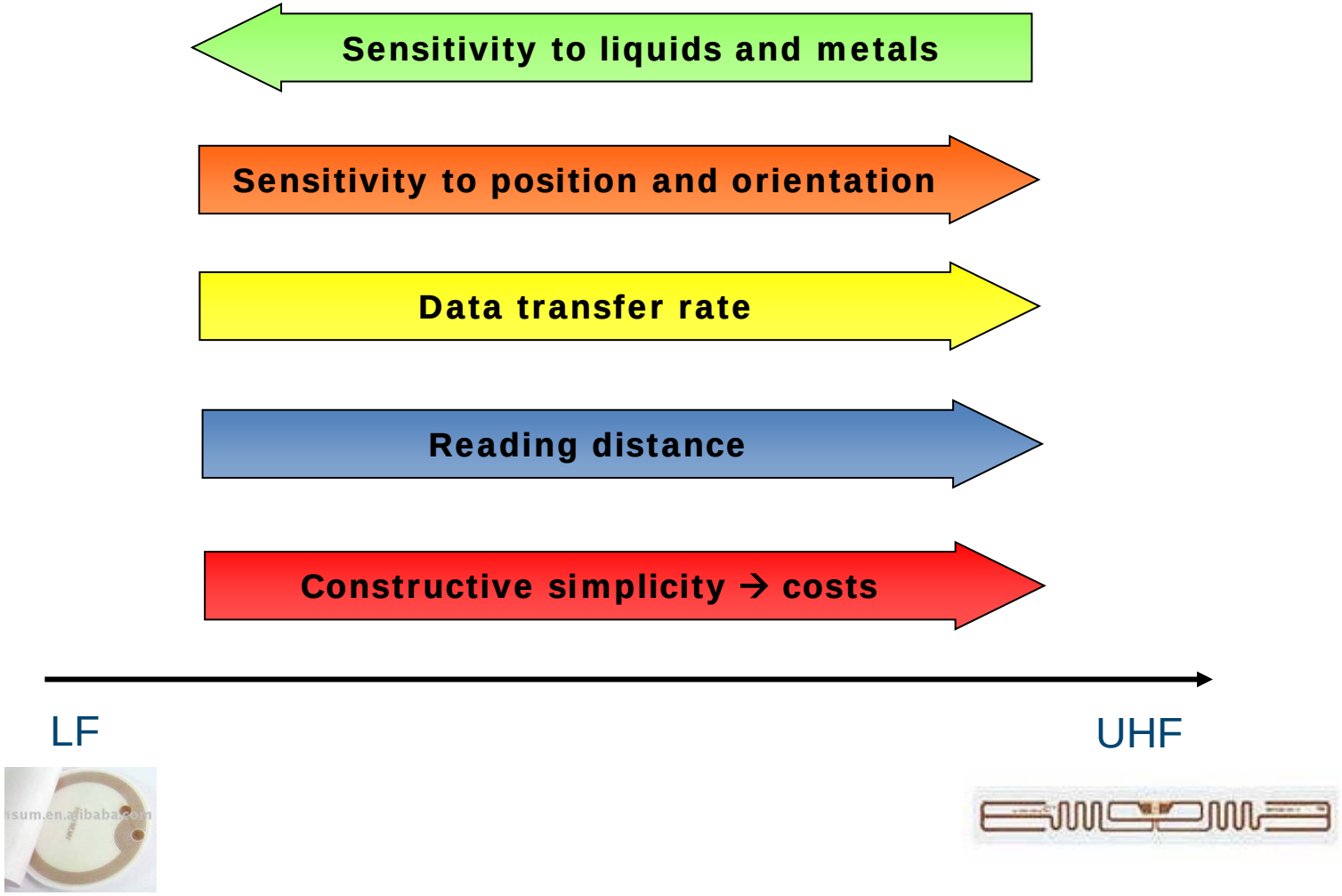
Radio Frequency Identification

Operating frequencies



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Radio Frequency Identification

Near Field Communication (NFC)

Near Field Communication

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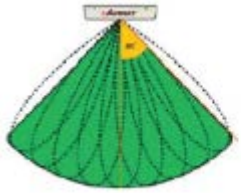
Radio Frequency Identification

Advanced applications

Passive RTLS

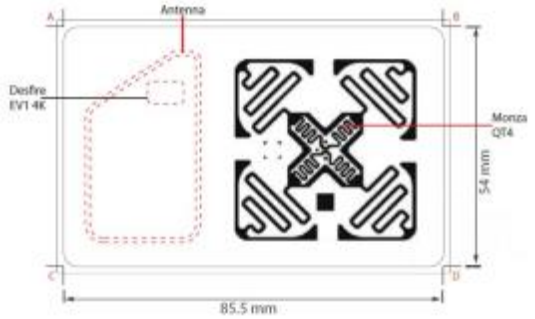
- Passive tags (standard ones) with dedicated readers infrastructure:
  - 3-5 mt height
  - 1 reader can cover up to 130 sqm
  - Simple installation, Power-over-ethernet
- Precision: ≈1.5 mt:
  - Wide Area Monitoring (tag inventory);
  - Tag movement (through sectors)



The xArray gateway provides exceptional location assignment and wide-area monitoring with its 52-beam phased array antenna.

Special Tags

Double frequency



Sewn-in antenna

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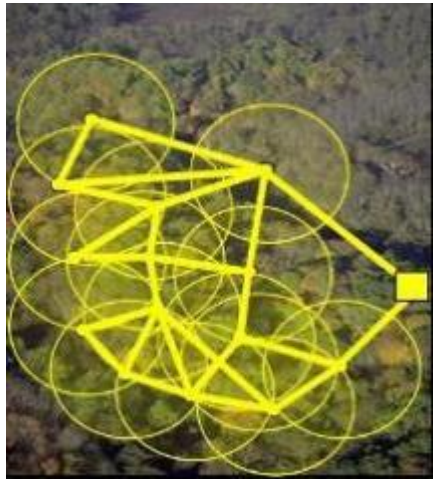
Radio Frequency Identification

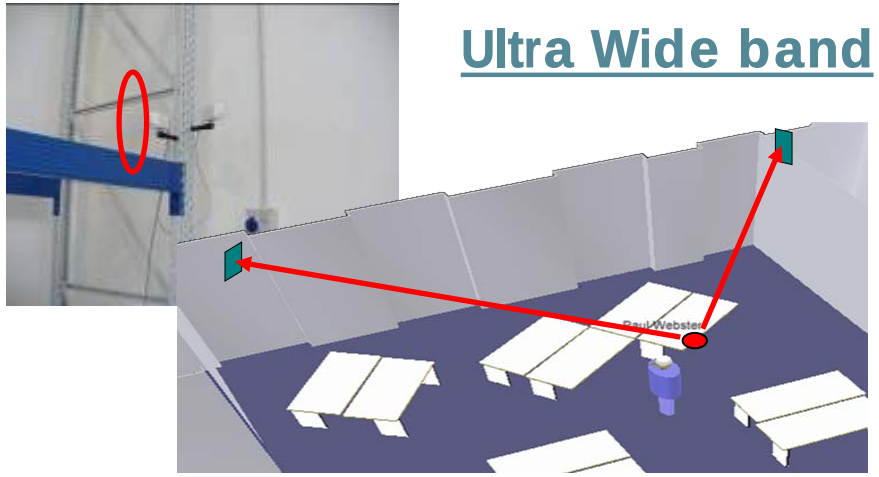
Advanced applications

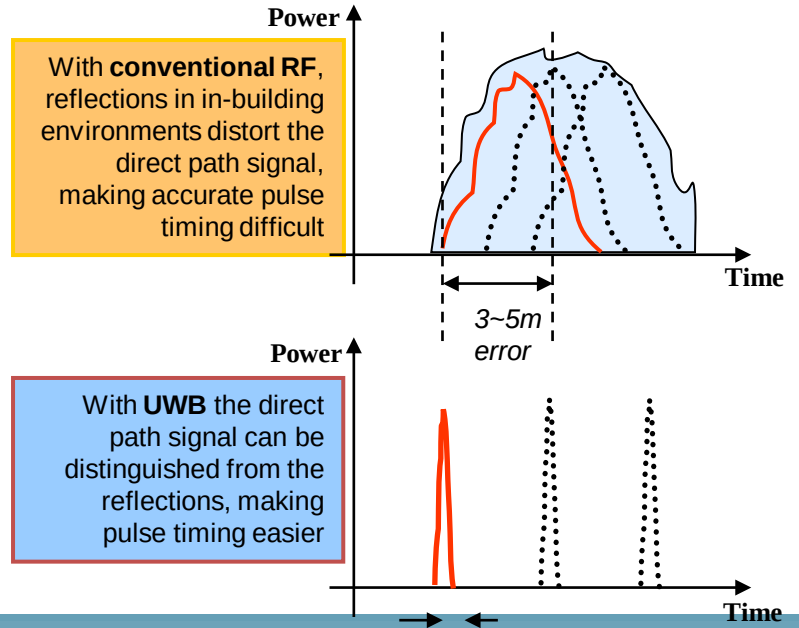
Wireless Sensor Networks

(Zigbee et similia)



Ultra Wide band





With **conventional RF**, reflections in in-building environments distort the direct path signal, making accurate pulse timing difficult

With **UWB** the direct path signal can be distinguished from the reflections, making pulse timing easier

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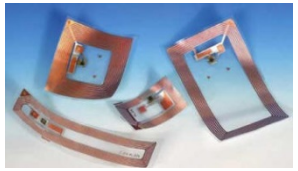
Radio Frequency Identification

A comparison with barcode…



- Automated reading
- No line of sight
- Multiple reading
- Data transfer speed
- Secured information
- Large storage capacity
- Read / Write
- More robust
- Smaller
- Reusable
- Sensors, etc…

- Cheap
- Simple
- Feasible expectations…

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Did it work?

The Walmart mandate (2003)

Wal-Mart Expands RFID Mandate

The world's largest retailer says that it will ask *all* suppliers to tag pallets and cases by the end of 2006.

By Bob Violino

Tags: Manufacturing, Retail, Standards

PDF | Email | Print | Definitions | Save Article

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Aug 17, 2003—Aug. 18, 2003 – If anyone still has any doubts that Wal-Mart is serious about deploying RFID technology in its supply chain, they should be dispelled by its latest revelation. The world's largest retailer says it will require all suppliers to put RFID tags carrying Electronic Product Codes on pallets and cases by the end of 2006.

"We have asked our 100 top suppliers to have product on pallets employing RFID chips and in cases with RFID chips," says Wal-Mart spokesman Tom Williams. "By 2006, we will roll it out with all suppliers."

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Did it work?

The Walmart mandate (2007-2009)

October 2007: Wal-Mart announces a major change in its RFID strategy, largely abandoning the initial pallet/case focus on shipments going to Wal-Mart stores in favor of three focus areas: (1) shipments going to Sam's Club; (2) promotional displays and products going to Wal-Mart stores; (3) tests to see RFID's impact in improving category management in select areas. "We're coming at RFID from a different angle," Wal-Mart's VP of Information Technology, **Carolyn Walton**, says at the EPC Global conference.

January 2008: Wal-Mart announces its first real compliances "penalties" for failure to tag products, specifically for shipments to its Sam's Club chain. Wal-Mart says in letter to suppliers that a failure to tag pallets sent to its distribution center in DeSoto, Texas, or directly to one of its stores served by that DC after January 31 will be charged a service fee, starting at $2 per untagged pallet on Feb. 1, and capping at $3 per pallet on Jan. 1, 2009.

Wal-Mart also announced its plans for the Sam's Club rollout (later changed):

- Jan 30, 2008: pallet-level tagging for DeSoto, Tex., distribution center.
- Oct. 31, 2008: pallet-level tagging for an additional four distribution centers, case- and mixed-pallet level tagging for Texas distribution center.
- Jan. 30, 2009: pallet-level tagging for remaining 17 distribution centers, case- and mixed-pallet level tagging for an additional four distribution centers.
- Oct. 31, 2009: case- and mixed-pallet level tagging for the remaining 17 distribution centers; selling-unit -level tagging for Texas distribution center.
- Jan. 30, 2010: selling-unit-tagging for an additional four distribution centers.
- Oct. 31, 2010: selling-unit-tagging for remaining 17 distribution centers

January 2009: Sam's Club dramatically lowers penalties for failure to tag pallets from $2-3 dollars per pallet to just 12 cents – what Wal-Mart estimates it will cost Sam's to do the tagging itself. It also pushes back the rollout schedule announced the previous January, saying the tagging requirement will apply only to pallets sent to the DeSoto DC or stores served by that DC in 2009. DC. Pallet-level tagging is expected to be rolled out chain-wide in 2010, while the deadline for tagging sellable units is "under review."

February 2009: Procter & Gamble says that after "validating" the benefits of RFID in merchandising and promotional displays, it is ending its pilot program with Wal-Mart for those displays, implying Wal-Mart is not acting on the information to improve store execution.

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Why these failures?

The technology performances

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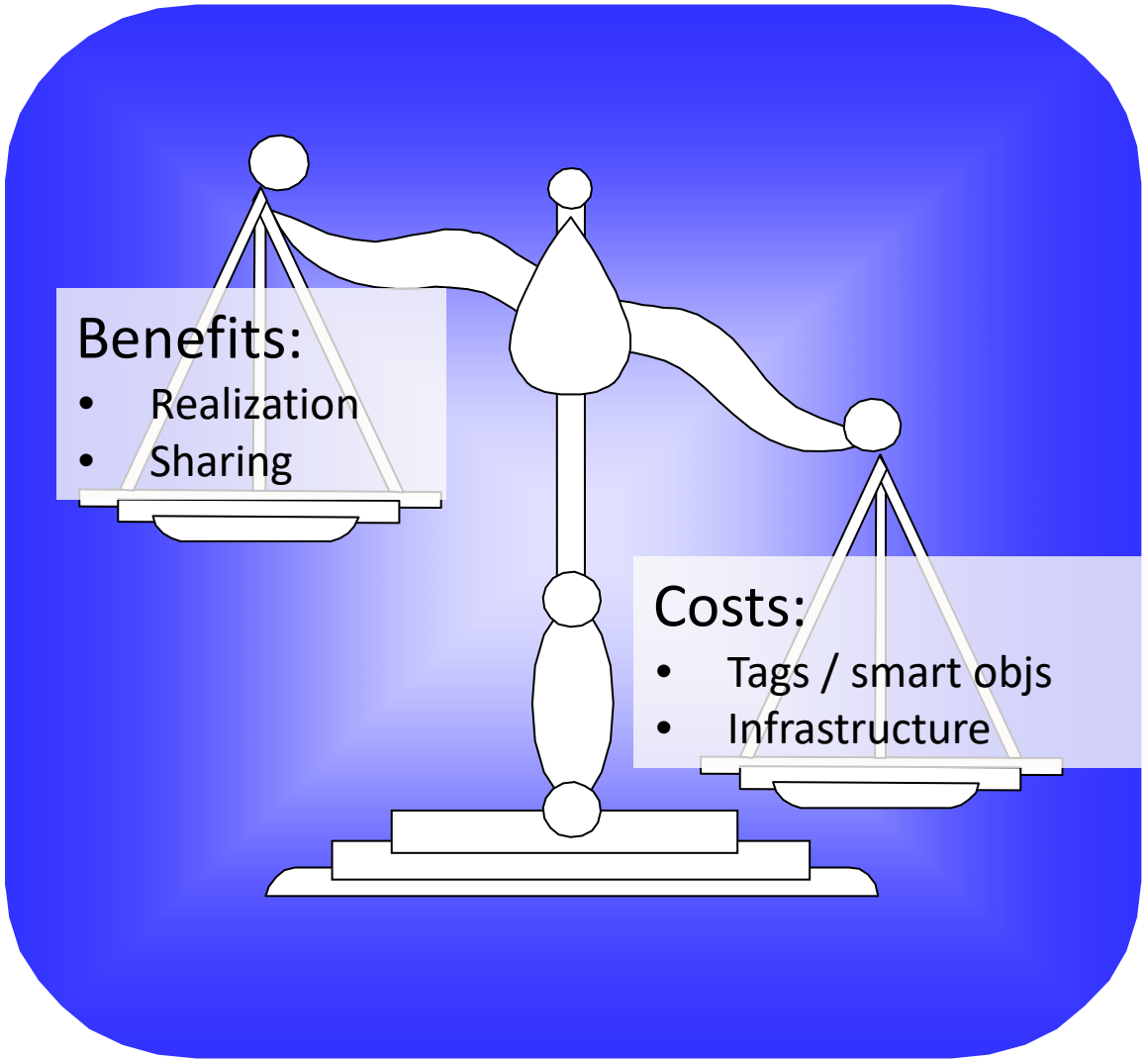
Why these failures?

The business reasons



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Why these failures?

The technology architecture

Level 3

Data center and application

- ❑ Network management platforms
- ❑ Data storage and elaboration

Level 2

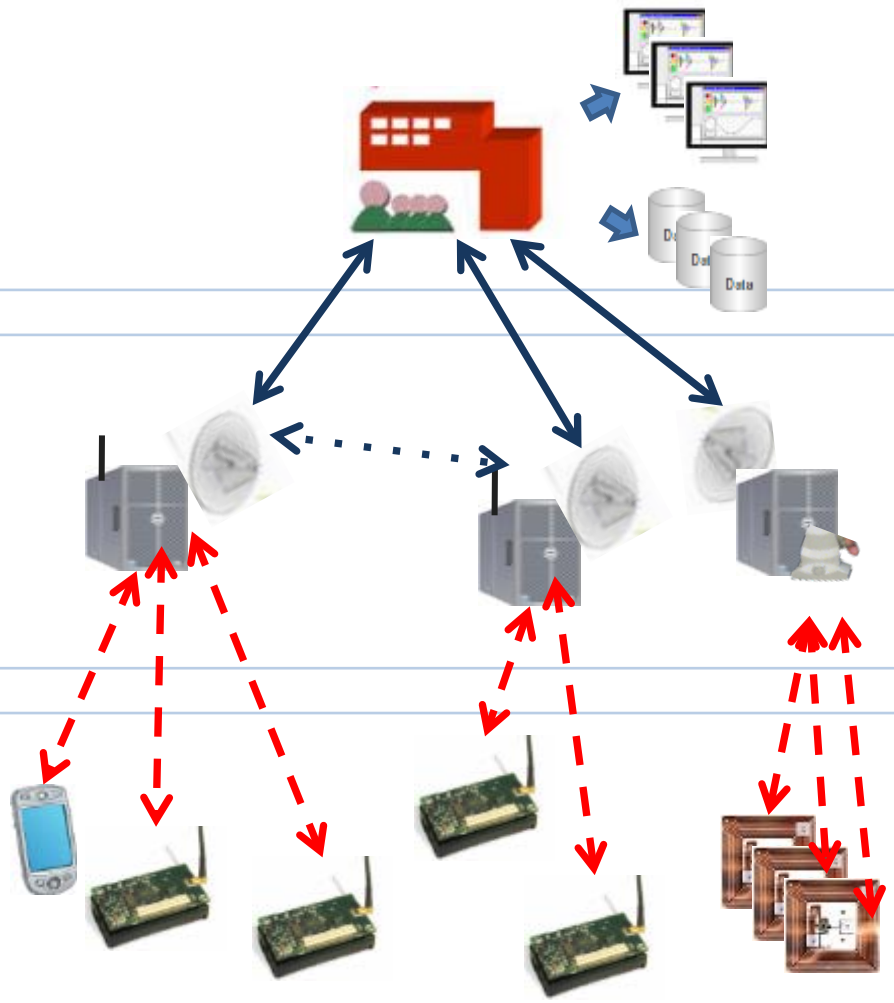
Mediation

- ❑ Gateway, repeaters

Level 1

Sensors and nodes

- ❑ Smart objects
- ❑ Widespread and pervasive
- ❑ Energy and/or band limitations



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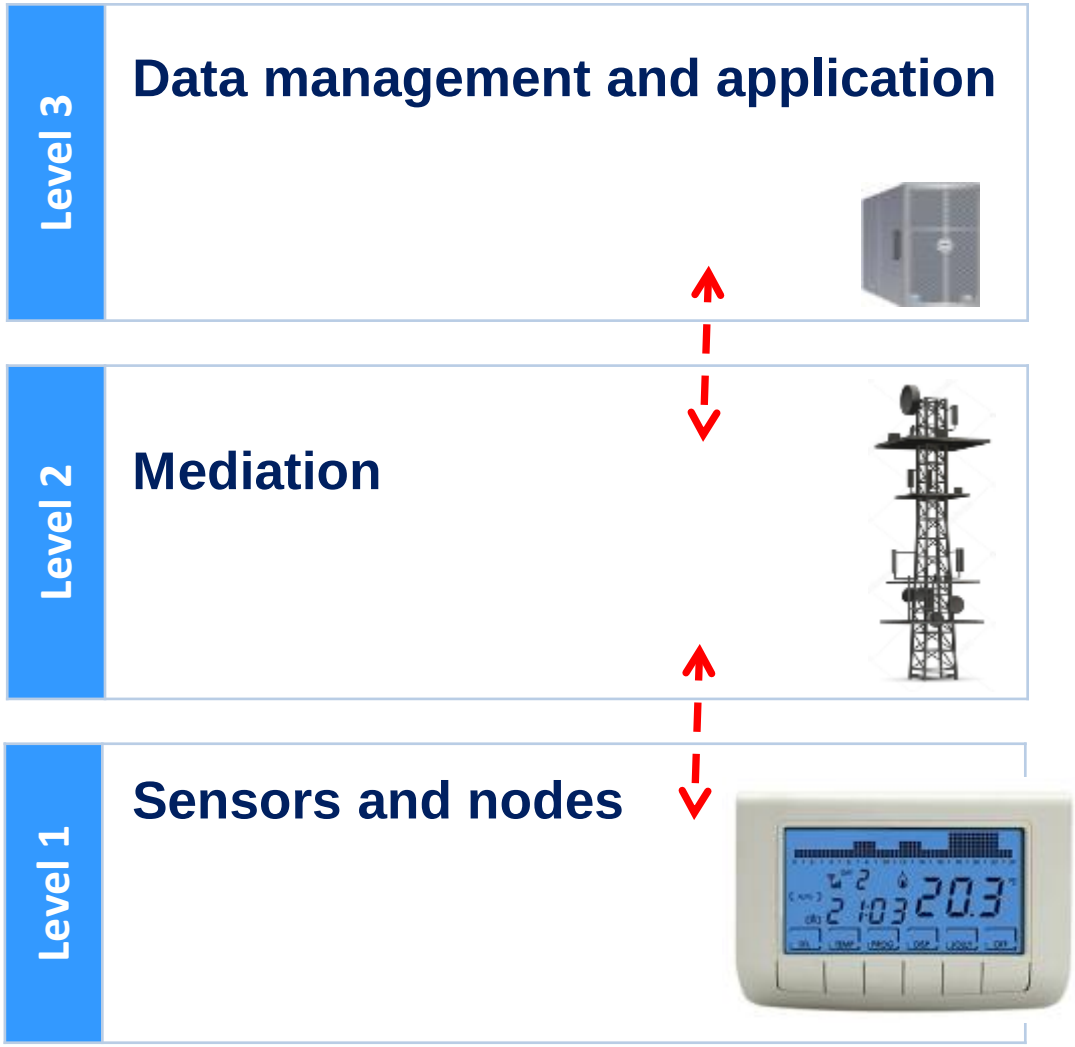
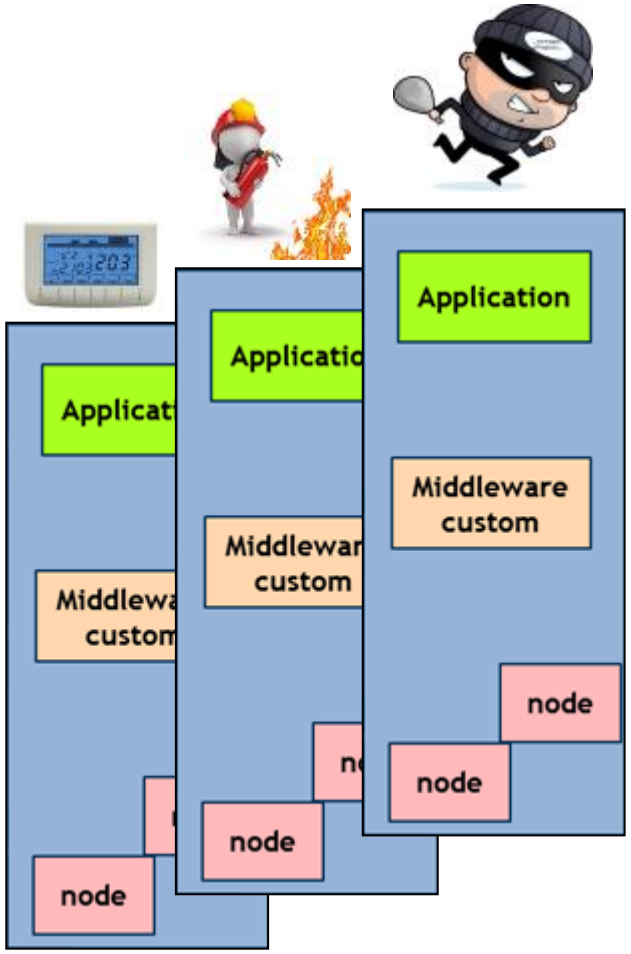
Why these failures?

The technology architecture





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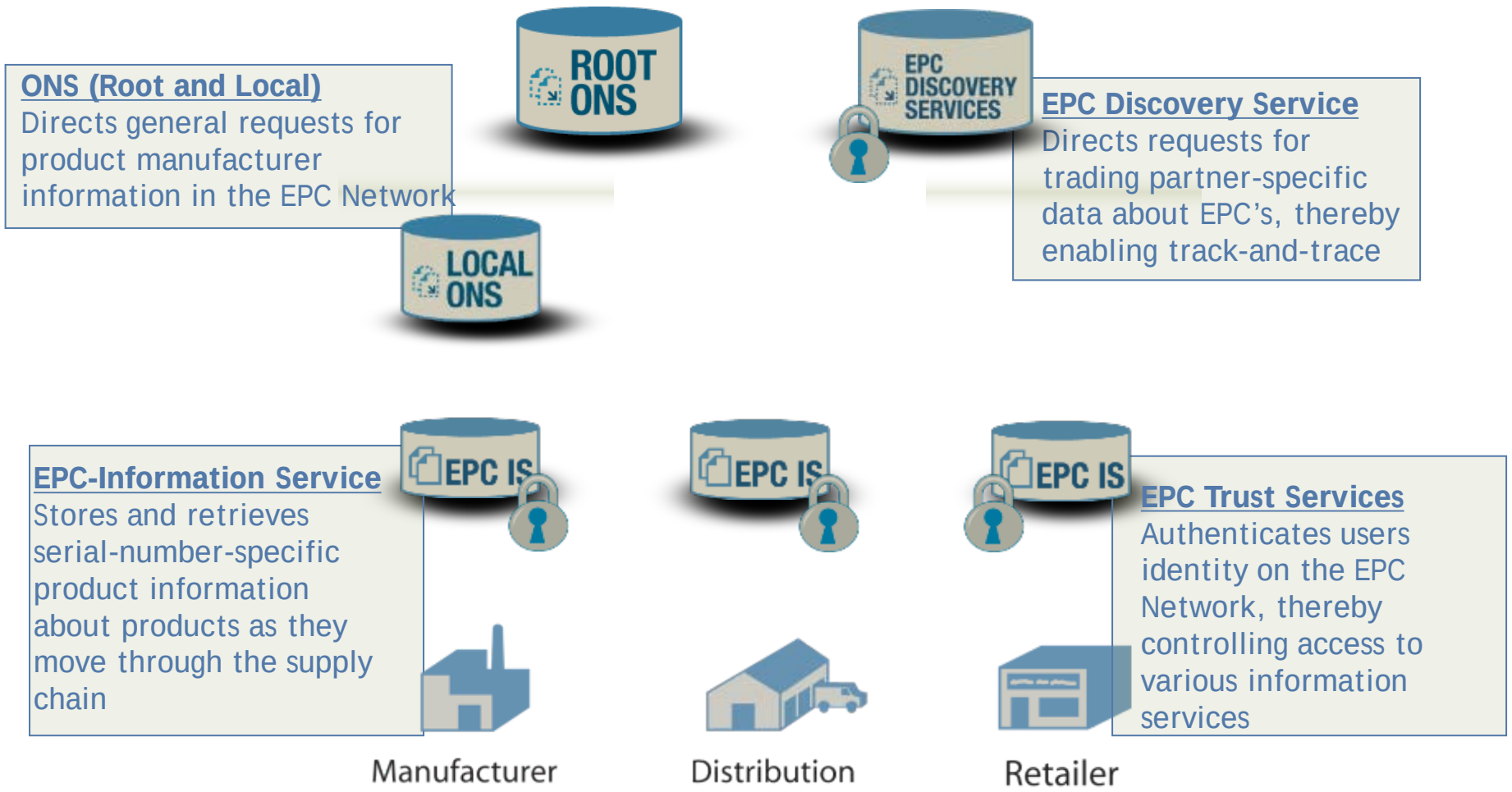
Something good…

The baby IoT (courtesy of EPC / Auto Id, 1999)



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What has changed in 15 (exciting!) years

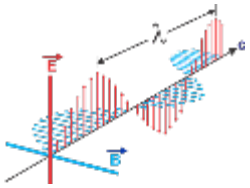
HW & Technology – New Sensing

New Sensors

New Sensing

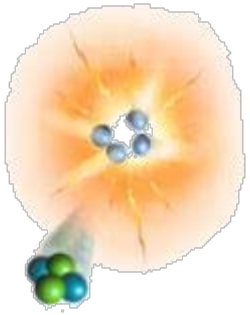
Video analysis

Electromagnetic field



Network devices

Sensing fusion



Sound and vibrations

Smart meters

Connected appliances

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What has changed in 15 (exciting!) years

HW & Technology – New Sensing

- What does "sensors" mean?

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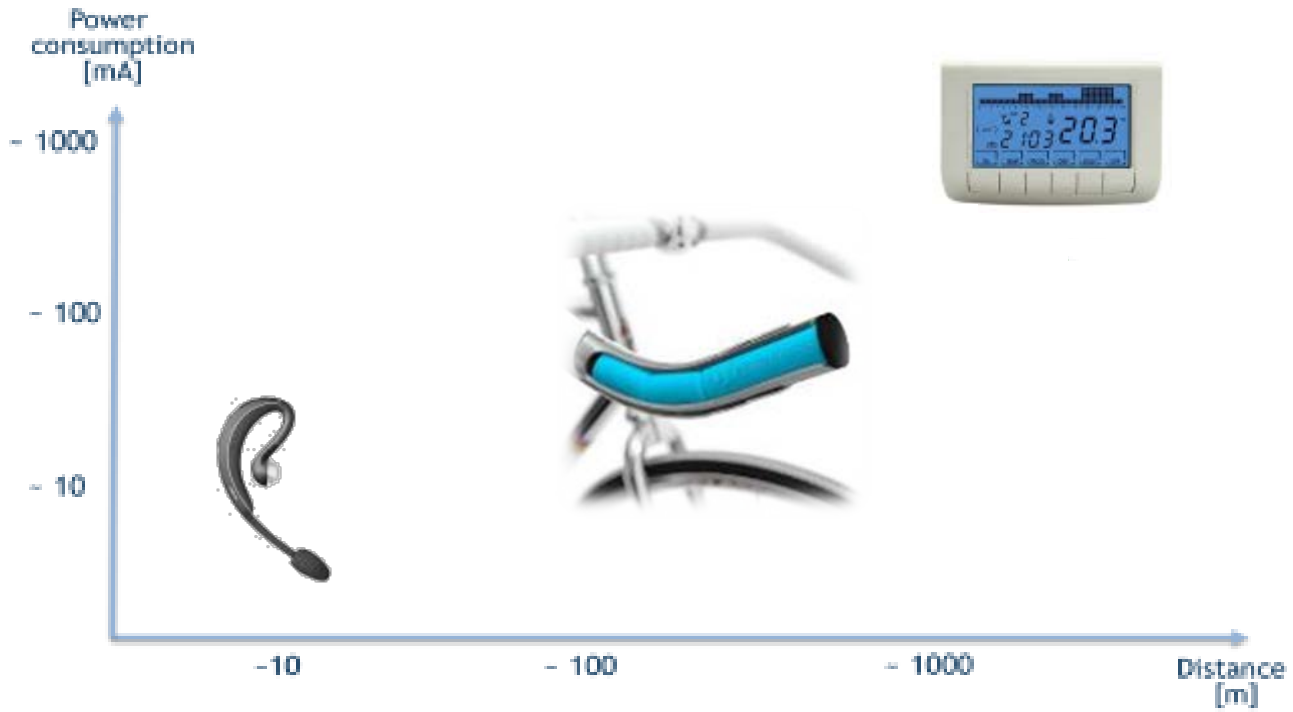
What has changed in 15 (exciting!) years

New networks



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What has changed in 15 (exciting!) years

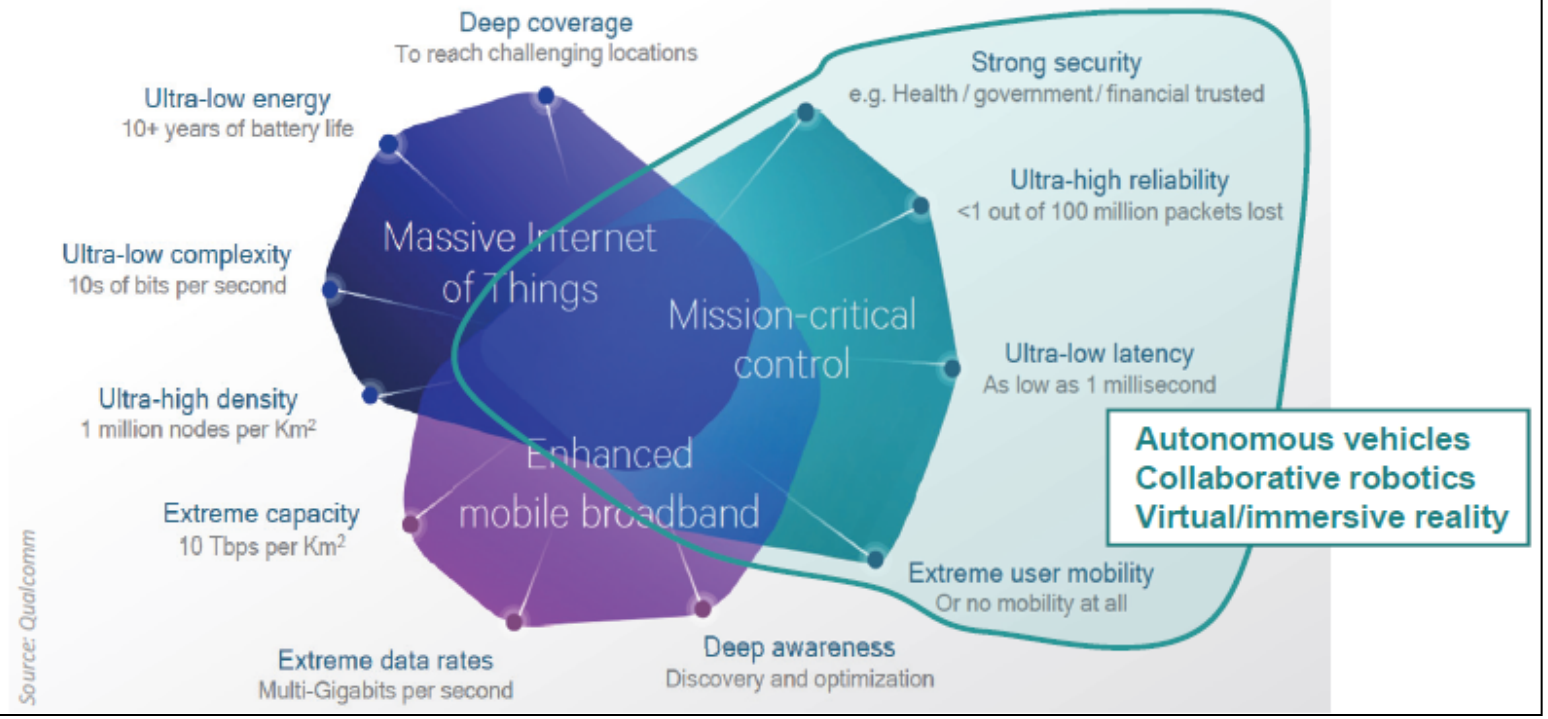
New networks: please welcome 5G

Industry-compliant 5G features

- mm-wave access, massive MIMO
- Network densification
- Slicing
- Mobile edge computing

Tactile Internet

- Ultra-low latency (down to 1ms)
- Ultra-high reliability (down 10^{-8})
- High access speed (Gb/s)



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What has changed in 15 (exciting!) years

New processors

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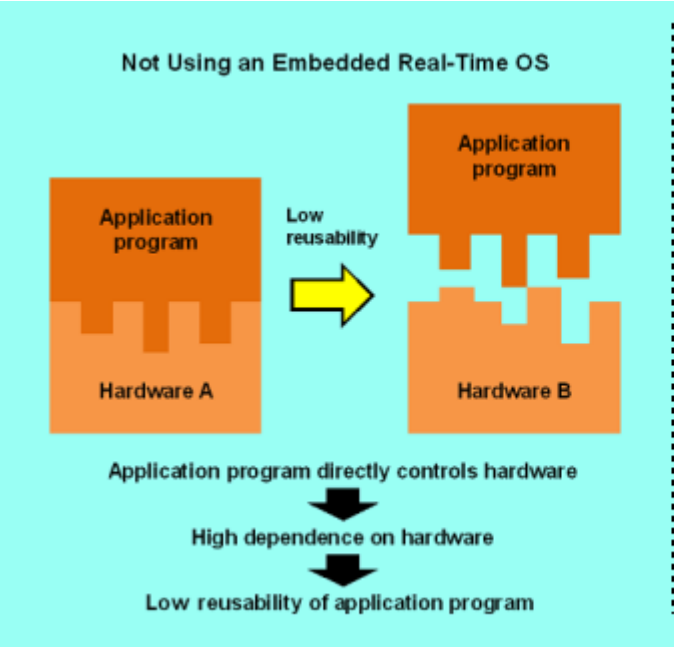
What has changed in 15 (exciting!) years

The advent of real time OS

- End-devices/sensors become capable to run Operating Systems
- Why is this important?



"Outsource" generic tasks to the OS (ex: connectivity, security, sensors, …)

Focus on the **application**!

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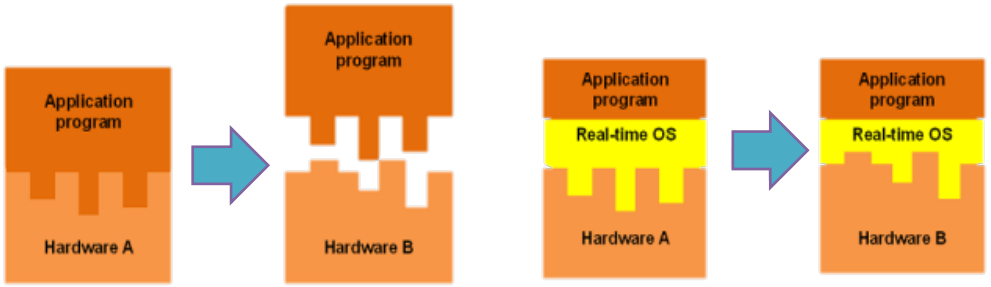
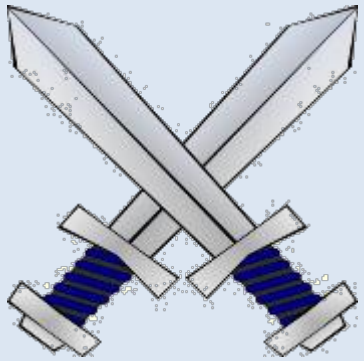
What has changed in 15 (exciting!) years

The advent of real time-OS



The battle for Real Time-OS



Open Source (RT)OS

RIOT OS

Linux

freeRTOS

ARMmbed

Offerte dei big players

Windows 10 IoT

Embedded Apple iOS

Weave

RTOS Commerciali

Nucleus RTOS

WindRiver VxWorks

Green Hills Integrity

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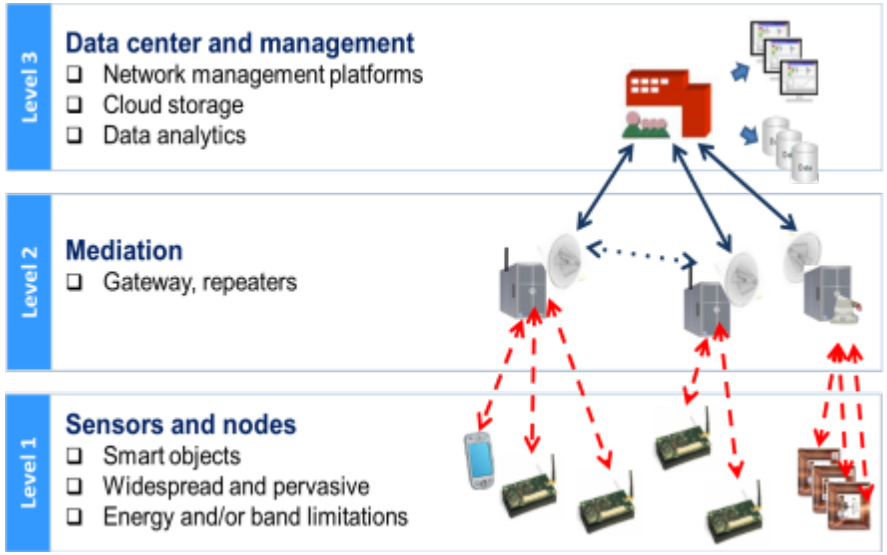
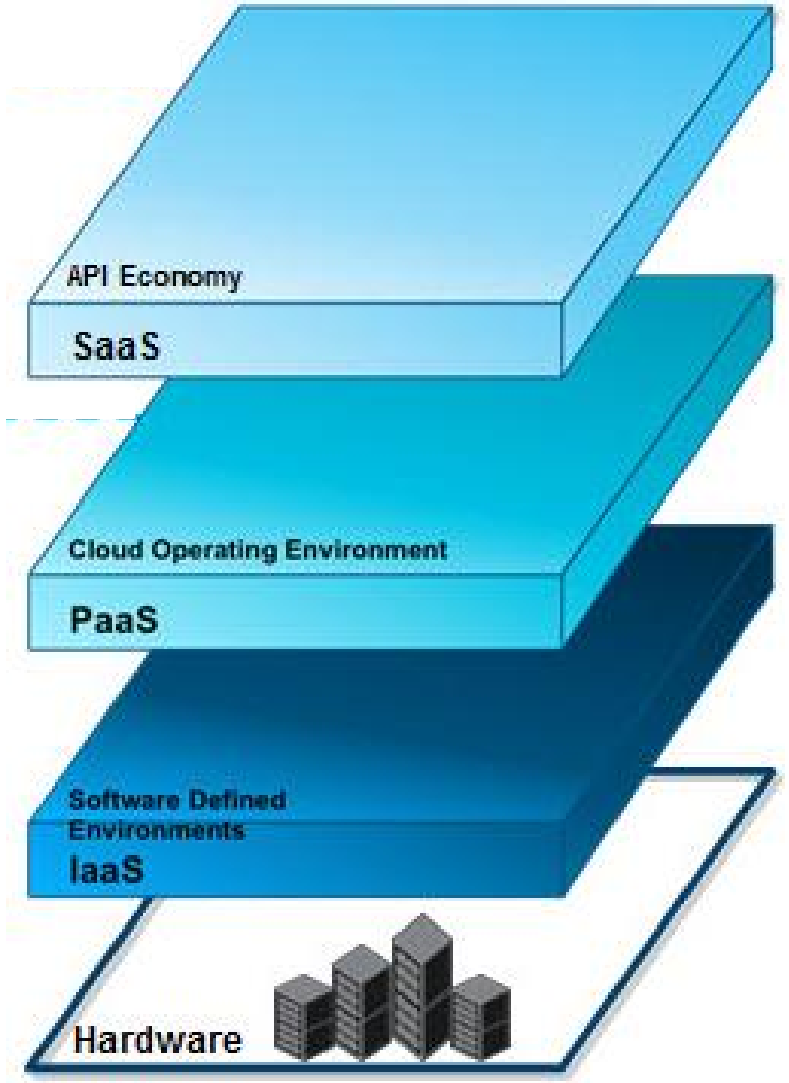
What has changed in 15 (exciting!) years

IoT Platforms





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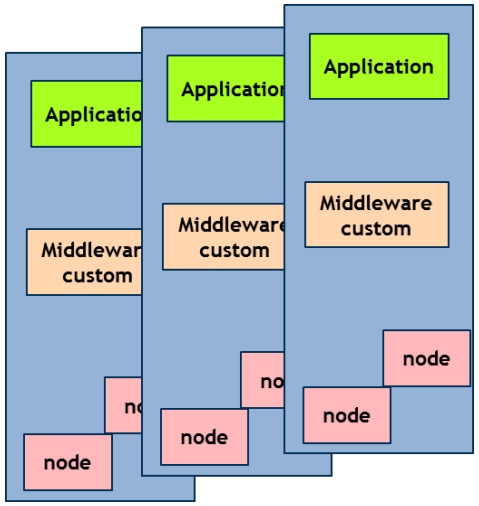
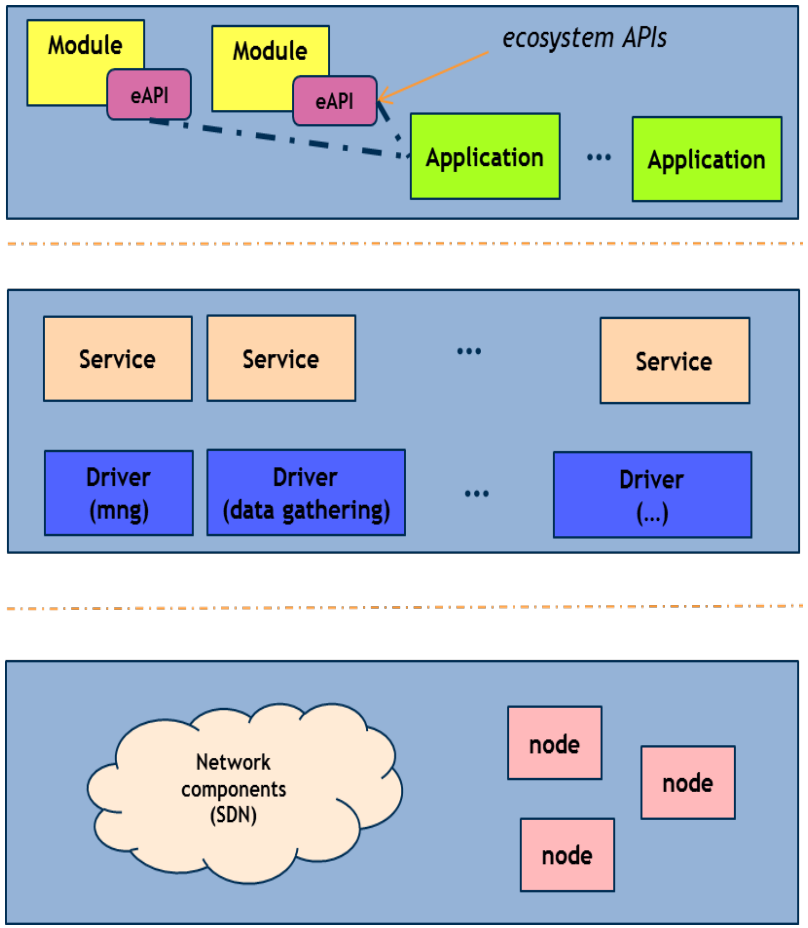
What has changed in 15 (exciting!) years

IoT Platforms (special thanks to cloud!)

From a *vertical* to a *horizontal approach*





Apps and/or Micro-services

Service Platforms delivered in the cloud

Virtualized interchangeable hardware

Cheap and fast development

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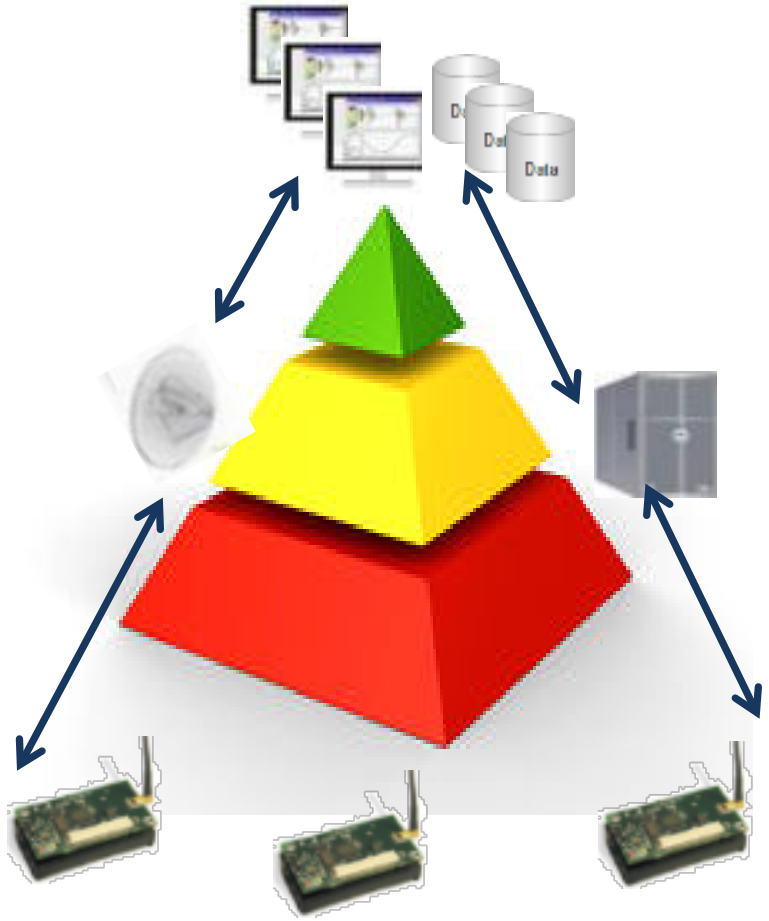
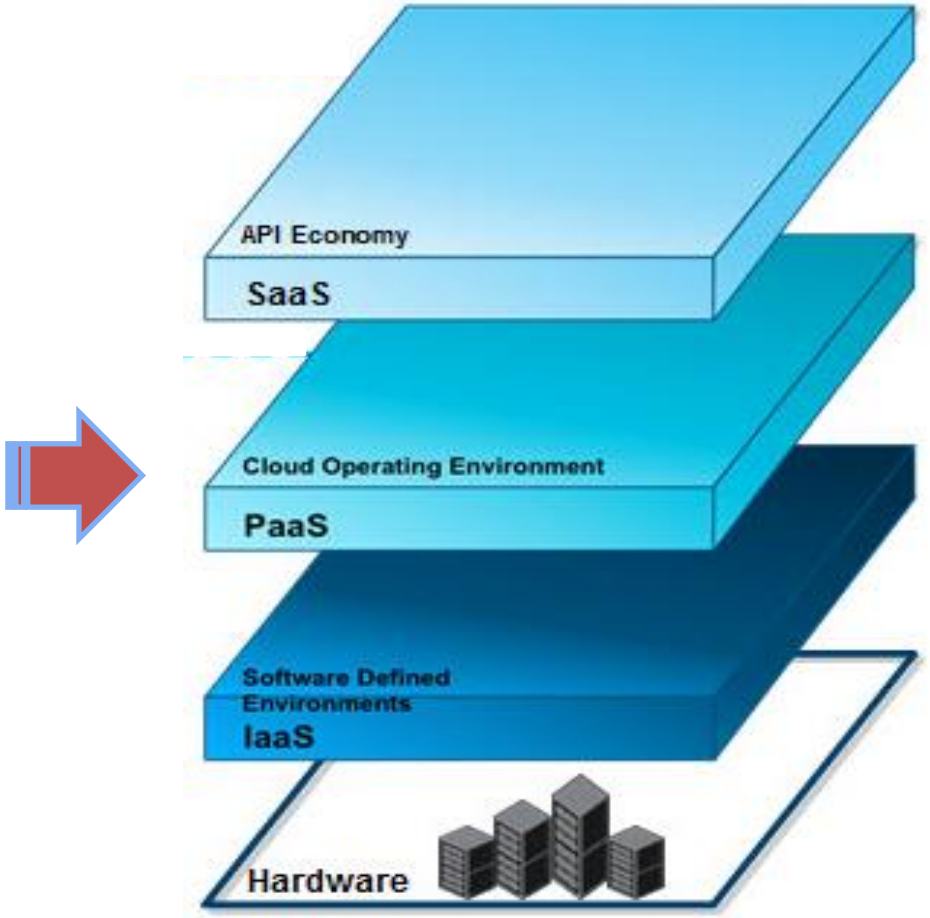
What has changed in 15 (exciting!) years

IoT Platforms (special thanks to cloud!)





Ecosystem of applications

Cloud platforms to manage and access to data

Field devices with Real-Time OS

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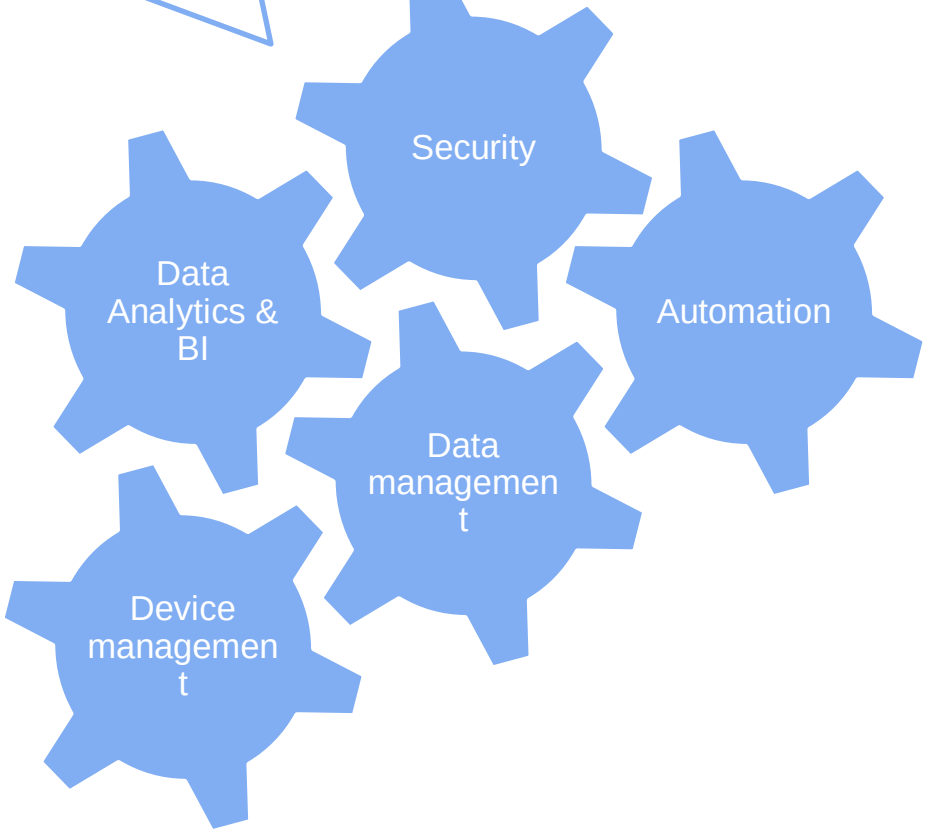
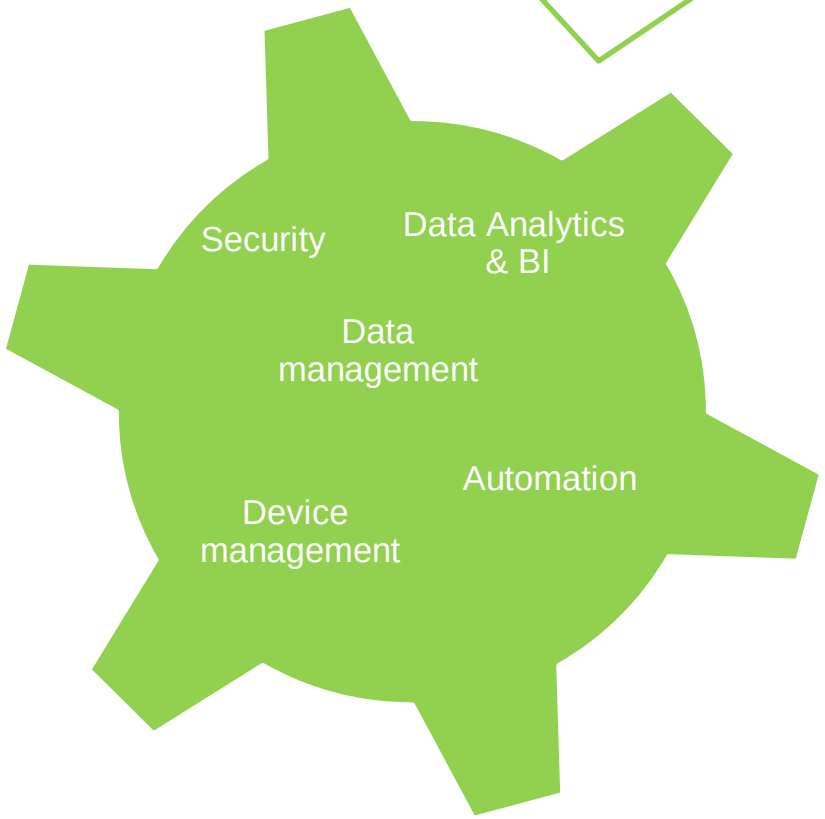
What has changed in 15 (exciting!) years

IoT Platforms (special thanks to cloud!)

Specialized Platforms:
one main feature



General Platforms:
every feature, with different degrees of completeness



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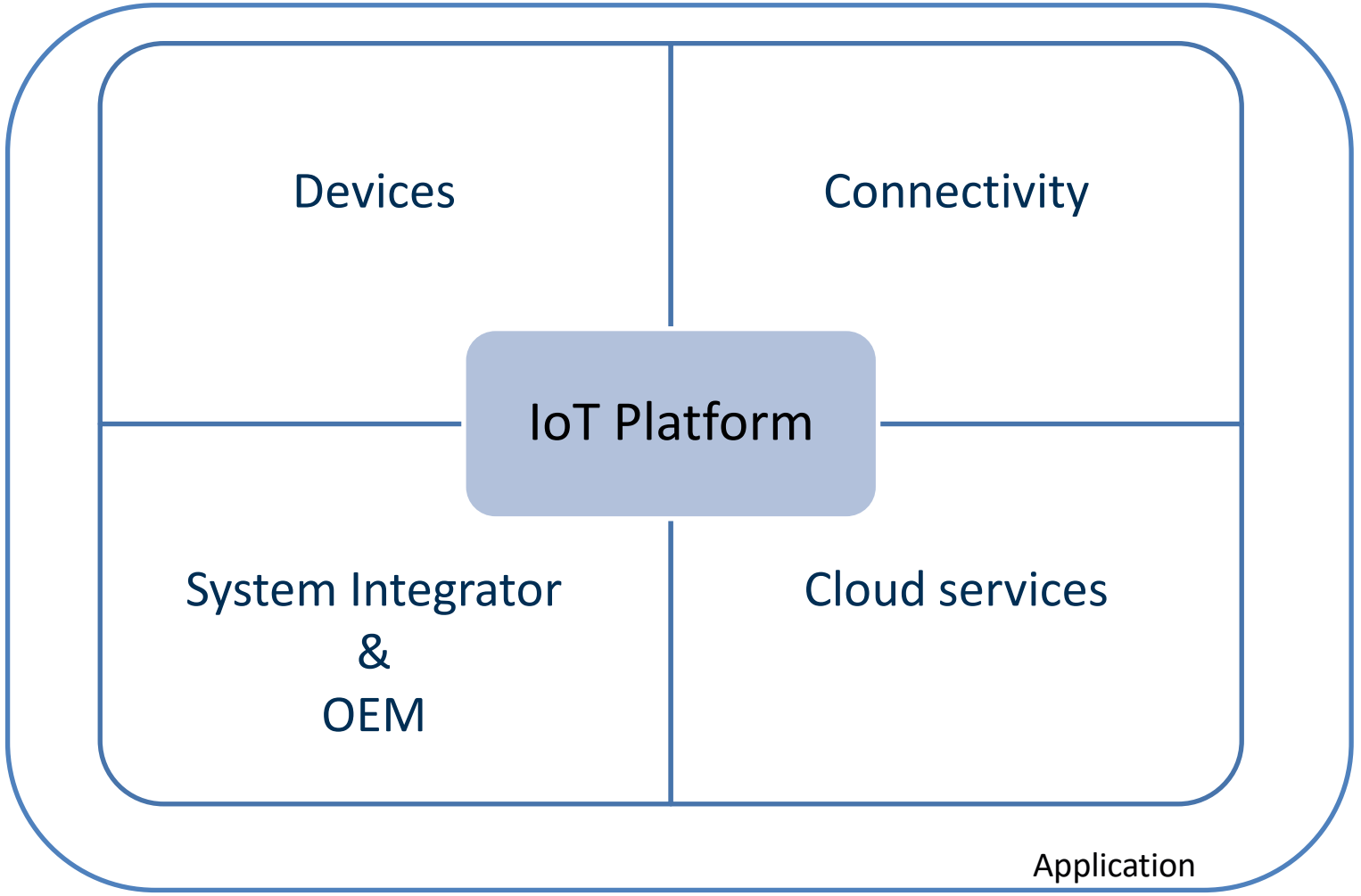
What has changed in 15 (exciting!) years

IoT Platforms (special thanks to cloud!)



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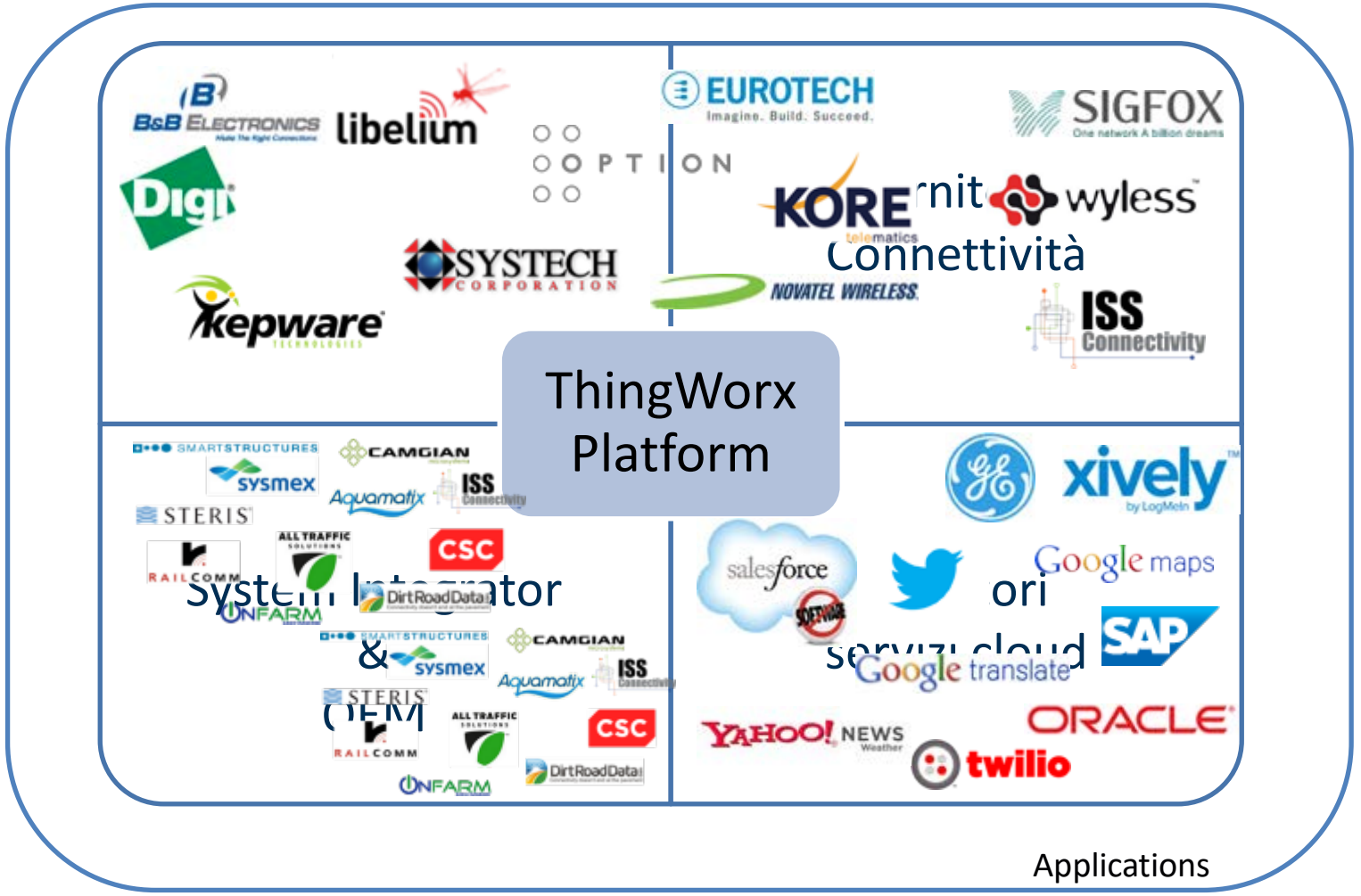
IoT Platforms (special thanks to cloud!)



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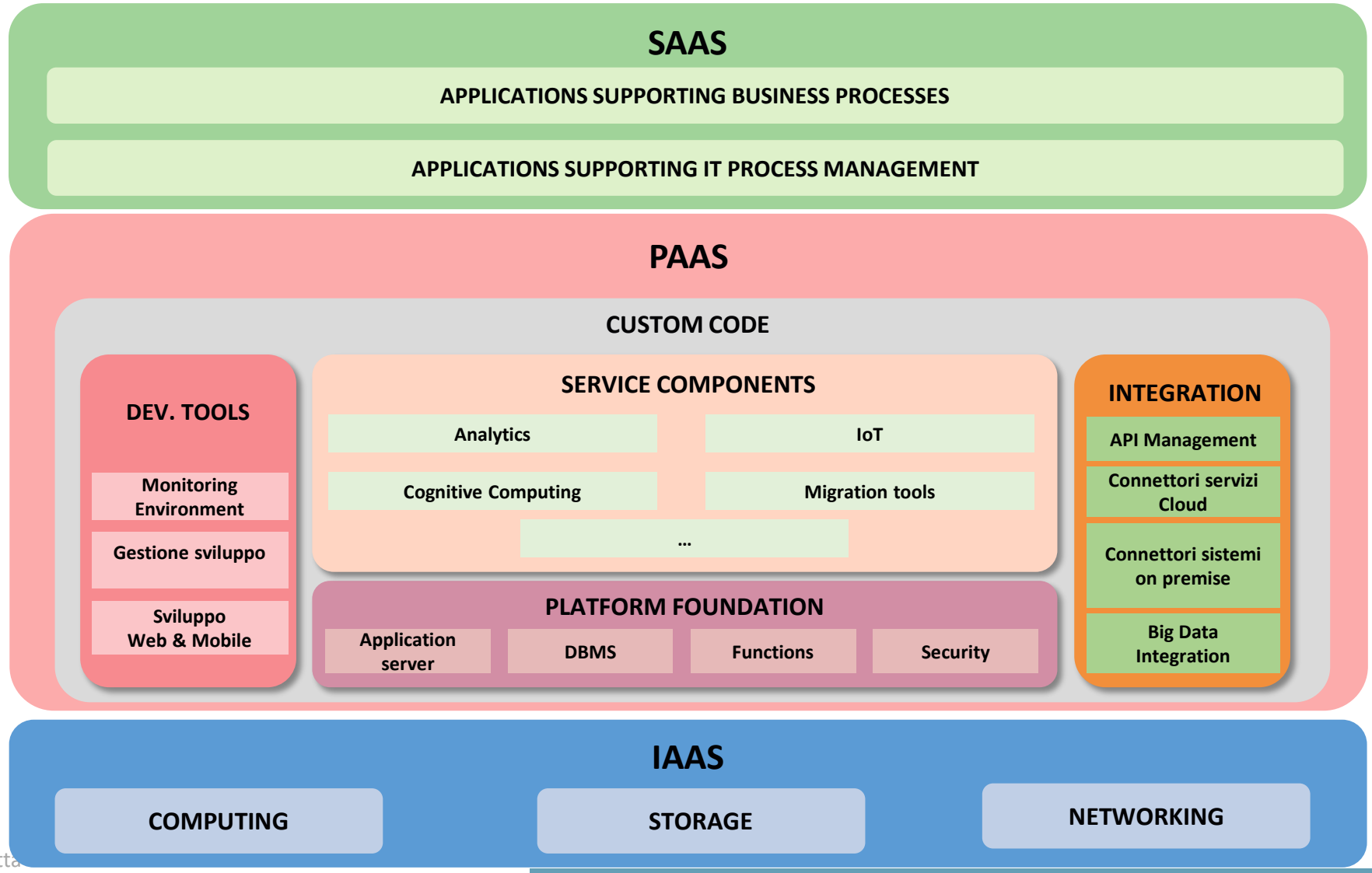
What has changed in 15 (exciting!) years

IoT Platforms (special thanks to cloud!)



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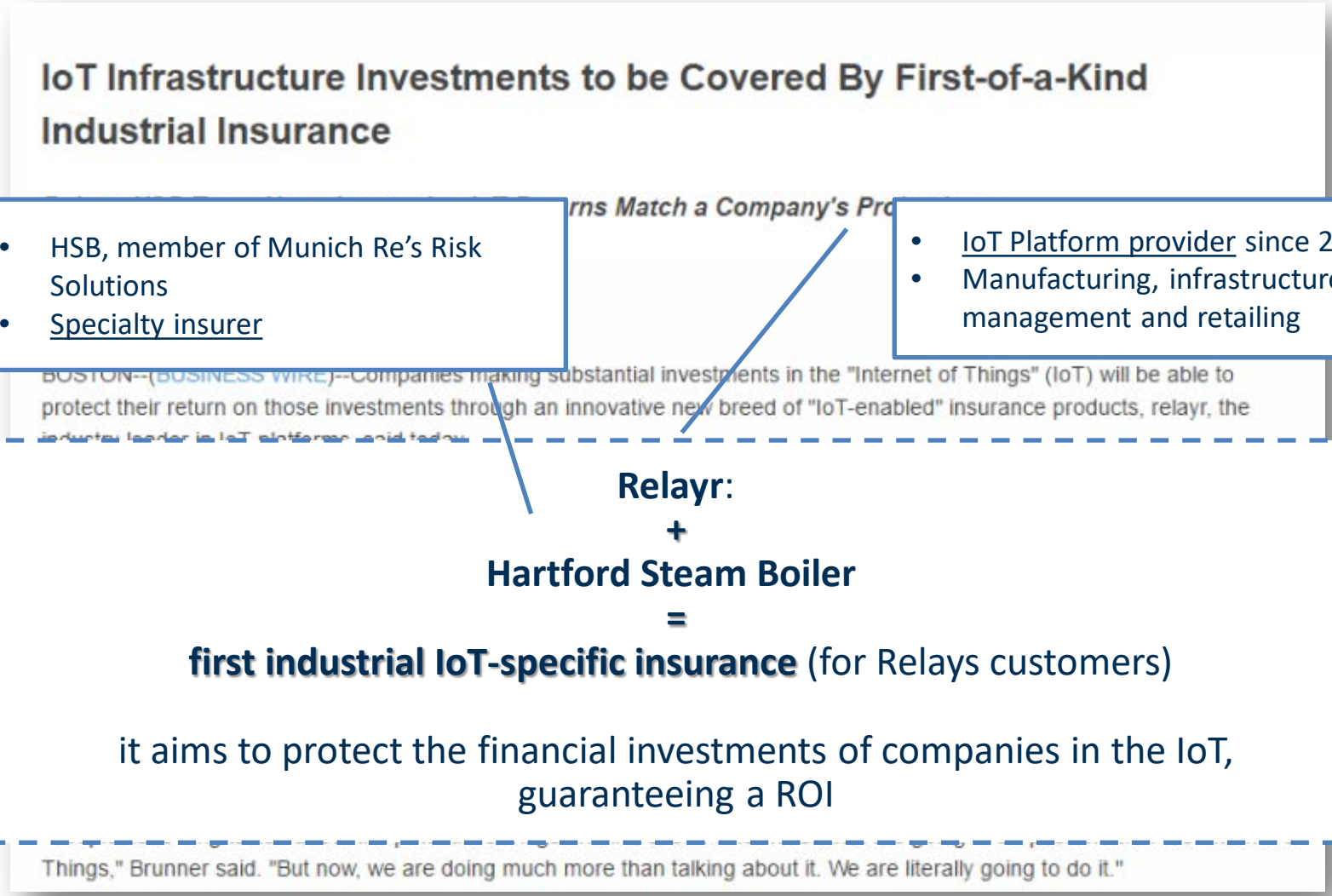
What has changed in 15 (exciting!) years

IoT Cloud Platforms services



- HSB, member of Munich Re's Risk Solutions
- Specialty insurer

- IoT Platform provider since 2013
- Manufacturing, infrastructure management and retailing

Relayr:

+

Hartford Steam Boiler

=

first industrial IoT-specific insurance (for Relays customers)

it aims to protect the financial investments of companies in the IoT, guaranteeing a ROI

https://www.munichre.com/HSB/relayr/index.html

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Now IoT means business…

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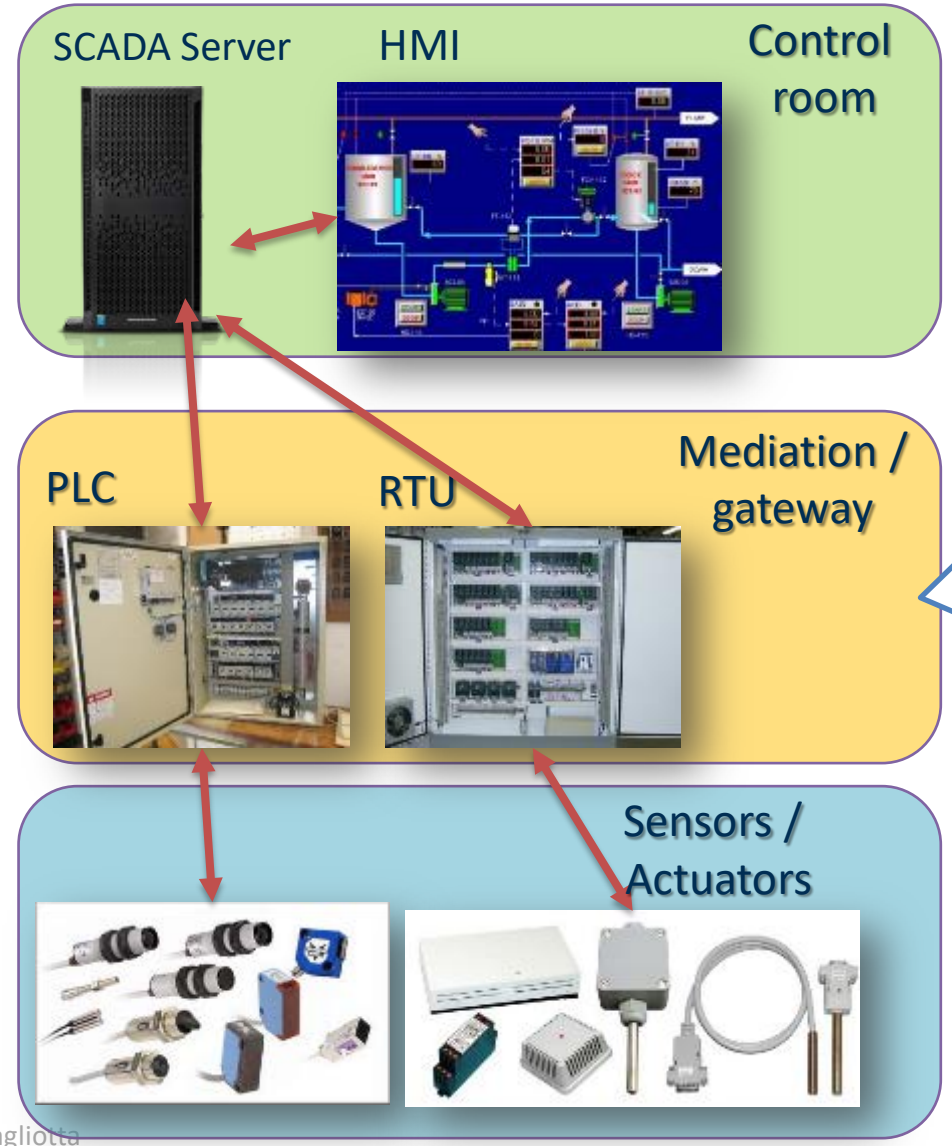
Nowadays Smart Factory

IT-OT convergence



- Single-vendor Hardware
- Scalability constrained by physical available connections (Controller I/O ports)
- Local-only-accessible dashboards
- Data confined within the SCADA system, connections with other systems to be custom-made

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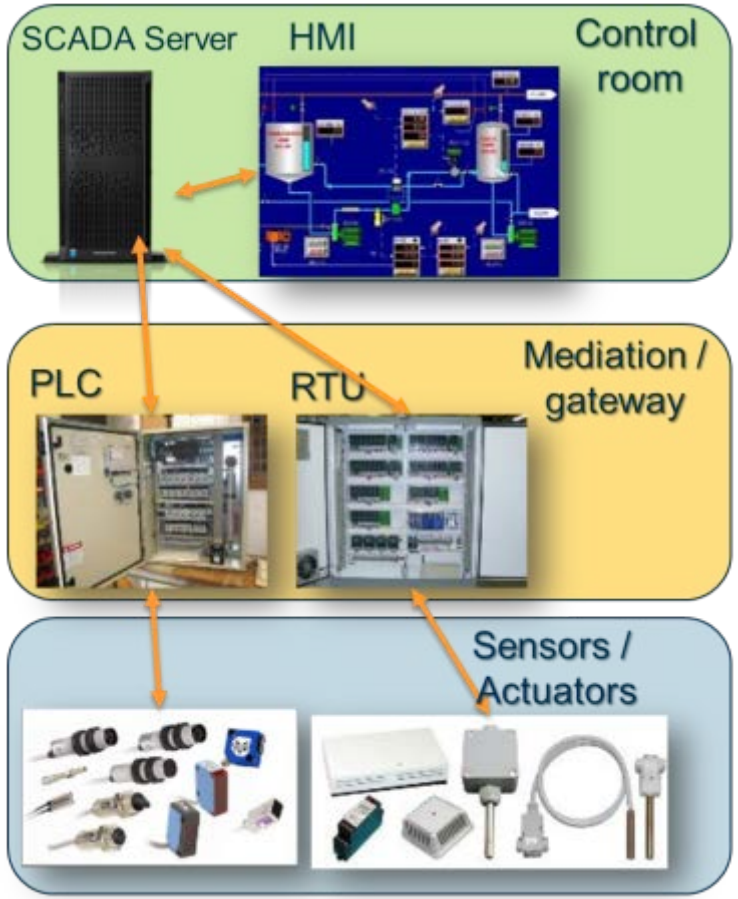
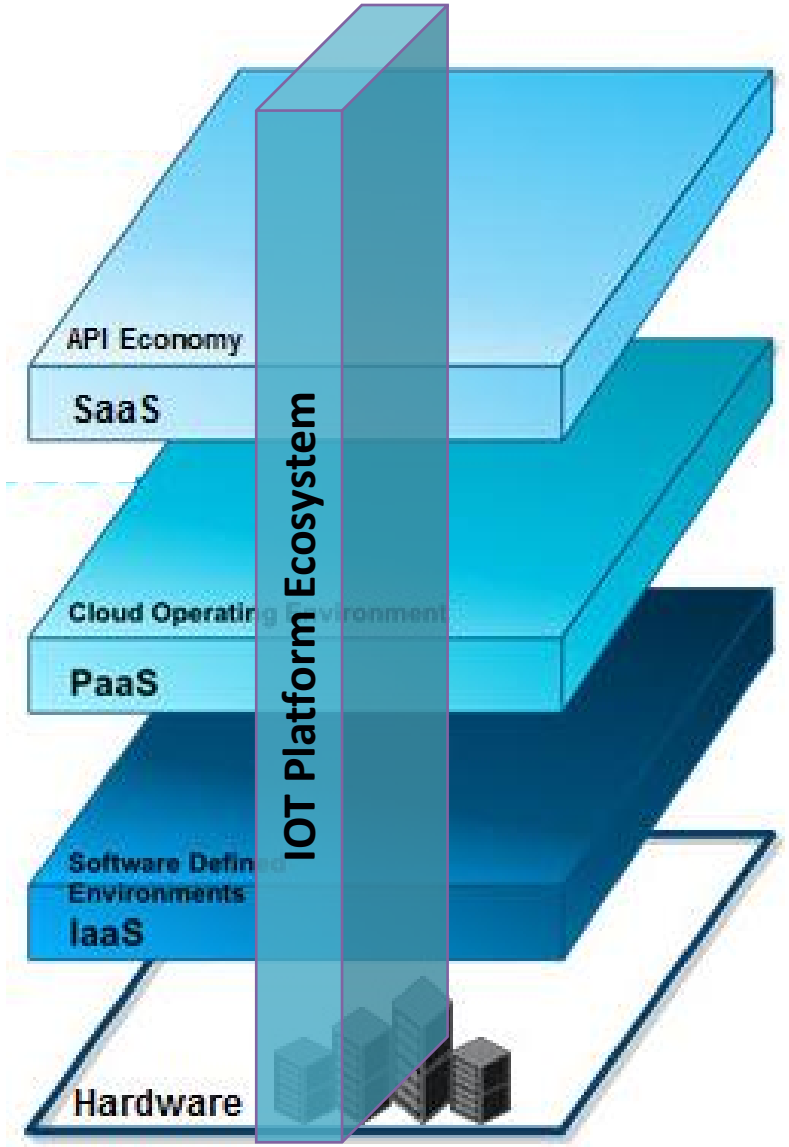
Nowadays Smart Factory

IT-OT convergence





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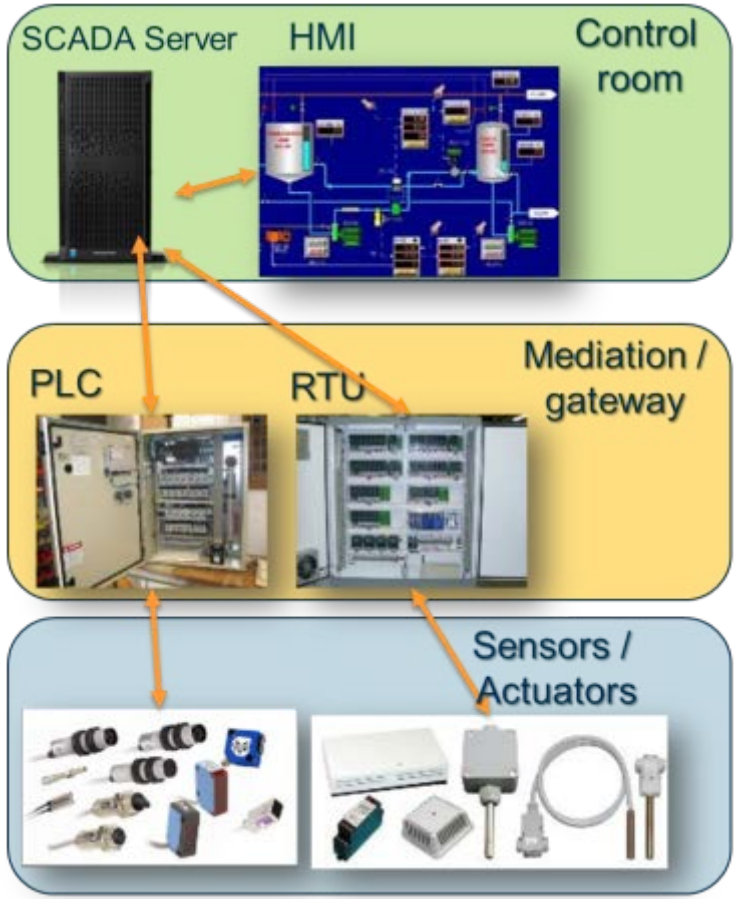
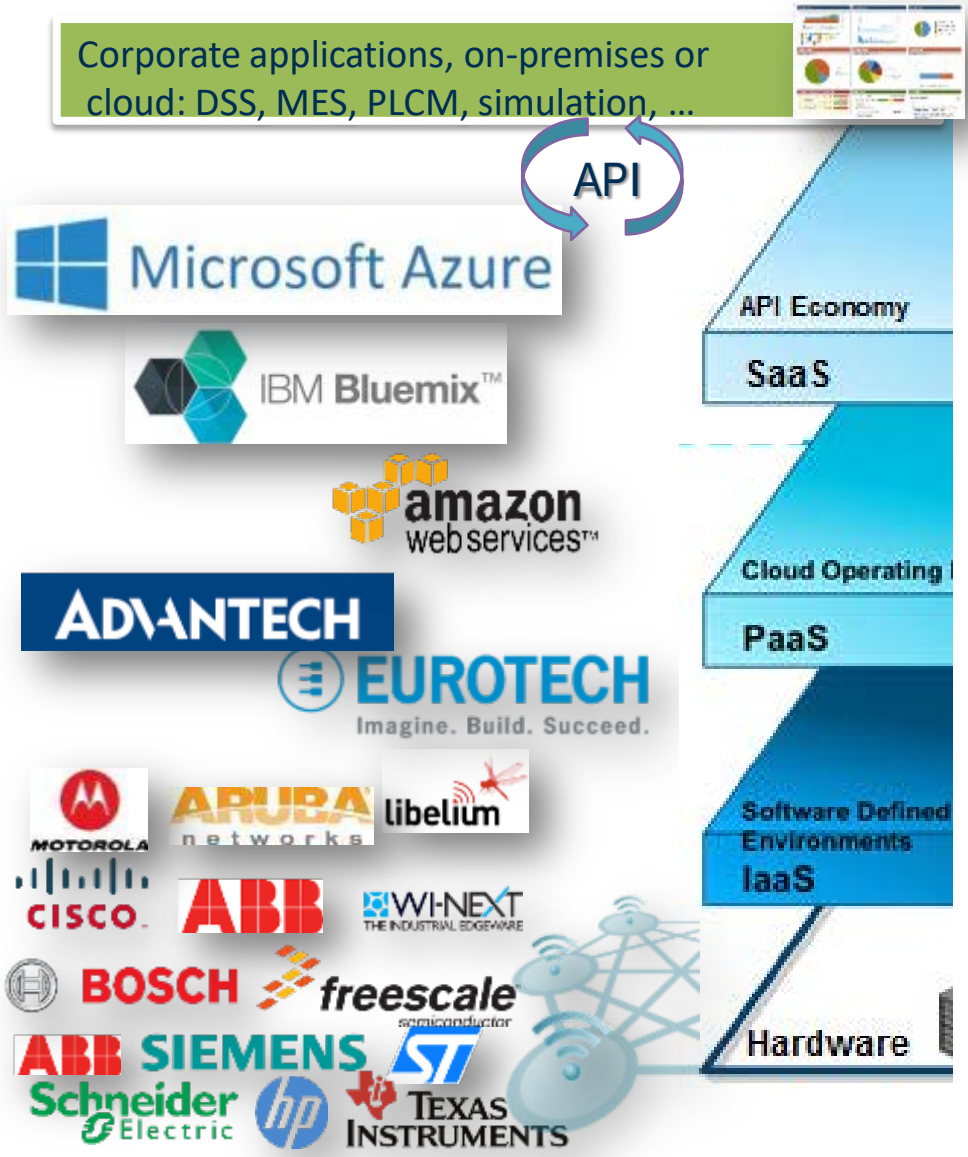
Nowadays Smart Factory

IT-OT convergence





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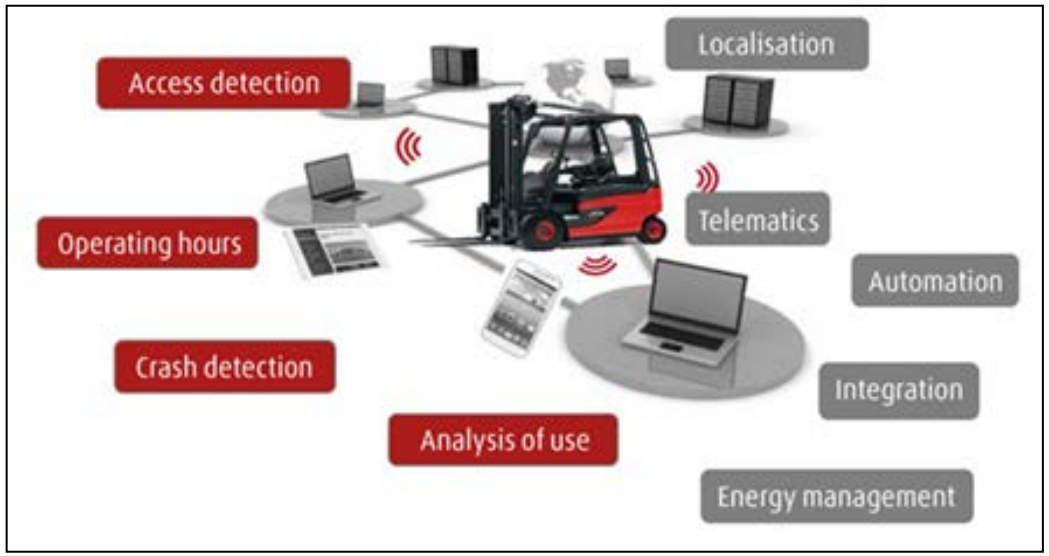
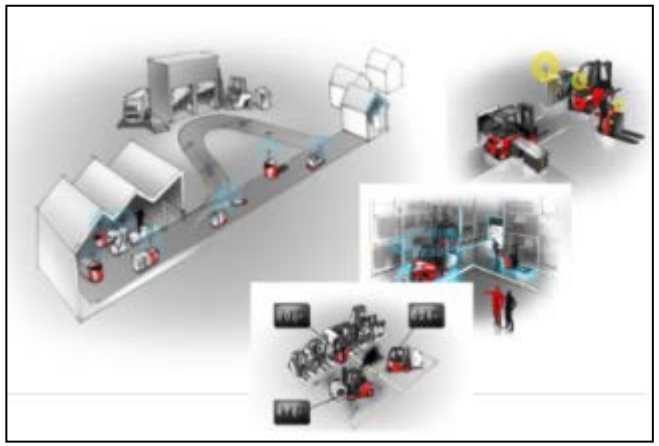
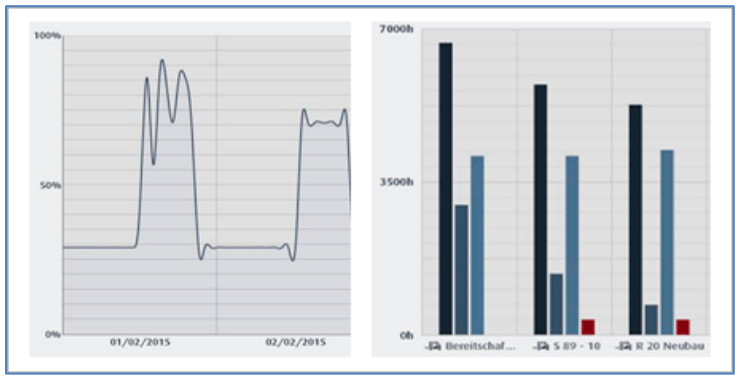
Nowadays Smart Factory

Tracking Fleets: the Lindte project







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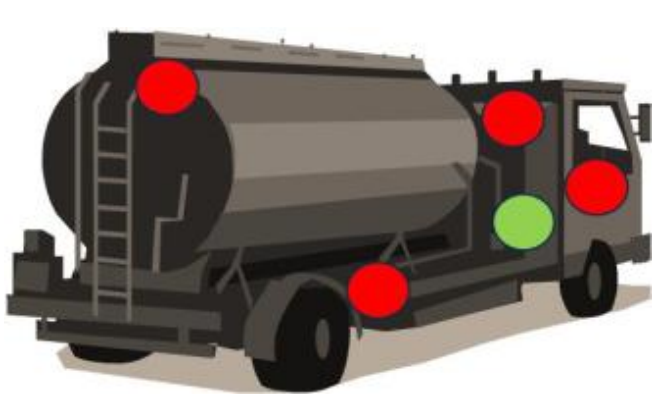
Nowadays Smart Supply Chain

Tracking Fleets: the ENI project



Objective: monitoring of a large fleet of tankers, anti-theft, anti-tampering

Sensing:

- GPS (**location**)
- ECU GPRS mirroring (**failures, engine on/off, pumps on/off**)
- Shock absorbers elongation (**payload stock and variation**)

Functionalities:

- Traditional fleet management
- Unscheduled stoppages, with or without payload variations

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Nowadays Smart Supply Chain

RFId at work: Decathlon Europe

Successful applications:

- POS management (inventory control, replenishment, anti-shoplifting)
- SC tracking & tracing

Is it profitable?

Miragliotta et. al, 2011, RFId adoption in the FMCG supply chain: an interpretative framework", Supply Chain Management: An International Journal

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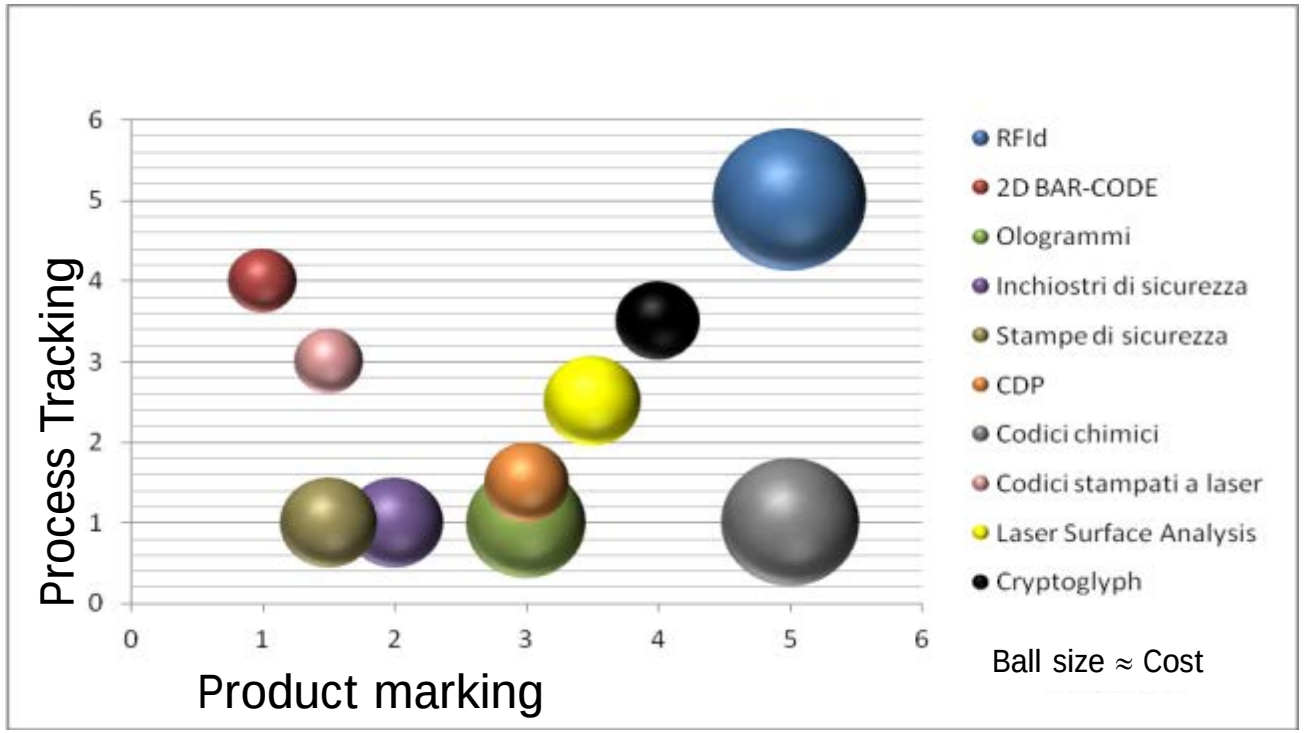
Nowadays Smart Supply Chain

RFId at work: GLOW project



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Agenda

- Foreword
- Technologies for the Extended Enterprise
- Data Architecture
- Benefits Evaluation
- Q&A

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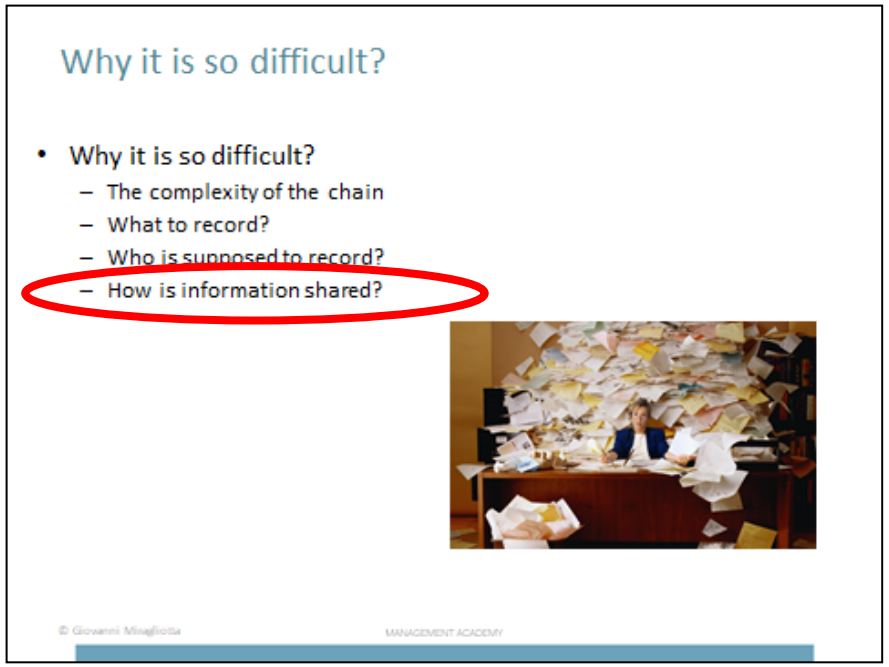
Data architecture



Use available standards

Make your own, and draw in anybody

Align to industry practices
(standards de facto)

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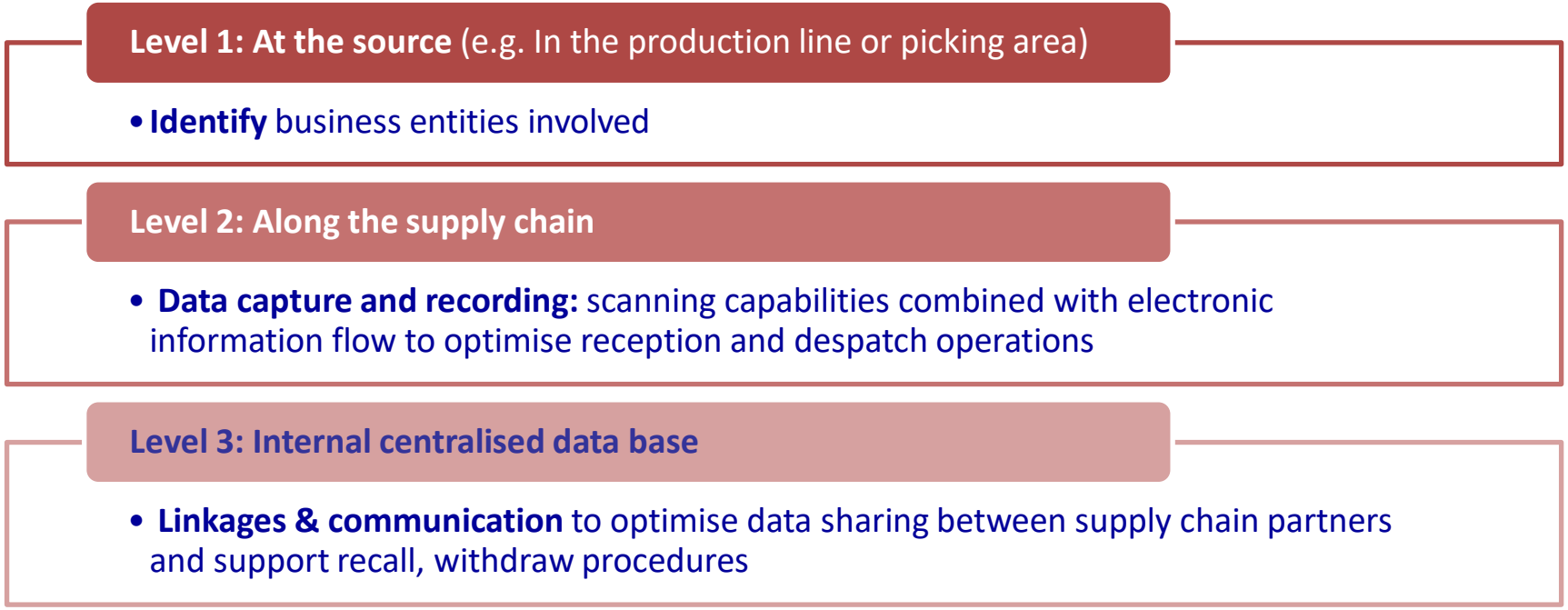
Traceability process: the GS1 EPC Architecture

- The traceability process consists of the implementation of three key sub-processes:



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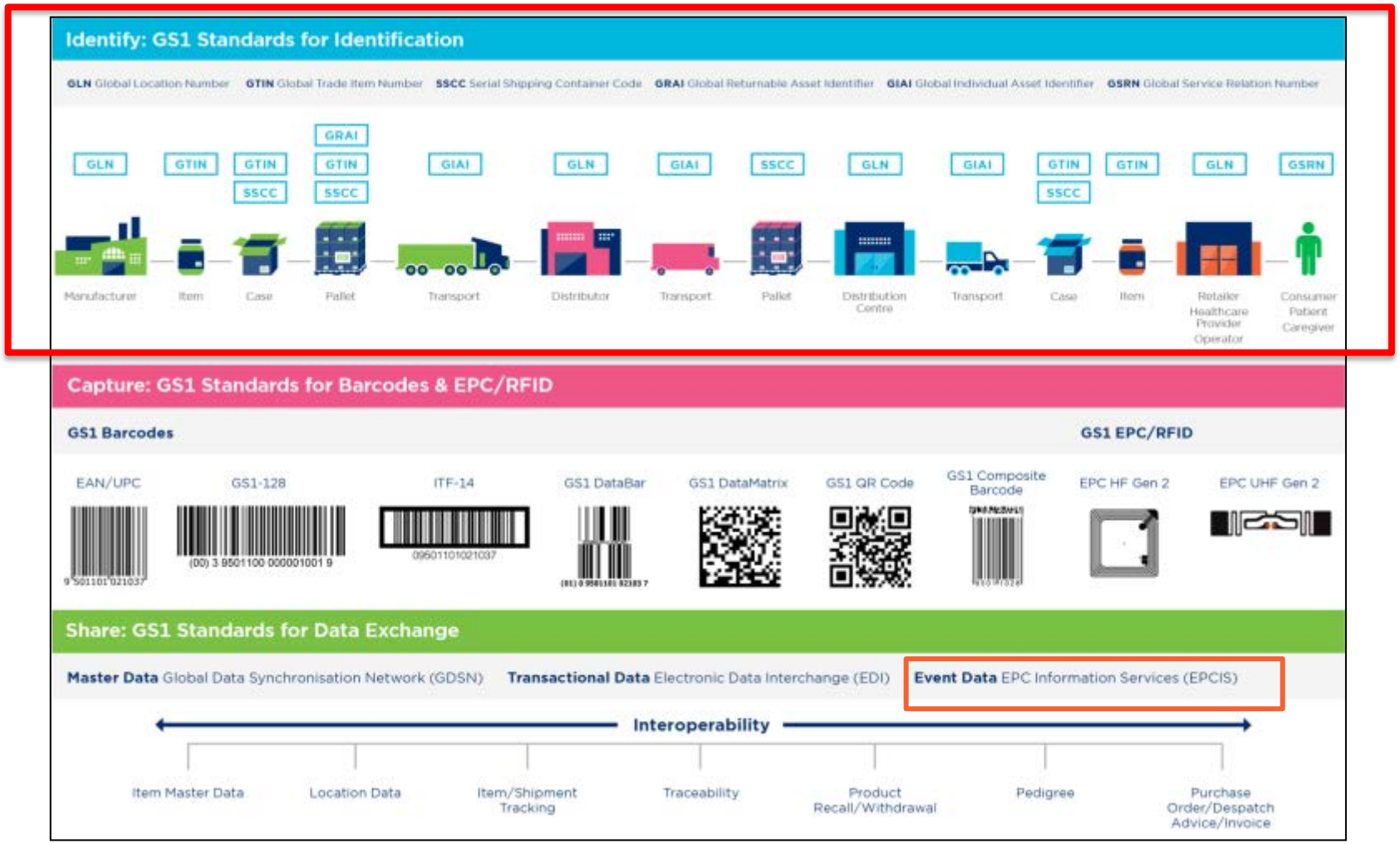
Identify, Capture, Share

The three layers of process visibility (courtesy of GS1)



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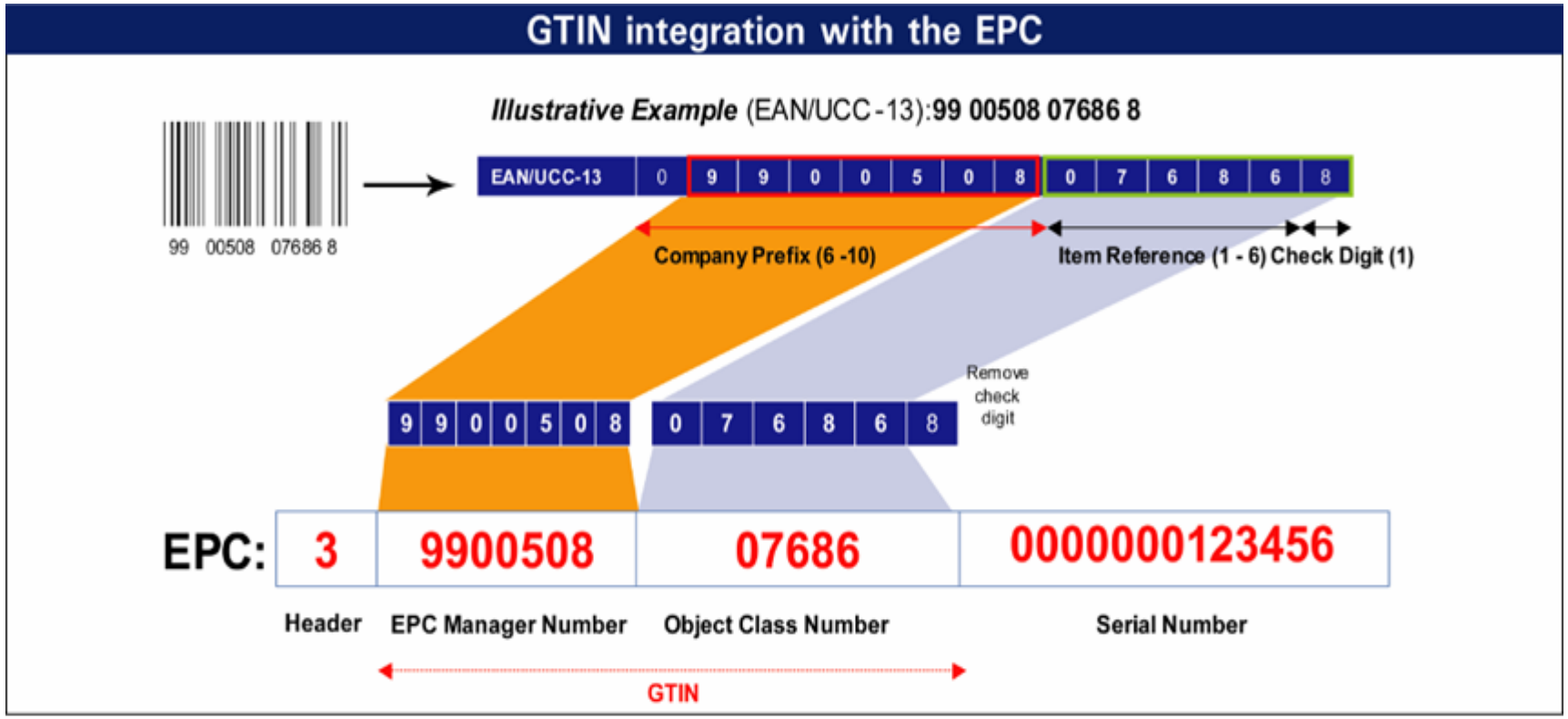
Identify, Capture, Share

Serialize products

- EPC = Electronic Product Code
- Serial number: not “an” object, but “the” object



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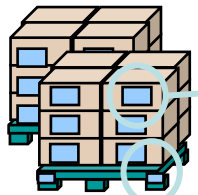
Identify, Capture, Share

Serialize everything

Pallets and cases provided with RFID tags

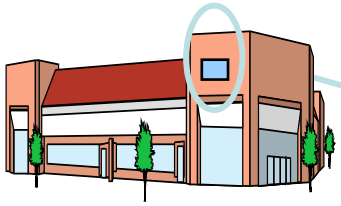


SGTIN

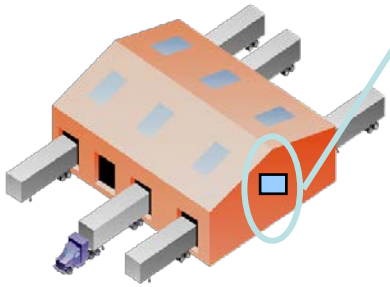
SSCC

GRAI

Warehouses and stores identified by EPC codes



SGLN

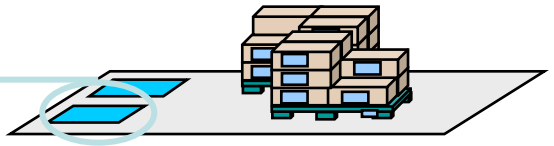


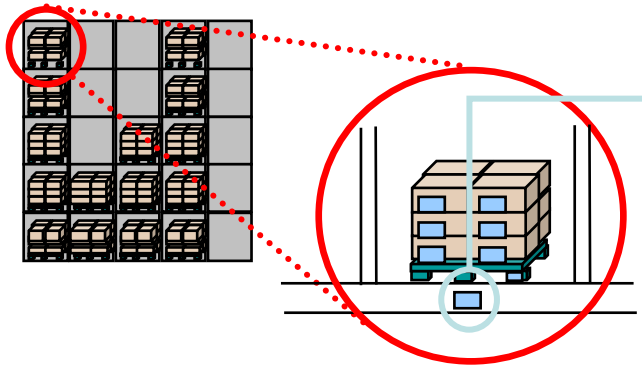
SGLN

Vehicles identified by RFID tags

GIAI

Pallet racks and shipping / receiving docks provided with RFId tags RFID





Non standard codes can be used as well, since they are not involved in the information exchange

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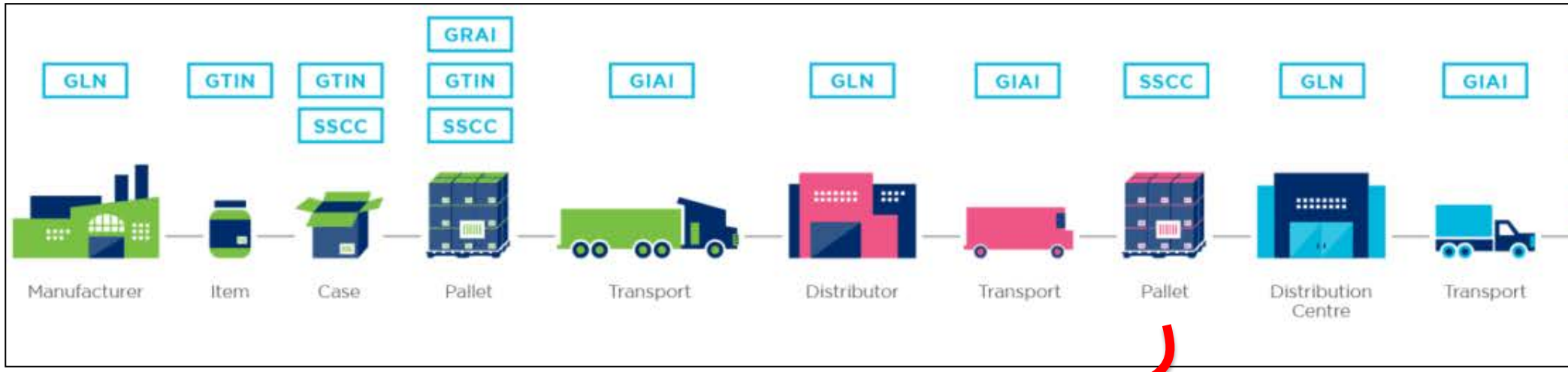
Identify, Capture, Share

Serialize everything



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Identify, Capture, Share

The three layers of process visibility (courtesy of GS1)

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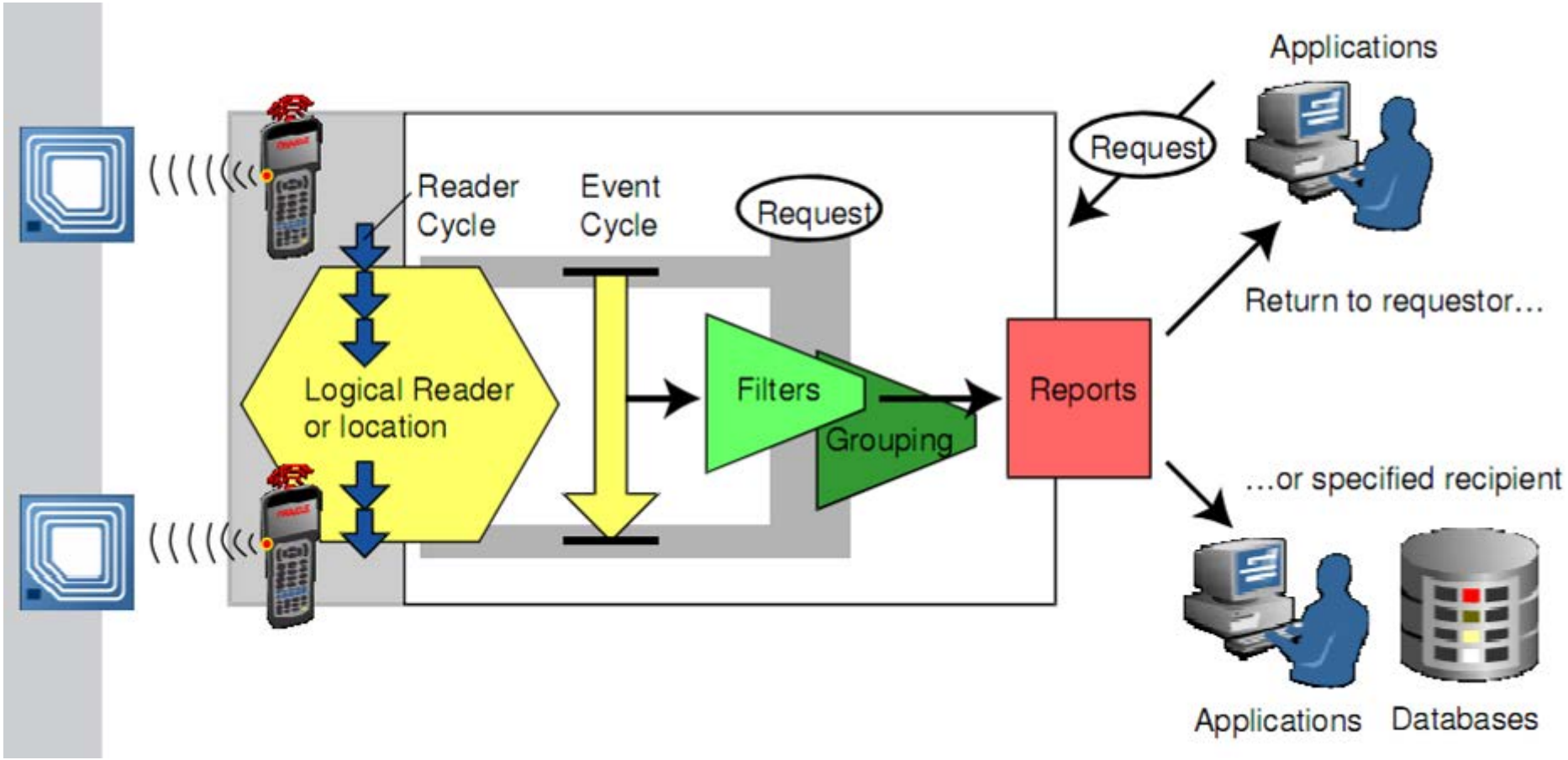
Identify, Capture, Share

From Automated readings to Business-sensitive information: ALE (Application Level Event)



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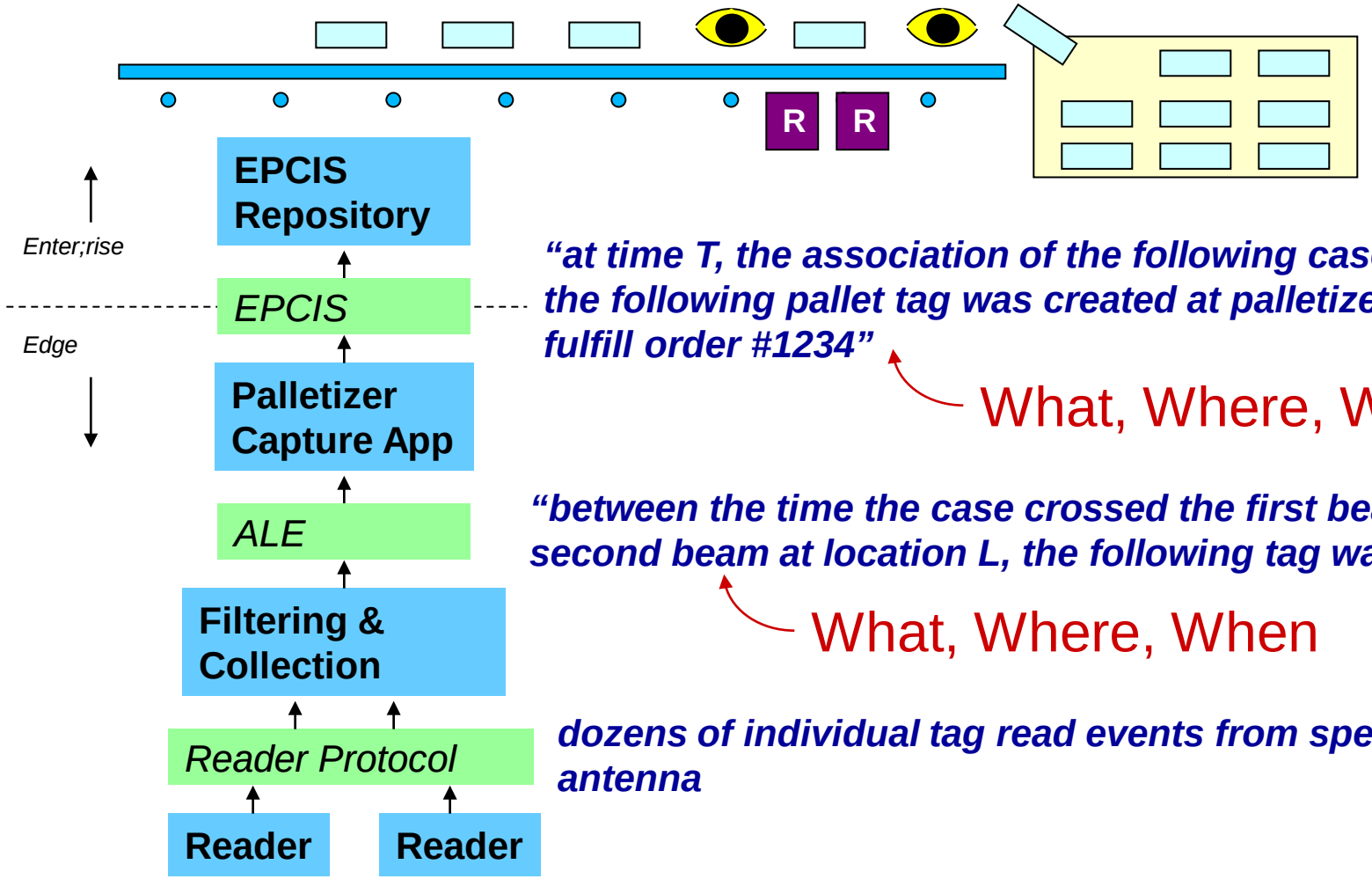
Identify, Capture, Share

From Automated readings to Business-sensitive information: ALE (Application Level Event)



"at time T, the association of the following case tags to the following pallet tag was created at palletizer #3, to fulfill order #1234"

What, Where, When, Why

"between the time the case crossed the first beam and the second beam at location L, the following tag was read"

What, Where, When

dozens of individual tag read events from specific antenna

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Identify, Capture, Share

From Automated readings to Business-sensitive information: ALE (Application Level Event)

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Identify, Capture, Share

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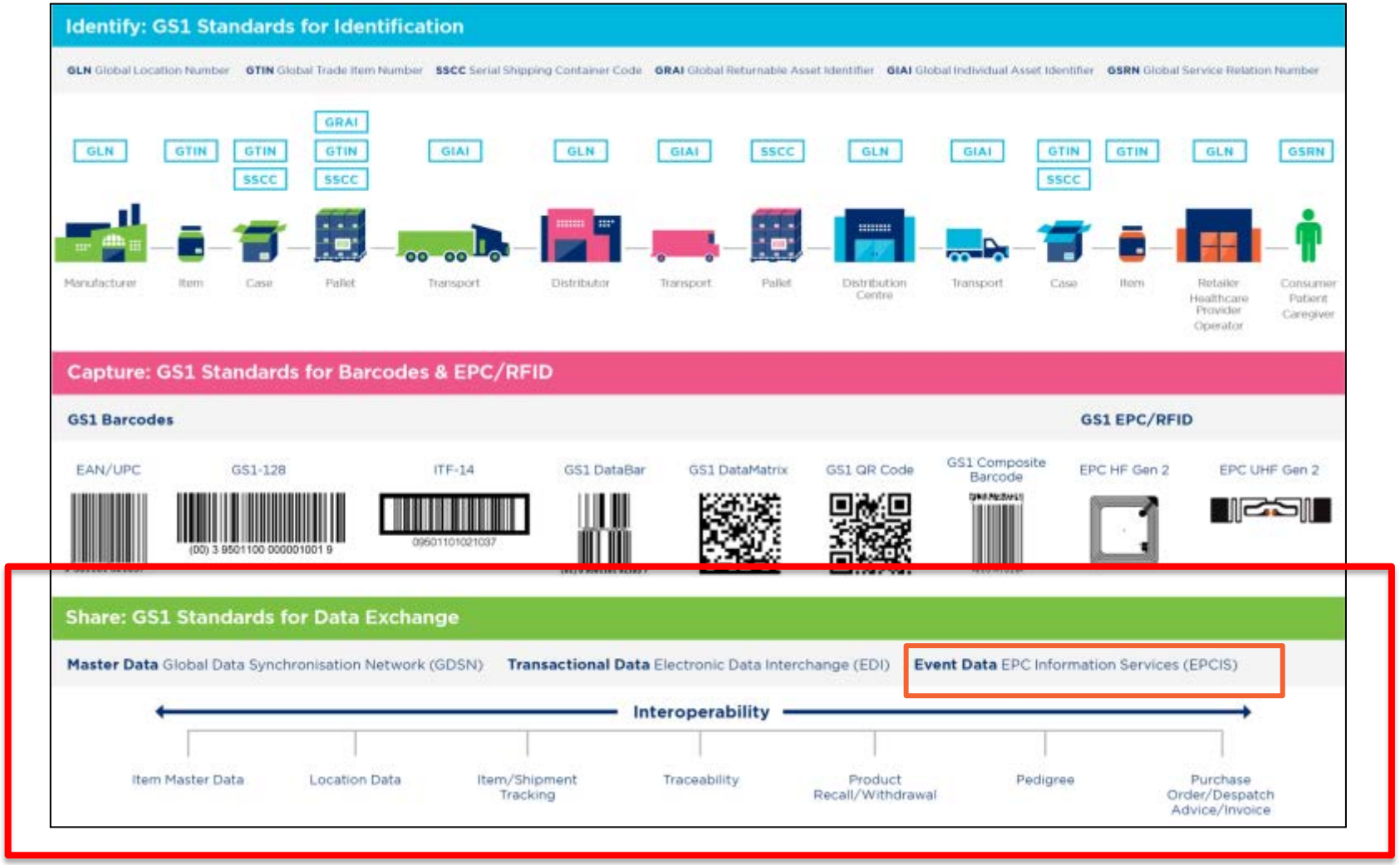

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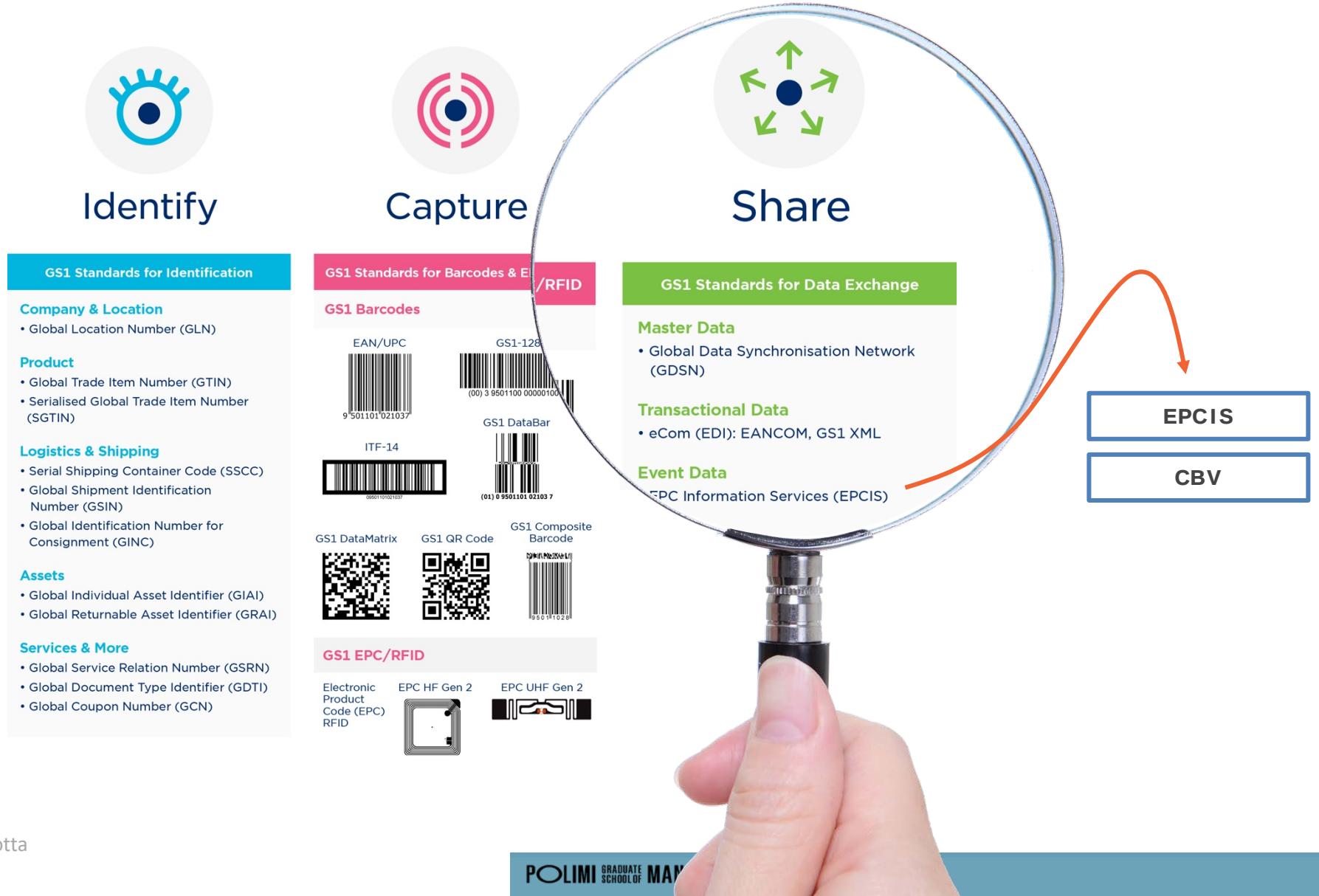
Identify, Capture, Share

The three layers of process visibility (courtesy of GS1)



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Identify, Capture, Share

EPCIS Standard

Electronic Product Code Information Services (EPCIS) defines standard interfaces to access informazion

- **Standard GS1**
- Natively integrated in common **ERP** and **track&trace** applications
- **Complementary to EDI**
- **Doen't need RFID**
- Works with GS1 barcodes
  - SGTIN
  - GTIN + batch number
- Approved **ISO / IEC** 19987

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Identify, Capture, Share

EPCIS Standard: the Core Business Vocabulary (CBV)

- Defines the semantic vocabulary of business interacation
- Standardizes semantics of information
- Fundamental for interoperability of EPCIS
  - Values and definition of **Standard Vocabularies**
  - Syntactic rules to define custom **User Vocabularies**
- Approved ISO/IEC 19988

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Identify, Capture, Share

Core Business Vocabulary (CBV) - examples

- accepting
- arriving
- assembling
- collecting
- commissioning
- consigning
- creating_class_instance
- cycle_counting
- decommissioning
- departing
- destroying
- disassembling
- dispensing
- encoding
- entering_exiting
- holding
- inspecting
- installing
- killing
- loading
- other
- packing
- picking
- receiving
- removing
- repacking
- repairing
- replacing
- reserving
- retail_selling
- shipping
- staging_outbound
- stock_taking
- stocking
- storing
- transporting
- unloading
- unpacking
- void_shipping

Example
<bizStep>urn:epcglobal:cbv:bizstep:**cycle_counting**</bizStep>

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Identify, Capture, Share

Application Level Event - examples

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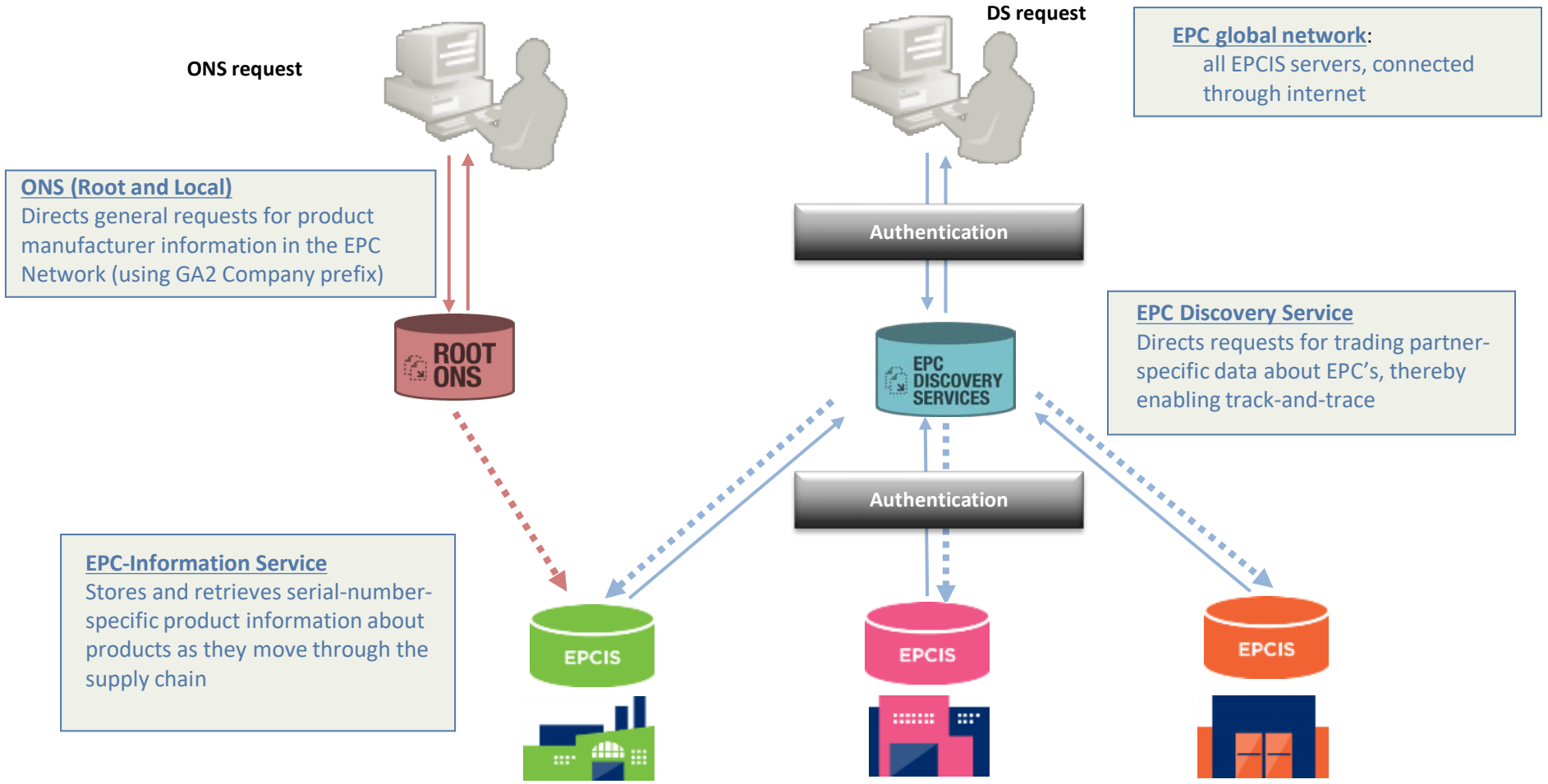
Identify, Capture, Share

The EPCIS network



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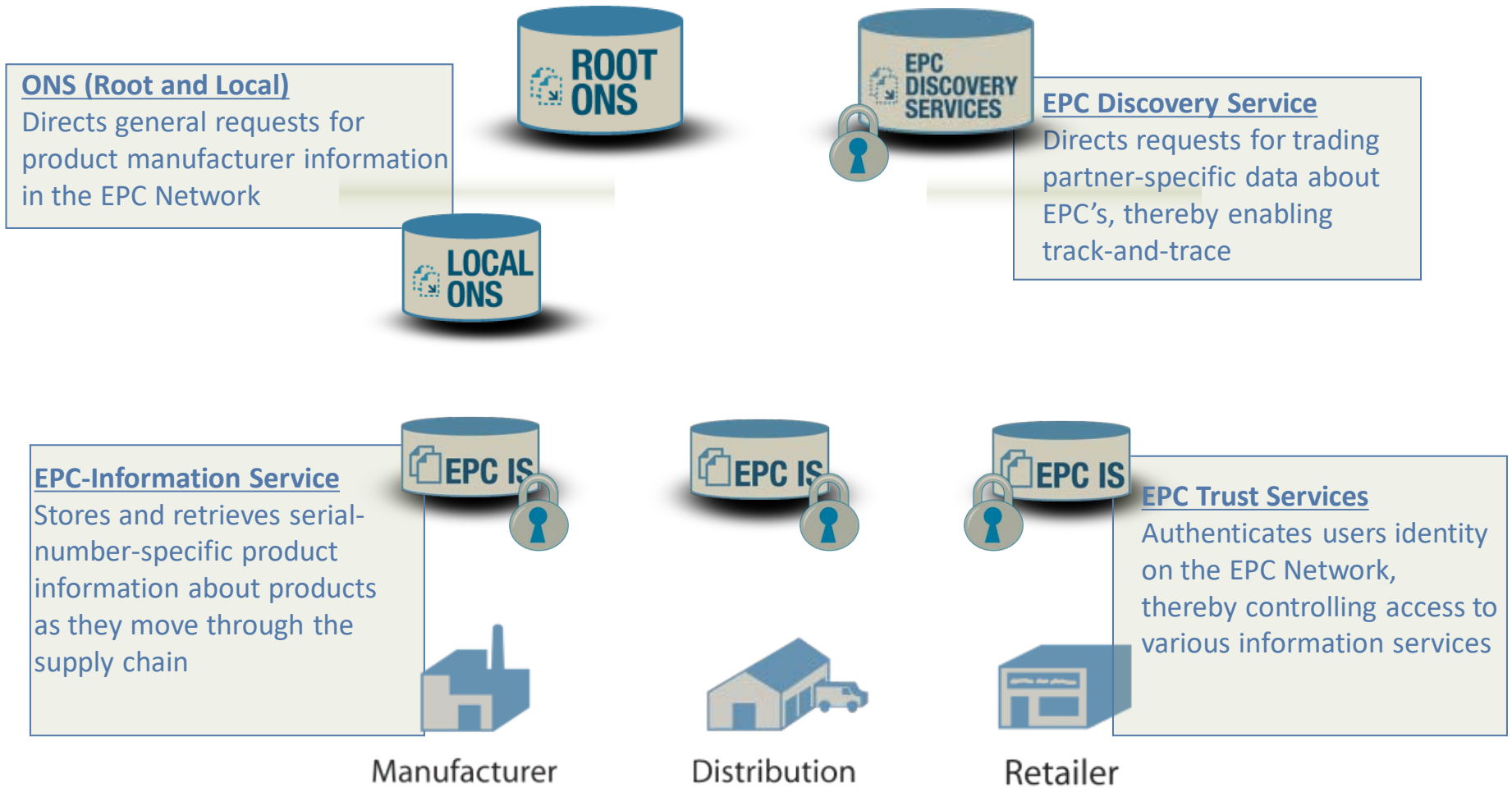
Traceability process: the GS1 EPC Architecture

(IoT birth, courtesy of EPC / Auto Id, 1999)



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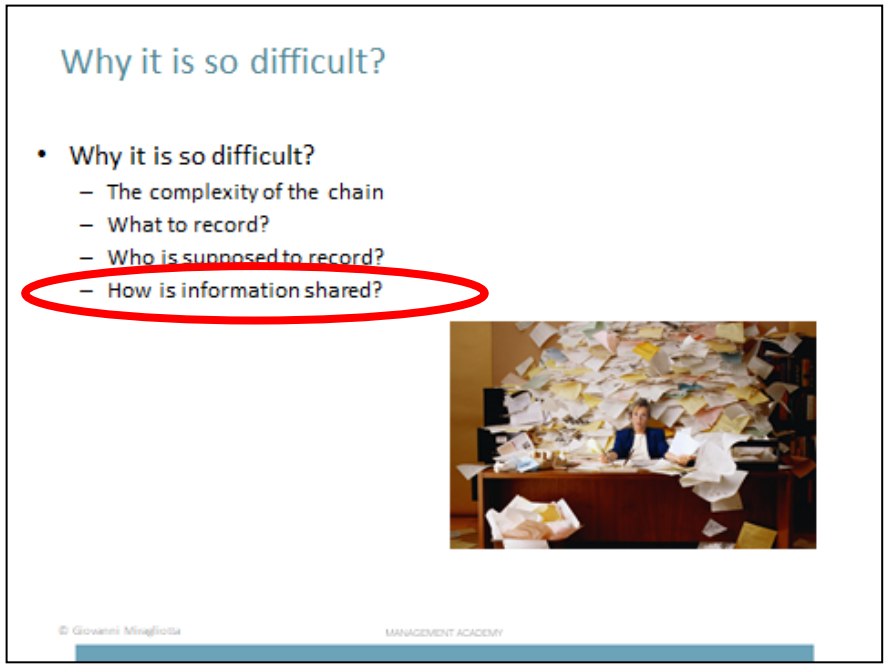
Data architecture



Use available standards

Make your own, and draw in anybody

Align to industry practices
(standards de facto)

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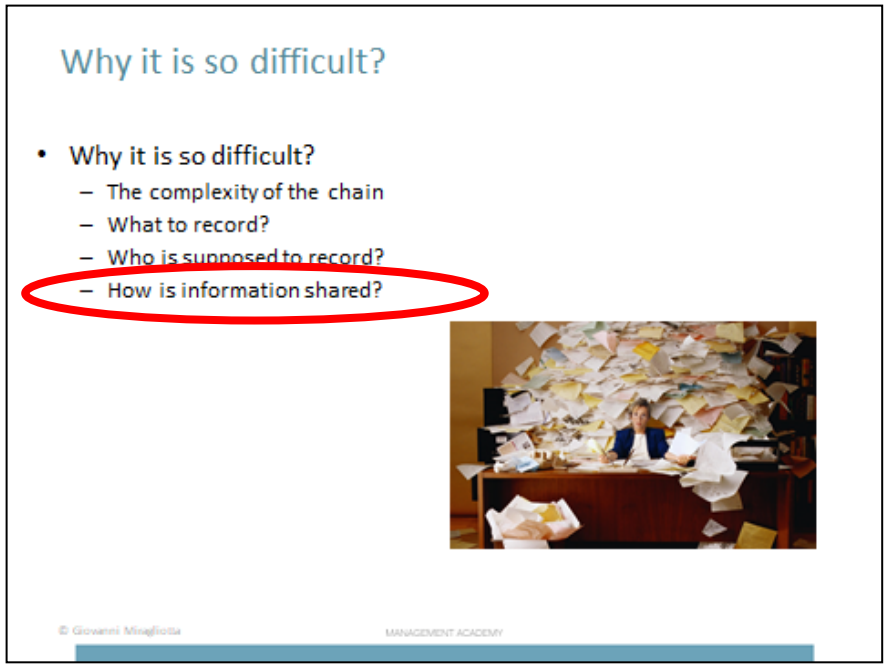
Data architecture



Use available standards

Make your own, and draw in anybody

Align to industry practices (standards de facto)

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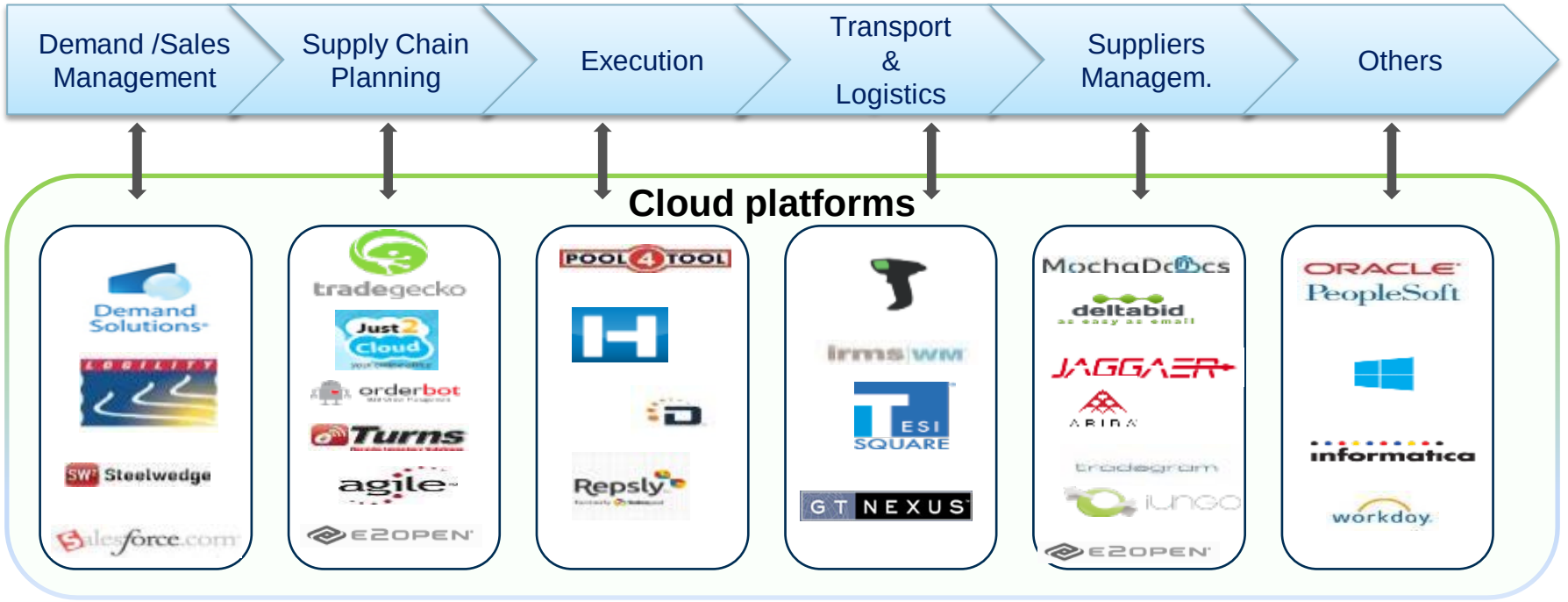
Align to industry (best) practices

Cloud platforms for SCM



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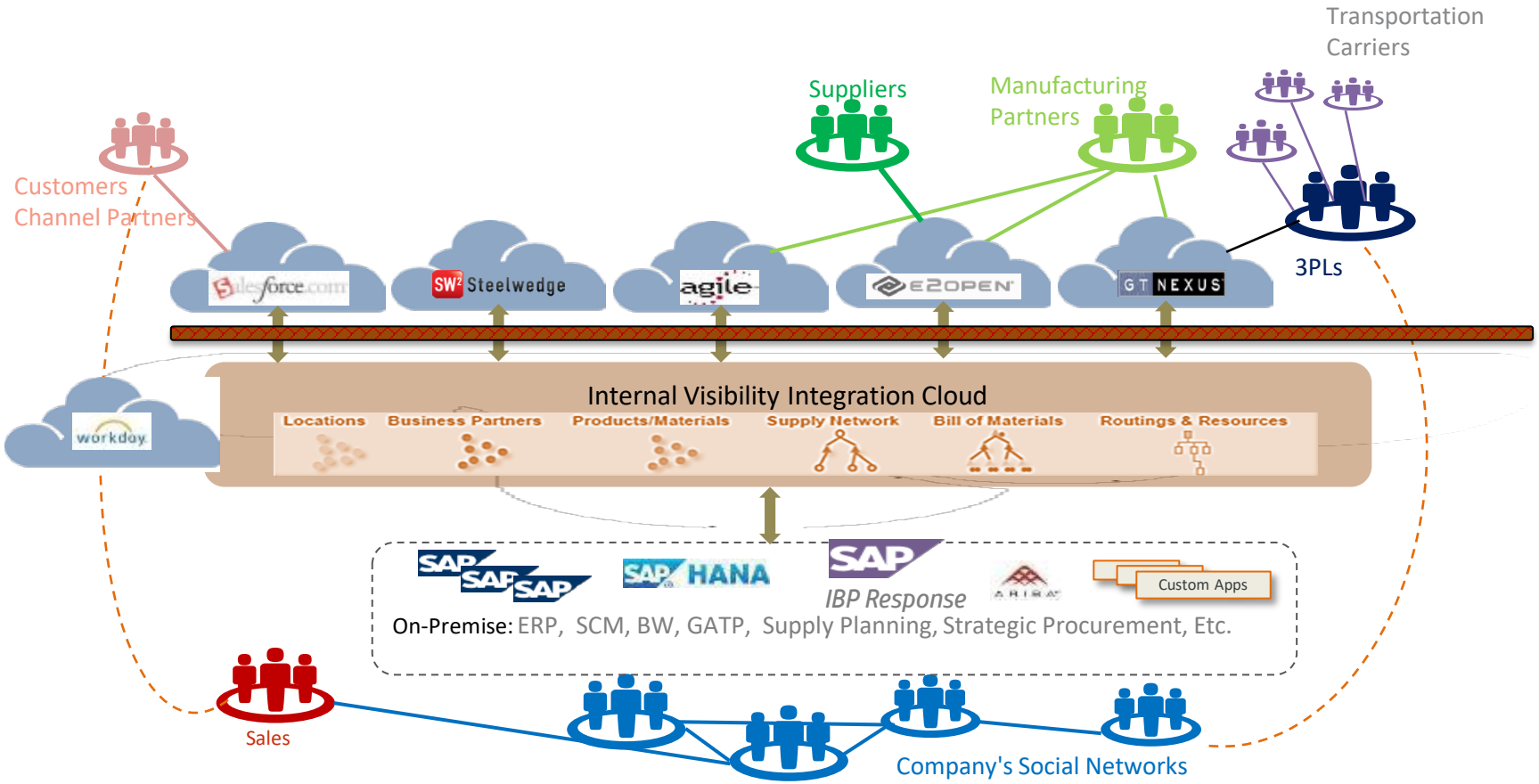
Align to industry (best) practices

Cloud platforms for SCM



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Data architecture

Is there a fouth way?

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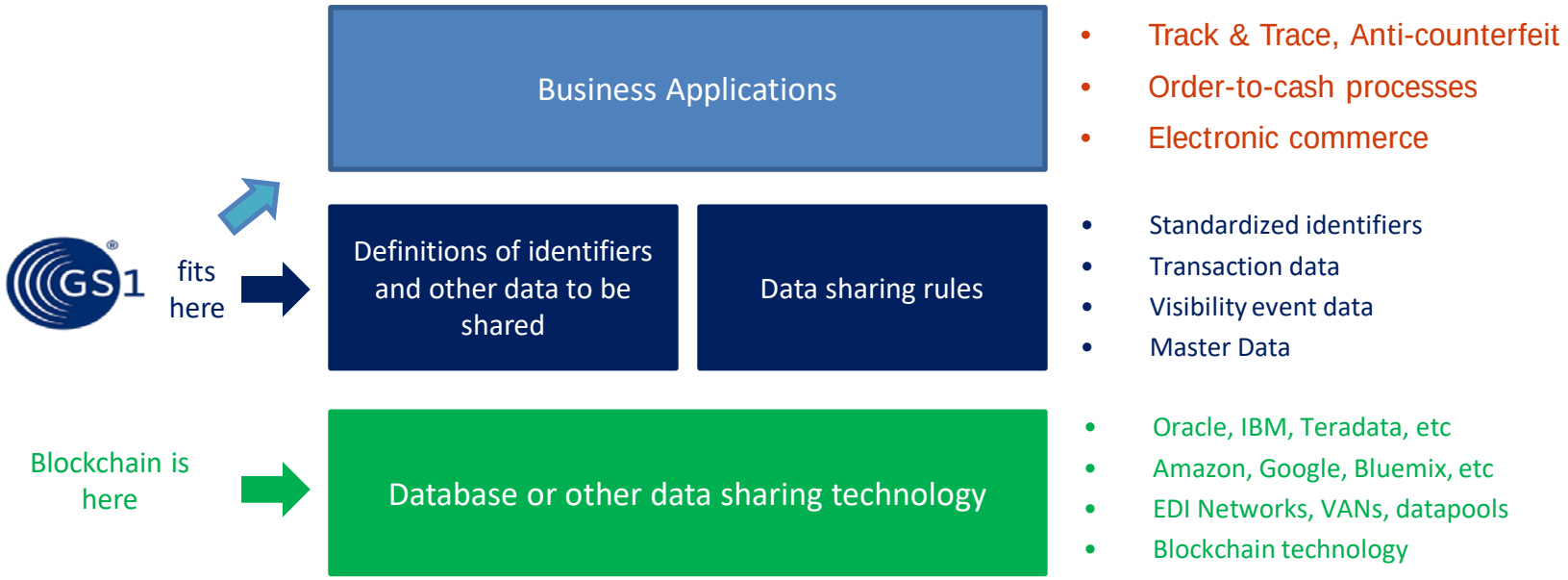
Does blockchain mean Traceability?



Blockchain is a shared, secure, distributed ledger
GS1 is about standards for data and business applications

- To achieve traceability, parties must agree on data **content (e.g. CBV)**
- **EPCIS** makes a **distinction between data and the database: EPCIS** is explicitly **agnostic** as to what sort of database is used… **also a blockchain**
- EPCIS defines interfaces between **different systems** so they can **share data** even if they use **different underlying DB technologies**

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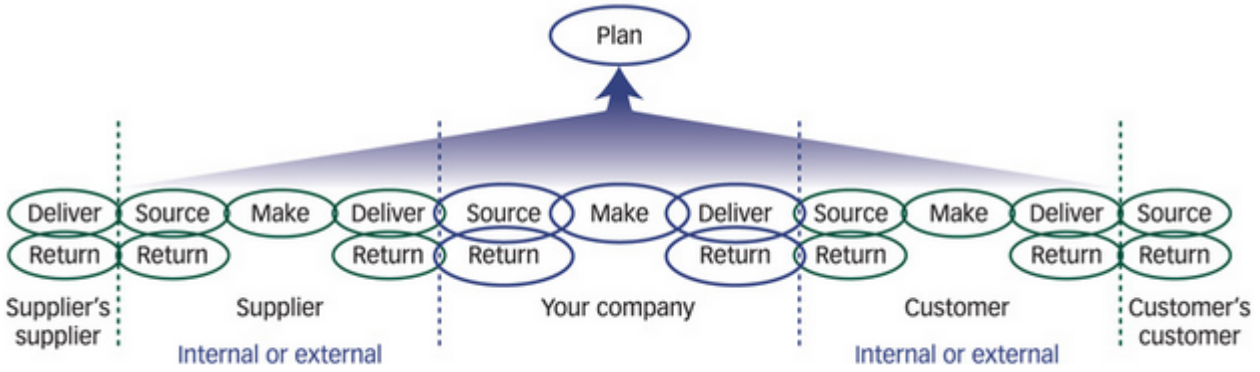
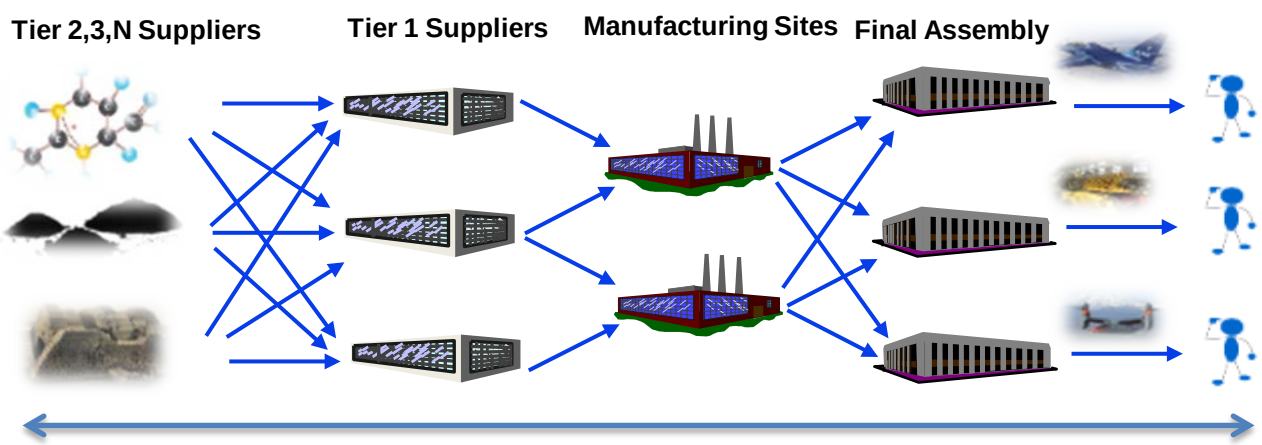
Is IoT ready for blockchain?





Native IoT Blockchain device?
No, a Third-party Oracle

Certifies the digital data

Acquires digital data about physical processes

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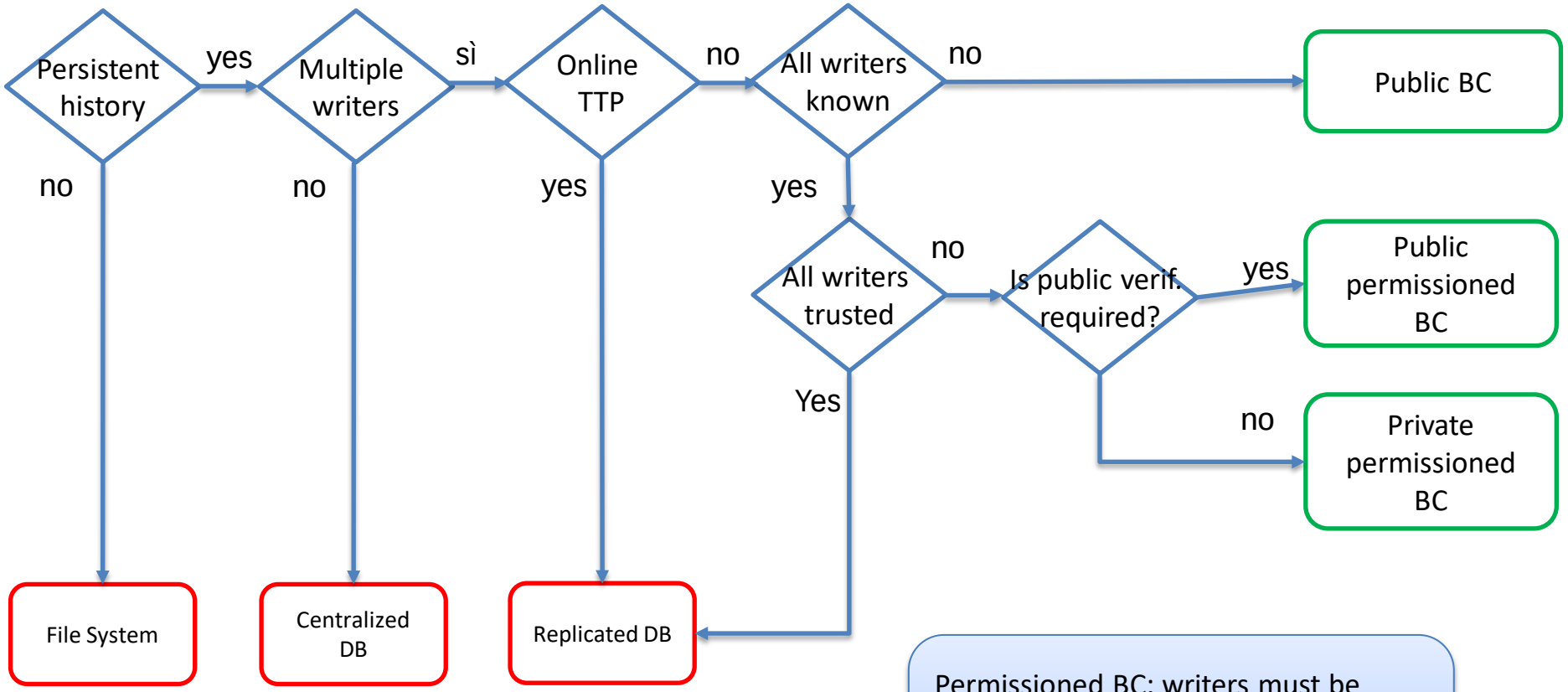
Do I need a BC?

Wüst & Gervais (ETH Zurigo)



Permissioned BC: writers must be approved by participants
Private BC: readers must be approved by participants

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Agenda

- Foreword
- Technologies for the Extended Enterprise
- Data Architecture
- Benefits Evaluation
- Q&A

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Adoption process of a new technology

- The adoption process of every new technology can be:
  - "Conditioned":
    - ROI>0
    - Given PBT, etc.
  - "Convincing":
    - Perceivable impact on a set of performances…
    - …aligned with the Entrepreneur's expectations
  - Emotional
    - *A posteriori* evaluation

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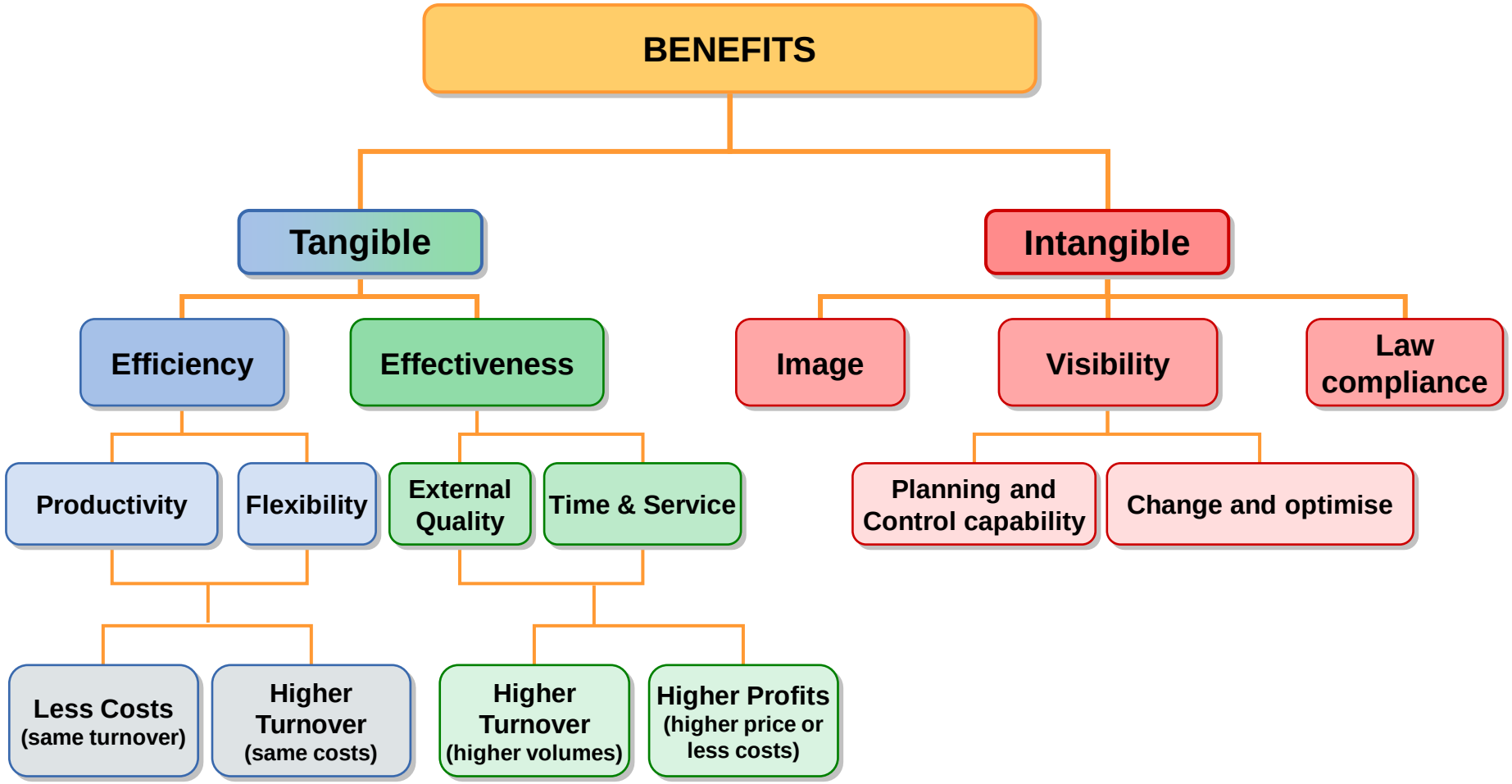
Evaluating the Extended Enterprise

A reference framework



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Efficiency benefits

Generalizing the method

- ABM / ABC methodology:
  - Map process (to the correct level of details) in the As Is situation
  - For each activity, identify the needed resources, and their unit costs
    - People, space, energy, capital, …
  - For each activity, identify resources' consumption drivers
    - # of Pieces, # of setups, …
  - Measure the consumption of drivers, and therefore used resources
  - Assess the cost of the As Is process

  - Re-engineer the process, define the To Be situation
  - Re-draw the new process map and modified activities
  - Re-apply ABC
  - Estimate the cost of the To Be process

Importance of realistic assumptions (e.g. people and costs not completely avoidable)

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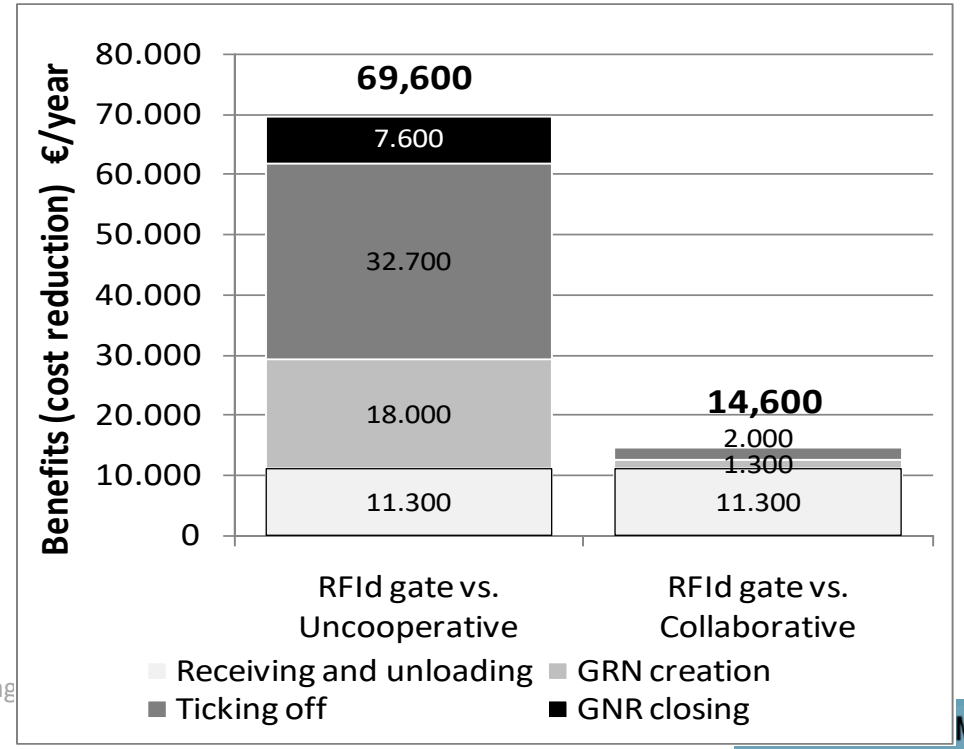
Efficiency benefits

Generalizing the results

- RFId Gate sc

	"As Is Uncooperative" base-line scenario	"Collaborative" base-line scenario
Base-line scenario COST (€/year)	**244,000**	**188,000**
"RFId Gate" COST (€/year)	**174,400**	**173,400**
"RFId Gate" BENEFITS (€/year)	69,600	14,600
"RFId Gate" %BENEFITS	28.7 %	7.5 %



RFId tags paid by	Base-line scenario	"RFId gate"	
		NPV (€)	Payback (years)
Wholesaler	**As-Is**	**- 170,000**	**∞**
Wholesaler	**Collaborative**	**- 340,000**	**∞**
Manufacturer	**As-Is**	**250,000**	**0.2**
Manufacturer	**Collaborative**	**40,500**	**1.0**

RFId tag prices enabling a positive NPV (tags paid by the wholesaler)

Base-line scenario	"RFId gate"
As-Is	**0.12 €**
Collaborative	**0.04 €**

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Efficiency benefits

Open issues

- What if 100% reading accuracy cannot be achieved?

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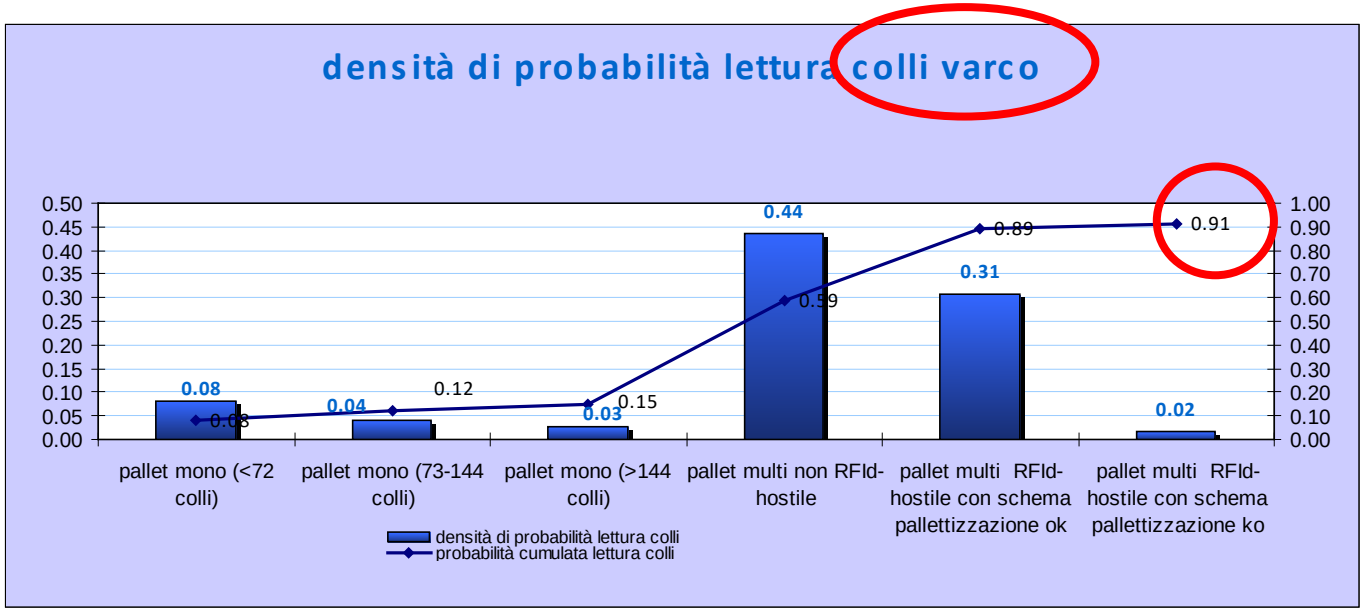
Efficiency benefits

Open issues

- What if 100% reading accuracy cannot be achieved?



- Only 91 % of cases could be accurately read

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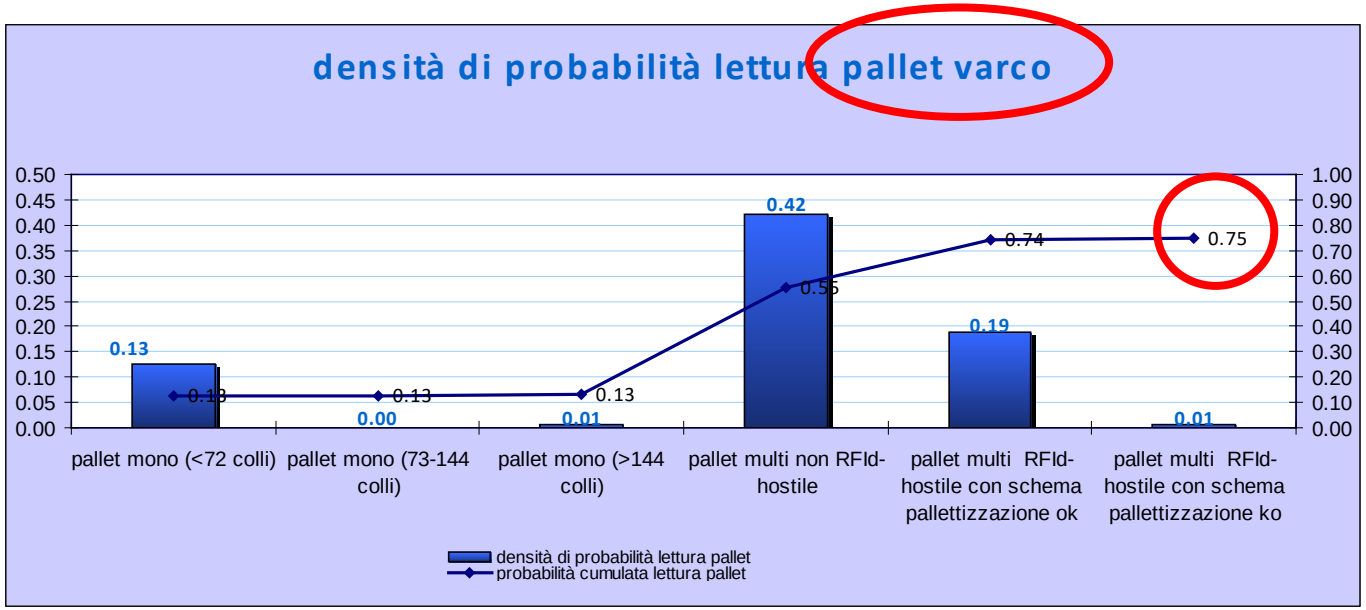
Efficiency benefits

Open issues

- What if 100% reading accuracy cannot be achieved?



- 91% of cases → 75% of pallets

  → Proportional impact on measured benefits

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Efficiency benefits

Open issues

- What if 100% reading accuracy cannot be achieved?

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Efficiency benefits

Generalizing the method

- Activity Based Modelling methodology
- Realistic assumptions, reliable cost accounting data
- Identification of relevant impacts depending on tech reliability

		Impact	
		Single company	Supply Chain
Target	Administrative		
	Operational		
	Statistical		

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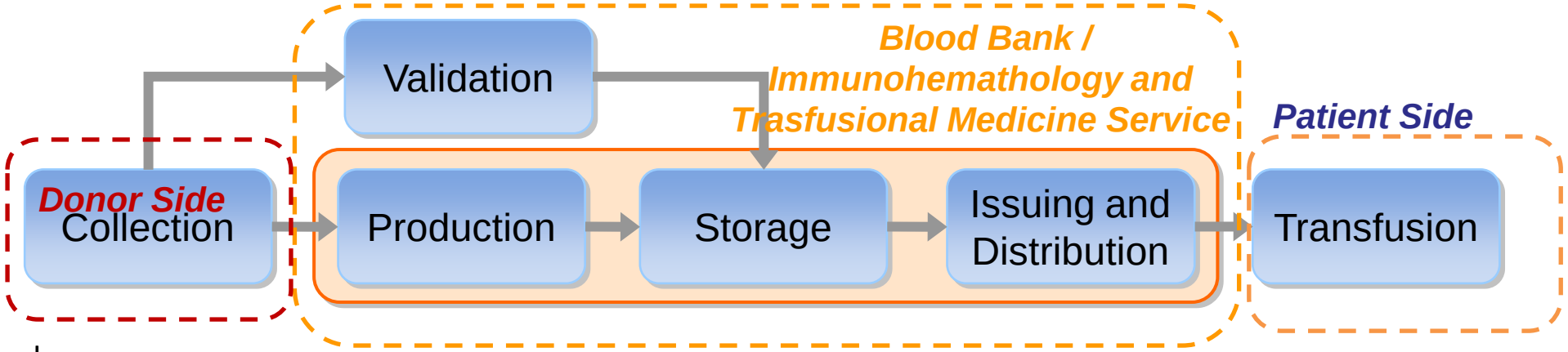
Efficiency benefits

The case of Healthcare (Blood Transfusion SC)

- Analysis of RFId technologies in supporting the whole blood supply chain (vein-to-vein process)



- Main goals:
  - Automating bags identification to enhance quality and safety of blood supply chain
  - Analysing how the processes can be re-designed thanks to RFId:
    - **supporting the centralization of the production and the biological validation of the blood collected)**
    - **enhance resources employment**

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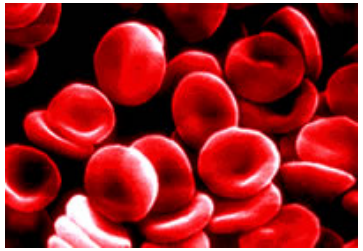
Efficiency benefits

The case of Healthcare (Blood Transfusion SC)

- Risk-based method to assess the impact of RFId on:
  - Patient safety
  - Quality of blood products
  - Service continuity
  - Donor care



FMECA (HFMEA) approach:

$$RPN_i = OSR \times SSR_i \times DSR$$

RPN = Risk Priority Number
OSR = Occurrence Score Rank (probabilità di accadimento)
SSR = Severity Score Rank (Severità del danno associato)
DSR = Detectability Scale Rank (Rilevabilità dell'errore)

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Efficiency benefits

The case of Healthcare (Blood Transfusion SC)

- Risk-based method to assess the impact of RFId on:
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  - Quality of blood products
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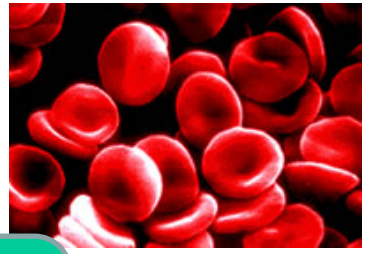
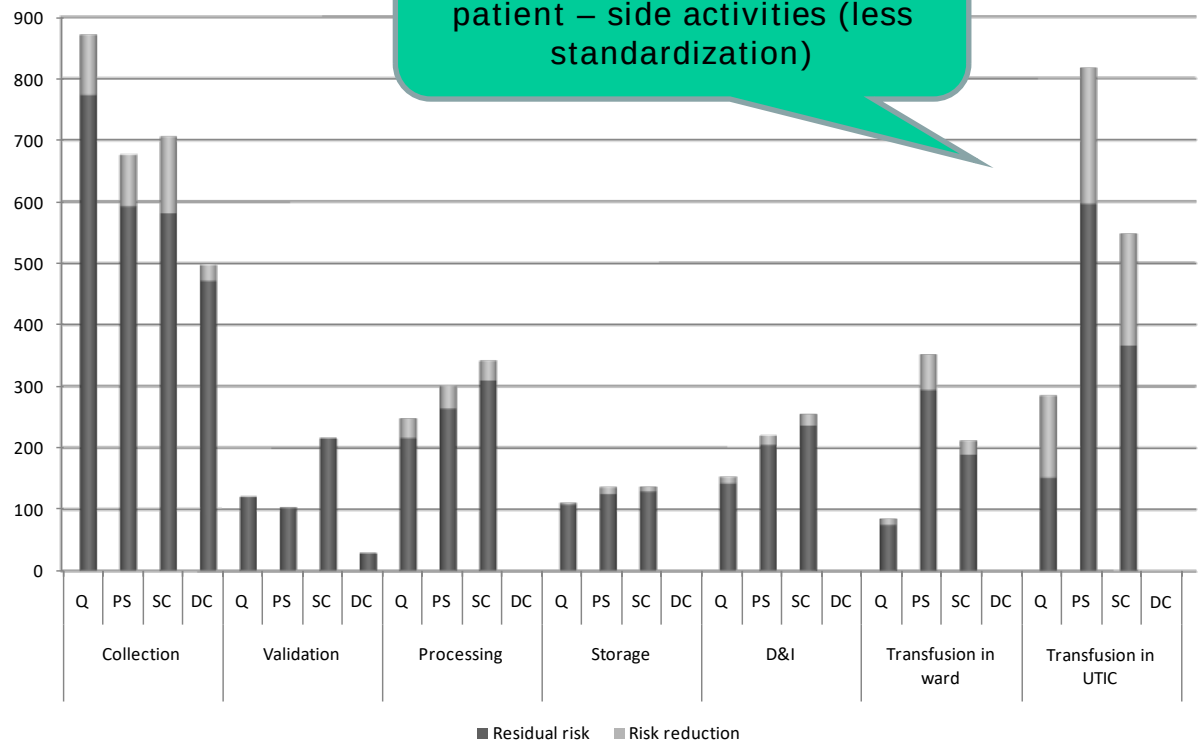


Positive performance improvement, especially on patient – side activities (less standardization)

The extent of performance improvements is mainly dependent on the ability to design better (e.g. safer) processes and activities



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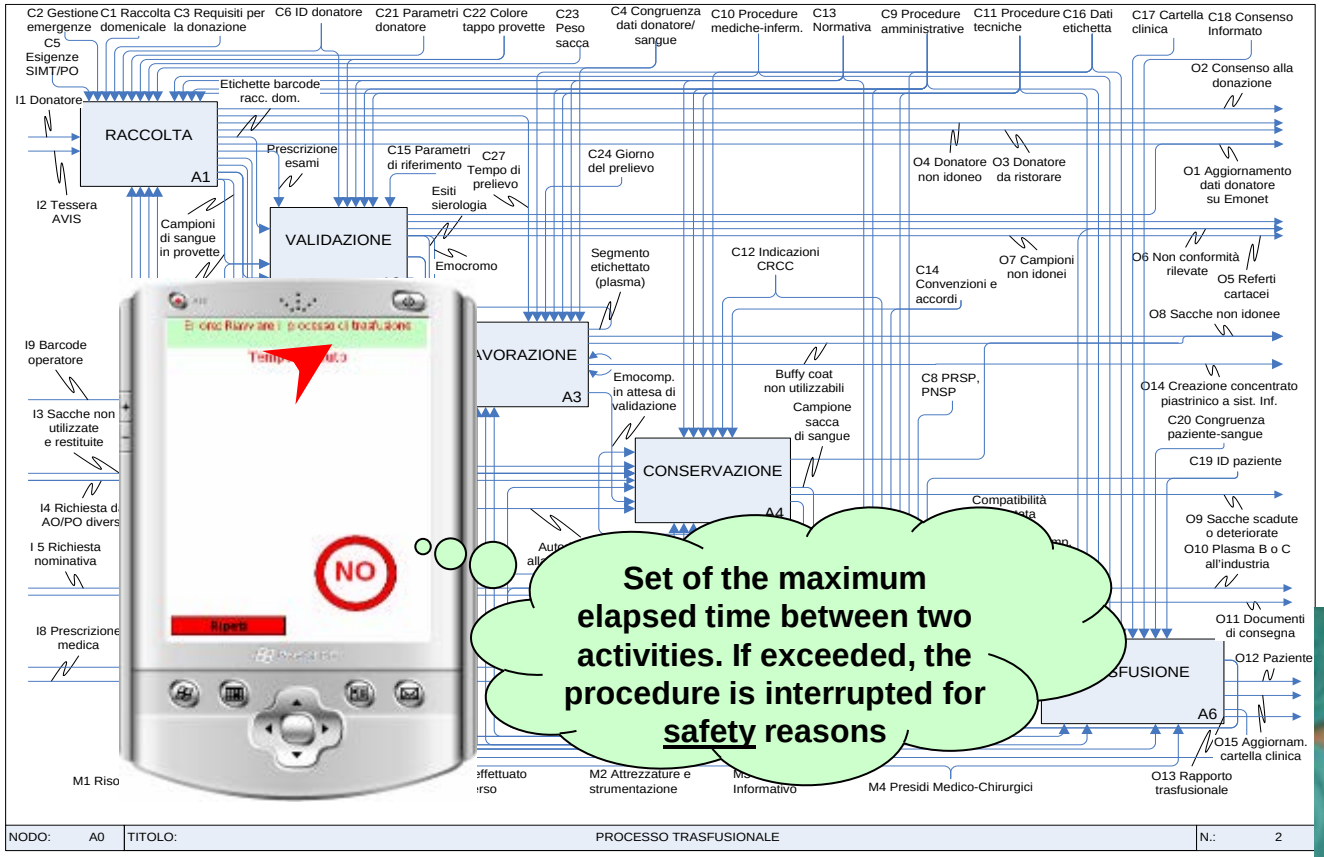
Efficiency benefits

The case of Healthcare (Blood Transfusion SC)



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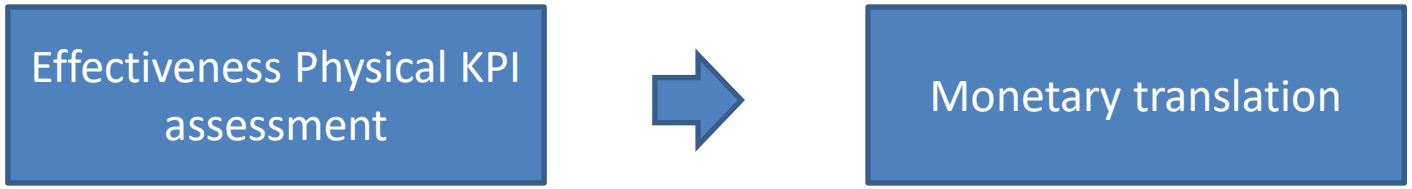
Efficiency benefits

Generalizing the method

- A two step evaluation…



- Available options:
  - Direct analytical evaluation
  - Direct measurement
  - Computer simulation
  - Queuing theory
  - FMEA
  - …

- Available options:
  - Direct analytical evaluation
  - B-plan estimates
  - Educated Guess
  - Benchmarking

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How to assess the benefits in this case…

Tracking returnables: the Cablecom(*) case

Objective: real-time monitoring of location and state of the cable returnable drum

Sensing:

- GPS (**location**)
- MEMS accelerometer (**shocks, rotation**)
- **Smart energy management** (sleep mode, LPWA ready)

Functionalities:

- 2-year operating life, with real time monitoring (location, hits)
- Local algorithm to estimate the remaining wire (as a function of wire thickness and number of revolutions)

(*) Fictional name due to confidentiality reasons

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Q&A Addendum

- Innovazione e outsourcing
- Flexa, la piattaforma di continuous learning di GSOM
- Piattaforme e Transaction Cost Theory
- Extra readings

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Innovazione e outsourcing

Gary P. Pisano, 2009, "**Is the U.S. killing its innovation machine?**"

"The prevailing view of the past 25 years has been that the U.S. can thrive as a **center of innovation** and **leave the manufacturing** of the products it invents and designs to others. **Nothing could be further from the truth.**

This logic is predicated on utterly false assumptions about the divisibility of R&D and manufacturing… **R&D and manufacturing are tightly intertwined**. **Unless you know how to manufacture a product, you often cannot design it**. And, to understand how to manufacture it, you have to have manufacturing competencies and experience.

To innovate, you need great two-way feedback. You need to transfer knowledge from R&D into production, but you also need to move knowledge from production back to R&D. … What this means is that **when manufacturing capabilities migrate from a country, design and R&D capabilities eventually follow**."

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Piattaforme e Transaction cost Theory

- *https://en.wikipedia.org/wiki/Transaction_cost*

- *The rise of platform economy: a framework to describe multisided platforms,*
  M. Ardolino, N. Saccani, M. Perona, 2016, Università di Brescia

- *A strategic outlook on Manufacturing-as-a-Service (MaaS) Platforms: differences and inspirations from "traditional" platforms ecosystems*
  G. Tedaldi, G. Miragliotta, L. Gastaldi, 2022, Politecnico di Milano

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Extra readings

- *Kai Fu Lee, 2018, AI Superpowers: China, Silicon Valley and The New World Order, Houghton Mifflin Harcourt.*
- *Erik Brynjolfsson, Andrew McAfee, 2017, "Machine, Platform, Crowd: harnessing our digital future", W&W Norton & Company (Italian edition available)*
- *Gary Marcus, Ernest Davis, 2019, Rebooting AI: Building Artificial Intelligence We Can Trust, Vintage Publishing*
- *Luciano Floridi,2022, Etica dell'Intelligenza Artificiale, Scienza e Idee*
- *Samuele Mazzini, 2022, Il futuro elettrico, Sole24Ore ed.*