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Smart Systems and Cyber Physical Systems paradigms in an IoT and Industry/ie4.0 context

Drs Cees J.M Lanting[1], Eng. Antonio Lionetto[2]

[1]CSEM, M&BD, Jaquet-Droz 1, 2002 Neuchatel, CH; e-mails: cees.lanting@csem.ch
[2]STMicroelectronics srl, Stradale primosole 50, 95121 Catania, IT; e-mail: antonio.lionetto@st.com

- The aim is to bring about a better understanding of the relationship between Cyber-Physical Systems (CPS) and Smart Systems and Smart System Integration paradigms, analysing the coexistence, overlap and specific differences in terms of domains of application of the two concepts, in an IoT and Industry/ie4.0 context;
- A first look is taken at definitions;
- The analysis presented has been proposed to EPoSS in order to improve the perception of these paradigms within the EPoSS and ECSEL communities, and outside in the FoF and Industry/ie4.0 communities;

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Smart Systems promise to bring a wealth in capabilities and functionalities in every sector in which they can be introduced and applied

It is their intrinsic nature/scope to provide innovative solutions in even more application fields, further increasing their pervasiveness in all possible sectors:

- (Manufacturing / Factory automation,
- Health & Beyond,
- Aerospace & Defence,
- Clothing & Textiles,
- Transport & Mobility,
- Security & Safety,
- Energy, Environment,
- Communications,
- Home & Entertainment,
- Agriculture, fisheries, food & drinks
- …

acquiring a fundamental role on social challenges too.

The acronym SSI refers to the principles and techniques that are used in the realisation of Smart Systems and Cyber Physical Systems.

Smart Systems and manufacturing can be related to two categories of primary importance:

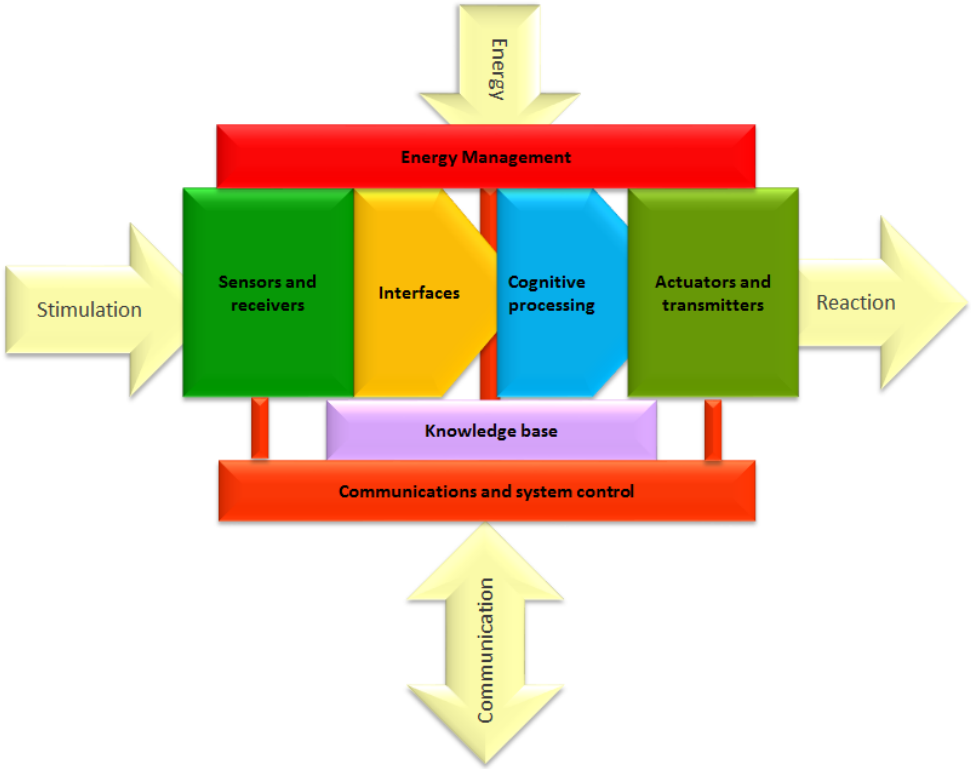
- Smart System Integrators,
  - To apply new technologies provide new capabilities and functionalities to their product (finished system or subsystem).
  - This category looks for the application of Key Emerging Technologies or KETs and adopts the advanced manufacturing for the developments and products
  - Theyare solution provider and enabler of methodologies strictly related to technological base principles,
- developers, Smart System Users
  - use and the in the field application of the Smart System solutions

- A definition for Smart Systems in common use emphasises externally visible functionality and the heterogeneous components required to realise Smart Systems, in particular direct or indirect sensing and actuating functions and respective interfacing:
    - *(Integrated) Smart Systems are defined as (multi-) sensor and actuator based devices that are capable to describe, diagnose and qualify a given complex situation, to make predictions, to cast decisions and to take actions. They are networked, autonomous and as small as possible*.

- The common CPS definition emphasises collaboration and communication between the CPS nodes, treating sensing, actuation and external communications technologies more as an abstract given:
    - *Cyber-Physical Systems (CPS) are the next generation embedded intelligent ICT systems that are interconnected, interdependent, collaborative, autonomous and provide computing and communication, monitoring/control of physical components/processes in various applications incl. safety critical*

The analysis here observes that SSI and CPS are largely overlapping paradigms describing what is considered to be the essentially the same phenomenon; however, differentiated by the fact that each includes an area not, or not so well covered by the other

the well asserted model for Smart Systems



The energy management block can also include the energy harvesting from several sources

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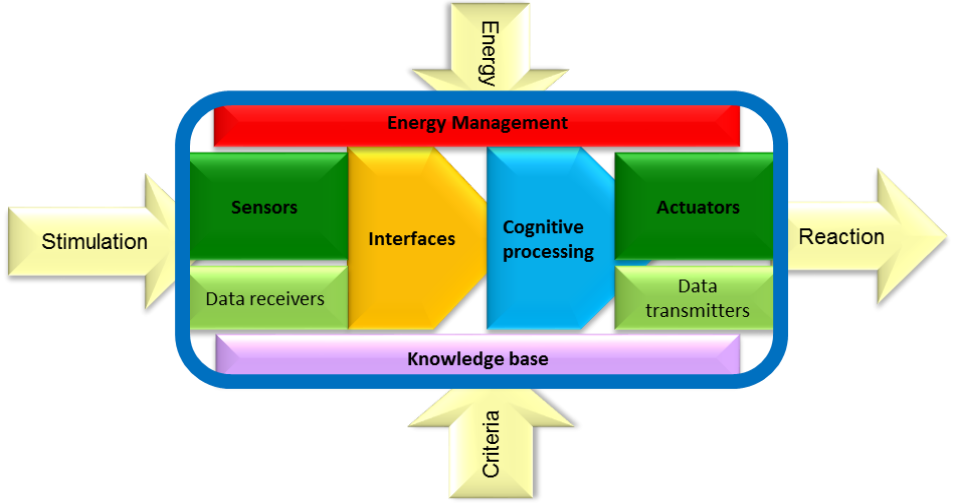
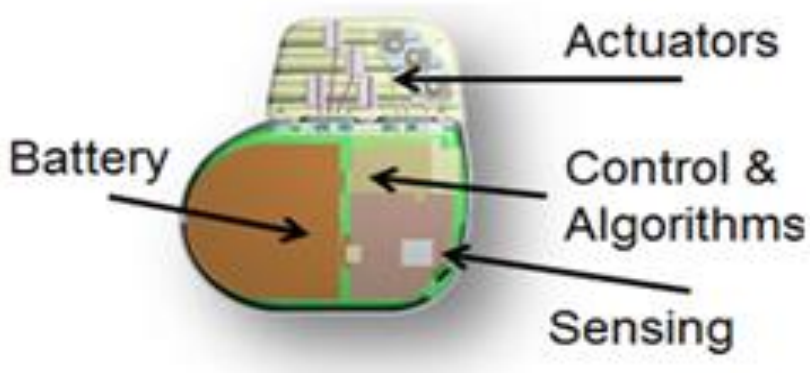
- We can define three typologies on the basis of their interaction capability that can be defined as
  - stand-alone solution,
  - solution as part of an overall well defined system, and
  - solution as part of system of systems in which there isn't a unique and fixed system to refer to

- We then introduces three 'views'":
  - the Edge view
  - the System view
  - the System of Systems or Distributed Autonomous Dynamic decisions (DAD) view

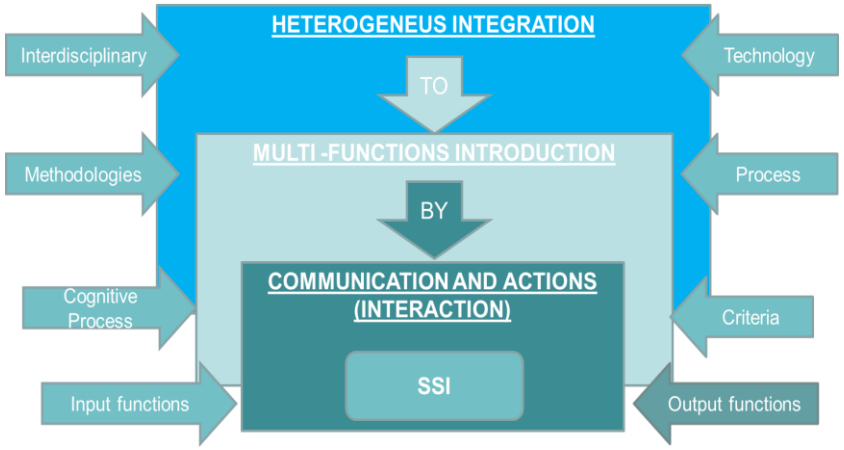
The first manner to recognize the application of Smart Systems is to consider an ‘edge view’, in which a well-defined boundary between ‘the system’ and the outside can be recognised as defined by the application.

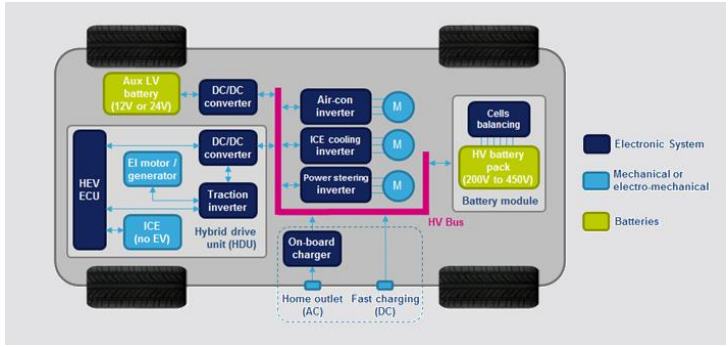


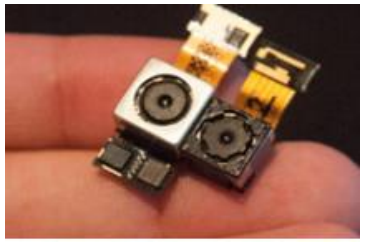


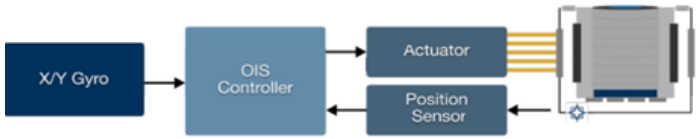
A typical example is a cardiac stimulator that provides specific functions on the basis of its own context awareness without or with very limited interaction with other electronic systems. In this description, generally, the Smart System represents the whole system

A ‘system view’ emphasizes the externally visible functionality for a more or less complex system, in which an interdisciplinary knowledge is applied, by means of heterogeneous integration, with the aim to provide multi-functional solutions, integrating sensing, actuating, processing, power management, control, communication:









In this view, Smart Systems have and ensure specific functions on base of their specific integration of heterogeneous technologies, and this will be delegated by and under control of a main system by means of specific communications

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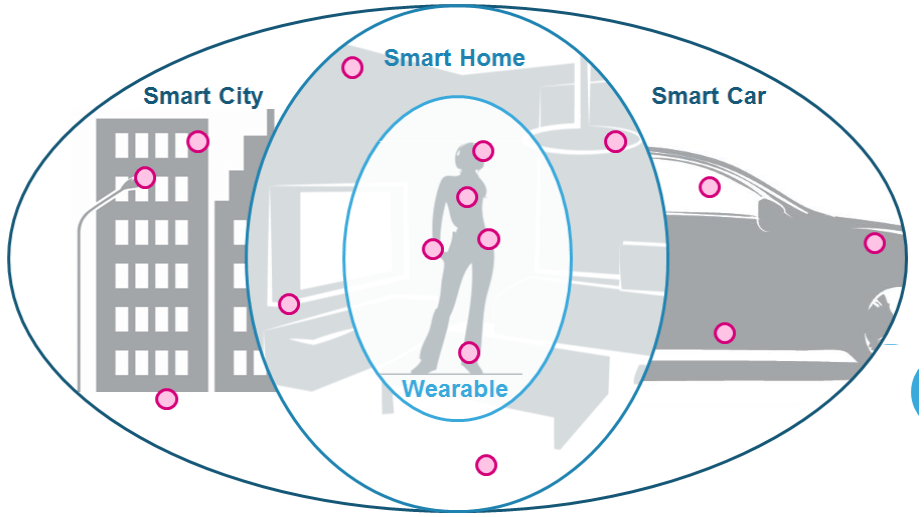
The third representation, system of systems, is linked to the recent evolution on communication, protocols stacks and in which are becoming affordable sophisticated communication methodologies and tools characterized by high data throughput and more complex handshakes that need an improvement on processing capabilities to be fully adopted in Smart Systems:



Physical Interaction
- Sensing
- Actuation
- Energy Management
- …

Elaboration Capability
- To provide function
- Context awareness
- …

Communication Capability
- Low latency
- Connectivity
-

This has an impact on the architectural definition and design for the Smart Systems that will be able to provide different ways of communications, generally for short range interaction with other devices and users, and for a vertical integration and contribution in the overall system domain.

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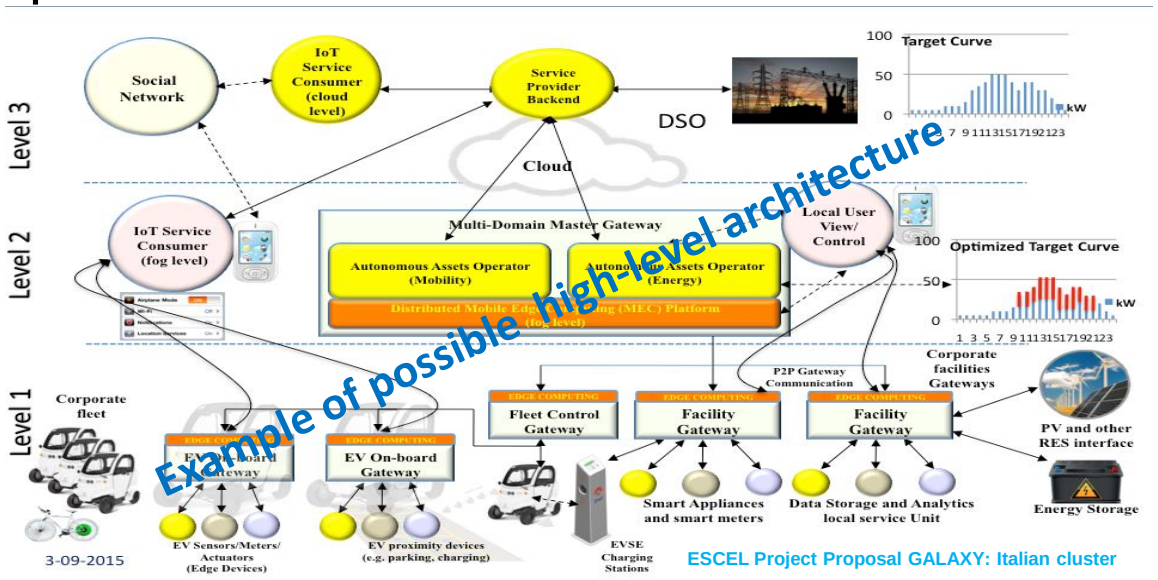
The communication vertical path to the cloud is realised through a collection of heterogeneous communications layers/domains, coordinated and organised in the shape of a unique environment with seamless continuity, in which connected things/objects and devices realise the common interactions by means of a cooperative provision of digital information and data manipulation

On base of the own capability to participate to this common interaction, Smart Systems become part of

IoT as physical edge and objects of this vertical integration.



Smart Systems move into IoT context with specific aimed and clear functions, as well as sensing and actuation, deploying the interface between the real physical and its cyber augmented world by means of accessible services on networks

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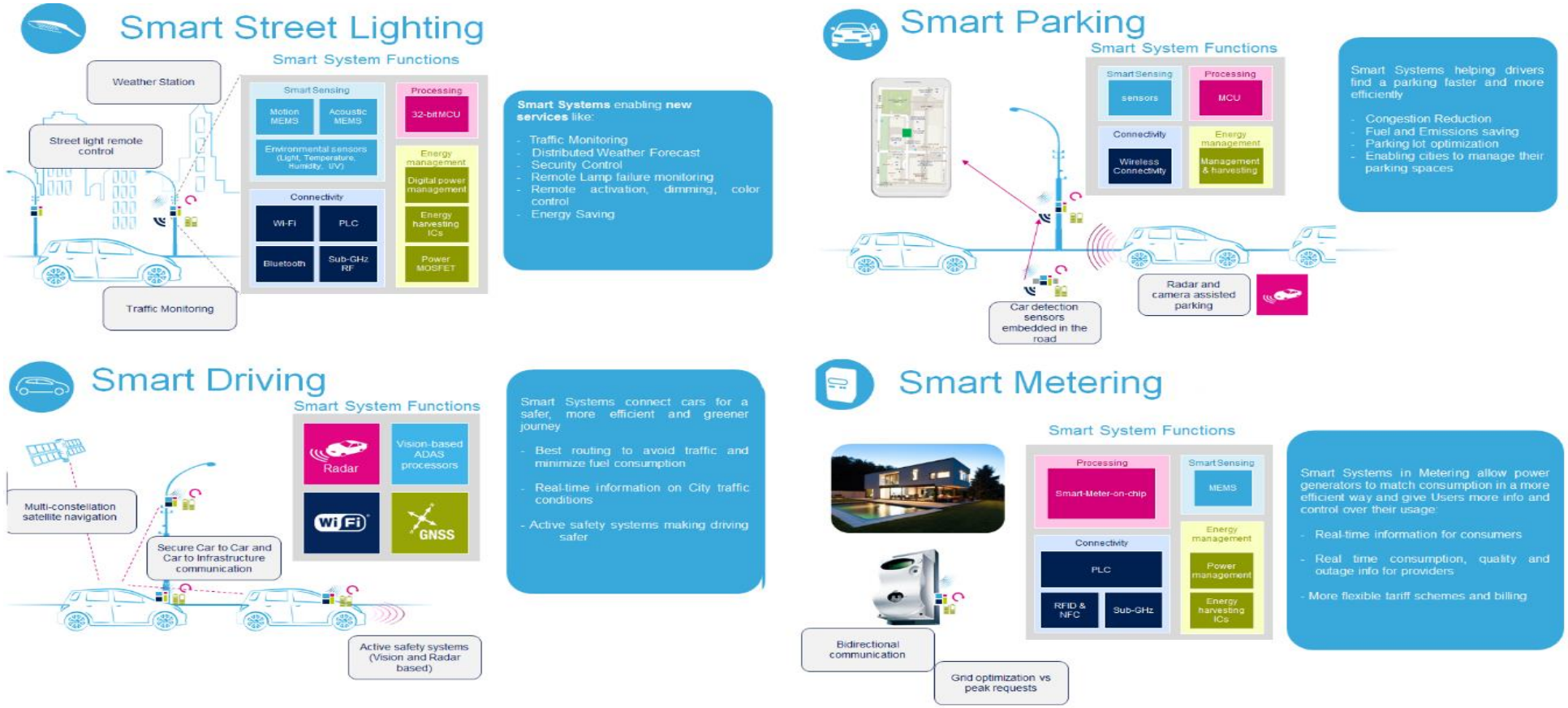

A vision for a smart node, able to support and to be integrated on this kind of high level architecture, has been defined as ‘System of Systems view’ or ‘DAD view’: Distributed, Autonomous and Dynamic decision taking clusters.

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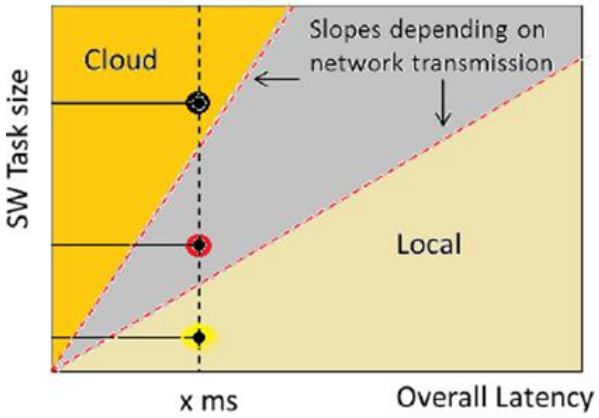
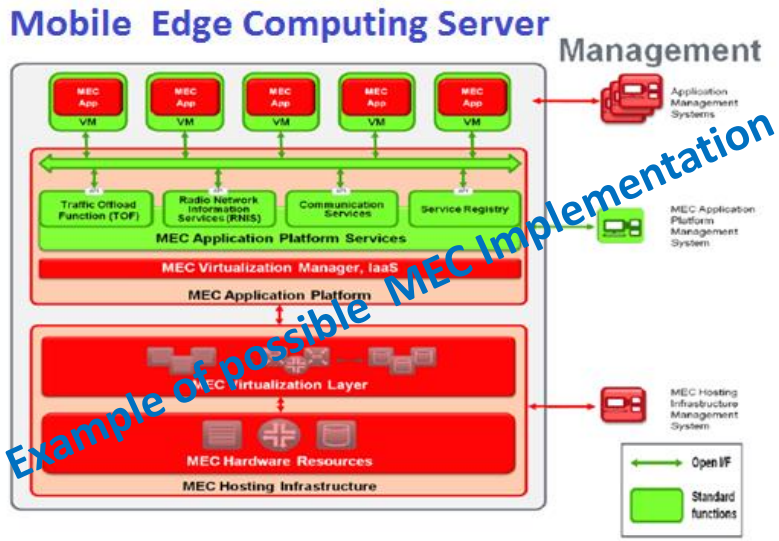
This includes large clusters and ‘cloud’ interactions, with local decision taking according to a Distributed, Autonomous and Dynamic paradigm, characterized by a low latency on communications and large connectivity and adequate processing capability of the local context awareness.

Actually, due for the latency and limited data throughput on the network, the awareness of the context, especially the real time or the just in time more than the near in time, cannot be obtained with Big Data management so it is required to turn to edge/local computational capabilities increasing the low level processing and interpretation..



We can define 3 areas in which, on the basis of communication skills and the time to respond, the “action” has to be the responsibility of the Cloud (high software task and high amount of data to manage) or of the local devices.



the introduction on edge level of ever more processing and interpretation capability, exploiting the adoption of sophisticated communications protocols, moving the handshaking among devices into an applications management under M2M paradigms.

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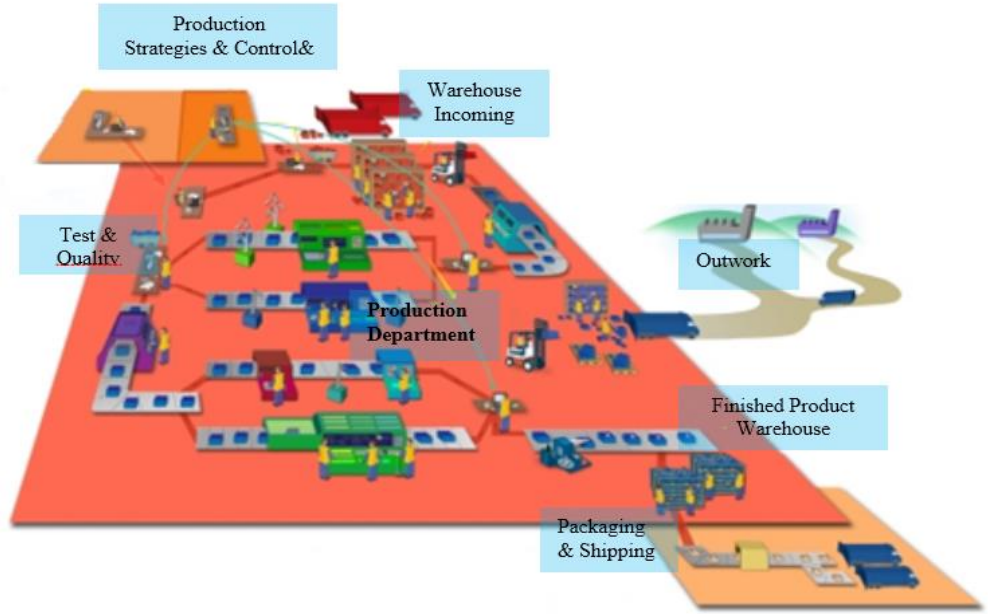
A production line involves activities and services that are not restricted to the effective production of goods, but that are required for the process

- logistics of materials/parts,
- the energy supply/consumption,
- the management of waste,
- the planning process that orchestrates the elements of the process,
- just-in-time provisions with suppliers,
- the delivery schedules to customers
- …



- We are facing an imminent change in the factory and manufacturing domain,
- A remarkable evolution of the entire manufacturing sector by means the exploitation of the high potential offered by new technological and smart solutions in synergy with an advanced integration of ICT solutions.
- This change seems able to revert the current trend to move production into countries with low labour (and other societal) costs.

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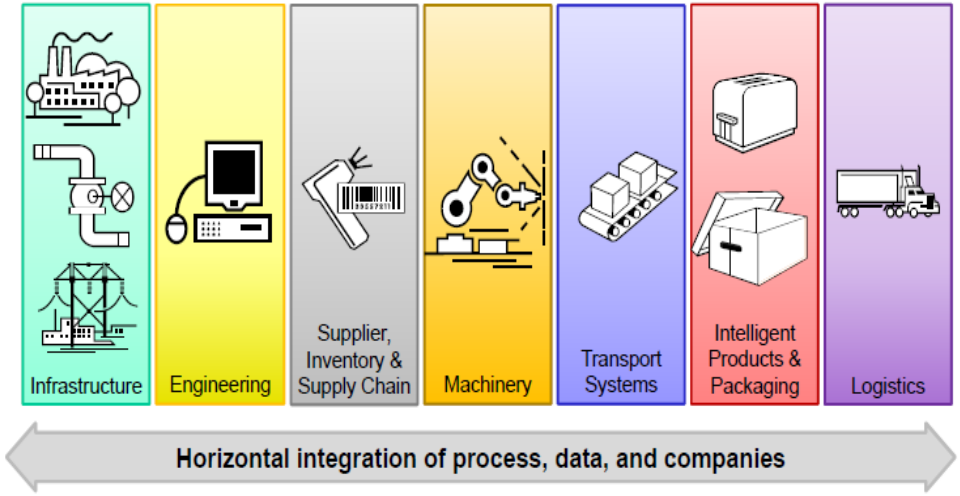
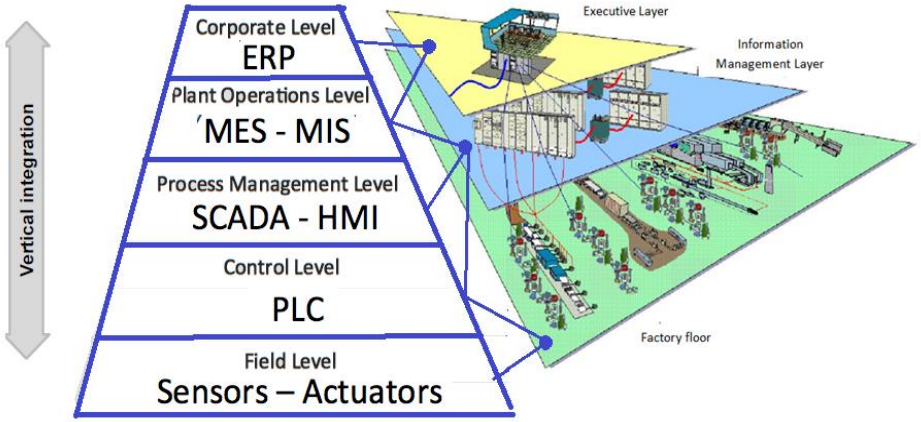
This evolutionary change will be realised through revolutionary new production manners and flexibility to allow goods customization with a better management of the inside and outside factory resources, whose coordination becomes an active part of the production process.





Characteristic of this evolution is both a large horizontal integration across multiple value chains on process, data, and companies, and a strong interaction by means of a vertical integration among Corporate levels (Business Process/Enterprise resource plan), Plant Operational level (Manufacturing Execution Systems and material, quality management, KPI determination), Process management level, control level, field level (sensor and actuators, shop-floor).

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Realising a dynamic value chain, from customer and retailers up to production planning and logistic, is the vision of Industry/ie4.0.

- Industry/ie4.0 is design to improve the ability to combine and overlay the real world on the virtual world in the form of Cyber-physical Systems (CPS) that will be deploy this new production approach.
- In this new approach, the smart machineries, the warehousing systems, the production facilities, the business processes, in brief every part of the manufacturing eco-system, will be capable of autonomously exchanging information, triggering actions and controlling each other autonomously and independently

The Introduction of Smart Systems, in their third view, into the manufacturing is able to ensure the wanted evolution for the factory and to bring inside the production line the capability of Smart Systems to manage sensing and actuation and, at same time, to manipulate information

This will allow the analysis on real production status, allowing changes in parameters to react better on variations and to take advantage of maintenance plans by a pervasive ICT with distributed awareness and smartness in the equipment that become ever more able to collect and cluster information.

For example, the massive introduction of Smart Systems into the manufacturing equipment allows to catch the benefits form a distributed intelligence and smartness promising more flexibility for product changes, customisation and optimisation, increasing the overall throughput and line quality and controlling of the process' micro-environment and providing a more continuous information on these.

On the production floor, advanced ICT architectures, in synergy with a large introduction of Smart Systems, will provide efficient functional "layers" able to provide and sustain the required innovation for this "(r)evolutionary" industrial production.

These solutions will be also able to overcome the typical issues that appear when an updating in the production line is required to satisfy constraints and requirements that are more stringent on flexibility, sustainability and in time to market.

Smart Systems and ICT introduction will ensure the needed flexibility to implement changes in process control, accomplishing needed changes inside the organization of work/production, such as:.

- moving/splitting the production departments into coordinated sets of working isles/modules to favour an increased flexibility of the production (improving customisation),
- Drastic reduction of minimum quantity for orders and speed in response (reduction on stock),
- Moving from a production model linked to the concept of "proximity and territorial community", into a “simultaneous” model, where a worldwide networked manufacturing is part of the production strategy.
- Carry out local optimization underpinned by local knowledge bases, ranging from the examination of raw materials and parts and thereby suggesting subsequent machine settings to compensate for variation.
- Moving the test and inspection from off-line laboratory instruments into procedures for in-line and on-line use.
- optimized machine parameters based upon measured product performance
- …

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To form a vision on the achievable innovation in relation with the introduction of Smart Systems in manufacturing and in factory automation process, we have to observe not only the improvements allowed by exploitation of technology and by advanced manufacturing, but also the developments on:

- Communications infrastructure,
- Standardisation and protocols able to ensure the data ownership management, security level and the privacy in compliance with requirements of industry and industrial production,
- improved workers' skills, to allow the adoption of new design and modelling tools able to better describe and deal with the growing request of integration of ever more heterogeneous systems/domains for Smart Systems application,
- Possible evolution of the regulatory framework to support the introduction and to ensure the new achievable innovations comply with new and existing legislation.
- …

A long-term vision requires to look at the future possible interaction on different domains and environments, allowing new kind of solutions and applications

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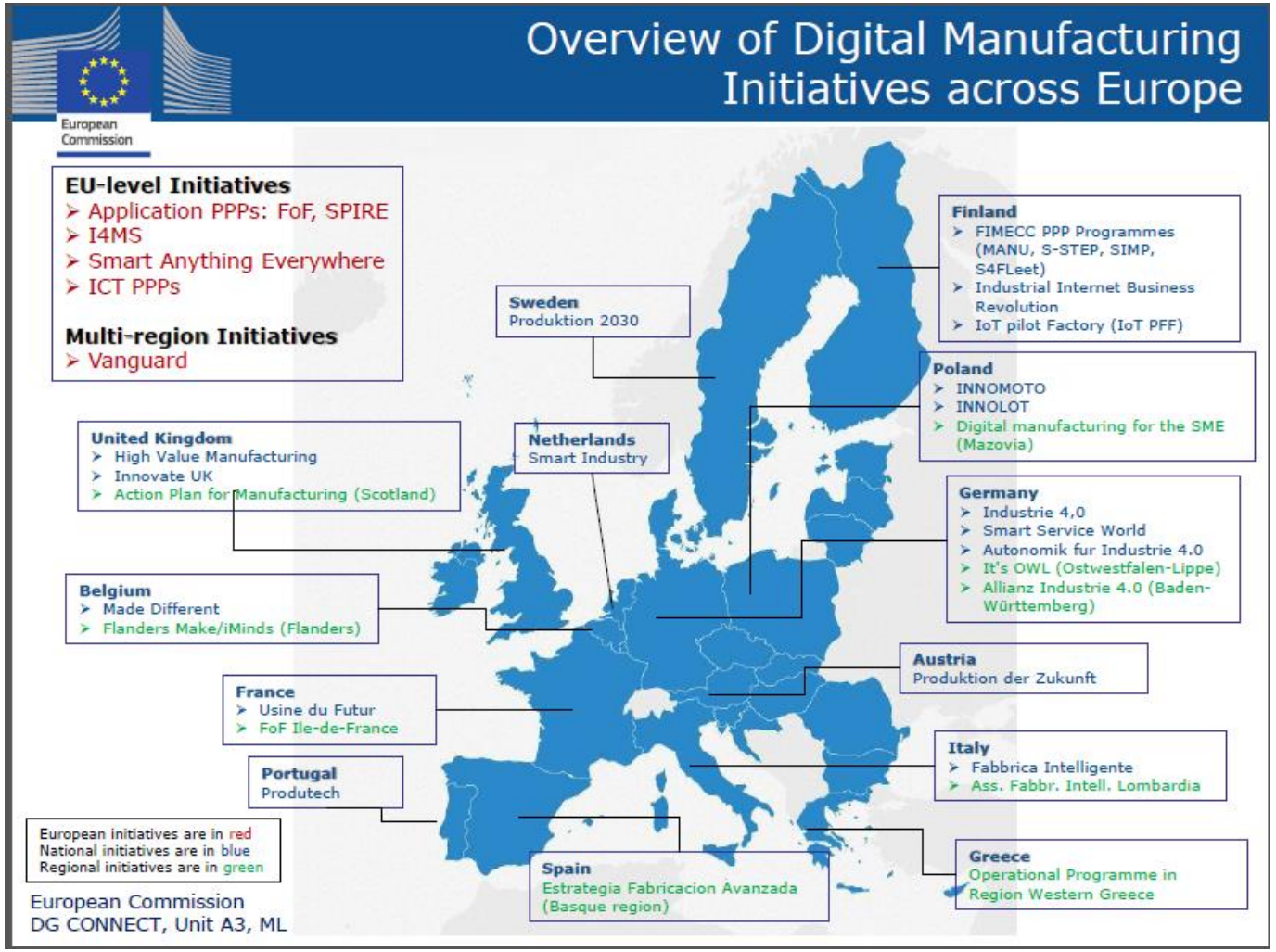
The interest of this kind of approach is confirmed by several initiatives related to the Factories of the Future, at national and regional level, as such:

- Industry/ie4.0 (originating from Germany)
- High Value Manufacturing (UK, Catapult, the MTC)
- Fabbrica Intelligente (Italy, in particular Lombardia and Piedmond)
- Basque and Catalane initiatives (Spain)
- Smart Industry (Netherlands)
- Produtech (Portugal)
- Usine du Future (France)
- Made Different, Flanders Make (Belgiumwith new and existing legislation.
- …

At global level, for exploitation and the synergy between the SSI, IoT and CPS and the industry paradigms, we can refer to:

- Re-industrialization", "Smart Manufacturing
- Leadership Coalition" (USA)
- "Industrial Internet" (GE)
- "Connected Enterprise" (Rockwell Automation)
- "Industrial Intelligence" (Japan)
- "Manufacturing Intelligence 2025" (China)
- "Manufacturing Innovation 2.0" (Korea)
- …

http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=8587



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