
Smart Industry Services in Times of Internet of Things and Cloud Computing

Martin Serrano — Panos Dimitropoulos

*Insight Centre for Data Analytics, NUI Galway, Galway City, Ireland
(Digital Enterprise Research Institute – DERI)
martin.serrano@deri.com*

*Sensap Microsystems, Athens City, Greece
pdimi@sensap.eu*

ABSTRACT. This paper discusses about today's industry transformation process towards smarter industry, by means of semantic technologies, Internet of things and cloud computing enabling more intelligent services. In the field of smart industry services there are high demands for using information interoperability to, for example, enable automated services composition and provide to the systems with intelligence. It is challenging to make smart systems capable to deal with such automation and enable complex operations in the absence of high degree of interoperability, as main requirement a large number of open services that must be integrated are defined by diverse and heterogeneous systems. By using Internet of things, heterogeneity issues can be overcome and by means of cloud computing, the distributed storage and large-scale processing required capacity addressed. A specific scenario from the OpenIoT framework is briefly discussed as an exemplar approach to support the transformation towards smarter industries in times of Internet of Things and Cloud Computing.

KEYWORDS: Cloud Computing, Internet of Things, Service Openness, Service Composition, Smarter Industry, Manufacturing.

1. Introduction – Internet of Things in the Manufacturing Industry

The benefits of the Internet of things (IoT) technologies in the area of manufacturing have motivated enormous progress and potentially are generating big economic impact. Based on the advent and deployment of RFID solutions, the Internet of things is being consolidated as the progress engine in the manufacturing sector and smart industry in general [Johnson02], [Rockwell04]. RFID deployments have exposed benefits associated with the reduction of labour and inventory costs, as well as other techno-economic benefits [Lee04], [Toffaletti10]. These benefits stem

from the use of unique identification (including the ability for serialization), item level track and trace and enhanced track and trace, automated genealogy, elimination of the need for line-of-sight for data readability and, finally, historical tracing. This gave rise to a number of RFID deployments for manufacturing, which however tend to be isolated and focused on specific companies and cases studies [Brintrup08].

In general, RFID deployments in manufacturing cover all the different stages of the production process. For example, in the area of product design the EU FP6 PROMISE project [Promise04] has validated the RFID based linking of field usage data with the product design stage, with a view to improving future designs of products. In terms of production planning, RFID has been used to optimize production rescheduling [Hozak08], as well as dynamic improvements in production planning [Li06].

Several case studies have also focused on the production stage, mainly based on tracking and tracing of the production processes/steps towards improving quality [Huang07], scheduling and production decision making. Other (validated) RFID applications in manufacturing include storage management of perishable materials [Mills-Harris05], Internet-based inventory control [Zhou07], automating outbound shipments of a product after manufacturing [Wessel06], as well as reconfiguring machines in response to changed product configurations [Huang07]. Most of the above RFID-based solutions are custom system integrated on the basis of the specific manufacturing requirements (for various industries), and implemented in a way that data silos have been created rather than solutions derived from general-purpose platforms using more large-deployed infrastructure (cloud).

IoT solutions for manufacturing have been gradually extended in order to include multiple sensors, actuators and devices of the shop floor in addition to RFID. Practical solutions have been developed as part of recent IoT projects (such as IoT@Work – see [Dürkop12] and [Gusmeroli12]), but also as part of IoT vendors' offering. Cisco, SAP and Bosch have undertaken prominent commercial efforts leading the market and opening a new vision towards how the Internet in general will look like in the future.

A prominent example is advertised by Ford Focus Electric, which has built its own Internet of Things that enables communication and data exchange across devices within its vehicles, but also between in-vehicle devices and the company that built it. Ford has built a cloud-based secure server enabling vehicle owners to access a wide range of information via an on-board wireless module and a smartphone app or through Ford's website. The vehicle information provided includes battery state of charge, overall efficiency, energy consumption, and braking regeneration. This infrastructure enables the issue of appropriate alerts in the case of

problems. Furthermore, it provides the means for reporting the car's location when it's lost in a parking lot, being used by the owner's teenage drivers, or stolen¹.

Cisco emphasizes on the convergence of factory systems with IT networks, as part of its wider portfolio of IoT-related solutions. On the other hand, SAP and Bosch promote the communication and interconnection of the numerous devices that comprise a plant for tasks such as manufacturing performance monitoring and predictive maintenance. Recently, solutions that combine IoT with the cloud (i.e., as promoted by OpenIoT) have been also reported [Soldatos12][Serrano13].

In general, IoT Cloud solutions are expected to play significant role in the manufacturing industry, as also proclaimed by the initiative Industry 4.0², a term introduced by representatives of German industry leaders, researchers, industry association, and unions.

2. Smarter Services by Service Composition in Cloud Environments

Currently it is more than evident the business benefits of cloud systems, apart of the reduction in maintenance cost the capacity to run more robust processes, cloud significantly increase systems flexibility to react to user service demands efficiently and by replacing, in a best practice manner, a plethora of proprietary software platforms with generic solutions supporting standardised development and scalable stacks over the Internet. Thus Cloud is ideally the best ecosystem for service composition. Research initiatives addressing this cloud-based design trend and inspired mainly by software oriented architectures (SOA) requirements argue that the future rely in application layers above virtual infrastructures that can meet various requirements whilst keeping a very simplistic, almost unmanaged network. IP for the underlying Internet for example, GENI NSF-funded initiative to rebuild the Internet [GENI, online Feb 2011] is an example of this. Others argue that the importance of wireless access networks requires a more fundamental re-design of the core Internet Protocols themselves [Clean Slate, Online April 2011][AKARI, Online May 2011]. Whilst this debate rages nothing is a clear outcome in terms of information interoperability or data models sharing.

The service composition is a complex process; it implies the identification of service features and elements, as well as it implies the possible evaluation of operation and functionality before the new service can be composed. Thus it can be regulated by semantic rules where if multiple operations are required, then these

1. Karen Wilhelm, "The Internet of Things in Manufacturing", *Manufacturing Pulse Feature Story*, May 13, 2013, available at: <http://www.manufacturingpulse.com/>.

2. Stefan Ferber, "Industry 4.0 – Germany takes first steps toward the next industrial revolution", available at: <http://blog.bosch-si.com/industry-4-0-germany-takes-first-steps-toward-the-next-industrial-revolution/>

operations are performed using the appropriate applications, as defined by service composition rules and/or policies defined by the data associations. Best practices in SOA suggest that a narrow focus on designing optimal networking protocols in isolation is too limited; instead a more abstracted view is required. This offers the advantage of non-dependency on physical infrastructures offering limited amount of services. In this view multiple services are now result of subservices, this method is commonly called composition. When meaning of various distributed protocols and delivering sub-services orchestrate multiple sub services, the operations (e.g., applications, computing processing, distribution of services, networking) can be done more efficiently. In other terms, a more realistic way of offering services is following mechanisms to organise operations according to changes in the parameters and based on users needs. However, realistically this new holistic view increasingly stops to become a matter of critical infrastructure, in this sense cloud computing infrastructures with virtualisation, as main driver is a promising alternative of solution to this stopping problem.

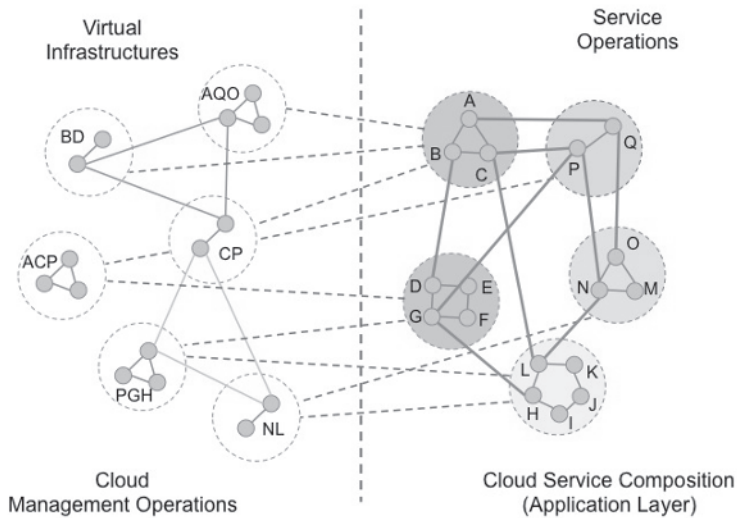


Figure 1. *Service Composition processes representation on Cloud Environments*

Figure 1 depicts the mentioned cloud service composition, its implementation relies on the inference plane [Serrano09], or knowledge layer where the exchange of information (Linked-Data structures) [Decker08] facilitates knowledge-driven support and generation of cloud composed services with operations by enabling interoperable information on networked connected objects [Hauswirth11]. From down to top and having cloud infrastructures representation as example, isolated components representations are depicted with no capacities of sharing information,

linked data mechanisms are missing and “X” represented. In an upper Layer linked mechanism are represented and used to define virtual infrastructure operations and expose them externally. So the migrations towards composed services and networks increases providing solutions to a number of significant technical issues by using more standard information exchange and promoting sharing information. At the upper part of the linked data mechanisms are supported by ontology representations and ontology-based mapping allowing at the same time original services (e.g., ABC) can be managed effectively and most important offering open opportunities for a knowledge-based service-oriented support having a fundamental impact on cloud composition of services (e.g., BD, AQO, PGH, etc.) by a complete information sharing and sub-services representation (e.g., bd, cl, pnl, nl).

In this sense, there are some interesting approaches, some of them following linked-data principles some others SOA principles; the commonality in all of them is the nature of information sharing between the different components or subservices. [Chen09] introduces an approach where a matching algorithm SMA between cloud computing services of multiple input/output parameters is used. The algorithm considers the semantic similarity of concepts in specific lexical parameters. Particularly a service composition algorithm Fast-EP and the improved FastB+-EP were used as reference. Within this approach QoS information is utilized to rank the search results and it is shown based on experiment that this approach has better efficiency of service composition than other traditional approaches.

In other interesting approach [Gutierrez-Garcia10] concentrates on cloud service provider requirements and their mappings with the cloud infrastructure resources in order to automate the service composition process. Founded on agent-based applications their propose a three-layered multi-agent system which by using self-organizing principles the agents make use of contract net protocol to evolve and generate adaptive service compositions. This approach demonstrates how by composing the incomplete information and make a comparison with available information about resources operations for generating a new service can be to allocate.

Further activities have been proposed [Deloitte09] more in the sense of what cloud computing can offer for new services definition rather than for re-using of services that are suitable to host new enterprise services. But while these different approach concentrates on offerings new services, even if they provide clear benefit to particular corporations, it is limited the capacity of what offers they have for composing services. The fact that applications or service systems cannot post the information they can offer as a sub-service does not help to scale or generate new enterprise enriched services. From this point of view and as an inherent feature in cloud systems, service composition is restricted or limited. However this last has not to be understood as a weakness, it is a particular and specific service-goal orientation in how to cope with the service definition and their requirement. It is just meaning that in cloud systems, it simply means composition is limited for regulations or policies and not for computing resources. In this paper we just

concentrate on describing the alternatives and not to compare one or other design approach.

3. Linked Data and Services Management

A current activity, attracting the attention of many research and industrial communities is the formalization of data models (ontology engineering). Enabling information for management of services and control of operations is an example where this formalization is used [Serrano07]. This process focuses in the semantic enrichment task where descriptive references about simple data entries are used to extend data meaning (semantic aggregation), to for example, provide an extensible, reusable, common and manageable linked data plane, also referenced as inference plane [Serrano09]. Thus management information described in both enterprise and infrastructure data models (physical or virtual) with ontological data can be used inherently in both domains

The semantic aggregation can be seen as a tool to integrate user data with the management service operations, to offers a more complete understanding of user's contents based on their operational relationships and hence, a more inclusive governance of the management of components in the infrastructure (resources, devices, networks, systems) and or services inclusive. The objective is sharing the integrated management information within different management systems (liked data). This approach is to use ontologies as the mechanism to generate a formal description, which represents the collection and formal representation for network management data models and endow such models with the necessary semantic richness and formalisms to represent different types of information needed to be integrated in network management operations. Using a formal methodology the user's contents represent values used in various service management operations, thus the knowledge-based approach over the inference plane [Strassner07] aims to be a solution that uses ontologies to support interoperability and extensibility required in the systems handling end-user contents for pervasive applications [Serrano09].

4. Smarter Services for Manufacturing Industry

In the manufacturing industry there is huge demand for making services more efficient; on-demand usage of computing resources and services seems as a viable alternative, but as the same time a restriction because of the limited control on aspects related with the services provisioning (privacy and security mainly) in order to provide scalability and other features by means of using cloud infrastructures. However, in the race for deploying cloud computing services, solutions enabling information interoperability between the different service applications or service

stacks (information sharing) have emerged and as consequence the industry of services is every day getting more importance and evolving positively towards enabling smarter services.

The OpenIoT Cloud-based platform provides opportunities for integrating such solutions, while providing compelling features in terms of sensors and data streams integration, but also in terms of dynamic sensors and sensor data discovery and use between different manufactory environments as depicted in Figure 2.

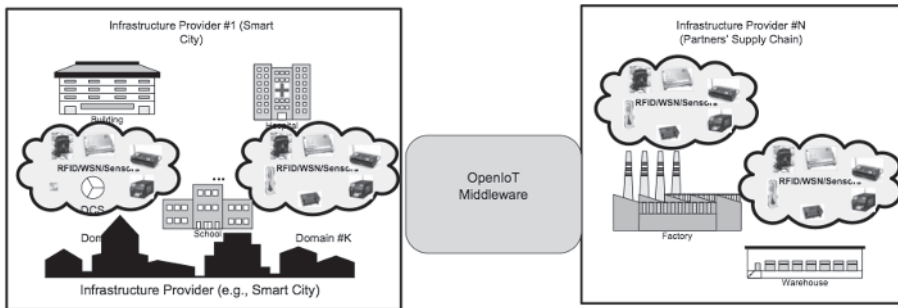


Figure 2. *OpenIoT manufacturing use case on Cloud Environments*

OpenIoT can act as a blueprint framework that will allow solution makers (notably SMEs) to provide and experiment with novel IoT cloud-based technologies for manufacturers, notably small or medium end users that do not have the equity capital to invest on the emerging solutions of the large vendors. OpenIoT's strong points relate to versatility and innovation, yet the prototypes to be developed in the scope of the project will not be able to compete in terms of maturity and robustness with the above-mentioned commercial solutions. However OpenIoT can be seen OpenIoT as a novel sensor cloud system, which allows users/integrators to select the most appropriate sensors for a given job/task, while also filtering their data. Currently existing solutions offer only primitive sensor discovery and virtually no sensor orchestration functionalities so far.

OpenIoT is perceived as a middleware solution for the Dynamic Integration and Discovery for the Internet of Things enabling Service Creation and Delivery by means of interoperable self-organizing management on cloud environments for sensors, sensor networks and smart devices along with semantic open-linked data techniques, utility computing, and including security and privacy schemes.

The OpenIoT manufacturing application showcase the ability of a cloud-based system platform to deploy and execute multiple on-demand utility-based services over a sensor and actuator infrastructure within a manufacturing plant. For the purposes of the use case, manufacturing tasks that maintains warehouses of source

and second materials, as well as manufacturing plants is described. The basic setting considers that within each manufacturing plant, there are multiple production lines. Each of the production lines executes a production phase or a task of the production processes. Each production line involves certain machines, which feature a specific serial number. In the scope of the production process, different production resources (e.g., tools) are associated with the machines of the production lines for specific time intervals. This association concerns the production of specific numbers/units of finished products. While the manufacturing sector is wide, there are common features a cloud-based system must support.

In the area of *performance monitoring*, the cloud deployment must support:

- Performance monitoring requests concerning one or more KPIs (Key Performance Indicators) associated with the plant operation.
- On-demand calculation of KPIs associated with multiple sensors and Internet-connected objects of the plant.
- Generate dashboards for automatically displaying the KPIs and their evolution. These dashboards will be based on OpenIoT's HMI/mashup capabilities.

Likewise, in the area of production process traceability, the cloud deployment must support:

- Requests for tracing specific production orders, task or steps and report on their quality.
- Be able to trace production orders, steps or tasks (i.e., different granularities).
- Be able to connect to actionable logics including M2M interactions (e.g., tagging of a lot, configuration of a machine or tool).
- The process and its quality characteristics will be visualised (e.g., based on appropriate mashups).

A possible implementation of the OpenIoT middleware in the manufacturing domain could leverage readily available blueprint implementations of semantic infrastructures for other areas (such as IoT), which have been already realized by IERC projects (e.g., the OpenIoT open source cloud-based discovery infrastructure for IoT resources, which is available at: <https://github.com/OpenIoTOrg/openiot/>).

5. Conclusions

In this paper research trends and main efforts for service composition have been discussed towards designing and building composed services in cloud environments for the Internet of Things in the framework of Smarter Industries as implementation main scenarios in Manufacturing is given as an application example in the framework of the OpenIoT project.

Information sharing is a crucial activity to satisfy the requirement in convergence service and particularly manufacturing systems. Implications for composing services and virtual infrastructures management are still under research (service composition in cloud).

In cloud environments high demands of information interoperability and of semantic annotation (linked data) are demanded to satisfy service discovering and services composition requirements being controlled by diverse, heterogeneous systems and thus make more dynamic the perform of cloud-based system.

Remaining research challenges regarding information model extensibility and information dissemination conduct our attention to continue our activity towards virtual infrastructure management, perform more cloud service control experiments and look for full linked data representations for service composition in cloud environments.

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