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AN ARCHITECTURE FOR ORGANIZING AND LOCATING SERVICES TO THE INDUSTRY 4.0

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Abstract. *Research and government agencies from Germany has been leading the fourth industrial revolution, also referred as Industry 4.0, a concept that have been gaining force and new followers around the world. The main purpose of this emergent concept is to consolidate the smart factory, to enable the creation of on-demand and personalized smart products and services that meet the consumers' individual needs. It is based-on Cyber-Physical Systems, and Internet of Things, which use resources of information and communication technology integrated to the shop floor. Amid global trends and market fluctuations, the Industry 4.0 may benefit industries regardless of size, but especially small- and medium-size enterprises and startups with regard to the establishment of virtual enterprises. However, recent studies show that between so many concerns about the Industry 4.0, stand out the needs for architectures, methods and standards to organize and locate services of virtual entities that can contribute to the performing of on demand services. This paper presents an architecture for organizing service in hierarchical structure and locating them on a system similar to Domain Name System, in a way to enable products to be treated according its needs. To achieve it, the fundamental concepts around the Industry 4.0 are presented and architectures are investigated, followed by an application sample based on a hypothetical engine factory.*

Keywords: *Cyber-Physical Systems, Hierarchical Service Organization, Industry 4.0, Internet of Things, Service Composition, Service Location.*

1. INTRODUCTION

The Industry 4.0, also called fourth industrial revolution, is a new era of industry that is centered on the extensive use of advanced resources of information and communication technologies (ICT) to improve the manufacturing processes and business, which has been known as smart factory (Lasi *et al.*, 2014). This term was originated by high-tech strategy from German government that has been funding research and development activities over this issue, which has been adopted by other countries around the world (Kagermann *et al.*, 2013). The Cyber-Physical Systems (CPS) and the introduction of the Internet of Things (IoT) into industry characterize this new industrial period (Kagermann *et al.*, 2013). In fact, it is a virtualized world that is supported by ICT. The CPS are focused on an integrated network of physical resources and processes to enable the fusion of the real and virtual systems (Gorecky *et al.*, 2014; MacDougall, 2014). The IoT enable the communication between sensors, actuators and smart objects to provide the information exchange between objects and machines (Lasi *et al.*, 2014), which contribute for a more autonomous system in the shop floor (McFarlane *et al.*, 2013; Ungurean *et al.*, 2014).

An overview of the Industry 4.0 is depicted on Fig. 1, where physical systems such as Consumers, Factories, Partners, etc. are mapped to the virtual world, turning them accessible from anywhere and allowing communication between them through collaborative networks in order to meet common needs.. All the contents of this scenario are virtualized services available over the Internet (Kagermann *et al.*, 2013; Kagermann *et al.*, 2014), which are focused on design and creation of smart products, procedures and processes, in a way to create on-demand personalized services that can meet the needs of individual consumers (Kagermann *et al*., 2013; Pisching *et al.*, 2015). In the Industry 4.0 as well as in the IoT, the cloud computing is a promising technology to support the publication and sharing of large volumes of heterogeneous data and services (Bechtold *et al.*, 2014; Gubbi *et al*., 2013).

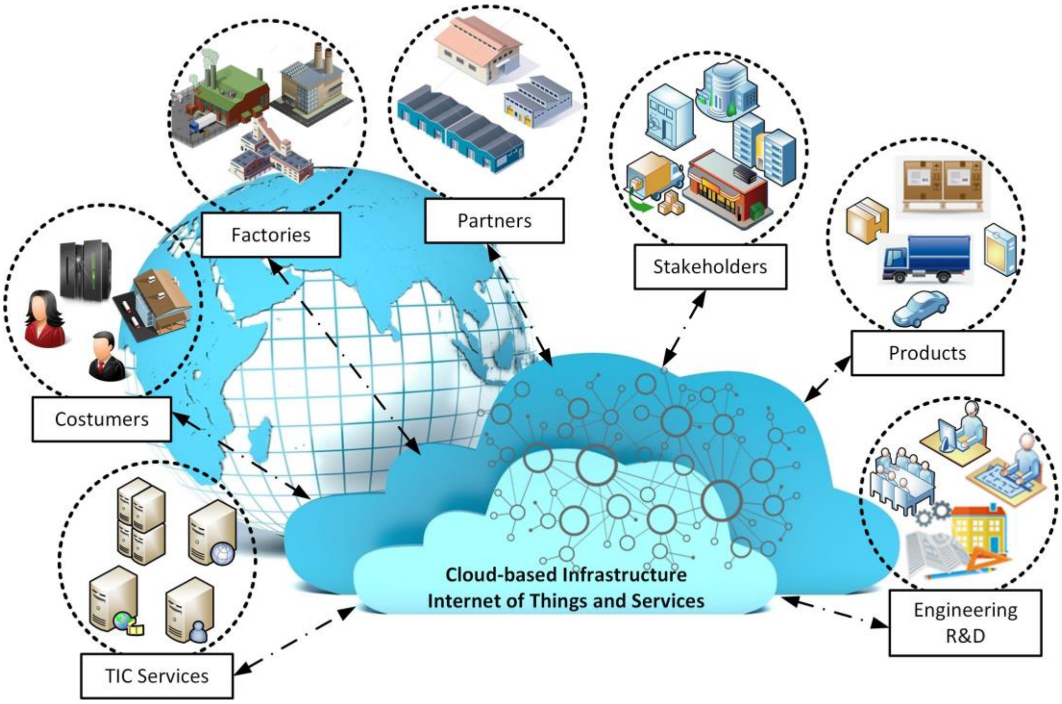

Figure 1. A global vision of Industry 4.0

The Fig. 2 shows the Industry 4.0 and its main involved concepts around of virtual services. By CPS and IoT concepts are possible to virtualize and track the physical resources and services, turning them virtual objects, as well as possible, to allow the integration of the virtual world with the real-world (Kagermann *et al.*, 2014). Products, objects, people and services become part of a large group of virtual services, also called everything-as-services (Li and Wei, 2012). Thus, in the industrial sector, manufacturing processes can also be converted to virtual services - "Manufacturing Processes as Services". The virtual services converge to the "Internet of Services" that could be published and deployed on cloud-based technologies, which must be integrated to the physical processes, enabling that services can be shared and accessed by local or dispersed partners in order to allow service composition (Pisching *et al.*, 2015).

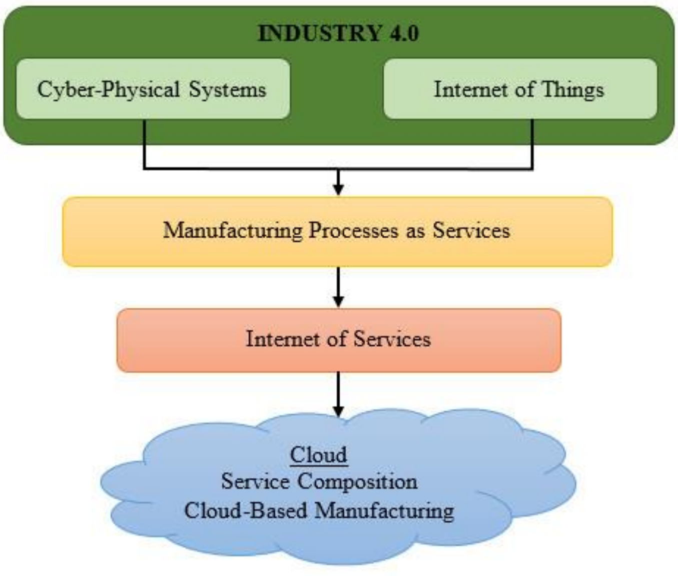

Figure 2. Industry 4.0 and its relations with CPS, IoT, Services, and Cloud (Adapted from Pisching *et al*., 2015)

To Bauer *et al.* (2013), any physical entity can be mapped to virtual entities (VE) in the IoT. Each VE is able to represent its real state including attributes and operations, which are available in the Internet. Additionally, in this emerging concept the products and raw materials can carry their own information, such as features, destination and tasks to be performed on its production cycle. Objects with these capabilities are called smart products, and are based on the IoT and have as main characteristic the traceability, which contains information ranging from the production process to the after-sales, which can contribute to the implementation of more autonomous production systems (Gutierrez *et al.*, 2013). To McFarlane *et al*. (2013), the approach that follows the smart product paradigm for industrial control and monitoring can be described as the ability to treat each product individually, depending on their characteristics and needs. According to Xu *et al.* (2014), technical standards and architectures must be designed to define the specifications for information exchange between "things". To Bandyopadhyay and Sen (2011) the success of the IoT in the industrial context depends on standardization and architectures, which should provide interoperability, compatibility, reliability and effective operations on a global scale. In the IoT is expected the multiplication of heterogeneous "things" and services interacting with the physical environment autonomously. The location of these objects and services amid of thousands things is essential to the IoT.

The trends and expectations of the Industry 4.0 involve many emerging concepts, therefore it have been presenting many opportunities with regard to research and development (Kagermann *et al.*, 2013; Kagermann *et al.*, 2014; Lasi *et al.*, 2014; Bechtold *et al.*, 2014).

This paper aims is a proposal of an architecture based on a hierarchical services network to identify and locate services for an autonomous negotiation between products and machineries of a production cell, in a way to contribute for Industry 4.0 implementations.

2. STATE OF THE ART

According to Kagermann et al. (2013), the Industry 4.0 need reference architectures. Based on its relationship with the IoT, in this section the architecture around the IoT focusing on communication, identification and location of things is exploited, in order to contribute for an architecture with the same purpose for the Industry 4.0.

2.1 Architectures and reference model for IoT

Since the rise of IoT some architectural proposals were presented, essentially addressing the form of intercommunication between things in a communication network environment, the representation of these as services and the interface with other systems. Between the researches, four different proposals were found, but that converge to a model based on layers which represent the interconnection between applications, services and physical devices. Table 1 provides an overview of each architecture contemplating authors, layers and a brief summary.

2.2 Research on location of IoT Services

The paper developed by Heras and Santos (2011) in the IoT-ARM project, describe concepts and solutions for the identification and discovery of IoT resources. The authors also consider the main methods for locating and resolution of services, based on five approach: Domain-oriented approach; Location-oriented infrastructure; Semantic web; Distributed Hashtable-based peer-to-peer; and Federation-based approach. The conclusions of Heras and Santos (2011) is that each approach need more investigations.

Yan et al. (2013), presents a scheme for solving universal object names considering a point-to-point resolution, whose purpose is to identify each object in the IoT. The scheme presented is based on the ONS (Object Naming Service). In this proposal the author locates the object identifier and, through this, find the location of the object in the Web Services server.

The paper of Karakostas (2013) presents a proposal based on DNS (Domain Name System) for the IoT. This has the function of translating unique identifiers (URI - Uniform Resource Identifier) of physical objects for network addresses, from which can be obtained information about the objects (e.g., status, location, etc.). Karakostas (2013) also presents a DNS infrastructure for IoT with a sample application applied to transport logistics.

3. IOT ARCHITECTURE FOR ORGANIZING AND LOCATING SERVICES

The basic architecture proposed in this paper is shown in Fig. 3 [a]. It is based on the Application, Communication and Device layers of IoT-ARM. In this section the Entities and Services layer is more emphasized, as it has the resources for the organization and location of entities and services. This layer is responsible for locating the entity to perform a particular type of service according to the parameters obtained from a product in a production process.

To do the location of an entity to perform a particular service, the layer 3 is subdivided into sublayers, which are shown in Fig. 3 [b]. Compared to the IoT-ARM suggested by Bauer *et al.* (2013), there is the presence of four modules, called VE, SM, FOVES and LSVES, which are detailed in the following items:

Table 1. IoT architectures and reference model.

Authors	Layers[(1)]	Summary
Bandyopadhyay and Sen (2011)	Applications Middleware Internet Access Gateway Edge Technology	The two lower layers deal with data capture, followed by an intermediate layer that allows intercommunication of different types of communication media, and finally, the two upper layers which are responsible for data use in different types of applications.
Xu *et al.* (2014)	Interface Service Network Sensing	This four layer architecture provides methods for interaction between users and other applications. The service layer is responsible for the creation and management of services. The network layer can support communication and data transfer. Finally the sensing layer is integrated into the hardware to detect and control the physical world.
IoTWF (2014)	Collaboration & Processes Application Data Abstraction Data Accumulation Edge Computing Connectivity Physical Devices & Controllers	It is a proposal of a reference model for IoT based on seven layers. The Collaboration and Processes layer offers features to organize collaborative business processes involving groups of people and organizations. The Application layer allows interaction with the data stored and Data Abstraction layer. The Data Abstraction layer is responsible for the representation of data. The Data Accumulation layer deals with the storage of data and determines the actions on them. The Edge Computing layer is responsible for converting data flowing over the network. The Connectivity layer deals with communication and connectivity operations. The Physical Devices & Controller layer are the devices and controllers that can control multiple devices.
Bauer et al. (2013a)	Application Service Organization IoT Process Management Virtual Entity IoT Services Communication Device	An architectural reference model for IoT (IoT-ARM) divided into nine Functional Group (FG), was designed by IoT-A project. The Application FG allows interactions with IoT systems. The Organization Service FG acts as a central point of communication services between other layers. The IoT Process Management FG aims to provide functional concepts to conceptually integrate the particularities of the IoT world with conventional processes/business. The Virtual Entity FG contains functions that allow interaction with IoT systems and virtual entities, as well as features for service discovery and location that can provide information about virtual entities. The IoT Services FG contains the IoT virtual services. The Communication FG abstracts a variety of derivatives interaction schemes of various technologies belonging to the IoT systems (devices) and provide a common interface to IoT Service FG. The Device FG is responsible for mediating the interactions between physical and virtual entities.

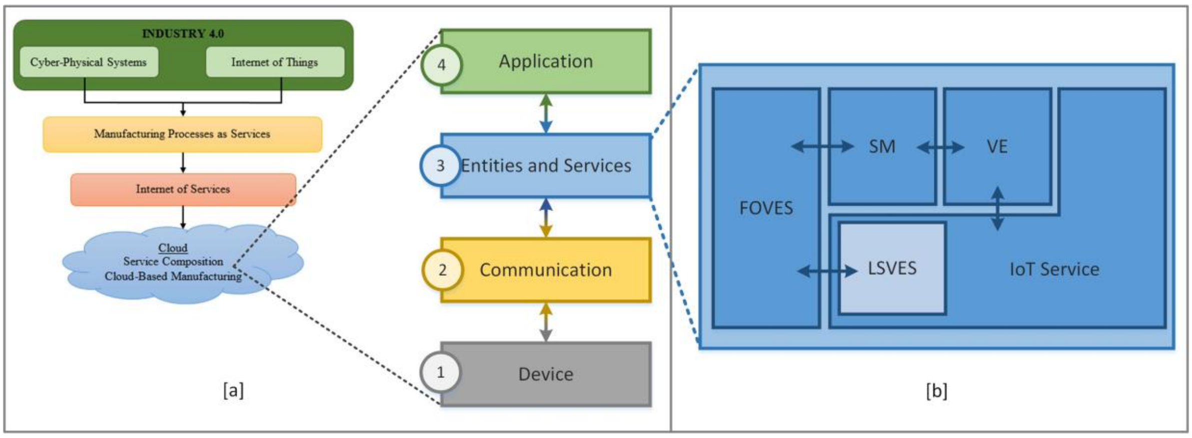

Figure 3. [a] IoT basic architecture. [b] IoT basic architecture for organizing and locating services (Adapted from Bauer *et al*. (2013))

• VE - Virtual Entities - represent physical entities, such as products, robots, conveyors, manufacturing cells, etc. Each VE keeps its attributes and services. This layer should provide functions to maintain and update the data of VE, so that VEs reflect their real state and vice versa;

• SM - Service Manager - is the application interface, which should offer resources for service composition based on collaborative service network (CSN). The composition can be performed by operators or SOA-based systems, as a result of industrial designs that are organized hierarchically and in a federated manner. This means that each industrial sector must be organized as a domain and subdomains, and within each are the equipment and machines as well as the services that each can perform to allow the execution of a complete job in a productive sector;

• FOVES - Federated Organization of Virtual Entities and Services - the main function of this layer is storing and providing information about the virtual entities and services offered by them. This information must be maintained in hierarchical form, allowing the location of resources that can meet a specific demand or sequence of operations in a location system similar to the DNS - the dynamics and details of the hierarchical organization are presented in subsection 3.1. The hierarchical organization is formed by entities belonging to CSN, i.e. entities that are present into the company and its group of partners, even those outside the industry;

• LSVES - Location Service of Virtual Entities and Service - the purpose of this layer is to meet the requirements arising the communication environment between the IoT systems and devices. Based on parameters provided by products, as well as the type of service to be performed, this layer interacts with the FOVES in order to find an entity able to perform such service. When this action is held, the FOVES returns the VE identifier, which is located and ordered to perform the service through the IoT Service layer;

• IoT Service - corresponds to the IoT service interface, among them stands out the LSVES. The function of this layer is to do the interface with the communication elements to send and receive commands and actions for/from devices that will perform the services.

3.1 Hierarchical structure for collaborative service network

The aim of hierarchical organization, which is maintained on FOVES, is to provide elements to an entity location service that can perform a certain task on demand and autonomously that is supplied by LSVES. The LSVES and FOVES have the function of assisting in controlling the operational flow of the production system. To do the location of entities and services it is proposed a location system similar to DNS. The information are stored in a tree-based structure to search services, where each node is a VE with its available services. The tree is the result of a CSN.

The CSN is a chain of production systems, whether local or dispersed. In order to organize VEs and capabilities representing real-world situations, these are organized by the SM functions according to divisions and subdivisions of productive systems, involving from sectors to equipment and machines present in each environment, like a domain and subdomain of network computers with its resources. Each unit consists of segments and their equipment, which may be part of a shared organizational structure to provide services to third parties as well as obtain cooperation from other stakeholders. The representation of an organizational hierarchy maintained on FOVES is shown in Fig. 4.

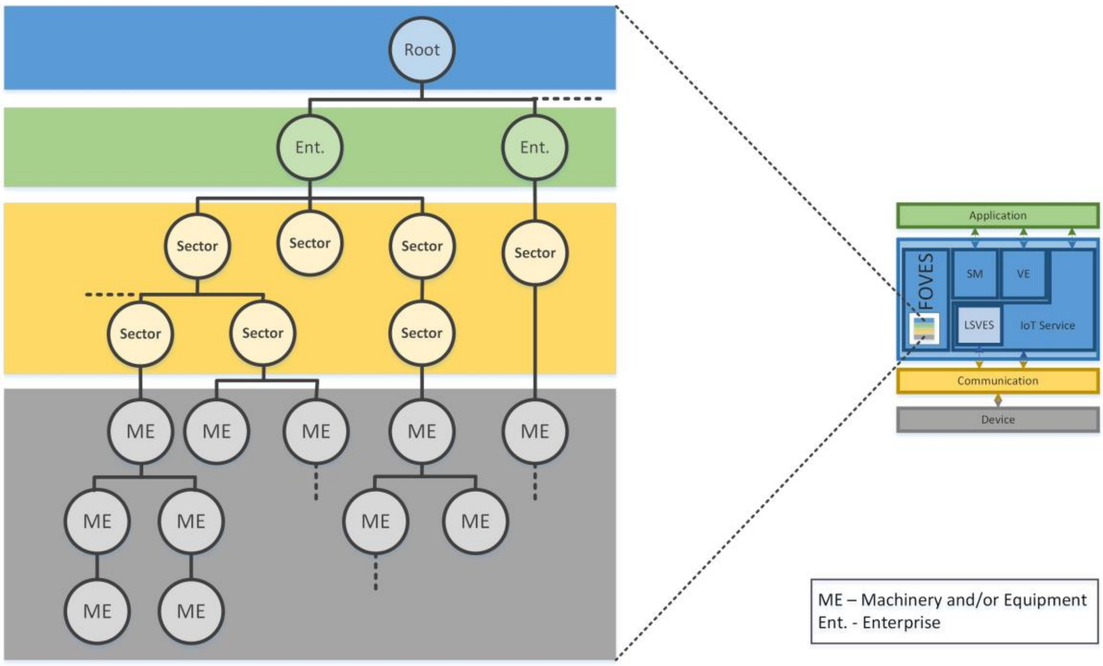

Figure 4. Hierarchical structure for locating entities and services on a CSN

In the location system, for the composition of the hierarchical tree of VEs and services, each node is configured with the services and capabilities, as well as the identification and capacity of each underlying node. For locating the services are used two tables: one to keep the information on services and current node capabilities (Table 1 of Fig. 5); another one to keep the information that guide the location of services in underlying nodes (Table 2 of Fig. 5), as well as those belonging to other threads that may have already been researched and used in other situations, thereby also expedite searches in the CSN. The first table is used in the first instance, i.e. when a product brings the information concerning the demand for a service, it verifies the VE ability to execute the current task. If the first table does not meet the need, then the second table is used to determine if any underlying entity has the ability (as well as the availability). If none underlying VE can meet the demand, then it is necessary to use other VE belonging to the hierarchical tree. It start with the VE that is just above the current VE, doing a recursive location in its nodes until a VE can be found to perform the service. When a solution is not found on its scope, the "Root" node, which has knowledge about all VEs, may be able to indicate a VE to do the task. The contents of Table 2 shown in Fig. 5 can drive to the service location. The first column corresponds to the service identifier, followed by the respective level of service, which may be executed by a VE. The third column deals with the identification of VE, which will be the key to verify their ability and availability to perform the task. Finally, the fourth column is the priority that the VE has on others to perform a certain task.

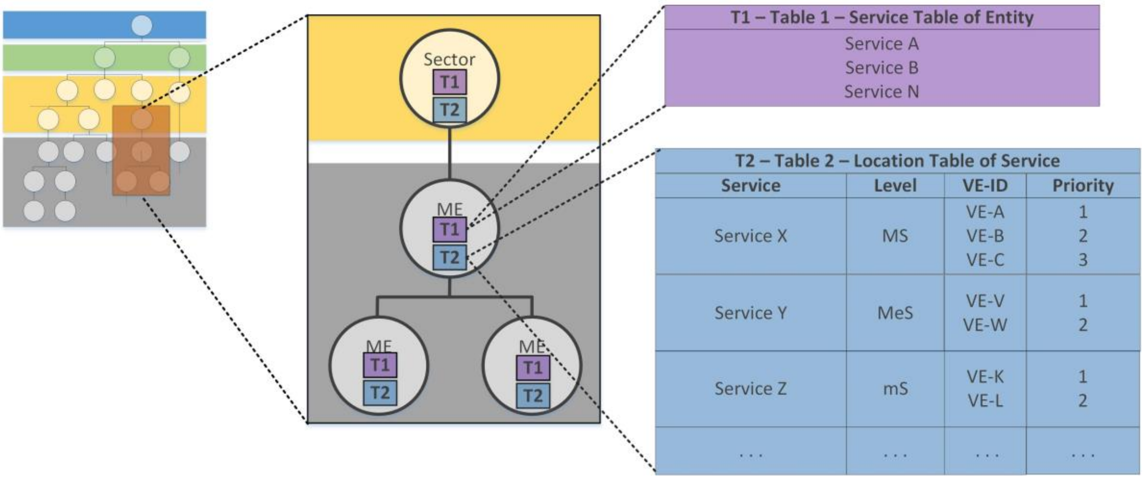

Figure 5. The tables to locating VE to perform a service

4. AN APPLICATION EXAMPLE

Figure 6 shows a layout of an assembly line of a hypothetical engine factory as an application example of the service location in the proposed architecture. The "Engine Factory" consists of several sectors, each one with machinery and equipment (ME). The sectors are "Machining", "Warehouse", "Assembly", "Inspection/Test", "Logistics", "Remanufacturing", and "Discard".

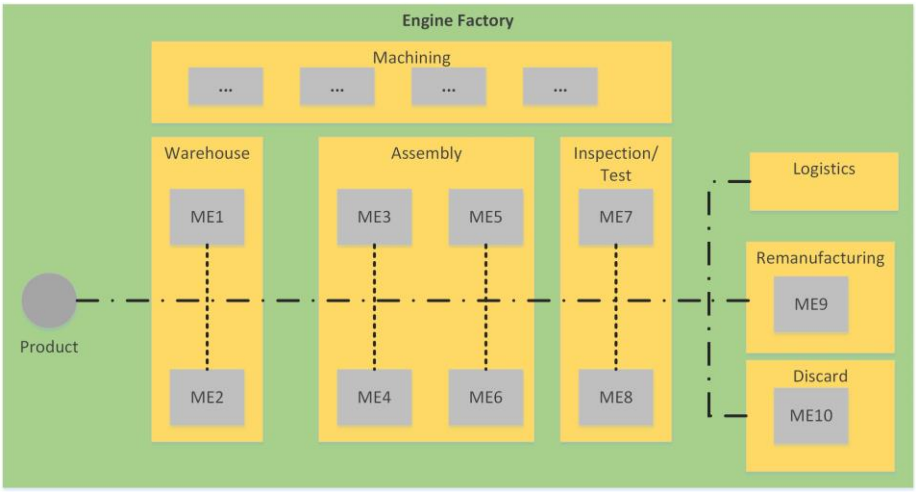

Figure 6. A hypothetical engine assembly line

In this scenario, the product (represented by a circle) follows the production line through different sectors according to the information and services it has carrying. The MEs have systems to identify and communicate with the VE. The VE must recognize which service is requested by the product. To do this the positioning of it is checked and whether the ME is able to perform the task or not. E.g. one product can go into the "warehouse", where a ME (1 or 2) can do the inspection. If the product is right for use it can be sent to the "Assembly" sector – ME 3, 4, 5, or 6, according to its capabilities and availability, and the type of service required by the product, as shown in the flow of Fig. 7 [a]. If the product presents some kind of unforeseen during the inspection, it can be sent to other sectors, such as "Logistics" (e.g. devolution to the manufacturer), "Remanufacturing" (e.g. an adjustment), or "Discard "(e.g. no solutions). This situation is shown in Fig. 7 [b]. In the case of remanufacturing, for example, the product can return to the "Warehouse" or to the "Assembly" sector to continue the process where it has stopped (Fig. 7 [c]).

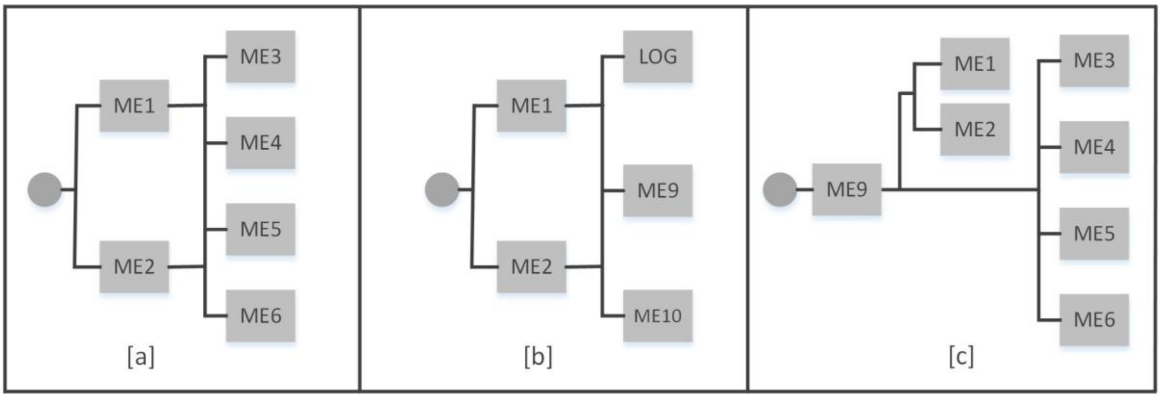

Figure 7. Some possible flows to product in the factory

The Table 2 presents a sample of the product information to guide its required services. The purpose of each column is: "Object" contains the unique identification of the product; "Attributes" refers to the fields and object data, such as material type, batch, manufacturer specifications, dimensions, etc.; "Service" is the list of services to be performed on the product. Each service must have a unique identifier; "Order" determines the service execution order; "Status" corresponds to the current state of each service, such as "Open", "Done", "Running", "Error", or "Cancelled".

Table 2. Product information to guide the performing of services.

Object	**Attributes**	**Service List**		
		Service	**Order**	**Status**
Product.X	Material; batch; manufacturer; size.	service_1	1	Running
		service_2	2	Open
		service_4	3	Open
		service_7	4	Open

5. CONCLUSIONS

Thousands of objects are expected to be available in the IoT, thus it is raising up concerns about how these objects will be identified and located with lowest cost and time in order to allow real time communication between products and equipment. The data and services of virtualized entities generate a large volume of information that needs right handling to allow the communication between products and machines. In the industry, the communication between products and machines can allow that the products may receive different treatment during the manufacturing process, since machines can receive individual information of each component. This characteristic is one demand of Industry 4.0, i.e. manufacturing on demand and personalized products.

The architectural proposal to identify and locate services aims to contribute to the Industry 4.0, with regard of the smart factory. The concept of IoT and Industry 4.0, does not include concrete architectures for such a task. Therefore, this research can contribute for these emerging concepts, which requires means to streamline the communication processes between products and machines, especially when the issue is the information search between a large volume of data. The use of a system similar to DNS can improve the method for locating things and services. This issue must be more investigated in our future researches, in a way to contribute for organizing and locating entities and services as well as to advance in researches about interactions between machines and things in the Industry 4.0.

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7. REFERENCES

Bandyopadhyay, D.; Sen, J., 2011. “Internet of Things: Applications and Challenges in Technology and Standardization”. *Wireless Personal Communications*, Vol. 58, p. 49-69.

Bauer, M., Bui, n., Loof, J. de; Magerkurth, C., Nettsträter, A.; Stefa, J.; Walewski, J. W., 2013. “IoT Reference Model”. In: Bassi, A. et al. *Enabling Things to Talk: Designing IoT solutions with the IoT Architectural Reference Model*. Ch. 7, p. 113-162. Springer.

Bassi, A., Bauer, M., Fielder, M., Kramp, T., Kranenburg, R. van, Lange, S., Meissner, S., 2013. Enabling Things to Talk: Designing IoT solutions with the IoT Architectural Reference Model. Heidelberg New York Dordrecht London: Springer.

Bechtold, J., Lauenstein, C., Kern, A., Bernhofer, L., 2014. “Industry 4.0 - The Capgemini Consulting View”. *Capgemini Consulting*. 2014.

Gorecky, D., Schmitt, M., Loskyll, M. and Zühlke, D., 2014. “Human-Machine-Interaction in the Industry 4.0 Era”, INDIN 2014, p. 289-294.

Gubbi, J., Buyya, R., Marusic, S., Palaniswami, M., 2013. “Internet of Things (IoT): A vision, architectural elements, and future directions”. *Future Generation Computer Systems*, Vol. 29, p. 1645-1660.

Gutierrez, C.; Garbajosa, J.; Diaz, J.; Yague, A., 2013. “Providing a Consensus Definition for the Term Smart Product". 20th IEEE ECBS, p. 203-211.

Heras, R.D.L., Santos, N., 2011. “Internet of Things Architecture - IoT-A: Project Internal Report D4.1 Concepts and Solutions for Identification and Lookup or IoT Resources”. IoT-A.

IOTWF, 2014. “The Internet of Things Reference Model”. *Internet of Things World Forum*. 12 Apr. 2014 <http://cdn.iotwf.com/resources/71/IoT_Reference_Model_White_Paper_June_4_2014.pdf>

Kagermann, H., Riemensperger, F., Hoke, D., Helbig, J., Stocksmeier, D., Wahlster, W., Scheer, A.-W. and Schweer, D., 2014. “Smart Service Welt”. ACATECH. Frankfurt.

Kagermann, H., Wahlster, W. and Helbig, J., 2013. “Recommendations for implementing the strategic initiative Industrie 4.0”. ACATECH. Frankfurt.

Karakostas, B., 2013. “A DNS Architecture for the Internet of Things: A Case Study in Transport Logistics”. *Conference on Ambient Systems, Networks and Technologies*. p. 594-601.

Kramp, T., Kranenburg, R.V., Lange, S., 2013. “Introduction to the Internet of Things”. In: Bassi, A. *et al*. *Enabling Things to Talk: Designing IoT solutions with the IoT Architectural Reference Model.* Ch. 1, p. 1-10, Springer.

Lasi, H., Kemper, H.G., Fetkke, P., Feld, T. and Hoffmann, M., 2014. “Industry 4.0”. *Business & Information Systems Engineering*. Vol. 4, p. 239-242.

Li, G. and Wei, M., 2012. “Everything-as-a-service platform for on-demand virtual enterprises”. *Journal of Information Systems Frontiers*, Vol. 16, p. 435-452.

MacDougall, W., 2014. “Industrie 4.0 - Smart Manufacturing for the Future”. 10 May 2015 <www.gtai.de>.

McFarlane, D., Giannikas, V., Wong, A.C.Y. and Harrison, M., 2013. “Product Intelligence in Industrial Control: Theory and Practice”. *Annual Reviews in Control*, Vol. 37, p. 69-88.

Pisching, M.A., Junqueira, F., Santos Filho, D.J. and Miyagi, P.E., 2015. “Service Composition in the Cloud-Based Manufacturing Focused on the Industry 4.0”. In *Proceedings of the 6th Doctoral Conference on Computing, Electrical and Industrial Systems – DoCEIS’ 2015 – IFIP AICT,* Caparica, Lisboa, Portugal, Vol. 450, p. 65-72.

Souit, S., Fattori, C.C., Junqueira, F., Santos Filho, D.J. and Miyagi, P.E., 2013. “Orchestrating dispersed productive systems”. In *IEEE ETFA*, p. 1-4.

Ungurean, I., Gaitan, N.-C. and Gaitan, V.G., 2014. “An IoT Architecture for Things from Industrial Environment”. *10th International Conference on Communication*, p. 1-4.

Xu, L.D., He, W., Li, S., 2014. “Internet of Things in Industries: A survey”. *IEEE Transactions on Industrial Informatics*, Vol. 10, p. 2233-2243.

Yan, Z., Kong, N., Tian, Y., Park, Y.-J., 2013. “An Universal Object Name Resolution Scheme for IoT”. IEEE GreenCom, 2013 and iThings/CPSCom, p. 1120-1124.

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