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Integration of digital factory with smart factory based on Internet of Things

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Abstract

Internet of things (IoT) in manufacturing can be defined as a future where every day physical objects in the shop floor, people and systems (things) are connected by the Internet to build services critical to the manufacturing. Smart factory is a way towards a factory-of-things, which is very much aligned with IoT. IoT not only deals with smart connections between physical objects but also with the interaction with different IT tools used within the digital factory. Data and information come from heterogeneous IT systems and from different domains, viewpoints, levels of granularity and life cycle phases causing potential inconsistencies in the data sharing, preventing interoperability. Hence, our aim is to investigate approaches and principles when integrating the digital factory, IT tools and IoT in manufacturing in a heterogeneous IT environment to ensure data consistency. In particular this paper suggests an approach to identify what, when and how information should be integrated. Secondly it suggests integration between IoT and PLM platforms using semantic web technologies and Open Services for Lifecycle Collaboration (OSLC) standard on tool interoperability.

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Keywords: Digital factory; Internet of Things; Smart factory

1. Introduction

Internet of things (IoT) is defined as the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data [1]. In Smart factory products, resources and processes are characterized by cyber-physical systems (CPS) [2]. CPS is analogous to the Internet of Things (IoT) sharing the same architecture, however, CPS presents a higher combination and coordination between physical and computational components of production systems [3]. The digital factory is a model of a planned or real factory used for design, planning and operations .In the smart factory, the digital factory developed during engineering should be integrated with the smart factory with its real time data and inferred statistics and information. One significant capability is thus the integration of the digital factory with the smart factory. This capability includes the ability to create interfaces of digital things which are linked with physical things. Further, functionalities needs to be implemented for receiving data from the IT applications of the digital factory to the IoT platform which implements the smart factory, and providing feedback to the digital factory through IoT services. However, in the IT environment, data and physical resources are typically heterogeneous and a good integration strategy is needed to assure the consistency of the data which is pushed to or pulled from the IoT platform. There is a need for a common language for presentation and representation of data together with a protocol that enables IoT devices to communicate to the digital factory. For interoperability within a digital factory, many ontologies and information standards such as ISO 10303 have been developed. In the smart factory, the Resource Description Framework (RDF) is used to achieve interoperability [4], for instance, Semantic Sensor Network (SSN) [5] answers the need for a domain-independent and end-to-end model for sensing applications by merging sensor-focused, observation-focused and system-focused views.

The integration of digital factory and smart factory in a holistic way has not been considered in research. Furthermore, companies develop vendor specific solutions for their own IT architectures. They do not standardize the services and functionalities and they lack either semantic or

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syntactic solutions. Hence, This paper suggests a solution for integration which not only encompasses standardized protocols and information models to exchange data, but also a methodology for the necessary steps which must be taken to adapt a general solution among the current approaches and technologies to achieve interoperability. It is based on an approach to integrate the IoT platform of the virtualized factory with the PLM platform of the digital factory. IoT platform is a type of cloud which can store real time data, retrieve data and enable users to connect, create, analyse and experience things. First, the paper presents this platform-based system architecture. Secondly it presents a generic framework for creating communication interfaces between the two domains. The generic solutions is based on basic read and write, update operations, to be extended into more advanced service interfaces provided by IoT platforms.

Open Services for Lifecycle Collaboration (OSLC) initiative provides a minimalistic set of standardized information models. Assuming a loosely-coupled distributed architecture of tools and services, OSLC adopts the Linked Data (LD) approach to ensure data consistency across the data resources. Hence, this paper adapts it for developing integration specification.

2. OSLC as a specification for smart and digital factory integration

OSLC is an industrial effort which develops standards that make it easy and practical for software lifecycle tools to share data with one another. OSLC standards apply the principles of linked data (LD) and REST protocol to provide an interoperable web standards-based environment [6]. In other word it is a framework that standardizes the data format of data to be exchanged, the protocol to communicate data and services to create, read, update and delete (CRUD) data.

The LD framework allows linking between data from heterogeneous systems and it is considered a flexible approach that provides support for integrating data through different tools [7]. OSLC is built on web specifications and uses RDF as a fundamental data model. RDF is a framework that represents the LD and it provides a generic graph-based data model for describing resources, including their relationships with other resources. LD consists of two technologies; Uniform Resource Identifiers (URIs) and the HyperText Transfer Protocol (HTTP). Although HTTP may be expensive for many IoT devices, it can be beneficial for the web and IoT interoperability since it is developed originally for the web. That is one of the reasons to select OSLC as a specification for IoT and PLM integration in our approach.

An OSLC adapter is the software that represents tool data in the form of an OSLC resource and makes these resources available to other tools. These resources are available through web services. OSLC defines the concept of ServiceProvider for each tool adapters to expose containers of resource that is hosted by a tool for integration.

3. Why OSLC?

There are three ways to configure physical things, services and end users in an IoT context (see figure 1). In the first case from the left, physical entity, software, and the service are running on the same physical entity (a manufacturing resource). This is a configuration in which we have a powerful physical entity which can support for example the HTTP protocol and services are deployed on the physical entity. In the second case from the left, the service of the user is running in the cloud. The API used between the service client and the service, however, is the same. In the third configuration the service is not running on the physical entity, but in the cloud. This can be the configuration for a constrained device that may not be able to expose a user interface across the network For example, due to energy consumption limitation [8]. The third scenario is the subject of this work, in other words we investigate how we virtualize a physical resource in an IoT platform, how we process this data and extract information, how we integrate this derived information with digital factory information management application.

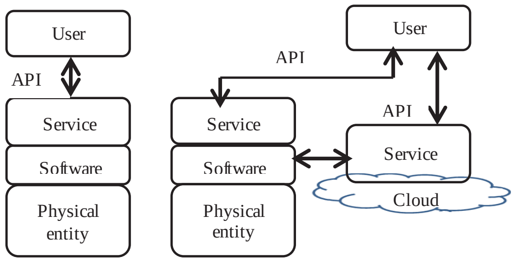

Fig. 1. Three types of configurations of physical entities and services

In order to provide structure to the Internet, network designers organize protocols. All protocols belong to one of five layers and provide services to the layer above. Figure 2 shows the traditional five-layer Internet protocol stack. The application layer is the top layer which is visible to the end-user; this is where the applications and their application-layer protocols reside [9].At this level the data is provided to the user.

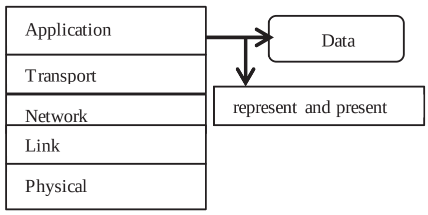

Fig. 2. Five layer internet protocol

CoAP is specialized web transfer protocol for use with constrained nodes and constrained networks in the IoT [10]. As mentioned, OSLC uses HTTP which can also be used as communication protocol of IoT devices if they are not constrained devices. This makes it a suitable framework for linking and integrating heterogeneous data. If IoT devices are constrained devices and use CoAP, OSLC still can be used since CoAP can be implemented of the REST pattern using HTTP. Hence, in this work we assume that physical entities work over internet protocol (IP) and that there are gateways