SOFTWARIZATION OF THE PRODUCTION: THE INDUSTRY 4.0 APPROACH

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Abstract: *Industry 4.0 is a very broad domain that includes: production processes, competitiveness, business decisions, partner and consumer relationships, all centered around cyber-physical systems.*
This paper aims to introduce main aspects of Industry 4.0 in the relation between physical and digital systems, along with new enabling IT technologies.
The paper presents the Industry 4.0 concept and components, and also the IT technologies for implementing a Smart Factory: Industrial Internet-of-Things, Big Data, Cloud Computing, Machine Learning, Digital Twin and Data Analytics.
A Smart Factory model is described and a review of several software tools for its building is performed. The case study was realized with ThingsBoard free software, in order to show the steps in building a Smart Factory model and the potential of such an advanced tool for smart manufacturing.

Keywords: Industry 4.0, Industrial Internet-of-Things, Big Data, Machine learning, Smart manufacturing.

JEL Classification Codes: L60, C88, C63, M15.

1. Introduction

In recent years, manufacturing has faced increased demands for competitiveness, caused by the flexibility and changing consumer preferences. The main ally in support of these efforts was the digitization of the production, applying the new Information and Communications Technologies (ICT), which defined the core of the Fourth Industrial Revolution: Industrial Internet of Things (IIoT), Cyber-Physical Systems (CPS), Big data, Artificial intelligence (AI) and machine learning.

Industry 4.0 is an approach based on the integration of all objects, activities, manufacturing processes as well as data flows with business partners, suppliers and customers of a company in a unitary value chain, completely digitized.

The big software companies have already launched IIoT platforms on the IT market and adapt or extend their functionalities to integrate the manufacturing processes with the business ones into the Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) information systems.

The paper aims to present the concept of Industry 4.0 and its components (section 2), as well as a review of the software that can be used in the design of the Smart factory (section 3). Section 4 describes the architecture of a model proposed by the authors and the stages of implementation using the ThingsBoards platform.

In the last section the conclusions and some directions are presented, for approaching the topic in the future research.

The paper is structured in five sections, as follows: Section 2 (Literature Review) that starts from the definition and the characteristics of the concept, and presents an overview of the microservice-based architecture for IoT, Section 3 (Methodology) presents several methods and technologies for achievement such an application. Section 4 (IoT platforms based on microservices) realizes a comparative analysis between a monolith application and an application-based microservices. Also, there will be presented some known IoT platforms based on the microservices approach. The final section (Conclusions) provides concluding remarks about this concept and its applications and some directions regarding our future work in domain.

2. Literature Review

It is considered that we are in the fourth industrial revolution that "was triggered by the development of Information and Communication Technologies (ICT)" and achieve an end-to-end digitization of the manufacturing sector (Rojko, 2017).

According to Margaret Rouse, Industry 4.0 is the "cyber-physical transformation of manufacturing" (Rouse, 2018).

The term "Industry 4.0" was initially used by the German government in 2011, when launching a strategic project to promote connected manufacturing and a digital convergence between industry and businesses (Industry 4.0 - European Parliament, 2016).

I 4.0 is based on the convergence of several methods and technologies:

- Industrial IoT (IIoT)
- CPS (Cyber-Physical Systems)
- Big Data
- Cloud Computing
- Machine learning

The concept of Industrial Internet was launched by General Electric at the end of 2012, and refers to the extension of the Internet of things (IoT) to the industrial applications, in order to have a higher degree of efficiency and reliability.

Industrial Internet of Things (IIoT) starts from collecting information from sensors, actuators and other devices used by the industrial application, storing and processing it in Big Data and analysing data in order to make improvements and optimize the manufacturing activities and processes.

Industrial Internet-of-Things is evolving as the technologies on which it relies are developing: IoT, Cyber-physical systems (CPS), Big Data, Cloud Computing, Fog/Edge Computing, Machine Learning and Digital Twins:

Cyber-physical systems (CPS) are "integrations of computation, networking, and physical processes" (Lawr et al., 2019). The role of computers and networks embedded into CPS is "to monitor and control the physical processes, with feedback loops" (NIST, 2019).

Cloud computing allows the delivery of IT services based on resources that are retrieved from the Internet rather than from local storage devices; with its different models and implementation platforms, CC enables companies to store, manage and analyse the data, and also to scale up the ecosystem, without setting up additional hardware and infrastructure components (Bănică et al., 2017).

Fog / Edge computing is an intermediate layer, placed closer to the "smart objects", a way to decentralize operations from Cloud, whereby data storage and processing occurs closer to the location that produces them (Zhang, 2016).

As the volume of data collected from the manufacturing process has grown at a such high rate, dedicated instruments have been designed in order to process that flow in a scalable and efficient manner – it is known as *Big Data platforms* (like Hortonworks Data Platform). When dealing with tens of terabytes of data, identifying patterns and trends becomes a tedious task, tough the results of the analytics can give valuable insights that are able to support faster and better business decisions.

By having huge volumes of data at the disposal, intelligent algorithms (known as *Machine Learning*) are able to gain knowledge and predict future behaviours, make correlations and improve the accuracy of the human decision makers (Klass, 2018).

The new *Digital Twin technology* uses the data collected to compare the physical product with the virtual prototype, providing continuous status information for analysing its behaviour and make adjustments when required.

Industry 4.0 is the natural consequence of the emergence of these new technologies, and it also has the support of large industrial companies, being associated with the possibility of increasing the profit in the manufacturing process. The first obvious effect was the decrease of the production costs considering the continuous monitoring by sensors, especially by implementing the Digital Twin technology, which allows the operation of a virtual model in parallel with the physical system, signalling the alerts and generating valuable feedback to avoid the issues.

3. Methodology

From our point of view, an Industry 4.0 Smart Factory model includes:

1. Industrial IoT platform - sensors, devices, connectivity and decentralized processing into an edge / fog computing architecture;
2. Cyber Physical Systems (CPS) - Virtual machines and Machine to Machine (M2M) communication into Cloud computing;
3. Services and Applications - Artificial Intelligence, Machine Learning, Big Data Analytics into Cloud computing.

This section is designed to provide a brief overview of the features offered by the software tools available for IIoT Cloud platforms.

The increasing number of objects connected to the Internet, due to the progress made in the mobile device industry, as well as the development of services in Cloud technologies, capable of collecting and processing information, generating feed-back to the end users, have led to a true revolution in the field of IoT.

Cloud computing is a technology having an instrumental contribution to the development of IoT, through the infrastructure services (processing, storage, sharing of network resources, etc.) and the specific applications in a secure environment, remotely accessible.

Cloud computing removes the limitations of local hardware resources and those imposed by software licenses, by providing access to a common pool of configurable processing resources. The business model of the companies is defined by requests for services, which can be extended and adapted to the client's needs.

The IIoT platforms are built on 3-layer architectures:

- **Physical layer** – containing the devices connected to the Internet and having the role of collecting data and doing the primary processing (connection and authorization, device start/stop);
- **Fog / Edge layer** - is an intermediate level between the Physical and the Application levels, having the role of relieving the upper layer of certain user-device and device-device communication flows, and providing storage space for the primary information, which can then be filtered and processed by the upper level; this layer provides simple services to the devices and ensures a quick and efficient response to their requests (connecting / disconnecting, authenticating and transmitting data or receiving signals). This layer consists of several nodes, which have their own storage capacity and service running abilities.
- **The Application-Cloud level** - is intended to store large volumes of data, structured and unstructured (Big Data) and perform analytical processing, with the help of business intelligence software tools, scientific forecasting applications, neural networks, etc.

There are hundreds of platforms on the IT market that can be used to develop IoT solutions in any field (business, education, health, communications, transportation, etc.), some of them open-source and others commercial, developed by major software companies. Examples of commercial IoT platforms are: Google Cloud Platforms, Microsoft Azure Cloud, IBM Blue Mix, Amazon Web Services, Oracle Integrated Cloud.

Among the examples of free software, open source platforms available in 2019, most commonly used are: KAA IoT platform, CARRIOTS IoT platform, Everything IoT platform, ThingsBoard.

The evolution of IoT is aimed at the Internet of Things as a Service (IoTaaS), offered to businesses as a Cloud platform, accessible from any station through a friendly graphical interface, allowing the development, customization and operation of IoT services attached to a business.

When choosing an IIoT platform software, the following are taken into account: integration with the current business applications (on your own business model), facility for developing and maintaining multiple applications, scalability, ability to process data from multiple datasets.

ThingsBoard platform has variants that have been implemented in the industrial environment, for real-time production monitoring, machine connectivity (M2M communication and protocols), Machine Control and IoT Data analytics.

4. Using ThingsBoard software in IIoT platforms

In the next section, we will briefly present the components of the ThingsBoard software and their functionality, and we will finally highlight the pros and cons of its implementation in a business environment.

Some of the features of this software are:

- Attributes - the ability to assign entities attributes related to configuration, data processing, visualization parameters.
- Telemetry - API (application programming interface) for collecting data provided by time series, representing the status and the evolution of the monitored devices.

The API is a set of definitions of subroutines, communication protocols and tools which allow the access to the important operations and data needed to be downloaded from the IoT platform.

The elements used by ThingsBoard are the following:

- Entities and relationships - the ability of modelling the objects (devices and sensors) and the relationships between them.
- Data visualization – refers to data visualization by dashboards.
- Sets of rules - performs a data processing chain and actions related to the received events.

Furthermore, we present the steps for creating devices associated with certain users and the related event chain:

1) The user creates an account on the ThingsBoard platform, and after logging he/she has access to the main menu (Figure 1):

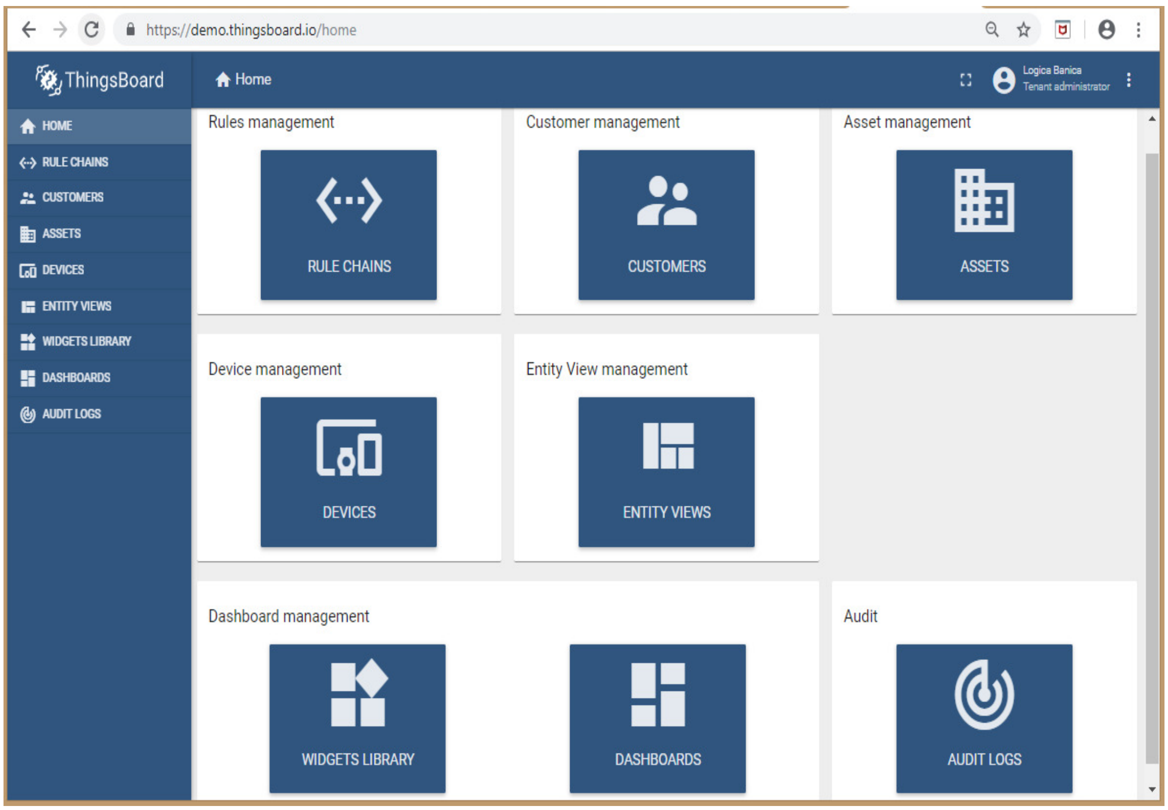

Figure 1. The main menu of ThingsBoard platform

2) Defining the test devices A1 and A2 (Figure 2) and the telemetry data. Because this is a prototype, we consider using MQTT over Wi-Fi.
MQTT (Message Queuing Telemetry Transport) is an ISO standard messaging protocol designed for connections with remote locations where the network bandwidth is limited.

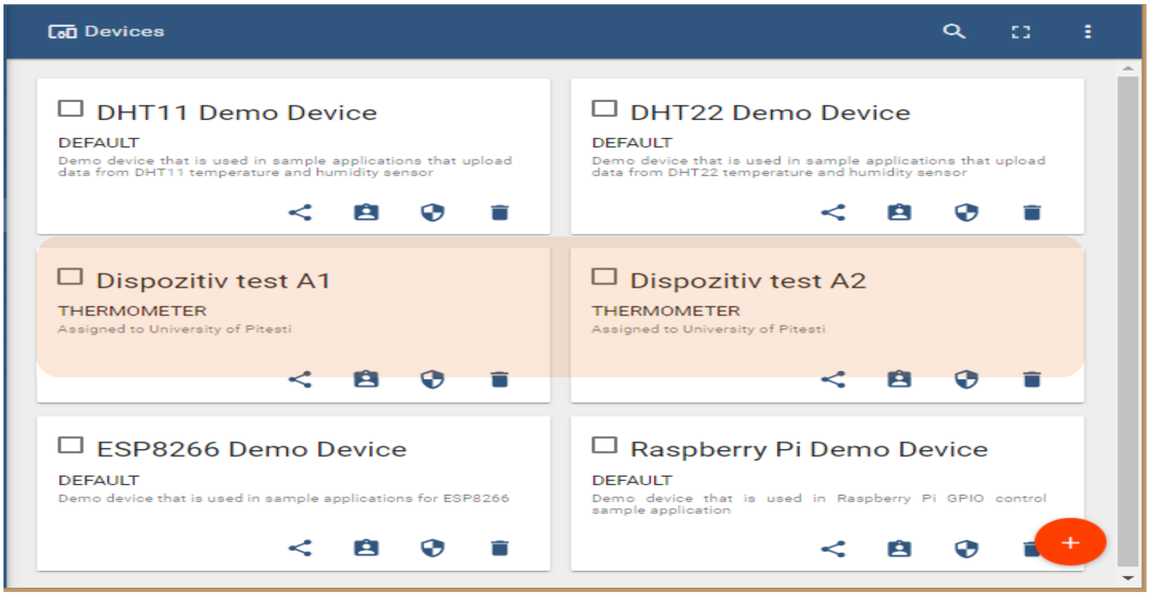

Figure 2. Defining the devices

The administrator is able to copy *device_id* and use it to fetch device by REST APIs or Web UI.

3) Defining a set of rules assigned to objects and users (rule chains): *Event chain testing*
During this step, we have provisioned rules that analyse temperature against configurable thresholds. The rules are included into a set of logical expressions written using a JavaScript syntax.

```
(
    typeof temperature !== 'Room1'
    && (temperature <= 10 || temperature >= 25)
)
```

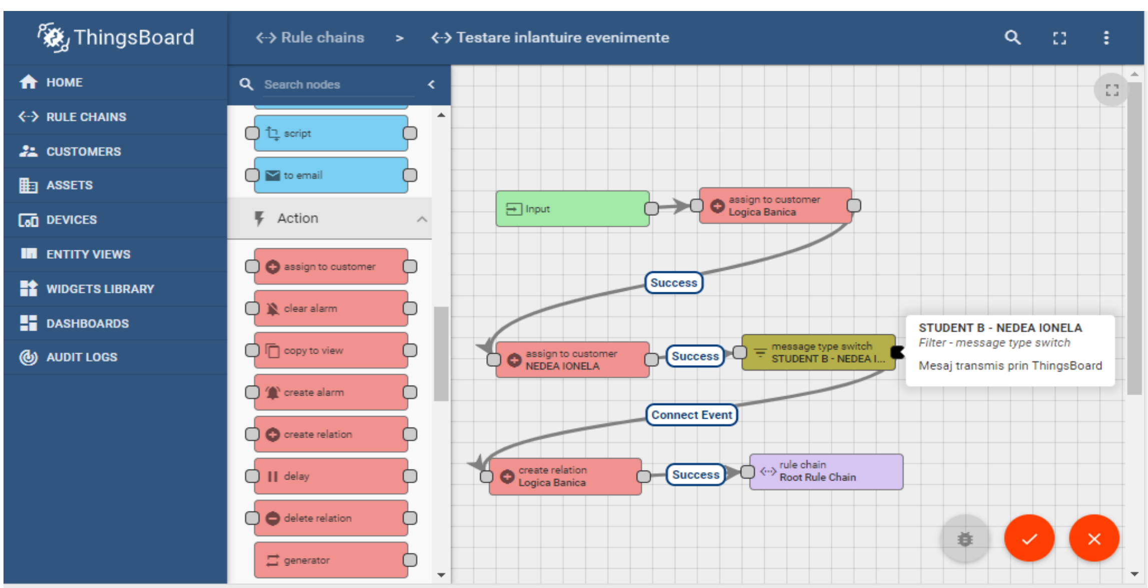

Figure 3. Defining the set of rules assigned to objects

4) Creating the Dashboard to visualize the behavior of the devices A1 and A2 (Figure 4):

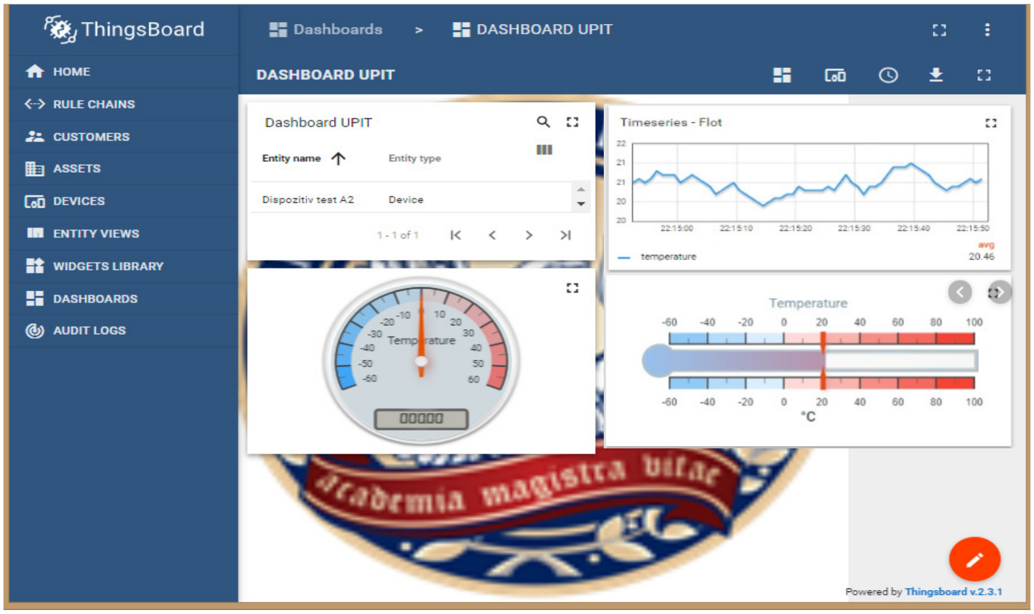

Figure 4. Creating a dashboard for monitoring devices

The IIoT concept is the blending of IoT principles with industrial use cases. In this area, the smart production devices are communicating between themselves, and the data that they produce is analysed by massive parallel approaches (Big Data and AI). This comprehensive ecosystem is the foundation of the scalable, future-proof fabrication concept, that simulates and minimizes issues by monitoring the production in real time. The concept refers to 3D printing, telemedicine, semi-autonomous robots and high-end automation strategies.

The final goal is the Software-Defined Manufacturing (SDM), similar to the highly successful software defined networks (Trend Micro site, 2019).

5. Conclusions

The advances in Industry 4.0 are powered by the evolution of other IT areas, such as: IIoT, Big Data, Cloud Computing, Machine learning, Digital Twins and Data Analytics.

As the manufacturing evolution unfolds, the Digital Twin concept will be more and more at the core of the Intelligent Factory, continuously monitoring the parameters that the robotic workers are using, in order to elevate the quality standard and efficiency level for the whole production chain.

The major ideas that emerge from this paper:

a) **The benefits of Industry 4.0 -** transforming manufacturing and all its related industries, from design to the end of product-lifecycle into a more efficient and innovative chain of activities and processes, having as result new business models and profit sources.

b) **The conditions to switch to this new way of manufacturing –** the companies are expected to make considerable financial efforts, especially due to the costs of these emerging technologies, and also for human resource training. The cooperation with all partners across the supply chain is another issue for companies.

c) **The ned of standardization and security** – a major attention should be paid to all aspects of Industry 4.0 applications and platforms develop.

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