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A Cloud-based Architecture for the Internet of Things targeting Industrial Devices Remote Monitoring and Control

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Abstract: The process of acquiring, analysing and managing data obtained by sensors and actuators in industrial environments can benefit from modern Cloud-based platforms towards a complete implementation of the *Industrie 4.0* concept. The analysis of huge data sets produced by these sensors (*Big Data*) could allow quick and accurate decision making. For example, productivity improvements can be achieved by analysing device performance and degradation for real-time feedback on configuration and optimization. This work proposes a Cloud-based architecture for Internet of Things (IoT) applications to improve the deployment of smart industrial systems based on remote monitoring and control. By using specific technologies available as a service, we demonstrate the proposed architecture on an automated electric induction motor use case. This approach includes layers for sensor network data gathering, data transformation between standard protocols, message queuing, real-time data analysis, reporting for further analysis, and real-time control. Particularly, by using the proposed architecture, we remotely monitored, controlled and processed data produced by sensors and actuators coupled to the motor. Preliminary results indicate this foundation can support predictive methods and management of automated systems in the *Industrie 4.0* context.

Keywords: Internet of Things (IoT); Industry 4.0; Tele-maintenance

1. INTRODUCTION

The transformation of society demands towards technological and cheaper products and services is a strong stimulus for improvements on industrial processes. The development of connected devices and instrumented environments combined with available techniques of data analysis and cognition provided the conditions to consolidate what is now known as *Internet of Things* (IoT). According to Hermann et al. (2015), interoperability, modularity, distributed processing of huge amounts of data produced by these heterogeneous devices, and the integration with other systems for industrial processes are still research challenges, including in the core context of *Industrie 4.0*.

In an industry, manufacturing processes are the core activity and, among several equipments, one omnipresent is the electrical motor. This can easily explain why 40% of the electrical power consumption is related to motors, thus representing 2/3 of the electrical power consumed by the industry sector (Saidur (2010)). The electric motor is used in several configurations of the automation process. As an example, our case study focused an exhaustion system, which is critical to keep the working environment within acceptable conditions in several phases of the production chain (e.g., from electronic industry, passing to coal-based thermoelectric electric power plant, to grain warehousing).

Currently, not only the setup and operation of automated industrial systems can be remotely controlled by sensors, actuators and suitable data systems, but also the performance condition of the evolved devices. Additionally, this scenario can generate huge amounts of data during operation time due to potential presence of hundreds or even thousands of sensors, considered as *Big Data* by Manyika et al. (2011). Analytic models can be applied on these data, helping to optimize industrial operation procedures and extending the life cycle of the monitored machines. These are the key goals and explain why this industrial revolution wave is in ascension.

This article proposes an architecture for rapid time-to-market deployment of an industrial automation system with remote monitoring and control services. It is an on-demand platform based on Cloud Computing underpinned by standard industrial protocols and relying on IoT concepts. It is considered that services on Cloud Computing environment can consume data on-demand (generated by sensors), execute analysis and send (real-time) control actions. This allows taking actions accordingly, not only with the system conditions information, but also including data provided by external sources, such as weather forecast data. This capability provides insights that could influence the operation conditions of a certain industrial activity - in this case, the exhaustion system. Even though the proposed infrastructure is generic enough to be applied in a wide array of industrial scenarios, we demonstrated the described concepts for an industrial electric motor in the context of a machine to be monitored and controlled by

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sensors and actuators in an exhaustion system managed by such a Cloud platform.

The work is structured as follows. Section 2 presents a background. Section 3 details the proposed architecture along with protocols and technologies used to develop our IoT-to-Cloud infrastructure. Section 4 describes the use of the infrastructure in a real industrial automation case study. Section 5 gives an overview of related work in comparison to our proposal. Finally, conclusions are exposed in Section 6.

2. BACKGROUND

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services). According to Mell and Grance (2011), Infrastructure, Platforms, and Services can be rapidly provisioned and released with minimal management effort or service provider interaction; it also has essential characteristics (on-demand self-service, broad network access, resource pooling, rapid elasticity, measured service), service models (IaaS, PaaS, and SaaS), and deployment models of infrastructure (private, community, public and hybrid) that an organization needs to understand well in order to benefit and improve its environment. IaaS (Infrastructure as a Service) provides infrastructure capabilities to deploy and run software in general. PaaS (Platform as a Service) provides capabilities to develop applications and deployment in the Cloud. SaaS (Software as a Service) provides resources to use software applications through a thin-client interface, such as via Web Browsers or Application Program Interface (API).

Currently, a number of research studies are investigating the use of Cloud Computing resources as an alternative to the expensive on-premise clusters (CAPEX investments). In fact, the Cloud approach is a technology and a business model that allows users to allocate resources on-demand. Cloud providers make profit by placing workloads of several clients together, i.e., leveraging the economies of scale. A wide number of applications are being moved to the Cloud, including sensitive financial, scientific and engineering applications, like industrial and IoT-based applications. Initially, the computing resources were only *virtualized* (one physical processor shared by several virtual ones), but a few providers are now allowing users to rent physical machines in a private and secured micro-Cloud. This way, what was initially created to host web applications recently shifted to other types of workloads that require more privacy and processing power.

A Cloud environment can provide several operational benefits to industries, particularly the IoT, such as: installation costs reduction (i.e., pay-per-use), flexibility to provision specific infrastructure (hardware and software), ease expansion of the infrastructure when necessary, among others. In this work, we particularly use the IBM Watson IoT Platform [1] and the PaaS capabilities of IBM Bluemix [2], both from the IBM provider, as an implementation example of the proposed architecture. The IBM Watson IoT Platform makes it easier for any device to publish data to a back-end message broker and also to receive control messages from other devices or IoT applications. On the other hand, the IBM Bluemix allows to easily create IoT applications that communicates to the IBM Watson IoT Platform, so that these applications can consume data coming from devices or even send control messages to them.

3. A CLOUD ARCHITECTURE FOR DEVICE MONITORING AND CONTROL

The proposed Cloud architecture for monitoring and controlling devices is composed by three main layers (Figure 1): wireless device network; gateway; and, Cloud service. The wireless device network corresponds to the set of sensors and actuators attached to the system (*e.g.*, exhaust system) to be monitored and controlled. The gateway converts messages coming from the wireless network to the Cloud protocol. The transformed messages are consumed by the Cloud Service, which in turn, after evaluating overall systems conditions (including data obtained by other systems such as a weather forecast system), can send back commands to the actuators on the controlled network.

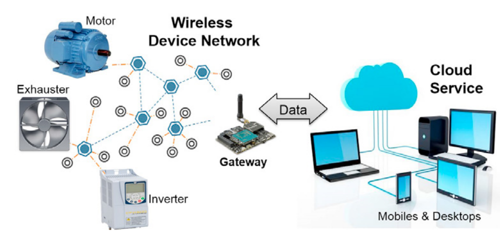

Fig. 1. Architecture overview

Figure 2 details the components of this architecture, which are described in the next subsections.

- Devices: a network of sensors and actuators for data gathering and control;
- Gateway: performs data transformation to adapt acquired device data to the enterprise Cloud environment;
- Cloud Services:
  - Broker: receives and organizes data streams coming from the gateway or mobile and desktop clients and dispatches them the message queue, that performs data cleansing, transformation, and queueing; besides, it routes queued messages to be processed by the other architecture modules;
  - Database: stores received data;
  - Front-end server: supports data analytics visualization, reporting, and recommendations for user actions;
  - Event managers: supports rules authoring, and performs real-time data analysis to deal with urgent event handling, firing alerts if conditions are met.

3.1 Wireless Device Network

The sensor network is based on IEEE 802.15.4. This standard allows the devices to: (i) create routes for multi-

[1] https://internetofthings.ibmcloud.com
[2] https://www.bluemix.net