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Architecting an IoT-enabled platform for precision agriculture and ecological monitoring: A case study

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ABSTRACT

This paper discusses a case study of designing a private Internet of Things (IoT) enabled platform for the research in precision agriculture and ecological monitoring domains. The system architecture is gradually derived using an approach of multiple, concurrent views. Each view represents an architectural perspective describing the solution from the viewpoint of different stakeholders, such as end-users, researchers, developers, and project managers. The end-user requirements have been identified using a set of high-level scenarios, which capture the context and illustrate the motivation for building the platform. The requirements and architecture of the proposed platform have been derived so that the users of the platform, researchers, and developers on the project, can utilize it for prototyping solutions for these high level use cases. The paper further describes the implementation of the platform and its evaluation using various sensor nodes deployed at the research and end-user facilities. The solution is open to further development with respect to supporting additional IoT protocols, data types, and interfacing to various analytics tools. The proposed architecture can also be implemented using different server platforms and cloud technologies.

1. Introduction

In the time of increasing demand for food, precision agriculture provides higher yields with a lower input cost and leads to a reduction in environmental pollution and labor (Shirish and Bhalerao, 2013). Modern day food production and precision agriculture are expected to dramatically increase the usage of the latest computer and electronic technologies (Cho, 2012; Zaks and Kucharik, 2011). In accordance to this, decision support systems have been developed in the last decades in order to provide expert knowledge needed for farmers in their agricultural management. In Rossi et al. (2014), the authors present a good example of such solution, which is designed to help grapevine farmers make the right decision on the proper time for pesticide treatment based on sustainable agriculture. It consists of a system for monitoring basic parameters in the vineyard such as air, soil, plants, pests, and diseases and software tools that analyze these data providing alerts and decision support information. In 2009, for example, the European Parliament and the Council established Directive 2009/128/EC to achieve the sustainable use of pesticides (Directive 2009/128/EC, 2009). According to this directive, integrated pest management is obligatory in all the European Union (EU) Member States by 2014. In order to achieve integrated pest management, modern information technology and decision support systems have an important role to decrease use of plant protection products and improve the quality and yield of crops (Vujović et al., 2016). For the purpose of public health and mariculture protection, monitoring water quality and biomonitoring in fishing sea are conducted regularly (Law on Marine Fisheries and Mariculture, 2009). This monitoring is at this moment partially aligned with EU regulations Directive 2006/113/EC, Regulations (EC) No 853/2004 and (EC) No 854/2004 and in the next period will be fully harmonized (Directive 2006/113/EC, 2006; Regulation (EC) No 853/2004, 2004; Regulation (EC) No 854/2004, 2004).

During past decade, monitoring marine environment has become one of the most important issues of marine investigations due to high pressure of human activities through industrial, tourist, and urban development in coastal areas. Physical and chemical seawater parameters represent the base for every investigation of marine environment, hydrographical and biological. Parameters such as temperature and salinity influence horizontal and vertical

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distribution of water masses, density of water, and distribution of dissolved particles. Together with pH and oxygen, these parameters influence and determine the distribution and biology of all living beings in the seas and oceans, which has an important impact on human health as well. With its access to the coastal line, Montenegro is using its aquaculture capacities, including fish and mussel farms. Both aquaculture farming and expanding tourism require advanced marine environment monitoring and water quality assessment (Cater, 2008; Xu et al., 2014). In addition to weather data, which is important for both the agriculture and aquaculture, the water quality assessment employs smart buoys (Helmi et al., 2014; Nam, 2005), as well as systems for the use in inland waters (Papoutsa and Hadjimitsis, 2013). As a candidate country for the EU, Montenegro is evaluating and adopting the use of latest technology in the domains of precision agriculture and ecological monitoring.

In recent years, the development of information and communication technology (ICT) resulted in the emergence of two important concepts that affect the world around us: Internet-of-Things (IoT) and Cloud computing (Evans, 2011; Mell and Grance, 2011). Both concepts are expected to be put to use in agriculture on a much larger scale in the near future (Vermesan and Friess, 2013; Kaloxylos, 2012). The IoT is a network of physical objects (i.e. devices, vehicles, buildings) instrumented with embedded electronics, sensors, software, and networking connectivity enabling these objects to collect and exchange data (Ojha et al., 2015). The IoT equips objects of interest to be sensed and controlled remotely over existing and future network infrastructure, which creates various opportunities to integrate physical objects with computer-based systems. The main goals of IoT include improved efficiency, accuracy, economic gains, and better quality of life (Holler, 2014). Cloud computing is based on the utilization of computer resources (processors, memory, storage, network), which can be located and managed remotely. Cloud computing service models include infrastructure-as-a-service (IaaS), platform-as-a-service (PaaS), and software-as-a-service (SaaS). Clouds can be deployed as public, private, or hybrid (Mell and Grance, 2011). Our goal is to implement a private IoT cloud platform that can be used as a foundation for research and development in the domains of precision agriculture and ecological monitoring. The mission of the project is to create a research and development platform in the areas of sustainable agriculture, monitoring of the crops, forest and water ecosystems, development of techniques for controlling and reducing pollution, analysis and standardization of food products, control of land quality, and improvement of the public health (Fig. 1). The project is focusing on the utilization of IoT and Cloud to support the adoption of these novel technologies and innovations in the areas of precision agriculture and ecological monitoring.

Designing and implementing computer and electronics systems, especially IoT, in the domains of precision agriculture and ecological monitoring can be challenging, therefore a systematic approach is needed (Krčo et al., 2014; Kruize, 2016). Several IoT cloud platforms are available in the form of public cloud services (Azure IoT Suite, Amazon AWS IoT, DeviceHive and others), but main requirements in this project were to focus on private deployment and the use of open source software. Few open source IoT platforms have been evaluated (Kaa, FiWare, ThingSpeak). Among those, the ThingSpeak platform has been identified as the closest fit for the project needs (ThingSpeak IoT Platform). However, the open source variant of that solution has not been as active recently since it has been commercialized and offered as a public cloud service.

This paper describes a case study of architecting an IoT-enabled platform aimed at the use for research and development. The paper is organized as follows: after the Introduction section, Section 2 provides context and motivation by illustrating the end-user requirements. Section 3 describes derivation of the platform architecture and its implementation. Section 4 discusses the evaluation and practical usage of the platform. Finally, the conclusions and references are provided at the end.

2. Context and motivation: high-level use scenarios

The IoT platform should provide support for researchers and developers on the project working on prototype solutions for various scenarios from the research domains of precision agriculture, mariculture, and ecological monitoring. The platform should enable rapid creation of testbeds and prototypes of new analytic, modeling, and predictive functions. The following sections discuss the context and motivation using examples of high level use scenarios.

2.1. Precision agriculture

The list of precision agriculture use cases currently being developed is given in Table 1. These end-user applications include smart

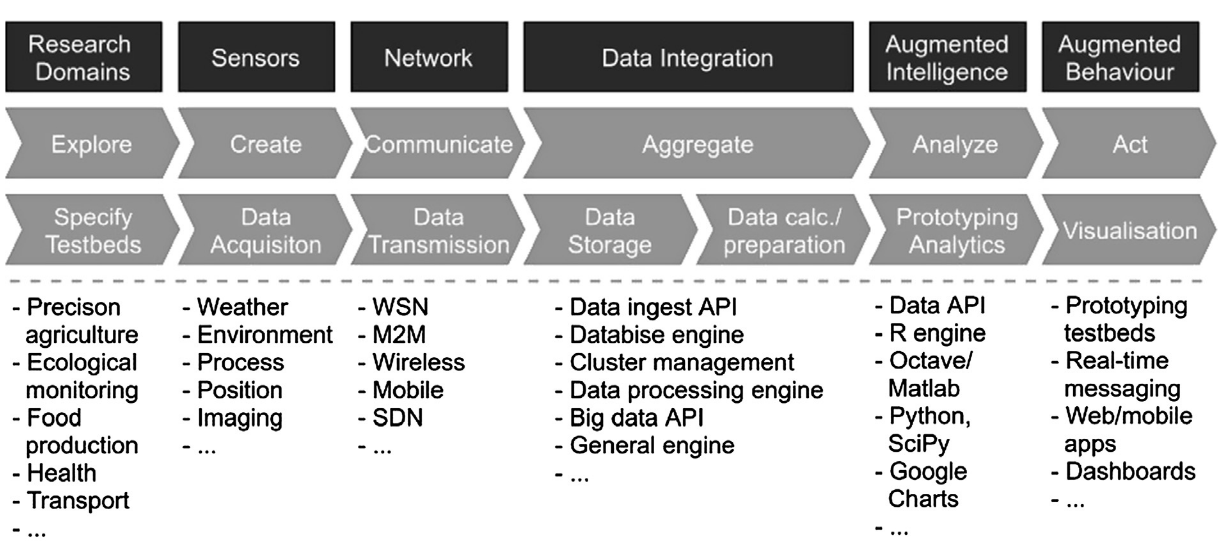

Fig. 1. Concept: an IoT-enabled research and development platform.