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Rules engine and complex event processor in the context of internet of things for precision agriculture

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ABSTRACT

The Internet of Things (IoT) applications monitor large data flows and events in real time, some raw data is captured from devices located in wireless sensor networks (WSN) and used to make control decisions about actuators. This can be a major problem when the devices grow in number as well as the data that is captured. In this paper, we propose an architecture called “RECEP” for the dynamic processing of events generated in the context of IoT and Precision Agriculture (PA); it is made up of two components: Rules Engine (RE) and Complex Event Processor (CEP). RE allows you to configure dynamic rules conditioning input data from different sources and planning control actions on actuators, alerts, and notifications for end users or applications. The CEP component fuses the input data at the rate at which they arrive, with the rules established in the RE and it performs a prescriptive analysis that consists not only in predicting or detecting patterns of events, but in making automatic decisions. RECEP was implemented in a virtual machine with a 1.9 GHz CPU and 6 GB RAM, then it was integrated into an intelligent irrigation system of an experimental banana plot located in Machala-Ecuador. A WSN simulator was also used to generate sensor data in large quantities, the CEP was evaluated with several test cases, and results show that it consumes computational resources with a growth trend, represented by a logarithmic regression model (r-squared > 0.9); that is, the more events are processed, there is a minimum consumption of resources. It was tested for fifteen days; around 25 thousand events/s were processed. Our RECEP can be implemented in low-cost infrastructure typical of small and large banana producers.

1. Introduction

Today, the Internet of Things (IoT) is having great success in many areas, allowing computers to see, hear and detect parameters of the world (Qin et al., 2016). The number of connected devices is increasing, and according to CISCO, it is projected about 50 billion objects connected by 2020 (Evans, 2011). Morgan Stanley; however, forecasts that by the end of 2020, around 75 million objects will be connected (Rose et al., 2015). On the other hand, Huawei (2015) projects that there will be 100 billion of IoT devices installed, connected, and autonomously managed by 2025.

IoT is based on a system of interconnecting heterogeneous devices to the Internet; these devices have a unique identity, physical attributes, virtual personality, and use intelligent communication interfaces to transfer data to the network without human interaction (Vermesan and Friess, 2015). The devices constitute Sensor Networks and Wireless Actuators (WSN or WSAN) and at the same time, they are connected through a Gateway to a larger technological infrastructure such as a data center or cloud computing which is responsible for the storage, processing, analysis, and other data management processes. IoT has several fields of application such as Healthcare, Logistics; Manufacturing, Smart Home; Smart Cities, Precision Agriculture (PA); among others. In the case of PA, it consists of crop integration or farm management that combines information technology with rational agricultural industries and tries to provide quantities and types of supplies based on the real needs of a crop (Far and Rezaei-Moghaddam, 2017). In the context of IoT, raw data obtained from sensors and transmitted to a Cloud Computing is abundant, reaching high speeds in real time or near real-time; consequently, the task of monitoring and controlling WSN devices becomes complex and almost impossible to carry out by humans. It is for this reason that the need for a Complex Event Processor (CEP) appeared.

There are several CEP tools for IoT. For example Google offers its Real Time Stream Processing for IOT tool (Google Cloud Platform,

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2017) that deals with probabilistic events that are stored and processed by machine learning techniques to predict patterns. There is also WSO2 (WSO2, 2017), consisting of the CEP and BRS components; the CEP component identifies significant events and patterns of multiple data sources, analyzes their impact and generates real-time alerts; while BRS manages business rules. Companies like Microsoft, IBM, AWS, Oracle and others, also offer similar tools. In the scientific community there are several proposals such as: An intrusion detection systems (IDS) architecture based on the mechanism of event processing in IoT environments for real-time data computing (Jun and Chi, 2014). Bruns et al. (2015) show how CEP can be used as the key technology for intelligent M2M systems. Another example is a rule engine for smart buildings that guarantees real-time response and quick match between events and rules (Sun et al., 2015). Zhou et al. (2017) raised the following: Knowledge-infused and consistent CEP over real-time and persistent streams; a semantic CEP model (x-CEP) is introduced to query across real-time and persistent streams applied to case studies from Smart Grid. Akbar et al. (2017) worked an architecture which exploits historical data using machine learning for prediction in conjunction with CEP for Complex IoT Data Streams. Gökalp et al. (2018) proposed a visual programming framework for distributed Internet of Things centric complex event processing to users who have limited or no experience in these technologies.

After reviewing related works and software tools according to the topic discussed, although there are several options of RE and CEP for IOT, they are partial solutions still which are complex to develop, integrate and deployment; it requires a specialist in IoT and PA to take it to the actual applications. In addition, some of these tools are expensive and inaccessible to farmers in a developing country such as Ecuador. Another difficulty is the demands to process large data-events in IoT, the existing options require high-performance hardware or monthly payments for cloud service; or simply, they don't adjust to the needs of Precision Agriculture and Internet of Things applications. In the context of PA-IoT, the work proposed by Kamilaris et al. (2017), it is a semantic framework for IoT, based on smart farming applications, which support reasoning over various heterogeneous sensor data streams in real-time and it can integrate multiple cross-domain data streams. This work focuses only on rule design and detection of event patterns, but does not integrate prescriptive analysis, i.e. it does not make decisions.

This work proposes a kind of architecture for the automatic management of structured decisions generated in Precision Agriculture applications that use telemetry technologies and control of systems based on Internet of Things. For example the following: irrigation systems in crops, fertigation or plant nutrition; disease or pest control, animal monitoring; agricultural robots, machinery, greenhouses, etc. This architecture has been called "RECEP" because it integrates two Rules Engine components (RE) and Complex Event Processor (CEP); the contributions made are described in greater detail below:

A. The design of the RECEP architecture in order to facilitate user tasks that manage, monitor and control the processes of systems based on IoT as a multi-tenant SaaS service model. For example, software as a service for agricultural enterprises is organized in one or more plots. The implementation of RECEP intends to automate the complexity of raw data processing in WSN and manage the dynamism of the structured decisions to be generated. The architecture consists of two components: (1) RE that manages event models, decision rules models, configuration of control actions, alerts and notifications that are sent to applications or users; and (2) CEP is conceived to work as a service in the background performing tasks in parallel and in real time; its function is to process incoming events, and complete rules with data flows (from WSN, internal databases, external data such as web services), evaluate real-time rules and make decisions involving output events.
B. The proposed architecture has been verified in two ways: (1) Trough a use case focused on the monitoring and control of an irrigation system of a banana plot located on an experimental farm belonging to the Technical University of Machala (UTMACH) in Ecuador. RECEP was designed, built and integrated as a subsystem in the IoTMach platform that is an IoT platform created by the AutoMathTIC research group of UTMACH. And (2) by running functionality and performance tests considering the use of computational resources, carried out with raw data taken from the experimental banana farm and also generated by a simulator to evaluate large data flows at high speeds.

This paper is organized in the following aspects: related work, proposed RECEP architecture and its components; use case of the architecture in a monitoring and irrigation control system for a banana plot, evaluation and presentation of results, discussion and conclusions.

2. Related work

2.1. Internet of Things and Precision Agriculture

Precision Agriculture (PA) combines diverse Information and Communication Technologies (ICTs) for process and data management in an agricultural production system, allowing it to increase efficiency and productivity, applying a scientific approach during all phases of the production cycle of plants and animals. Data that can be collected or generated with ICTs (Bendre et al., 2015; Wolfert et al., 2017) can be obtained from: field (physical-chemical soil characteristics, topography, productivity data), climate, interpretation of camera or satellite images (space and/or temporal variability of the crop), yield maps, maps with input application prescriptions, historical data, other internal or external data. The integration and analysis of this data can be used to generate automatic decisions (structured decisions that are executed in devices, robots or machinery) or to support human decisions (semi-structured decisions). PA and IoT have the purpose to optimize resources (energy, water, fertilizers, pesticides, etc.) in order to produce more food with less effort, costs and environmental impact; all this in order to help farmers achieve higher productivity, economic benefits, greater sustainability and environmental protection (Ojha et al., 2015; Ray, 2017).

PA and IOT technologies have the challenge of optimizing agricultural work, automating processes such as: precision soil preparation, precision seeding, automatic irrigation, precision crop management, greenhouse management, phenotype measurement, integrated pest management, precision harvesting, data analysis and evaluation (Greenwood et al., 2014; Juul et al., 2015; Minet et al., 2017; Nikolidakis et al., 2015; Ojha et al., 2015; Srbinovska et al., 2015; Talavera et al., 2017; Wolfert et al., 2017). To monitor and control these processes, a variety of technologies have been created and applied such as: drones for field monitoring, machines and robots for routine operations; sensors and remote sensing, high precision positioning systems; Geomapping, automated information systems; variable rate technology (VRT), integrated electronic communications; cloud computing, mobile and fixed computing devices, data storage; big data, data science, etc. (Kaloxylos et al., 2013; Ray, 2017; Wolfert et al., 2017).

In all IoT domains (Smart Cities, Smart Home, Smart Buildings, Precision Agriculture, etc.), the connection of new devices (motes grouping sensors and/or actuators) to several WSNs is increasing each time, and through a IoT Gateway (Hernández-Rojas et al., 2018c) and the Internet, they are integrated into a cloud computing system that captures, stores, and processes data streams from a variety of sources. Depending on the number of devices and sensors and the frequency of data reading, the transport of raw data can be increased in volume and reach high speed (Zhou et al., 2017), generating inconveniences such as unpredictable latency, bottlenecks, incomplete or erroneous data, storage and processing difficulties, among other problems (Hao et al., 2017); more efficient processing systems are needed to deal with dynamic and diverse data, complex events and automation of decisions.