

Data-Centric UML Profile for Wireless Sensors: Application to Smart Farming

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ABSTRACT

Modelling WSN data behaviour is relevant since it would allow to evaluate the capacity of an application for supplying the user needs, moreover, it could enable a transparent integration with different data-centric information systems. Therefore, this article proposes a data-centric UML profile for the design of wireless sensor nodes from the user point-of-view capable of representing the gathered and delivered data of the node. This profile considers different characteristics and configurations of frequency, aggregation, persistence and quality at the level of the wireless sensor nodes. Furthermore, this article validates the UML profile through a computer-aided software engineering (CASE) tool implementation and one case study, centred on the data collected by a real WSN implementation for precision agriculture and smart farming.

KEYWORDS

Aggregation, Data-Centric, Model-Driven, Node-Level, Precision Agriculture, Smart Farming, UML Profile, Wireless Sensor Networks

INTRODUCTION

The Agri-food sector plays a key role in the economy of almost every country in the world, not only for generating wealth and creating employment but also for the nutrition of the population in developed and developing countries (Lehmann, Reiche, & Schiefer, 2012; Ramirez-Villegas, Salazar, Jarvis, & Navarro-Racines, 2012). Different aspects, like increasing the sector profitability, adapting to the climate change, supplying the demands for emerging markets, or ensuring the products quality are currently challenging the Agri-food sector. Therefore, innovations as smart farming, precision agriculture or product tracking are vital for overcoming these challenges (Akanksha Sharma, Barbara Arese Lucini, Jan Stryjak, & Sylwia Kechiche, 2015; Lehmann et al., 2012; Plazas & Corrales, 2017; Ramirez-Villegas et al., 2012).

Such innovations rely on the intensive monitoring of the products and their environments, since the collected data allow for the detection of undesired situations, and the development of accurate information and forecasting systems. These complex systems are usually underpinned on complex simulation models calculated in real-time, which must rely on high-quality sensors data. Indeed, the advent of low cost sensors enabled the development of small sensing platforms with

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wireless connection capabilities (sensor nodes), which can be gathered and deployed as Wireless Sensor Networks (WSN) to monitor areas where wired connections are difficult or inadequate to establish (Wang, Zhang, & Wang, 2006). These WSN are one of the most important Information and Communication Technologies (ICT) for smart farming and numerous other applications domains since they provide right-time crucial data from the monitored environment (Lehmann et al., 2012; Plazas & Corrales, 2017; Plazas, López, & Corrales, 2017).

However, handling agricultural collected data is challenging since the monitoring sensors can collect and stream large amounts of raw data (e.g. embedded in tractors) and must deal with limited and depletable resources (e.g. deployed on the crop fields) (Anisi, Abdul-Salaam, & Abdullah, 2015; Jabeen & Nawaz, 2015). These big data heterogeneous streams must be correctly and timely processed in order to serve for the different applications aiming to improve the decision-making, control and definition of strategies in the Agri-food sector or any other domain, considering the end-user needs. Especially, WSN data processing and analysis is crucial in smart farming to handle complex agricultural applications, such as phenology monitoring, yield estimation or environmental risk assessment (Shao, Ren, & Campbell, 2018). Moreover, the deployment of such composite system using WSN, information systems, simulation models, etc., often leads to architectural complex ICT solutions, whose design, implementation and maintenance can be difficult and expensive.

Overcoming these issues is a challenging task. Therefore, an effective design of the WSN is the first mandatory step to grant a high-quality implementation of such complex systems according to decision-makers analysis needs. Hence, conceptual modelling has strong relevance and wide acceptance since it allows to build solutions for real complex tasks apart from the implementation problems and limitations (Abrial, 2010).

In this context, the Unified Modelling Language (UML) is one of the most powerful tools for formalizing conceptual models, a widespread extensible object-oriented standard that closes the gaps between designers, developers and final users (Bimonte, Schneider, & Boussaid, 2016). However, to the best of our knowledge, current approaches do not provide a complete and effective conceptual representation of Wireless Sensor node (WS) data, which makes difficult to design complex Agri-food applications and reduces the applications' capacity to completely supply the end-user needs (Marouane, Duvallet, Makni, Bouaziz, & Sadeg, 2017; Paulon, Fröhlich, Becker, & Basso, 2014; Prathiba, Sankar, & Sumalatha, 2016; Thang, Zapf, & Geihs, 2011; Uke & Thool, 2016).

Considering this scenario, in this work, we propose a data-centric UML profile for WS. Our profile enables the modelling of different WS implementations from the gathered/available data characteristics, allowing for the definition of ICT applications capable of answering the user requirements. Moreover, among the different sensors computation methods, in this paper, we focus on data aggregation since it is useful for complex applications and necessary for saving the battery life time of WSN. Though we have placed our profile in the Agri-food domain, considering smart-farming applications, it is general enough to model the data behaviour of any Internet Protocol Smart Object (IPSO) -compliant sensing platform ('Smart Object Interoperability,' n.d.).

The remainder of this article is arranged as follows: the next section presents the main characteristics, configurations and types of data to consider for a WSN abstraction. Section 3 presents the state of the art, describing different types of aggregation in WSN and highlighting relevant works that could be leveraged alongside our profile in order to design and configure the most important layers of a WS-based application. Section 4 presents our data-centric meta-model, including the UML profile with some theoretical examples and its implementation in a CASE tool. Section 5 presents the profile validation within a real smart-farming WSN application. Finally, section 6 presents our conclusions and proposed future works.

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