A Model-Based Approach for Building Ubiquitous Applications Based on Wireless Sensor Network

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Abstract. This paper presents a MDA approach to build WSN applications that allows domain experts to contribute in the developing of applications without knowledge on WSN platforms while allowing network experts to program nodes meeting application needs without needing specific knowledge on the application domain.

1 Introduction

There are several platforms that support the development and implementation of wireless sensor networks (WSNs) applications, each one with its own requirements and execution environments. Most of WSNs are designed for a target platform, operating system, and addressing the requirements of a single application. Application developers need to know several network specificities and built programs either by using the low-level abstractions provided by the sensor OS or directly over the hardware. The high coupling between the application logic and the sensor platform along with the lack of a methodology to support the development lifecycle of WSN applications result in projects with platform dependent code that are hard to maintain, modify and reuse. Therefore, building WSN applications imposes several challenges to the developer, requiring on one hand, specific knowledge of platforms and the need to deal with low level abstractions, and on the other hand, specific knowledge about the application domain. It is not usual that a same developer has both these expertise.

We argue that a promising solution to facilitate developing WNS applications and to promote a clear separation between the specification of requirements at the application level and the specification of such requirements in a given sensor platform is to adopt the Model-Driven Development approach, more specifically the Model-Driven Architecture (MDA) [3]. MDA is a development methodology proposed by OMG which defines a software development process based on successive model refinement, where more abstract models are (automatically) transformed to the more concrete models until it reaches the source code, considered as the most concrete representation of a system. In the MDA approach the system development is divided into three levels of abstraction: CIM, PIM and PSM, where the developed models pass from a higher abstraction level to a lower abstraction level through a set of transformations. MDA aims to provide a larger reuse of

P. Sénac, M. Ott, and A. Seneviratne (Eds.): MobiQuitous 2010, LNICST 73, pp. 350–352, 2012.

software artifacts independently on the target platform which the system will run in. With an MDA approach, WSN systems can be broken down into levels of abstraction dependent or not on the sensor platform, and the design of each level is upon the responsibility of their respective expert. This paper presents a MDA infrastructure and associated process to build WSN applications. The knowledge of the application domain is represented at the PIM level using a Domain Specific Language (DSL). The knowledge representing sensor platforms is specified at the PSM level. Therefore, the proposed MDA infrastructure encompasses different PSM meta-models, one for each WSN platform.

2 A MDA Based Solution to Build WSN Ubiquitous Applications

WSN applications are built according to two viewpoints: one is the application domain expert's (biologists, engineers, etc.) and the second is network expert view. Building WSN application using our MDA process promotes the division of responsibilities among developers of these different standpoints, allowing them to use their specific knowledge and unburdening them from the need to deal with requirements that do not belong to their expertise field.

The first activity in the proposed process "Requirements Analysis", is performed by both the experts, where they get all information needed to build the application. The software artifacts produced as outcome of this activity (UML diagrams as Use Cases, textual documents, etc) represent the system requirements and compose the CIM, which will be used in further phases for both the developers. The requirements document includes functional requirements (related to the application logic) and non-functional requirements (related to the configuration of the WSN platform). We do not address the built of CIM. CIM is used by the domain expert in the activity "Model application with DSL", to specify the PIM model. This model is based on the previously developed DSL meta-model. CIM is also used by the network expert in the activity "Choosing Platform", where he/she will evaluate the available platforms and choose the one that best meets the elicited requirements. Following, the activity "Apply transformation M2M" is performed by the MDA infrastructure. Such activity takes as input the PIM model, with its associated meta-model, and the PSM meta-model of the WSN platform chosen by the network expert, to generate as output a PSM instance that represents the realization of the application in this specific platform. Such PSM is refined by the network expert to augment the model with information referring to network related specificities of the target platform. Finally, the activity "M2T Transformation" is accomplished, taking as inputs: the PSM model refined by the network expert and the chosen platform code templates and generating as output the application source code to be deployed in the sensor nodes. The generated code is then refined by both the developers to add improvements as application specific functions or protocol parameters that are not automatically generated by the process.

To specify the PIM metamodel of our infrastructure we chose the DSL described in [2]. Such DSL includes structural and behavioral characteristics of the application. We specified PSMs for two sensor platforms: TinyOS [5] and SunSPOT/J2ME [4], upon an extensive review of works about WSN development using such platforms (see project site[1] for details). The PSMs include a set of implementation characteristics that the DSL does not encompass (for instance, event or command creation in the TinyOS), since these low-level features are often out of scope for the application domain expert. The designed meta-model defines the basic feature of any application implemented in nesC [1] or JME [4] to

[1] http://labdist.dimap.ufrn.br/twiki/bin/view/LabDistProjects/WSN

run in TinyOS 2.x or SunSPOT/J2ME platforms, respectively. For each sensor platform added in the MDA infra-structure, the respective M2M and M2T transformations were defined. Two M2M transformations (DSL to tinyOS and DSL to SUNSpot) and two M2T transformations (tinyOS to nesC and SUNSpot to java) are currently available in our MDA infra-structure. Code templates for nesC and J2ME languages are available in the web page[1] of this work. It is worth noting that M2M and M2T transformations are defined only once, being reused in several WSN systems that share the same target platform (i.e., the same PSM).

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