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Abstract

Application development in the Internet of Things (IoT) is challenging because it involves dealing with a wide range of related issues such as lack of separation of concerns, and lack of high-level of abstractions to address both the large scale and heterogeneity. Moreover, stakeholders involved in the application development have to address issues that can be attributed to different life-cycles phases. when developing applications. First, the application logic has to be analyzed and then separated into a set of distributed tasks for an underlying network. Then, the tasks have to be implemented for the specific hardware. Apart from handling these issues, they have to deal with other aspects of life-cycle such as changes in application requirements and deployed devices.

Several approaches have been proposed in the closely related fields of wireless sensor network, ubiquitous and pervasive computing, and software engineering in general to address the above challenges. However, existing approaches only cover limited subsets of the above mentioned challenges when applied to the IoT. This paper proposes an integrated approach for addressing the above mentioned challenges. The main contributions of this paper are: (1) a development methodology that separates IoT application development into different concerns and provides a conceptual framework to develop an application, (2) a development framework that implements the development methodology to support actions of stakeholders. The development framework provides a set of modeling languages to specify each development concern and abstracts the scale and heterogeneity related complexity. It integrates code generation, task-mapping, and linking techniques to provide automation. Code generation supports the application development phase by producing a programming framework that allows stakeholders to focus on the application logic, while our mapping and linking techniques together support the deployment phase by producing device-specific code to result in a distributed system collaboratively hosted by individual devices. Our evaluation based on two realistic scenarios shows that the use of our approach improves the productivity of stakeholders involved in the application development.

1. Introduction

The recent technological advances have been fueling a tremendous growth in a number of smart objects [65, p. 3] such as temperature sensors, smoke detectors, fire alarms, parking space controllers. They can sense the physical world by obtaining information from sensors, affect the physical world by triggering actions using actuators, engage users by interacting with them whenever necessary, and process captured data and communicate it to outside world. In the *Internet of Things* [10], smart objects (or "things") acquire intelligence thanks to the fact that they can communicate with each other and cooperate with their neighbors to reach a common goal [2]. For example, a building interacts with its residents and surrounding buildings in case of fire for safety and security of residents, of-

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