

# Modeling Process-Aware Internet of Things Services over an ARDUINO Community Computing Environment

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**Abstract**—The authors' research group had excogitated a conceptual architecture and its functional reference model [1] for realizing a process-aware services over Internet of Things collaborative community computing environments, and it had released it to the academic worlds of the Internet of Things and the workflow technologies, as well. As a consecutive research work, we are now on the validation phase of the proposed architecture through modeling and enacting process-aware services over a practical Internet of Things community computing environment. The purpose of this paper<sup>1</sup> is to model a process-aware service and organize an ARDUINO-based Internet of Things community computing environment to show the feasibility of the concept of the process-aware Internet of Things. In order to define the process-aware service, we especially, use a business process modeling tool, which is supporting the business process modeling notations based upon the standard specification of OMG-BPMN. Each of the activities made up of a process-aware service is associated with either a sensor or an actuator of ARDUINO with a control program embodying its related service. As an operational example, we model an imaginary process-aware service fulfilled by two ARDUINO-sensors such as hygrometer and thermometer, and two ARDUINO-actuators such as buzzer and LED-lighter, and implement their control programs. Through the operational example, we are able to practically prove that the concept of process-aware Internet of Things services ought to be a reasonable and applicable concept in any forms of the real Internet of Things community computing environments.

**Keywords:** Internet of Things (IoT), ARDUINO, community computing, process-aware IoT-service, process-aware Internet of Things Architecture

## I. INTRODUCTION

Recently, the advent of ubiquitous societies gives us radical changes on our corporate, communities, and even personal spheres, too. Particularly, the widespread of the Internet of Things (IoT) newly forms a communication channel among Things including people. Technically speaking, we know that the meaning of the Internet of Things is to add the mechanism of anything connectivity to the conventional world of information and communications technologies characterized with anytime connectivity and anyplace connectivity for anyone. By completely supporting these three dimensions of connectivity, we came to possibly create an entirely new dynamic network

of networks—the Internet of Things (IoT)—as a future network. Consequently, the collaborative works of the IoT-related study groups and focal groups of ITU-T [2] like SG13, SG16, JCA-IoT, IoT-GSI, and other European groups [3][4] such as EPOSS and CASAGRAS have delivered the conceptual idea and its referential model[?] of the Internet of Things platforms, which is called *the conceptual architecture of the Internet of Things platform*. Even though, as the possible approaches to specify how to achieve the goal of a corresponding IoT-community, the groups have suggested the three types of collaborative approaches such as static, dynamic and autonomous collaborations according to the way for the Things to specify their own roles (functions) in achieving their desired goals in an IoT-community computing environment. [5]

Our research group has proposed a conceptual architecture of the Internet of Things, which is extended from the ITU-T's framework and functional architecture [2] of the Internet of Things and named as *process-aware Internet of Things* [1]. In order to validate the feasibility of our conceptual architecture, this paper proposes a notion of process-aware IoT-services that can be supported by the conceptual architecture, and implements a process-aware IoT-service running on an ARDUINO-based IoT-community computing environment. The service is systematically described by a business process modeling system supporting the standardized business process modeling notation. The goal of the service is to perform all the procedural tasks, each of which is fulfilled by either actuator or sensor. This paper provides the details of an operational example imaginarily depicting a process-aware IoT-service that is built on an ARDUINO-based IoT-community computing environment. Through this validating works with an operational example, we were able to see that the process-aware IoT's conceptual architecture is realizable and tangible if we can organize a reasonable IoT-community computing environment and systematically define a series of process-aware IoT-services to be running over the environment.

## II. AN OPERATIONAL ARCHITECTURE

Before excogitating a way of modeling a process-aware Internet of Things service, we conceptually illustrate an operational architecture for the service to be enacted over an ARDUINO-based community computing environment as depicted in Fig. 1. The operation architecture is made up of

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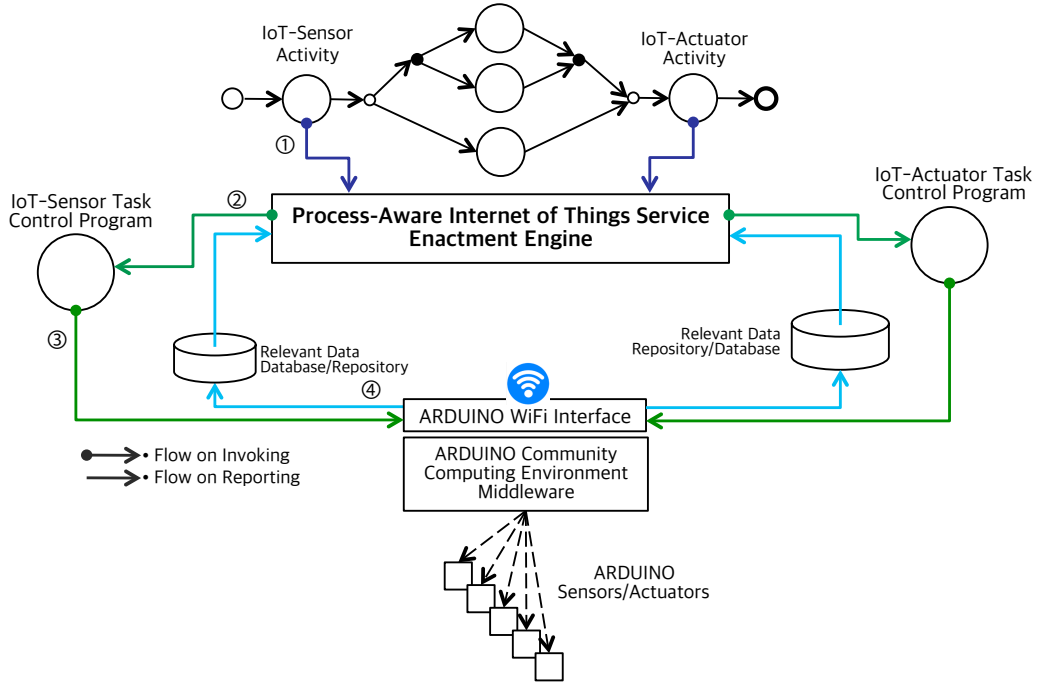


Fig. 1. An ARDUINO Community's Operational Architecture for Process-Aware Internet of Things Services

five compartments such as modeling part, enacting part, invoked control program part, relevant data part, and ARDUINO Things part. The following are the conceptual descriptions of the architectural compartments:

- The modeling part is supported by a business process modeling tool based on the standardized graphical notations of BPMN<sup>2</sup> released by the OMG-BMIDTF<sup>3</sup>. Our research group is trying to devise a new shape of notational constructs to be used for graphically representing the ARDUINO Things' activities as procedural services of a corresponding Internet of Things community computing process model [6].
- The enacting part is embodied by any of the traditional business process enactment engines, and it is able to control, audit, and monitor the Things' tasks in a corresponding ARDUINO-based community.
- The invoked control program part is a group of ARDUINO control programs corresponding to the concrete tasks of the ARDUINO Things's activities fulfilled by ARDUINO-sensors and ARDUINO-actuators.
- The relevant data part plays an important role as communication channels between the enacting engine and the Things on the Internet of Things community computing environments. It prepares a set of pre-conditional values and a set of post-conditional values to each of the Things' activities and its task. All the activities in a Internet of Things community computing process are able to launch their tasks right after completely preparing their

own relevant data predefined in the build-time of the corresponding Internet of Things community computing process model.

- The ARDUINO Things part builds an ARDUINO community computing environment that is organized by a group of devices, sensors and actuators controlled and supervised under an ARDUINO middleware. For the sake of modeling a process-aware Internet of Thing collaborative service to be described in this paper, we built an ARDUINO community computing environment that is made up of two types of ARDUINO-sensors such as hygrometers and thermometers, and two types of ARDUINO-actuators such as buzzers and LED-lighters.

### III. MODELING A PROCESS-AWARE IoT-SERVICE OVER THE OPERATIONAL ARCHITECTURE

In this section, we build a process-aware Internet of Things collaborative service that is modeled by the extended business process modeling tool that is graphically supported by the business process modeling notations (BPMN)[7] released from the business modeling and integration domain task force in the object management group (BMI-DTF). In order to model a collaborative IoT-service based upon the process-aware IoT community computing environment, we need to design a couple of notational constructs that can be used to represent the activities fulfilling those sensors' and actuators' roles in achieving a procedural goal[8] of the corresponding IoT-community. In this section, we describe the details of designing the graphical notations and using them to model a process-aware ARDUINO-community service as an operational example.

<sup>2</sup>BPMN stands for business process modeling notation.

<sup>3</sup>OMG-BMIDTF is an international *de facto* standardization organization named as the business modeling and integration domain task force in the object management group.

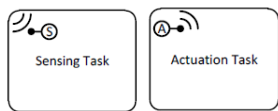


Fig. 2. Graphical Modeling Constructs for Sensor and Actuator Activities

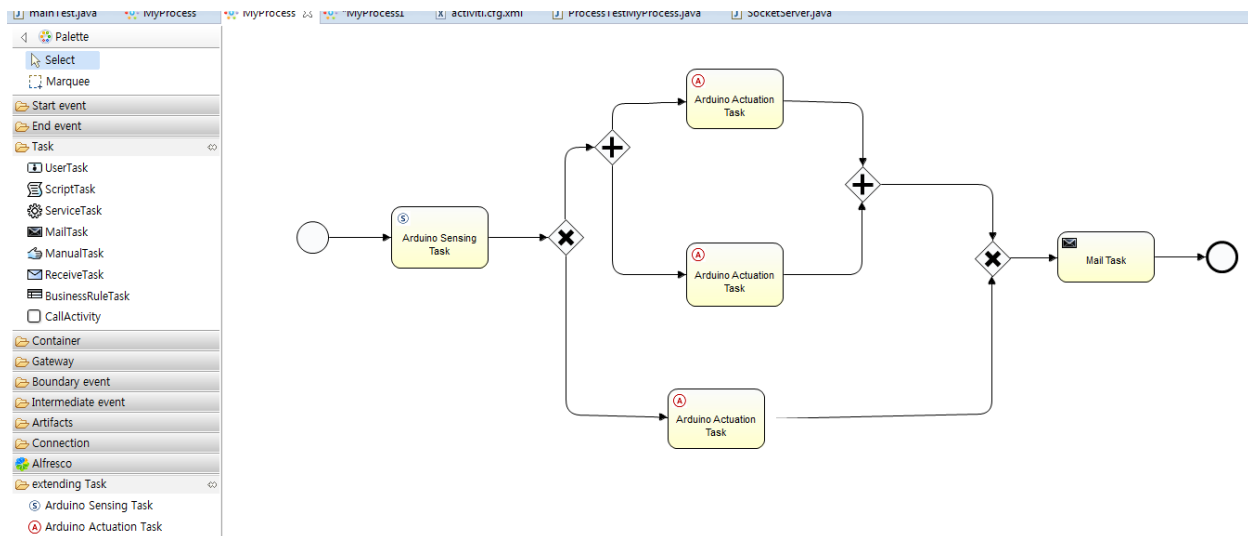


Fig. 3. A BPMN-Modeling Screen-Capture of an Imaginary Process-Aware Internet of Things Service

#### A. Designing Graphical Notations of the Things' Activities

As shown in the operational architecture, it is very important to develop a modeling tool that is able to support all the build-time functionality from graphically modeling a procedural IoT-service to systematically verifying all the compositional artifacts that are produced from the build-time operations. The authors' research group has already developed a business process management system accompanying an auxiliary graphical modeling tool, which is technically and functionally supported by the open source BPM-platform, ACTIVITI<sup>4</sup>, that supports open standards such as BPMN and DMN(Decision Model and Notation) with open REST APIs for the most demanding human- and system-centric processes. In this paper, we extend the modeling tool so as to deal with the functionality of modeling process-aware IoT collaborative services. Fig. 2 shows two graphical constructs as the manifestations of IoT-sensor and IoT-actuator tasks/activities, respectively, and both of them are designed by the ACTIVITI designer, and finally appended into the modeling tool. In this paper, we won't describe any further the details of designing these graphical constructs and their implementations.

#### B. Modeling of a Process-Aware IoT-Service on an ARDUINO Community

In this section, we try to model a procedural IoT-service that aims to achieve a goal of an ARDUINO community over the process-aware IoT community computing environment constructed by a group of ARDUINO sensors and actuators. As an operational example, we build an ARDUINO

community, model an imaginary process-aware service model fulfilled by two ARDUINO-sensors such as hygrometer and thermometer, and two ARDUINO-actuators such as buzzers and LED-lighters, and implement their control programs. Fig. 3 is a computer screen window captured from the operational business process management system. The model of a process-aware IoT-service is represented by a graphical BPMN process model consisting of five ARDUINO activities, two pairs of gateway nodes (exclusive-OR split and join gateway, parallel-AND split and join gateway), and two event nodes (start event, end event), and all the building constructs are linked by arrows that represent the temporal order of control flows.

As you can see in Fig. 3, there are one ARDUINO-sensor activity and three ARDUINO-actuator activities in the procedural service model. Also, you can see three ARDUINO-actuator activity rectangular shapes with red-colored capital letter, 'A,' inside a circle on the computer screen window. Actually, the screen-window is captured from the monitoring function of the BPMN-based process-aware IoT-service enactment engine that is corresponding to the operational architecture of Fig. 1. The red-colored letter of each rectangular activity implies that the corresponding activity is on running status. Additionally, we would stress that all the ARDUINO-sensor task and ARDUINO-actuator task control programs are implemented by the JAVA programming language and the ARDUINO APIs.

#### IV. CONCLUSION

In this paper, we suggested a feasible way of organizing an ARDUINO-centric Internet of Things community computing environment and modeling a process-aware Internet of

<sup>4</sup><https://www.activiti.org>

Things service to be performed on the environment. The main purpose of the paper was to verify the feasibility of the conceptual concept and architecture of the process-aware Internet of Things by practically implementing an ARDUINO community computing environment and its procedural service. Conclusively speaking, we proved and verified the feasibility of the process-aware Internet of Things concept and its referential architecture through this modeling work and its implementation on the extended BPMN-based business process modeling tool and enactment engine developed by the authors' research group. As the future work, we have a plan to develop the whole of the functionality that is able to fully support the process-aware Internet of Things architecture and its referential model.

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terms, and the Internet of Things collaboration architectures and services.

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