A Resource Oriented Modeling Approach for the Internet of Things: A Business Process Perspective

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***Abstract*—Recently, the rapid development of Internet of Things (IoT) has attracted growing attention from both industry and academia. It means that innumerable IoT resources could actively participate in the future internet and be able to flexibly perform considerable parts of traditional business processes. However, most of the current work is in its infancy and focuses on technical implementation details, little attention is given to the mapping of business process resources from an IoT domain to a standard business process model. In this paper, we present a resource oriented modeling approach and integrate IoT paradigm on the business process layer to make it fit in the traditional business process environment. A running case of IoT-aware business process application in the smart house is given to validate our proposed approach.**

***Index Terms*—Internet of Things, resource oriented modeling, BPMN 2.0, IoT devices**

I. Introduction and Motivation

IoT brings together real-world devices which have never been connected before. That means that further integration of physical entities into internet applications will be a trend. Business Process Management (BPM) systems will benefit from the integration with IoT resources, if typical devices such as RFID readers, sensors and actuators could directly take over responsibility as business process resources for individual business process tasks. As we know, the basis of the lifecycle before any business process automation is the creation of a business process model. Furthermore, a model is composed of many business process tasks. A business process task corresponds to a special unit implemented by a service [1], [2]. Therefore, from a business process perspective, this integration requires a special task which has the ability to interact with its physical environment through service interfaces. In order to build our work on a scientific foundation, we have investigated most of the existing Business Process Notation (BPMN, BPEL and JPDL) [3]. BPMN 2.0 not only supports the creation of a graphic model, but also supports the generation of a machine-readable model. Thus, BPMN 2.0 was evaluated as the most IoT-aware modeling standard [4] and will serve as the basis for the mapping work of business process resources from an IoT domain to a standard business process model in this paper.

Although BPMN 2.0 standard could provide theoretical support for the modeling, challenges still remain to be solved. First of all, the role of IoT devices as a resource type of a business process could not be directly represented in BPMN 2.0 standard. It implies that without the proposed approach, IoT devices could not be considered as potential executive parties in the automatic resolution phase. Furthermore, most of the existing approaches only focus on the phase of creating business process models and lack of the corresponding logic validation, which might cause serious logic problems during the business process execution phase. Finally, the modeling process is still a complicated and time-consuming issue for developers. They need not only to focus on the mapping of resources, but also to have an excellent programming skill

The main contributions of our work are as follows.

- We extend the graphic model and machine-readable model consisting of XML Schema Definition (XSD) specification of the business process metamodel of the notation BPMN 2.0, making it support the direct modeling of IoT devices.
- We design a Validator to provide support for detecting whether there are logic errors of the pre-defined business process metamodel during the phase of modeling.
- We develop a UI-friendly Eclipse-based editor for developers to manage the full lifecycle of the business process, including graphic creation of process model, dynamic definition of interaction interface, logical validation and execution.

II. Related Work

In this section, we compare our proposed resource-oriented modeling approach with other existing approaches. We will clearly point out the similarities and differences with their works. Yang Liu et.al. [5] propose a generic resource management model, which is composed of users, devices and resources. Two cases are given to describe how users can obtain the logical information through this model. However, this model is human-oriented and the modeling is complicated due to the lack of theoretical support for mapping physical entities to standard business process resources. Sonja Meyer et.al. [6] present how the real-world services used for the implementation of business processes differ from one another. Although they extend BPMN 2.0 standard at the level of graphical and machine-readable model, this extension is based on the Lane. A Lane is a sub-partition within a process (often within a pool) and is a coarse-grained process unit. Similar to them, we also extend BPMN 2.0 standard at these two levels.

However, our extension is based on the Activity, which is a fine-grained unit and could directly inherit the model associations of ResourceRole. Furthermore, they assign the IoT resources at the time of process modeling. But we decouple the internal connection between IoT devices and services through a special class Interface, which supports the assignment of IoT resources throughout the lifecycle of business process. Patrik Spiess et.al. [7] present an approach where BPEL processes are automatically partitioned and executed within the sensor network using lightweight node services among different engines. However, there might be many logic errors in the execution phase of the process, which should be checked out during the design phase. Thus, we design a Validator to detect logic errors of the pre-defined business process model.

III. Resource Oriented Modeling Specification

In this section, we propose a resource oriented modeling specification as an extension to BPMN 2.0 standard. When integrating IoT paradigm on the business process layer, we face two main challenges. First, the role of IoT device as a process resource could not be directly represented in BPMN 2.0 standard. Second, we have to deal with the IoT device and the service hosted on it at the same time. However, BPMN 2.0 could not fully consider two types of resources on different levels concurrently in the same process metamodel. To address these issues, we will extend BPMN 2.0 standard in both graphic model and machine-readable model.

A. Graphic Model

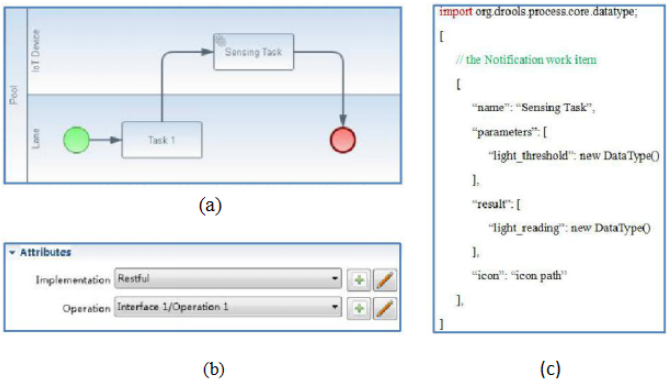

Fig. 1. The implementation and operation of Graphic Model.

An Activity is an unit that is performed within a business process and could directly inherit the model associations of ResourceRole. In order to explicitly distinguish IoT devices from traditional business process performers and bind IoT services to the graphic element through an interface component, we design a characteristic icon at the level of Activity. Fig. 1 (a) illustrates a business process pool called "IoT Business Process", which contains a regular lane "Lane" and an IoT-aware lane "IoT Device". The task of "IoT Device" is a "Sensing Task", which could expose its sensing service through the restful interface. However, the sensing service is not directly visible as part of the graphic business process model, but is included in the implementation and operation of attributes, as shown in Fig.1 (b). In addition, the extended version of the service handler is shown in Fig.1 (c), which could realize the attributes in a service definition file and be used to further specify the "Sensing Task".

B. Machine-readable Model

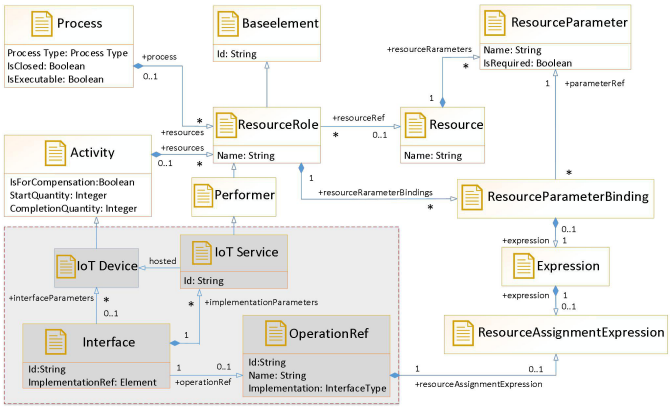

Fig. 2. The extension class of XSD specification of BPMN 2.0 standard

Besides the graphic model, we also extend the BPMN 2.0 machine-readable model of the process to map IoT resources to the activity level while maintaining compatibility with the standard as much as possible. Although BPMN 2.0 standard already supports the allocation of resources at the activity level, it could not directly reference the IoT-associated parameter for a resource role, which is not known in XML format to the BPM environment. To address this issue, we introduce a subclass to the Activity class and bring the resource allocation of devices directly to the activity level, compatible with the graphic model. The IoT Device class inherits the model associations and attributes of the Activity class. The OperationRef class supports the definition of IoT-associated parameters, which will pass over the generated XML document to the execution phase of the business process. In this case, an available IoT Device class could be found by the parameters at runtime. The IoT Service class defines the actual services that are hosted on the physical devices and exposes these services through the Interface class. Consequently, a process resource could be defined and mapped from an IoT domain to a machine-readable business process model, without being known previously to the BPM environment. Fig. 2 shows the XSD specification extensions.

C. Validator

As mentioned above, we design a Validator to provide support for detecting whether there are logic errors of the pre-defined business process metamodel during the phase of process modeling. Validator has three function components: converter, parser and analyzer. Converter first converts the BPMN elements to the corresponding petri net modules, then integrates these modules into Petri Net Markup language

(PNML) file using the latest ISO/IEC 15909-2 International Standard. Parser adjusts the layout of PNML file through Design Structure Matrix (DSM) and calculates the reachability matrix. Based on the reachability matrix, Analyzer uses depth-first strategy to validate logic features (e.g. Loop, Deadlock, Accessibility, etc.) of the pre-defined business process meta-model. Fig. 3 depicts the realization of Validator reference architecture. In order to better understand our work, we designed a business process with a logic error due to the improper using of gateways. A demonstrative video of Validator can be found at the following URL: https://youtu.be/T5HN0AboJ2A.

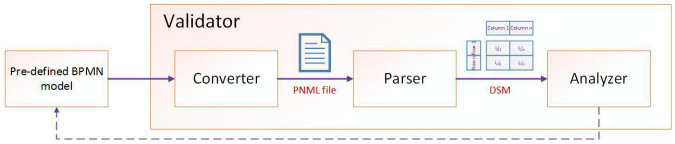

Fig. 3. The realization of Validator reference architecture

IV. Case Study

In the previous section, we have introduced our approach of modeling IoT devices as process resources in the conventional BPM environment by extending the BPMN 2.0 standard. In order to further illustrate the benefits of using our proposed approach, we discuss an actual IoT-aware business process example using our extended Eclipse-based modeling tool. We design a business process of automatic curtain, showing the linkage mechanism between different devices in a smart house. The process includes two IoT devices: a light sensor providing the sensing service through a Restful-based interface perceiving light intensity and a actuator providing the actuating service of opening or closing according to the measurement of the sensor. Developers only need two steps to create this IoT-aware business process: dragging graphic elements from the element library and binding services to standard interfaces. Fig. 4 illustrates the corresponding graphic model in our IoT-aware business process modeling tool.

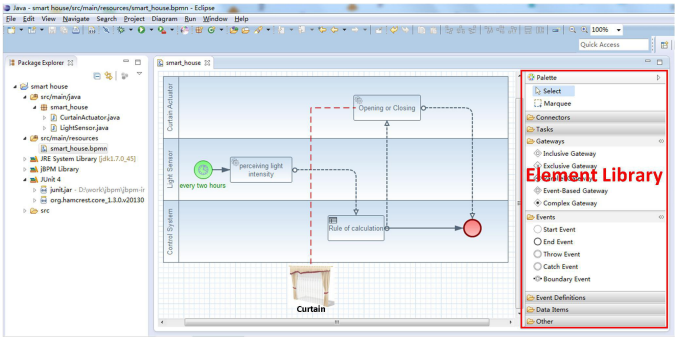

Fig. 4. Dynamic opening or closing business process of a smart curtain

V. Conclusion and Future Work

In this paper, we presented a resource oriented modeling approach for the Internet of Things to make IoT fit in the traditional BPM environment. In order to reach the goal, we initially extended the graphic and machine-readable model of BPMN 2.0 standard, making it support the direct modeling of IoT-aware business process. Furthermore, we introduced an auxiliary tool to detect logic errors of the IoT business model during the phase of process modeling. Finally, we tested our proposed approach practically by implementing a prototype of an IoT-aware business process model in our extended UI-friendly Eclipse-based modeling tool. It is worth mentioning that the work in this paper is a part of our entire project related to IoT-aware business process applications. More information about our work can be found in https://youtu.be/Cw1tXlMMIUM.

However, our work is still in its infancy and requires more actual applications to prove its applicability. Thus, we plan to leverage our proposed approach to implement advanced IoT-aware business process applications in a cloud environment.

Acknowledgment

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