Towards Robustness of IoT devices in BPMNE4IoT

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Abstract

Integrating the Internet of Things into Business Process Management has gained traction for several years to improve smart applications (e.g., smart homes, Industry 4.0). Different frameworks have been proposed to integrate IoT in all stages of the BPM lifecycle. However, current frameworks lack proper support for dealing with issues related to error handling, like sensor faults, fallback strategies, and redundancies. Therefore, it has to be assessed to what extent error handling should be included in the abstraction layer of IoT-aware processes to increase both robustness and reliability. This paper discusses five research questions on the challenges regarding the integration of error handling in existing frameworks throughout the BPM lifecycle.

Keywords

BPM, IoT, Error handling, IoT-aware business processes

1. Introduction

The Internet of Things (IoT) is an important part of digitization in the personal space, like smart homes or connected cars, as well as in the industrial space with Industry 4.0 and smart logistics. These complex systems combine a wide range of IoT devices to form highly automated systems, relying on sensors for collecting data from the physical world (e.g., temperature, air quality, humidity) as well as actuators (e.g., motors), for altering the physical world by either mechanical motion (e.g., movement or rotation) or environmental changes (e.g., light, humidity, pressure) [1, 2]. Utilizing data generated from IoT devices can improve IoT-aware business processes (BP) [3, 4]. Integrating IoT devices into Business Process Management (BPM) systems shows the potential of merging both areas [5, 6]. BPM is a paradigm to model, implement, execute, monitor, and analyze business processes [7]. Providing support for IoT capabilities in BPM systems can enhance the awareness of the physical world by connecting the digital to the physical world via IoT devices along the entire BPM life-cycle. Besides optimized business processes and better decision-making, the added IoT capabilities can be used to automate physical tasks, like turning on/off lights or tracking the location of physical devices [6]. Modeling IoT-aware business processes has been extensively studied in literature [2]. In this paper, we consider five research questions to assess the extent of IoT-related errors in an IoT-aware business process. Besides understanding common IoT errors, the goal is to investigate different strategies on how to include error handling into IoT-aware business processes to provide a set of recovery

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strategies, and to study the effects these strategies have on the business process. We developed a holistic framework - BPMNE4IoT - for modeling, executing, monitoring, and logging IoT-aware processes [5]. The framework can already detect faulty sensors and actuators and visualize them in the BPMNE4IoT monitoring tool. However, the IoT-aware processes that can be built with our framework have not yet matched the needed resilience regarding IoT errors. More research is needed to not only detect, but also to cope with a wide range of errors, like failing sensors, sensor drifts, and stuck actuators. Considering the research questions presented in this paper, we plan to investigate possible improvements to the BPMNE4IoT framework to increase its resilience.

The paper is structured as follows. Section 2 outlines the overall problem statement and provides a real-world example. In Section 3, we define a set of research questions, that need to be answered in the context of the above problem statement. In 4, we present related work. Finally, Section 5, presents a summary and an outlook.

2. Problem Statement

Error handling is a multi-phase problem. Besides modeling, systems should be able to cope with errors during IoT-aware process execution. Here, we focus on approaches based on the combination of BPMN with IoT, however, other modeling approaches (e.g., Petri-nets or state machines) do exist. BPMN 2.0 does not provide the tools and notation to design IoT-aware processes [3, 5]. By introducing a holistic framework, i.e. BPMNE4IoT for modeling, executing, monitoring, and logging IoT-aware processes, the involved IoT devices can be incorporated with the business process. However, the framework contains a limited set of features to increase the robustness and reliability of IoT-related errors. We want to illustrate this based on the BPMN model, depicted in Figure 1.

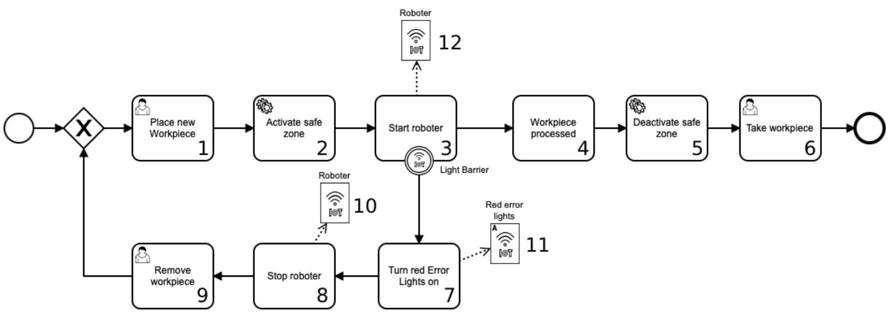

Figure 1: An example of an IoT-aware business process

In this scenario, different IoT-related errors may occur. To illustrate these errors, we focus on two scenarios—a faulty robot, which is an IoT object, comprising different types of sensors and actuators, and a faulty light barrier. For example, the robot might malfunction and refuse to start in step 3 of the IoT-aware process depicted in Figure 1. Currently, the process will be stuck forever in this step until a worker intervenes and manually handles the malfunction, alerted by the monitoring. Depending on the specific robot, calibrating or restarting the robot may fix the error, however, this is often not supported by BPM systems, like BPMNE4IoT, which we use as an example. Here, an IoT device could include strategies to handle common errors automatically and report their state (e.g., re-calibration, restarting). Depending on the domain, this might decrease the amount of human intervention and the time consumed to treat the malfunction.

Note that there might also be life-threatening errors. In a second scenario, we consider the effects of a malfunctioning light barrier. When the robot is working on a piece and is standing still, waiting for a workpiece to cool down, the worker might believe the robot has finished its task and walk into the security zone. If the light barrier does not trigger, the robot is not aware of the human in range which could harm him significantly.

From these two scenarios we may conclude, robustness and reliability concerns need to be investigated for IoT-aware processes. Moreover, process execution opportunities to increase safety, reduce downtime, and increase availability.

3. Research Questions

Although BMPNE4IoT [5] offers a promising approach to model IoT devices in IoT-aware business processes, further research is needed. Currently, faulty sensors can be represented in the execution stage of the BPMN4IoT pipeline. However, BPMNE4IoT has not yet considered robustness and reliability issues regarding IoT devices. We plan to investigate if including IoT devices down to the hardware is the appropriate abstraction level for IoT-related error handling. Furthermore, we need to assess in future work, if changes to the handling of IoT devices in BPMNE4IoT are necessary to include and aggregate reliability information. The following research questions (RQs) must be explored to gain a deeper understanding.

RQ1: How can the appropriate abstraction level for a given IoT device be determined when integrating into IoT-aware BPs?

In BPMNE4IoT, devices can be represented either as a single device or as a group of devices or as a complex object with multiple types of devices. Defining error handling techniques is influenced by the access to the device. Low-level access to IoT devices in IoT-aware BPs enables more complex error handling by the process, however, this is not always desired [8]. Developing metrics to determine the appropriate abstraction level on a process level should be pursued.

RQ2: Can monitoring on an IoT device level contribute to identifying error-prone IoT devices across processes?

Monitoring IoT devices on a process level may provide domain experts with more detailed insights into which situations specific IoT devices produce errors. Currently, IoT devices in BPMNE4IoT are represented multiple times in the modeling stage (10 and 12 in 1), even though they are the same physical device. Connecting data from different IoT-aware BPs by a shared device pool may provide a better understanding of the reliability of specific IoT devices.

RQ3: Is the added complexity of IoT-related error handling over native BPMN 2.0 error handling techniques justifiable to enhance expressiveness?

Including IoT-related error handling in IoT-aware BPs could yield the benefit of a more descriptive modeling stage. Based on RQ1, implementation-specific logic can be pushed to the execution or device level by choosing a higher abstraction degree for the IoT device in the modeling stage.

RQ4: Which patterns for dealing with self-healing and recovery can be realized in a framework like BPMNE4IoT?

Currently, failing IoT devices lead to a stuck or terminated BP. Patterns to include self-healing capabilities, providing the ability to detect and compensate for IoT-related errors, are desired in BPMNE4IoT. It should be investigated which techniques (e.g., MAPE-K feedback loops) for dealing with self-healing can be incorporated into BPMNE4IoT.

RQ5: How can IoT device redundancies be integrated into IoT-aware BPs?

Especially in critical applications, redundant IoT devices are used to ensure the reliability of the system, however, they come at a price (e.g., device cost, and complexity). It should be investigated if IoT device redundancies should be incorporated on a BP level. Defining redundancies, receiving detailed insights while monitoring, and refining processes based on redundancy data linked to specific tasks could lead to an easier optimization of processes. However, it is open for debate which of these abilities should be controllable on a process level, especially due to redundancies being highly dependent on the context, software, and hardware.

4. Related Work

Several approaches have been proposed to include IoT-awareness into the BPM lifecycle [5, 9, 10, 2, 11, 12, 13]. uBPMN extends BPMN 2.0 by defining five task types, sensor task, reader task, image task, audio task, and collector task, to represent incoming and outgoing data streams as well as their respective context [14]. BPMNE4WSN specifically aligns with Wireless Sensor Networks (WSNs) [15] by introducing WSN task, WSN pool, and WSN performance annotations. BPMNE4CPS extends the BPMN 2.0 service task to provide dedicated support for web services, embedded services, and cloud services [16]. While these approaches enable IoT-aware processes, they do not specifically focus on robustness or reliability issues. Outside the BPM context, work was conducted to investigate IoT robustness and reliability [17, 18, 19, 20]. [21] provides a methodology for measuring task reliability by block reduction. For IoT-aware processes, [22] and [23] investigated the reliability of the BPMN extension relyBPMN when associating human and IoT-related information resource information for given tasks. [24] and [25] investigated the use of self-adaptive processes in distributed workflows. By using a modified MAPE-K feedback loop, known from self-driving frameworks to detect and compensate for errors in distributed processes. Finally, [26] proposes an approach to fault management for distributed sensor networks on the edge.

5. Conclusion

As discussed, robust and reliable IoT-aware processes should be pursued. As shown in two scenarios, handling IoT-related errors not only increases availability and decreases cost, but also increases safety by managing safety-related topics (e.g., redundancy). The paper introduced five research questions to assess and improve the extent of error handling of IoT-aware business processes in BPMNE4IoT. Existing approaches, like relyBPMN, do improve error handling in IoT-aware BPs for specific scenarios, however, a holistic approach is still missing.

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