# Enhancing BPMN 2.0 with IoT Modeling Aspects: How Much Language is Enough?

Yusuf Kirikkayis[1], Florian Gallik[1] and Manfred Reichert[1]

[1]*Institute of Databases and Information Systems, Ulm University, 89081, Germany*

### Abstract

Extending Business Process Management (BPM) with Internet of Things (IoT) capabilities enables real-world aware process automation, business rule execution, and process monitoring. As a prerequisite for exploiting the benefits of this real-world awareness, IoT behavior needs to be captured in business process models. The de facto standard for business process modeling, BPMN 2.0 seems to be appropriate for covering IoT aspects as well. However, modeling IoT-aware processes might be hindered by the ambiguous use of the BPMN 2.0 modeling elements. Still it has to be evaluated how process model readers actually perceive IoT aspects captured in BPMN 2.0 process models. This paper discusses the challenges of modeling IoT-aware business processes with BPMN and derives research questions to be investigated in future work.

### Keywords

IoT-aware business process, BPM, IoT, BPMN 2.0

## 1. Introduction

The IoT represents a network of interconnected physical devices, i.e., sensors and actuators, that allow capturing, exchanging, and collecting data to respond to physical events. Thus, the dynamic context of the physical world can be captured and transformed to a digital shadow. The IoT, therefore, is a fundamental technology in areas likes smart manufacturing, smart logistics, or smart healthcare. In these areas IoT-aware business process support can create a competitive edge by exploiting the data produced by IoT devices [1]. We refer to processes that utilize IoT devices and map IoT behavior to process activities and events as IoT-aware.

The incorporation of IoT capabilities into IoT-aware business processes offers promising perspectives for bridging the gap between digital processes and the physical world [2]. While IoT enables collecting and exchanging data about the physical world, Business Process Management (BPM) enables modeling, implementing, executing, monitoring, and analyzing business processes [2]. In the context of BPM, moreover, IoT devices can be used to automate different types of tasks, to enhance process and task monitoring, and to support real-world aware decision-making [3]. An essential challenge of modeling IoT-aware business processes is to properly capture IoT-related aspects in the process models [4, 5]. Amongst others, modeling

IoT aspects shall foster the understanding of how the process works and facilitate the discovery of potential problems (e.g., deadlocks).

As many of the BPMN 2.0 modeling elements can also be found in IoT-aware business processes, researchers have argued that BPMN 2.0 is capable of modeling IoT-aware business processes [3, 6, 7, 8, 9]. As example consider Figure 1, which depicts an IoT-aware light control process expressed in terms of the BPMN 2.0.
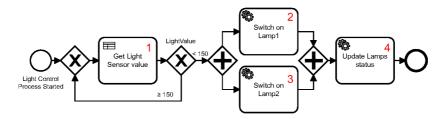


**Figure 1:** Example of an IoT-aware process model expressed in terms of BPMN 2.0.

Other works have explicitly indicated the need for modeling IoT participation in business processes [5, 10, 11, 12]. In particular, they recommend to visually distinguish between common and IoT-related modeling elements by extending the BPMN 2.0 meta-model with IoT-specific modeling elements. Consequently, the involvement of IoT devices in process enactment becomes apparent, fostering the comprehensibility of IoT-related process models and, thus, their maintenance. Corresponding works further argue that due to the extension of BPMN 2.0 with IoT-specific modeling elements, no ambiguities occur when reading process models. In Figure 1, Tasks 2&3 are IoT-related, whereas this does not apply to Task 4.

Modeling IoT-aware business processes with BPMN 2.0 has been extensively studied in literature [3, 6, 7, 8, 9, 13]. However, the evaluation of IoT-aware process models from a user perspective is still missing. In particular, we are interested (1) whether IoT-related processes modeled in terms of the standard BPMN 2.0 notation are as comprehensible as (2) IoT-aware processes modeled with BPMN 2.0 and explicit IoT-specific elements, with the latter constituting an extension of BPMN 2.0. A particular challenge is to identify those factors that foster the understanding of IoT involvement in BPMN 2.0 process models from a user perspective. To determine whether IoT aspects in BPMN 2.0 process models are properly recognized by users, human cognition and mental effort needs to be considered when reading corresponding process models. Related works neither cover the perspective of IoT-aware process models nor cognitive aspects of understanding corresponding models. In particular, decisions on how IoT aspects shall be captured in BPMN process models have been primarily based on technical issues. This paper derives research questions to investigate how IoT aspects shall be captured in BPMN process models taking the user perspective into account as well.

## 2. Research Questions

Although BPMN 2.0 offers various elements (e.g., *Activities*, *Events*, *Pools*, and *Lanes*) that allow modeling IoT-aware business processes, different aspects need to be considered. In particular,

additional research is required to investigate how IoT aspects shall be visually covered in BPMN 2.0 models, while fostering model comprehensibility (i.e. whether to opt for variant (1) or (2)) [14]. In detail, the following research questions (RQs) need to be considered to understand whether a BPMN 2.0 extension for IoT-aware processes becomes necessary. Note that these research questions were derived from systematic literature reviews [15, 16] as well as a comparison of the two modeling approaches, i.e., modeling IoT-aware processes with standard BPMN (1) vs. modeling them based on an extension of BPMN with IoT-specific elements (2).

**RQ 1**    Is BPMN 2.0 suitable for modeling IoT-aware business processes?
**RQ 2**    Is there any IoT-specific behavior that cannot be modeled in terms of BPMN 2.0?
**RQ 3**    Can IoT-related modeling elements be identified in BPMN 2.0 from a user perspective?
**RQ 4**    Are there patterns in modeling IoT-driven business processes?
**RQ 5**    Does the use of different BPMN modeling elements influence the cognitive load during the comprehension of IoT-aware processes?

*RQ1* aims to identify whether BPMN 2.0 is suitable for modeling IoT-aware processes. *RQ2* intends to investigate whether there exists any IoT-specific behavior which is relevant for process execution, but cannot be properly represented in terms of BPMN 2.0. To answer *RQ 2*, IoT-aware processes from different domains need to be analyzed and modeled with standard BPMN 2.0. In particular, this might unravel IoT behavior that cannot be directly modeled in BPMN 2.0. In contrast, *RQ 3* aim to identify whether IoT aspects captured in BPMN 2.0 process models can be visually or textually recognized from a user perspective when using standard modeling elements (e.g., pools, lanes, activity types, and event types). *RQ 4* aim to determine whether there are patterns of IoT-driven business processes when modeling them in terms of BPMN 2.0. In turn, *RQ5* investigates the cognitive load of users when reading and comprehending IoT-aware processes in BPMN 2.0. For this purpose, for example, a NASA-TLX questionnaire may be used. Answering *RQs 3 - 5* shall allow us to understand how IoT-aware business processes modeled in terms of standard BPMN 2.0 affect human cognition and how far the respective process models are perceived as IoT-aware from a user perspective. All five research questions need to be answered in order to assess whether an IoT-specific BPMN 2.0 extension is beneficial to foster real-world IoT-driven business processes.

## 3. Conclusions

This paper introduced five research questions that need to be addressed when modeling IoT-aware business processes with BPMN 2.0. In literature, two approaches are proposed for modeling IoT-aware processes: (1) using standard BPMN 2.0 as (2) extending the BPMN 2.0 standard with IoT-specific modeling elements. However, existing works have neglected the user perspective when deciding which of these two variants shall be used. Consequently the pros and cons on how to model IoT aspects in BPMN-based processes have primarily been considered form a technical perspective taken by IoT experts. User studies are needed that address the presented research questions. In corresponding studies, different aspects such as the recognition of IoT aspects in BPMN-based process models, the cognitive load of users when reading IoT-aware processes in BPMN 2.0, and different modeling patterns for IoT-aware

processes in BPMN from user perspective can be identified. Various techniques may be used for this purpose, such as the survey of study participants and conducting a within-subject study.

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