The Real-time Enterprise: IoT-enabled Business Processes

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Abstract. The Internet of Things (IoT) offers a great potential in many different application areas for improving enterprise applications – from efficiency gains to completely new business processes and even business models. However, in order to realize this potential, significant hurdles still have to be overcome. This position paper focuses on one of these hurdles: The integration into business processes by means of process modelling and the orchestration of IoT services.

Introduction

The Internet of Things (IoT) is a hot topic world-wide, both in research as well as in the media. As one aspect of a Future Internet, many application areas have been postulated – not only in industrial domains such as manufacturing, logistics, retail, service management, energy, public security, and insurance, but also for the life of every citizen – where IoT can bring significant improvements, leading even to new business models [1] [2]. In order to realize this vision many obstacles have to be overcome. Systems have to be opened up, secured, and made highly reliable to facilitate global collaboration across multiple organizations similar to the services offered on today's Internet. Globally accepted standards, methods, and tools have to be developed to enable large scale infrastructures that can be configured, integrated, and monitored efficiently. Intelligent systems with substantial self-configuration, self-monitoring, and self-healing properties are required to manage the large and fast growing number of devices. Progress is being made in many of these areas; this position paper will thus focus on an issue that has not received enough attention yet, but is crucial for building and deploying IoT applications in industrial or enterprise settings on a wider scale: The modelling of IoT-aware business processes.

Service-enablement of the IoT

Enterprise systems nowadays are built on service-oriented architectures, and business processes in such systems are modelled as an orchestration of underlying services. In order to integrate the IoT into business process systems it is therefore necessary to service-enable IoT resources, e.g., the sensors and actuators that are used to interact with the physical environments. This can be done either through full-blown Web Services [3], or more likely, using REST-based approaches [4]. Using a service-based approach offers the additional advantage of hiding the heterogeneity of IoT device and data protocols from the business application.

It is noteworthy that such IoT services have some different properties compared to common enterprise services. Not only might the technical implementation of the services be different, also thecommunication model and orchestration of services might be different, as the dynamic nature of the real world demands for flexible inter-service communication that must take unexpected events into account and, consequently, provide means of dealing with complex events patterns. Secondly, locality is of much more importance, both regarding the origin of the data delivered (e.g., the temperature in a specific room) as well as where the service is executed – not just anywhere in the cloud. Thirdly, we often have to deal with streaming data from which relevant information and events have to be extracted in (soft) real-time. And maybe most importantly, IoT services are inherently unreliable: the data delivered might be wrong, for example because of a decalibrated sensor, or they may suddenly become completely unavailable because the device hosting the service has run out of power or has been moved out of communication range. These different properties need to be taken into account when modelling processes that include IoT services.

Modelling of IoT-aware Business Processes

Currently, integrating IoT devices – RFID, sensors, actuators etc. – into enterprise systems requires a lot of engineering, deployment and configuration of middleware, as well as some custom development. Every new installation requires again a significant effort. On the other hand, Business Process Modelling (BPM) is an established technique for modelling and executing complex processes in enterprises. If now these techniques could also be used for IoT-aware processes, a significant step towards wider deployment of IoT technologies would be made. In fact, one can even say this is an absolute requirement, since many enterprises rely on BPM for their processes.

However, current business process modelling is geared towards planned and deterministic processes. The related tools don't yet support the challenges that IoT-aware processes bring well. The challenges include:

Adaptive and event-driven processes: One of the main benefits of IoT integration is that processes become more adaptive to what is actually happening in the real world. Inherently, this is based on events that are either detected directly or by real-time analysis of sensor data. Such events can occur at any time in the process. For some of the events, the occurrence probability is very low. But one knows that they might occur, but not when or if at all. Modelling such events into a process is cumbersome, as they would have to be included into all possible activities, leading to additional complexity and making it more difficult to understand the modelled process, in particular the main flow of the process (the 80% case). Secondly, how to react on a single event can depend on the context, i.e. the set of events that have been detected previously. A simple example: If people had entered a certain area, *and* later a sharp rise in temperature is detect there, *as well as* smoke, then the rescue team needs to be sent. Or, if the truck is delayed so that the delivery cannot reach the intended B customer in time, *and* if the company just has received an urgent order from its preferred A customer, then the truck is rerouted to the A customer.

Processes dealing with unreliable data: When dealing with events coming from the physical world (e.g., via sensors), a degree of unreliability and uncertainty is introduced into the processes. If decisions in a business process are to be taken based on events that have some uncertainty attached, it makes sense to associate each of these events with some value for the quality of information (QoI). In simple cases, this allows then the process modeller to define thresholds: e.g., if the degree of certainty is more than 90%, then it is assumed that the event really happened. If it is between 50% and 90%, some other activities will be triggered to determine if the event occurred or not. If it is below 50%, the event is ignored. Things get more complex when multiple events are involved: E.g., one event with 95% certainty, one with 73%, and another with 52%. The underlying services that fire the original events have to be programmed to attach such QoI values to the events. From a BPM perspective, it is though required that such information can be captured, processed and expressed in the used modelling notation language, e.g. BPMN. Secondly, the syntax and semantics of such QoI values need to be standardized: Is it a simple certainty percentage as in the examples above, or should it be something more expressive (e.g., a range within which the true value lies)?

Processes dealing with unreliable resources: Not only the data from resources is inherently unreliable, but also the resources providing the data themselves, e.g., due to the failure of the hosting device. Processes relying on such resources need to be able to adapt to such situations. The first issue is to detect such a failure at all: In the case that a process is calling a resource directly, this detection is trivial. When we're talking about resources that might generate an event at one point in time (e.g., the resource that monitors the temperature condition within the truck and sends an alert if it has become too hot), it is more difficult: Not having received any event can be because of resource failure, but also because there was nothing to report. Some monitoring software is needed to detect such problems; it is unclear though if such software should be part of the BPM execution environment or should be a separate component.

Highly distributed processes: When interaction with real-world objects and devices is required, it can make sense to execute a process in a decentralized fashion. As stated in [1], *the decomposition and decentralization of existing business processes increases scalability and performance, allows better decision making and could even lead to new revenue streams through entitlement management of software products deployed on smart items*. For example, in environmental monitoring or supply chain tracking applications, no messages need to be sent to the central system as long as everything is within the defined limits. Only if there is a deviation, and alert (event) needs to be generated, which in turn can lead to an adaptation of the overall process. From a business process modelling perspective though, it should be possible to define the process centrally, including the fact that some activities (i.e., the monitoring) will be done remotely. Once the complete process is modelled, it should then be possible to deploy the related services to where they have to be executed, and then run and monitor the complete process.

Conclusion

Integrating Internet of Things aspects into Business Process Modelling and related tools is one of the key challenges that need to be overcome in order to see wider deployment of IoT technologies, and thus, to be able to reap the many potential benefits that have been postulated for the IoT. When doing so, the special characteristics of IoT services and processes have to be taken into account and likely existing business process modelling and execution languages like BPMN [5] and WS-BPEL [6], as well as service description languages like USDL [7], need to be extended.

Regarding the modelling of distributed processes, in a first step it should be possible to define in the modelling environment which activities should be executed where, and to select the services that implement these remote activities. It has to be noted though that these services – as they are implemented on resource-constrained devices – are often not based on SOAP, but rather use REST. A second and more advanced step is then to use the model also for the deployment of the services: All required services are if necessary deployed to the target devices/environments once the model is instantiated, or even a complete subprocess is deployed to a remote BPM execution engine. In addition, it would also be desirable to support the business process modeller in deciding what activities should be executed where, initially through guidelines, later maybe even through (semi-) automatic decomposition.

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