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From BPM to IoT

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Abstract—IoT becomes more and more present, the market is here, and sales are starting to increase. As there are lot of research in order to propose a global architecture to build IoT applications, the domain will rise as soon as a solution will widespread. Next, we will need to build bridges between IoT application and the legacy data processing solutions. Business Process Model is a common concept used to build and compose software. Could the Internet of Things becomes an active shareholder in this approach ? The Internet of Things has specific constraints and peculiar organizations based on its dynamicity and heterogeneity. We propose, in this paper, to analyze the difficulties that may arise, and we propose a gateway to adapt our own IoT platform to the needs of the BPM approach.

Index Terms—BPM, IoT, BPM in IoT

I. INTRODUCTION

BPM is made for building a workflow of services provided. BPM describes the interactions and the sequence of request/responses to/from services. IoT is the gathering of data collected by sensors, and the triggering of actions provided by actuators. We can say that there are similarities between the two, as requests/responses of objects can be seen as services provided by these objects. But there are differences: In BPM, services at stack are unique and rich (offering complex interactions and detailed responses). There are very distinct, and stable in time. On the contrary, in the IoT, data gathered can be from only one sensor, or from multiples sensors (average temp, consumption, etc). Objects sensing or acting can be changed, be unreachable, running out of energy, then start again, replaced by a different one giving the same data, but under another format.

There is a conflict between the stability, unicity, meaningfulness of the services at work in BPM, and what can offer the IoT. But with the emergence of the IoT as part of the IT, there is a need to interconnect the two worlds, and to make them interact. We propose in this paper the description of a software bridge between the needs of the BPM and their translation to the IoT world.

This paper is organized as follow: Section II presents related works and some background for our solution. Section III describes the proposed architecture. Section IV gives an example through a use case. Finally, concluding remarks end this paper in Section V.

II. STATE OF ART

Business process management (BPM) is a field in operations management that focuses on improving corporate performance by managing and optimizing a company's business processes. [1] It can therefore be described as a "process

optimization process". It is argued that BPM enables organizations to be more efficient, more effective and more capable of change than a functionally focused, traditional hierarchical management approach. These processes can impact the cost and revenue generation of an organization.

The objective of BPM is to facilitate the management of the services offered by an organization. It aims to describes the enterprise activity as a set of processes, and to help the invocation of these processes, from within the organization or from its partners (clients or providers) [2]. The modeling of the Business Process can be done using tools [3], describing the interactions and the work-flow that involve the different tasks, input and output at stack.

The Internet of things (IoT) is the inter-networking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data. [4]

Proposing an Architecture for IoT applications [5] is a very active domain in which the academic research and the industry try to cope with the issues raised by the IoT, mainly in their wireless part. Providing a network access to everyday's life objects adds new opportunities, but is subject to many constraints [6].

Incorporation of heterogeneity is the key foundation underlying a global IoT network. This, on one hand brings tremendous possibilities with turing complete solutions, on other hand, makes the system more difficult to handle. A "All-are-Welcomed" approach is not only difficult in its flawless application but also subject of scrutiny in connected world's domain.

The essence and success of IoT lies in its RR - viz., "Remote Robustness". This constraints the energy resources available at disposal. Energy for operation of devices is very limited because objects must remain autonomous (some of them are not wired to any energy source). Sometimes, they are not physically accessible (for example, metal sensor in the pavement of parking lot) so battery can't be replaced. The network protocol used to offer the connectivity is dramatically thrifty.

To cope with this energy issue, [7] Small payload, Small throughput, sleep mode, etc are used to reduce energy consumption [8]. Smaller payloads and throughput with increased sleep time severely limits the use of reduced available bandwidth. This, in turn forces one to use efficient and innovative network protocols.

Accessing to the data gathered by devices, or using the ability to act on the real world are also a subject of studies. In order to facilitate their integration with a well-known programming paradigm, Erik Wilde has proposed to give access to data and actions provided by objects through a REST API [9]. This Resource Oriented Approach is described by D. Guinard et al. in [10] and [11]. Using such an approach leads to simplify the writing of applications using IoT devices because SOA, ROA and REST are mastered by programmers. It also gives an opportunity to integrate IoT solutions in a more global vision of IT Enterprise services [12].

Recently, 6LowPAN, [13] a version of IPv6 for IoT devices, has been standardized by the IETF. Opening a direct access to devices to the IP world, a specific REST protocol has been proposed by the same author: CoAP [14]. A more global access to IoT devices called LwM2M [15], secure, with configuration settings and over-the-air firmware update is proposed on the top of CoAP and 6LowPAN. If the proposal is widely adopted by the industry, it will provide a common way to access, use, configure and update any kind of devices. This unification of a standard access to a huge variety of devices is also the purpose of architectural solutions as oneM2M [16] for example.

An architectural solution provides a complete structure aiming to interact with objects. It solve the access to services provided by each object, but also their description, the requesting (which object can answer my query, which objects implement this service), security, authentication [5]. Still, the IoT world and the Internet of Data are different in their characteristics, in response time, unicity of provider, reliability of the network, persistence of the service provider, throughput, payload...

III. PROPOSED ARCHITECTURE

IoT architectures provide solutions to use objects, with identification, localization, data adaptation to the needs.. They must react to various issues and multiple changes. First, IoT devices are etherogeneous. They can dramatically differ in terms of network protocols, operating systems and software used to solve the same problem. As industries give tools to access these devices, the users may encounters issues to make them interact, or simply gather data under the same format.

Another issue is the number of objects that are at stake for one defined purpose. For example, the temperature value gathered for a part of a building maybe the average of data gathered from an important number of devices. The reaction to this aggregated value can be to switch on a set of air conditioner. This specificity of a unique value/service gathered/triggered from multiple sources is different from the common BPM approach in which a service/event is unique in its format and source. This multiplicity leads to another difference, because some element can fail, and be replaced by new ones, that may differs in terms of API, services, and format.

Last issue is related to network bandwidth and throughput. These characteristic are fluctuating and often limited compared

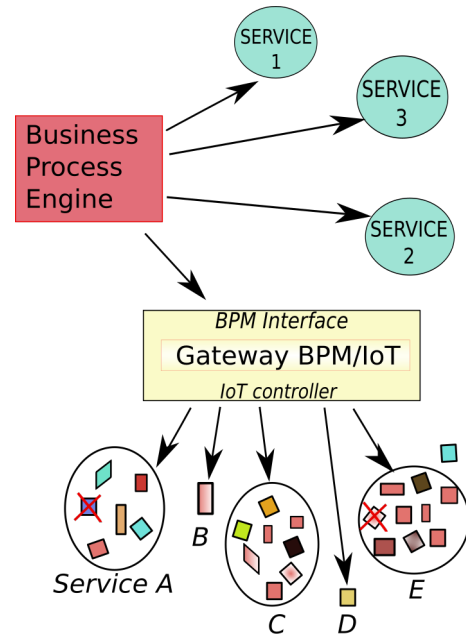


Fig. 1. The proposed gateway offers a BPM Interface to interact as a standard service used by BPM (the Business Process Engine), while the other side is able to interact with multiple IoT services. IoT Service A, C and E are build from multiple devices. Service B and D are offered by a single device. Devices are provided by different industrials. One device of Service A is not running. In Service E, one device is broken, and another one is out of reach.

to usual values encountered in wired networks. Because of their specific constraints (especially energy), wireless networks used by sensors and actuators are slow and not reliable. In order to prevent energy loss, the number of messages sent can be limited in time, and depending on the direction. For example, long range protocols (such as Lora or Sigfox) used by embeded devices can send data more often that receive (only few messages per day).

On the other side, BPM is an approach that aims to build a centralized control flow that require and use services provided by other entities. This work-flow is characterized by events, activities, flows and gateways. An event is the input or an output, and represents something that happens. On the contrary, an activity is a work that must be done, it is an action that is under our responsibility. Flows (or connections) represent the sequence, the order in which the activities are done. Gateway show the different decisions that can be taken, and their impacts on the work-flow.

To be usable by BPM, we propose a software adapter, that on one side provide the stability and meaningfulness required by BPM, and on the other side the agility needed to drive an IoT set of Objects (see Fig 1). This software adapter can be realized as bridge between the IoT network which is dynamic and the BPM architecture which is strongly defined. To realize this, we have running on a gateway a BPM client that works with the central control point. This BPM client offers services that are provided by the Iot Framework. This software gateway provides to the BPM side a invariable API to access data and services provide by the IoT platform. The

gateway gives a stable point of view over the IoT devices, hiding their heterogeneity, the difficulty to access data in terms of response time, throughput, and failure.

On the IoT side, the gateway is aware of the various technologies used, their different API, and the data format. It gathers data, computes them if the BPM side needs a unique value made of multiple sources, store values to provide quick response time and provide a stable way to actuate devices even if they change in times.

To test the BPM-IoT gateway, we use our IoT framework which is called BeC³ [17]. BeC³ is a framework that shows all the devices as generic ones. Then, it is possible to remotely program them, using pre-written set of commands, in order to build a distributed applications. In BeC³ applications (we call them *compositions*), Objects act and react depending their environment and others Objects.

For the purpose of this demonstration, we will create a "communication object" (in the programming design patterns paradigm, this is called an *Adapter*) which interacts with other Iot Objects handled in BeC³, inside the IoT network. This gateway will give a unique representation of actions that are available through IoT objects (such as switch on a device, set a value on a device, display a message, measure a physical value, etc). It can also collect information from sensors.

IV. CASE STUDY

IoT can be used in various environment and for different purpose, such as home automation, smart cities, electronic health or green monitoring. Smart building is a branch of IoT: The supervision of different physical values (water consumption, electricity, temperature) measured by sensors is used in IoT applications to build automation, gather data, offer new service to inhabitants and save energy.

For example, sensors can detect presence of people in rooms, floors, lavatories, and actuators can control lights, door locks, temperature, connectivity, depending on the activity detected. This IoT application can interact with other BPM services as an events provider. Human presence detected at a given floor, in certain rooms can trigger the activation of a service, inform security dashboard, activate a work-flow, etc.

In another example, the opened door and electrical consumption of the computer reveals the activity of a given staff member. The calls are transmitted to the room's phone. On the contrary (no electrical consumption and door locked), lights are switch off, heaters put to low energy by the IoT. The BPM receives the information (the member staff is absent) so the PBX is configured to store incoming calls in the member's voice box, or route them to another member, generating voice box message mails, the cleaning service is informed that the room is empty and to be cleaned, any work-flow involving the control of this member is aware that no action will be taken for a while. Moreover office supplies such as papers in printers/photocopiers, even trash bins (empty or full) can be input for the IoT. At the local stage, the IoT can stop the printer/copier, redirects the printing order to another printer automatically while at the global stage (BPM), an alarm is

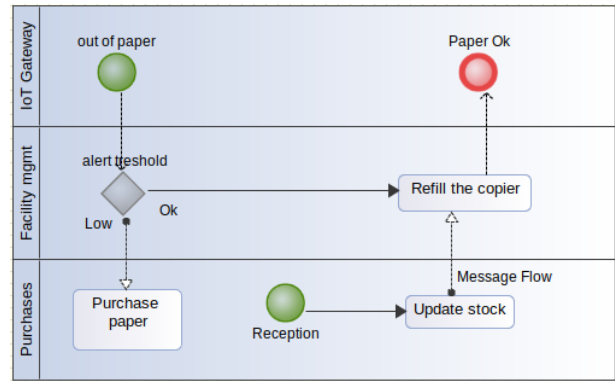


Fig. 2. This Figure shows a BPMN workflow. The IoT application has detected a lack of paper in a printer, and reconfigured the default printer for users. The IoT gateway sends an event to the BPM application in order to trigger the paper refill workflow. This work-flow may purchase paper, if the stock is low.

sent, an automatic re-servicing can be ordered (see Fig 2), and the work-flow organization can be rescheduled accordingly.

Already existent services can be improved by the use of the IoT and its connection to the building work-flow. For instance, the cleaning service can be more efficient inside the building. If the trash bins are equipped with sensors able to indicate when they are full, the cleaning service can be reorganized based on real needs and not on a pre-established sequence. As a result, the building is cleaner while the service is more efficiently requested. Here again, the input of the usual BPM work-flow that is in charge of setting the cleaning service schedule reacts to events generated by the IoT, while these events are also taken into account inside the IoT application for other needs (for example, the automatic close of the trash bins to avoid its usage) and an automatic alert on the cleaning person smart-phone).

V. CONCLUSION

In this paper, we have presented an example of the possible interactions between the IT usual approach of Business Process Management and the upcoming domain of the Internet of Things. As the IoT is an extension of the Internet to the physical world, its inclusion within the standard paradigm of the computerized management of a company. We propose to build a gateway between the IoT applications and the BPM work-flow. On one side, the gateway offers a bridge to make the two worlds communicate, while it hides their specificity, such as multiplicity of sensor, non-reliability of IoT networks, dynamic changes of the set of devices, etc.

In the future, we will explore the effect of this gateway in terms of services discovery and fault-tolerance.

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