From BPM to IoT

Sylvain Cherrier, Varun Deshpande

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Sylvain Cherrier[1] and Varun Deshpande[2]

[1] Université Paris-Est,Laboratoire dInformatique Gaspard Monge (CNRS: UMR8049), cherrier@u-pem.fr
[2] Université Paris-Est Marne-la-Vallée, France, vdeshpan@etud.u-pem.fr

Abstract. IoT's presence is increasingly felt. There are already more connected devices to the internet than total human population and sales are starting to rise. As there is extensive research ongoing in order to propose a global architecture to build IoT applications, the domain will rise as soon as a common solution will be widespread. Further, we would need to integrate IoT applications into the legacy data processing solutions. Business Process Model, for example, is a common concept used to build and compose software. Could the Internet of Things become an active shareholder in this approach? The Internet of Things, unlike BPM (which is more static), has specific constraints and peculiar organisations based on its dynamicity and heterogeneity. We propose, in this paper, a gateway to adapt our own IoT platform to the needs of the BPM approach and we also try to analyse the difficulties that may arise therein.

Key words: BPM, IoT, BPM in IoT

1 Introduction

BPM is made for building a workflow of services to be provided. BPM describes the interactions and the sequence of request/responses to/from services. The Internet of Things has an extremely broad definition. In principality, it's interconnected network of things but if viewed objectively in pursuit of this paper, can also be viewed as a heterogeneous network of sensors and actuators where data is collected by sensor(s) and the triggering of action(s) is done by actuator(s).

There are similarities between the two when we visualise the requests/responses of objects as services provided by these objects. But there are differences as well: 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 indistinctly come from only one sensor or from multiple sensors (average temp, consumption, etc). Objects' sensing or acting can change, they may be unreachable or running out of energy, their responses may be intermittent, they may be replaced by a different one giving the same data but under another format, etc.

In a nutshell, there is a conflict between the stability, unicity, meaningfulness of the services at work composed in BPM as opposed to the unreliable and changing environment IoT offers. But with the emergence of the IoT as part of the IT, there is an increasing need to interconnect the two worlds and make them interact. We propose in this paper the description and the intended functioning of a conceptual software bridge. This software bridge aims to be a connecting link between the stability needed by BPM and the dynamic IoT environment.

This paper is organised as follows: Section II presents related works and background for our solution. Section III describes the differences in architecture, as this paper presents a conceptual middle-ware intended to serve as a bridge between IoT services and a BPM application. Section IV gives an examples through an use cases. Finally, concluding remarks end this paper in Section V.

2 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 coordination of services, the procedures constraints and the work-flow that involve the different tasks, input and output at stack.

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

The key foundation underlying a global IoT network is its true incorporation of heterogeneity. This, on one hand, brings tremendous possibilities with improved solutions, on other hand, makes the system more difficult to handle. A fully inclusive approach for connected objects is not only difficult for its flawless implementation but also subject of scrutiny in connected world's domain.

The essence and success of IoT lies in its "Remote Robustness" approach. This approach 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). There are others constraints as well: devices are not always physically accessible (for example, a metal sensor in the pavement of parking lot) so battery can't be replaced, the network protocol used to offer the connectivity is sometimes dramatically thrifty, etc.

To cope with this energy issue [5], IoT uses application and network protocols that are very different (and often not compatible) from those used in the Internet of Data. Small payload, small throughput, sleep mode, etc are used to reduce energy consumption [6]. Smaller payloads and throughput severely limits the use of available bandwidth (which is already reduced due to increased sleep time). This, in turn forces one to use efficient and innovative network protocols.

The purpose of IoT application is mainly to access the data gathered by devices or using the ability to act on the physical world. In order to facilitate object's integration with a well-known programming paradigm, Erik Wilde had proposed to give access to data and actions provided by objects through a REST API [7]. This Resource Oriented Approach is described by D. Guinard et al. in [8] and [9]. Using such approach, the writing of applications using IoT devices is simplified 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 [10].

Recently, 6LowPAN, [11] 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 [12]. A more global access to IoT devices called LwM2M [13], 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 such as LWM2M [13], oneM2M [14], or IoTA and SENSEI [15] for example.

Proposing an Architecture for IoT applications [16] is a very active domain in which the academic research and the industry is trying to cope with the issues raised by the IoT, mainly in their wireless part. Providing a network access to everyday life objects adds new opportunities, but is subject to many constraints [17].

An architectural solution provides a complete structure aiming to interact with objects. It solves not only the access to services provided by each object, but also their description, the requests (i.e., which object can answer a query, which objects implement this service), security, authentication [16].

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, etc. One of the IoT's architectural approach is based on data: sensors measure the physical world, data is sent to a central point with powerful processing capabilities. This popular architectural approach is provided by solutions such as Thread, OneM2M, IoTA, LwM2M in addition to closed source manufacturer solutions. As none of them became the market leader, the integration of the constantly moving IoT resources in a stable BPM may encounter compatibility issues, forcing company to be linked to an unique provider, or facing the impossibility to integrate new devices as they are not taken into account because of their IoT architectures.

Besides this data-centric architectural approach, IoT proposes multiple architectural approaches viz., *Three-layer, Middle-ware, SOA, Five-layer* [17]. In these architectural approaches, IoT offers services to be used by applications. U. Kannengiesser describes one architectural solution [18] to integrate IoT in a Business Process Management: "*Smart devices and processes at all levels in the industrial control hierarchy need to interact*". Following the same line, we propose in this paper a reflection about the difference between the solidity of BPM and the agility of the IoT, and how it could be solved.

3 Differences in 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 heterogeneous. 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 (same manufacturer, same protocol), or simply gather data under the same format (from temperature to motion, accelerometer value, sensitivity, etc).

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 may be 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 conditioners. This specificity of a unique value/service which is 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 rigidity of implementation in BPM works well when situation in question is non-dynamic/non-evolving in a very short period of time. But in IoT's context, such rigidity almost act as a disadvantage. Moreover, the multiplicity leads to another major difference as some elements can fail and can be replaced by new ones, that may differ in terms of API(s), services, and format or a mix of them. As a conclusion, the direct use of Objects of the IoT by BPM seems difficult to achieve. The mediation of specialized IoT middle-ware can introduce a loosely coupled link between the two domains, providing a easier integration.

Last issue is related to network bandwidth and throughput. These characteristic are fluctuating and often limited compared 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 (depending on the direction) can be limited in time. For example, long range protocols (such as Lora or Sigfox) used by embedded devices can send data more often than they receive (only few messages per day). Thus data-centric approach may not be the best solution to integrate IoT in BPM as its effectiveness can be challenged.

On the other side, BPM is an approach that aims to build a centralized control flow that require services provided by other entities for its use. This work-flow is characterized by events, activities, flows and gateways. In BPM, an event is the input or an output, and represents something that happens. On the contrary, an activity is a task that must be done; it is an action that is under responsibility. Flows (or connections) represent the sequence i.e., 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 bridge, that on one side provides 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 bridge can be seen as a link between the IoT network, which is dynamic and the BPM architecture, which is strongly defined. This software bridge is a conceptual model which is underway to its physical and practical implementation.

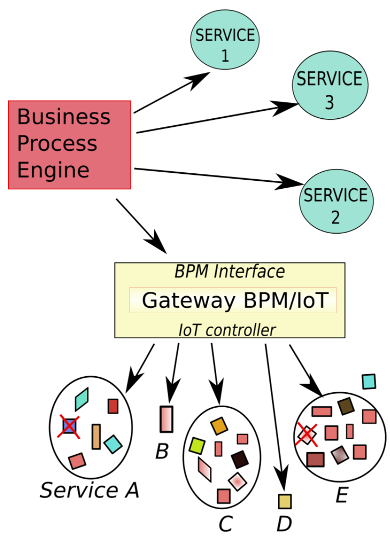

Fig. 1. The proposed conceptual gateway runs a software bridge that offers on one side, a BPM Interface to interact as a standard service used by BPM (the Business Process Engine), while on the other side, is able to interact with multiple IoT services. IoT *Service A*, *C* and *E* are build from multiple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

To realise this, the proposed software gateway provides the BPM side with an invariable API to access data and services provided by the IoT platform. On the BPM side, the gateway along with software bridge, gives a stable point of view over the IoT devices, hiding their heterogeneity, the difficulty in accessing data in terms of response time, throughput, and failure. The gateway is responsible for transferring events detected inside the IoT network as an input to the BPM. The Gateway also provides services that can be invoked from a BPM process in order to trigger actions on the physical world as a response to activity in BPM.

On the IoT side, the gateway is aware of the various technologies used, their different APIs, 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 with time. Data is treated by objects themselves, and reactions are triggered by actuator(s) as described by the IoT programmer. This computed data, changed into events, can be transmitted to the BPM via gateway. Orders from the BPM can be transformed in an incoming event in the IoT, triggering actuation and reaction inside Objects.

To materialise the conceptual BPM-IoT gateway, we plan to use our ingeniously developed BeC^3 [19] framework. BeC^3 is a framework that shows all the devices as generic ones inside the framework. Then, it is possible to remotely program them, using pre-written set of commands, in order to build a distributed applications. In BeC^3 applications (we call them *compositions*) and Objects act/react depending their environment and others Objects. Programming an object to compute data and send results/orders to other objects provides an event-centric approach that is useful to interact with BPM architecture.

The software bridge running on the gateway is written following the design patterns *Adapter* (a programming Design pattern proposed by the Gang of Four [**?**]) which interacts with other IoT Objects handled in BeC^3. This Adapter gives an 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 events (as we use an event-centric approach) from sensors.

4 Use Cases

IoT can be used in various environment(s) and for different purpose(s), 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(s) to inhabitants and save energy.

At first, as IoT provides sensors specialized in very specific measure, we can imagine a scenario using activity sensors as a first link between BPM and IoT. 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. Human presence detected at a given floor, in certain rooms can trigger the call to 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. Inside the IoT architecture, this computed event can order a reconfiguration of the user's room (temperature, lights, connectivity). On the contrary (no electrical consumption and door locked), lights are switched off, heaters hibernated to lower energy consumption by the IoT.

These interactions inside the IoT can be used to trigger processes in the BPM, to interact with a procedure or coordination of services provided by the

IT. E.g. 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. At the IT level, through the BPM, the cleaning service is informed that the room is empty and has to be cleaned. Beside, any work-flow involving orders from this member is aware that no action will be taken for a while. The cleaning person receives a notification (this is IoT work) and the central service is notified (BPM side) that the cleaning service is running in the room.

Thus, IoT events become part of the BPM processes involving the IT management of employees, thereby, monitoring and logging the person's activity in the Human Resource Management's IT Application which can be included as a constraint that drives the IT procedural treatment of the service activity in the Services Management statistics, in the building maintenance organisation, etc.

Events detected by the IoT, treated inside the IoT or even inferred from multiple internal measure(s) can be a source of a more conventional procedure of the BPM. On the other side, the BPM can trigger action in the real world through the IoT, and be a source of information for an IoT application, e.g. 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, redirect the printing order to another printer automatically while at the global stage (BPM), an alarm is sent, an automatic re-servicing is (see Fig 2), and the work-flow organization is rescheduled accordingly.

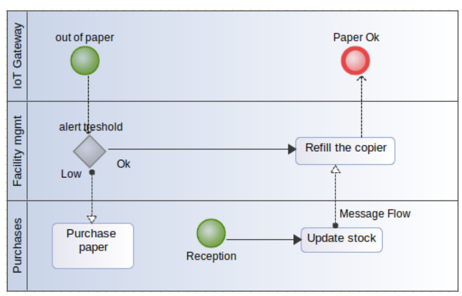

Fig. 2. This Figure shows a BPMN workflow. The IoT application has detected an empty paper-tray in a printer, and therefore, reconfigured the default printer for users. The IoT gateway sends an event to the BPM application in order to trigger the paper refill workflow. This work-flow may purchase paper,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

Already existent processes handled by BPM can be improved by the use of the IoT and its connection to events generated by the physical world. For instance, the cleaning service can be more efficient inside the building. If the thrash bins are equipped with sensors sensing if they are full (smart trash is a successful example of IoT impact [20]), the human cleaning service can be reorganized based on real needs and not on a pre-established sequence that may not always fit the needs. Event(s) sent by the IoT smart trash application is/are used as input(s) in the BPM in order to trigger the human activity and to start a specific associated process at the BPM level. The real time spend for cleaning is measured, treated as an input in IT applications, costs are affected based on a real measure. As a result, the building is cleaner while the internal service is more efficiently requested, and costs are more precisely evaluated. The inputs of the BPM work-flow in charge of setting the cleaning service schedule reacts to events generated by the IoT, while outputs of the BPM workflow can become events taken into account inside the IoT application for other needs. For example, the automatic closing of the trash bins to avoid its usage, and an automatic alert sent on the cleaning person's smart-phone.

This example can be extended to sensors that are in charge of the specific activity in a company, for example on assembly lines, inside warehouses, in malls, shopping centers, in offices, etc. Physical measures are treated inside the IoT, and linked to BPM processes as new inputs. These inputs can be useful to create new workflow that add more information to the global perception of the activity. A link between IoT and BPM also gives the ability to offer an output to BPM, that triggers a physical response to the workflow handled in BPM.

5 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 is imperative. We describe a software gateway between the IoT event-centric applications and the BPM work-flow. The gateway offers a proposed 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. On one side, it offers BPM a stable view of services provided by the IoT, providing physical inputs and outputs while on the other side, it take into account the dynamicity of the IoT environment, the heterogeneity of devices at stack, and the specificity of the IoT protocols.

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

References

1. T. Panagacos, "The ultimate guide to business process management: Everything you need to know and how to apply it to your organization," 2012. [Online]. Available: https://books.google.fr/books?id=AyCQMQEACAAJ
2. O. Danylevych, D. Karastoyanova, and F. Leymann, "Service networks modelling: An soa & bpm standpoint." *J. UCS*, vol. 16, no. 13, pp. 1668–1693, 2010.
3. J. Mendling, J. C. Recker, and J. Wolf, "Collaboration features in current bpm tools," in *EMISA Forum*, vol. 32, no. 1. Gesellschaft für Informatik eV, 2012, pp. 48–65.

4. E. Brown, “Who needs the internet of things?” 2016. [Online]. Available: https://www.linux.com/news/who-needs-internet-things
5. L. Atzori, A. Iera, and G. Morabito, “The internet of things: A survey,” *Computer Networks*, vol. 54, no. 15, pp. 2787 – 2805, 2010. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1389128610001568
6. G. Anastasi, M. Conti, M. Di Francesco, and A. Passarella, “Energy conservation in wireless sensor networks: A survey,” *Ad Hoc Netw.*, vol. 7, no. 3, pp. 537–568, 2009.
7. E. Wilde, “Putting things to rest,” *School of Information*, 2007.
8. D. Guinard, V. Trifa, F. Mattern, and E. Wilde, “From the internet of things to the web of things: Resource-oriented architecture and best practices,” *Architecting the Internet of Things*, pp. 97–129, 2011.
9. Guinard, D. and Trifa, V. and Wilde, E., “A resource oriented architecture for the web of things,” *Proceedings of IoT*, 2010.
10. P. Spiess, S. Karnouskos, D. Guinard, D. Savio, O. Baecker, L. Souza, and V. Trifa, “Soa-based integration of the internet of things in enterprise services,” in *Web Services, 2009. ICWS 2009. IEEE International Conference on.* IEEE, 2009, pp. 968–975.
11. Z. Shelby and C. Bormann, *6LoWPAN: The Wireless Embedded Internet.* Wiley, 2010.
12. Z. Shelby, “Embedded web services,” *Wireless Communications, IEEE*, vol. 17, no. 6, pp. 52–57, 2010.
13. S. Rao, D. Chendanda, C. Deshpande, and V. Lakkundi, “Implementing lwm2m in constrained iot devices,” in *Wireless Sensors (ICWiSe), 2015 IEEE Conference on.* IEEE, 2015, pp. 52–57.
14. S. K. Datta, A. Gyrard, C. Bonnet, and K. Boudaoud, “onem2m architecture based user centric iot application development,” in *Future Internet of Things and Cloud (FiCloud), 2015 3rd International Conference on.* IEEE, 2015, pp. 100–107.
15. S. Krco, B. Pokric, and F. Carrez, “Designing iot architecture (s): A european perspective,” in *Internet of Things (WF-IoT), 2014 IEEE World Forum on.* IEEE, 2014, pp. 79–84.
16. J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, “Internet of things (iot): A vision, architectural elements, and future directions,” *Future Generation Computer Systems*, vol. 29, no. 7, pp. 1645–1660, 2013.
17. A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, “Internet of things: A survey on enabling technologies, protocols, and applications,” *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, pp. 2347–2376, 2015.
18. U. Kannengiesser, M. Neubauer, and R. Heininger, “Subject-oriented bpm as the glue for integrating enterprise processes in smart factories.” in *OTM Workshops*, 2015, pp. 77–86.
19. S. Cherrier, I. Salhi, Y. Ghamri-Doudane, S. Lohier, and P. Valembois, “Bec3: Behaviour crowd centric composition for iot applications,” *Mobile Networks and Applications*, pp. 1–15, 2013. [Online]. Available: http://dx.doi.org/10.1007/s11036-013-0481-8
20. Y. Glouche and P. Couderc, “A Smart Waste Management with Self-Describing objects,” in *The Second International Conference on Smart Systems, Devices and Technologies (SMART’13)*, W. Leister, H. Jeung, and P. Koskelainen, Eds. Rome, Italy: IARIA, Jun. 2013. [Online]. Available: https://hal.inria.fr/hal-00924270