Integrating the Internet of Things with the Business Process Management: Case study

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Summary
IOT (Internet of Things) is the way to interconnect intelligent objects that can collect data via sensors and make appropriate decisions. The data collected and the treatments can be done locally at these objects, just as they can be outsourced to the Cloud given its theoretically unlimited capabilities. In this context, one of the major difficulties is the programming of data transfer between objects and/or in the Cloud. This challenge is comparable to that of Business Process Management (BPM) in firms, whose data management is often driven by workflow processes because of their efficiency in automation, optimization and scheduling. These processes are modeled using methods such as the Business Process Modeling Notation (BPMN) method, which is based on three elements for modelling - tasks, events and gateways. This latter element is represented by flow control operators such as AND, OR and XOR that are intended for business processes, and are limited to processing several cases of data flow processes that flow between connected objects. In this article, we propose adapting the BPM to IOT process management, to improve the automation, scheduling and optimization of data flowing between objects and in the Cloud by proposing a new semantic operator called: Gateway for Internet of Things (GIOT) to facilitate intelligent data transfer by taking an intelligent house study case.

Key words:
Internet of things, Buisness Process Management, processing data, data mangement, Gatway of Internet Of Things

1. Introduction

IOT (Internet of Things) is a technological revolution in information and communication. It describes a world of networked intelligent equipment [1], which can be connected to each other but also to the outside environment [2]. This technological evolution is generating new forms of communication between real world objects that are capable of perceiving and sharing accurate information [1, 4]. But how and when can these smart devices that collect information know how to exploit that information? Because without proper controls, connected objects may not perform their assigned task, thereby disrupting the entire information system that relies on these objects.

Society's interest in connected mobility will influence the market for the Internet of Things. By 2020, there will be seven billion human beings on earth for more than seventy billion communicating objects [5].

The integration of mobile and smart equipment into the computing ecosystem is revolutionizing information systems and in particular business process-oriented (BPM) applications.

Several recent work on enterprise data management has opted for workflows to manage the information routing phase and thus benefit from benefits such as enabling automation of document routing, ensuring better security by reducing the risk of human error, and scheduling and orchestration to ensure that relevant data transmission times are reduced at the right time and at the right destination.

The processing of data from the Internet of Things relies primarily on data analysis, query and synthesis tools such as Hadoop, Hive [6], etc. However, these tools present challenges in dealing with data flow mechanisms, which remain a challenge as long as these tools do not manage data loss or transfer scheduling.

The aim of this article is to propose a solution to the problem of scheduling data transfer by using workflows for better management of data from the Internet of Things.

Modelling methods, dedicated to BPM, such as the Business Process Model and Notation (BPMN), are oriented towards business processes and limited in terms of workflow processing, as shown by the BPM-based mobile applications that we will describe in state of the art.

This is why we propose a Meta model for scheduling management of data transferred from IOT, which we enrich with a dedicated IOT flow control operator called GIOT to ensure the intelligent transfer of IOT data.

The rest of this article is structured as follows: in Section 2 we present the basic concepts on which our problem rests. Section 3 details our management approach to scheduling control of data flows from connected objects using workflows. In Section 4, we illustrate our approach using a study case on the smart home. Then there is a discussion of the paper. Finally we conclude with a conclusion and future research perspectives in Section 6.

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2. Basic Concepts

2.1 Internet of Things

Kevin Ashton, Brand Manager at Procter and Gamble, first used the Internet of Things concept in 1998. He said at a group meeting, “if we can add radio frequency identification and other sensors to everyday objects, then we can create an Internet of Things and lay the foundation for a new era of machine perception.” [5] So he began to focus on the development of an open universal system that connects objects to the Internet.
Today, more and more domains (smart home, smart transportation, smart medicine, etc.) grouped under the concept of “smart city” or “smart cities”, are being deployed or experimented with a variety of smart objects equipped with sensors to collect data for outsourcing to the Cloud through their Internet connectivity capability. Depending on the field, we can point to different advantages [8-9]. In agriculture, for example, production can be increased through the introduction of farming robots, thereby reducing labour costs. In the field of the Internet for health, it is possible to monitor different parts of the human body using biometric sensors. In the smart Grid context, smart street lighting saves up to 30% of electricity. Finally, in the field of domotics, smart objects with sensors can help control the safety of an intelligent home. [10]

2.2 Integrating the Object into a Process

A process represents actions with associated enforcement mechanisms. These actions can be configured to collect data from devices such as a smartphone via a human-machine interface. This data can be exploited to trigger other processes.

2.3 Business Process Engineering (BPM)

BPM (Business Process Management) is the engineering of business processes that relies on automated workflow work using computer technology.
A workflow can be defined according to the workflow management coalition as “the automation of trade procedures, in part or in whole, during which documents, information and tasks are transferred from one participant to another under an established system of rules”. [11]
To effectively manage an organization, the BPM’s role is to model, deploy, execute and optimize business processes using new information technology. The data model combined with the business process model together form the basis for designing new generations of applications.

2.4 BPMN Business Process Modeling Notation

According to the authors of [4], "Business Process Model and Notation (BPMN) is a standard notation used to graphically represent flow control operators and business processes using simple and understandable elements". It also allows diagrams of the workflow and sequence of tasks to be drawn.

3. From the BPM Approach to the BPMN Standard 2.0

BPMN provides a graphic representation for business managers and process designers to organize and manage their business process models. BPMN has recently evolved to BPMN 2.0, which defines the formal semantics of its elements. Thus, a process delivery engine will include how processes are to be integrated and executed. The vision of BPMN 2.0 is to make processes executable from top to bottom, where process designers can deploy, test and execute developed processes without having to face the details of running low level processes. Another interesting feature introduced in the latest version of the language specification is its scalability. BPMN 2.0 flow objects and artifacts can be expanded, allowing us as process designers to express additional functionality of BPMN 2.0 process models.

3.1 BPMN 2.0 Workflow Elements

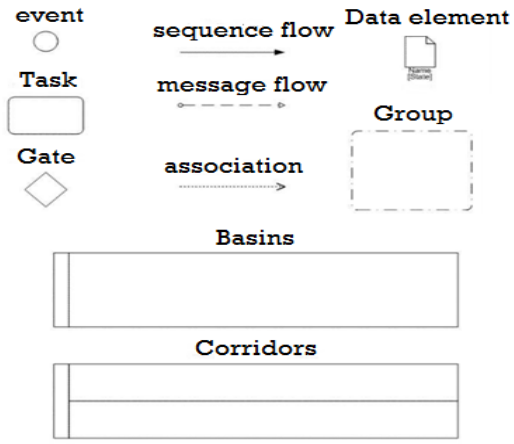

Fig. 1 Major components of BPMN

In Figure 1, any action performed by a human or a computer service is represented by a task. The sequence flow, which indicates how the process unfolds, is represented by connecting arrows that link these actions. Each gateway represents a junction point where the flow is divided into parallel or conditional paths. Note that the flow of a flow can be influenced by instantaneous events

such as start, break, end, stop, error, signal expectation, etc., all these elements are placed in pools, themselves divided into corridors to represent the actors and actions of the scheme.
This workflow is illustrated by Figure 2.

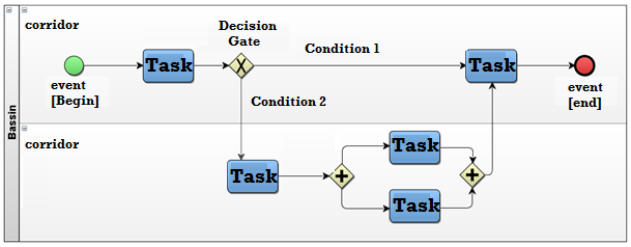

Fig. 2 Example of how BPMN works

3.2 Characterization of Workflows

The functions of a workflow system are characterised by the '3Rs' metaphor: Roles, Routing, Rules. [4]
Roles: It is a list of the attributes, skills and know-how of a workflow player that he puts into practice. This role defines the position of the actor in an organization.
Routing: represents the path of the different outcomes moving from one activity to another.
Rules – in workflow modeling there are generally three types of gateways represented by Boolean operators; AND, OR and XOR used in logical expressions.

3.3 Type of Gateways or Connections Used in BPMNs

Table 1: Gateways used in BPMN

Gateways BPMN	Description
	AND gateway
	OR gateway
	XOR gateway

Table 1 shows the existing gateways in BPMN. These gateways are intended for business process management and are adaptable for certain IOT domains but do not cover all domains and thus do not guarantee the automation and orchestration of data between objects and objects; and user objects especially in smart homes that rely on the mobility of both inward and outward data at the same time. Here we propose a specified gateway (operator) for the internet of objects, which presents an extension to existing operators in BPMNs, designated by GIOT: Gateway for Internet of Thing.

3.4 Development Principles

Unlike the instructional modeling languages that are lacking, BPMN is supported by an important industry developing many software solutions. These tools are distinguished by the workflow management system (WFMS) which defines implements and manages the execution of one or more workflows using a software environment operating with one or more workflow motors. WFMS is able to interpret the definition of a process, manage the coordination of participants and call external applications.
A WFMS consists of two environments [4]:
The modeling environment, also known as "Build-time", which allows the definition and modeling of workflow procedures,
The running environment or the Run-time, which includes the workflow engine to instantiate processes.
WFMS automates and supervises the flow of work within the process.

4. Process Modeling in IOT

Based on the concepts presented above, we propose a workflow process modeling approach for smart homes. These present a domain of IOT that we have chosen to demonstrate the limitations of existing Boolean operators and to show the usefulness of our GIOT semantic operator for scheduling data through connected objects. This new gateway provides a dedicated scheduling and orchestration process for the data transfer phase from the workflow management plant to the IOT application domains.
This process is based on data attributes that we will propose and flow management rules that we will adapt for IOT.
Our approach is based on two environments (Build-time and Run-time) as shown in Figure 3. The Build-time environment in which we focus in this article contains two phases:
A first phase in which we propose an intelligent house architecture that contains a workflow orchestration server to properly automate and schedule outgoing data.
In a second phase, we contribute to the design of the meta-model of data transfer processes in an orderly and optimal manner.
The Run-time environment refers to the instantiation of processes that involves generating model instances and tracking their execution using a workflow management system (WFMS) that interacts with the Database Management System (DBMS). This environment will not be the subject of this study.

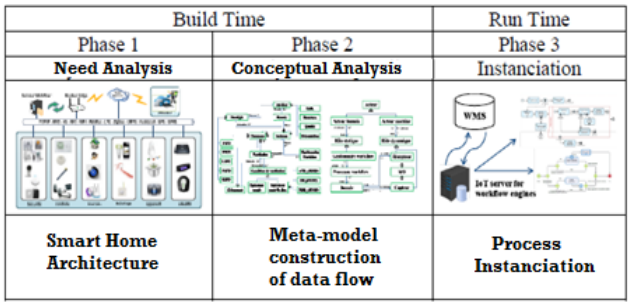

Fig. 3 Steps in the development of a scheduling process

In the following, we present the first phase of intelligent house architecture as illustrated in Figure 4. We will then detail the second phase in which we provide a meta workflow model to build the process models and we offer a semantic operator complementary to the existing operators in the so-called GIOT NMPs, to show how this additional feature can be used in the IOT through workflow processes.

4.1 Build Time Phase 1: Needs Analysis

The architecture we propose consists of three domains, as shown in Figure 4, which are defined as follows:
The area of perception: which presents the data source for the smart house and includes data detection sensors.
The management plant – which contains a server for the use of workflows for automation and scheduling of data circulating in the smart house and Cloud. It also contains a gateway (e.g. 4G Edge router) for IOT data routing.
The receiving domain that represents the user as an entity that can control and manage their home remotely with their Smartphone, for example.

Fig. 4 Smart Home Architecture

4.2 Build Time Phase 2: Conceptual Analysis

This phase allows us to build process models based on the workflow meta-model [5-11] and covers four aspects – organizational, functional, behavioral and informational. To this end, we will develop the meta-model of our two-diagram study case by merging two to two the behavioral aspect with the functional and organizational aspect with the informational aspect for complementary purposes.
We combined the organizational aspect with the informational aspect, as shown in Figure 5, to describe the players involved and their interaction with the information system and the resources needed to be used.
An incoming event is a type of data captured such as humidity that triggers an outgoing event. An outgoing event is a data such as a video, message, etc., which is a component of a delivery process, as the execution process may be a component of another delivery process.

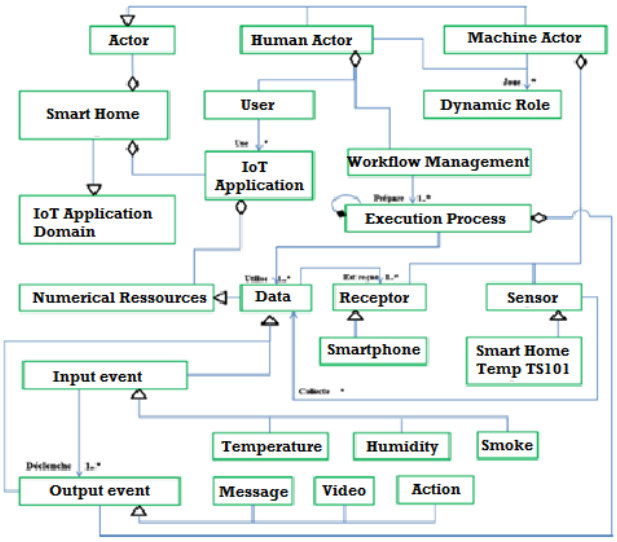

Fig. 5 Class diagram to describe the organizational and informational aspect of the model

4.3 Run Time Phase 3: Process Instances

Although the Run-time environment is not the subject of our study here, we can say that the data will be transferred via workflow engines according to the case models we have proposed.

4.4 GIOT Gateway

By adapting the BPM to the management of intelligent house processes, this means adapting the semantic processing of data between objects-objects and human-objects. The activities or tasks coming in E1 and

E2 will be represented by captured data and the S output will be represented by a resultant action (outgoing data).
The data collected will be processed according to the degree of importance specified by the manager, and will be represented by a semantic value such as:

- E=1 means that there is an inward and important data;
- E=0 means there is an inward and less important (usual) data;
- S=1 means that there is an output that contains one or more of the resulting actions such as: message, ringing, etc. following a significant input or not;

As a result, we see that all existing gateways have instances where the output is inactive, making it difficult or even impossible to adapt the processing of semantic data using these operators. We therefore propose to expand the existing gateways in the BPMN to improve execution or transfer policies by adding a semantic gateway that represents a control operator named "GIOT" to ensure automation and scheduling of data handled in smart homes.
GIOT can support multiple data captured (inward) and one output (S) that contains multiple outputs such as messages, triggers, ringing, etc. The S-output is active if the E1 and E2 input events are the same or are in different states (a statement that does not exist in current Boolean operators).

4.5 GIOT Utilization

The GIOT gateway has the following features:

- Manages multiple inputs and multiple outputs via the workflow server.
- It ensures the transfer of data between objects in the smart house and between user objects via the Cloud.
- Triggering processes from other processes via GIOT.

In Table 2, we provide the formula for the GIOT operator and describe its semantics in the following paragraph.

Table 2: GIOT Operator Specification

Table			Formula	BPMN Gateway
E1	E2	S	$S = E1.E2 + \overline{E1}.\overline{E2}$	
0	0	1		
0	1	1		
1	0	1		
1	1	1		

E: is a captured data, to which we assign an attribute that represents the importance of this data, specified by the workflow administrator, namely:

- E=0: not significant captured data (usual). Example: fasting blood glucose measure = 1g regular state.
- E=1: significant captured data. Example: fasting blood glucose measure = 0.6g given important as there may be hypoglycemia. In this case, this will be a priority in the routing.

The "S" represents the output with S=1 to express the fact that there are one or more outgoing actions such as actions, messages or triggers that represent the results of entries whether or not they are significant.
Note that in our gateway, "S" is always different from 0 because objects always communicate in the IOT. Indeed, even with two non-significant entries E1=0 and E2=0, there will certainly be an exit as we will see in the next section.
We are going to propose a domotic remote patient control solution that incorporates automatic management of processes between objects inside and outside the home with the user through the Cloud. This solution enhances existing solutions, in that it relies on orchestrating and optimizing the execution processes via a workflow server.
We proposed adding our smart gateway, to govern multiple inputs and outputs in parallel to automate and optimize processes.

5. Case Study

5.1 Context

Let's say Alex owns a smart house and works 30 kilometers from where he lives. His father, who lives in his home, is an old, hypertensive, diabetic man with early Alzheimer's. Alex goes to work every day at 7 a.m. and leaves his father asleep.
During the day, Alex calls his father to control his condition. Let us suppose that one day the father's phone blows up and goes out. When he woke up at 8:30, the father forgot to check his laptop. A 10h00,
Alex wants to make sure his father is well. The question in this case is, how can it control it remotely?

5.2 Scenario Description

From his Smartphone, Alex launches the Smart Home Process Management (SHPM) application and tries to control his father's blood pressure using the E-Health platform connected to his body to see whether or not he has taken his medication. He makes a request for his blood pressure and questions the drug distributor. The capture, orchestration and distribution of this data require the GIOT gateway, which intelligently manages multiple inputs and outputs. The data captured are:

- Low blood pressure or low blood pressure (important data): E1=1
- No interaction with drug distributor (important):

E2=1

- These incoming data are important. They involve triggering two parallel processes for the S1 output:
- A Cloud process in the form of a message to Alex saying, "The patient is in hypotension and no interaction with the distributor"
- A process between objects in the form of an action that automatically triggers the distributor's alarm iteratively to remind the patient to take their medication.

5.3 Mechanism of Workflow 1

The workflow manager specifies important and non-significant data based on the user needs analysis. In our case, the data is specified as follows:

Talbe 3: Interpretation of the first WORKFLOW

E1	E2	S1	Input Data (E1,E2)	Data Output S1
1	1	1	- Hypotension detection. - No Interaction with medicine distributor.	- Message to owner that tension is down and there is no interaction with medicine distributor. - Distributor Alarm Triggering to remind the patient to take medicine.

Alex has the choice of whether or not to continue remote control of his father. He decides to continue because his father did not take his medication and he is in hypotension. Alex knows that hypotension is not dangerous, but it causes hot flashes. He then queries for his father's temperature detection and body movements to ensure he has not dropped. The data captured are:

- High temperature detection (important data): E3=1.
- Detected movements of the patient (not significant data): E4=0.

The first process that automatically runs is that of the major data E3 that triggers two events to run in parallel:

- A message to Alex saying, "The patient has the high temperature and the patient's movements are detected"
- Lower the heat: following the hot flashes.

Following the execution of these two events sequentially, a third automatic process is triggered to specify:

- The start of the surveillance camera: following the detection of motion at home that causes the video to be sent to Alex in real time.

Alex receives the video recording from his father who is looking for his drugs in the distributor.

5.4 Mechanism of Workflow 2

The data identified in Table 4 is specified using the workflow manager as follows:

Talbe 4: Interpretation of the first WORKFLOW

E1	E2	S1	Input Data (E1,E2)	Data Output S1
1	0	1	High temperature detection (important data) Mouvement detection (not important data)	Message to Alex Turn down the heating Start the camera

Note that despite the detection of the patient's movement, which is not significant, the workflow manager can activate the automatic activation of the surveillance camera if Alex requests the detection of motion in the home by prevention.

Alex decides to continue monitoring because his father is hypotension, so he queries the capture of blood sugar and the query of the coffee maker for information on the blood glucose result, whether it was measured before or after breakfast.

6. Discussion

The IoT provides many opportunities for industry as well as for personal use through the meaningful, yet dynamic inter-action of humans, software, machines, and things. BPM is a well established discipline that deals with the discovery, analysis, (re-)design, implementation, execution, monitoring, controlling and evolution of business processes.

So far, both areas have been considered separately. In this paper we have formulated a model of the amalgamation of the IoT and BPM, which we deem important to be tackled in the near future in order for the IoT to benefit from business processes and vice-versa.

Before concluding, we would like to highlight a cross-issue, i.e., dealing with security and, in particular, privacy issues. For example, privacy levels that exist at the sensors level might be different with respect to those at the BPM side. A full-disclosure approach should be avoided, especially in contexts where sensitive (i.e., personal) information is collected. The most relevant challenge, in this case, is the communication between the two worlds, each of them with corresponding privacy/security levels and policies. The layer in charge of integrating these two sides should be de-signed according to the principles of privacy by design: identify and examine possible data protection problems when designing new technology and to incorporate privacy protection into the overall design.

7. Conclusion

IOT and BPMN workflow are revolutionizing the field of information systems, which is now required to adapt to new architectures. These architectures can be based on cloud-based virtual machines, but also on any type of smart equipment capable of providing data and with computing and communication capabilities.

In this context, we discussed two main challenges: the proposal for smart home and BPMN architecture. We have also shown how to use workflow management systems within this architecture, that is, how to manage and control the data that circulates in an intelligent home using workflow processes.

We then proposed a SHPM solution that is based on a smart app that can assist sick people living in smart homes remotely. This application builds on the GIOT gateway that we have proposed to expand BPMN and integrate it into the management of data transfer on the internet of things.

The GIOT gateway is a semantic operator referring to a policy of scheduling data transferred from connected objects, as in the smart home example.

We considered for each of these data an attribute of their importance to ensure automation and scheduling of data transfer via the metamodel we proposed.

As a perspective to this work, we intend to complete our study by studying the environment

Run-time. The GIOT operator is implemented on the workflow server and if the server fails the solution is penalized. A redundant workflow server system can be considered in future work in such a way that if one fails, a second automatically takes over without users knowing it (fault tolerance principle).

We are also looking at improving data transfer management through the integration of multi-agent systems by developing smarter agent-based gateways to manage data flows from connected objects.

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