

EXTENDING THE BPMN MODEL FOR IOT DESIGN

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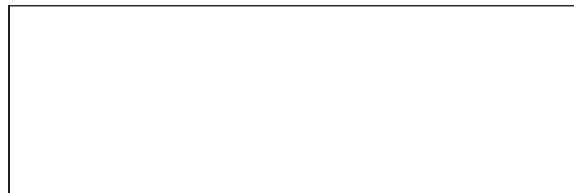
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Signature of candidate

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I would like to thank and acknowledge God above all for everything and everything was provided by Him. My mother whom left the physical world in 2012 to be with God and is very proud of me. To Matet whom supported me with Love, faith and Hope, she means a lot to me. This is a journey of continuous learning. Information Communication and technology is the best passion I could have.

Abstract

The continued extension of the BPMN modeling for IoT is done in this work. The need of modeling processes in BPMN and using an appropriate extension to represent IoT is a focus of attention for academia. Academic research has been focused on the definition of requirements for new BPMN extensions for IoT while including devices and behaviours. We extended work in this area to make possible the inclusion of extended properties for each BPMN Task element in the BPMN for IoT extension. The XPDL generation of the process flow was adapted as well. A case study is presented with the importance of gathered data by an IoT sensor device. BPM life-cycle was followed, the business process was modeled using the iterative As-Is, To-Be and To-Be with IoT process modeling technique. A real IoT device was used to gather data. Future work on extending the tool and a suggestion to automated modeled BPMN for IoT processes in an open source engine are provided.

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Chapter 1

Introduction

1.1 Background

Technological advancement must always propose benefits and continuously be useful to humanity. Internet of Things (IoT) is revolutionizing the way we interact with digital devices. IoT is a paradigm of using connected smart electronic devices with sensors and actuators based on events for the collection of valuable data. IoT works through the software defined product (SDP) and hardware defined products (HDP). IoT produces value to enterprises and people in almost any imaginable area (Biron & Follett, 2016). A sensor could be defined as a transducer component that converts signals from analog to digital and the other way around. Sensor captures signals from the physical environment, transforms the signals to information and stores this information in a data system.

IoT displays its capabilities through the use of sensors and actuators based on events. Smart devices are embedded devices that provide a specific functionality to users. Connected devices have been around for some time but IoT is the evolution of intelligent devices in which the connected devices provide a significant value. From a business point of view the concept of IoT includes a Software defined product (SDP) and hardware defined product and (HDP) both of them produce business and customer

value. SDP is a virtual representation of the hardware product. The value model of IoT is expressed in three steps: value proposition with its goal and efficiency to achieve the goal, quantification of the value proposition by adding more variables to the value model and use of analytic to optimize and constantly improve the model. IoT devices in general should add value because they contribute through their functionality and power of collecting data to the value model.

the HDP works based on sensors and actuators. IoT devices gather an immense amount of data that should be processed by a middle-ware component and through the communication capabilities of the Internet. (Sinclair, 2017). In few words IoT paradigm is a distributed computing architecture using ubiquitous intelligent and embedded devices to interact and obtain information. The SDP is the heart of IoT and the value comes from the gathered data.

When it comes to sensors there are some type of sensors: light sensors, temperature sensors, location sensors, vehicle on board, files sensors, moisture sensors, files sensors. A sensor could be defined as a device that reads, takes, captures from the environment and transforms to digital information.

Research and development efforts by some companies have been made so that IoT can be integrated in different areas with the focus on cost reduction and a high proposition of value. One good example is smart cities an effort carried out by IBM (Scuotto, Ferraris & Bresciani, 2016). IBM has put great effort in the development of IoT for smart cities. A smart city is defined as a data focus and connected global system that takes advantage of the optimal interconnected information available. Information allows to optimize control of the operations and find points of improvement to make a better usage of the limited resources such as budget. For IBM the smart cities strategy must be carried out in 3 main goals: planning and management, people, and infrastructure.

From the 3 main goals that IBM proposes planning and management refer to the

strong use of data analytic to find improvement and generate efficiency and collaboration among different stakeholders. One key area is public safety with the use of IoT to reduce criminal events. Reconnect use of information communication and technology (ICT), policies and regulations with the aim of addressing the needs of the people. gathered Data from IoT devices could help in the design and implementation of cities, better planning and advanced operation. The goal of the use of data is for return of investment and one key activity from any city that can see a benefit is the planning and optimization of building construction.

People are also included in the smart cities proposal and it includes social programs, health-care management and education. The third main goal of smart cities is the infrastructure and resources: transport, housing, energy, water and environment. For IBM the proposition of using IoT is just a mere tool for obtaining massive amounts of valuable data that can be used further with advanced analysis tools to improve cities and make them more livable and desirable (Formisano et al., 2015).

All the benefits of IoT involve the application of its proposed value in different underlying processes. A need arises because of the importance of documenting and describing business processes that involve the use of IoT devices.

The importance and steady growth of IoT has captivated the attention of enterprises when it comes to Business Process management. BPM as a process and management discipline covers IoT now that many enterprises are using IoT devices in their business processes. BPM is also recognized as a powerful holistic process management approach striving for continuous improvement, efficiency and effectiveness while focusing in flexibility, adaptability to needs of the customers and integration with technological services. BPM grows as a discipline in the industry. New process technologies quickly emerge all the time and BPM is of great concern for small medium Enterprise (SME) companies to robust multinationals. (Gao, 2013)

A process as a concept is a set of tasks or steps that are taken in an orderly fashion

to produce a result or outcome. A process might have inputs and could produce and output or product outcome. Based on this definition processes are implicitly involved in any organization and even daily life activity. Enterprises realized the importance of processes and the idea of successfully describing processes was proposed with the use of process descriptions, work-flow diagrams and nowadays Business Process Management Notation (BPMN) to easily describe processes. (Orlikowski & Iacono, 2001)

As the steady growth of IoT usage in different areas continues, successfully modeling processes with BPMN and including IoT is a necessity. Business processes are impacted by the use of IoT devices. direct benefits to BPM might come in the form of more in depth data available. Some business logic is now executed by the IoT devices. The concept of distributed architecture takes a higher connotation when deploying IoT devices in business processes.

BPMN is capable of representing IoT interactions through the use of events but it might require the use of sub processes and extra elements, hence making the solution more complex as it increases the number of elements required to properly represent the process. During process run-time many element might impact execution and create complexities in the process automation and finally the performance. (Martins & Domingos, 2017).

Proposals for the extension of BPMN for IoT have been suggested in recent academic research (Meyer, Ruppen & Magerkurth, 2013). Academic Research considers new BPMN artifacts and elements required to correctly describe business process. Unfortunately there are implicit data attributes related to this new elements that might need to be addressed. The importance of adding meta-data and attributes to extended BPMN elements plays an important role as future BPMN for IoT enabled models could contain extra meta-data about processes with complex presence of IoT devices. This meta-data and attributes present in a business process with IoT devices could be used for purposes of process mining, data analysis and process optimization within the BPM discipline.

1.2 Research Question

There is a need for BPMN modeling and the inclusion of IoT as an extension for BPMN. The ability to include inherent attributes from IoT devices into the BPMN meta-model could contribute for easier interpretation of business process diagrams. This thesis extends current effort in the area of BPMN for IoT extensions and explore the possibility of execution of the process in a BPMS engine. A research in Business Process modeling for the Internet of things is been an ongoing effort from Auckland University of Technology (AUT) by author (Ratnayake, 2018). The purpose of this work is to extend the current work and proposes to answer the following questions:

- How to extend the BPMN model with the IoT Properties?
- How to transform the XML Process Definition Language (XPDL) generated from the model to an executable code skeleton?

1.3 Motivation

In this global service economy individuals use technological devices for every day purposes. Companies are shifting their focus to a connected workplace to increase their value proposition. IoT is interpreted as an innovative framework that could be applied in a broad scale from personal usage, enterprise, academic research and even integrated system of systems.

As the name suggests the "Thing" of the word relates to enhanced electronic objects that will provide value through the interconnected features offered by the internet. The internet of things is obtaining high interest and special attention by the public. IoT has motivated many research companies and academic investigation to deepen the understanding and capabilities of IoT. Companies such as Gartner, IBM and Cisco have foreseen a great impact for the IoT in the world. An estimate of 25 billion connected

devices are expected by 2020 (Biron & Follett, 2016), the estimation provided by Gartner research suggests that the biggest growth will be in the consumer space although generic business will have a big participation in the IoT market.

In table 1.1 for an estimate of expected growth in IoT units being installed. By 2020 the consumer market would have changed into a distributed ecosystem of connected devices. IoT might require the adaptation and adjustment to a new business model to be able to increase the value proposition of their digital devices.

Table 1.1: Categories of IoT Units (Eddy, 2015)

Category	2013	2014	2016	2020
Automotive	96.0	189.6	372.3	3511.1
Consumer	1842.1	2244.5	2874.9	13172.5
Generic Business	395.2	479.4	623.9	5168.6
Vertical Business	698.7	836.5	1009.4	3164.4
Grand Total	3032.0	3750.0	4880.6	25006.6

For the general public the understanding of IoT is focused on smart devices. Nowadays the use of devices that allow Voice User Interface (VUI) and the use of intelligent virtual assistants (IVAs) that allow humans to interact by voice with the machines. These systems help humans to automate several tasks, while still in development is very promising as it might reduce the need of physically interacting with digital devices. Through the use of voice commands several functions could be executed. (Chung, Iorga, Voas & Lee, 2017)

To illustrate some of the benefits of IoT in the consumer market, the following table 1.2 describes a comparison of a daily routine without IoT integrated devices and with

IoT inter-operability for the consumer market.

Table 1.2: Value of using IoT within consumer market

Without IoT	With IoT	Value of using IoT
Manual processes	Smart processes connected to house systems	automate daily life processes such as waking up in the morning with the use of IoT
Need of manually interacting with electronic devices	Use of VUI to command the IoT Hub to perform automated tasks	an orchestrator component is centralized to offer control with ease of access
Calendar planning done with physical planner or mobile devices	Recommendations on different areas of life such as health and fitness, professional, social, personal growth are given by the virtual assistant	Due to the processing and machine learning based on collected data. Data is collected from all interconnected IoT devices. Behavioral patterns are analyzed and based on goals of optimizing time suggestions are automatically given
User adapts to the given technology	Technology adapts to user's preferences based on gathered data	through the use of data analytic the IoT connected system is able to predict and react to the users preferences. Recommend based on upcoming event and provide value to all processes of the user during the day

1.4 Research Scope and Methodology

The constrain of time limits the depth of the research scope. This thesis aims to propose the extension of an ongoing academic work in the area of BPMN. The focus is the use of IoT extensions in business process modeling specifically using BPMN language. The research is limited exclusively to extend the work on the proposed modeling tool by proposing new general attributes. In the literature review section current research on the specific field of IoT modeling in BPMN is carried out.

The methodology involves a literature review on the topics of IoT, BPM, BPMN, extension of BPMN and execution of process languages in process engines. For the software tool the data properties and attributes are proposed.

The JavaScript online modeler is to be extended and modified by adding the property table with the general attributes defined for IoT. Some visual improvements to the modeler and the generation of an executable language that is to validated and conformed to language processing standards such as XML Process Definition Language (XPDL) (Coalition, 2018)

1.5 Contribution

This document aims to propose improvement to the ongoing research on BPMN modeling for IOT devices. The contribution opens the knowledge for more future work in the area of business process modeling with IoT. The implementation of an automated business process that uses IoT sensors devices could be feasible by following the analysis and basis of this work.

First, a contribution to BPMN for IoT modelers. There is little ongoing research on this area and the exposure of such a tool in a GIT open public environment can be used for further research. The inclusion of a property table that contains extensible

parameters per BPMN task allows for a better interpretation of the diagram. Also the use of extended attributes in a BPMN model could ease the implementation or automation phase as more meta-data is present.

Issues in the execution of XPD L processes with IoT extensions were found. This can lead to future work in the area. A set of suggestions are given to continue the ongoing work such as the use of BPMN for modeling and execution of processes.

The research allows for the successful integration of BPMS engines with IoT devices in a coming future.

1.6 Thesis Structure

The remaining part of this research is organized into five chapters. In chapter two, a literature review on IoT as a new Information Technology (IT) driven force is presented. BPM discipline is described and the importance of BPMN modeling with the inclusion of IoT extension is presented. Efforts in extending BPMN to successfully describe processes with IoT devices are introduced. Finally the automation of processes and the languages that are commonly used is presented.

Chapter three describes the changes applied to the online JavaScript modeler. The extension to the seven IoT requirements by using a table of general properties for IoT is presented.

Chapter four presents a business case study in the field of health care. A process that involves care assistance for elderly people is presented and the BPM discipline is followed in the stages of As-Is and To-Be process modeling. The processes are modeled using our online process modeler. The final model presents a diagram with the use of IoT extensions.

Chapter five concludes the document by presenting limitation of research in terms of

process executing languages. A table suggesting improvements and future work per section is introduced. A list of items with suggested improvements to the online modeler is given. Finally a set of suggestions for future work and research. A desired achievement of a BPMS engine connected with IoT devices using point to point integration and IoT gateway inter-operability is presented in an architectural view.

Appendix A contains instructions on how to access and operate the online BPMN4IoT modeler.

The structure of the thesis can be seen in a graph diagram in figure 1.1:

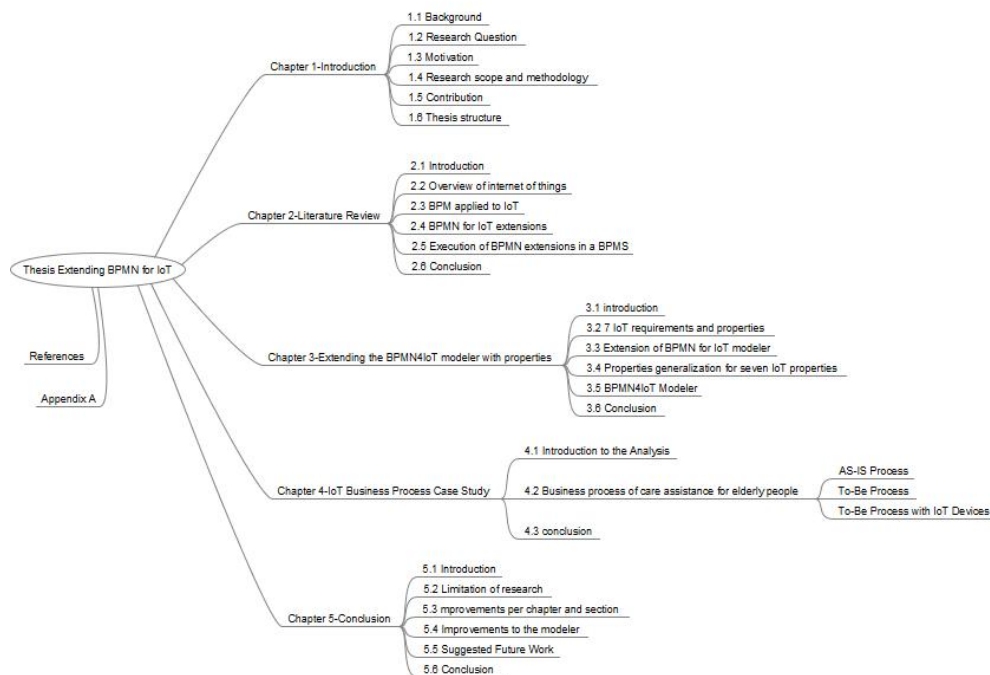


Figure 1.1: Graph with the structure of the thesis document

Chapter 2

Literature Review

2.1 Introduction

This chapter introduces and describes a literature review from different perspectives for IoT and its incidence in BPM modeling. IoT has been the focus of attention for the enterprise and academic communities. IoT is effectively emerging as a business perspective and revolutionizing the IT industry. IoT has been proposed as IoT as a Service (IoTaaS) and has become part of the cloud computing stack offering.(Celesti, Mulfari, Fazio, Villari & Puliafito, 2016)

The literature review presented in this document includes a focus on research efforts using BPMN extensions for IoT modelling.

2.2 Overview of the Internet of Things

The focus of IoT is connection and inter-operability among devices, information, operations and people. The world has realized the power of information at the right time and its effect on improving processes. Higher competitive entities but also a massive amount of data could result from using IoT.

IoT is an IT proposal of connecting and making inter-operable every possible available smart device. The goal is to make devices more intelligent and accessible for human benefit. Products then can be combined with electronic sensors, actuators and connected to the Internet. This premise is based on the concept of communication or allowing devices to talk to each other and provide informational value as a system. The real world can be expressed in a digital way. IoT proposes a way to enhance monitoring, processing power and information accessibility. It has been seen as an evolution of ICT and aims to improve and provide efficiency to enterprises and benefits for humanity in general. Del Giudice

IoT could be categorized with the use of 5 essential technologies: use of Radio frequency Identification (RFID), extensive composition of functionality by using wireless sensor networks (WSN), middleware, cloud computing and IoT application software and devices (Zhou, 2012).

use of RFID has become a norm for data identification with radio waves. The technology has been present in the IT picture since the 1980's when it was patented for the purpose of wireless data identification (Walton, 1983). RFID is born as an evolution of traditional 2 dimensional bar-codes that still work for most retail industries. The use of a small electronic component, low power consumption and storage made it very popular and now is a common standard.

The Wireless sensor networks uses as the name indicates an array of sensors with the purpose of collecting information. A sensor device is attached or embedded in any possible hardware object to perceive and collect information based on events. There are various types of WSN all related to a specific field or area such as: Body sensor network (BSN) used in medical health field. Visual sensor network (VSN) for fields such as surveillance and security monitoring through video cameras. underwater (acoustic) sensor networks (UW-ASN) for purposes of monitoring the ocean and bodies of water. All of these sensors usually work taking advantage of wireless technologies

(Han, Zhang, Shu & Rodrigues, 2015). There are Sensors for human social interaction such as social-participatory sensor networks for identification and tracking of people. interplanetary sensor networks used in astronomical research. In other words the use of WSN is extended to every capable physical object that can produce valuable data at any point in time. (Zhou, 2012).

For author Bing, the key hardware connecting technologies for IoT are: RFID, WSN and internet Transfer control Protocol (TCP). In Figure 2.1 the author represents the architecture of IoT using a multi-layered architecture in this case with 3 components. From bottom up the sensor layer is events based and captures data, events and triggers responses with Iot devices.

Network transport layer uses interconnection technology specially the internet as a backbone to transport information to the application layer. The application layer makes use of software to access the gathered data and as an orchestrator initiator for the management of the sensor layer.

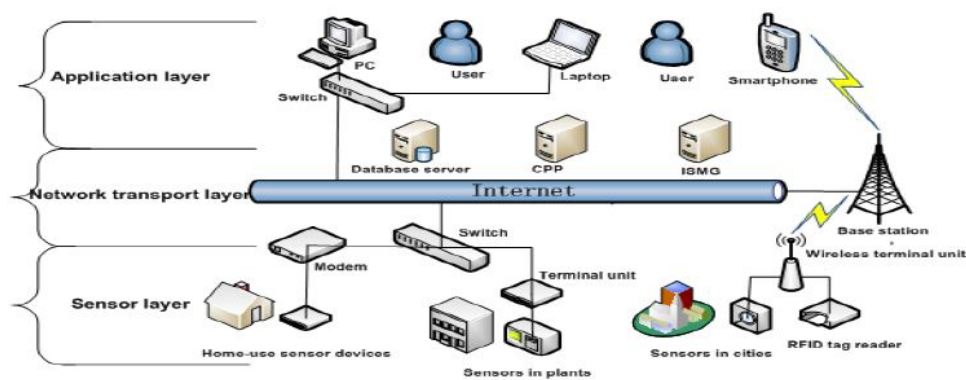


Figure 2.1: IoT Architectural model
(Bing, 2014)

A middle-ware hub component as a centralized layer of integrating technologies, devices, people and processes. Widely used in implementations of Enterprise Service Bus (ESB) for Enterprise integration. The hub or IoT Gateway plays an important role in IoT as many devices use different standards and protocols of communication. An

effort of standardization is still required as many IoT offerings are vendor dependent and do not inter-operate with one another.

Efforts for inter-operability and universal open source standards have been done by Global sensor networks (GSN) which is a middle-ware for processing and development of IoT services in the cloud computing environment. There is also the OpenIoT project which is supported by academic researchers.

OpenIoT offers semantic operability through the use of a semantic ontology proposed by Wide Web Consortium (W3C). The proposed ontology is Semantic Sensor Networks (SSN). The focus is to standardize a common language and describe the Quality of Service (QoS) parameters affecting the handling and management of IoT devices through recognized standards and a user friendly visual tool for device management. The issue of semantic inter-operability is approached by defining a well defined standard and implementing a stable product to portray the basic and robust functions available (Soldatos et al., 2015).

Cloud computing is a big technological world in itself that is constantly evolving and now takes part in IoT supporting device and software interactions (Buyya, Broberg & Goscinski, 2010). as an ubiquitous model, IoT is based on internet cloud connections for the heavy processing of growing and constant data-streams. The gathered data from IoT devices must provide a value for the purpose of optimization and autonomous behaviour. Cloud computing will play the front end solution for the end user and the back end processor for the information generated in IoT (Mandal, 2017).

IoT Devices and software as a key elements of the new IoT paradigm. Devices are capturing events and interacting with the real perceived world. The events are managed by the software. Hence the focus of an IoT software is to be user oriented and to manage new dynamic tasks and requirements.

Distributed computing architectures have evolved into complex service offerings in a very competitive and constantly changing technological market hence the concept of

IoT as a Service (IoTaaS) comes to represent the integration of current cloud providers with smart devices (Andersen, Fierro & Culler, 2017).

IoT devices run in embedded electronic components and connect to the internet to constantly gather and communicate data. For authors Celesti et al. the use of container virtualization could allow the cloud service providers to instantiate, relocate and optimize IoT capabilities in a virtual way.

Container virtualization is a type of resource virtualization in which there is a layer of virtual resources working on top of the host operating system. Several isolated instances of user spaces are created on the resources of the physical machine. Some benefits could include the resource control, isolation of functionalities and optimization of resources. There is some criteria of interest in which container based virtualization could perform better than traditional virtual machine methods. The criteria includes: benefits from use of containers in Start-Up-Time, Dynamic-Runtime Control, Speed, system Isolation, Flash Memory Consumption and Communication Channels Between Virtual and Physical environments.

It is important to note that container technology supports Single Board Computer (SBC) technology. In many cases SBC are linux powered devices running the latest linux kernel, this allows for the Linux Container virtualization (LCV) layer to run with high compatibility.

Operating containers with IoT devices such as Raspberry Pi (Maksimović, Vujović, Davidović, Milošević & Perišić, 2014) could bring business benefits such as: cost effective allocation of processing resources, power saving, on-demand resource provisioning, multi-purpose architecture within the IoT device but above all optimization of information processing.

On the business side IoT has a great significance. Companies want to obtain the Return on investment (ROI) and make a stable profit with the use of technological advances. The key to drive companies to quickly adopt IoT is the expectancy of a

profitable financial return.

When enterprises can perceive the value provided by the “productisation” of IoT, it is expected that the implementation and adoption of IoT as a must for companies then a good deal of adoption can be achieved. This is similar to compare Internet as a technology that works as utility computing and is required nowadays for any organization to be connected and fully functional. The IoT product becomes an asset and resource of the company increasing its propositional value and the net working capital of the company. (Bertocchi & Brazzelli, 2017).

A business model that is based in 9 building blocks elements (key partners, key activities, key resources, value propositions, customer relationships, channels, customer segments, cost structure and revenue streams) is presented by Dijkman, Sprenkels, Peeters and Janssen. The argument of this study is that IoT must be understood not only as a technological revolution but as an important business asset for almost any organization so that adoption rate increases among enterprise owners and highly positioned stakeholders. The framework is presented in figure 2.2

Key Partners Hardware producers Software developers Other suppliers Data interpretation Launching customers Distributors Logistics Service partners	Key Activities Customer development Product development Implementation; Service Marketing; Sales Platform development Software development Partner management Logistics	Value Propositions Newness Performance Customization „Getting the job done“ Design Brand/status Price Cost reduction Risk reduction Accessibility Convenience/usability Comfort Possibility for updates	Customer Relationships Personal assistance Dedicated assistance Self-service Automated service Communities Co-creation	Customer Segments Mass market Niche market Segmented Diversified Multi-sided platforms
	Key Resources Physical resources Intellectual property Employee capabilities Financial resources Software Relations		Channels Sales force Web sales Own stores Partner stores Wholesaler	
Cost Structure Product development cost IT cost Personnel cost Hardware/production cost		Revenue Streams Asset sale Usage fee Subscription fees Lending/renting/leasing Licensing Brokerage fees Advertising Startup fees Installation fees		

Figure 2.2: Business Model Framework with building blocks (Dijkman et al., 2015)

The business model framework could be used to evaluate any IoT project for any

organization. The simplicity of this tool is that any stakeholder can assign a value from 1 being the lowest to 5 being the highest and obtain a fast answer on whether or not adoption of IoT would bring beneficial value to the organization. The overview of each building block is analyzed:

Key partners: The involved stakeholders in the end to end process. The priority is the hardware producers as they are driving the manufacturing development. Software and data analysis both play a big role on the underlying functionality and further data analytic capabilities for process optimization.

Key activities: An important categorization that focuses on the research and development of a company. IoT is still developing to acquire product maturity. What Gartner defines as a Plateau of Productivity where the technology has a broad applicability in the market and the returns on investment are paying off. If IoT plays a role in the key activities performed by an organization this item increases the final score. (Steinert & Leifer, 2010).

Key resources: how the basic resources of a company integrate with the offering of IoT to increase the value proposition.

Value propositions: the most important building block that provides the final value to the customer. It is seen as the product providing the benefits and the key to revenue. In the IoT world the possibility for constant software updates on the product generates value. Latest functionality with updates is seen as the driven factor to have IoT devices without the need of acquiring a new product for the consumer market.

Customer relationships: An increased implicit participation of the customers through the use of IoT. Customers could have more control of the data and this could increase customer involvement with the device. The generation of data could allow companies to constantly improve in a personal level to offer a personalized service.

Channels: The expansion of information to the customers to reach and attract more public. In this item the value of Customer Relationship Management (CRM) based on

an effective communication strategy.

Customer segments: categories for the public that is to acquire the IoT products. Helps in defining the target scope of possible customers.

Cost structure: the investment the company makes considering the return on investment. A big investment must be considered in the marketing element to advertise the IoT product as a required asset.

Revenue streams: the strategy chosen by the company to satisfy the needs of the customer by focusing in a segmented area of the market.

For author I. Lee and Lee on the managerial side, the IoT paradigm comes as the most important area of future technology and must be fully realized when the devices are communicating with systems that go from vendor systems, data analytic system and customer support systems. There is a direct impact in BPM work-flows for many organizations as accuracy and the possibility of information in real time can be achieved with the use of IoT devices.

The focus of any enterprise is to improve operational and organizational agility, cut excessive costs and become ever more efficient to bring about the most profitable outcome.

2.3 BPM Applied to IoT

Business process Management (BPM) is a well established discipline containing a set of combined knowledge from IT, industrial engineering, processes, business management and operations research. The final aim of BPM as a mature discipline is to improve processes (Van Der Aalst, La Rosa & Santoro, 2016). BPM aims to improve the efficiency and execution of the process through constant analysis, optimization and iterative improvement of the business processes. When Business processes are constantly automated they could gain a competitive edge and the organization performs faster.

A Great definition of BPM as a horizontal discipline by CBOK is “BPM is a systematic approach to capture, execute, measure, document, monitor and control automated and non-automated processes to reach certain goals”. The definition considers non automated processes such as those that use manual tasks, physical entities or devices that do not generate digital information but are integrated into a business process and at some point could generate data that can be processed by a BPM system. BPM has a great focus on the use technological automation of business processes to have more control and better monitoring of the data. Many organizations have shifted to use BPM and BPMN the business process notation language to model their processes. BPMN helps in describing and documenting processes to have control of the complete business process life-cycle.

The BPM life-cycle is shown in Figure 2.3 and represents 4 stages of a BPM disciplined implemented in a military hospital. The stages are explained with more detail below:

1. The model stage is about documenting the current status of the existing processes. This phase is called AS-IS process. The processes are optimized and the outcome is called TO-BE processes in which optimization techniques are added.

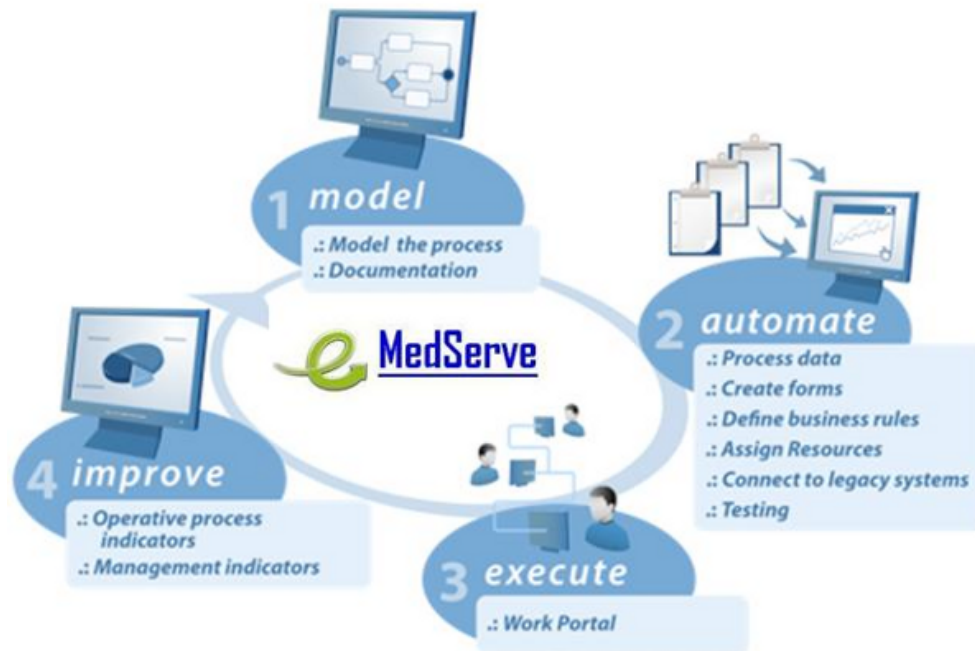


Figure 2.3: Business Process Management General View
(BPM.com, 2018)

2. The automation stage takes the TO-BE processes and adds adjustments, user forms and digital bindings to informational systems so that processes can be executed usually in process engines of a Business Process Management System (BPMS). Nowadays is common to use Service Oriented principles and API integration to communicate the people, processes and software systems.
3. Users access the runtime environment through the process portal which usually is a front end application. Monitoring of processes and some Business Analytics Monitoring (BAM) is done in this stage.
4. The underlying principle of BPM is the optimization of processes through constant analysis and process mining methods. The outcome of improve stage is a set of proposals on constant improvements and is the beginning of the continuous BPM life-cycle.

Business Process representation and modeling has always been an important focus of any enterprise for the achievement of their business goals (de Oca, Snoeck, Reijers & Rodríguez-Morffi, 2015). Business Process Management Notation (BPMN) is born as a standard notation that is user friendly and easy to understand in a horizontal way. Users from non technical background to technical users should be able to understand any process representation in BPMN. BPMN fills the gap between the process design and the final automated implementation. (management group, 2018)

Technically BPMN is a set of elements structured in layers with a core of main elements. the elements of the layer are represented formally in a XML Schema definition (XSD) (management group, 2011). The use of XML to structure the definition of BPMN helps in avoiding inconsistencies and helps in removing ambiguities in the created models. The layering has the ability of being extended easily by describing new elements as long as they conform to the core package.

The BPMN core layer model in the figure 2.4 shows the layers and how they are built on top of the core. The BPMN core is composed of 3 main elements: Foundation, service and Common (Process, collaboration and Choreography elements). BPMN is flexible in the sense that allows vendors to develop products that comply to the specification as long as the core elements are not modified but extended based on Object oriented programming principles (Dennis, Wixom & Tegarden, 2015). Another goal of the layers is to allow dynamism without compromising clarity of the model representation.

Figure 2.5 shows the structure of the BPMN core elements in an Unified Modeling language (UML) (OMG, 2011b) Class diagram representation. Process class extends from callable class and the top class is interface. A process can be exposed as a service so it can be invoked and composed into complex functionality as one of the principles of Service oriented Architecture (SOA) (Erl, 2007)

BPMN graphical notation is represented in 5 main categories:

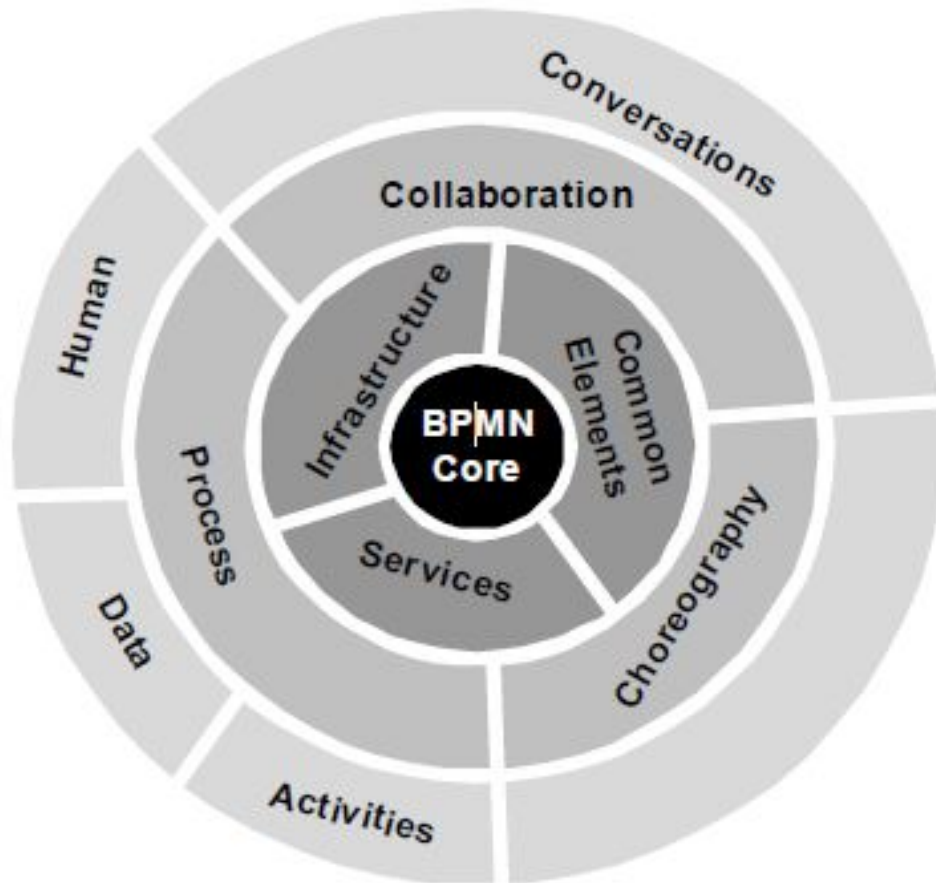


Figure 2.4: BPMN Layer Model
(OMG, 2011a)

1. Flow Object: elements that define normal behavior of a process
 - (a) Events: occurrence that is triggered and affects the process. In IoT the devices play a big role as in many cases they will trigger the events and start or disrupt the business process at run-time.
 - (b) Activities: actions performed in the process. For IoT the extensions consider especial customized BPMN activities with sensors and actuators.
 - (c) Gateways: controls the path of the process. Is a decision based element that considers conditions and business rules to manage the branching control of

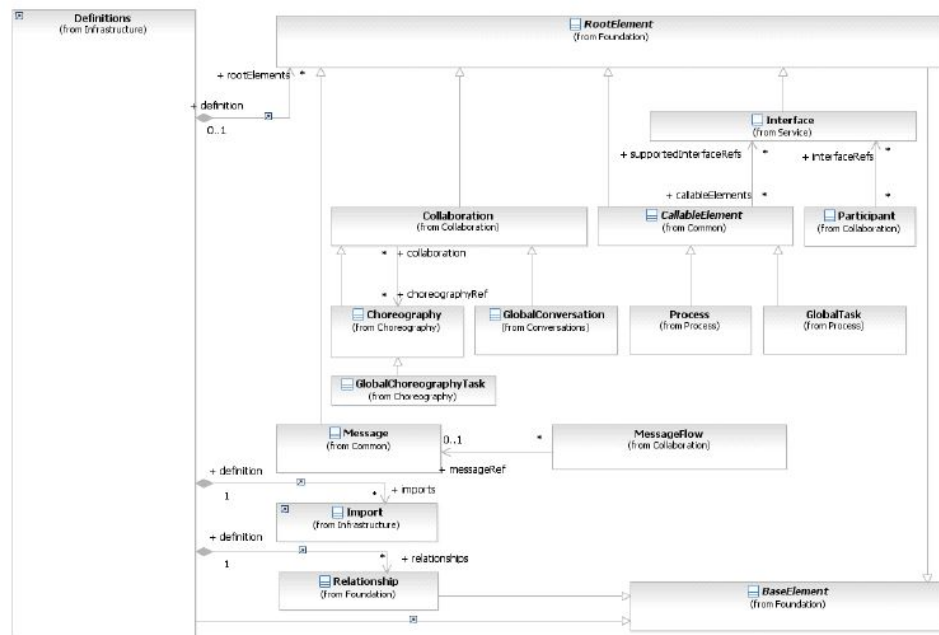


Figure 2.5: Core Class diagram
(Bing, 2014)

the sequence flows.

2. Data: represent digital information flow and persistence elements.
 - (a) Data Objects: represent information objects that are present in the business process
 - (b) Data Inputs: data elements that are inputs to a process or activity.
 - (c) Data Outputs: data elements that are outcomes in the process realization or output of an activity.
 - (d) Data Stores: represent the persistence of data in information systems such as databases or data files.
3. Connecting Objects: represent connection and flow between the process objects
 - (a) Sequence Flows: represents the flow and order of the execution in the process.

- (b) Message Flows: shows communication and interactions flows between participants and elements. Messages can use a synchronous or asynchronous pattern for the communication control (Kasi, Mehta, Sapuram & Venkat, 2016).
 - (c) Associations: used to associate to other elements such as text or artifacts. Expands graphical detail and information of the represented process. In IoT it can be used to describe main functions of the device or specify a particular case in the process execution. It can also expand details on the existence of certain business rules.
 - (d) Association Data: specifically associates data to the flow. It represents an exclusive data operation in the process.
4. Swim-lanes: represent grouping, role and categorization of process tasks.
- (a) Pools: represent participants
 - (b) Lanes: represent specific roles and give more details to organize the activities in the process. is a sub-partition to separate concerns.
5. Artifacts: Provide external and additional information about the process. In IoT artifacts can be used to fully extend the capacity of a BPMN model to describe IoT behaviours. During execution time artifacts are used to provide more information but are not considered by a process execution engine.
- (a) Group: used to categorize graphical elements. used for documentation and improve description of complex behaviour in a process.
 - (b) Text Annotation: provides additional information about any graphical element for a reader of the BPMN diagram.

The figure 2.6 shows the main graphical representation of elements in BPMN. The

categories: Data and artifacts have been extended in previous work and will be presented in following chapter.













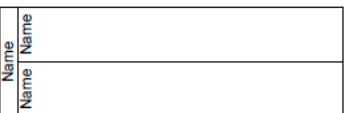


Category of Element	BPMN graphical Representation			
<i>Flow Object</i>				
	<i>Event</i>	<i>Activity</i>	<i>Gateway</i>	
<i>Data</i>				
	<i>Data Object</i>	<i>Data Input</i>	<i>Data Output</i>	<i>Data Store</i>
<i>Connecting Objects</i>				
	<i>Sequence Flows</i>	<i>Message Flows</i>	<i>Associations</i>	<i>Data Associations</i>
<i>Swimlanes</i>				
	<i>Pools</i>		<i>Lanes</i>	
<i>Artifacts</i>				
	<i>Group</i>		<i>Text Annotation</i>	

Figure 2.6: Principal Graphical elements in BPMN

Del Giudice suggests that IoT would bring innovation to business processes because of the effort from ICT in techno-scientific innovation. IoT could bring a new set of services to the competitive world market. The goal of BPM as a discipline of process improvement combined with IoT distributed sensing capabilities could optimize decision-making processes and accelerate IoT adoption as well as creating an edge for early adopter companies. The technological revitalization for industrial firms in the capitalist socio-economic system is likely to be impacted by the key role of IoT (Rifkin, 2014).

from the business side the impact of IoT in BPM is directly related to increase of business knowledge, focus on innovation and the competitiveness.

Competitiveness of the market requires intelligent equipment, expertise in data analysis and an inherent growth in technology (Al-Mashari & Zairi, 2000).

the correlated data that IoT could produce in the business processes plus other factory information could play a big role in the achievement of business process-oriented for the industrial sector (Carmona, Engels & Kumar, 2017). The standardization efforts of IoT are aiming to support the learning, application, adoption and implementation of IoT worldwide. Standard efforts support a globally accessible, open and simplified independent data service layer for IoT (Swetina, Lu, Jacobs, Ennesser & Song, 2014) allowing devices to easily communicate with each other. In the end the standards could bring more value as IoT devices become inter-operable and use a standard method of communication to keep their most valuable outcome: data.

With the increasing use of IoT and smart devices in many industries, BPM must include the technological benefits, principles and values from the BPM methodology framework. The key to optimizing processes is in the analysis and modeling of the processes which is usually done using BPMN language (Aagesen & Krogstie, 2015). A proper modeling of a business process could allow companies to identify weak points in the processes, further identify problems and propose a suitable solution using latest technology trends.

For author Martins and Domingos a business process that involves a SWN for an irrigation system is modeled by using BPMN standard only. The model is then translated to XML representation. The BPMN representation is translated into executable code that executes in Callas a formal language for language representation of WSN. The prototype is successful though Callas is limited in parallel tasks from BPMN concept. The proposal considers a use case scenario. the limit of the research is that when using complex sensor devices Callas is not capable of translating the code. BPMN models using this approach require to include a script task to express the constant polling of information that is performed by the sensor. Another difficulty with the proposal is

the need of extra mappings and adaptations so the semantics of Callas is functionally replaceable from BPMN.

It is crucial to include IoT in BPMN because of the great impact that is expected from smart devices. IoT capabilities in BPM could be enabled through the use of traditional service integration such as SOAP services or REST based services (J. Lee, Lee & Wang, 2015). The advantage of using intercommunication from IoT with BPMS with services is in the amount of information that is hidden from the business application separating the IoT heterogeneity and the data layer. As a quick resourceful solution many propose the BPMS to be connected with IoT devices or middle-ware through the use of services but this can increase execution times, synchronization of the devices, complexity in the implementation and security risks to the data functions exposed.

When IoT is combined with BPM discipline and BPMS automation and execution systems, the system evolves from deterministic process to become a complex event system. author Haller and Magerkurth focuses on some difficulties that must be overcome for IoT devices and real time business processes. BPMS must become more intelligent and event adaptive, in this case constant change is the challenge and the system must constantly conform to fast paced changing environments. A massive amount of data could be unreliable, where new paths in the process are taken the data must be filtered and only data that is relevant to the process must be used. Processing of massive amounts of data and using the appropriate data is key to the successful outcome of a process.

Another issue in the BPMS and IoT integration is dealing with devices failure or chaotic situations in the environment. Constant self monitoring and self healing techniques on both the BPMS and the IoT devices or IoT gateway middle-ware to effectively prevent possible occurrences.

the distribution of business processes in big organizations could bring management issues. The tendency to deploy functionality in the cloud and generate massive amounts

of data in normal BPMS processes could generate data redundancy (Wang, Da Xu, Bi & Xu, 2014). When IoT comes to the picture there is a high concentration of distributed processes and devices. Management and tracking of this complex system becomes a challenge.

Academic research has put a focus on defining new digital graphical elements for BPMN that successfully represent the IoT physical side. The effort is ongoing and there is still not a consensus from Object Management Group (OMG) which is the standard consortium in charge of BPMN standard (Specification, 2006) of any BPMN extension that includes IoT elements. There is no Revision Task Forces (RTF) on the work in progress from OMG at the moment (management group, 2018).

Effort by author Meyer, Ruppen and Hilty argues that since IoT is promising to change the business world, there is little effort to create BPMN representation for physical entities. To represent a physical entity in BPMN his work is done in 4 architectural components: device, the thing, and 2 services native services and IoT service. the 4 components are described:

- The device-bridge technical artifact connecting physical and digital world
- the thing-physical object that can create a relationship with the IoT device
- native services-capabilities of the devices to gather information and connect to other systems
- IoT service-service oriented software to augment the Iot device's capabilities, integrate, transform and persist data.

A functional formalization of the physical entity proposed by (Meyer et al., 2013) in which the existence of an inert physical element is suggested plus the BPMN activities Actuation task and sensing task are proposed. The BPMN meta model in Extensible Markup Language (XML) (Bray, Paoli, Sperberg-McQueen, Mailer & Yergeau, n.d.)

is proposed. This work is important as it highlights the importance of modifying the structured formal semantic meta-model of BPMN language to include IoT elements. This work shows the complexity of an appropriate IoT definition and fulfillment of data requirements.

A combination of BPMN modeling, IoT, BPMS and patient involvement in the health sector was proposed by Ruiz-Fernández, Marcos-Jorquera, Gilart-Iglesias, Vives-Boix and Ramírez-Navarro. In this work patients with high blood pressure were empowered with the use of IoT devices and access to the process portal from the BPMS. The data input by the patients affected the execution flow of the process. Patients were able to self manage their information about health and know in advance tips about health and prevention. The use of smart-phone devices was vital in this study as the BPMS would integrate via service based calls with the smart-phones and IoT sensing devices to deliver notifications and reminders.

The proposal is a top down approach that is process oriented and is focused on the main participants which are the patients and medical staff to meet the strategic goals. The life-cycle of BPM is followed: AS-IS process modeling that found the need for patient-doctor interaction. To-BE process optimization that proposed the use of IoT devices and a Service Oriented Architecture (SOA) based system. The implemented TO-BE process was executed, the platform was tested as a proof of concept during a couple of months and good outcomes were found. Patients were generating valuable data and became the key performers of the process.

To find weaknesses in the medical process involving high blood pressure patients the Ishikawa diagram was used (Enarsson, 1998). Once the weaknesses were identified the problems and objectives of the new To-Be process were easily identified. The main goal was to make information accessible not only to the proposed automated process but to all stakeholders. The goal is to access information in the most transparent, automated, simple and user interactive way.

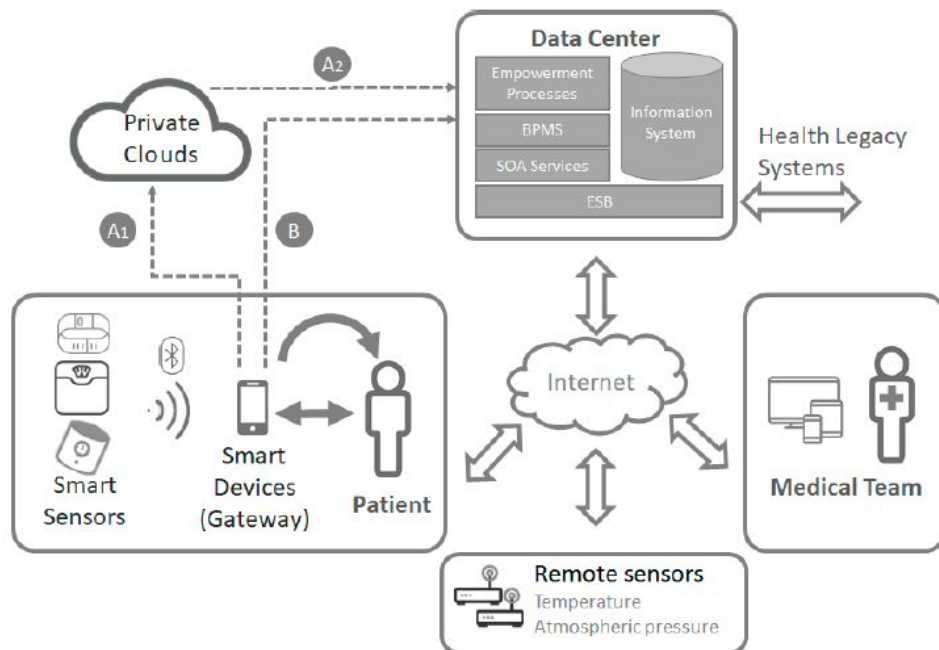


Figure 2.7: System architecture from Health process involving patient empowerment (Ruiz-Fernández et al., 2017)

The system architecture from figure 2.7 does not show the customized process portal user interface developed specifically to manage the proposed process. The Internet connects the different clouds and participants. Patients only access the process through smart devices while the medical team analyzes the gathered information from the process portals. IoT devices were deployed in many activities of the process. blood pressure sensors, temperature sensors, movement sensors, alarm actuators, doors actuators among others were utilized. The integration was done in some cases point to point and using the ESB as a hub for the service invocation and to trigger some functionality in the remote sensors. Services from the ESB were also used to orchestrate calls to the BPMS engine.

Although BPM advocates for process optimization and continuous improvements many BPMS vendors do not offer flexibility nor agility in their automated process execution. The BPM discipline offers best practices to fill this gap. Most BPMS do not allow the possibility to extend the functionality to work accordingly to IoT defined

architecture. Most proposals tend to integrate IoT devices through point to point service calls to either API or SOAP technologies.

Work by Cherrier and Deshpande utilized a gateway or ESB to interconnect the process orchestration and choreography from a BPMS to the IoT set of devices that are orchestrated and composed by an IoT Gateway. The project makes use of BPMN events and service activity elements to achieve this. A bigger effort is implicit in this work as more integration of systems were required and the model is not portable to other BPMS engines.

2.4 BPMN for IoT extensions

Several papers proposed to involvement of IoT as an extension in BPMN due to the lack of representation elements in BPMN. BPMN events elements do not properly represent the event functionality in IoT as the IoT devices use a continuous flow of event data stream while BPMN events react asynchronously to the received events. (Martins & Domingos, 2017; Dijkman et al., 2015; A. Caracaş & Bernauer, 2011; Haller & Magerkurth, 2011).

For author Meyer et al., IoT devices will become process resources that will challenge the typical enterprise process view. The Business process resource contains a physical part that is connected to a physical entity with many attributes. There is a software connector unit defined as the native service that connects with the IoT service exposed APIs. This adds two layers of direct communication via common service methods and an indirect communication via the physical entity in the real world that is bridged to the digital business process world through the IoT device. The proposed model can be observed in Figure 2.8.

In the set of extensions proposed by Meyer et al., some extra tasks such as sensing and actuator task are proposed plus a new layer of extension that extends the BPMN

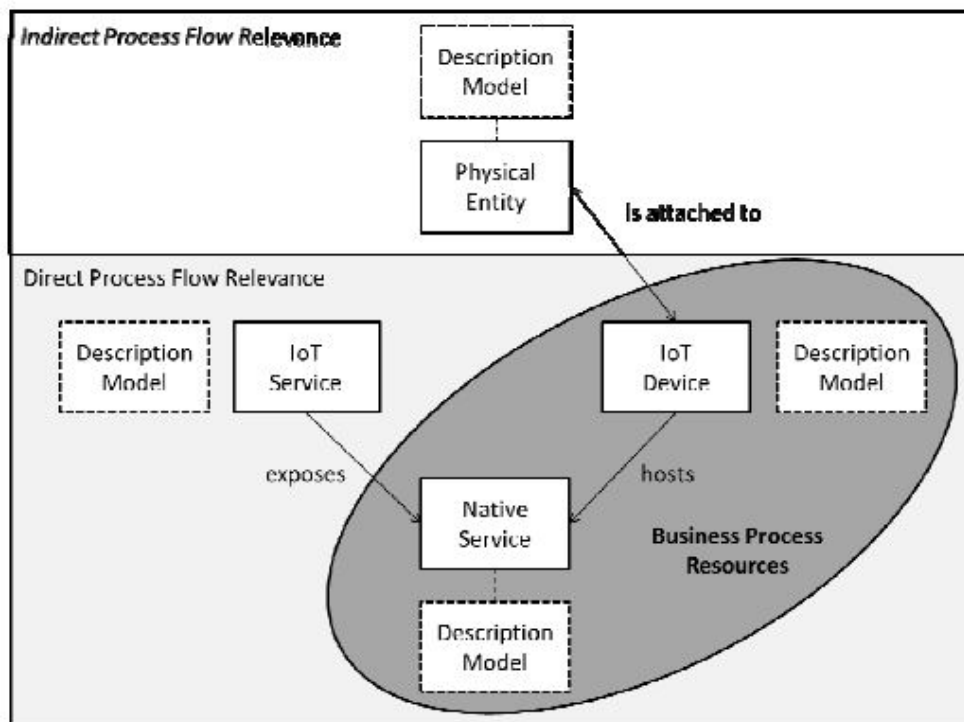


Figure 2.8: IoT as a business process resource
(Meyer et al., 2013)

meta-model to make it machine readable seeking automation in a BPMS engine. The BPMN editor is extended to include the new graphical elements as well as the process execution engine.

One important factor to be mentioned is that any proposal for an extension to BPMN must not contradict the semantics defined in the BPMN formal elements. Redundancy in functional semantic of the new BPMN elements must be avoided.

BPMN specification offers the possibility of extension in the official specification document chapter 7.6 "BPMN Extensibility" as it corresponds (OMG, 2011a): "BPMN 2.0 introduces extensible features as a mechanism that allows the inclusion of extra elements with additional attributes. It can be used by modelers and modeling tools to add non-standard elements or Artifacts to satisfy a specific need, such as the unique requirements of a vertical domain, and still have valid BPMN Core. Extension attributes **MUST NOT** contradict the semantics of any BPMN element. In addition, while extensible, BPMN Diagrams should still have the basic look-and-feel so that a Diagram by any modeler should be easily understood by any viewer of the Diagram. Thus the footprint of the basic flow elements (Events, Activities, and Gateways) **MUST NOT** be altered".

BPMN allows extension of elements as long as the core components are preserved. Any extension to the meta-model must be reflected in the executable code and defined in the BPMS engine.

For author Chiu and Wang, BPMN can be extended by taking advantage of the events elements semantic definition. BPMN defines the events as an activity or action happening at any moment. The author analyzes different architectures and proposals to use sensors and actuators in business processes. The use of an IoT Gateway as a layer between the BPMS and the IoT devices is suggested as a technical management tool and for a centralized management of operations and device control.

Chiu and Wang also introduces the concept of IoT-Aware Process Modeling Concept

(IAPMC) in which the focus is on the entity modeling and the information to be gathered as attributes of an entity could define the actions and events it can generate. The author proposes 8 requirements that can be summarized in table 2.1.

Table 2.1: 8 BPMN defined requirements

(Meyer et al., 2013)

Requirement	Description	Value of extension in BPMN
R1: Entity-based Concept	Abstraction of a physical object with certain attributes.	Due to the nature and diversity of IoT is important to extend BPMN to describe extra functionalities and capabilities of IoT devices.
R2: Distributed execution	Multi-Device availability and execution. Data can come from many sources using same device but in different locations	An integration with web services should be enough to manage this characteristic of IoT.
R3: Interactions:	IoT devices interact physically with the process and with software components	BPMN lacks the ability to model these interactions. A BPMN model can benefit from the use of interactions to represent complex deployment of multiple IoT devices in a big environment.
R4: Distributed Data	Data could be distributed in multiple locations.	With the continuous improvement on big data technologies data is stored automatically. The value that data provides could come from analyzed gathered data in a report and not necessarily for the representation of data storage in a business process model.
R5: Scalability	A requirement to represent the dynamics of increase and decrease of devices over time	The ability to represent a threshold of growth for certain devices and under specific business conditions. Could be beneficial during run-time execution of an automated business process
R6: Availability	Represents the possibility of devices failure, removal, quality of service.	Important in the definition of new IoT elements in BPMN and during run-time as the engine must manage intermittent devices.

Continued on next page

Table 2.1 – *Continued from previous page*

Without IoT	With IoT	Value of using IoT
R7: Fault Tolerance	IoT failure management	It could increase the complexity by adding new variables and requiring sub processes and prevention procedures for failure management.
R8: Quality of Information	The model should represent information that is relevant to the process	This requirement is needed in business Analysis and monitoring. Adding a requirement to ensure data quality increases the complexity and readability of the model in the analysis phase of BPM and might be disregarded in process automation phase.

A specific study on extensions of BPMN (Chen & Wang, 2017), considers the unreliability of using web services to integrate with IoT devices. In case of failure the BPMS could not monitor the availability of devices. Author suggests that specific extensions of BPMN for IoT make the meta-model too complicated to learn in a short time and BPMN 2.0 already has complexities and a steep learning curve.

The argument is that there are many proposed BPMN extensions which functionality is already available without the need of extending the BPMN specification. Finally The author Chen and Wang generalizes IoT extensions in 3 main categories, see figure 2.9.

1. Sensing type devices: to obtain information from the environment
2. Actuation type devices: to perform a change in the environment
3. Management: to update parameters on the devices.

Based on the specifics of the BPMN specification for extensions, IoT extensions are needed but are interpreted within the vertical business solutions. Every IoT extension should conform to the basic BPMN core but might contradict some of the semantics of

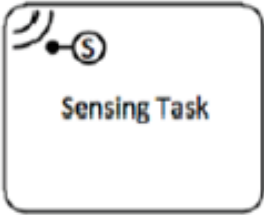
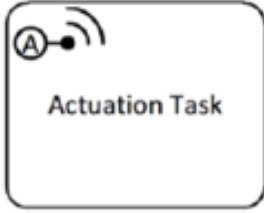
Category of Element	BPMN graphical Representation	Description
<i>Sensing task</i>	 <p>Sensing Task</p>	Get information from sensor
<i>Actuation task</i>	 <p>Actuation Task</p>	Change the parameter of Physical Entity

Figure 2.9: Two generalized IoT Categories in BPMN
(Chen & Wang, 2017)

the BPMN elements for example the BPMN events. The use of events is an issue that might bring latency, concurrency time, delay and wrong execution of a business process (Mandal, 2017).

May research efforts are focus on defining new missing attributes in BPMN and suggesting graphical elements and even semantic changes to the BPMN schema. Unfortunately the studies are theoretical and few of them suggest the possibility of testing the automation of BPMN modeled processes in a BPMS customized engine for BPMN for IoT extensions.

2.5 Execution of BPMN extensions in a BPMS

In the life-cycle of BPM automation of processes consists of taking the BPMN model and executing it in a process engine. XML based languages have been proposed to execute BPM in a machine (Hornung, Koschmider & Mendling, 2006). proposals such as XPDL, BPEL, WS-BPEL for orchestration of services and processes and nowadays the most popular BPMN 2.0 with automation and execution support.

A proposal of BPMN extension and execution was done by A. M. Caracaş. BPMN is extended for specific Wireless Sensor Network (WSN) the process is modeled and integrates with the IoT devices. The model is then transformed into executable code with a Domain Specific Language (DSL) for WSN. The proposal is done by using a Model Driven Development (MDD). The final generated code is in C# language and is executed in a mini BPMS light executable engine strategically integrated with the WSN devices with standard wireless technologies (Lu, Wang, Niyato, Kim & Han, 2016).

Business process languages for execution rely on advanced XML processing instructions, parsing and serialization. BPMS engines require an advanced and robust design so performance is not affected (Ivanchikj, Ferme & Pautasso, 2017). The languages for process execution are described below:

- **BPEL:** Business Process Execution Language. A process execution proposal that was focused on service composition and orchestration for the successful execution of business processes. A mapping between BPMN and BPEL was used in many BPMS products to automate processes. The transformation from BPMN 1.0 to BPEL proved to have some conceptual mismatching (Recker & Mendling, 2006). BPEL is no longer commonly used and have lost ground giving way to other technologies such as API, microservices and containers for the integration of processes and services (Lübke, Ivanchikj & Pautasso, 2017).

- **XPDL:** XML Process Definition language. based on work-flow methodology. XPDL framework is very strict regarding the compliance with the specification and the rigid block structure. It might require extra effort by BPMS vendors to make a product conform to the rigorous XPDL standard (Geiger et al., 2015).
- **BPMN:** notation that was born to be easy to read for business users. it is standard by the Object Management Group (OMG) organization. It is a multi-layered proposal that contains core packages and data elements to visually describe any business process. In its recent version 2 it has been extended and adapted so that BPMS engines can automate and execute the diagrams (OMG, 2011a).

The figure 2.10 represents the scope of popular process execution languages across 6 stages of BPM (Business Overview, AS-IS Process, TO-BE Process, Process automation and execution, BPMS integration with Systems and Data Services).

Business overview allows non technical users to easily understand the general purpose of a business process. As-IS process is a stage to define the correct execution of a process. To-Be stage is the optimized version of a modeled process. Process automation stage is the implementation of a modeled process in an integrated process engine. BPMS integration executes the modeled process and makes use of services and connectors to communicate with legacy systems and internet services. Finally data services allow process languages to extract data and use it in the internal process flow.

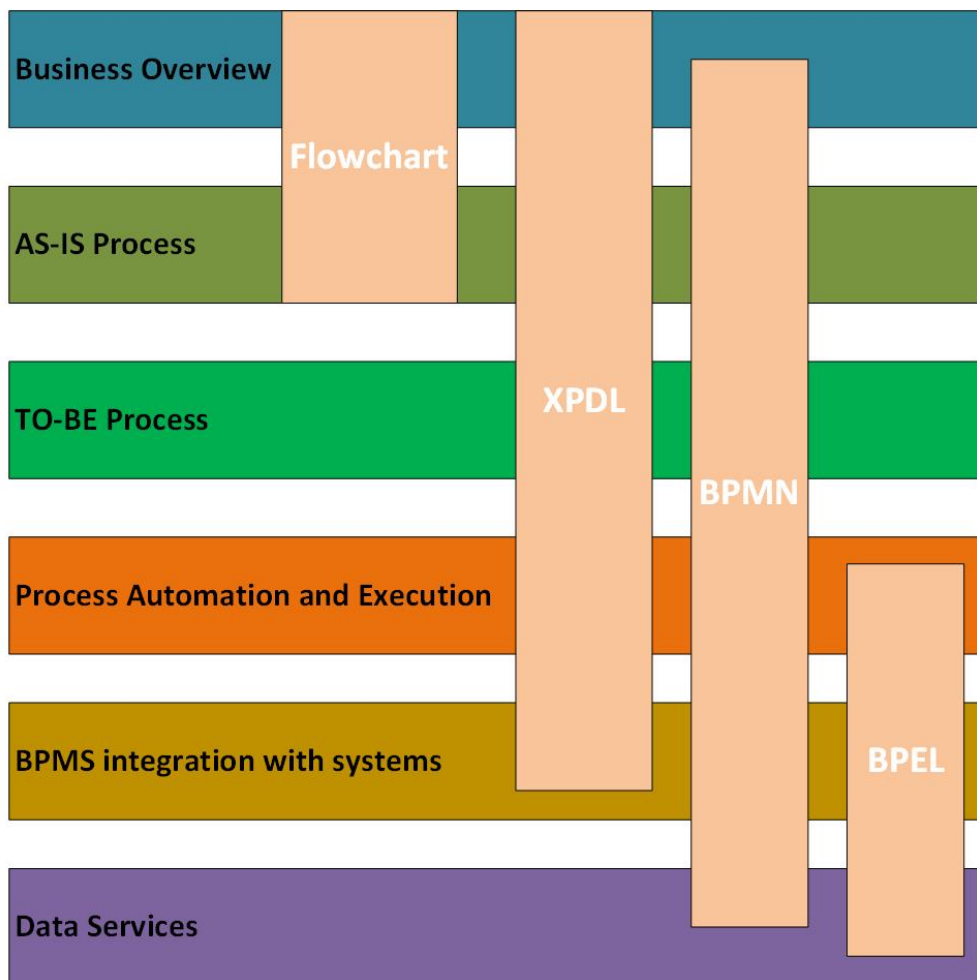


Figure 2.10: Execution of business process languages

2.6 Conclusion

This chapter was organized in five parts:

An introduction to the terms of IoT, BPM, BPMN and process automation is given.

An overview of IoT is presented with some of the latest research efforts up to date.

BPM life-cycle is introduced to show the importance of process optimization and the inclusion of IoT in any business process to provide significant and competitive enterprise value. Different work on the extension of BPMN to include IoT behaviour is presented.

The execution of automated processes using BPMN is considered by showing research examples in which BPMS engines are extended to integrate with IoT devices.

Finally, some issues arise in complexity when adding IoT extensions to the BPMN meta-model as it might lose standardization support from the specification and could affect the semantics of the process definition. Some elements in BPMN provide functionality that could be used in IoT behaviour such as BPMN events elements, there might be functional redundancy in extending BPMN elements as standard BPMN elements could be used to represent some IoT behaviour. The need for extension of BPMN is present.

Chapter 3

Extending the BPMN4IoT modeler with properties

3.1 Introduction

This chapter introduces the continuation of work on BPMN extensions for IoT. First, the seven IoT requirements that were proposed by author Ratnayake are described with practical examples in section 3.2. Second, the BPMN graphical elements are shown and mapped to each of the requirements. The explanation on the development and changes done to the modeler is described in section 3.3. A proposal for generalizing the properties of each BPMN element with a general IoT Task entity and global attributes is presented in section 3.4. Finally a conclusion on this work and suggestions for future development of the modeler BPMN4IoT is presented in section 3.6

3.2 Seven IoT Requirements and its properties

The seven IoT requirements with a practical example is shown in the table 3.1 below.

Table 3.1: 7 BPMN for IoT requirements

(Ratnayake, 2018)

No	Requirement	Description	Examples
R1	IoT Sensor	Collect information and act as input transducer. Any devices that can capture variables from the physical environment and translate to digital information to be sent either to the IoT Gateway or to be streamed to a business process with any communication method.	Acoustic, vibrations, automotive, transportation, chemical elements in the environment, electricity, physical waves, environment, weather, fluid, velocity, force, radiation, navigation instruments, optical light, position, location, distance, pressure, proximity, thermal, temperature (Zhou, 2012)
R2	Actuator	Transform through actions based on sensed events or pre-defined actions. Opposite of sensors. Commonly used in robotics and physical automation of tasks.	Categorized in 4 main set of actuators: pneumatic, Hydraulic, Electric and Thermal. Actuators affect the physical environment in response to the triggered activities of sensors
R3	Reader	Categorized from RFID and barcode devices. Based on the bridge of object orientation design and physical objects. Collect input data that is been assigned to a physical object for automatic detection of object and for systems for automatically obtain information from physical entities with minimum human interaction.	RFID technologies, Barcode scanners
R4	Collector	Could be defined as sub processes in the BPMN flow that are embedded in a hardware device. Collectors gather information from different sources and invoke software services and perform a very specialized function of data processing. Analogous to micro-services functionality.	An IoT device programmed to validate business rules within a business context and perform service calls or integration to a BPMS when required

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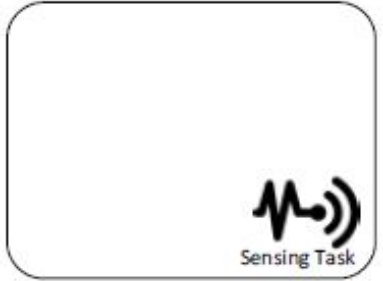

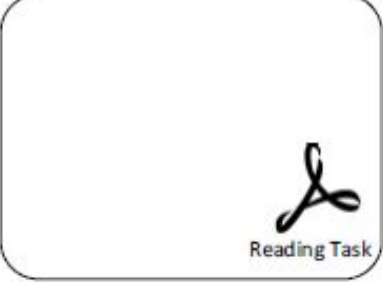

Table 3.1 – *Continued from previous page*

No	Requirement	Description	Examples
R5	event stream processing units	Continuous flow of information generated by the IoT device. The stream of events can flow through messaging systems that can be synchronous or asynchronous in nature	A special BPMN activity that during run-time constantly monitors for new messages to trigger certain functionality or invoke a process to achieve a business goal
R6	Specific data object	Digital representation in a business process of the entities that reader from R3 obtain. It has an entity representation with the values and dynamic attributes that can be gathered.	A digital data entity representing a physical object with attributes and values from the physical world. (Meroni, Di Ciccio, Mendling et al., 2017)
R7	Intermediary operation	Performing processing and operations in an IoT Application. Is BPMN element capable of processing raw data operation in the IoT device. (Sungur, Spiess, Oertel & Kopp, 2013)	In a run-time BPMS process instance an IoT device takes a parameter that is sensed from the environment, performs small business rules validations, invokes functionality from an actuator and then notifies the running business process of this event

The outcome of Ratnayake can be seen in the 7 graphical elements proposed in the author's work. The table below shows the proposed visual BPMN extended elements for IoT mapped with the corresponding proposed requirement see table 3.2.

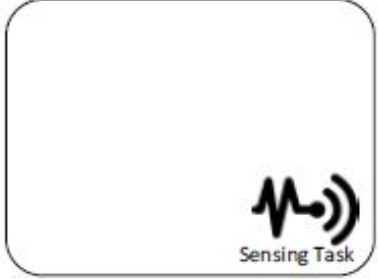
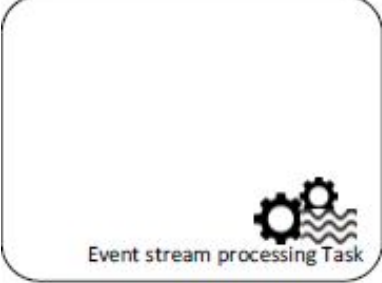
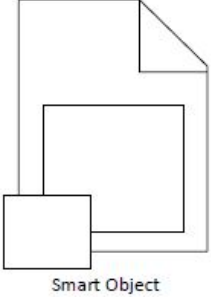
Table 3.2: BPMN4IoT Elements vs Requirements

(Ratnayake, 2018)

Proposed BPMN4IoT Element	BPMN4IoT Graphical Representation	IoT modelling requirements
Sensing Task		R1: Sensor
Actuating Task		R2: Actuator
Reading Task		R3: Reader
Collecting Task		R4: Collector

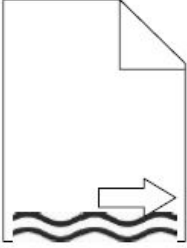
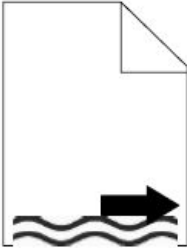

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Table 3.2 – Continued from previous page

Proposed BPMN4IoT Element	BPMN4IoT Graphical Representation	IoT modeling requirements
Intermediary Task		R5: Intermediary operation
event stream processing Task		R6: Event stream processing
Smart Object		R7: Specific data object and extension to BPMN data element

Continued on next page

Table 3.2 – Continued from previous page

Proposed BPMN4IoT Element	BPMN4IoT Graphical Representation	IoT BPMN modeling requirements
input event stream object	 <p data-bbox="767 801 932 831">Input Event Stream</p>	Extension to BPMN Data Input element adapted for event stream task R6
output event stream object	 <p data-bbox="761 1238 938 1267">Output Event Stream</p>	Extension to BPMN Data Output element adapted for event stream task R6
physical entity	 <p data-bbox="788 1675 911 1704">Physical Entity</p>	Representation of a physical object which the IoT device can interact

3.3 Extension of BPMN for IoT modeler

A Software requirements specification (SRS) document was created to describe the requirements and functional additions to the modeler. Once the changes were defined, an analysis of the different JavaScript libraries used in the project was done.

Based on the extension requirements described in table 3.3 the development stage was executed. the most important extension requirement is R4 as it translates the generalization from 3.3 in which IoT Task has global attributes that can be applied to IoT devices and the attributes are inherited by the 6 BPMN4IoT extension.

Table 3.3: Software Requirements for the extension of the BPMN modeling

ID	Name	Description
1	Add a file menu bar with option for cloud integration	include dummy option for BPMN export, export to an image, save to cloud storage services
2	Add most common BPMN activities to Activities section	Add normal, user, service, business rule, manual task to the modeler
3	Add more options to context menu	add options delete, bring to top, duplicate, properties
4	Add a property bar based on IoT Class	from the IoT class proposed for the extension of IoT elements, add the property bar for each one of the new 6 graphical activity elements
5	The tools and property panels must be collapsible	Add an option so the BPMN modeler can collapse and expand the tools and property panels
6	Add section for IoT Extension	Add section for IoT extensions with the 6 new task elements

The main purpose of the contribution is to add a properties table for each BPMN graphical element selected as per requirement 4 in table 3.3. For each new BPMN4IoT element more meta-data can be captured and used to describe the IoT BPMN elements in more detail.

In BPM As-Is analysis stage the value of meta-data information for IoT devices and how it relates to the process could help during process optimization, automation and management in later stages of the BPM life-cycle.

3.3.1 Physical Entity with Attributes

The physical entity and some properties are described in the work of Meyer et al.. Physical entity is given a high importance as an abstract representation of physical objects. The authors do not take into consideration that based on the BPMN formal specification an effort to represent physical item has already been done with the use the Class Item and the graphical element data object (management group, 2018).

Extending features of BPMN implies a big effort and a challenge is presented in the different artifacts that ought to be modified. Once BPMN is extended, the semantics of the extension must ensure that colliding with BPMN core semantics will occur. The graphical modeler must include the new changes, the modeler must export a XML based description of the process, the BPMS engine should also be modified and adjusted so that processes can be automated and executed.

OMG specifies the BPMN element item that has an enumeration literal with a physical or digital value see figure 3.1. The graphical element Data-Object could be used to represent the existence of physical or digital data elements. By using existing BPMN elements the effort on extension and automation of the process could be reduced.

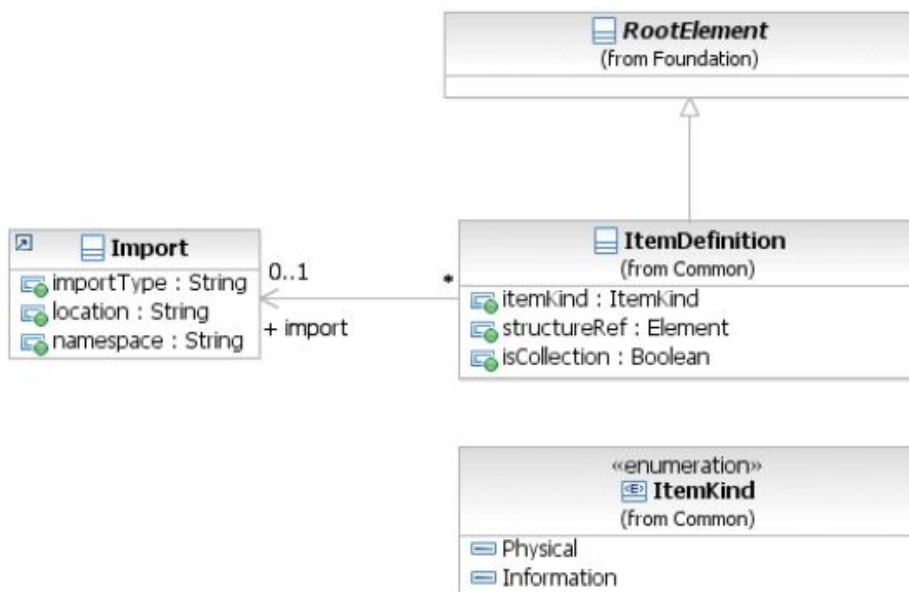


Figure 3.1: Class Diagram of Item element in BPMN
(OMG, 2011a)

3.3.2 UML Changes to Structure of the Software Architecture

The structure of the new modeler after the extensions is shown in figure 3.2. The IoT BPMN elements extension were organized in a new section in the BPMN toolbar. The property bar displays the proposed properties. Dummy functionality such as the Menu bar, cloud integration and the export to BPMN button were added to the modeler for suggested future work.

There are 4 main classes from figure 3.2:

- **Menu Bar:** contains dummy functionality aimed for future work that could include the ability to export a image, process description language and save to cloud service storage
- **Element Toolbar:** contains the left panel with all the BPMN graphical elements and the IoT extension elements.
- **Property Bar:** property bar that allows each BPMN element to contain meta-data

in the form of name-value attributes. The property data is exported to JavaScript Object Notation (JSON).

- **BPMN Export:** dummy functionality for future work as BPMN can be executed in a BPMS engine and a function to generate BPMN code can help to ease the automation of the modeled process.
- **XPDL Export:** The function was adapted to include the new structure of the modeler and the IoT extensions.

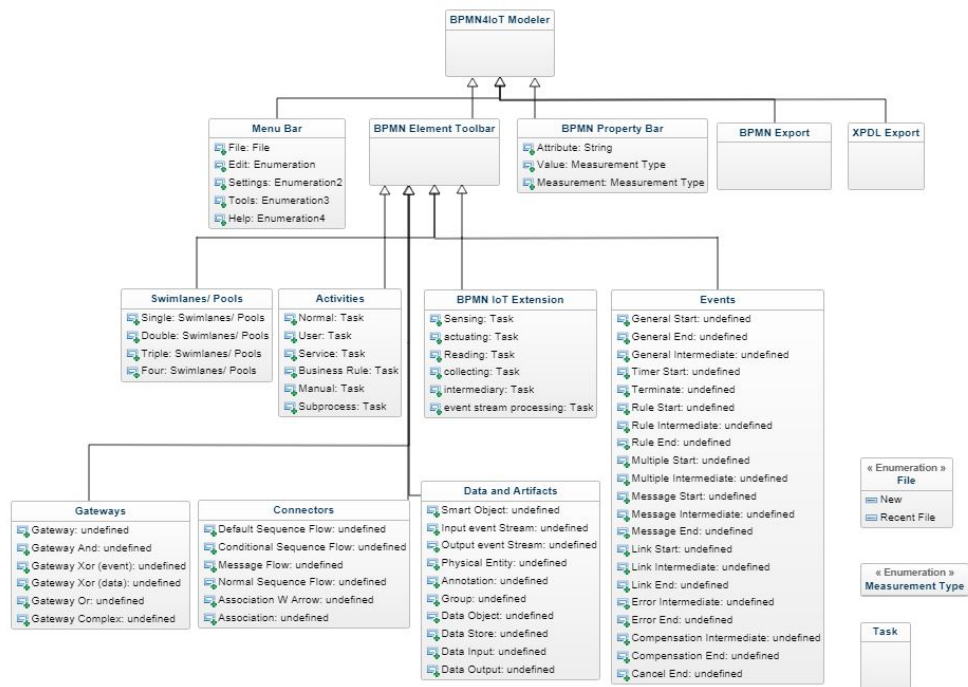


Figure 3.2: Software Architecture BPMN4IoT modeler

3.4 Properties generalization for seven IoT properties

The BPMN for IoT properties were generalized by adding the attributes: Attribute name, Measurement and Value type.

The UML class structure based on the BPMN formal specification was generalized. As seen in figure 3.3 the IoT inherits the attributes from the Task class defined in the BPMN specification. From the IoT Task as a layer extension to the meta-model, the 6 IoT task activities are described.

The new class IoT Task includes a generalized set of properties that any IoT device could use. based on ongoing research (Baumgrass, Herzberg, Meyer & Weske, 2014; Sang & Zhou, 2015; Bocciarelli, D'Ambrogio, Giglio & Paglia, 2017) the 4 proposed generalized properties are: Attribute, value, Measurement, Value Type. The practical explanation is given below uses an IoT sensor measuring heart rates.

- **Attribute:** heart rate
- **value:** 72
- **Measurement:** bpm (bits per minute)
- **Value Type:** number

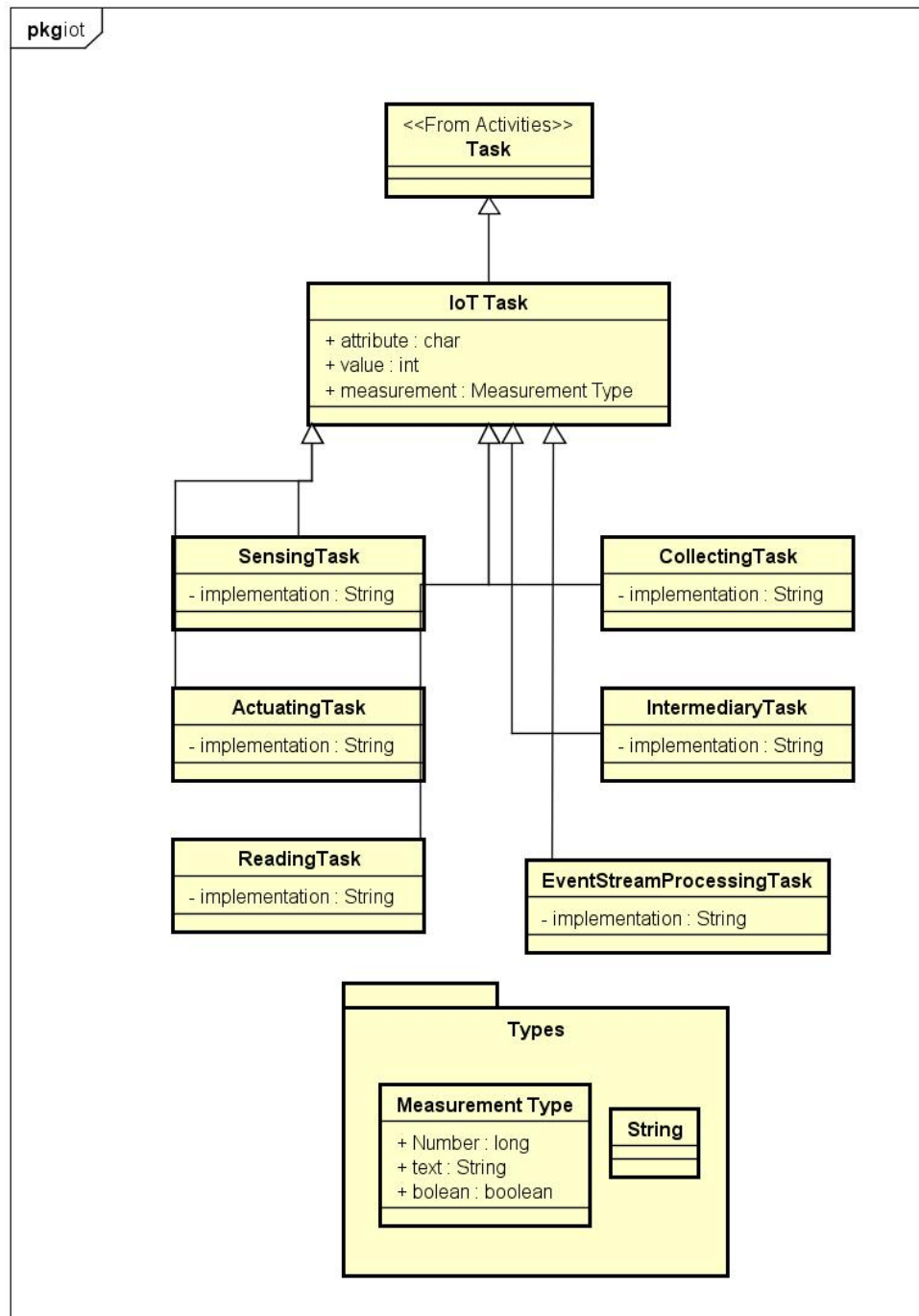


Figure 3.3: BPMN4IoT classes

3.5 BPMN4IoT Modeler

The JavaScript based modeler is tested in a local environment and then is published in a public github environment. Figure 3.4 shows the published modeler in an online git code repository.

The 6 requirements from table 3.3 were implemented. The properties table in the bottom section of the modeler allows to add properties to each BPMN activity element. Since the IoT devices vary in terms of capabilities and characteristics, general attributes are optional.

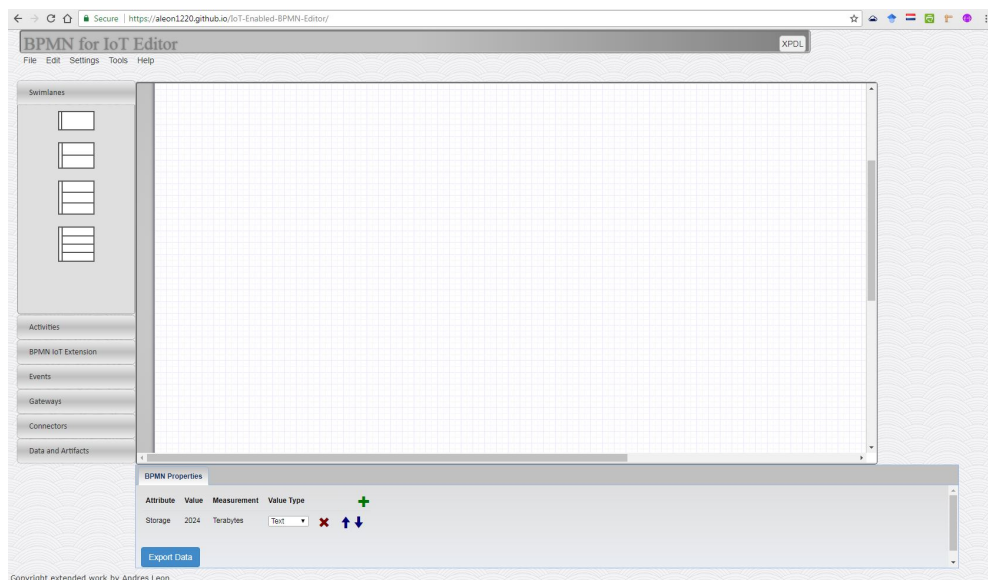


Figure 3.4: BPMN4IoT Modeler

3.6 Conclusion

In this chapter the changes and extension to the BPMN for IoT (BPMN4IoT) modeller had been described. The implementation of the properties bar for extra meta-data in the model and how the IoT Task Class contains 4 general characteristics: Attribute, Value, Measurement and Value Type have been explained. The development phase was done and the XPDL code generation function was also adapted. The properties for each BPMN task element can be exported to JSON file format.

The iot extension elements were moved to a new categorized section the the toolbar panel, changes to the software architecture were proposed and documented by using UML. in Appendix A, detailed instructions on how to use the modeler with the extension were provided.

Chapter 4

IoT Business Process Case Study

4.1 Introduction to the Analysis

The practical use of an IoT sensor device by a nurse in the health area for elderly care assistance is described. A business process for care assistance in which depends on several manual tasks to be executed.

By following the BPM life-cycle, in sub-section 4.2.1 the As-Is process is described and modeled using our modeling tool. sub-section 4.2.2 considers optimization to the process and the use of digital systems. sub-section 4.2.3 explain the To-Be process with use of IoT devices.

Section 4.3 analyses the data outcome of a sensor device used by the care giver role in the business process and aims to show the value of data from IoT devices.

Finally section 4.4 gives the conclusion of the chapter highlighting the value of data from the IoT sensor device.

4.2 Business process of care assistance for elderly people

4.2.1 AS-IS Process

The current process is described in figure 4.1. The process does not involve the use of any automated system nor IoT device. The only device that is used is a pager that activates and alarm in case an elderly residents press the button on their room.

Most of the activities carried out in the process are performed manually. To register key information throughout the process a physical book and a printed sheet are used.

The process to be described is the care assistance of elderly people in a rest home during morning shift from 7:00 a.m. start to 1:00 p.m. ending time.

The description of each activity from the process in its default flow is given in table 4.1. Each step of the process is described.

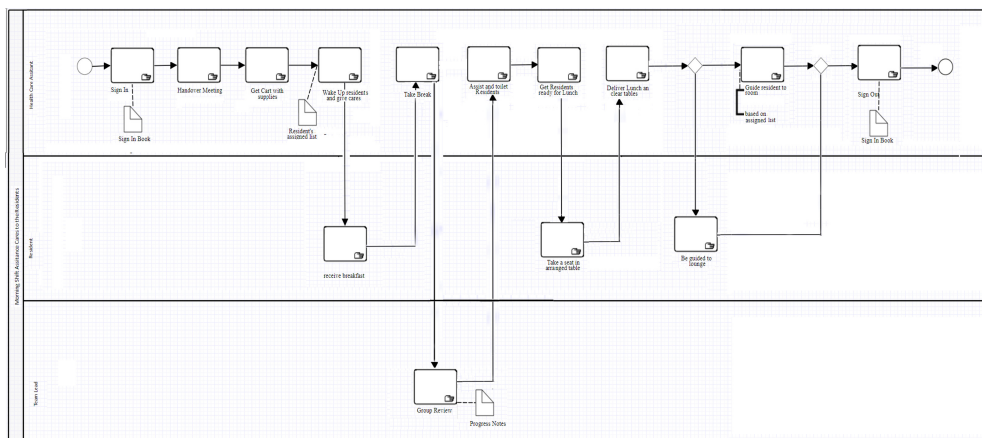


Figure 4.1: Morning Shift Health care assistance As-Is process diagram

Table 4.1: Description of As-Is process morning Shift Assistance Cares to the Residents

Activity	Description	Activity Type	Lane
Sign In	Using the sign in book each staff member must manually sign in and report time. Nurse signs in start date and time-stamp in the Sign In Book. The total time of the morning shift is 6 hours	Manual	Health Care Assistant
Handover meeting	The Team Leader hands out the results of the night shift and gives a general overview of what to do and which resident requires more attention for that day.	Manual Task	Health Care Assistant
Get Cart with supplies	The nurse gets the cart with all the supplies needed for the day	Manual	Health Care Assistant
Wake Up residents and give cares	based on the residents assigned list the actions include: validate basic health signs by sight, wake up residents, shower residents, personal hygiene activities	Manual	Health Care Assistant
Receive breakfast	Residents are given breakfast and delivered to the room	Manual	Resident
Take Break	Nurses are allowed to have 10 minutes breaks	Manual	Health Care Assistant
Group Review	The summary of activities and general comments on the health and response of all the residents. If any incident is to be reported everything is manually written in the progress notes of a physical book of all the morning shifts. This task generates the progress notes for the record book. some extra planning on later activities is done and added as commentaries in the morning shift book	Manual	Team Lead

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Table 4.1 – Continued from previous page

Activity	Description	Activity Type	Lane
Assist and toilet Residents	Residents are assisted in physiological activities and any other arising need	Manual	Health Care Assistant
Get Residents ready for Lunch	Residents are prepared for lunch and leisure time in the lounge	Manual	Health Care Assistant
Assist and toilet Residents	Residents are assisted in physiological activities and any other arising need	Manual	Resident
Get Residents ready for Lunch	Residents are prepared for lunch and leisure time in the lounge	Manual	Health Care Assistant
Take a seat in arranged table	Tables are arranged depending on social factors and the health status of the resident. For ease of logistics the positions are decide by the team Lead	Manual	Resident
Deliver Lunch and clear tables	Encourage that all food is delivered based on nutritional requirements Assist the residents in their lunch intake	Manual	Health Care Assistant
Be guided to lounge	If the resident is considered to be safe at the entertaining lounge the resident can be taken there	Manual	Resident
Guide resident to room	Some residents based on the Assigned List must go to their rooms to rest while others are taken to the lounge	Manual	Health Care Assistant
Sign Out	The nurse enters some brief commentaries and feedback on the progress of the day. The finishing time is manually entered	Manual	Health Care Assistant

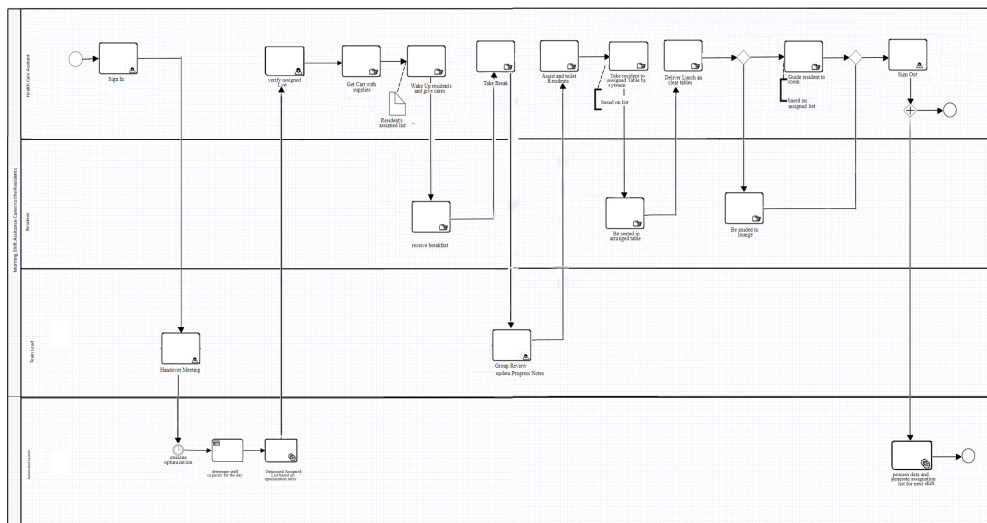


Figure 4.2: Morning Shift Health care assistance To-Be process diagram

4.2.2 To-Be Process

The process is optimized and for this example suppose the use of a web based application that offers user interface forms to replace any physical documents for digital persisted information.

The main impact in the To-Be process is the elimination of physical assets for data input and the migration to a software system. The nurse must login to a system, the meetings would produce as outcome a form with summary of the key points. Records must be filled and the IDs of the nurses must be entered.

The use of an automated system that is orchestrated by the BPMS engine creates a new lane or role in the process diagram. In the To-Be process based on data entered everyday the system executes business rules to determine staff capacity and improve efficiency in the list assignment. The list of residents to be cared for is now digital and is dynamic depending on some business rules such as number of staff, people on sick leave, staff on holiday, general report of each resident among others.

The BPMN diagram of the process is represented in figure 4.2 and table 4.2 describes the new tasks that were automated in the BPMS.

Table 4.2: Description of To-Be process morning Shift Assistance Cares to Residents

Activity	Description	Activity Type	Lane
Sign In	A digital form is offered to register the attendance. The User logs in by using username and password and the system automatically assigns time-stamp and relevant data.	User Task	Health Care Assistant
Handover meeting	The Team Leader discusses the results of the past shift. Notes, commentaries and group feedback for the current shift are added to the form in the process instance	User Task	Team Lead
execute optimization	triggers an optimization functionality on specific times of the day. The process engine constantly validates number of staff, average health and condition of the residents among other variables	timer event	Automated system
determine staff capacity for the day	analyzes the number of staff and improves the distribution of activities and assignation of residents to the list	Business Rule Task	Automated System
Optimized Assigned List based on optimization rules	A service is invoked to modify the dynamic list based on the process engine rules and process variables	Service Task	Automated System
Verify assigned List	The dynamic list is available in a user form by accessing the process portal in the BPMS or through a mobile phone device. The list is generated based on different variables to effectively optimize the time of the nurse.	User Task	Nurse
Group Review and Update Progress Notes	after the care activities, feedback from the team is presented and recorded in the progress notes	User Task	Nurse

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Table 4.2 – Continued from previous page

Activity	Description	Activity Type	Lane
Sign out	The user must log out and register their time out in a user form at the end of the shift	User Task	Nurse
process data and generate assignation list for next shift	The BPMS system invokes a service to process the data acquired on the process instance and persists the information for further analysis and processing. The valuable gathered information is used in the optimization of the next shift	Service Task	Automated system

4.2.3 To-Be Process with IoT Devices

A visual representation of the To-be process with the use of IoT devices and the BPMN4IoT extension is presented. New hardware devices such as a fingerprint scanner for the login activities and a wearable device such as Fitbit® to measure the health and performance of the nurses so that the system can properly assign the resident list without creating stress for the care givers while analyzing their performance.

The proposal in this diagram is based on the assumption that a healthy and energetic care giver would perform better. For this particular process the BPMS contains a business rule processor that leverages the optimization of the "assigned residents list" based on variables such as: caregiver's time of sleep, average heart bit per minute, weight and blood pressure. Based on the rules validation the system could automatically determine the best match for residents and caregiver to provide the cares of the day.

Figure 4.3 represents the new diagram with the use of IoT devices and the BPMN4IoT extension. The main change is in the use of a reader device with RFID for the login

activity. A wearable device is constantly monitoring data in the caregiver. As soon as the wearable device is within range with an IoT Gateway data is process by the intermediary task and data is transferred to the BPMS engine.

table 4.3 describes the new tasks that were automated in the BPMS for the To-Be business process. Only new tasks are added and described.

Table 4.3: Description of To-Be with IoT process morning Shift Assistance Cares to Residents

Activity	Description	Activity Type	Lane
Scan fingerprint for login	The user is assigned a swipe card and is used with a RFID device to register login and log out. The device connects with the IoT Gateway.	IoT Reading Task	Health Care Assistant
connect Fitbit® to IoT Gateway if in range	The wearable device connects to the IoT Gateway and synchronizes the data	IoT Reading Task	Health Care Assistant
process data and send to IoT Gateway	the task collects the data from the IoT wearable device and prepares it to be sent to the IoT Gateway and BPMS engine	Intermediary task	Health Care Assistant
Notify BPMS	collects the prepared data and notifies the BPMS engine so that business rules task can be executed	Business Rule Task	Automated System
Validate rules for the day	the business task rule activity processes the gathered data in the BPMS engine and determines the procedure to follow	Business Rules Task	Automated System
Optimized Assigned List based on optimization rules and IoT Data	Collected data is processed and an optimized list of residents is generated	Service Task	Automated System

Table 4.4: Summary table gathered data from sensor

Column Data	Median	Avg	Min	Max	Sum
BMI	20.99	21.11	20.99	21.39	654.49
Weight	52	52.31	52	53	1621.5
Calories Burned	1595	1672.03	1189	3008	51833
Steps	3720	6639.97	1982	18798	205839
Floors	10	11.45	1	35	355
Minutes Sedentary	1440	1300.19	934	1440	40306
Minutes Lightly Active	277	253.73	102	453	7865.6
Minutes Fairly Active	5	21.94	4	138	680
Minutes Very Active	12	25.55	9	209	792
Activity Calories	580	817.26	357	2188	25335
Distance	2.42	3.918	0.3	12.25	121.47

Figure 4.4 shows the relationship between the number of burned calories on the Y axis to the corresponding date on X axis. The gradient color is calculated by the change of weight. Surprisingly, the weight tends to increase as more calories are burnt.

Figure 4.5 compares the BMI and the date showing another view of increase in weight and hence BMI. the size of the markers is determined by the minutes where the nurse is very active. By the end of the month the weight seems to increase but the time of demanding activity tends to be on the average value of 22 minutes very active.

Figure 4.6 shows a scattered graph weight vs number of steps taken during the month. the color of the markers is indicated by the number of the week for the corresponding

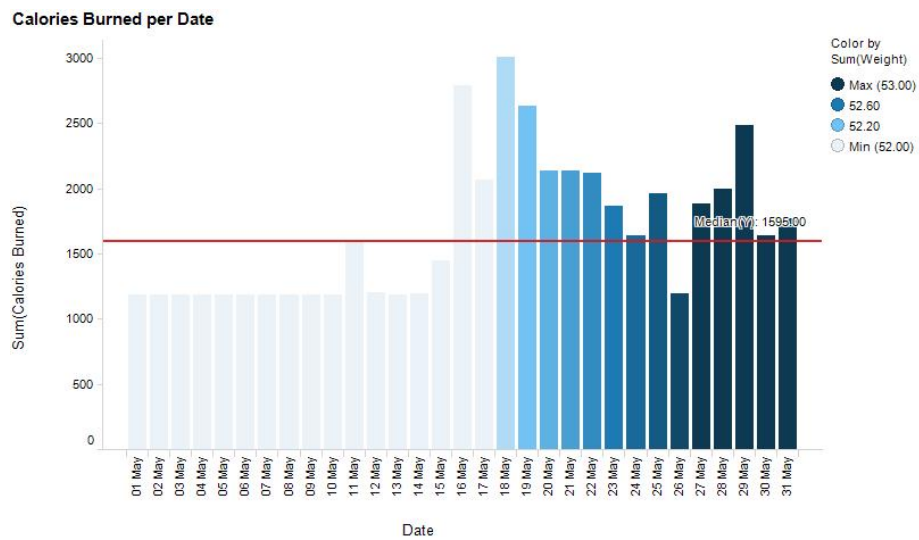


Figure 4.4: Calories burned per Date

month in this case is may 2018. The weight and the number of steps taken tend to increase by the end of the month or the last two weeks. By week 21 and 22 between 10000 and 16000 steps are taken.

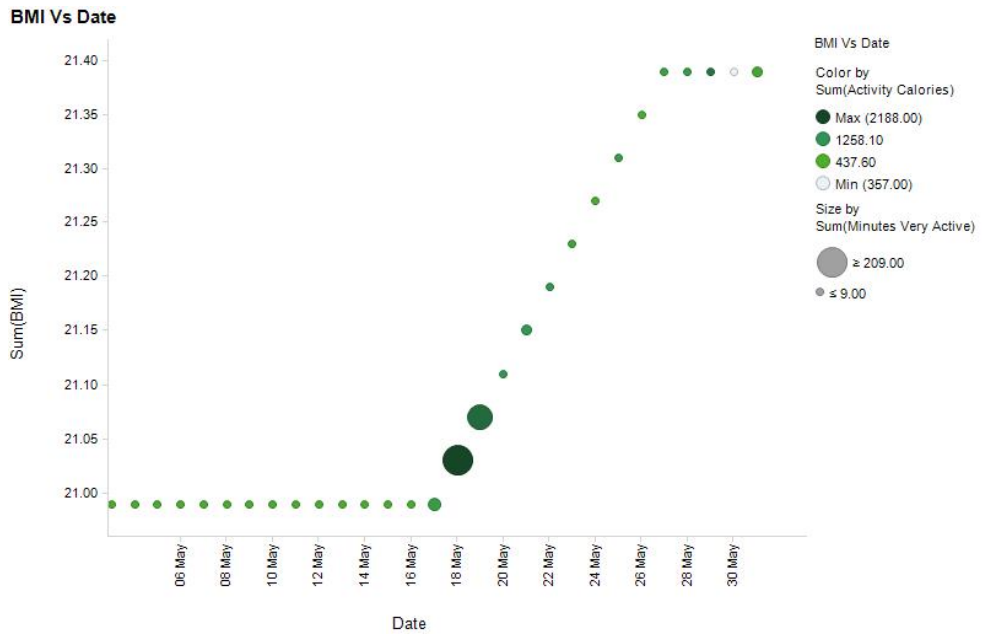


Figure 4.5: Body Mass Index per Date

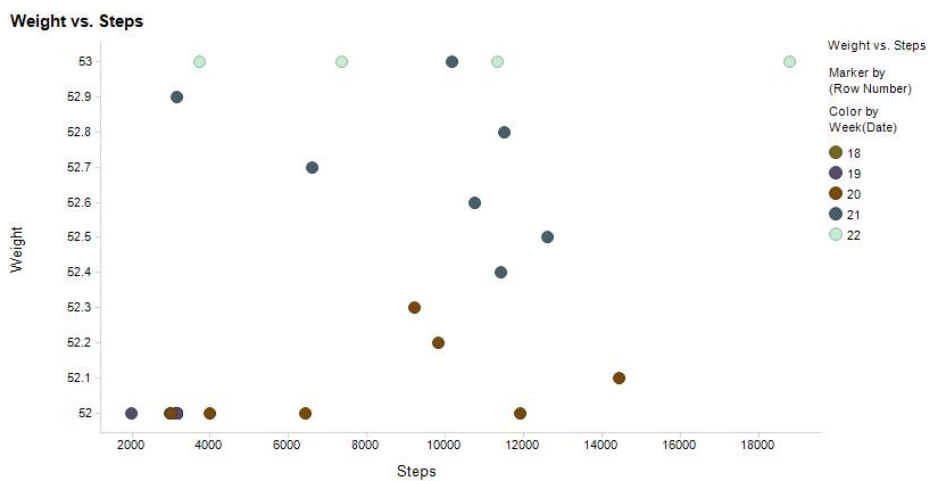


Figure 4.6: Weight Vs Steps taken in a day

4.4 Conclusion

The use of extended BPMN elements that functionally describe the capacities of IoT helps in designing complex but easy to understand business processes. In this section a business case that involves several manual tasks is described. Following BPM methodology the process is designed As-Is with several manual activities, To-Be process involving the automation of many manual tasks and finally a version of a To-BE process that integrates the BPMN4IoT extension with an optimized proposal of the business process. The process evolves in the modeling as digital technology is applied. When IoT elements are added the process in an automated environment could become complex.

The data that is gathered by a sensor provides valuable information to take quick decisions and analyze facts that were not easily perceived. Obtaining this sample of data encourages further questions for the caregiver such as: *what type of diet is affecting the increase of weight and BMI while the high number of burned calories is still present? what other variables or social factors intervene in the life of the caregiver so by the last two weeks of the month the effort seems to increase?*

The answer to this question could be answered only by detecting and filtering more valuable data. The use of a personal IoT device opens the imagination to formulate questions that could be answered by data analysis. The last phase of the BPM life-cycle uses the optimization or improvement activity. By analyzing data outcome from a process, new suggestions could be given to dramatically make the process more effective (LaValle, Lesser, Shockley, Hopkins & Kruschwitz, 2011).

Chapter 5

Conclusion

5.1 Introduction

IoT for BPMN is an area of growing academic interest and research. An early adoption of IoT could bring about return of investment for enterprises.

While the importance of integrating new BPMN for IoT elements into business process modeling is been portrayed in this work, research on the run-time capabilities of the BPMN extensions is required.

In this document an online modeler was extended to include attributes of IoT BPMN elements. A case study was proposed and the BPM discipline life cycle was applied. The outcome of real data from the proposed As-Is business process was used to show the value of an IoT sensor and its gathered data.

5.2 Limitation of Research

In general the main limitation or constrain were the time fpr research and the automation of XPDL process language with IoT extensions.

One big limitation that was faced is the use of XPDL to represent the model. XPDL is a rigorous graph model based on XML language. It is compatible with BPMN after several adjustments and correlational mappings in the process semantic. XPDL is not supported by many BPMS engines and to adapt it in a run-time engine the XPDL file must be mapped to BPMN first, BPMN must be adjusted with the extensions and the executing engine must be extended and tested. This series of steps made the goal go out of the scope of the initially defined goal.

For the first research question the BPMN modeler was extended by adding the properties bar to support the addition of many attributes with name value, measurement and value type.

The second research question could be answered by proposing an extension of this work and exporting the modeled process to BPMN to further customize an open source BPMS engine. XPDL is no suitable to be used in a process engine. BPMS engines are using BPMN language to automate the processes.

5.3 Improvements per chapter and section

A general overview on improvements or suggestions for in depth research per chapter and corresponding section is presented in table 5.1

Table 5.1: Improvement of section in the document

Chapter	Section	Suggested improvement
1	1.1	business processes are also evolving into Application Programming interfaces (API) function calls. This section could be extended by referring to current research on business process evolution and the use of APIs and services to achieve functionality in an enterprise
1	1.2	For the research question the ongoing work from AUT student could also be combined with research from other New Zealand tertiary education providers in this area
1	1.3	Recent trends in IoT move towards the large scale implementation of IoT in smart cities and health sector. The latest projects in these areas could be a focus on future research
1	1.4	Time constrains more in depth goals. BPMN as the executing language for the BPMS engine. XPDL is becoming an obsolete language hence the automation in future work should be done in BPMN
1	1.5	The contribution is a pathway to further research in the area. The suggestion is to enhance the proposed steps of BPM as a process discipline and suggest new practical research into the field of process automation with IoT devices
2	2.2	Focus on the proposed IoT architecture and references to IoT NIST standardized proposals
2	2.3	Research in the area of process management that includes the use of IoT devices for enterprise business

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Table 5.1 – *Continued from previous page*

Chapter	section	suggested improvement
2	2.4	A set of formal proposals to OMG should be a research topic. BPMN extensions should be standardized based on IoT architecture and be published by a regulatory organization such as OMG for ease of vendor adoption and implementation
2	2.5	Most proposals integrate IoT with BPMS either using ESB, IoT Gateway or APIs. Research that shows point to point integration IoT with the BPMS should be used. An example could be work that is focused on sensors directly connected to the BPMS so that the process can take dynamic paths at any point
3	3.2	References to similar research efforts on BPMN for IoT extension. Continuation of work by authors such as Meyer et al.; J. Lee et al.; Andersen et al.; Bocciarelli et al.; Chen and Wang
3	3.3	An example of run-time execution for each one of the IoT proposed requirements in different business areas should be provided
3	3.4	An evaluation framework should be used to test the quality and behaviour of the extensions and meta-data properties in a BPMN model. Suggested academic work is found in authors Rolón, Chavira, Orozco and Soto and Yan, Reijers and Dijkman
3	3.5	The use of best practices for front end development combined with efficient practices for academic research purposes. Work done by Jiménez et al. proposed important elements
4	4.1	The To-Be and To-Be IoT modeled processes were not validated in execution time. A functionality in the modeler to to Business Process Simulation (BPS) should be added. Simulation of a process could generate valuable data that might show weak points in the process while saving money in further implementation efforts (Pufahl, Wong & Weske, 2017)

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Table 5.1 – *Continued from previous page*

Chapter	section	suggested improvement
4	4.2	Gathered data from IoT devices could be useful to find optimization in the process. One issue is the limitation of product vendors to connect their devices to customized software systems such as BPMS. Data will likely play a key role in the integration and usability of IoT in the future (Díaz, Martín & Rubio, 2016)

5.4 Improvements to the modeler

Improvements to the software modeler are categorized in Graphical User Interface (GUI) such as user experience and visual look and feel. The functions category is about cloud integration and model validation and process portability describes proposed features to easily import/export the process diagram.

1. GUI:

- BPMN events should have a label on the bottom
- Implement Zoom in and zoom out function to the canvas
- Add a pop up box when the modeler opens to give the user a suggestion on first steps to be taken to start modeling
- implement a rename function to change the name of all BPMN elements in the canvas

2. Functions:

- Re-sizing of Pools, lanes and BPMN tool elements

- ability to login with a cloud service. Single sign on (Hinton, Bade, Linton & Rodriguez, 2017)
- Add an online manual for user's help

3. Process portability:

- export model to BPMN language
- export model to image format such as JPEG or PNG

5.5 Suggested Future Work

When it comes to the involvement of IoT in BPMN, the use of our modeler is recommended as an strategic objective of BPM projects involving IoT devices to leverage the organizational agility and operational efficiency goals (Van Der Aalst et al., 2016). If the modeled process with IoT features is to be automated technical considerations should be considered such as exporting the modeled process as BPMN format and modifications to the BPMS engine.

To execute BPMN in a BPMS engine, an open source BPM engine is recommended (Geiger et al., 2015; Schulte, Janiesch, Venugopal, Weber & Hoenisch, 2015). The BPMS engine should be adapted to execute the BPMN4IoT extensions. It is recommended to modify the BPMS engine with Requirement 1 sensing task element presented at table 3.2 and implement the properties for the corresponding IoT sensor representation.

Once the the BPMS engine is extended a process that uses a sensing task should be deployed and tested with any sensor directly connected to the BPMS engine. A suggestion is to connect a sensor through Bluetooth Low Energy (BLE) to a BPMS engine running in a containerized environment. This proposal would become a point to point integration that at the moment is not present in academic research as a proof of concept.

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Appendix A

Instructions for the JavaScript BPMN4IoT modeler

A.1 How to model and export

- Access the online modeler published at <https://aleon1220.github.io/IoT-Enabled-BPMN-Editor/>
- Select from the toolbar on the left side a single, double, triple or four lane pool according to the process definition
- From the events section drag and drop a General Start and General End event elements to the canvas on the right side of the screen see A.1
- Drag and drop a BPMN4IoT element from the "BPMN IoT extension" section of the toolbar to the canvas see A.2
- Add other BPMN elements as desired
- Click on "connectors" section from the toolbar panel, select a suitable connector

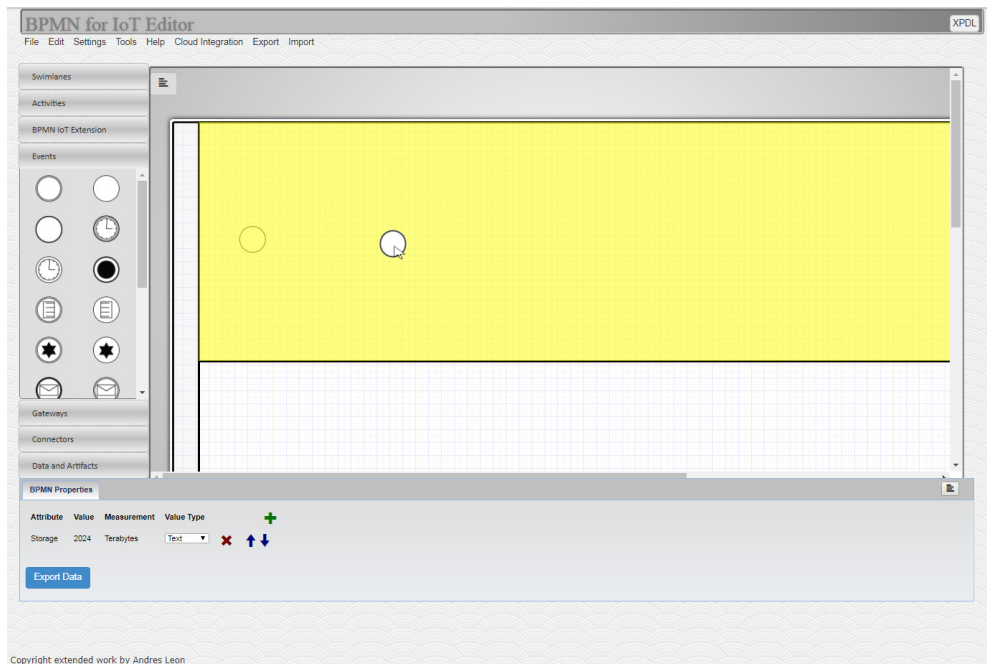


Figure A.1: Drag and drop start and end events from the left toolbar panel

- Connect the "start event" and other BPMN elements that have been added to the canvas to create the flow see A.3
- To name the BPMN elements present in the canvas, double click on the desired element and set the name as seen in A.4
- Select the BPMN task element and modify the properties as desired in the properties table located in the lower part of the modeler. see A.5
- After done with the process modeling click in the button "XPDL" located in the right corner of the modeler, select the XPDL code and save to a text file. See A.6.

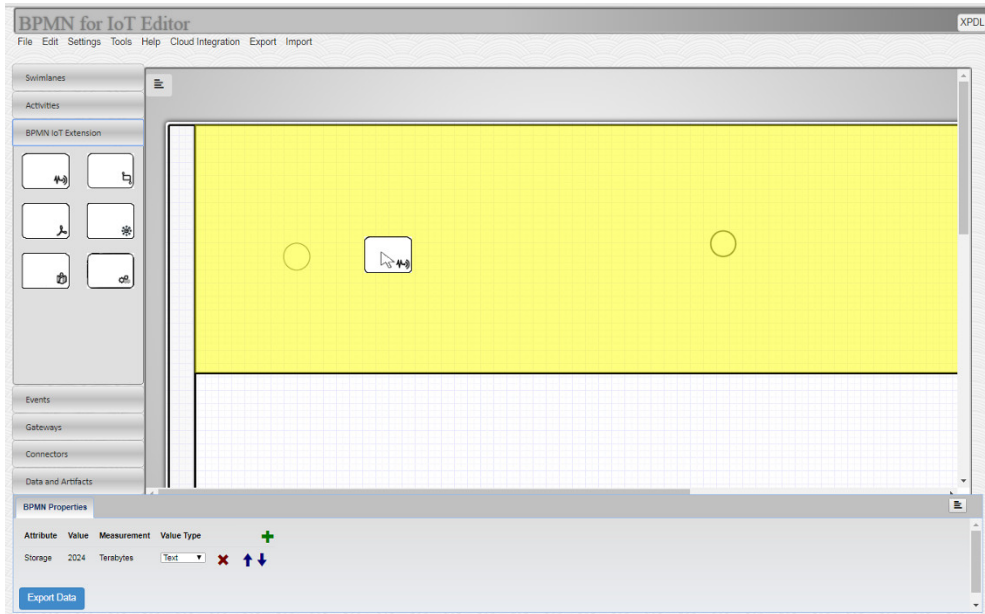


Figure A.2: Proof of Concept automated process with IoT

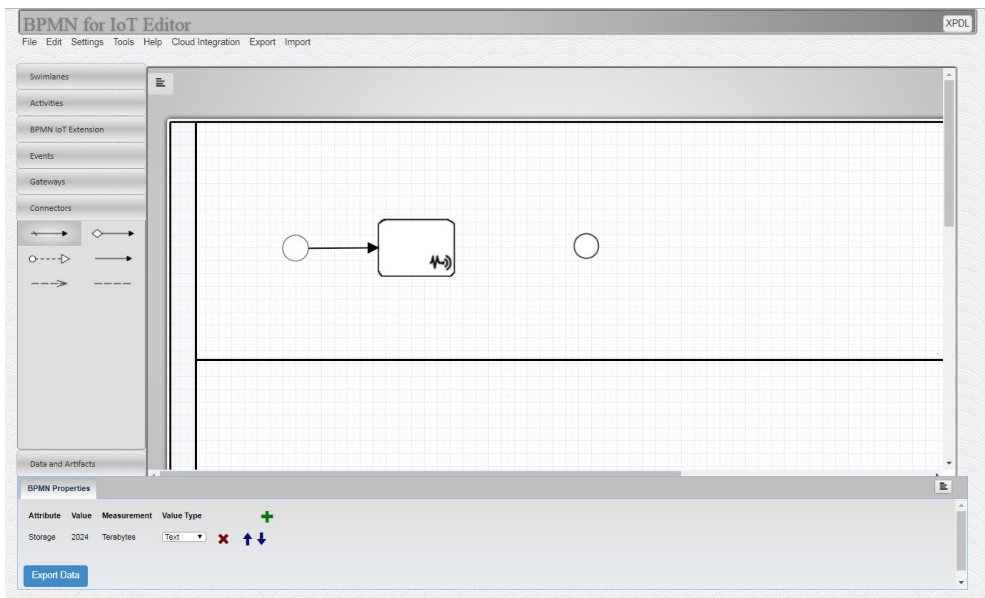


Figure A.3: Drag and drop elements from the left toolbar panel

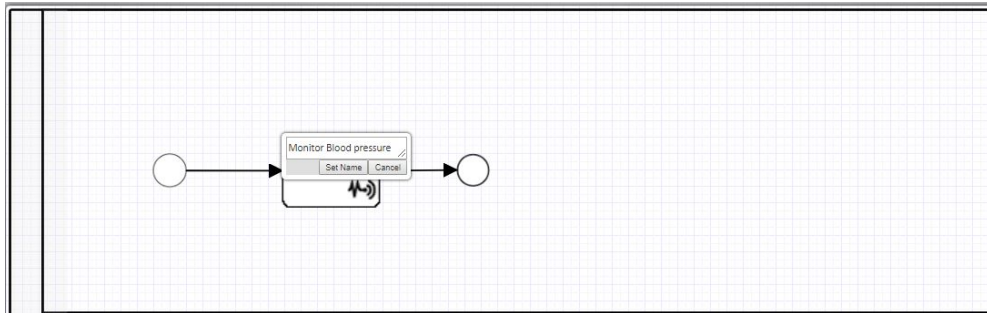


Figure A.4: Renaming BPMN element

BPMN Properties

Attribute	Value	Measurement	Value Type
pulse rate	80	Beats Per Minute	Number

Export Data

Figure A.5: adding properties for BPMN element

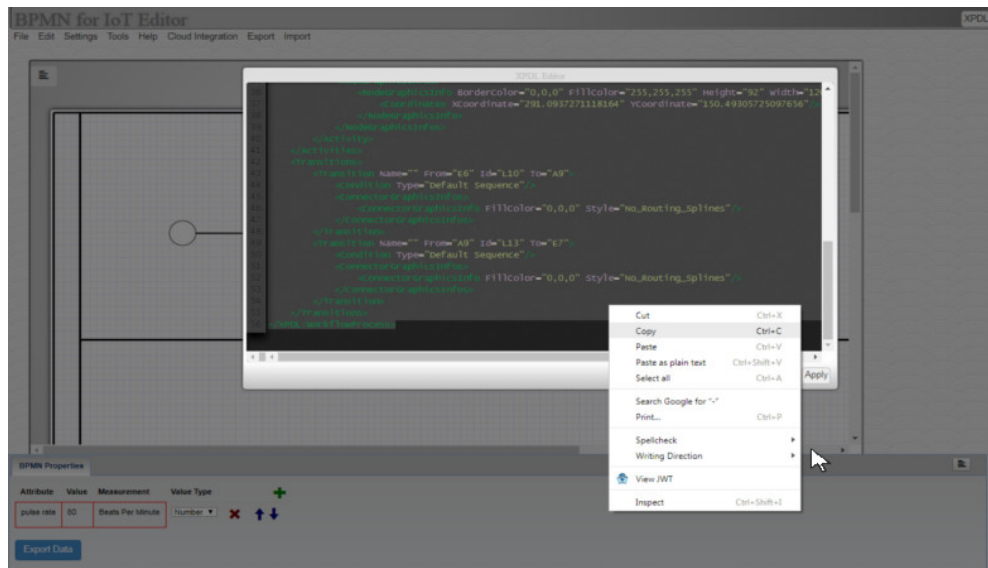


Figure A.6: exporting and saving XPDL