Business Process
Meets
Internet of Things

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Interests

- Business Process Management
- BPMN
- **BP** & **IoT** modeling and enactment

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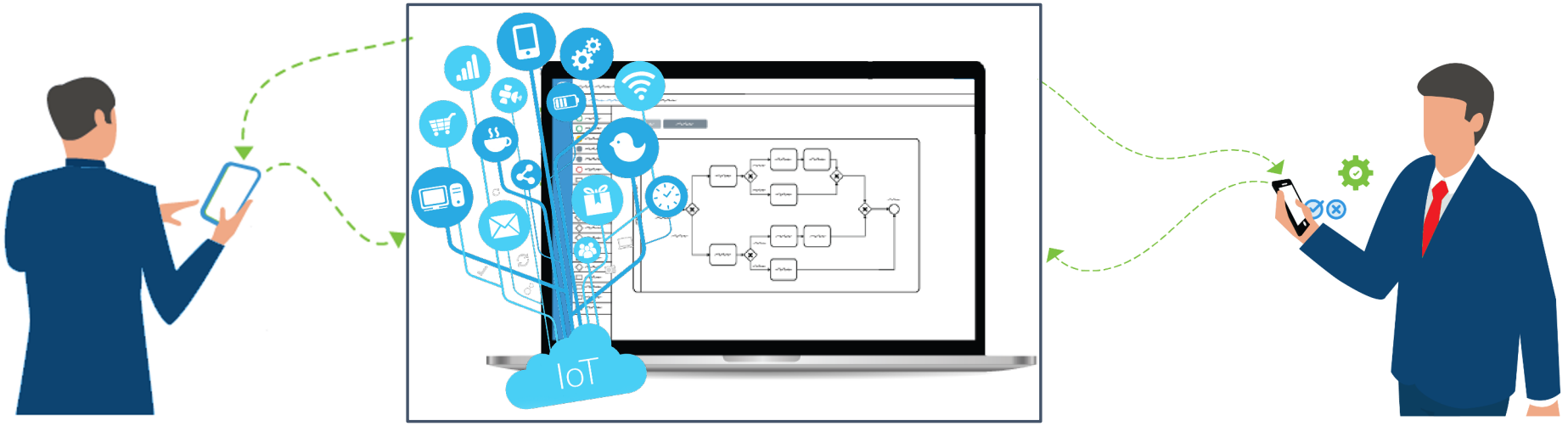
Business Process Meet IoT

Internet of Things

Network of interconnected devices that collect and exchange data to monitor, control or transfer relevant information so as to be able to perform consequent intelligent actions

Business Process

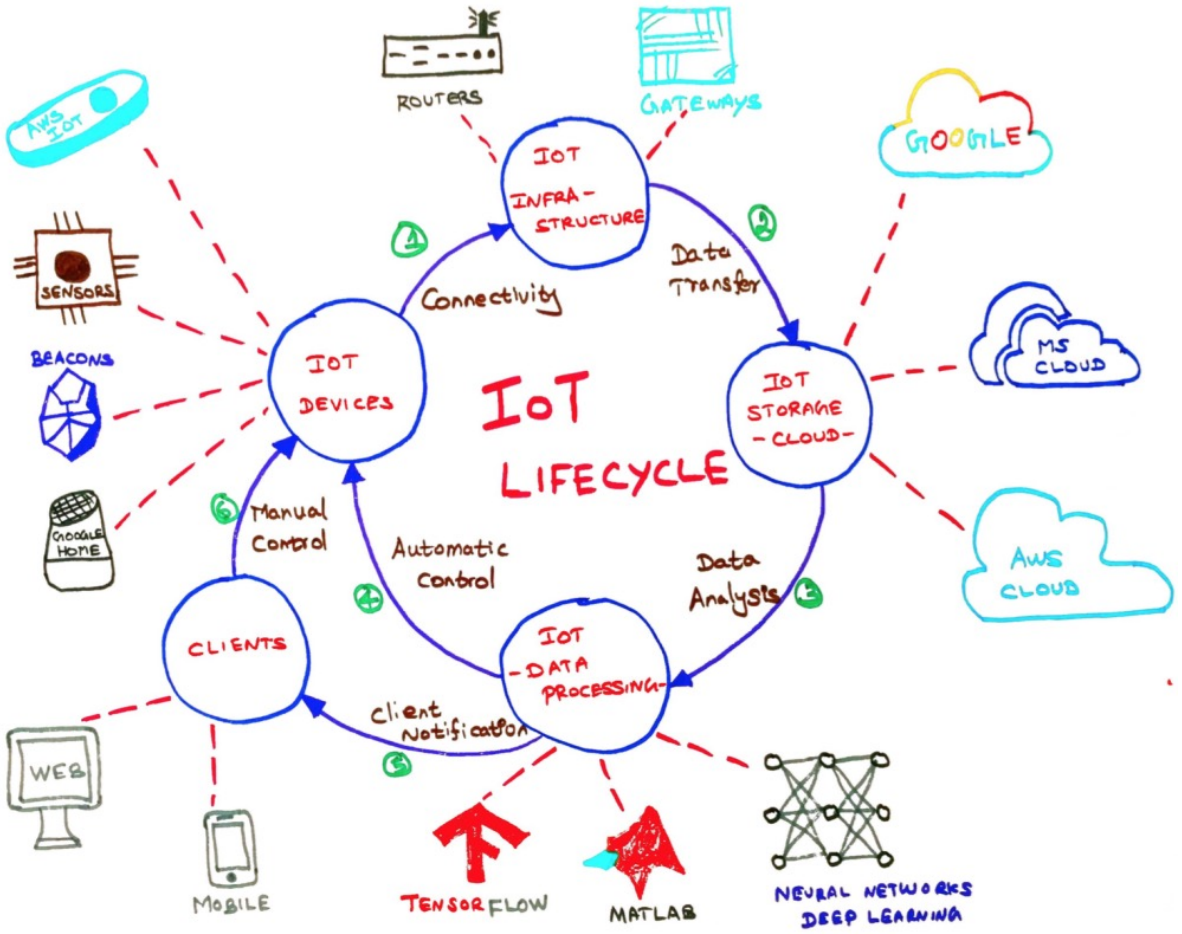
A set of activities, tasks or actions to carry out a specific organizational goal such as a service or a product



The Internet of Things

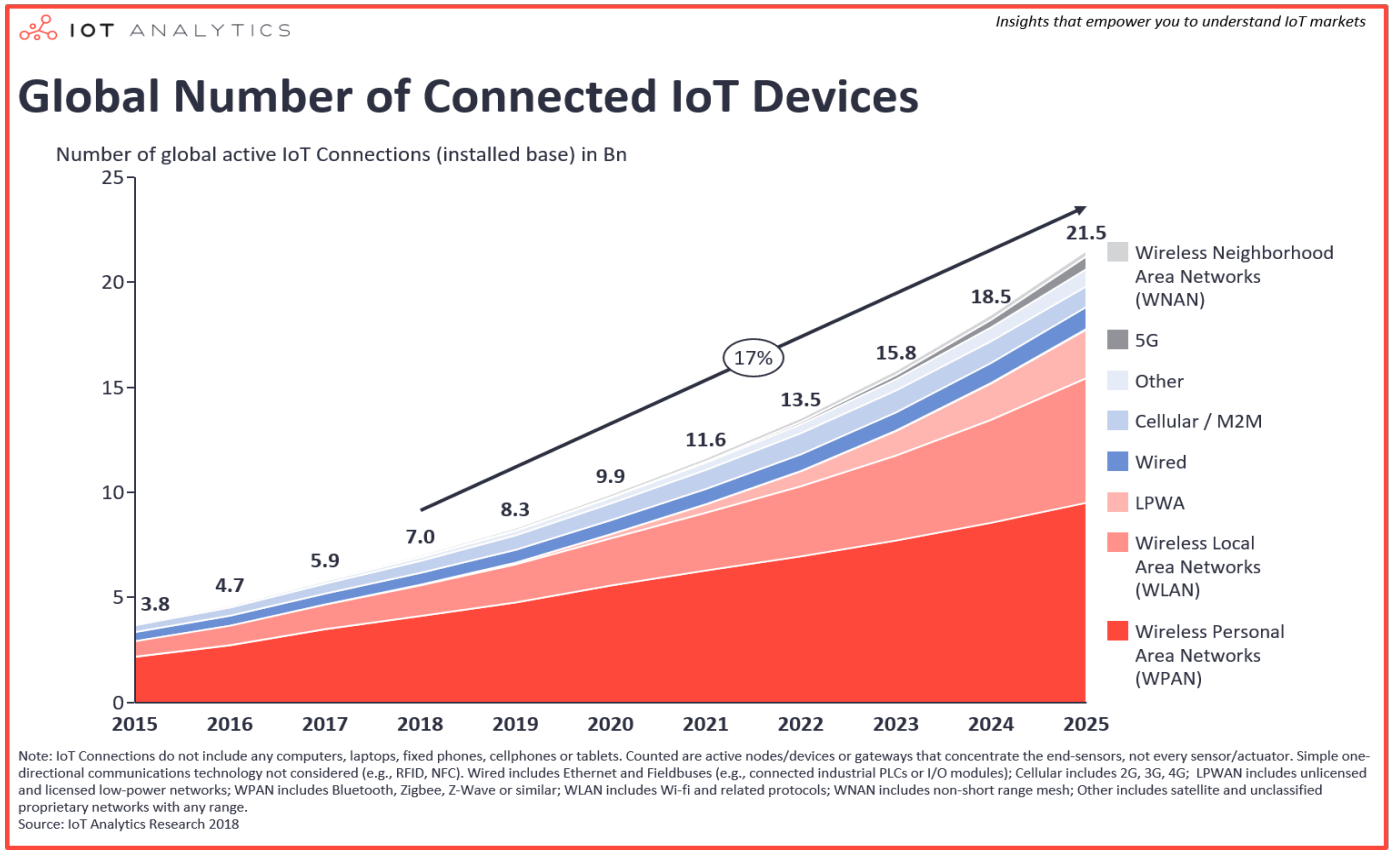
The *Internet of Things* is an eco-system generally composed by 5 elements:

- **IoT Devices:** *Sensors*, *actuators* or any device that produces data or events
- **IoT Infrastructures:** *Gateway*, *routers* or any device to ensure the communication across devices and cloud
- **IoT Cloud Storage:** Cloud to store raw device data
- **Data Processing:** Pre-processing data with Machine Learning or Artificial Intelligence techniques
- **Client Devices:** Data visualization and/or user interaction with the IoT system



The growth of the Internet of Things

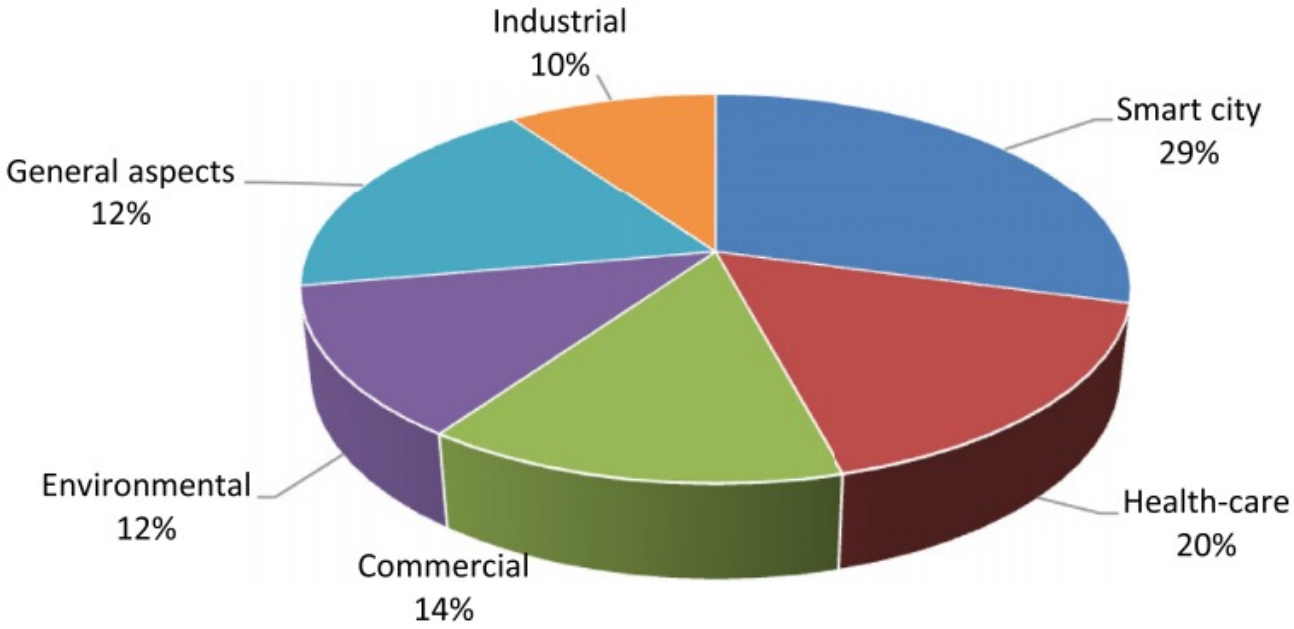
- The term «***Internet of Things***» has been introduced about 20 years ago
- The trend of the *Internet of Things* is growing
- Most common **application domains:** *Healthcare, Smart City, Industrial, Environmental and Commercal*



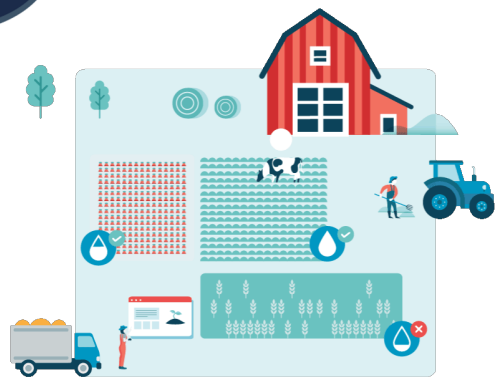
[1] IoT Analytics – State of the IoT https://iot-analytics.com/state-of-the-iot-update-q1-q2-2018-number-of-iot-devices-now-7b/

Internet of Things: Application Domains

- **Health-care:** (e.g. *localization and real-time information about a patient condition)*
- **Smart city:** (e.g. *smart parking, smart streetlights)*
- **Industrial:** (e.g. *Advantages of transformation into Industry 4.0)*
- **Environmental:** (e.g. *Environmental pollution monitoring)*
- **Commercial:** (e.g. *Improve a customer experience, Amazon go)*
- **General Aspects**

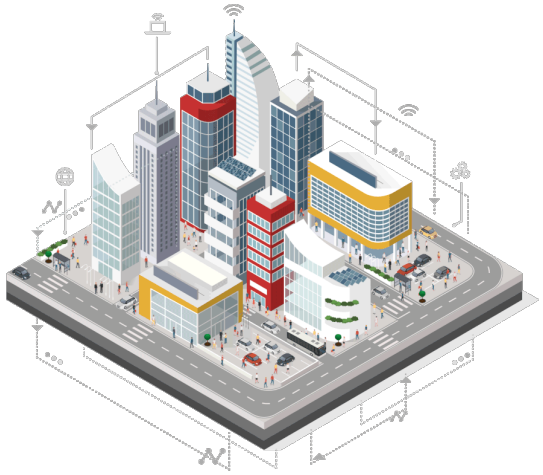


[1] Asghari, P., Rahmani, A.M., Javadi, H.H.S.: Internet of things applications: A systematic review. Computer Networks 148, 241–261 (2019)

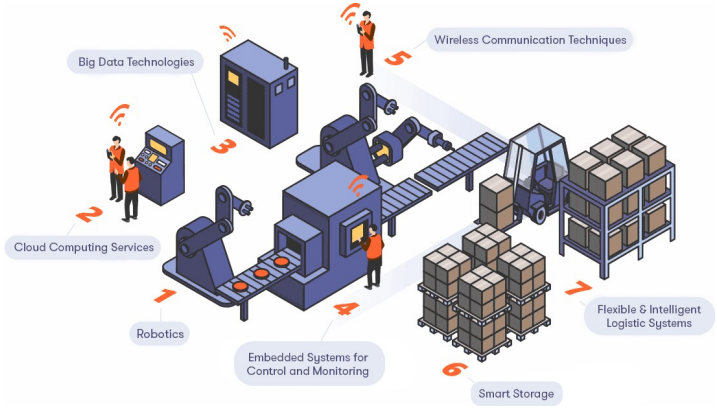


Smart Agriculture

Healthcare



Smart City



Industry 4.0

Smart Logistics

Business Process Management

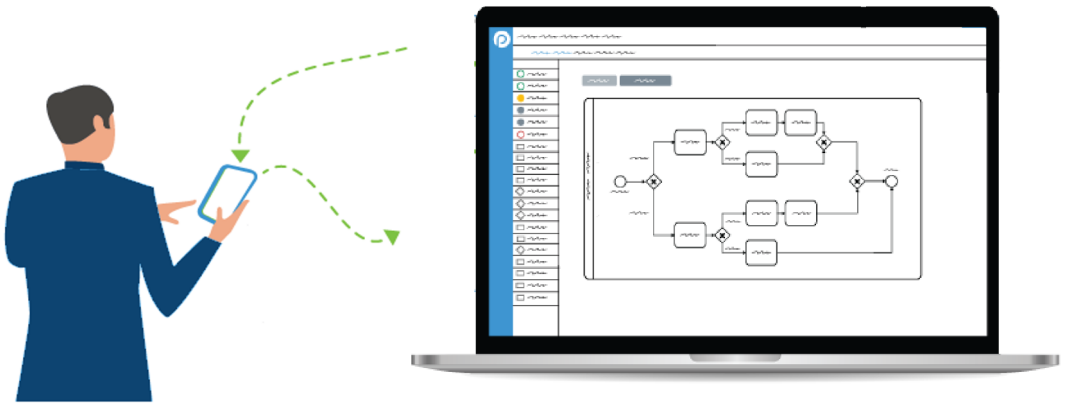
BPM enables organizations to **align business functions with customer needs**, and helps executives determine how to **deploy, monitor and measure company resources**. When properly executed, BPM has the ability to enhance **efficiency** and **productivity**, **reduce costs**, and **minimize errors** and **risk** – thereby **optimizing results**.

Not only enterprises...

...But also organizations of any kind

Continuously evolving processes

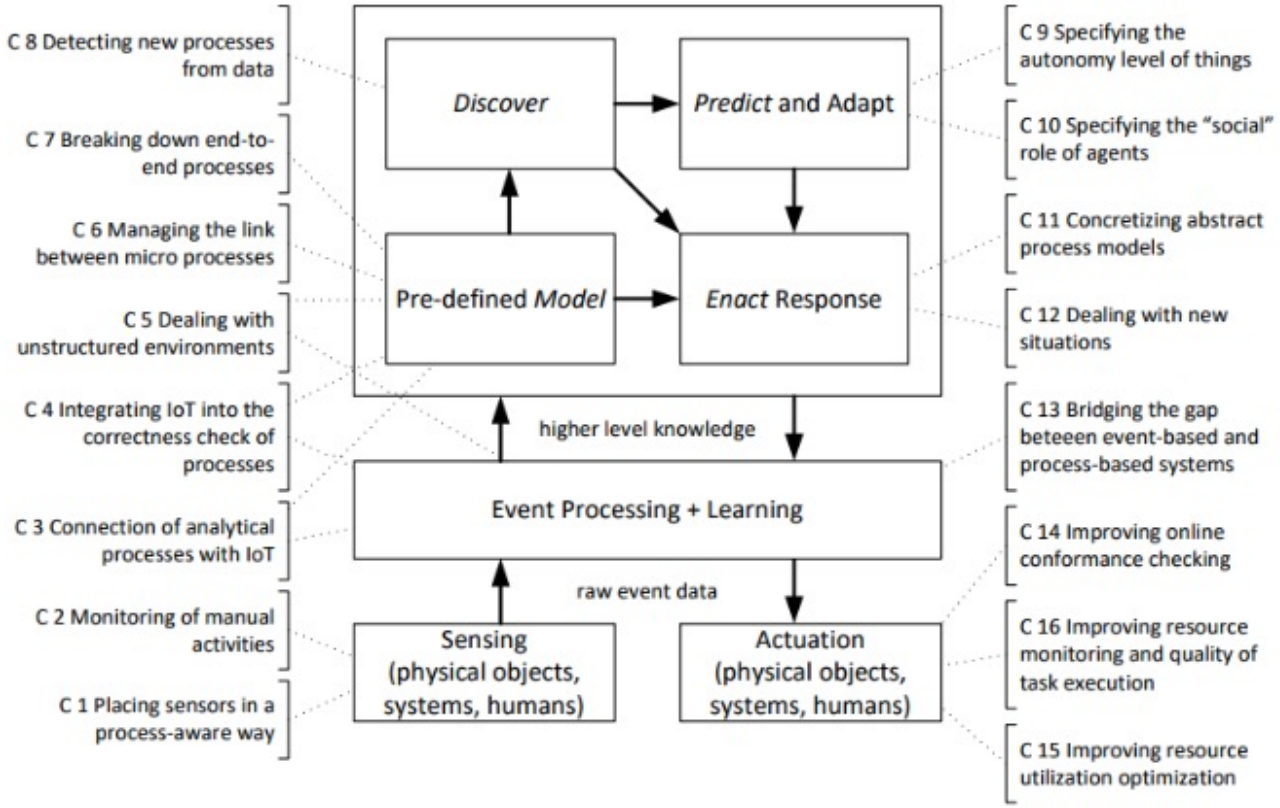
Through several iterative steps, it helps to improve and constantly update the organisational process.



Business Process Meet IoT… why?

- **Design** and **monitoring** of the smart environment for a **better execution**, **safety** and **less complexity**
- **Bridging the gap** between the high level of the Business Process and the low level of the IoT technologies
- Programming of "**dependencies between independent devices**“ in a process-oriented vision
- The spread of IoT technology must be aligned in organizational processes

The IoT Meets BPM Manifesto



[1] Janiesch, C., Koschmider, A., Mecella, M., et al. (2017). The internet-of-things meets business process management :mutual benefits and challenges, arXiv :1709.03628, 2017

Business Process Meet IoT … but Data?

Can represents a **real value** for an organization

Big Data as a business engine for enterprises

Can be transformed into **knowledge** to take **a decision** based on data analysis

Can represents a **fundamental role** in all business processes

The role of Data in the IoT

SMART CITY

- Data for the traffic management
- (e.g. *sensor data from public and private vehicles, may be combined with information on large events, in order to optimise traffic flow*)

SMART MOBILITY

- Data for the car management
- (e.g. *data sources such as car sensor data from a private vehicle, can pre-emptive maintenance and control the necessity to spare part requirements*)

SMART AGRICULTURE

- Data for the optimization of agriculture
- (e.g. *data from various sources such as soil conditions, climate, crop conditions, farm equipment, irrigation sensors, air pollution, cattle conditions, grain silos and more could be analysed to produce solutions that improve efficiency and increase yield*)

The role of data for the Enterprise

PREDICTIVE ANALYTICS

*Advanced tools that perform **data analysis to answer questions** about what might happen in the future*

DESCRIPTIVE ANALYTICS

*Tools oriented to **describe the current and past situation of business processes** and/or functional areas*

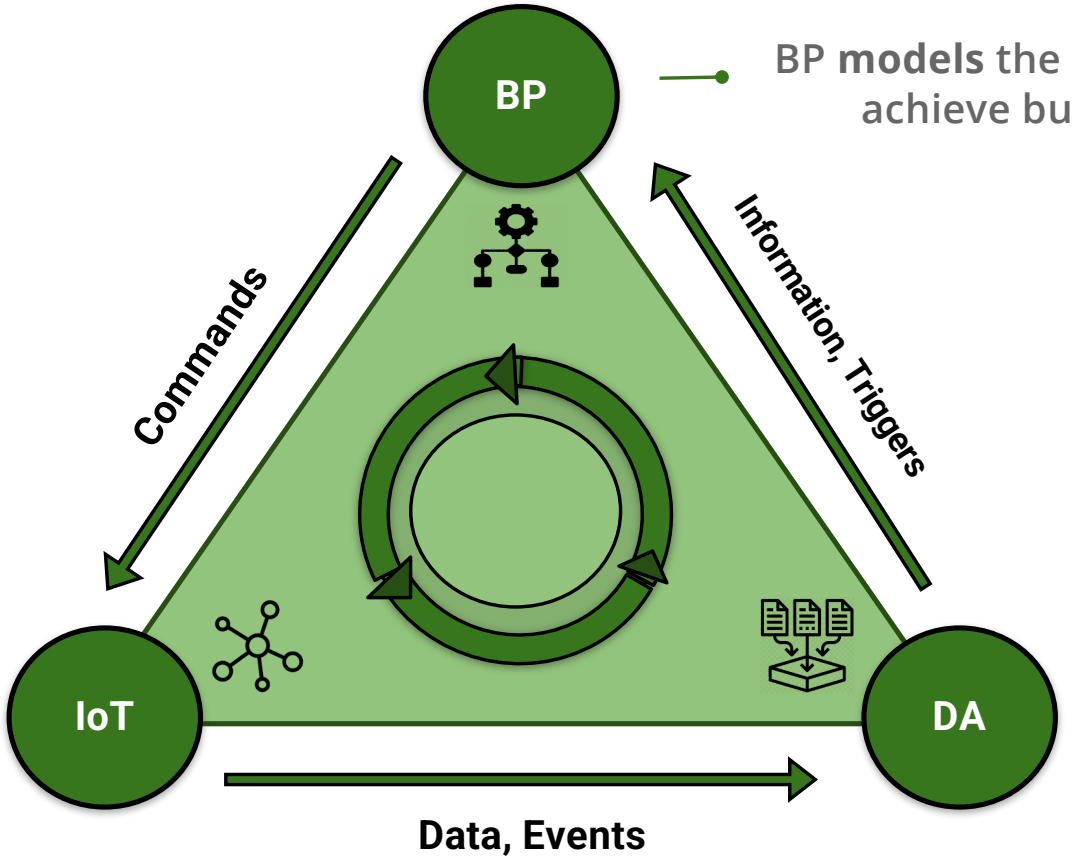
AUTOMATED ANALYTICS

*Tools capable of **autonomously implementing the proposed action** based on the result of the data analysis carried out*

PRESCRIPTIVE ANALYTICS

*Advanced tools able to **propose strategic solutions to the decision-maker** based on the analysis carried out*

Business Process Meet IoT … but Data?



BP **models** the process logic to achieve business **goal**

IoT elements represent **physical world** providing **data**

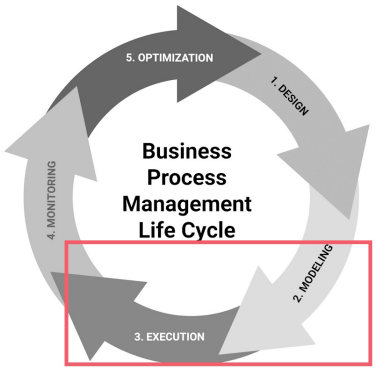
Data lead the **enactment** and the **logic** of business process

[1] Paul Grefen et al. "Complex Collaborative Physical Process Management: A Position on the Trinity of BPM, IoT and DA".

BP & IoT... let's discover something!

- Analysis of existing literature to discover the current state of the art

- Systematic Literature Review focus on the **modeling** and **enactment** (partially) phase of the BP life cycle



Modelling Notations for IoT-Aware Business Processes: a Systematic Literature Review

Ivan Compagnucci[1], Flavio Corradini[1], Fabrizio Fornari[1], Andrea Polini[1], Barbara Re[1], and Francesco Tiezzi[1]

University of Camerino, Computer Science Division, Camerino, Italy

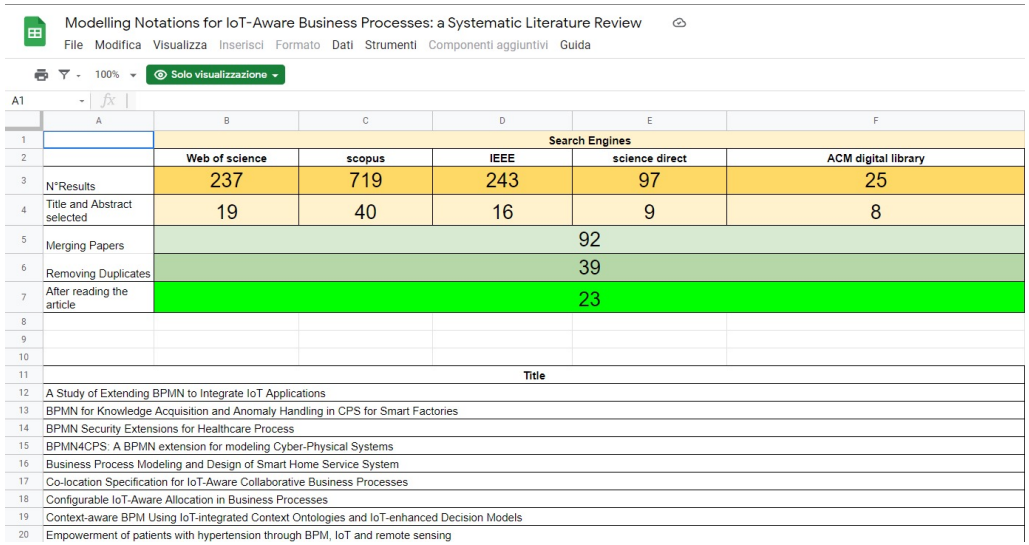
Abstract. The term *IoT-aware business processes* refers to the interplay of business processes and Internet of Things concepts. Several studies have been carried out on such a topic, so a better awareness of the current state of knowledge can be beneficial. In particular, in a given application domain, this can help the choice of the most suitable modelling approach. This paper reports on the results of a systematic literature review with the aim of developing a map on modelling notations for IoT-aware business processes. It includes 48 research works from the main computer science digital libraries. We first present a description of the systematic literature review protocol we applied, then we report a list of available notations, discussing their main characteristics. A focus has been devoted to modelling tools and application scenarios. Finally, we provide a discussion on the capability of the identified modelling notations to represent requirements of scenarios enriched by IoT adequately.

What is a Systematic Literature Review?

A **systematic and replicable procedure** that guarantees the validity of information obtained from the literature

- **Keeping track of how the research is carried out** (e.g. by using a Google Sheet)
- **Providing** such informations

By adopting this approach you will have a credible evaluation of the state of art of a specific research topic!



Modelling Notations for IoT-Aware Business Processes: a Systematic Literature Review

File Modifica Visualizza Inserisci Formato Dati Strumenti Componenti aggiuntivi Guida

100% Solo visualizzazione

A1

	A	B	C	D	E	F
1		Search Engines				
2		Web of science	scopus	IEEE	science direct	ACM digital library
3	N°Results	237	719	243	97	25
4	Title and Abstract selected	19	40	16	9	8
5	Merging Papers	92				
6	Removing Duplicates	39				
7	After reading the article	23				
8						
9						
10						
11	Title					
12	A Study of Extending BPMN to Integrate IoT Applications					
13	BPMN for Knowledge Acquisition and Anomaly Handling in CPS for Smart Factories					
14	BPMN Security Extensions for Healthcare Process					
15	BPMN4CPS: A BPMN extension for modeling Cyber-Physical Systems					
16	Business Process Modeling and Design of Smart Home Service System					
17	Co-location Specification for IoT-Aware Collaborative Business Processes					
18	Configurable IoT-Aware Allocation in Business Processes					
19	Context-aware BPM Using IoT-integrated Context Ontologies and IoT-enhanced Decision Models					
20	Empowerment of patients with hypertension through BPM, IoT and remote sensing					

Research questions

Research questions

RQ	Which are the notations used to model IoT-aware business processes ?
SRQ1	Which are the available tools supporting IoT-aware business process modelling ?
SRQ2	Which are the target application domains for modelling IoT-aware business processes ?

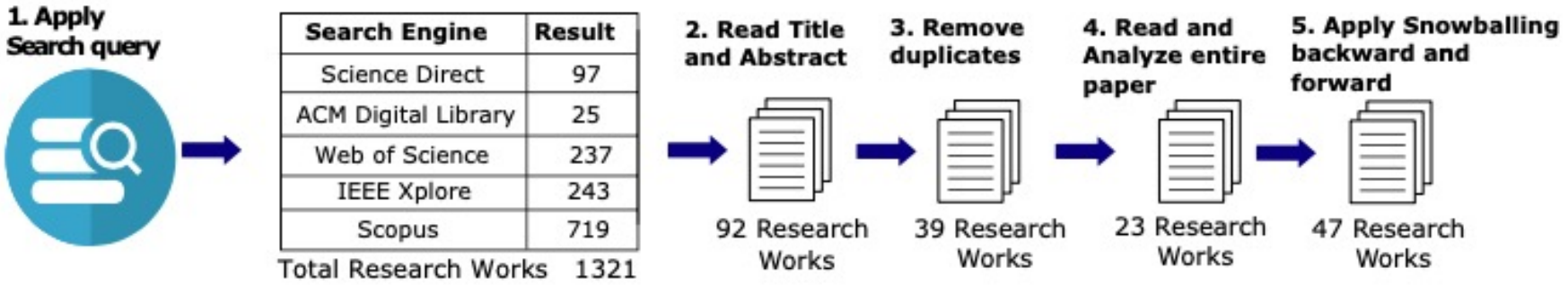
Research query

BPM		**IOT** [3]		**Modeling**
BPM + business process management + business process	&	IoT + Internet of Things + Cyber Physical Systems + CPS + Smart + WSN + Wireless Sensor Network	&	model + behavior + model driven

[2] Kitchenham, B., Charters, S. : Guidelines for performing Systematic Literature Reviews in Software Engineering. Tech. rep., EBSE-2007-01 (2007)

[3] Greer, C., Burns, M., Wollman, D., & Griffor, E. (1900). Cyber-physical systems and internet of things. NIST Special Publication, 202(2019), 52

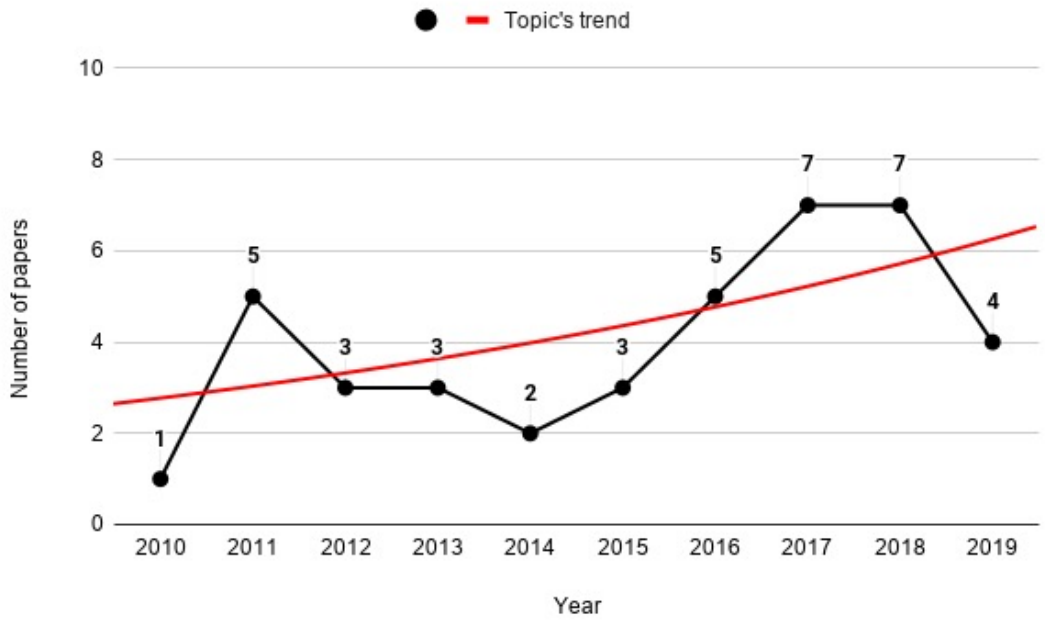
Conducting the SLR



All the details of our SLR are available at : `http://pros.unicam.it/BP-meet-IoT-2020`

[4] Jalali, S., Wohlin, C. : Systematic literature studies : Database searches vs. backward snowballing. In : ESEM. pp. 29–38. ACM-IEEE (2012)

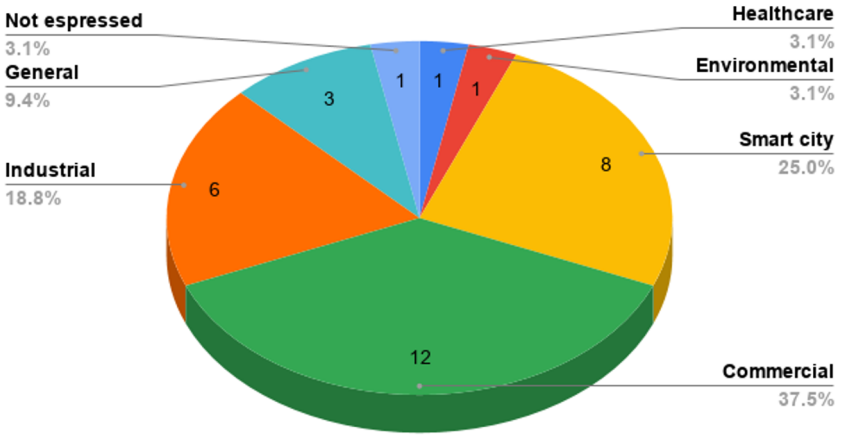
BP & IoT… a new research topic



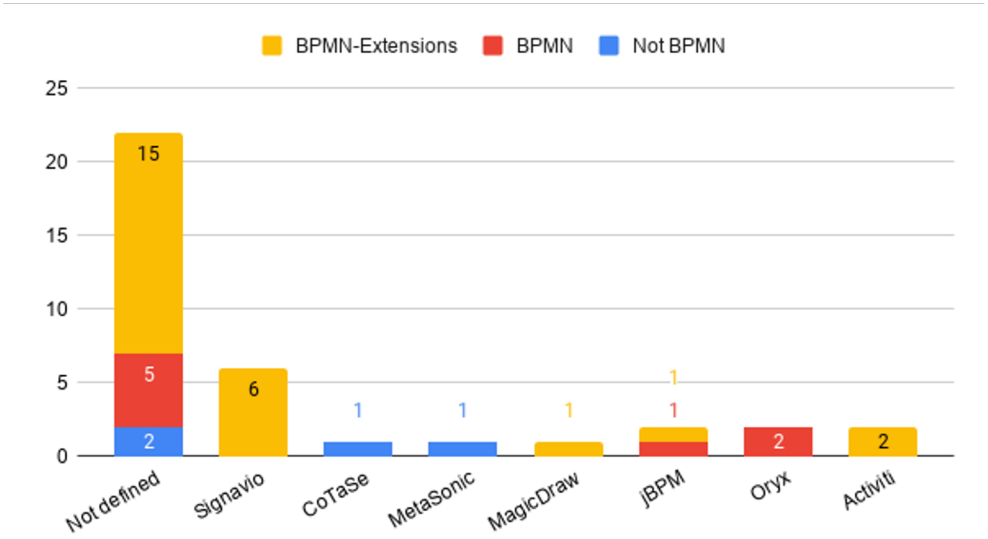
- The interest of the research community in combining *Internet of Things* and *Business Processes* is growing
- The study is based on research works up to September 2019

[1] I. Compagnucci, F. Corradini, F. Fornari, A. Polini, B. Re and F. Tiezzi. Modelling Notations for IoT-Aware Business Processes: a Systematic Literature Review. BPM to IoT workshop.

BP & IoT: Application Domains and Tools

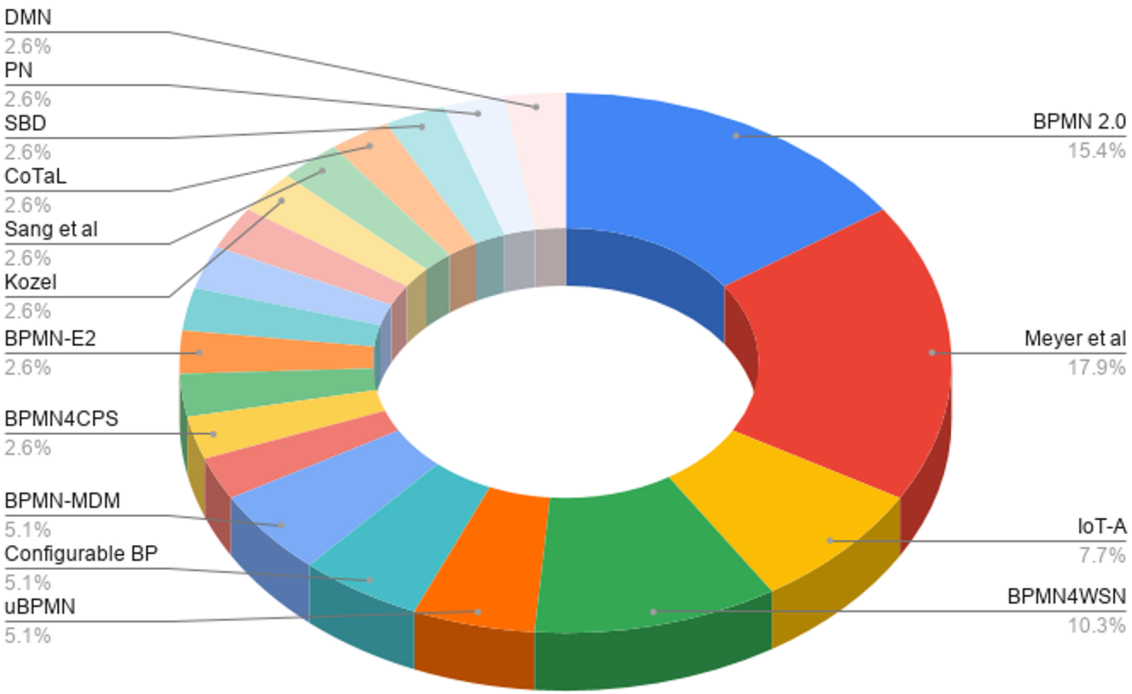


Application domains in modeling IoT systems using processes IoT-Aware



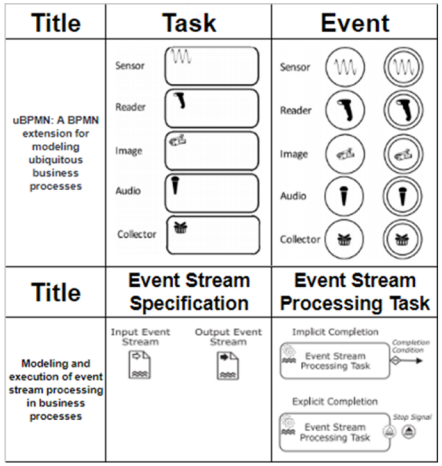
Modeling tools for modeling IoT-Aware business processes

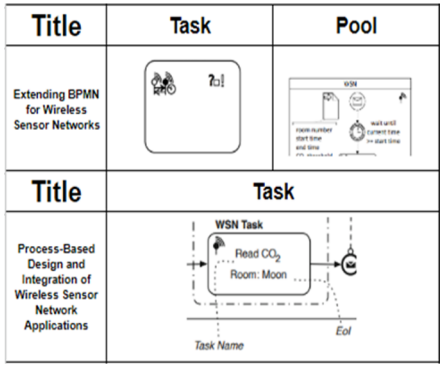
IoT-Aware Processes Modelling Languages



Distribution of modeling language used in design IoT-Aware processes

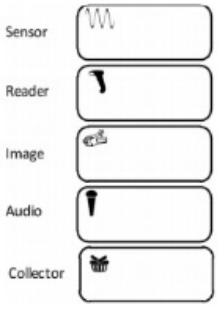
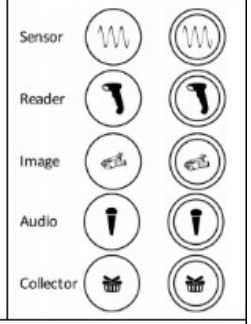
12 extensions have been **founded** and **cataloged** in a worksheet

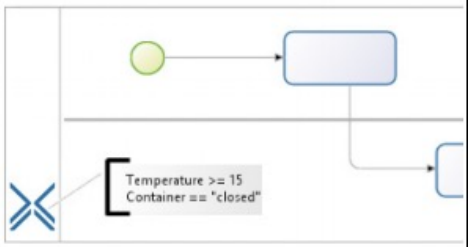


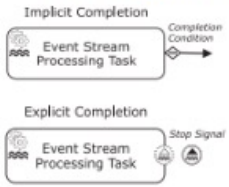


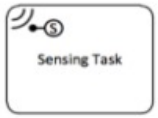
Meyer et al. **is most widely used** IoT-aware process modeling language

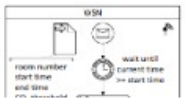
IoT-Aware Processes Modelling Languages

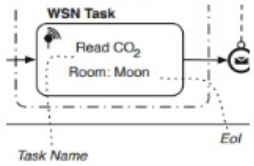
Title	Task	Event
uBPMN: A BPMN extension for modeling ubiquitous business processes		

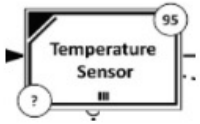
Title	Marker
Process invariants: an approach to model expected exceptions	

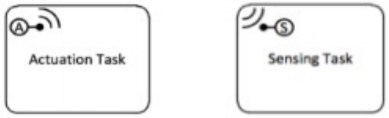
Title	Event Stream Specification	Event Stream Processing Task
Modeling and execution of event stream processing in business processes		

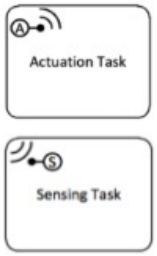
Title	Task
Internet of Things-Aware Process Modeling: Integrating IoT Devices as Business Process Resources	

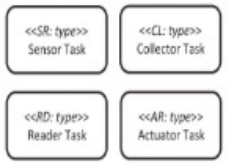
Title	Task	Pool
Extending BPMN for Wireless Sensor Networks		

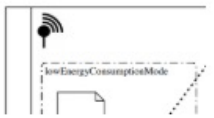
Title	Task
Process-Based Design and Integration of Wireless Sensor Network Applications	

Title	Task
Towards Modeling Real-World Aware Business Processes	

Title	Task
The Things of the Internet of Things in BPMN	

Title	Task	Data Object
Internet of Things Architecture - IoT-A - Project Deliverable D2.2 – Concepts for Modelling IoT-Aware Processes		

Title	Task	Data Object
Process modeling and analysis of service-oriented architecture–based wireless sensor network applications using multiple-domain matrix		

Title	Task	Pool
makeSense: Simplifying the Integration of Wireless Sensor Networks into Business Processes		

The IoT-A Approach

The IoT-A is an european project, Pioneer in the modeling of business processes that incorporate concepts from the world of IoT

Outcomes

- **Introducing the IoT-Aware process modeling concept** seeking to lower the barrier for applying IoT technology like sensors and actuators to current and new business processes
- **Extension of the BPMN standard** with 7 new IoT-related elements
- **Modeling** and **Enactment** of the extended model with Internet of Things concepts
- Increase the application of IoT technologies in the world of enterprise systems by **bridging the gap on business process modelling level**

[1] S. Meyer, K. Sperner, C. Magerkurth, S. Debortoli, M. Thoma – *Internet of Things Architecture: IoT-A Project Deliverable D2.2 – Concepts for Modelling IoT-Aware Business Process*

The IoT-A Approach: IoT concepts in Business Process

IoT Domain Concept	BPMN 2.0 Concept	Coverage by BPMN 2.0
User	Participant, Resource	Sufficient
Human User	Participant, Human Task, Manual Task	Sufficient
Physical Entity	Participant	Not sufficient
Device	Participant, Resource	Not sufficient
Sensor	Participant, Resource	Not sufficient
Tag	Participant, Resource	Not sufficient
Actuator	Participant, Resource	Not sufficient
Service	ServiceTask	Sufficient

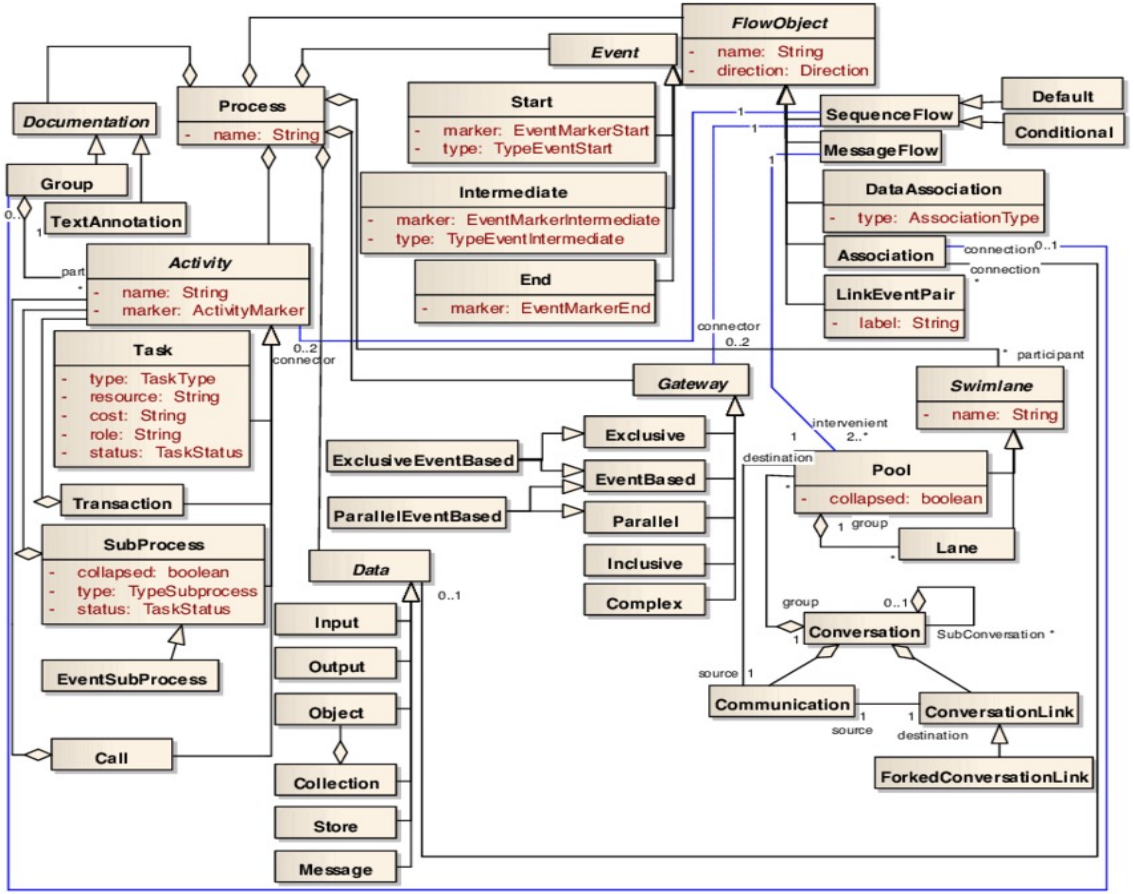
[1] S. Meyer, K. Sperner, C. Magerkurth, S. Debortoli, M. Thoma – *Internet of Things Architecture: IoT-A*
Project Deliverable D2.2 – Concepts for Modelling IoT-Aware Business Process

The IoT-A Approach: IoT concepts formalisation

The **BPMD** (*Business Process Definition Metamodel*) is a standard adopted by the **OMG** (Object Management Group) that defines concepts, relationships and semantics of the standard BPMN modeling constructs behaviors (e.g. activity tasks, data objects)

Idea

Extend the standard meta-model of BPMN 2.0 including concepts from the world of IoT



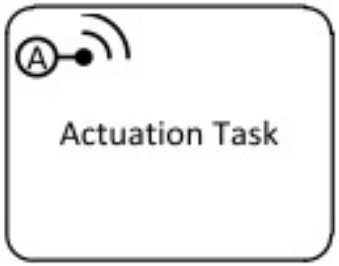
The IoT-A Approach: The Actuation Task

Real World Representation:

- *Relays, Smart light, Smart irrigator, …*

Additional features and extensions

- Extension of an atomic Task Activity
- Task to model a physical action performed by a device
- Require some parameters:
  - ***Implementation:*** describe the communication technology between the device and the process
  - ***taskRequirementsParameter:*** e.g. deviceID, device type, device action…



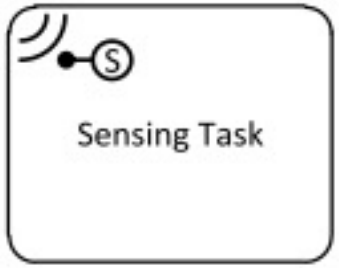
The IoT-A Approach: The Sensing Task

Real World Representation:

- *Noise sensor, Presence sensor, Smart thermometer…*

Additional features and extensions

- Extension of an atomic Task Activity
- Task to model the sensing action and then receive data from a device
- Generate a Smart Data Object containing the device data stream
- Require some parameters:
  - ***Implementation:*** describe the communication technology between the device and the process
  - ***taskRequirementsParameter:*** e.g. deviceID, device type, device source…



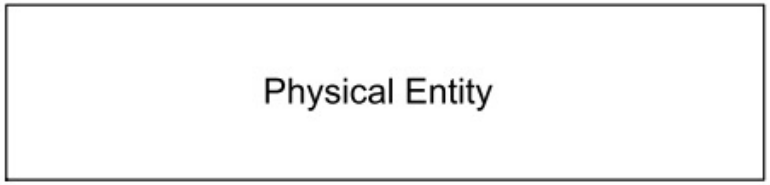
The IoT-A Approach: The Physical Entity

Real World Representation:

- *Environment, a physical object, …*

Additional features and extensions

- The physical entity is represented as a participant
- It does not contain any executable process activities
- Require some parameters:
  - ***taskRequirementsParameter:*** e.g. entityID, position, inputSensingAssociation, outputActuatingAssociation



The IoT-A Approach: The Smart Data Object/Store

Real World Representation:

- *Data extracted from devices*

iot.nortcele.win/api/Danon1

File Origin

65001: Unicode (UTF-8)

id	device_uid	username	received	temperature	humidity	light	battery
1904	3e581e	Danon1	14/12/2018 5:37:08 PM	28	42	818.717	4.89697
1907	3e581e	Danon1	14/12/2018 5:37:18 PM	28	42	811.893	4.91515
1910	3e581e	Danon1	14/12/2018 5:37:28 PM	28	42	802.817	4.87875
1914	3e581e	Danon1	14/12/2018 5:37:39 PM	28	43	800.552	4.89697
1916	3e581e	Danon1	14/12/2018 5:37:48 PM	28	43	784.741	4.88485
1919	3e581e	Danon1	14/12/2018 5:37:58 PM	28	42	805.083	4.86061
1923	3e581e	Danon1	14/12/2018 5:38:08 PM	28	42	818.717	4.75758
1926	3e581e	Danon1	14/12/2018 5:38:18 PM	28	42	814.166	4.70303
1928	3e581e	Danon1	14/12/2018 5:38:28 PM	28	42	782.488	4.89091
1932	3e581e	Danon1	14/12/2018 5:38:39 PM	28	42	789.25	4.86061
1934	3e581e	Danon1	14/12/2018 5:38:48 PM	28	42	782.488	4.88485

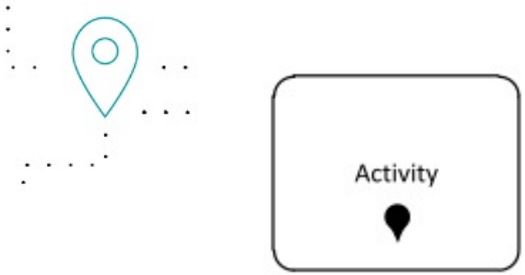
Additional features and extensions

- Extension of a Data Object and Data Store
- Incorporates data flow generated by the Sensing Task
- Require some parameters:
  - ***taskRequirementsParameter:*** e.g. dataID, inputSensingAssociation, physicalEntityAssociation

The IoT-A Approach: The Location-Based Property

Real World Representation:

- *Concept of space*



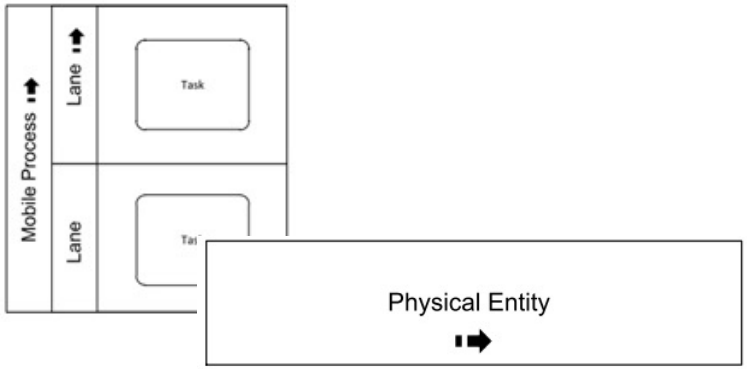
Additional features and extensions

- The extension is represented by a marker
- The marker offers the possibility to indicate a precise position where something happens in order to trigger events
- Can be applied to:
  - **Activity Task:** To indicate where an action is performed

The IoT-A Approach: The Mobile Property

Real World Representation:

- *Concept of mobility*



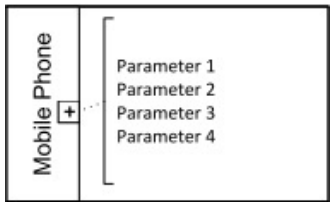
Additional features and extensions

- The extension is represented by a marker
- The marker offers the possibility to indicate the change of position of a physical entity or a process
- Can be applied to:
  - **Physical Entity:** To indicate if the entity can change its location over time
  - **Pool/Lane:** A business process is called mobile in case process decisions or activities depend on the location

The IoT-A Approach: The IoT-Collapsed Property

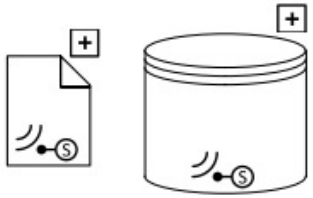
Real World Representation:

- *Technical concepts of IoT Device*

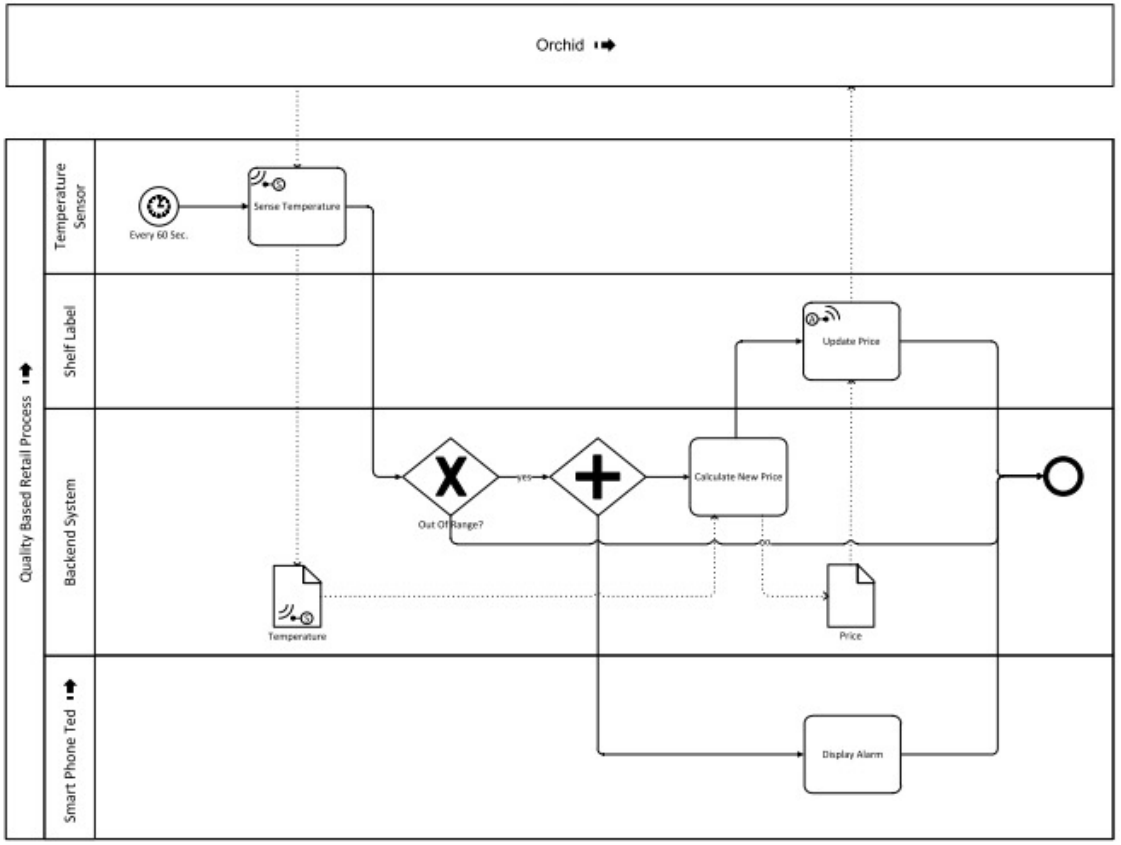


Additional features and extensions

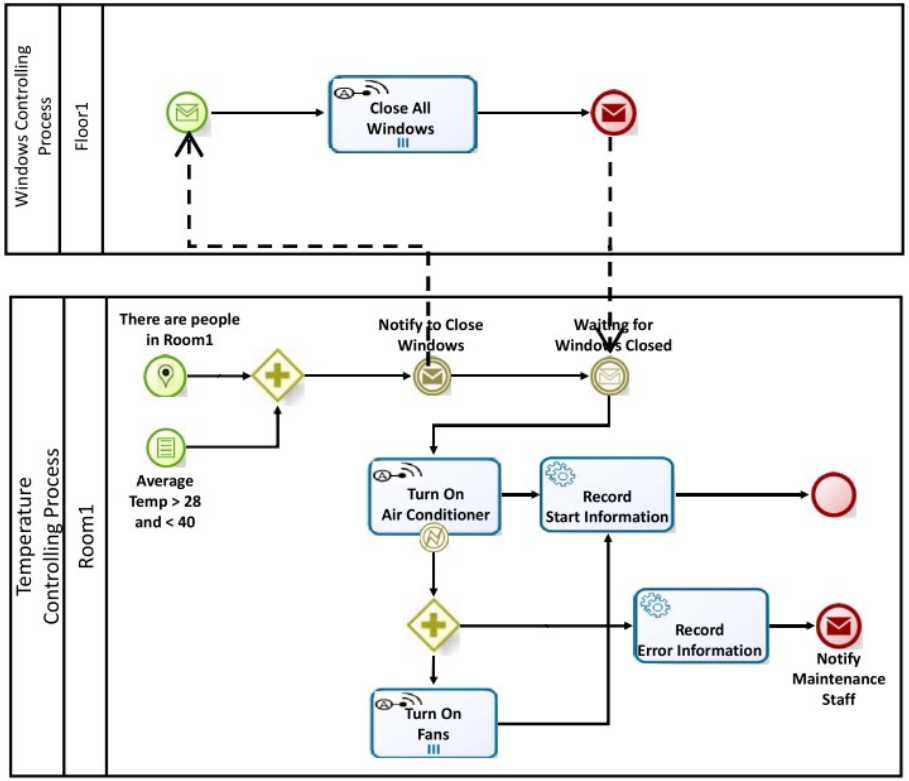
- The extension is represented by a marker
- The marker offers the possibility to indicate a set of technical parameters of a specific device
- Can be applied:
  - **Pool/Lane:** To indicate if in a pool or lane is modeled the behavior of a device and its technical parameters
  - **Smart Data Object/Store:** Technical parameters of the device from which data is extracted



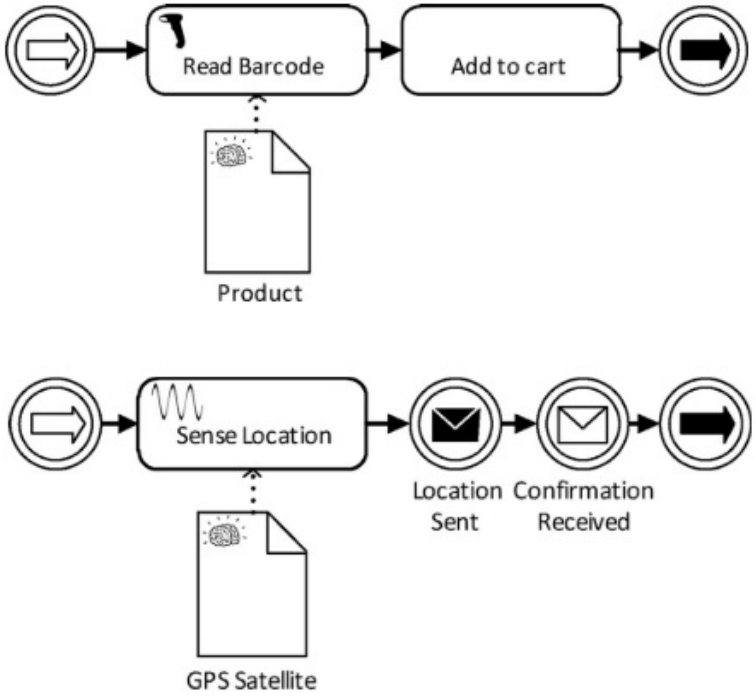
The IoT-A Approach: Example of quality check for orchids



Other IoT-Aware business processes examples

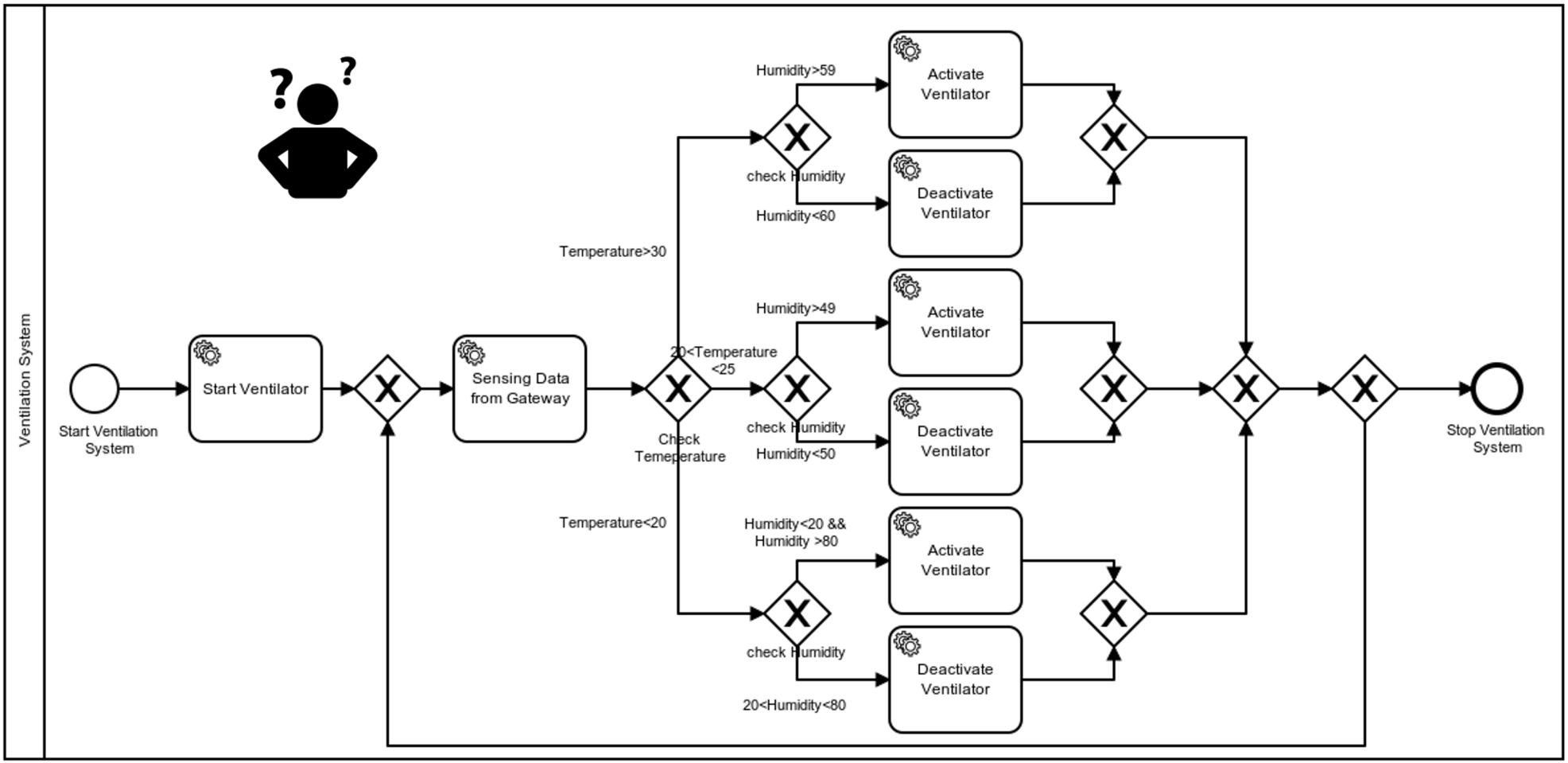


[1] Extending event elements of business process model for internet of thing, Chiu, Hsiao Hsien, Wang, Ming Shis, 2015



[2] UBPMN: A BPMN extension for modeling ubiquitous business processes, Yousfi, Bauer, Saidi, Rajaa, Anind. 2016

Model a Ventilation System

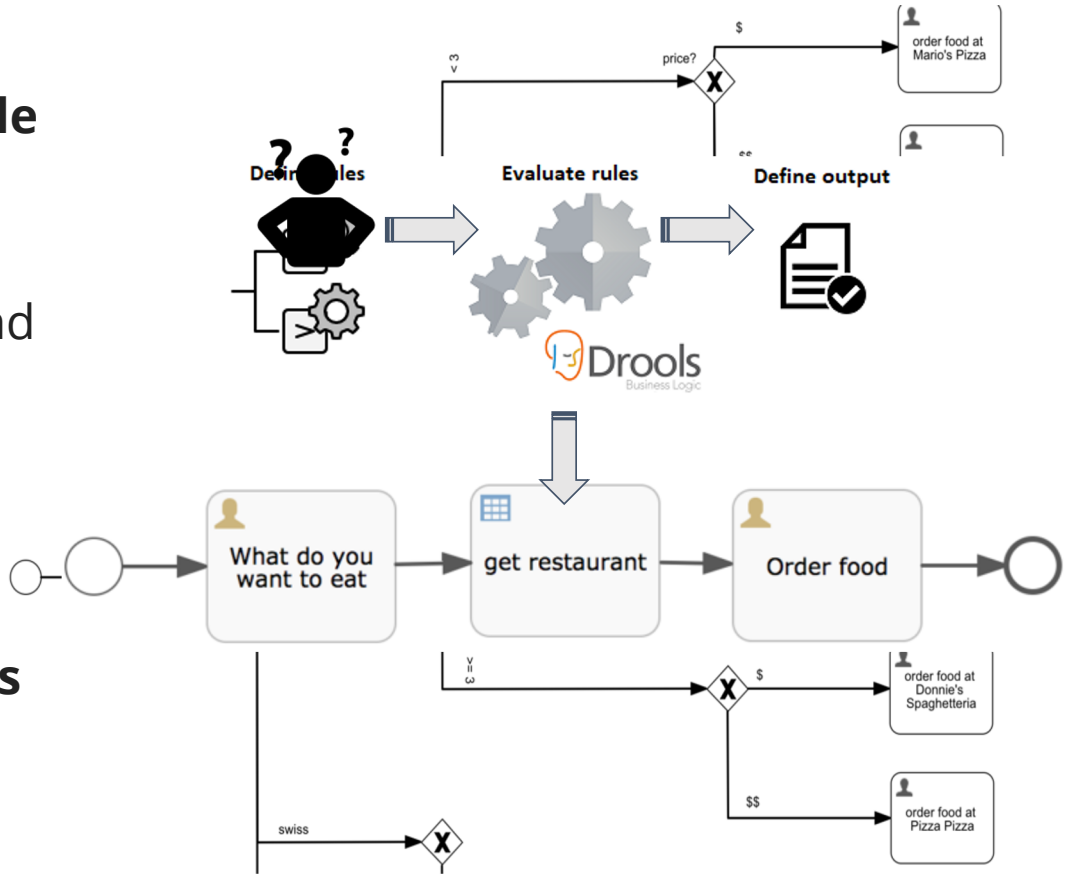


Integrating DROOLS Rule Engine

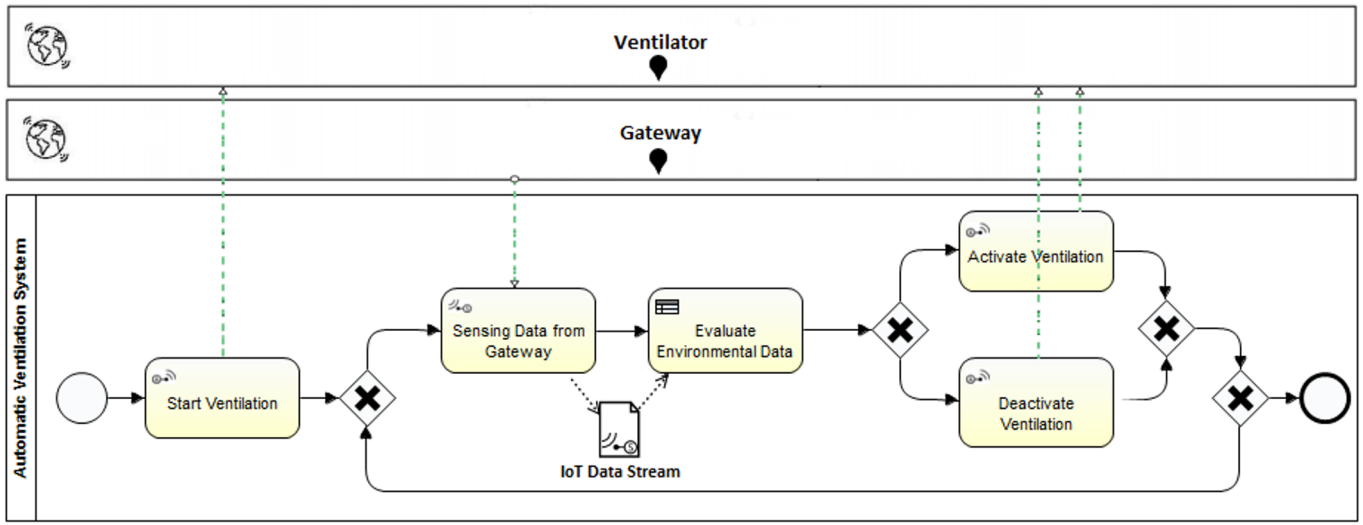
Complex IoT Systems generally have to **handle many data-driven decisions**

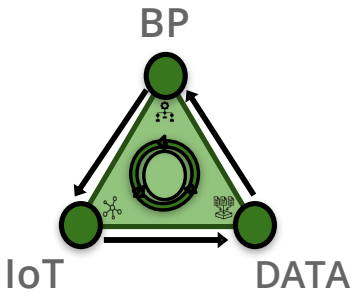
BPMN models **increasing the complexity** and the **legibility** of the model in such situations

Define a set of **internal rules**, **improve the overall quality of the model, especially in IoT Systems where data-driven decisions need to be taken**



Proposed Extension: Automatic Ventilation System

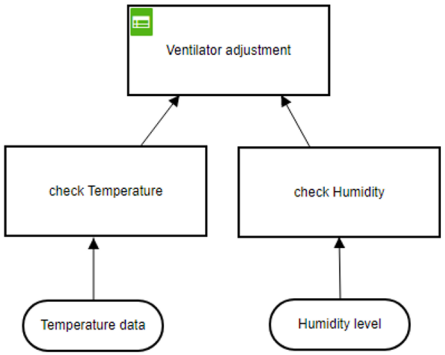




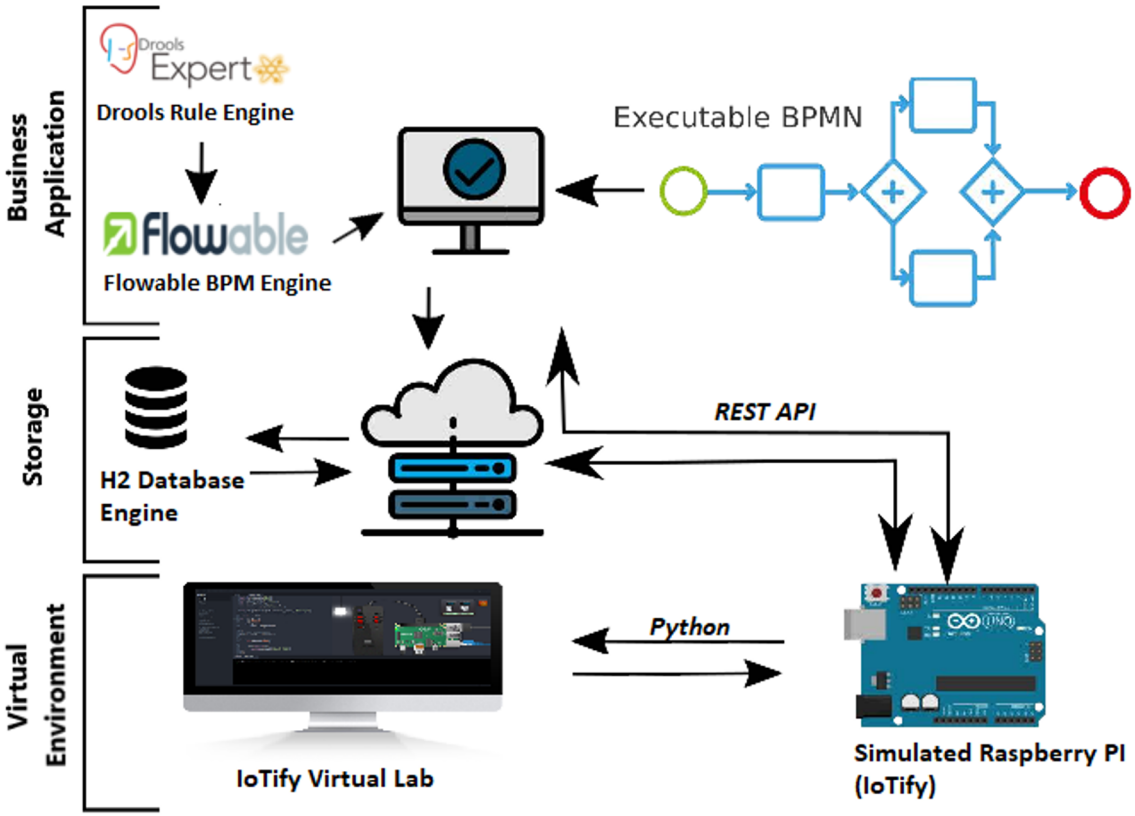
Ventilator adjustment

adjustment

U	Input +		Output +
	Temperature	Humidity	Ventilator
	double	double	string
1	>20	>40	ON
2	>20	[30..40]	ON
3	<20	[30..40]	OFF
4	<20	<30	OFF



IoT-Aware Modelling and Enactment Architecture



1 Business Application Level

+ Flowable IoT-Aware extend modeler
+ Flowable Business Engine
+ Drools Rule Engine

2 Storage level

+ Flowable storage systems

3 Virtual Environment

+ IoTify Virtual Lab for virtualized developing environment

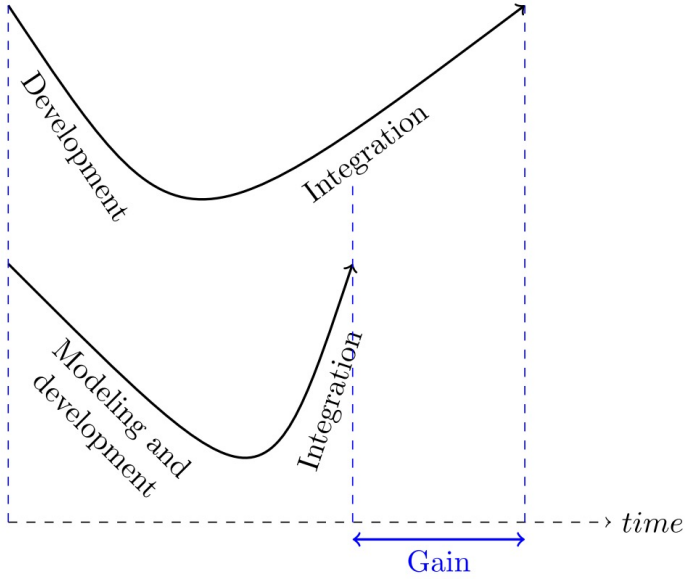
Why BPMN model as Input?

Model Driven Approach (MDE)

The model-driven approach makes it possible to **move away from the standard canons related to the extreme verticality of which most applications are generally affected** generalizing the logic of the application with respect to a Input model.

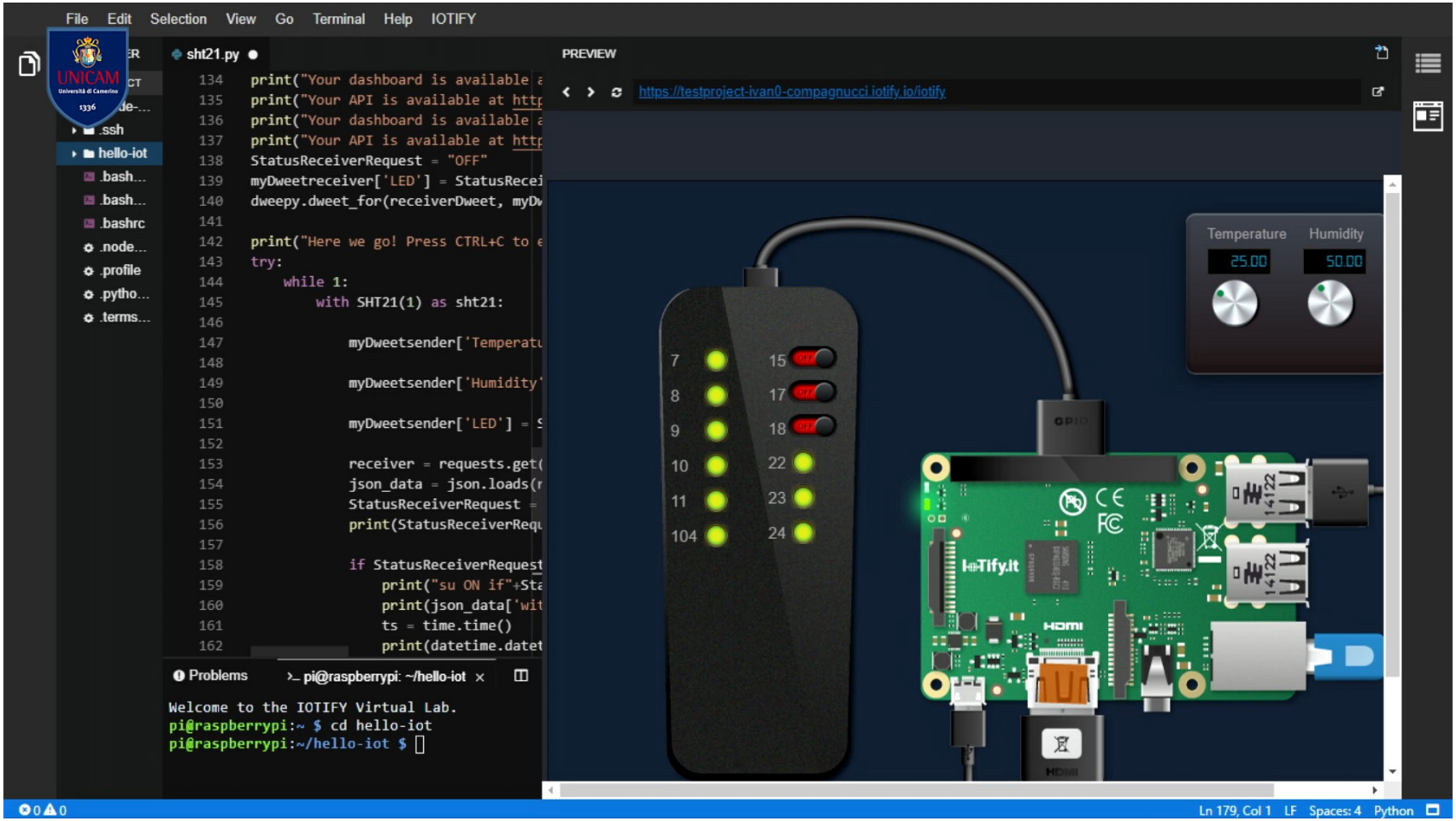
Benefits

- **Reducing costs** and **development time**, we just need to develop the input model
- **Reusability** of software with different models
- **Platform independent application**
- **Bridge the gap** between Business and IT (high and low levels)



[1] Model-Driven Engineering, DC Schmidt - 2006

Demo


File Edit Selection View Go Terminal Help IOTIFY
sht21.py
PREVIEW
https://testproject-ivan0-compagnucci.iotify.io/iotify
Temperature
Humidity
25.00
50.00
Problems
pi@raspberrypi: ~/hello-iot
Welcome to the IOTIFY Virtual Lab.
pi@raspberrypi:~ $ cd hello-iot
pi@raspberrypi:~/hello-iot $
Ln 179, Col 1 LF Spaces: 4 Python

Exercise

Smart Ventilation System

Model the behavior of a smart room for internal temperature management. The room includes a **smart fan** and a **thermometer** that can detect the current room temperature. In the room you want to maintain a fixed temperature of 20°, so if the temperature is higher than 20° the fan must be activated to cool the room.

The room is also equipped with a **presence sensor** that has to verify that:

- There is someone inside. If not, to avoid wasting power, the entire system must be turned off.
- If the system is turned off, turn it back on if someone enters in the room

Exercise BPMN - Solution