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INTEGRATING THE INTERNET OF THINGS WITH BUSINESS PROCESS MANAGEMENT: A PROCESS-AWARE FRAMEWORK FOR SMART OBJECTS

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Integrating IoT with BPM
Context

- Growing interest for the Internet of Things in later years
  - Both by industry and academia
- Smart Objects decentralize computation and data acquisition
  - Such tasks are moved to the physical world
- Solutions relying on Smart Objects for business processes execution are becoming popular

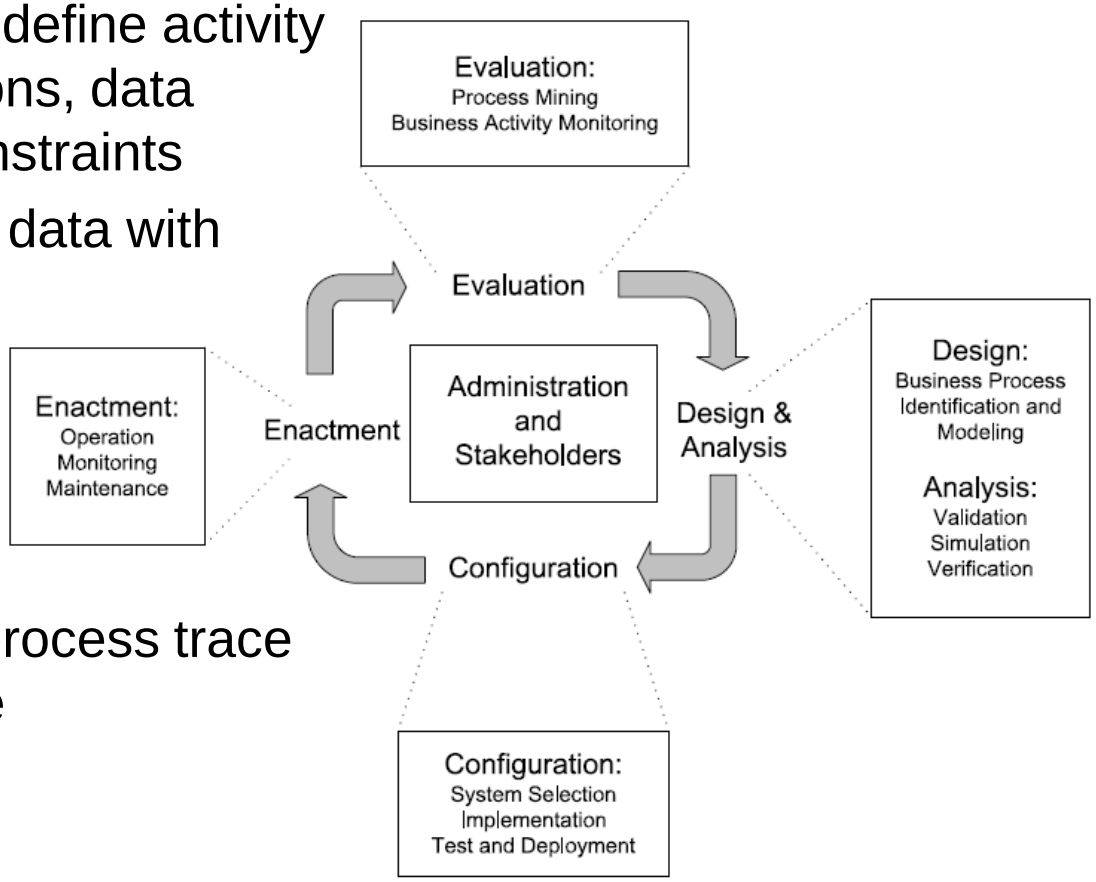
Integrating IoT with BPM
Problem statement

- Integration among business processes and IoT is far from trivial [1]:
  - Data are unavailable
  - Data are inconsistent
  - Process compliance is difficult to assess on Smart Objects
  - Smart Objects have limited computational resources and battery life

[1] Haller et al.: The real-time enterprise: Iot-enabled business processes

Integrating IoT with BPM
Main objective

- Extend the business process management lifecycle [2] to explicitly support Smart Objects:
  - Design and analysis: define activity start and end conditions, data requirements and constraints
  - Configuration: collect data with required quality level
  - Enactment: log activity execution order and constraints violations
  - Evaluation: analyze process trace to assess compliance



[2] Weske: Business Process Management - Concepts, Languages, Architectures

Integrating IoT with BPM
Research questions

- RQ1 – How can we monitor the process execution?
  - Infer activity start and termination based on events captured by Smart Objects
- RQ2 – How can we define requirements on activity data?
  - Use business processes to drive sensor configuration
- RQ3 – How can we identify process execution violations?
  - Identify violations both with respect to activity execution order and constraints fulfillment
- RQ4 – How can we support multiple actors?
  - Support concurrent execution of processes belonging to different actors having potentially conflicting requirements

Integrating IoT with BPM
State of the Art

- BPMN 2.0 extensions to model Smart Objects interactions [3] [4]
  - Process knowledge outside Smart Objects
  - Data uncertainty and requirements not dealt
- Translators from BPMN to executable code for sensor network configuration [5]
  - Process model used only at design time
  - Process cannot be changed easily at runtime
- BPM-based frameworks relying on events by Smart Objects with data quality mechanisms [6]
  - Process knowledge centralized
  - No process compliance mechanisms at runtime

[3] Meyer et al.: Internet of things-aware process modeling: integrating iot devices as business process resources

[4] Thoma et al.: On iot-services: Survey, classication and enterprise integration

[5] Tranquillini et al.: Process-based design and integration of wireless sensor network applications

[6] Schief et al.: Enabling business process integration of iot-events to the benet of sustainable logistics

Integrating IoT with BPM
State of the Art

- Process compliance mainly focuses on process flow [7]
- Few solutions extending compliance to data flow:
  - BPMN extensions to define constraints on activity-related data [8]
  - Constraints on control flow based on process data [9]
  - Complex Event Processing techniques on process data to infer execution flow [10]
- However,
  - No solution covers all these aspects
  - No solution explicitly supports multiple actors

[7] Kharbili et al.: Business process compliance checking: Current state and future challenges

[8] Awad et al.: Specification, verification and explanation of violation for data aware compliance rules

[9] Ly et al.: On enabling integrated process compliance with semantic constraints in process management systems

[10] Weidlich et al. Event based monitoring of process execution violations

Integrating IoT with BPM
Case study: multimodal transportation

- Planning and enactment of transportation of goods via multiple means of transport belonging to different transportation companies.
- Stakeholders needs to track the status of the goods during each phase that involves their participation
- Smart Objects-based solution already exist [11] [12] [13], but have some limitations:
  - Process definition is made at design time
  - Sensor configuration does not change during transportation
  - They are tailored for a specific business process
  - They do not support multiple stakeholders

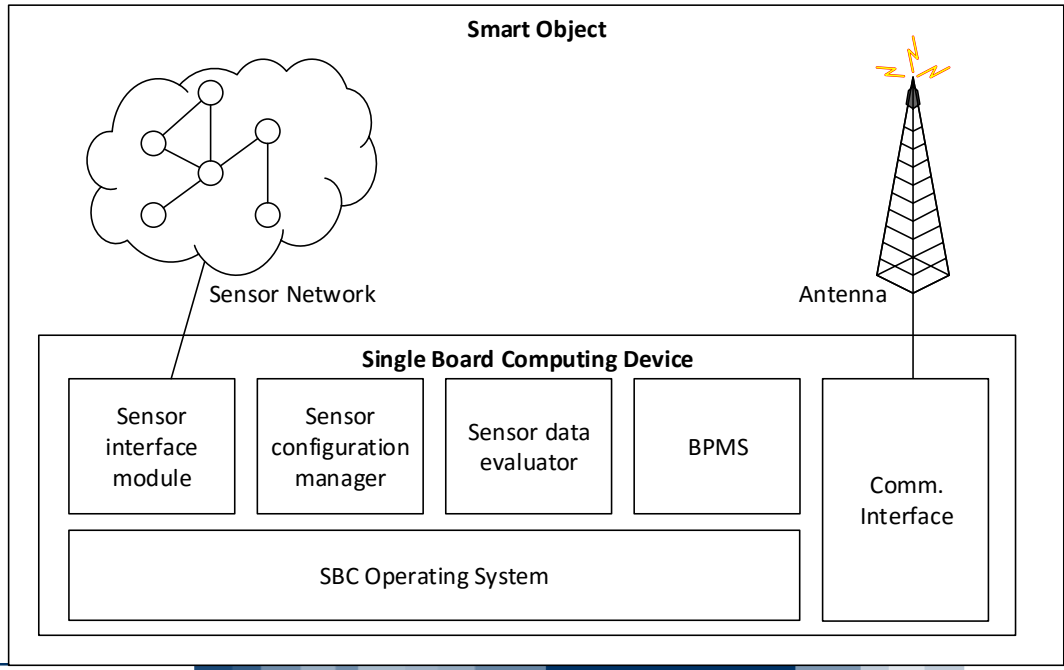
[11] Lang et al.: "the intelligent container" - a cognitive sensor network for transport management.

[12] Kim et al.: Intelligent networked containers for enhancing global supply chain security and enabling new commercial value.

[13] Baresi et al.: A service-based infrastructure for advanced logistics.

Integrating IoT with BPM Solution

- Smart Objects equipped with sensors, a Single Board Computing device and communication interface
- Lightweight BPMS
  - Downloads process definitions
  - Determine which activities are running
  - Keeps track of activities execution order
- Sensor Configuration manager
  - Interprets requirements on sensor data
  - Instructs sensors
  - Resolves conflicts
- Sensor Data Evaluator
  - Verifies process and data constraints
  - Reports violations

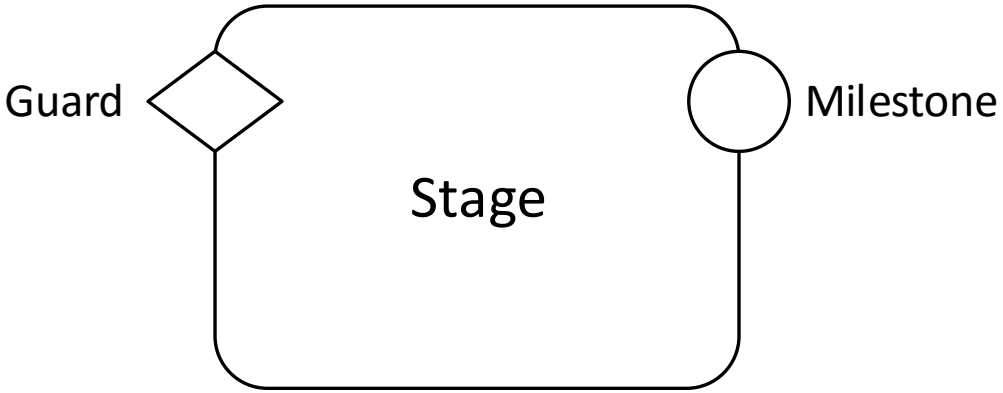


Integrating IoT with BPM Solution

- Extend business process definitions with the following constructs:
  - Start and Termination Conditions
    - Specify which conditions determine the start or the end of activities
    - Allow the BPMS to automatically infer which activities are running
  - Data requirements
    - Specify quality requirements for sensor data
  - Data constraints
    - Specify conditions that, if not true during activity execution, determine a violation

Integrating IoT with BPM
GSM extension

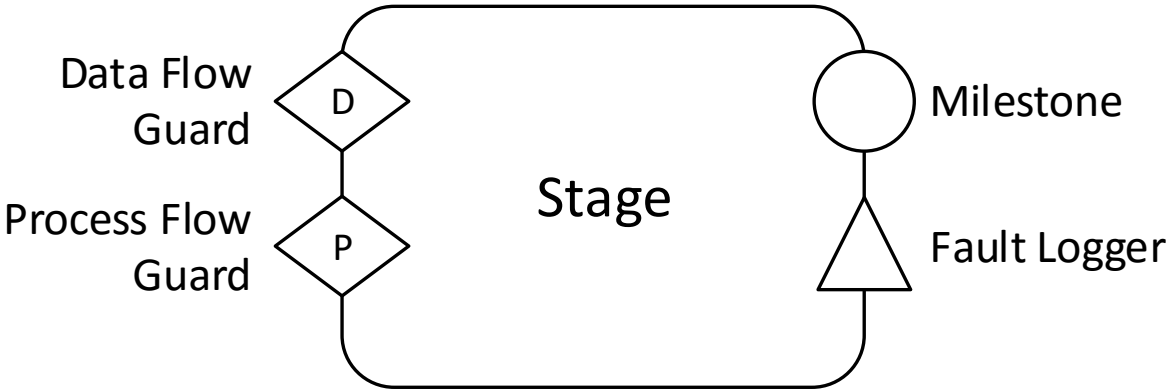
- The Guard-Stage-Milestone (GSM) notation [14] is the ideal candidate for modeling processes on Smart Objects:
  - Guards determine the start of each task based on events
  - Milestones determine the end of each task based on events
  - Events can be internal or external, involving conditions on sensor data



[14] Hull et al.: Introducing the guard-stage-milestone approach for specifying business entity lifecycles.

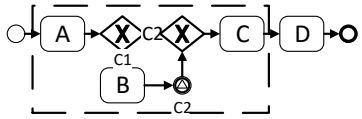
Integrating IoT with BPM
GSM extension

- We extend GSM by introducing the following changes:
  - Guards distinguished in Data Flow Guards and Process Flow Guards:
    - Data Flow Guards determine task activation based on external events
    - Process Flow Guards define the expected process flow
  - Fault Loggers annotations are introduced:
    - Conditions on sensor data that determine violation of the task's constraints and invalidate it
    - If a task is invalidated, it is not terminated

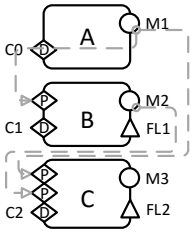


Integrating IoT with BPM
GSM extension

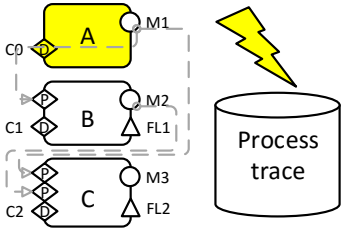
- Integration methodology among processes and Smart Objecs made of three phases:
  - Identification of activities:
    - Starting form BPMN process model, activities that will run on the Smart Object are selected.
  - Generation of extended GSM definition
    - The portion of the process model that includes the selected activities is converted in extended GSM
  - Execution and monitoring
    - The extended GSM definition is loaded onto the Smart Object and executed
    - A process trace is generated and compliance assessed at runtime
    - Notifications are sent whenever violations are detected



Identification of activities



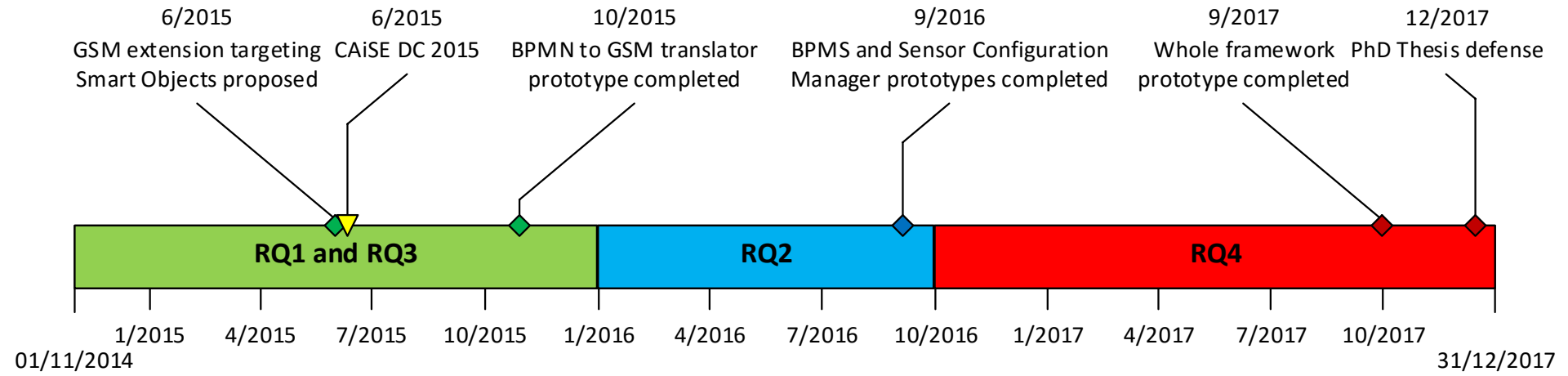
Generation of extended GSM definition



Monitoring of goods

Integrating IoT with BPM Timeline

- RQ1 and RQ3: process modeling notation and integration methodology targeting Smart Objects by the end of 2015
  - Modeling notation proposal submitted for the DAB-BPM2015 Workshop in September 2015
- RQ2: notation extension to model data requirements, BPMS and Sensor Configuration manager modules prototype by the 4th quarter of 2016
- RQ4: support for multiple actors, whole framework prototype and PhD thesis by the end of 2017.



Thanks for your attention

Any question?