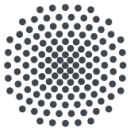
Goal-driven Context-sensitive Production Processes: A Case Study using BPMN

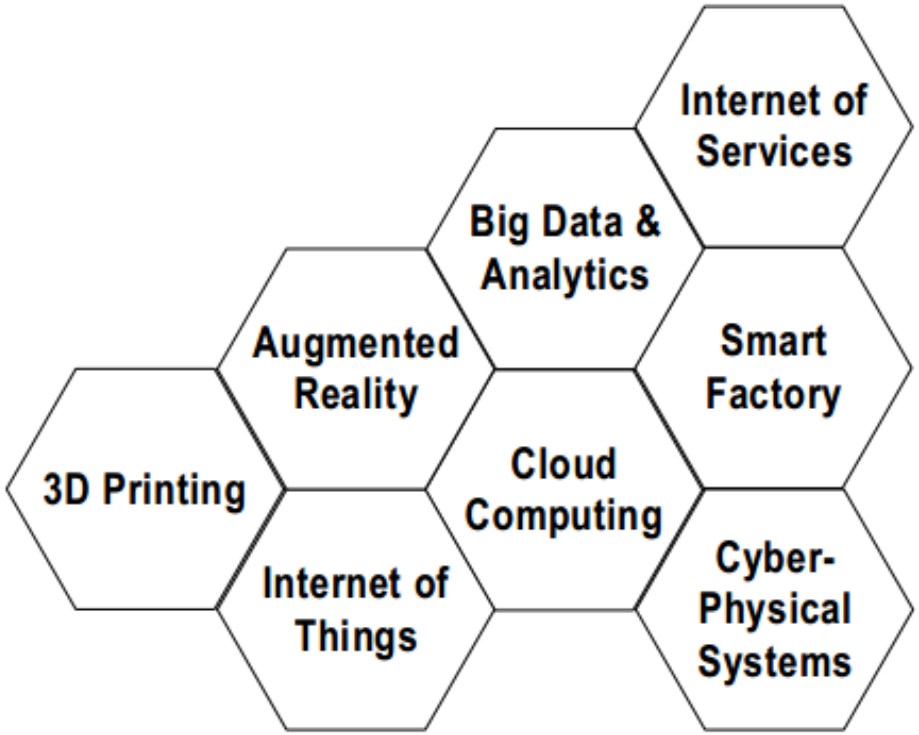
Debasis Kar
debasis.babun@gmail.com



Universität Stuttgart

Supervisor: M.Sc. C. Timurhan Sungur

Motivation



Forthcoming Industrial Revolution

Industrie 4.0 (Germany) / Industrial Internet (USA)

Outline

- Background
- Problem Statement
- Requirements
- Case Study : CES Realization using BPMN
- Existing Approaches & Comparison
- Summary & Outlook

Background

- *Internet of Things (IoT)* - Interconnection of everyday objects with ubiquitous intelligence such that they can sense and actuate upon it if required
- *Cyber-Physical Systems (CPS)* - Integrated embedded computers and physical processes where physical processes affect computations and vice versa
- *Context-sensitive Process* - Processing unit that performs processing depending on the available context, i.e., characteristic of an entity or situation
  - Context Attribute describes a context, e.g., <sensor-name, sensed-value>
- *Smart Factory* - Context-sensitive production environment that can react to changes in real-time using IoT and CPS

Problem Statement

What Customer Wants?	What Manufacturer Wants?
Highly Individualized Products	Simple Supply Chain
Competitive Price	High Profit and Efficiency

How next-generation manufacturers can

- adapt to manufacturing intelligence?
- integrate technologies like IoT, CPS, etc.?
- establish a balance among *changeability, cost, time, and quality?*

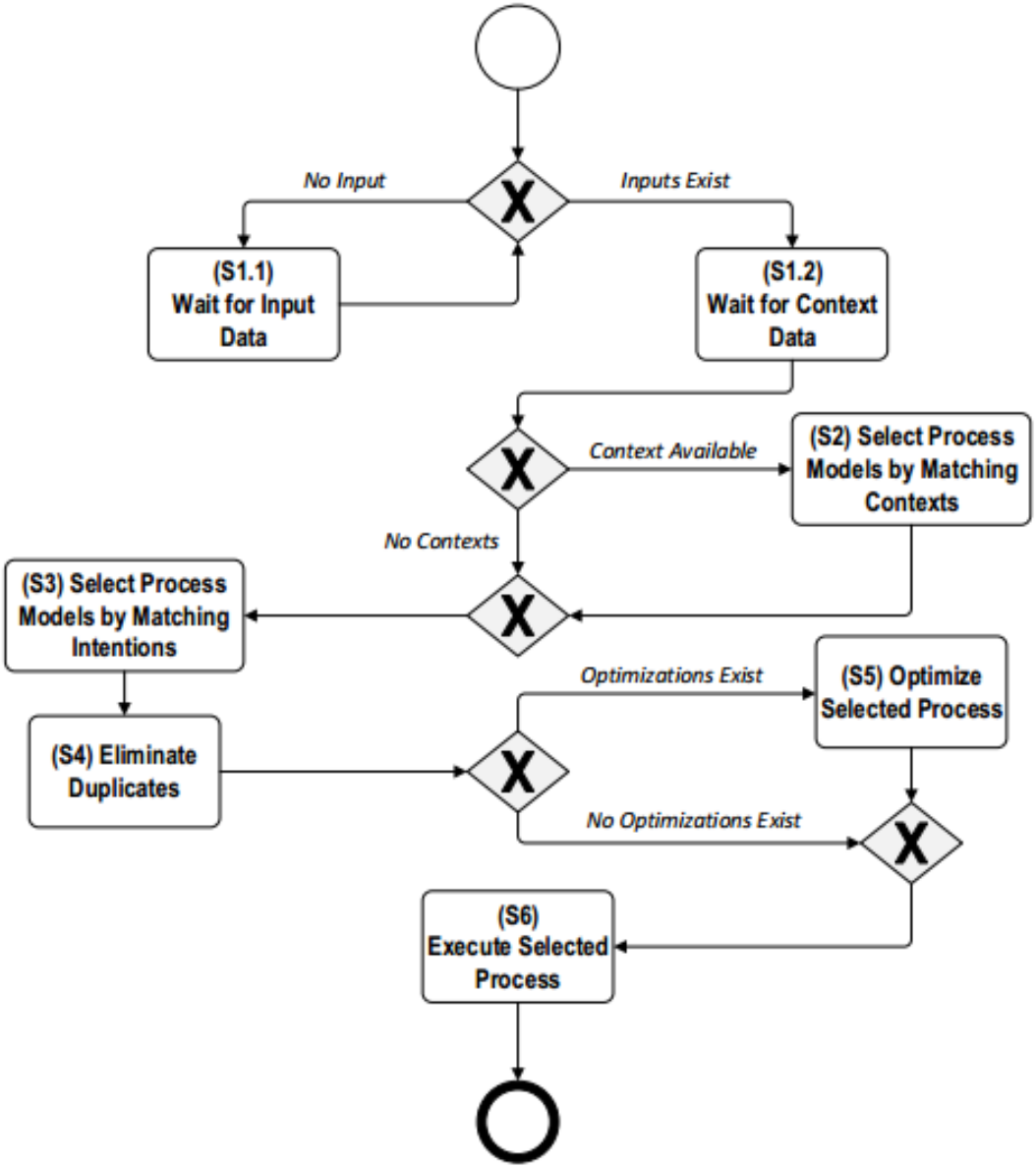
Requirements

- IoT Incorporated Process Modeling (R1)
- Goal-driven Production Process Execution (R2)
- Context-sensitive Production Process Execution (R3)
- Optimizable Production Processes (R4)
- Prioritization of Goals (R5)
- Resilience to Minor Changes (R6)

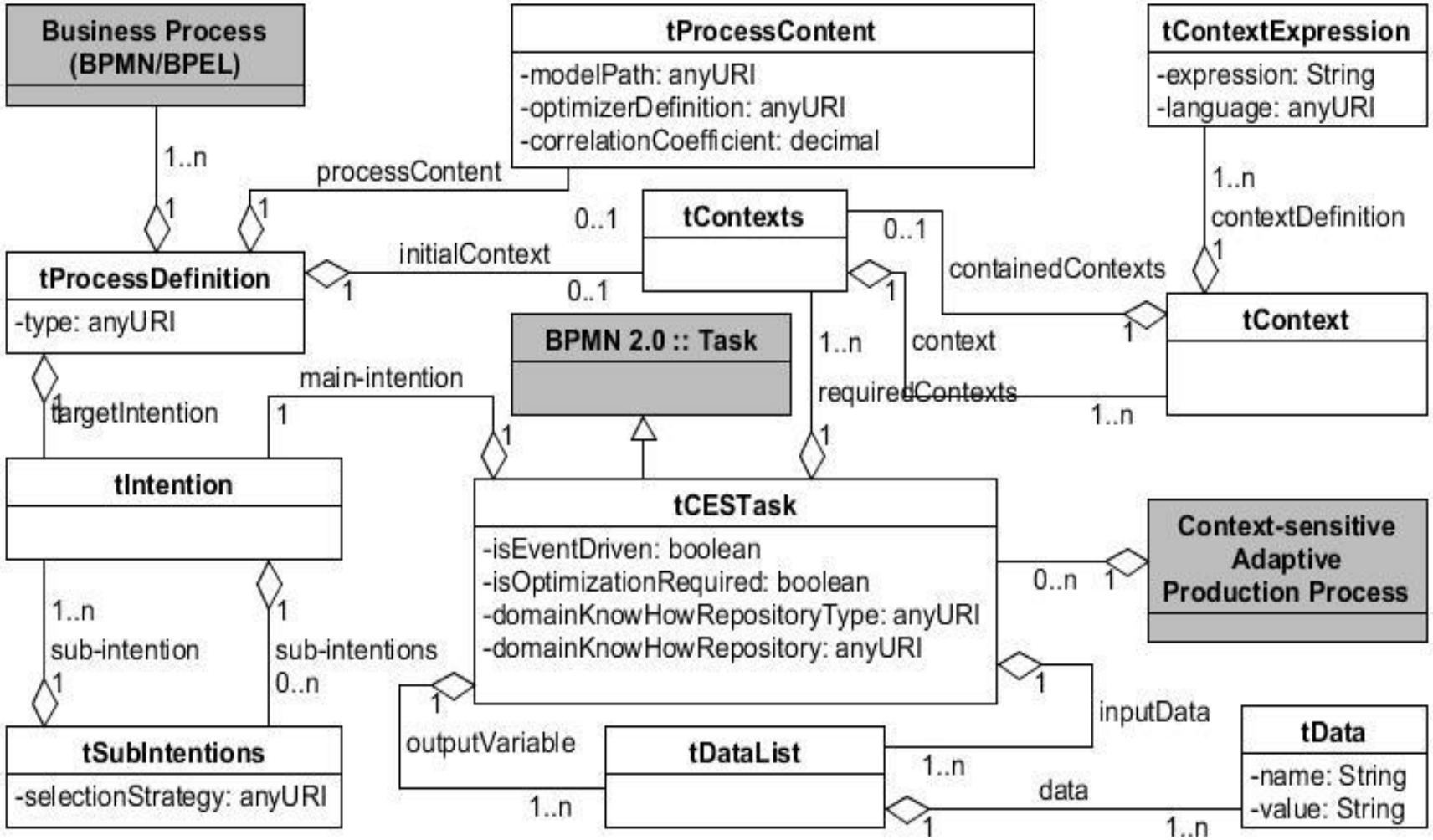
Context-sensitive Adaptive Production Processes (CAPP)

- CAPP
  - facilitates intelligent production processes.
    - Adapt to the changing business objectives
    - Flexible to the changing production environment.
  - leads to innovative modeling of production activities and its know-how.
    - Context-sensitive Execution Step (CES), a logical sub-process type construct, that encompasses multiple alternative processes executed in runtime.

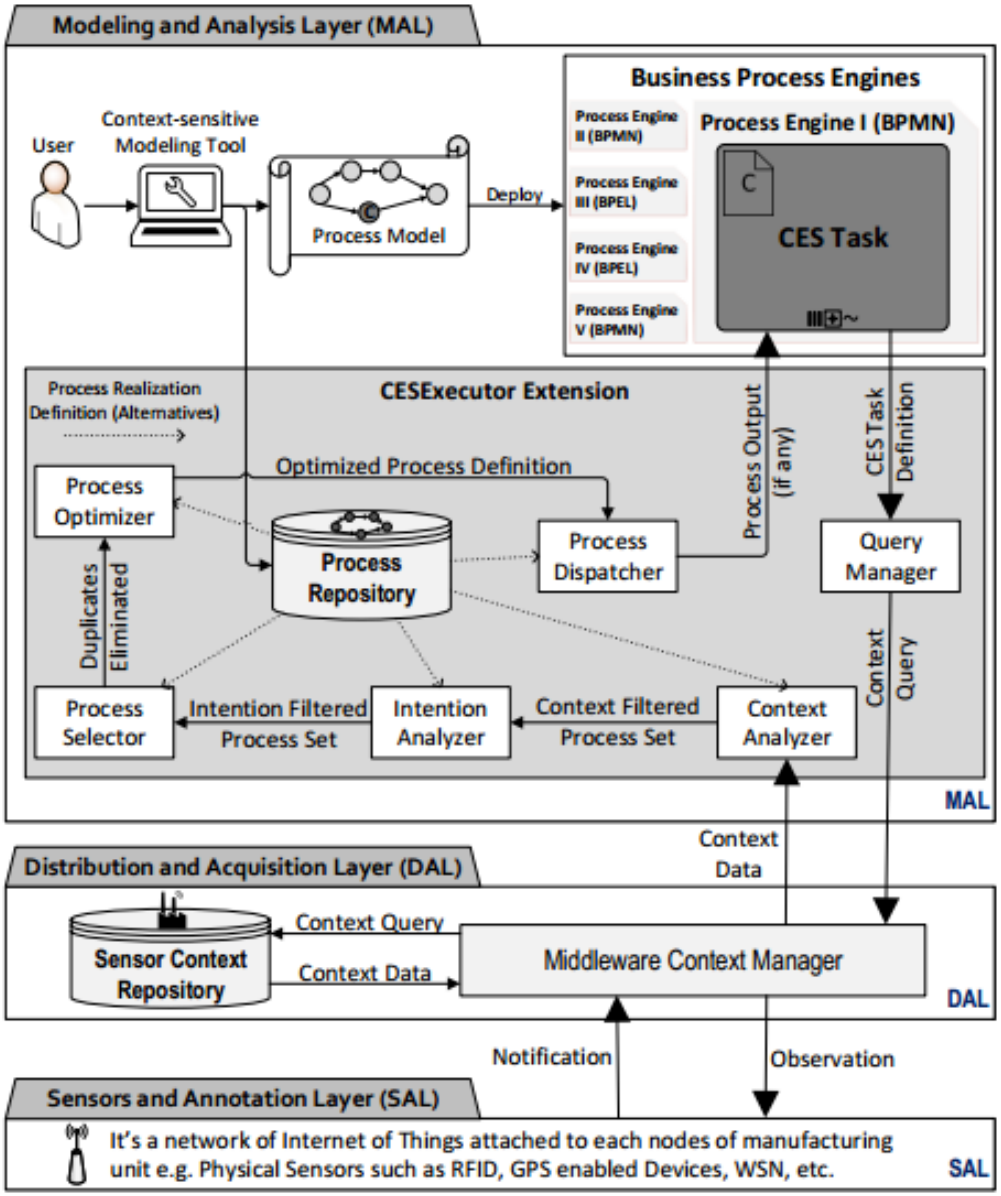
Execution Semantics of a CES



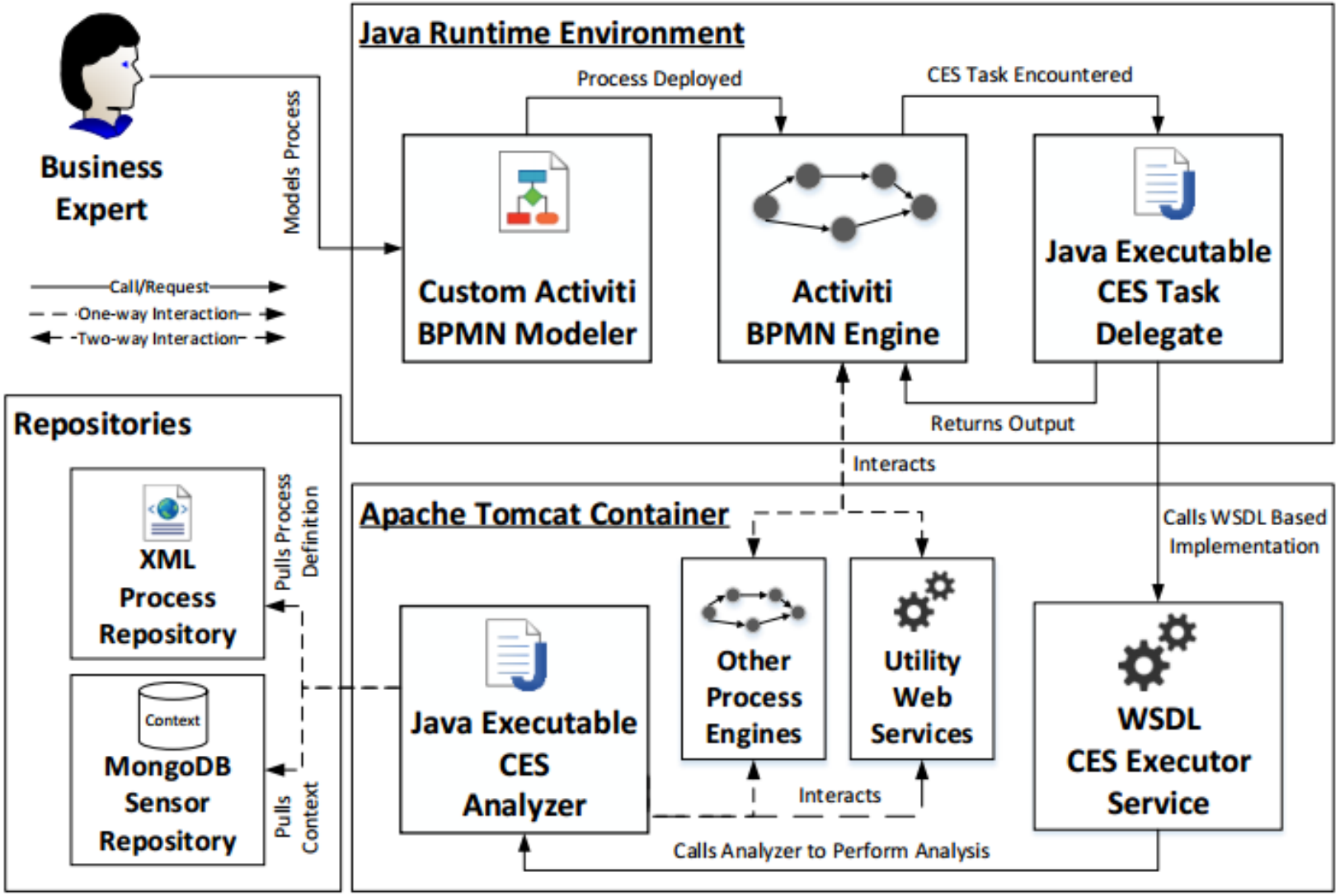
Relation among CES Attributes



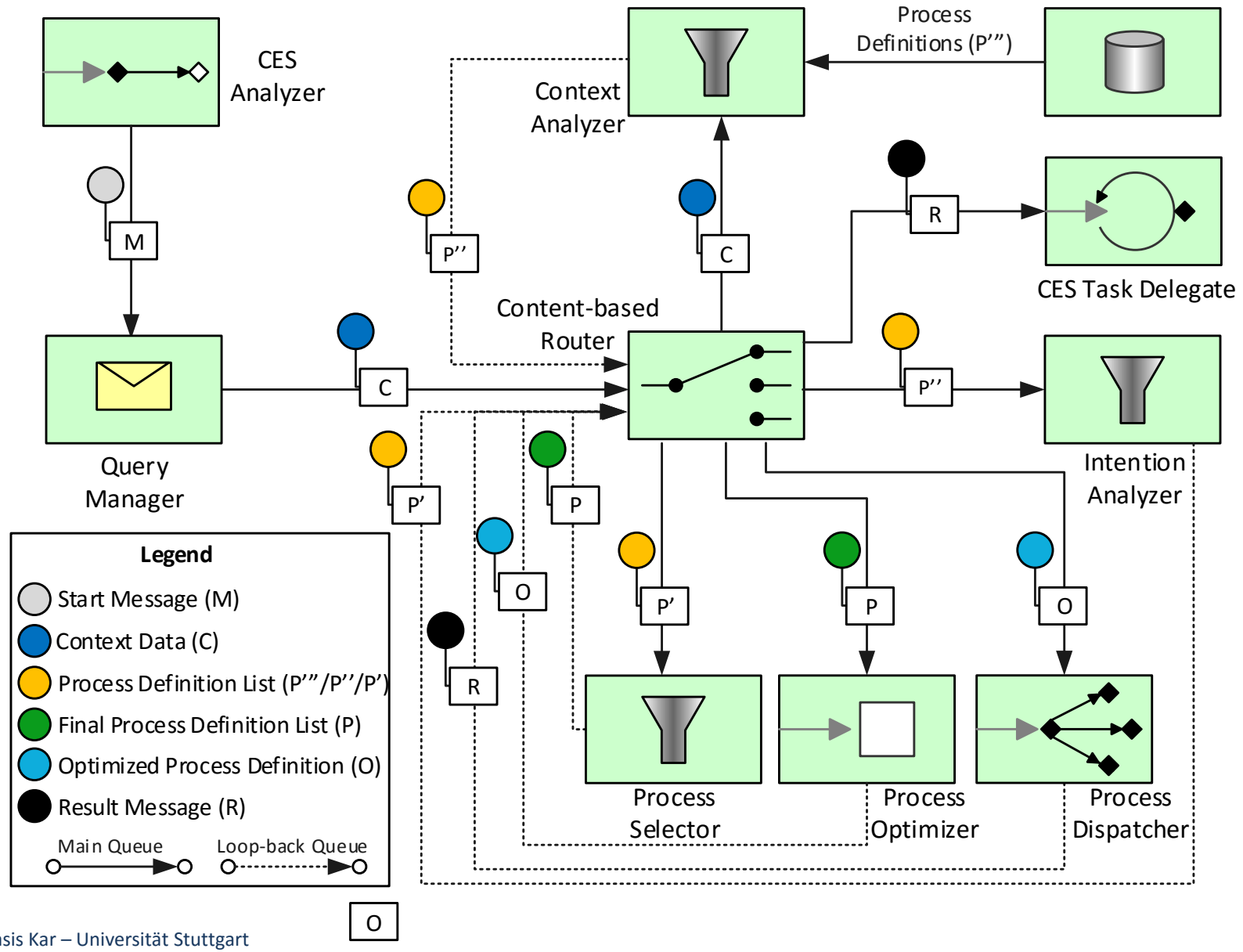
Architecture of CAPP Runtime



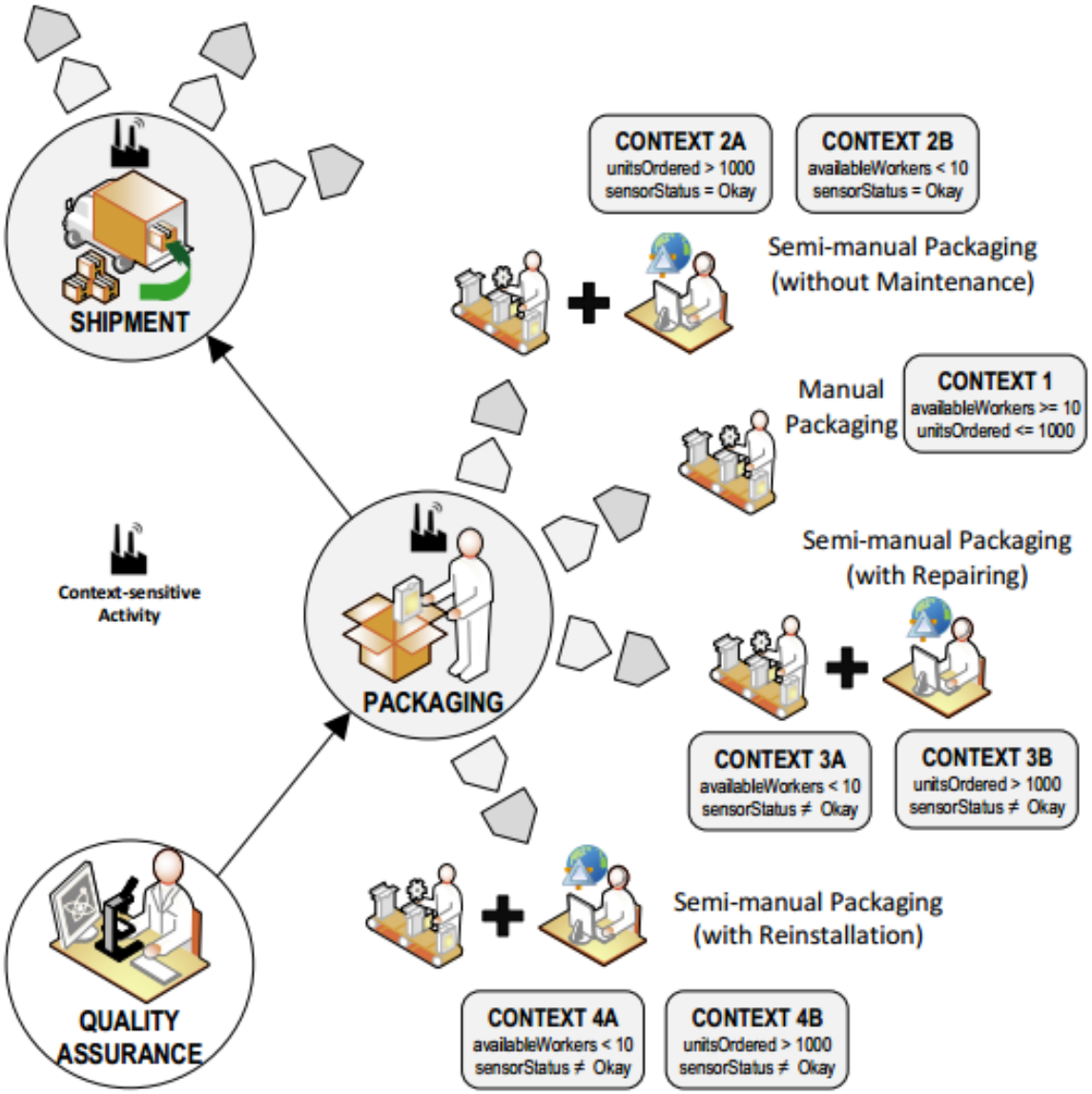
Case Study : CES Realization using BPMN



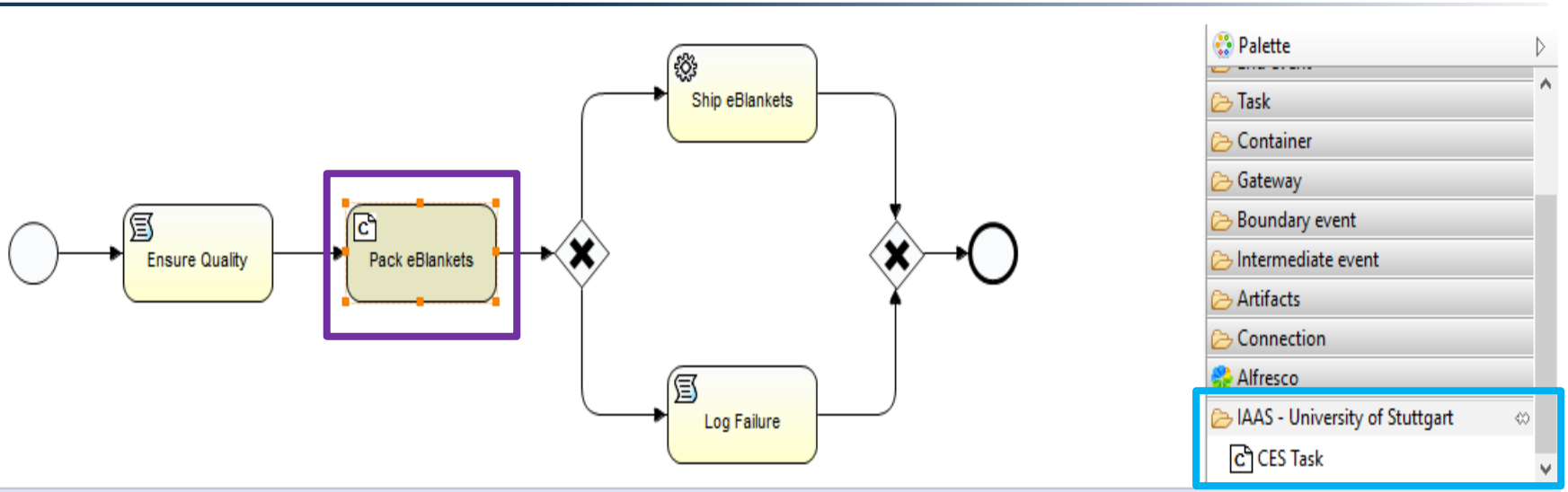
Case Study : Message-based Integration

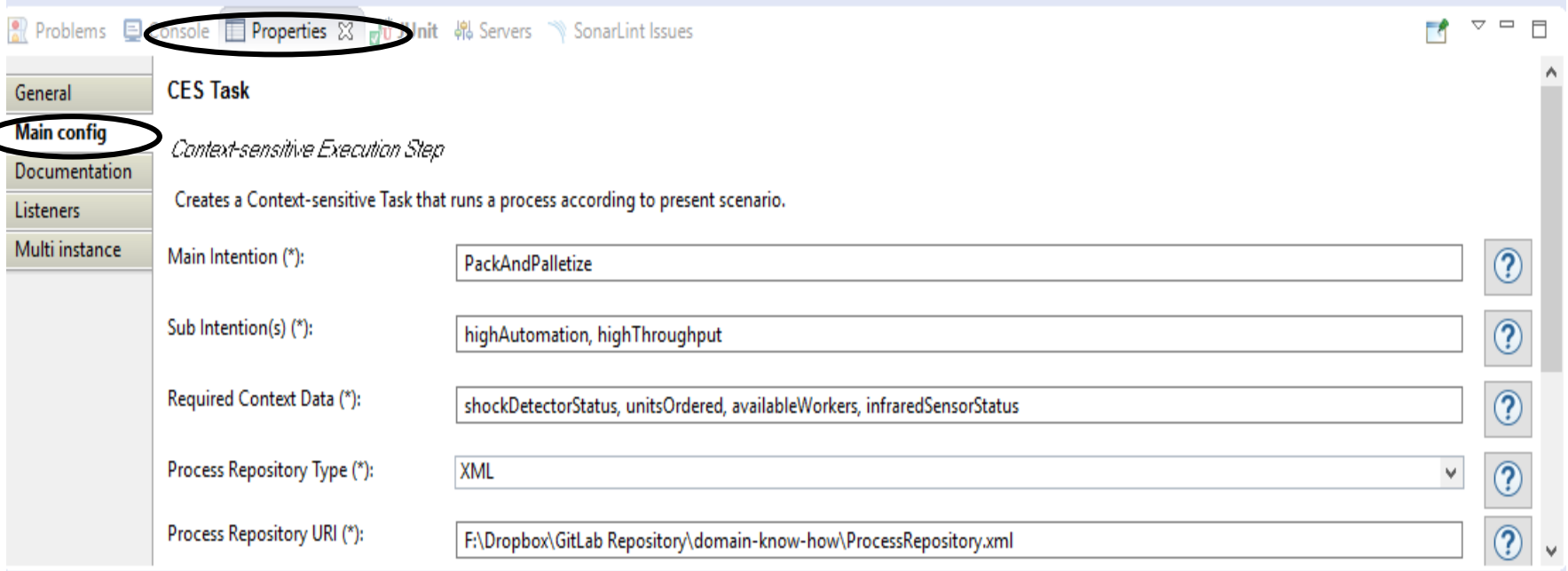


Case Study : Application Scenario



Custom Activiti Designer





Case Study : XML Excerpt of CES Definition

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<CESDefinition xmlns="http://www.uni-stuttgart.de/iaas/cmp/v0.1/" xmlns:ns2="http://www.uni-
stuttgart.de/iaas/ipsm/v0.2/" xmlns:ns3="http://docs.oasis-open.org/tosca/ns/2011/12"
isEventDriven="false" isCommandAction="true" targetNamespace="http://www.uni-
stuttgart.de/iaas/cmp/v0.1/">
    <Intention name="PackAndPalletize">
        <ns2:SubIntentions>
            <ns2:SubIntentionRelations>http://www.uni-stuttgart.de/iaas/cmp/weight-
based</ns2:SubIntentionRelations>
            <ns2:SubIntention name="highAutomation"/>
            <ns2:SubIntention name="highThroughput"/>
        </ns2:SubIntentions>
    </Intention>
    <RequiredContexts>
        <ns2:Context name="shockDetectorStatus"/>
        <ns2:Context name="unitsOrdered"/>
        <ns2:Context name="availableWorkers"/>
        <ns2:Context name="infraredSensorStatus"/>
    </RequiredContexts>
    <InputData>
        <DataList name="operatorName" value="Wolfgang"/>
        <DataList name="supervisorName" value="Frank"/>
        <DataList name="orderID" value="DE37464358BY"/>
        <DataList name="qualityCheck" value="passed"/>
        <DataList name="machinistName" value="Erick"/>
    </InputData>
    <OutputVariable>
        <DataList name="finalStatus" value=""/>
    </OutputVariable>
    <OptimizationRequired>true</OptimizationRequired>
    <DomainKnowHowRepositoryType>xml</DomainKnowHowRepositoryType>
    <DomainKnowHowRepository>F:\Dropbox\GitLab Repository\domain-know-
how\ProcessRepository.xml</DomainKnowHowRepository>
</CESDefinition>
```

Case Study : Query Manager

"Query Manager prepares context query and pushes the query to the for the underlying sensor based context middleware."

```
INFO: Starting to graceful shutdown 1 routes (timeout 300 seconds) [Thu Mar 17 18:03:41 CET 2016]
INFO: Waiting as there are still 1 inflight and pending exchanges to complete, timeout in 300 seconds. Inflights per route: [route1 = 1]
INFO: Connecting to Middleware... [Thu Mar 17 18:03:41 CET 2016]
INFO: Refreshing org.springframework.context.support.ClassPathXmlApplicationContext@25b15e82: startup date [Thu Mar 17 18:03:41 CET 201
INFO: Loading XML bean definitions from class path resource [META-INF/beans.xml] [Thu Mar 17 18:03:41 CET 2016]
INFO: Fetching Collections from MongoDB Sensor Data Repository... [Thu Mar 17 18:03:41 CET 2016]
INFO: Acquiring Context Data... [Thu Mar 17 18:03:41 CET 2016]
INFO: Context Acquisition is in Progress... [Thu Mar 17 18:03:41 CET 2016]
INFO: Acquiring Context Data... [Thu Mar 17 18:03:41 CET 2016]
INFO: Context Acquisition is in Progress... [Thu Mar 17 18:03:41 CET 2016]
INFO: Acquiring Context Data... [Thu Mar 17 18:03:41 CET 2016]
INFO: Context Acquisition is in Progress... [Thu Mar 17 18:03:42 CET 2016]
INFO: Acquiring Context Data... [Thu Mar 17 18:03:42 CET 2016]
INFO: Context Acquisition is in Progress... [Thu Mar 17 18:03:42 CET 2016]
INFO: Closing org.springframework.context.support.ClassPathXmlApplicationContext@25b15e82: startup date [Thu Mar 17 18:03:41 CET 2016];
INFO: Connection to Middleware is Closed. [Thu Mar 17 18:03:42 CET 2016]
INFO: Context Acquisition is Finished. [Thu Mar 17 18:03:42 CET 2016]
INFO: Waiting as there are still 1 inflight and pending exchanges to complete, timeout in 299 seconds. Inflights per route: [route1 = 1
INFO: Context Data is Available on Message Queue. [Thu Mar 17 18:03:42 CET 2016]
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<ContextSet xmlns="http://www.uni-stuttgart.de/iaas/ipsm/v0.2/" xmlns:ns2="http://docs.oasis-open.org/tosca/ns/2011/12" xmlns:ns3="http
    <Context name="shockDetectorStatus" targetNamespace="http://www.uni-stuttgart.de/iaas/cmp/v1/packaging">
        <ContextDefinition definitionLanguage="en_US">
            <DefinitionContent>
                <ns3:ManufacturingContent>
                    <ns3:OrderID>DE37464358BY</ns3:OrderID>
                    <ns3:SenseValue>Okay</ns3:SenseValue>
```

(S1.1) Wait for Input Data

(S1.2) Wait for Context Data

Case Study : Context Analyzer and Intention Analyzer

"Context Analyzer fetches the available process definition inside process repository to nominate the suitable definitions valid for the received contexts."

```
            <ns3:ManufacturingContent>
                <ns3:OrderID>DE37464358BY</ns3:OrderID>
                <ns3:SenseValue>Malfunctioned</ns3:SenseValue>
                <ns3:DeliveryDate>2016-01-10T00:00:00.000+01:00</ns3:DeliveryDate>
                <ns3:Location latitude="48.145199" longitude="11.576567">
                    <ns3:MachineName>Sealing Machine: SMEX207</ns3:MachineName>
                </ns3:Location>
                <ns3:Timestamp>TS time:Thu Nov 26 00:54:32 CET 2015 inc:1</ns3:Timestamp>
            </ns3:ManufacturingContent>
        </DefinitionContent>
    </ContextDefinition>
</Context>
</ContextSet>
INFO: Waiting as there are still 1 inflight and pending exchanges to complete, timeout in 298 seconds. Inflights per route: [route1 = 1
INFO: Phase-1 Context Analysis Report: {CON1=false, CON2A=false, CON2B=false, CON3A=false, CON3B=false, CON3C=false, CON3D=true, CON3E=
INFO: Phase-2 Context Analysis Report: {PMX001=false, PRS001=true, PRS002=true, PSM001=false} [Thu Mar 17 18:03:43 CET 2016]
INFO: 2 Processes Passed Context Analysis. [Thu Mar 17 18:03:43 CET 2016]
INFO: Context Matching Process is Completed. [Thu Mar 17 18:03:43 CET 2016]
```

(S2) Select Process Models by Matching Contexts

"Intention Analyzer analyzes the received process definitions by filtering them with required main-intention (goals) defined for the specific business scenario."

```
INFO: Intention Analysis is Started by Deserializing the ProcessRepository.xml [Thu Mar 17 18:03:44 CET 2016]
INFO: PRS001 Passes Intention Analysis. [Thu Mar 17 18:03:44 CET 2016]
INFO: Waiting as there are still 1 inflight and pending exchanges to complete, timeout in 297 seconds. Inflights per route: [route1 = 1
INFO: PRS002 Passes Intention Analysis. [Thu Mar 17 18:03:44 CET 2016]
INFO: Overall 2 Processes Passed Intention Analysis. [Thu Mar 17 18:03:44 CET 2016]
INFO: Intention Analysis is Completed. [Thu Mar 17 18:03:44 CET 2016]
```

(S3) Select Process Models by Matching Intentions

Case Study : Process Selector and Process Optimizer

"Process Selector filters the received process definitions from Intention Analyzer with a predefined selection strategy (if no strategy -> random strategy)."

```
INFO: Selection by Strategy analysis is being done. [Thu Mar 17 18:03:44 CET 2016]
INFO: Refreshing org.springframework.context.support.ClassPathXmlApplicationContext@259a071d: startup date [Thu Mar 17 18:03:44 CET 201
INFO: Loading XML bean definitions from class path resource [META-INF/beans.xml] [Thu Mar 17 18:03:44 CET 2016]
INFO: Weight Analysis is in Process... [Thu Mar 17 18:03:44 CET 2016]
INFO: Process is Selected. [Thu Mar 17 18:03:44 CET 2016]
INFO: Closing org.springframework.context.support.ClassPathXmlApplicationContext@259a071d: startup date [Thu Mar 17
INFO: PRS001 Is Selected for the Realization of Business Ojective. [Thu Mar 17 18:03:44 CET 2016]
```

(S4) Eliminate Duplicates

"Process Optimizer looks for the process descriptor of any defined optimization model for the process, deploys, and executes the optimization model with the required process engine instance.."

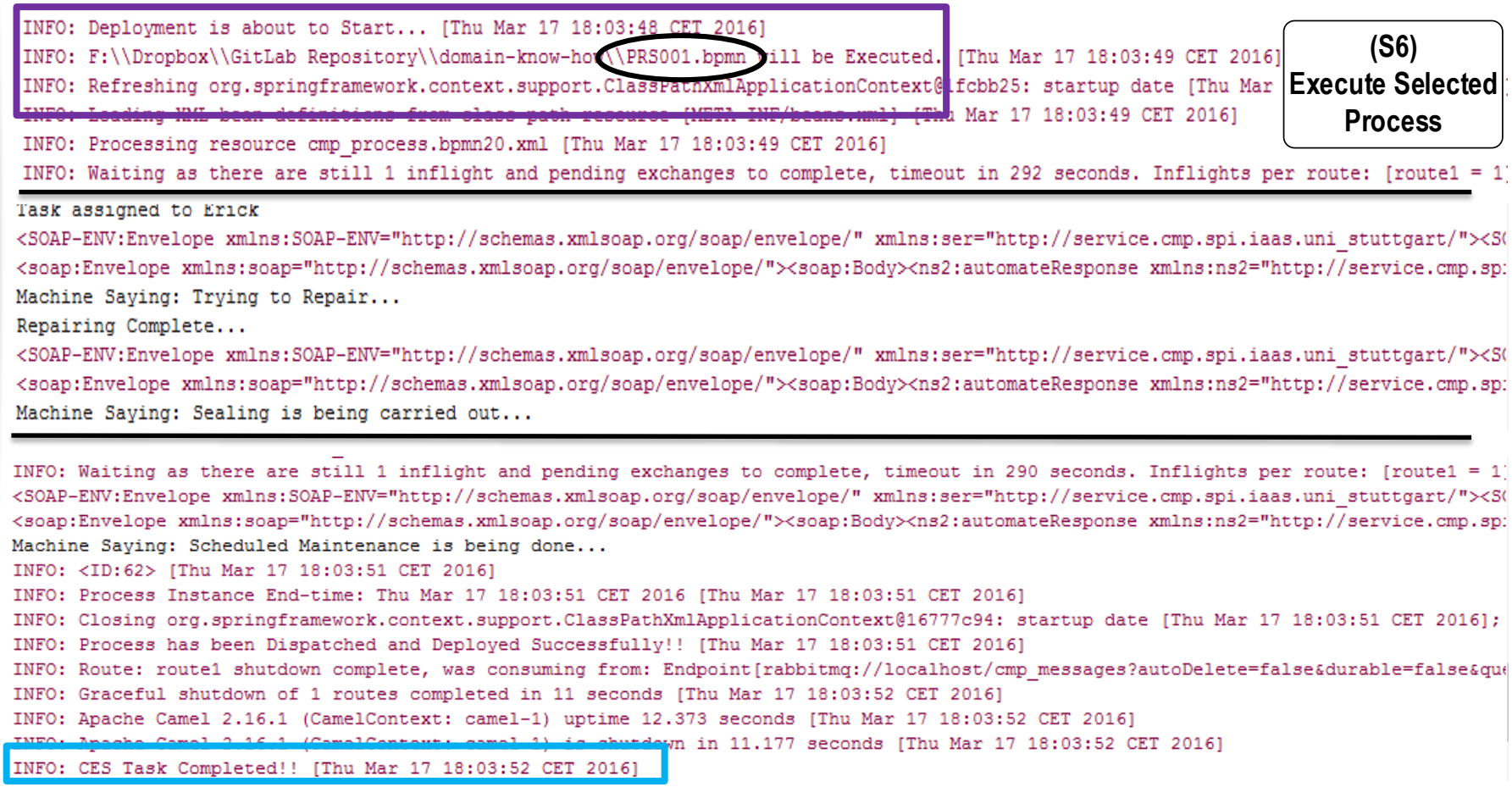
```
INFO: Optimization is being Carried Out... [Thu Mar 17 18:03:44 CET 2016]
INFO: Waiting as there are still 1 inflight and pending exchanges to complete, timeout in 296 seconds. Inflights per route: [route1 = 1
INFO: POPT01 Will Be Executed. [Thu Mar 17 18:03:45 CET 2016]
INFO: Refreshing org.springframework.context.support.ClassPathXmlApplicationContext@2b6af133: startup date [Thu Mar 17 18:03:45 CET 201
INFO: Loading XML bean definitions from class path resource [META-INF/beans.xml] [Thu Mar 17 18:03:45 CET 2016]
```

```
<SOAP-ENV:Envelope xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelope/" xmlns:ser="http://service.cmp.spi.iaa
INFO: Waiting as there are still 1 inflight and pending exchanges to complete, timeout in 293 seconds. Inflights pe
<soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"><soap:Body><ns2:automateResponse xmlns:ns2="h
Machine Saying: Optimizing resources in Factory...
INFO: <ID:16> [Thu Mar 17 18:03:48 CET 2016]
```

(S5) Optimize Selected Process

Case Study : Process Dispatcher

"Process Dispatcher deploys the main business process chosen to an underlying process engine. This sub-component is also responsible for executing the complementary business processes."



Case Study : Process Output and Final Status

```
INFO: Route: route2 started and consuming from: Endpoint[rabbitmq://localhost/cmp_messages?autoDelete=false&durable=false&prefetchEnabl
INFO: Total 1 routes, of which 1 is started. [Thu Mar 17 18:03:52 CET 2016]
INFO: Apache Camel 2.16.1 (CamelContext: camel-2) started in 0.152 seconds [Thu Mar 17 18:03:52 CET 2016]
INFO: Apache Camel 2.16.1 (CamelContext: camel-2) is shutting down [Thu Mar 17 18:03:52 CET 2016]
INFO: Starting to graceful shutdown 1 routes (timeout 300 seconds) [Thu Mar 17 18:03:52 CET 2016]
INFO: Waiting as there are still 1 inflight and pending exchanges to complete, timeout in 300 seconds. Inflights per route: [route2 = 1
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<ns3:CESDefinition xmlns="http://www.uni-stuttgart.de/iaas/ipsm/v0.2/" xmlns:ns2="http://docs.oasis-open.org/tosca/ns/2011/12" xmlns:ns
    <ns3:OutputVariable>
        <ns3:DataList name="finalStatus" value="done"/>
    </ns3:OutputVariable>
</ns3:CESDefinition>
INFO: Route: route2 shutdown complete, was consuming from: Endpoint[rabbitmq://localhost/cmp_messages?autoDelete=false&durable=false&pr
INFO: Graceful shutdown of 1 routes completed in 1 seconds [Thu Mar 17 18:03:53 CET 2016]
INFO: Apache Camel 2.16.1 (CamelContext: camel-2) uptime 1.178 seconds [Thu Mar 17 18:03:53 CET 2016]
INFO: Apache Camel 2.16.1 (CamelContext: camel-2) is shutdown in 1.024 seconds [Thu Mar 17 18:03:53 CET 2016]
INFO: Proceeding to next activity. [Thu Mar 17 18:03:53 CET 2016]
<SOAP-ENV:Envelope xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelope/" xmlns:ser="http://service.cmp.spi.iaas.uni_stuttgart/"><S
<soap:Envelope xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"><soap:Body><ns2:automateResponse xmlns:ns2="http://service.cmp.sp
Machine Saying: Shipping will be Begun by the Logisitics Company.
INFO: <Process Instance ID:5> is Realized. [Thu Mar 17 18:03:53 CET 2016]
```

Existing Approaches & Comparison

	R1	R2	R3	R4	R5	R6
Ad-hoc Sub-processes	-	~	~	-	-	-
Adams et al.	✓	✓	✓	-	-	✓
Andrikopoulos et al.	✓	✓	✓	-	-	✓
Bucchiarone et al.	✓	✓	✓	-	-	✓
Hallerbach et al.	✓	-	-	-	-	✓
Hirmer et al.	✓	-	✓	-	-	✓
Marconi et al.	✓	-	✓	-	-	✓
Pfeffer et al.	✓	✓	-	-	-	-
Reichert et al.	✓	-	-	-	-	✓
van der Aalst et al.	✓	-	-	-	-	✓
Wieland et al.	✓	-	✓	-	-	✓
Wolf et al.	✓	-	✓	-	-	-
Sungur et al. (CES)	✓	✓	✓	✓	✓	✓

Summary and Outlook

We have

- realized CAPP based CES construct using BPMN.
- extended Activiti BPMN tool for incorporating CES entity.
- integrated business objectives with the production context.
- proposed architecture for realizing CAPP based systems.
- implemente CES construct.
- presented t emain process language ag

Thank You for Your Attention!

We will like to

- realize CES based on CAPP approach using WS-BPEL.
- integrate dynamic process optimization schemes.
- develop GUI tool for Process Repository modelling.
- match goals recursively inside Intention Analyzer.