A Methodology to Define QoS and SLA Requirements in Service Choreographies

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Agenda

SOC

SOC (Service Oriented Computing)

It is a new computing paradigm that utilizes services as the basic constructs to support the development of rapid, low-cost and easy composition of distributed applications even in heterogeneous environments. [Papazoglou et al., 2006].

Key elements:

- Services (mainly Web services).

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Web Services and SOA

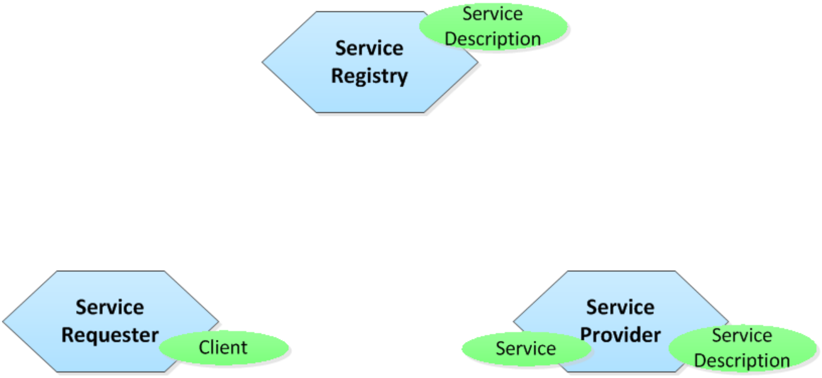

Figure: SOA triangle (based on [W3C, 2002])

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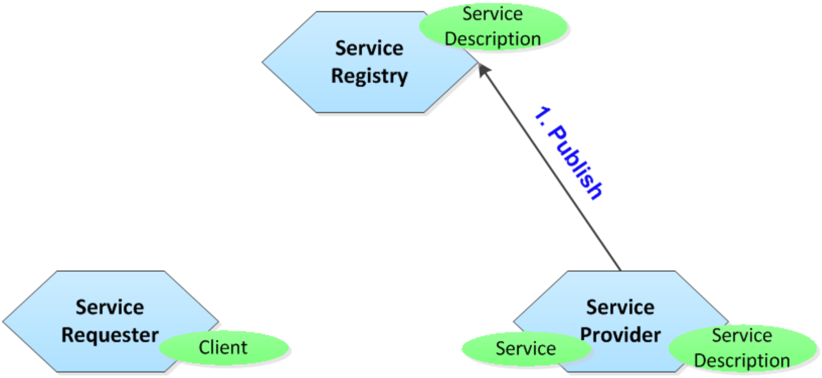

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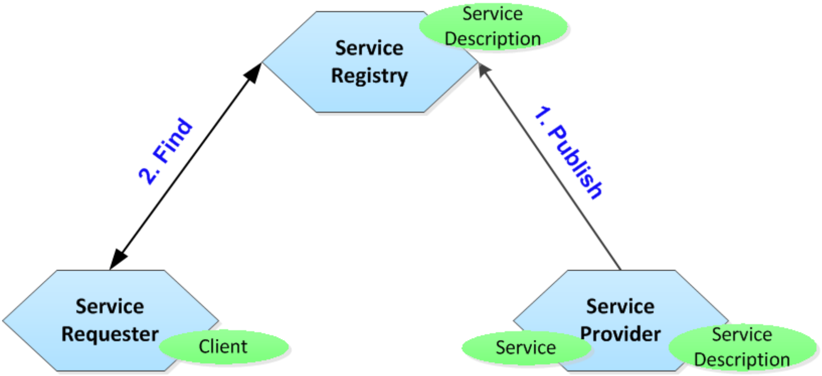

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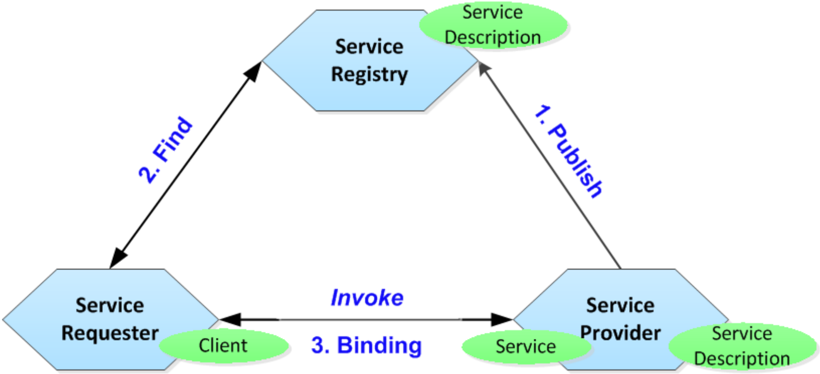

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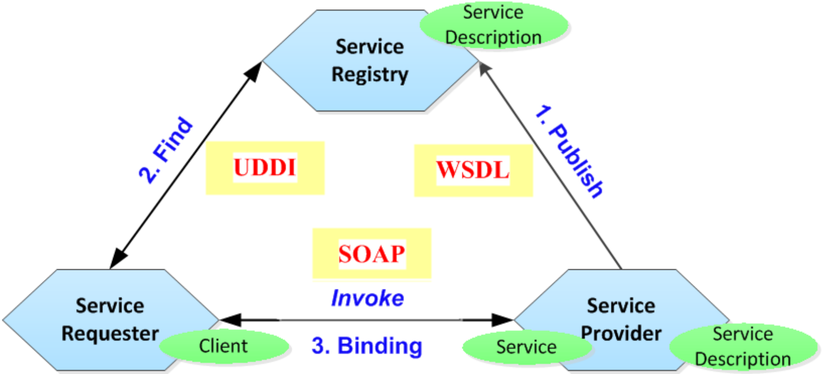

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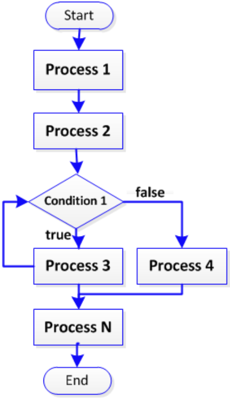

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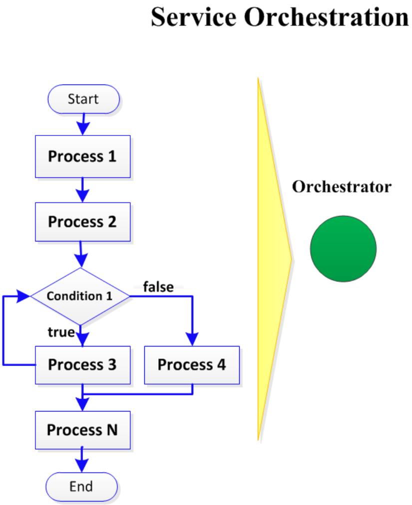

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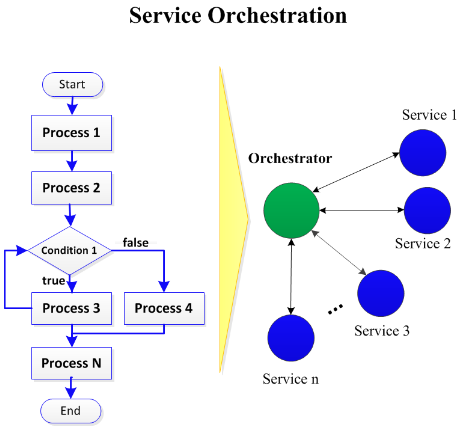
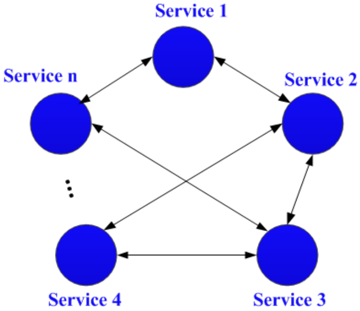


Figure: Service Orchestration

Service Choreography

- Allows service composition in a **collaborative** manner.
- Describes the **P2P interactions** of the externally **observable behavior of its participants**.
- Don't have a single point of control or coordination.



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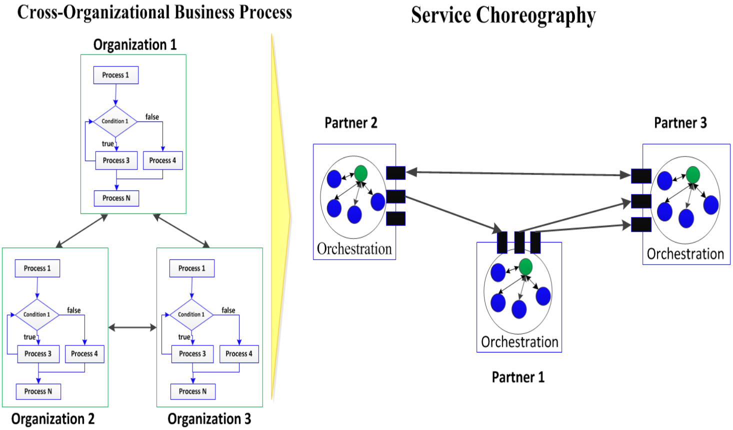

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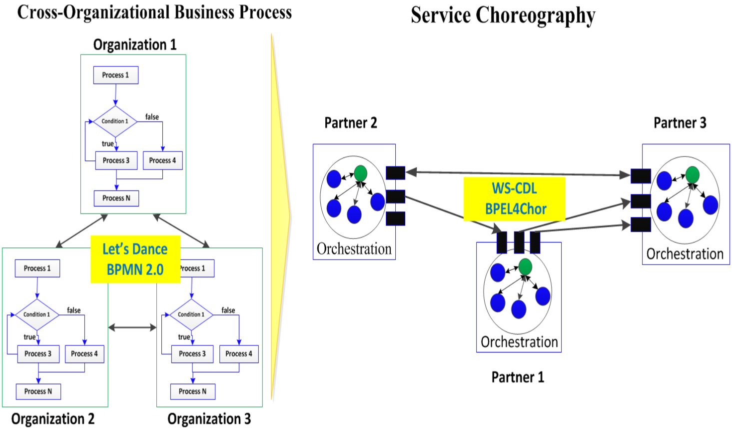

Figure: Service Choreography

BPMN and Choreography

- A Choreography is a type of process.
  - Differs in purpose and behavior from a standard BPMN Process (Process Orchestration).
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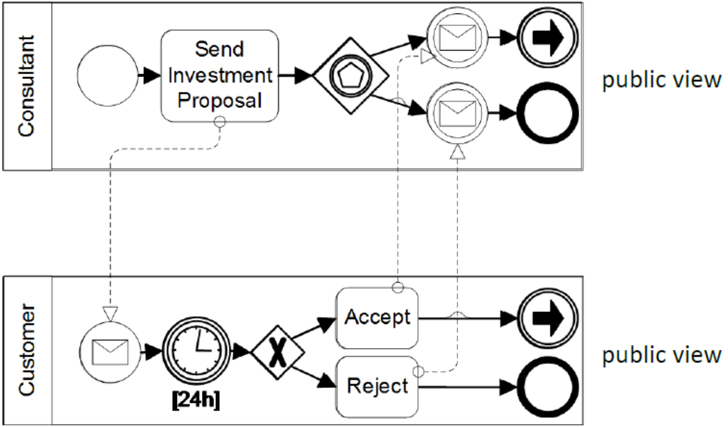
- Two approaches:
  - Interconnection Model : With collaborations diagrams.
  - Interaction Model : BPMN Choreographies. using special activities (*Choreography Activity*).

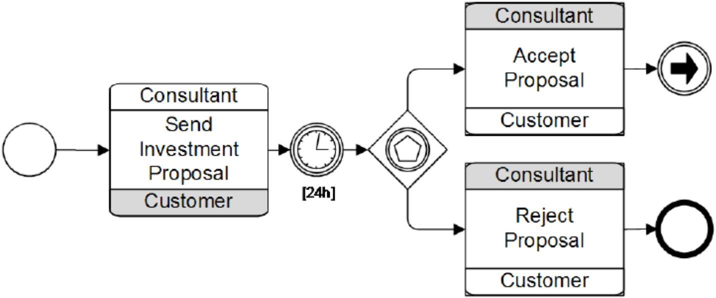
Interconnection Model

- Interconnected public views.
- Use of standard activities.
- "Collaboration" in BPMN 2.0.



Interaction Model

- Interactions **globally captured**.
- Basic building block: **atomic interaction** between two parties.
- "Choreography" in BPMN 2.0.



BPMN Choreography

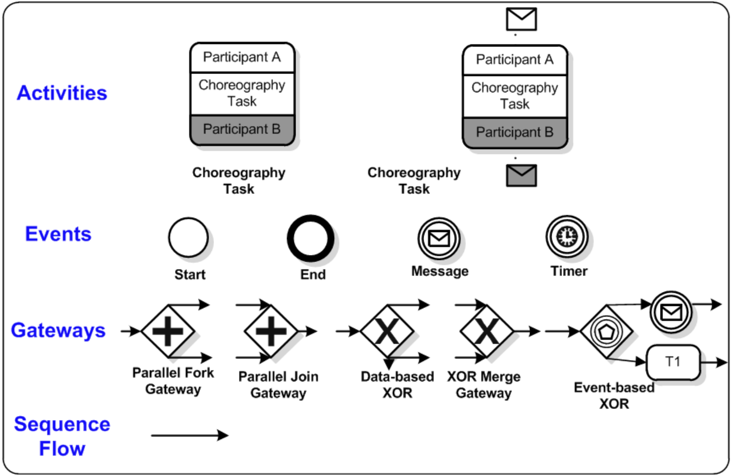


Figure: BPMN elements for modeling choreographies (BPMN 2.0).

Generalized Stochastic Petri Net (GSPN) (I)

Generalized Stochastic Petri Net (GSPN) (II)

Problem to Solve

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- Planning of resources before/during development of choreography.
- Little approaches don't evaluate choreographies:
  - focusing on **QoS** or
  - in earlier stages of development.
- To guarantee QoS about communications (network) is important.

Objectives

- To assess the **impact of QoS** attributes in a **choreography interaction model**.
- To propose a novel methodology to establish **requirements for QoS and SLA** in **early stages of development**.
- To plan the capacity of the network elements in choreographies.
- To convert a interaction model to a GSPN (Generalized Stochastic Petri Net) with QoS.

Description

1. Mapping of a choreography to a GSPN.
   - The choreography is specified according "interaction model".
   - The choreography is specified in BPMN 2.0.
   - The resulting GSPN include a QoS model.

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2. Configurations of resulting GSPN.
3. Simulations of scenarios.

Choreography Formalization

Definition: Process Choreography

A process choreography is a tuple:

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$PC = (\mathcal{O}, \mathcal{A}, \mathcal{E}, \mathcal{G}, \mathcal{T}, \{e^S\}, \mathcal{E}^I, \{e^E\}, \mathcal{E}^{I_M}, \mathcal{E}^{I_T}, \mathcal{G}^F, \mathcal{G}^J, \mathcal{G}^X, \mathcal{G}^M, \mathcal{G}^V, \mathcal{F})$

where:

- $\mathcal{O}$ is a set of objects and it's partitioned in **activities** $\mathcal{A}$, **events** $\mathcal{E}$ and **gateways** $\mathcal{G}$.

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- $\mathcal{A}$, is the set of **choreography tasks** $\mathcal{T}$.
- $\mathcal{E}$ is the set of **events** and it's is partitioned in **Start event** $e^{\mathcal{S}}$, **Intermediate events** $\mathcal{E}^{\mathcal{I}}$ and **End event** $e^{\mathcal{E}}$.

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- $\mathcal{E}$ is the set of **events** and it's is partitioned in **Start event** $e^{\mathcal{S}}$, **Intermediate events** $\mathcal{E}^{\mathcal{I}}$ and **End event** $e^{\mathcal{E}}$.
- $\mathcal{G}$ é the set of **gateways** and is partitioned in **parallel fork gateways** $\mathcal{G}^F$, **parallel join gateways** $\mathcal{G}^J$, **data-based XOR gateways** $\mathcal{G}^X$, **XOR merge gateways** $\mathcal{G}^V$ and **event-based XOR gateways** $\mathcal{G}^M$.

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- $\mathcal{A}$, is the set of **choreography tasks** $\mathcal{T}$.
- $\mathcal{E}$ is the set of **events** and it's is partitioned in **Start event** $e^{\mathcal{S}}$, **Intermediate events** $\mathcal{E}^{\mathcal{I}}$ and **End event** $e^{\mathcal{E}}$.
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- $\mathcal{F} \subseteq \mathcal{O} x \mathcal{O}$ is the control flow relation, i.e. a **set of sequence flows connecting objects**.

QoS Model

- Defining the QoS attributes involved in **service**, **network** and **message** aspects.
- QoS attributes:
  - In service operation : **time to complete the service**.
  - In network : delay and **communication errors**.
  - In message : **message format**.

Mapping BPMN to Petri Net (I)

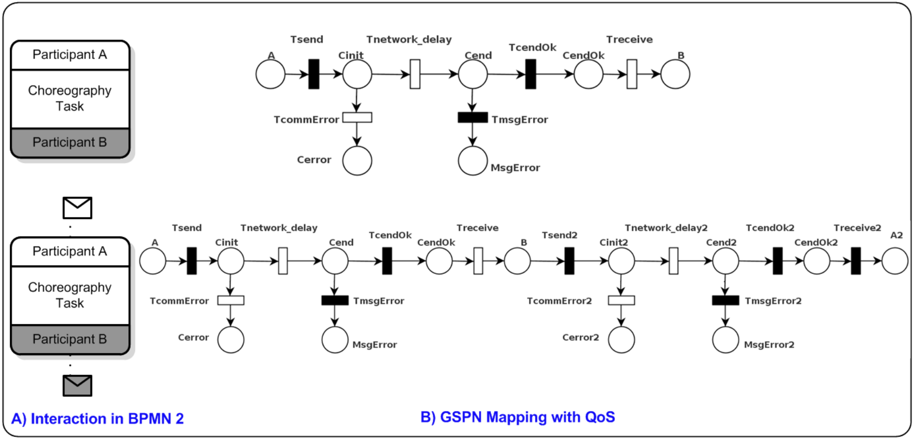
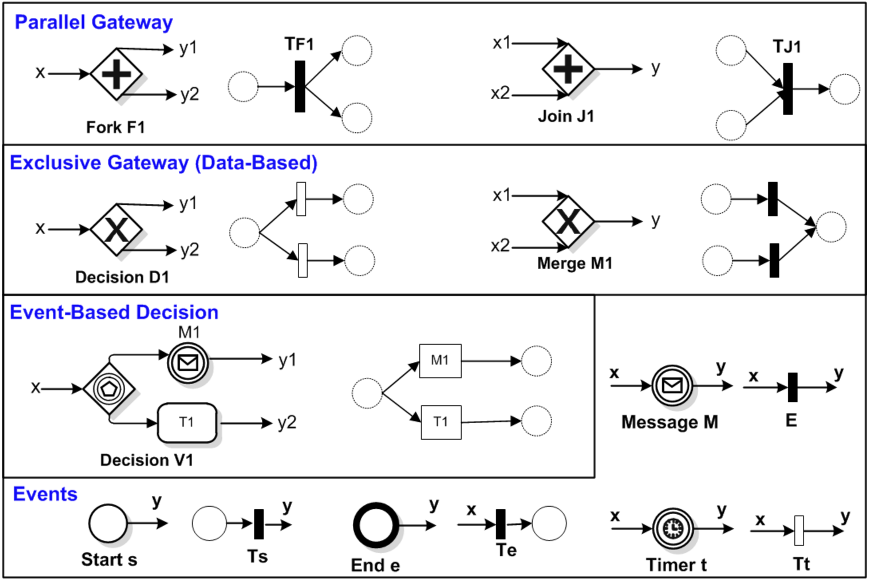


Figure: Mapping of two different choreography tasks with the QoS model

Mapping BPMN to Petri Net (II)



Mapping Algorithm (I)

Algorithm 1 Mapping of choreography specified in BPMN 2.0 to a GSPN with QoS model

Input: **Process Choreography** $PC = (\mathcal{O}, \mathcal{A}, \mathcal{E}, \mathcal{G}, \mathcal{T}, \{e^S\}, \mathcal{E}^I, \{e^E\}, \mathcal{E}^{I_M}, \mathcal{E}^{I_T}, \mathcal{G}^F, \mathcal{G}^J, \mathcal{G}^X, \mathcal{G}^M, \mathcal{G}^V, \mathcal{F})$ in BPMN 2.0.

Output: Generalized Stochastic Petri Net $GSPN_{QoS}$.

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Algorithm 2 Mapping of choreography specified in BPMN 2.0 to a GSPN with QoS model

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Output: Generalized Stochastic Petri Net $GSPN_{QoS}$.

Consider $CT_i \in \mathcal{T}$, $G_j \in \mathcal{G}$ and $E_k \in \mathcal{E}$. where $i, j, k \in \mathbb{N}$.

Algorithm 3 Mapping of choreography specified in BPMN 2.0 to a GSPN with QoS model

Input: **Process Choreography** $PC = (\mathcal{O}, \mathcal{A}, \mathcal{E}, \mathcal{G}, \mathcal{T}, \{e^S\}, \mathcal{E}^I, \{e^E\}, \mathcal{E}^{I_M}, \mathcal{E}^{I_T}, \mathcal{G}^F, \mathcal{G}^J, \mathcal{G}^X, \mathcal{G}^M, \mathcal{G}^V, \mathcal{F})$ in BPMN 2.0.

Output: Generalized Stochastic Petri Net $GSPN_{QoS}$.

Consider $CT_i \in \mathcal{T}$, $G_j \in \mathcal{G}$ and $E_k \in \mathcal{E}$. where $i, j, k \in \mathbb{N}$.

Consider $PNQoS(CT_i)$ is a function of the type of CT_i that returns a GSPN according to mapping rules.

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Algorithm 4 Mapping of choreography specified in BPMN 2.0 to a GSPN with QoS model

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Algorithm 5 Mapping of choreography specified in BPMN 2.0 to a GSPN with QoS model

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Algorithm 6 Mapping of choreography specified in BPMN 2.0 to a GSPN with QoS model

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Consider $\oplus$ the binary operator of composition of two GSPNs that returns other GSPN.

Mapping Algorithm (II)

$GSPN_{QoS} \leftarrow Empty\ Petri\ Net$

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For $CT_i \in \mathcal{T}$ **Do**

End

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For $CT_i \in \mathcal{T}$ **Do**

$\quad GSPN_{QoS} \leftarrow GSPN_{QoS} \oplus PNQoS(CT_i)$

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  Add a arrival **timed Transition** at beginning of the $GSPN_{QoS}$.
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For $G_j \in \mathcal{G}$ **Do**

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End

For $G_j \in \mathcal{G}$ **Do**

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For $E_k \in \mathcal{E}$ **Do**

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For $E_k \in \mathcal{E}$ **Do**

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Add a starting Place and **immediate Transition** at the beginning of the $GSPN_{QoS}$.

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For $CT_i \in \mathcal{T}$ **Do**

$GSPN_{QoS} \leftarrow GSPN_{QoS} \oplus PNQoS(CT_i)$

Add a arrival **timed Transition** at beginning of the $GSPN_{QoS}$.

End

For $G_j \in \mathcal{G}$ **Do**

$GSPN_{QoS} \leftarrow GSPN_{QoS} \oplus PN(G_j)$

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For $E_k \in \mathcal{E}$ **Do**

$GSPN_{QoS} \leftarrow GSPN_{QoS} \oplus PN(E_k)$

End

Add a starting Place and **immediate Transition** at the beginning of the $GSPN_{QoS}$.
Add a ending Place and **immediate Transition** at the end of the $GSPN_{QoS}$.

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$GSPN_{QoS} \leftarrow GSPN_{QoS} \oplus PNQoS(CT_i)$

Add a arrival **timed Transition** at beginning of the $GSPN_{QoS}$.

End

For $G_j \in \mathcal{G}$ **Do**

$GSPN_{QoS} \leftarrow GSPN_{QoS} \oplus PN(G_j)$

End

For $E_k \in \mathcal{E}$ **Do**

$GSPN_{QoS} \leftarrow GSPN_{QoS} \oplus PN(E_k)$

End

Add a starting Place and **immediate Transition** at the beginning of the $GSPN_{QoS}$.

Add a ending Place and **immediate Transition** at the end of the $GSPN_{QoS}$.

Return $GSPN_{QoS}$

Scenario

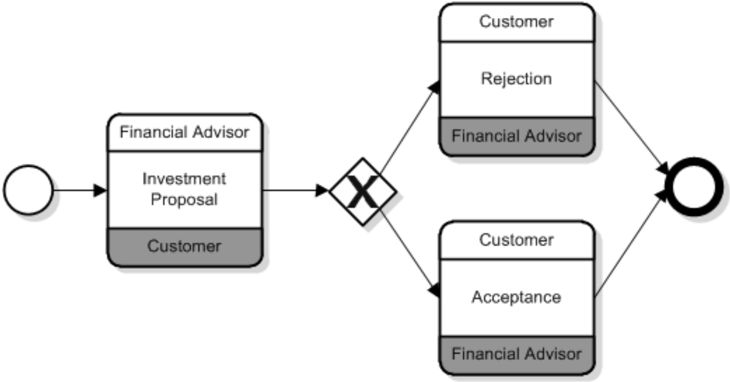

Figure: Example of choreography using BPMN2 elements.

Mapping

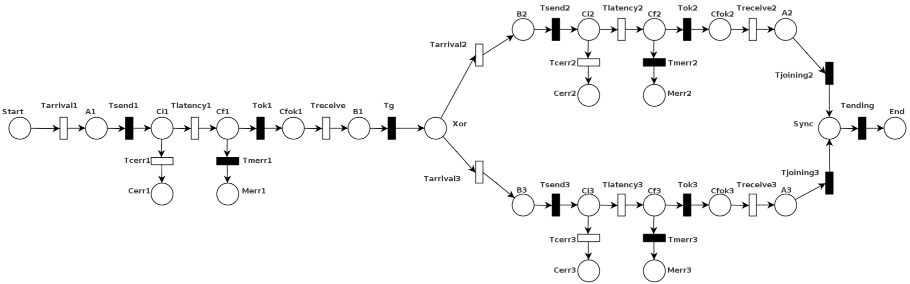

Figure: GSPN obtained from the choreography.

Configuration

Table: Weights of Scenario 1 and Scenario 2

	Weights	
Transition	**Scenario 1**	**Scenario 2**
$T_{latency1}$, $T_{latency2}$, $T_{latency3}$	0.99	0.94
T_{cerr1}, T_{cerr2}, T_{cerr3}	0.01	0.06
$T_{receive}$, $T_{receive2}$, $T_{receive3}$	99	97
T_{merr1}, T_{merr2}, T_{merr3}	1	3
$T_{arrival2}$, $T_{arrival3}$	0.5	0.5

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- The **Pipe2** tool was used to **model** and **simulate** the **GSPN**.
- 1500 fires and 10 replications.
- Confidence level of 95%.

Results (I)

Table: Results (in %)

	Average number of tokens		95% Confidence interval (+/-)	
Place	**Scenario 1**	**Scenario 2**	**Scenario 1**	**Scenario 2**
Start	35.28	40.15	5.83	6.23
End	41.95	38.78	2.53	3.82
M_{err1}	0.39	0.91	0.95	1.92
M_{err2}	0.00	0.93	0.63	0.64
M_{err3}	0.00	0.66	0.87	0.74
C_{err1}	0.74	2.94	0.82	2.02
C_{err2}	0.00	0.00	0.67	1.75
C_{err3}	0.78	0.16	0.92	1.52
C_{i1}	8.32	8.90	5.33	7.48
C_{i2}	0.63	0.69	0.23	0.52
C_{i3}	0.75	8.90	0.39	0.21

Results (II)

- **Communication errors**: An average of $C_{err1} + C_{err2} + C_{err3}$ of instances **didn't finish the process**.
  - Scenario 1: 1.52%.
  - Scenario 2: 3.10% (more errors).

Results (II)

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- **Invalid format message**: An average of $M_{err1} + M_{err2} + M_{err3}$ of instances **didn't finish the process**.
  - Scenario 1: 0.39%.
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  - Scenario 2: 2.50% (more invalid messages).
- **Bottleneck**: It was found a communication bottleneck in the first interaction (C_i place).
  - Scenario 1: 8.32%.
  - Scenario 2: 8.90%.

Conclusions

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- We have proposed a Novel methodology to aid define QoS and SLA requirements in service Choreography.
- First and initial approach using the "interaction model" (supported by BPMN 2.0).
- The GSPN is good to model and analyze several aspects involved into service choreography.
- The simulation is needed for supporting analysis of complex process (e.g. process choreography).
- The simulation results can be used to establish early QoS and SLA constraints.
  - Integration is expensive, then early detections are needed.
  - Establishing SLAs according to resources.
  - Planning in order to reduce failures.
  - For example: the detected bottleneck can be solved by changing the interaction (modeling issues) or by employing QoS mechanisms in the network to prioritize the traffic affected (resource planning).

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- To expand our methodology to support generic probability distributions in the decision points. Using Colored Petri Nets (CPNs) can be a alternative.
- To make more analysis and to use complex scenarios, where correlations problems could happen.
- To include more QoS attributes.

Thanks so much!