ServiceWave 2008

Conference:
Madrid, 10-13 December, 2008

Model Driven QoS Analyses of Composed Web Services

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Agenda

- Motivations
- Architectural Evaluation Framework
- Composed WS Optimizator
- Composed WS Quality Analyzer
- Reference Example
- Conclusions and Future Work

Motivations

- SOA provides a new paradigm for the creation of business applications: decentralized development and distributed systems compositions
- SOA can benefit from the Model Driven Development (MDD):
  - Models are built to support software engineers in reasoning at the software architecture level
  - Early QoS assessment of a service composition
  - Design time QoS evaluation on abstract processes

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Motivations

- The use of models extends beyond the initial design of an application:
  - Support both the initial derivation of an implementation and then an evolution of the software architecture
  - Devise suitable reconfiguration strategies for the dynamic contexts

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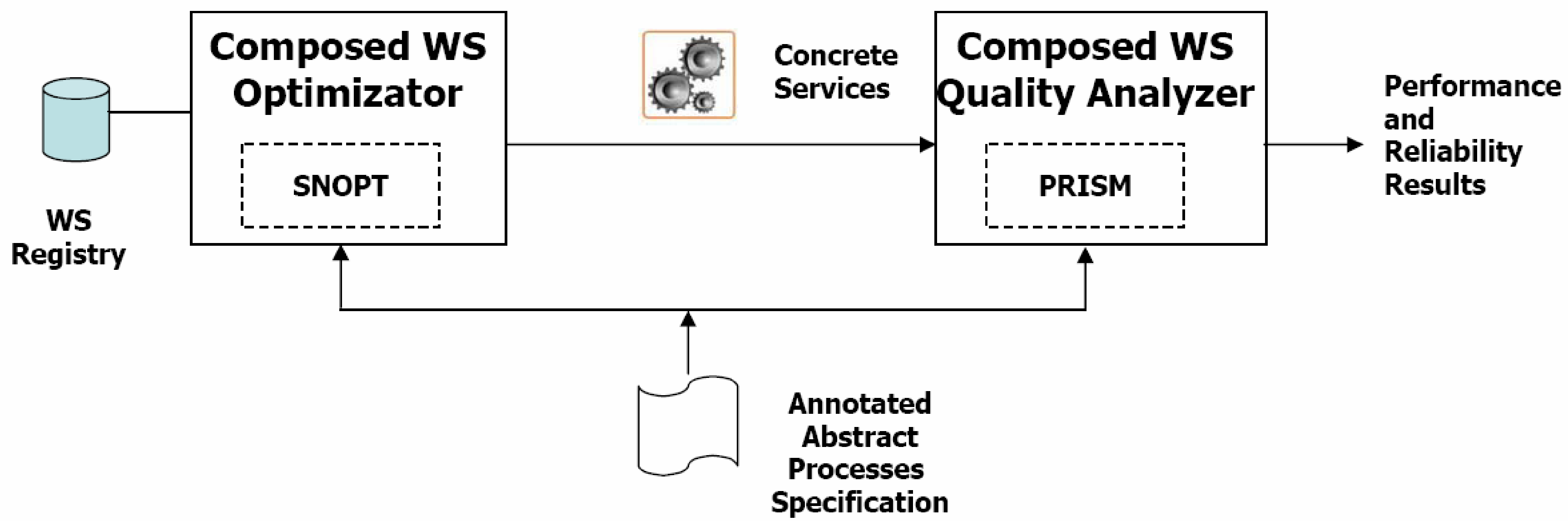
Our work

- Overall framework for the automatic service selection and QoS analysis of composed Web services:
  - Service selection through the solution of a non-linear optimization problem
  - QoS analysis built on stochastic model checking

Architectural Evaluation Framework



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Architectural Evaluation Framework

- Applications functional and non-functional requirements described as annotated abstract BPEL processes
- Abstract services and dynamic/late binding mechanism
- Specifications annotated in order to provide statistics on processes executions

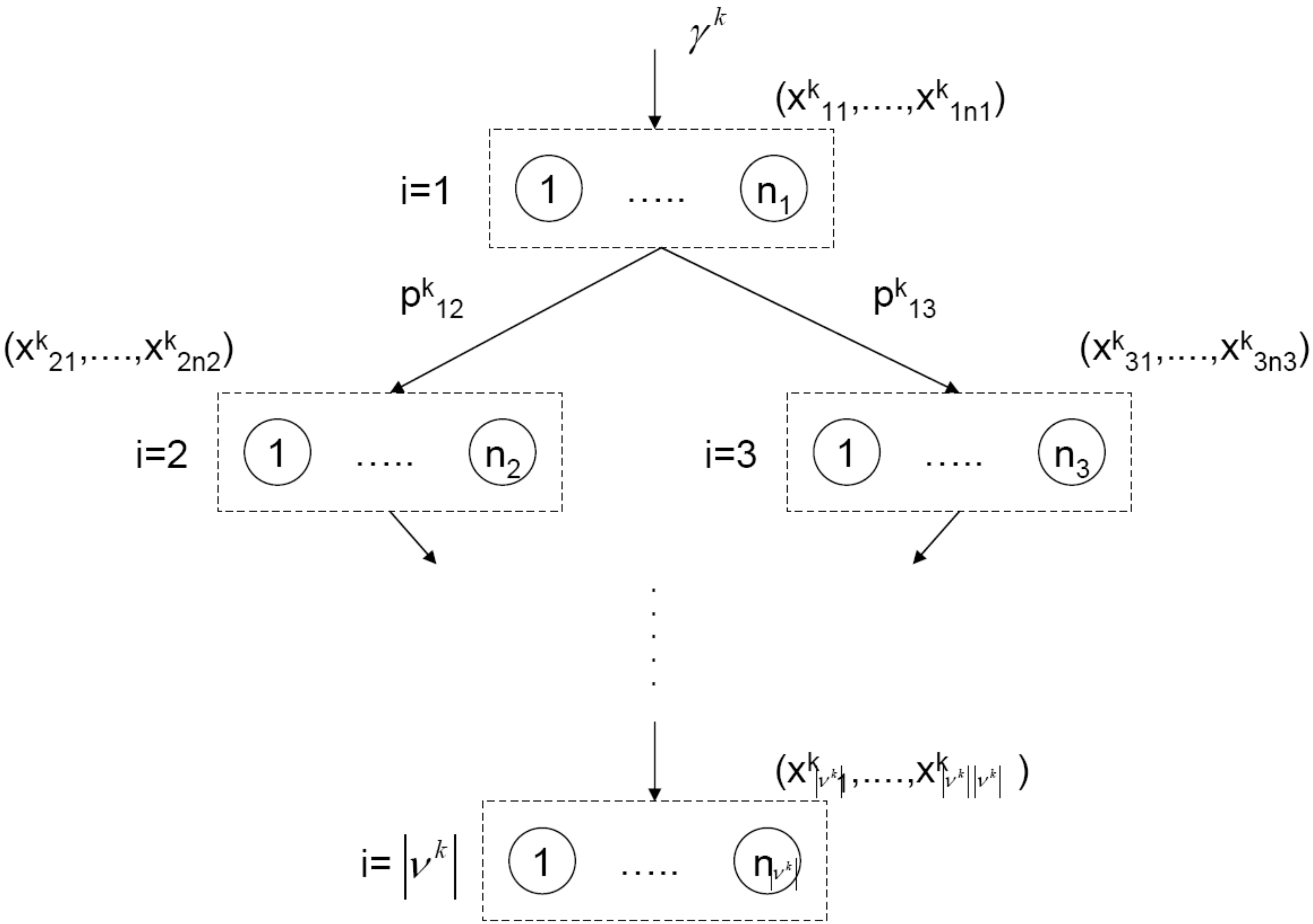
Architectural Evaluation Framework

- Each composed process is transformed in a Directed Acyclic Graph (DAG)
- Quality model:
  - Service Reliability r_j
  - Service Execution e_j
  - Service Cost c_j
- Service Invocations Attempts

Composed Service Model

- SPs store their maximum service rate μ_j in the registry and resources are pre-allocated
- Each service ws_j is modelled as a M/M/1 queue
- *K:* set of QoS classes
- γ_k *:* class-k requests incoming workload
- ν^k *:* the set of indexes of abstract services specified in class-k process
- J^k_i the set of all concrete services ws_j, that implement the abstract service i
- Let be $\mathcal{J} = \bigcup_{k \in K} \bigcup_{i \in \mathcal{V}^k} J_i^k$

An example



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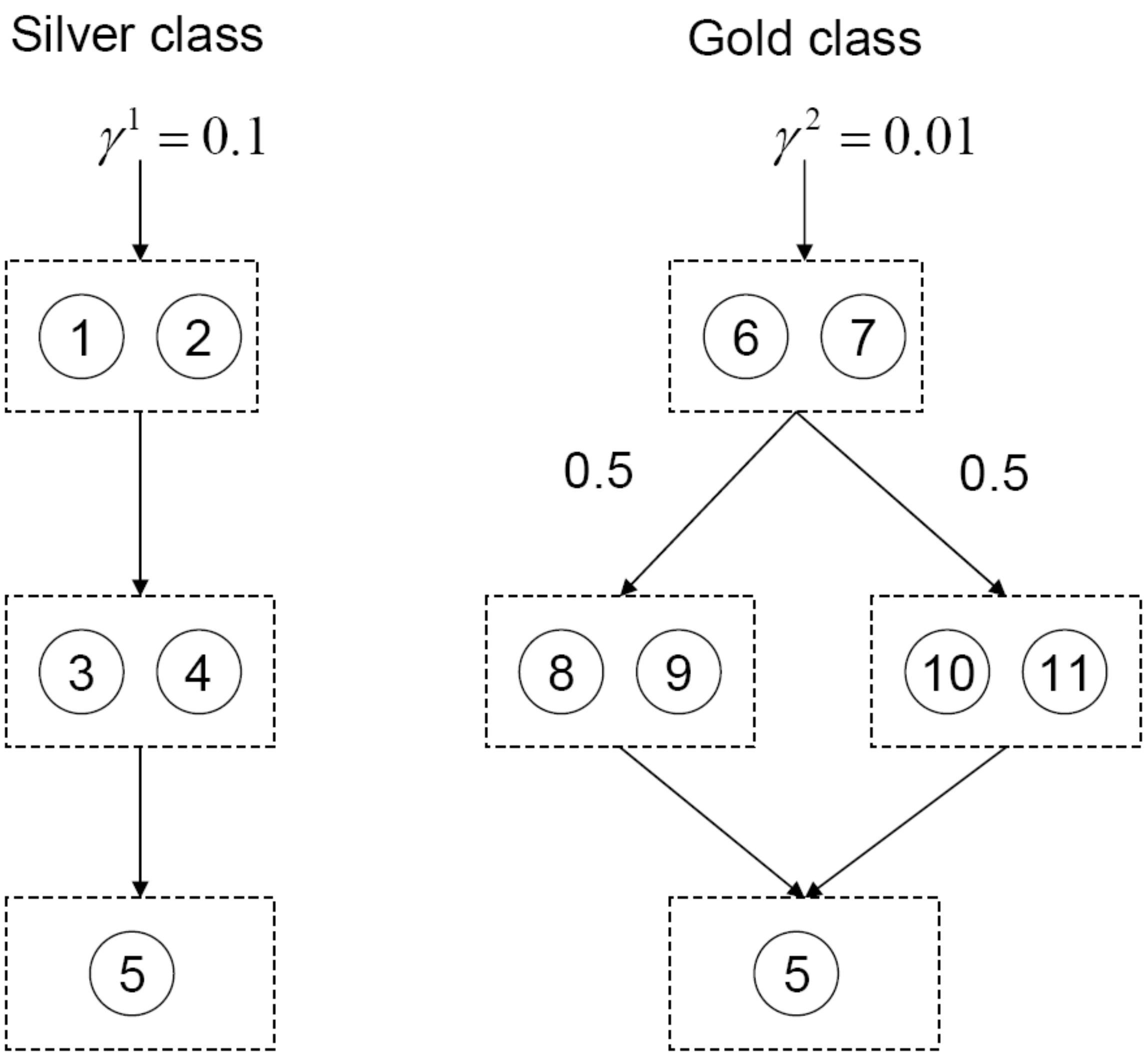
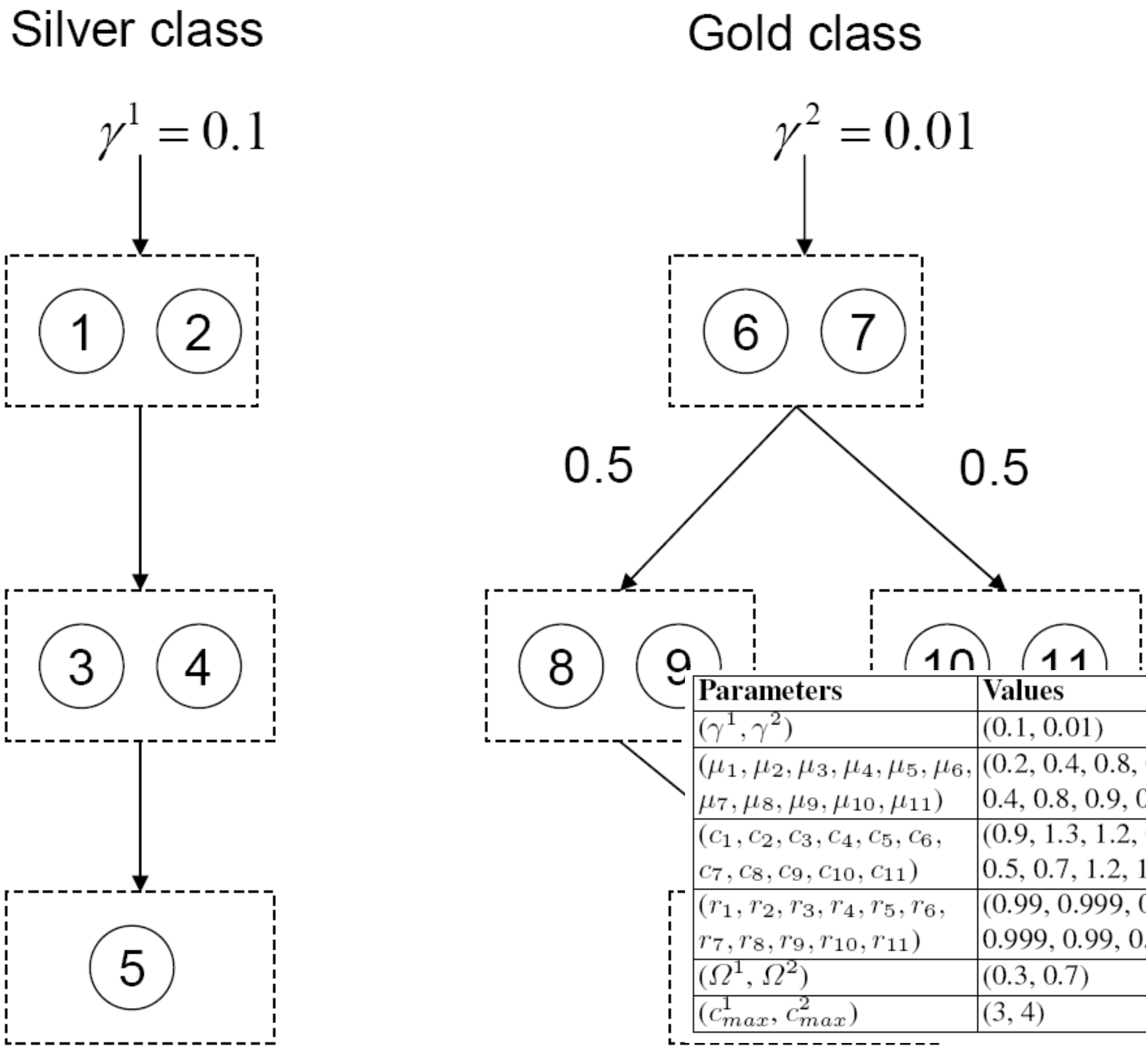
Composed Service Model

- λ_i^k: rate of class-k requests that arrive at the abstract service *i*
- set of normalized weights $\{w^k_e, w^k_c, w^k_r\}$ indicating a relative priority among the set of quality dimensions for class k end users
- Global QoS constraints $e^k_{max}, c^k_{max}, r^k_{min}$
- Ω^k: class-k relative priority

Reference Example



Reference Example



Parameters	Values
(γ^1, γ^2)	(0.1, 0.01)
$(\mu_1, \mu_2, \mu_3, \mu_4, \mu_5, \mu_6, \mu_7, \mu_8, \mu_9, \mu_{10}, \mu_{11})$	(0.2, 0.4, 0.8, 0.5, 0.3, 0.3 0.4, 0.8, 0.9, 0.9, 0.3)
$(c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8, c_9, c_{10}, c_{11})$	(0.9, 1.3, 1.2, 0.3, 0.8, 1.1 0.5, 0.7, 1.2, 1.8, 2.6)
$(r_1, r_2, r_3, r_4, r_5, r_6, r_7, r_8, r_9, r_{10}, r_{11})$	(0.99, 0.999, 0.99, 0.999, 0.99, 0.999 0.999, 0.99, 0.999, 0.99, 0.999)
(Ω^1, Ω^2)	(0.3, 0.7)
(c^1_{max}, c^2_{max})	(3, 4)

Service Selection Problem

P1)

$$max : F(\mathbf{x}) = \frac{\sum_{k \in K} \Omega^k \gamma^k F^k(\mathbf{x})}{\sum_{k \in K} \gamma^k}$$

$$\sum_{j \in J_i} x_{ij}^k = 1 \qquad \forall k \in K, i \in \mathcal{V}^k \qquad (1)$$

$$\sum_{h \in K} \sum_{a \in \mathcal{V}^h} \frac{x_{aj}^h \lambda_a^h}{\mu_j} < 1 \qquad \forall j \in \mathcal{J} \qquad (2)$$

$$E^k(\mathbf{x}) \leq e_{max}^k \qquad \forall k \in K \qquad (3)$$

$$C^k(\mathbf{x}) \leq c_{max}^k \qquad \forall k \in K \qquad (4)$$

$$R^k(\mathbf{x}) \geq r_{min}^k \qquad \forall k \in K \qquad (5)$$

$$0 \leq x_{ij}^k \leq 1 \qquad \forall k \in K, i \in \mathcal{V}^k, j \in J_i^k$$

Service Selection Problem

$$F^k(\mathbf{x}) = w_e^k \frac{E^k(\mathbf{x}) - E^k_{min}}{E_{max} - E_{min}} + w_c^k \frac{C^k(\mathbf{x}) - C^k_{min}}{C^k_{max} - C^k_{min}} + w_r^k \frac{R^k_{max} - R^k(\mathbf{x})}{R^k_{max} - R^k_{min}}$$

$$\begin{aligned} E^k(\mathbf{x}) &= \textstyle\sum_{i \in \mathcal{V}^k} \; exeTime_i \\ C^k(\mathbf{x}) &= \textstyle\sum_{i \in \mathcal{V}^k} \; \frac{\lambda_i^{k*}}{\gamma^k} \sum_{j \in J_i^k} \; x_{ij}^k c_j^k \\ R^k(\mathbf{x}) &= \textstyle\prod_{i \in \mathcal{V}^k} \; \frac{\lambda_i^{k*}}{\gamma^k} \sum_{j \in J_i^k} \; x_{ij}^k r_j^k \end{aligned}$$

$$exeTime_i = \frac{\lambda_i^{k*}}{\gamma^k} \sum_{j \in J_i^k} \frac{x_{ij}^k / \mu_j^k}{1 - \sum_{h \in K} \sum_{a \in \nu^h} \frac{x_{aj}^h \lambda_a^h}{\mu_j^h}}$$

- Problem P1) is a non linear optimization problem in the continuous variables x^k_{ij}
- The objective function of problem P1) is neither concave nor convex
- Heuristic algorithm, problem instances up to 300 abstract services and 100,000 candidates concrete services in less than half an hour

Composed Service Quality Analyzer

- WS optimizator output: x^k_{ij} variables
- The aggregated value of QoS for the abstract service *i* can be computed as the average of the quality dimensions of the invoked services weighted by x^k_{ij}
- The composed service quality analyzer derives through PRISM:
  - Success probability
  - Mean response time

Composed Service Quality Analyzer

- DAG representation translated to a Markov models:
  - Discrete Time Markov Chains (DTMC)
  - Continuous Time Markov Chains (CTMC)
- Properties specified in temporal logic, as an example:
  - P [F (system state = success)]
  - $P_{\geq threshold}$ [F (system state = success)]

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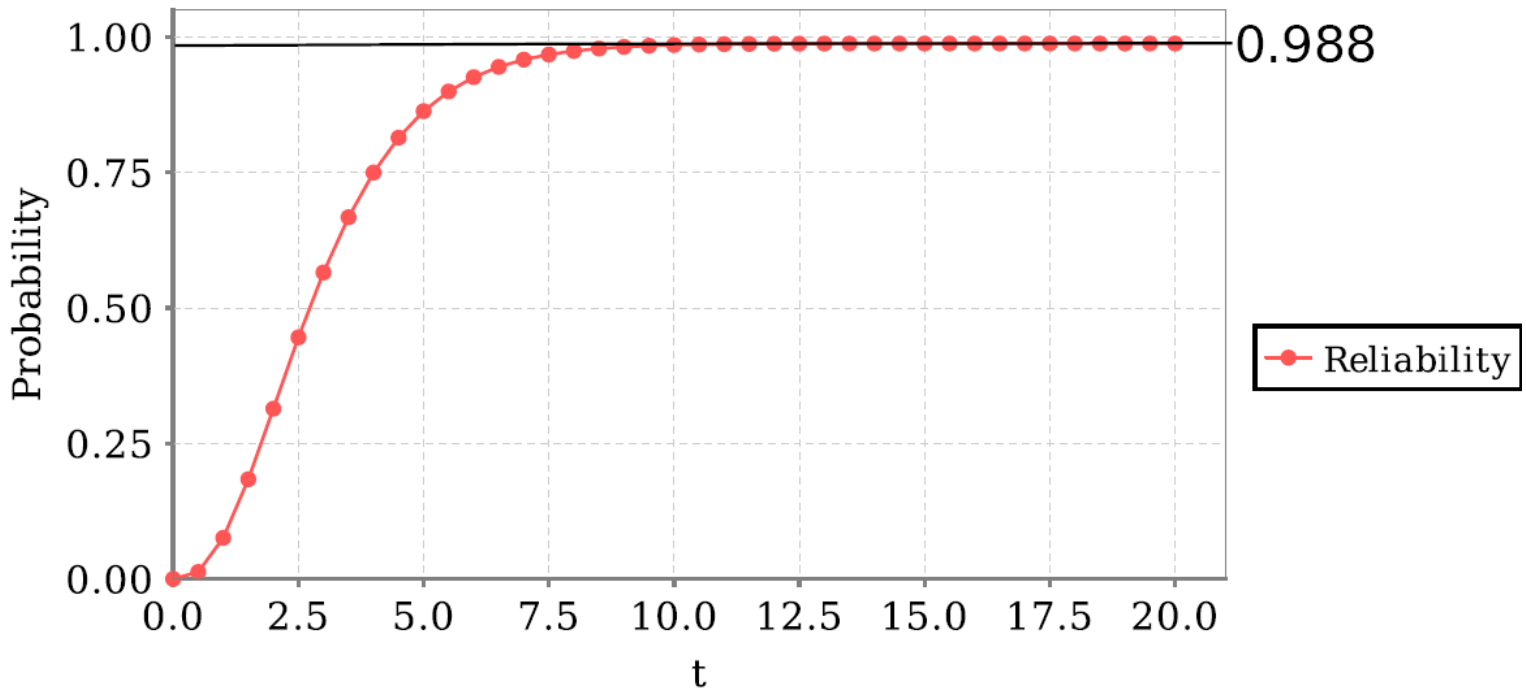
Reference Example

- Gold class probability of success evolution



- Average execution time for the silver class equal to 17.22 sec

Conclusions and Future work

- Model-driven approach for automatic selection of Web services and probabilistic model checking analyses
- Extend the optimization model in order to include the parallel execution pattern
- Validation on industrial case studies from Q-ImPRess and S-Cube
- Close the loop between runtime observations and the design environment

December 2008