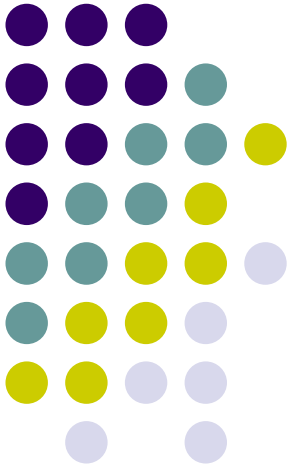
Formal Behavioural Models and Compliance Analysis for Service Oriented Systems

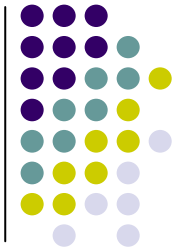
Natallia Kokash

and

Farhad Arbab

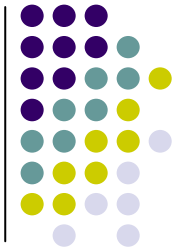


Introduction



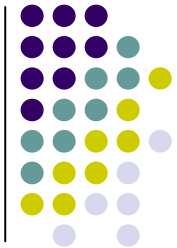
- Role of Formal Methods in SOA
- COMPAS Project
- Reo Coordination Language
- From Business Process Modeling (BPM) to Web Service (WS) Composition
  - BPMN to Reo mapping
  - Process analysis, examples
- Support for Business Process Compliance
  - Control flow, transactions, temporal requirements, Quality of Service (QoS)
- Related Work
- Conclusions and Future Work

Role of Formal Methods in SOC



- Analysis of composition/coordination languages (e.g., WS-BPEL, WS-CDL)
- Complete unambiguous description of service behavior and non-functional properties
- Verification of service interaction protocols
- Analysis of WS compositions (behavioral compatibility of services, performance analysis, security, etc.)
- Support for automated WS composition
- …

COMPAS project

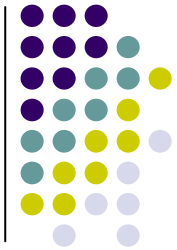


- COMPAS = Compliance-driven Models, Languages, and Architectures for Services
  - *Ensure dynamic and on-going compliance of software services to business regulations and user requirements*
  - *Help organizations to develope business compliance solutions easier and faster*
  - *Use model-driven techniques, domain-specific languages, and service-oriented computing*
  - http://www.compas-ict.eu/

What is Compliance?

- A multi-faceted concept that encompasses the capability of an organization to meet requirements coming from
  - Regulatory/legislative documents
    - Basel II2, Sarbanes-Oxley6, IFRS2, MiFID3, LSF4, HIPAA, Tabaksblat5, etc.
  - Business contracts
  - Organization movements towards Quality of Service (QoS)
- Compliance can be seen as
  - A state of “adherence of one set of rules (source rules) against another set of rules (target rules)”
  - A process, which is about “ensuring that business processes, operations and practice are in accordance with a prescribed set of norms”

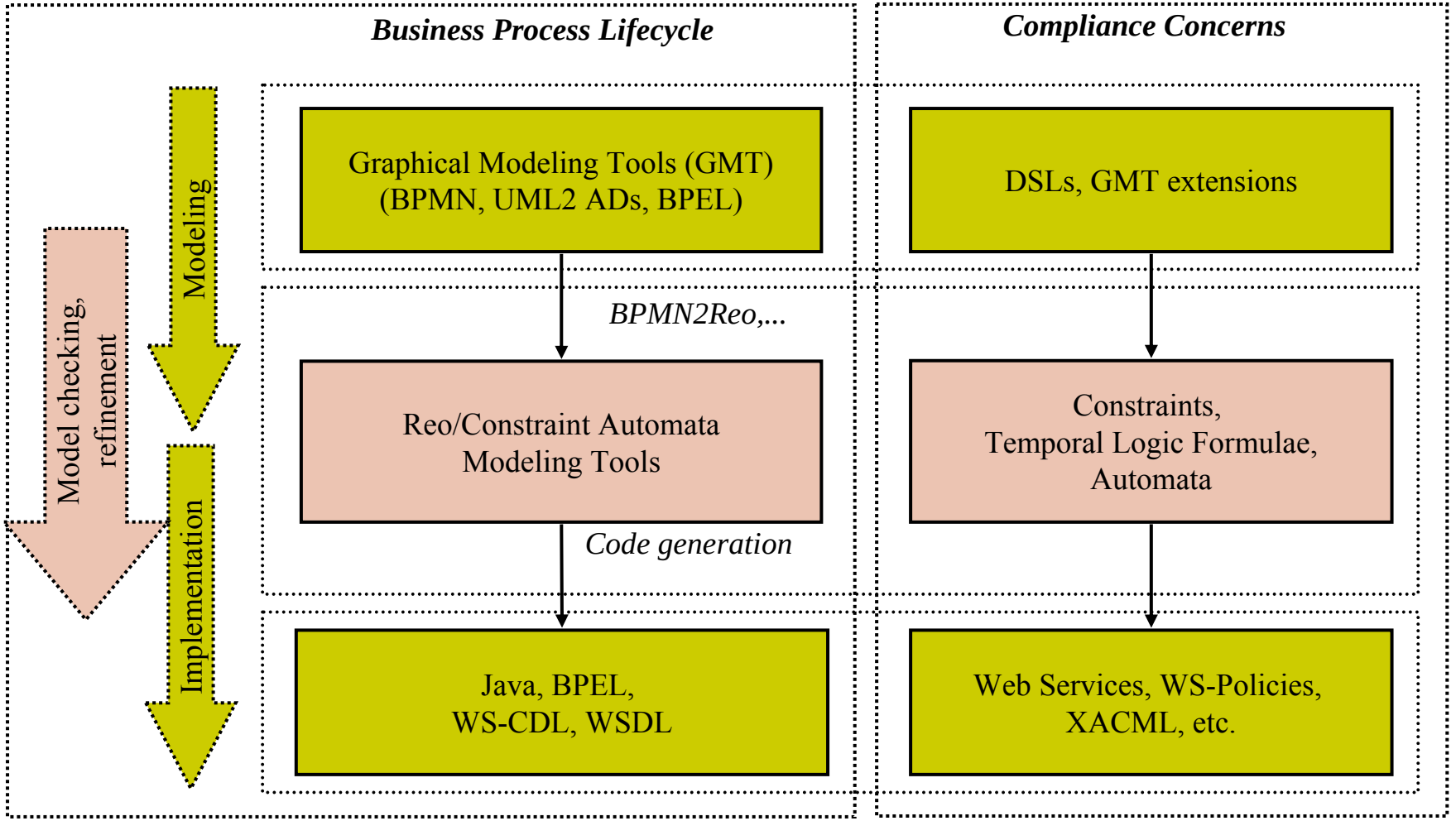
Compliance categories



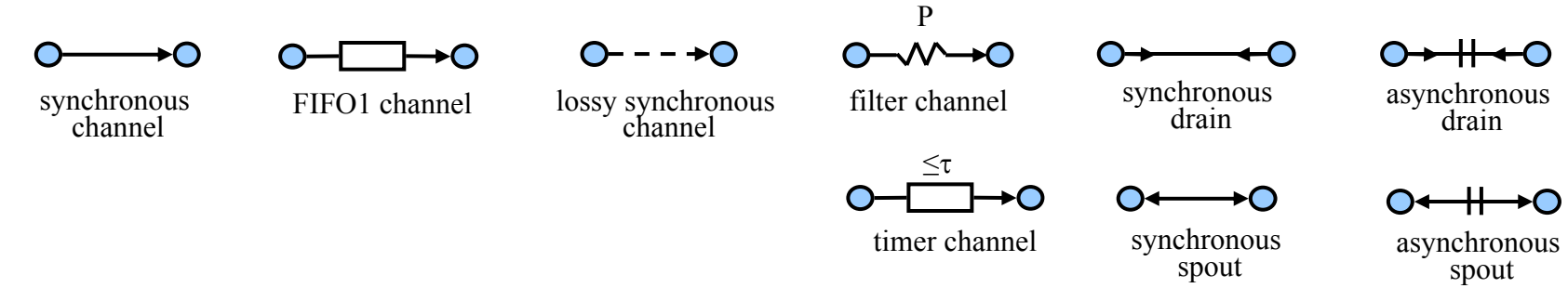
- COMPAS has identified
  - Control flow, locative, information, resource and temporal compliance concerns
  - Monitoring, payment, privacy, quality, retention, security and transaction compliance concerns

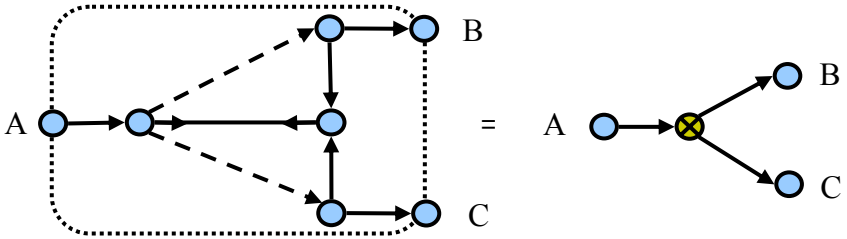
- Constraints on business process behavior
  - Workflow structure, data visibility, temporal constraints…
  - We aim at dealing with (at least) control flow, resource, temporal, quality and transaction compliance

Compliance-aware SOA design

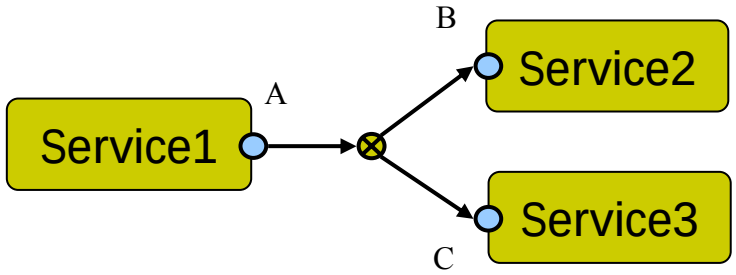


Reo Coordination Language





Exclusive choice (deffered XOR)



Semantics

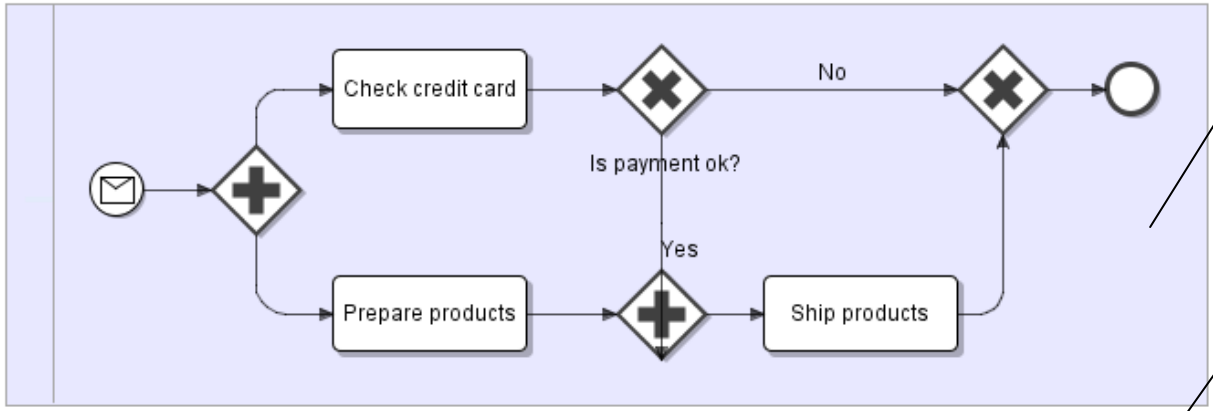
- Constraint automata
  - [Baier et al., 2006]
- Connector coloring
  - [Clarke et al., 2006]

Reo Coordination Tools

- Reo Connector Editor
- Animation Plug-in
- Reconfiguration Plug-in
- Converter to Extended Constraint Automata (time, QoS)
- Model Checking Tool (provided by University of Dresden)
  - http://wwwtcs.inf.tu-dresden.de/~klueppel/TUD_CWI/Welcome.html
- Java Code Generator (distributed version is also available)
- http://reo.project.cwi.nl/

- BPEL to Reo converter (provided by University of Tehran)
  - [S. Tasharofi et al. 2008]
- UML Sequence Diagrams to Reo converter – work in progress
- BPMN to Reo converter – work in progress

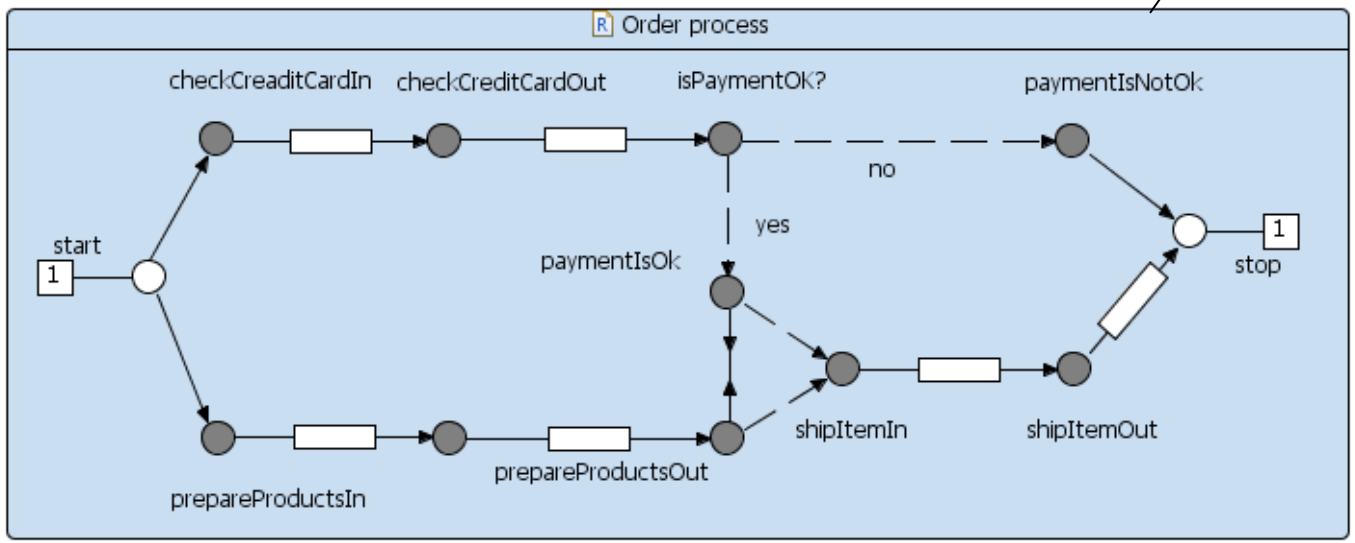
Business Process Design



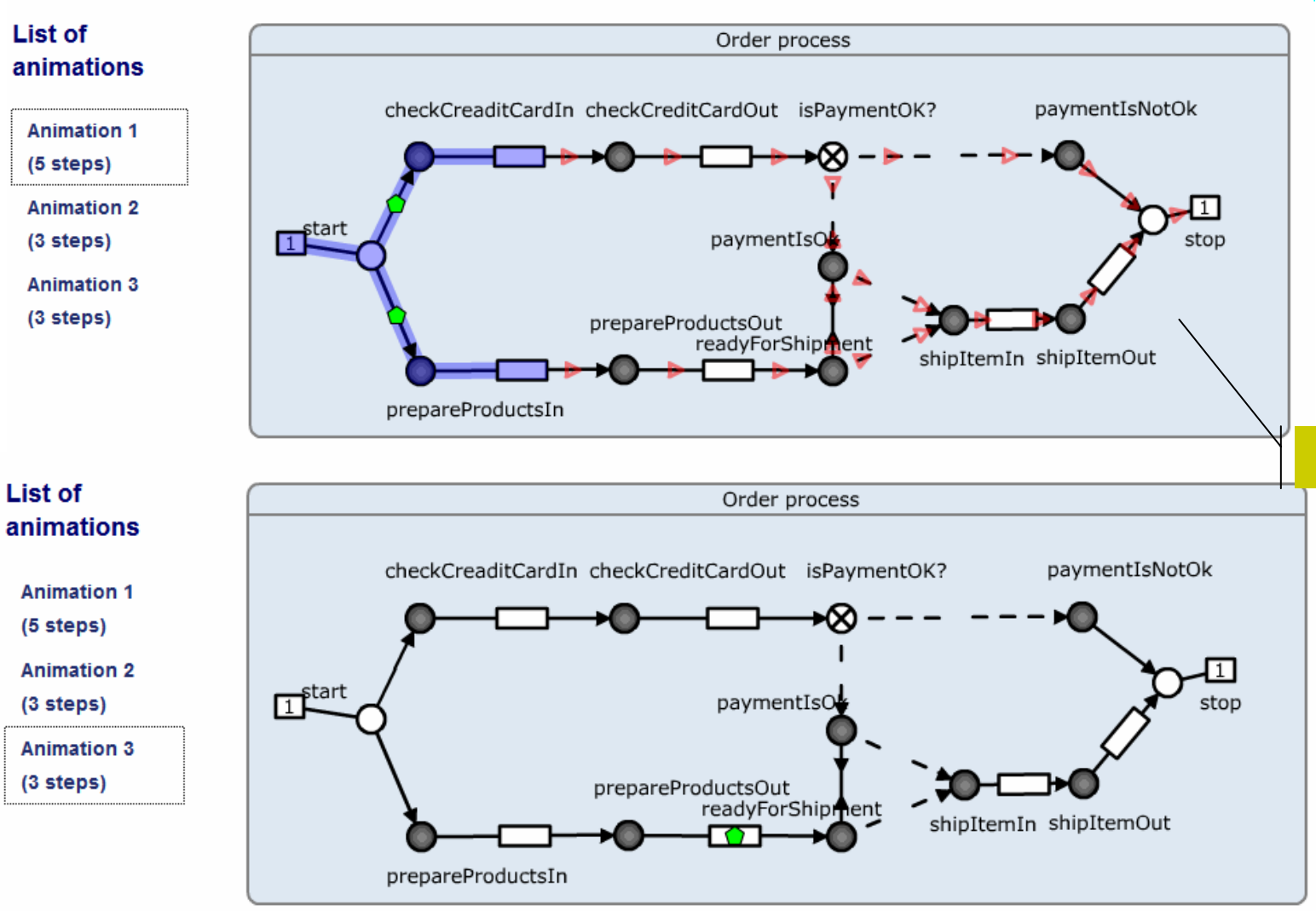
1. BPMN diagram

[Dijkman et al. IST'08]

2. Reo process model

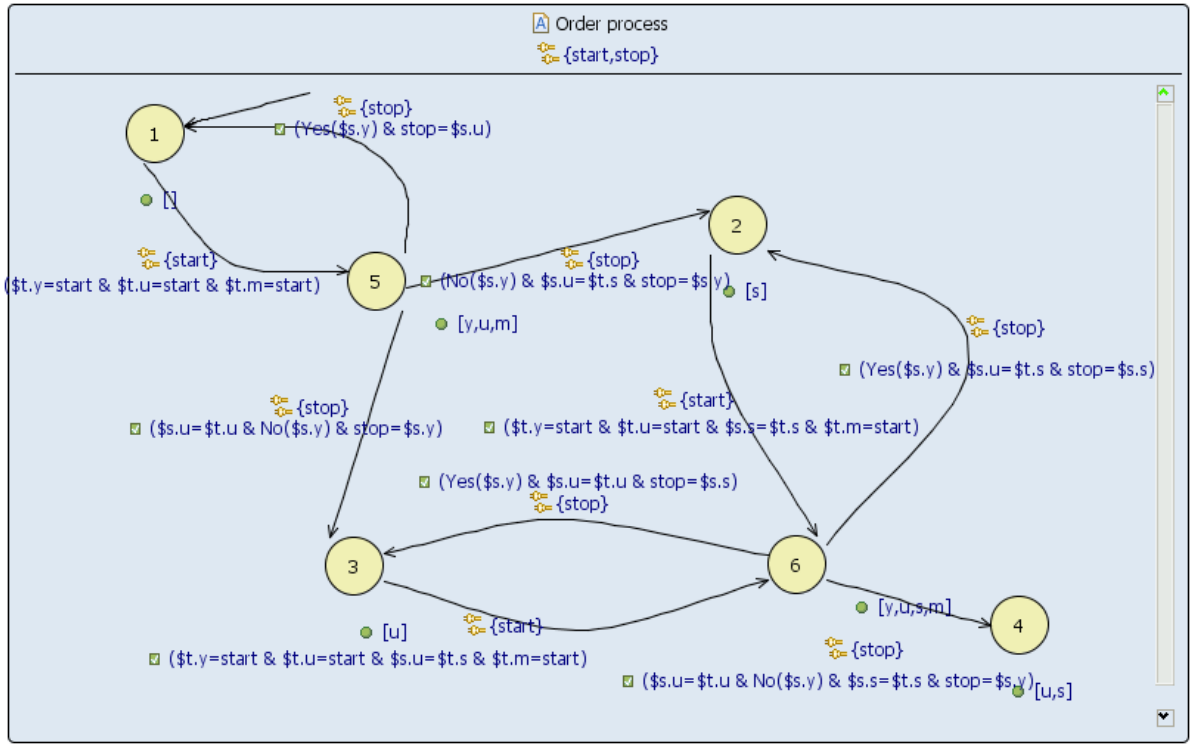


Business Process Analysis



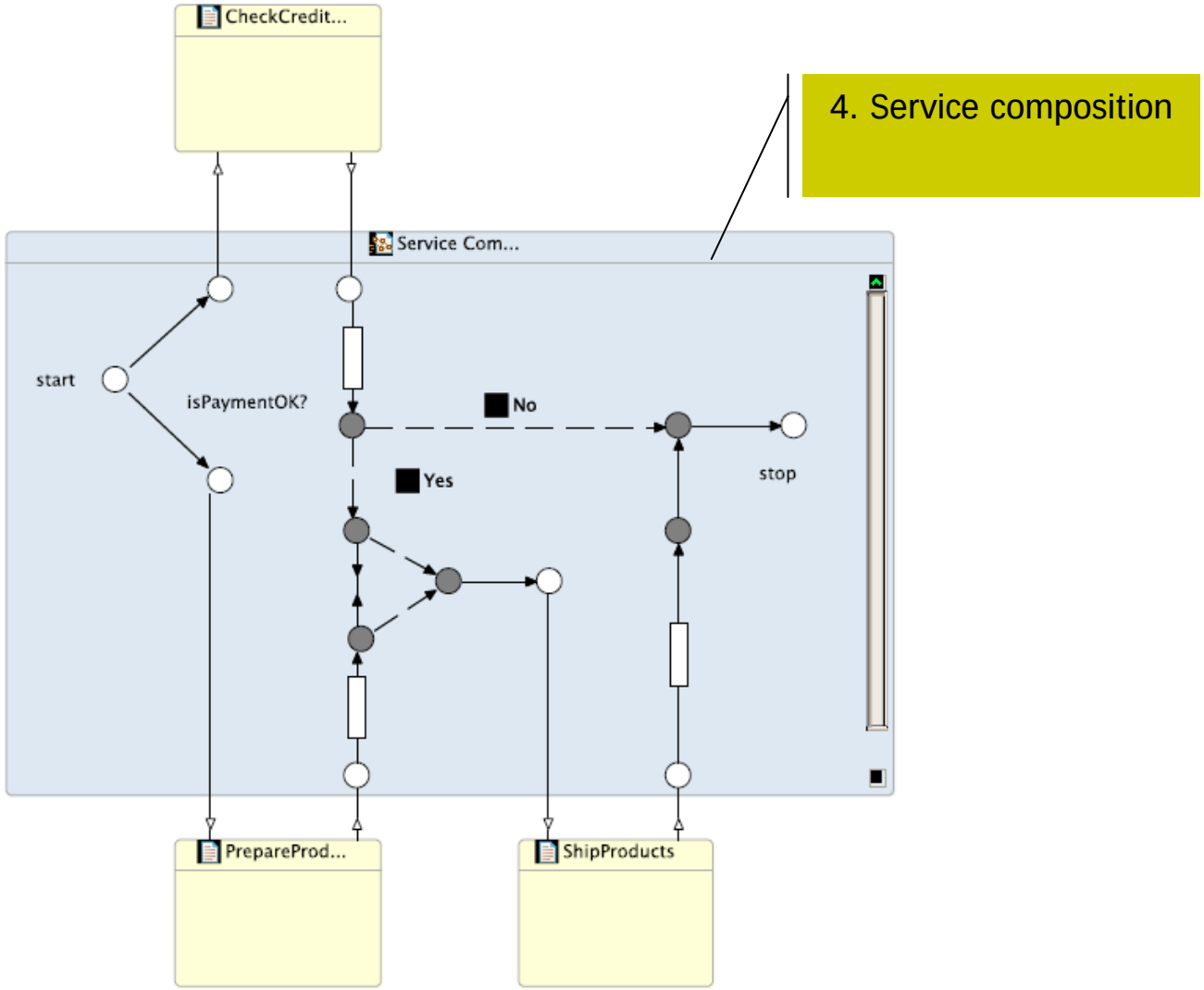
3. Reo animation

Business Process Analysis

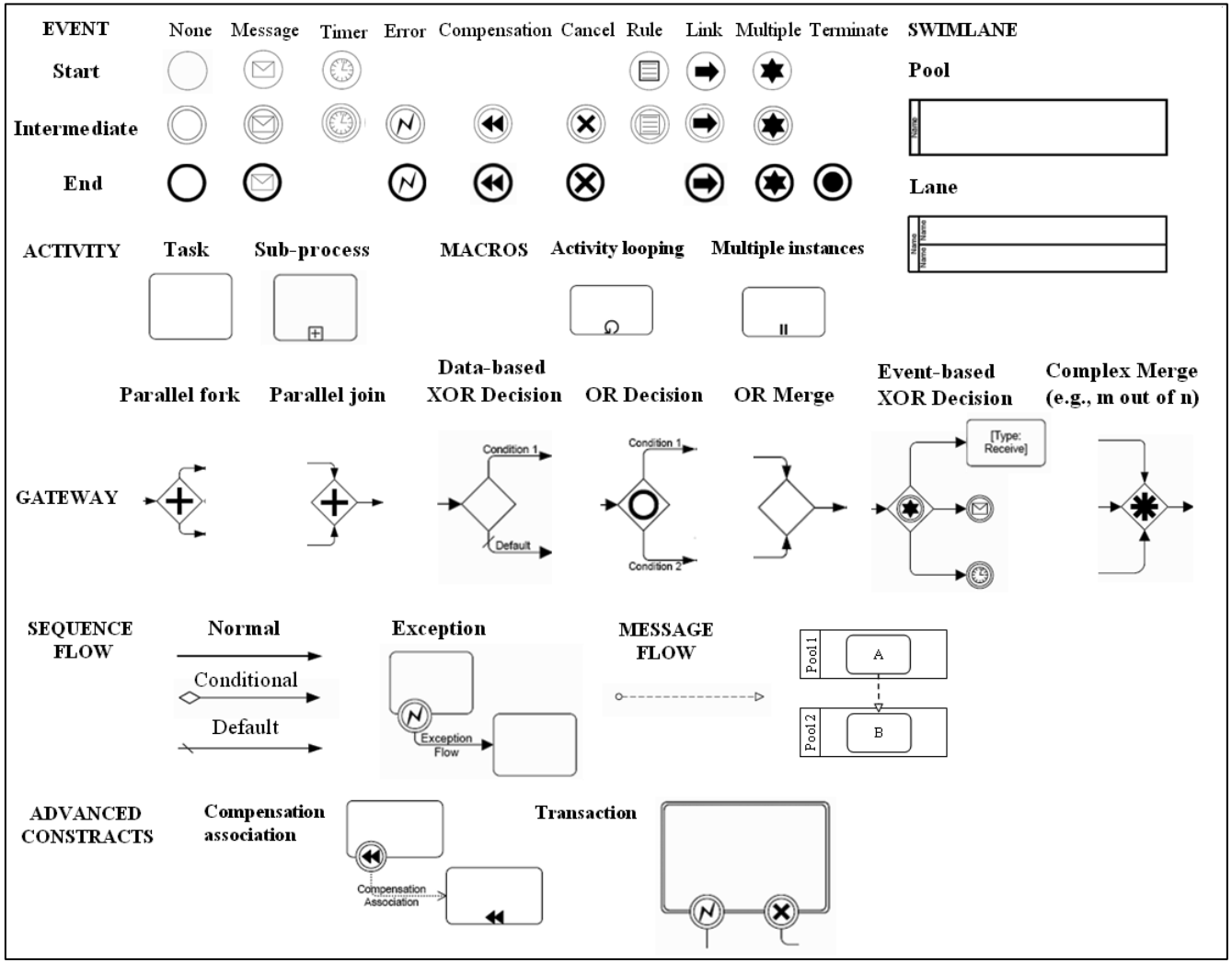


QoS analysis with Quantitative Intentional Automata (QIA) –
Constraint Automata with quantitative properties,
(e.g., arrival rates at ports and average delays of dataflows between ports).
For performance analysis, these automata are translated to Continuous-Timed Markov Chains and fed into the PRISM model checker.

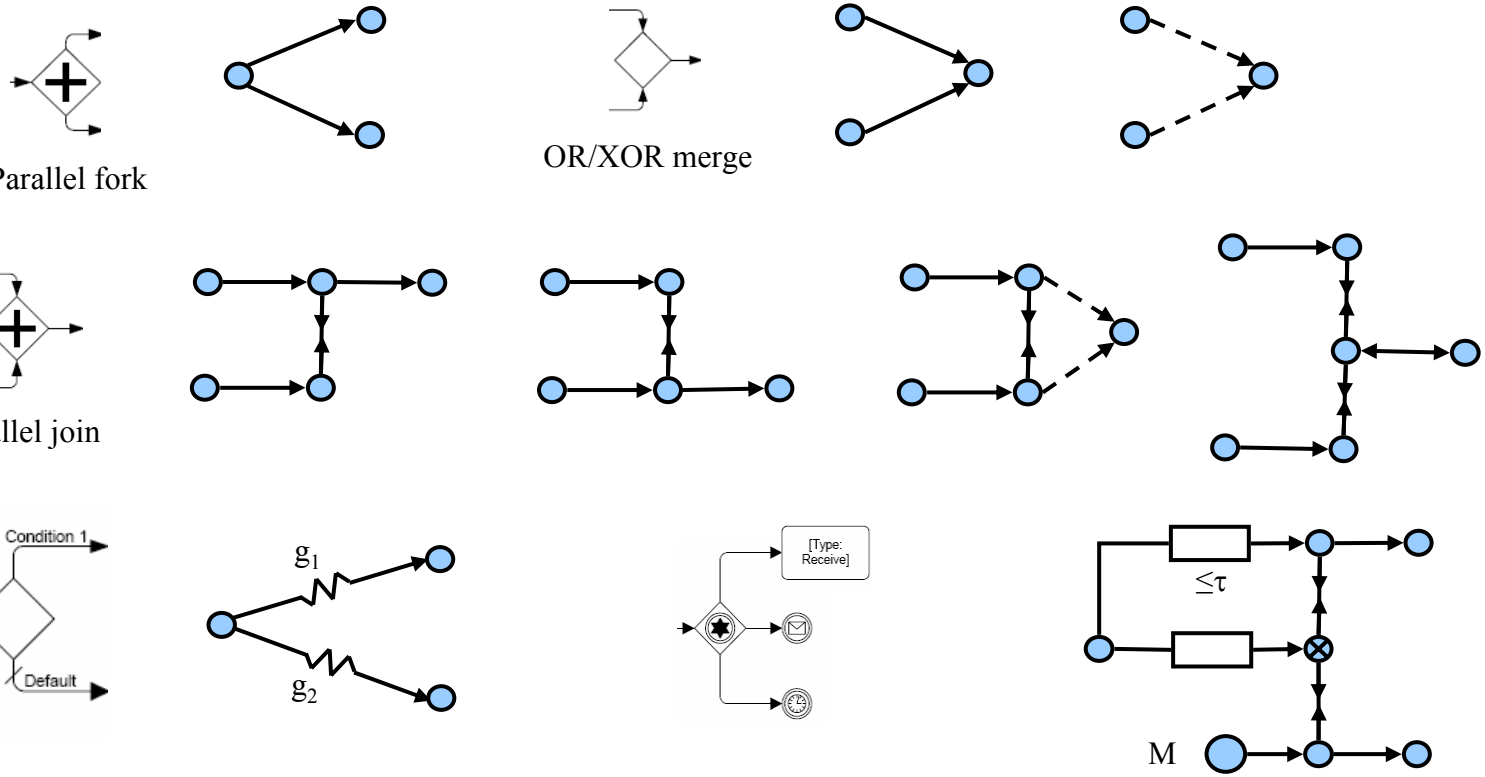
Web Service Composition



BPMN


EVENT
None
Message
Timer
Error
Compensation
Cancel
Rule
Link
Multiple
Terminate
SWIMLANE
Start
Intermediate
End
Pool
Lane
ACTIVITY
Task
Sub-process
MACROS
Activity looping
Multiple instances
Parallel fork
Parallel join
Data-based XOR Decision
OR Decision
OR Merge
Event-based XOR Decision
Complex Merge (e.g., m out of n)
GATEWAY
Condition 1
Default
Condition 1
Condition 2
[Type: Receive]
SEQUENCE FLOW
Normal
Conditional
Default
Exception
Exception Flow
MESSAGE FLOW
Pool 1
A
Pool 2
B
ADVANCED CONSTRACTS
Compensation association
Compensation Association
Transaction

BPMN2Reo: basic gateways

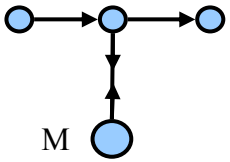


Data-based OR/XOR decision

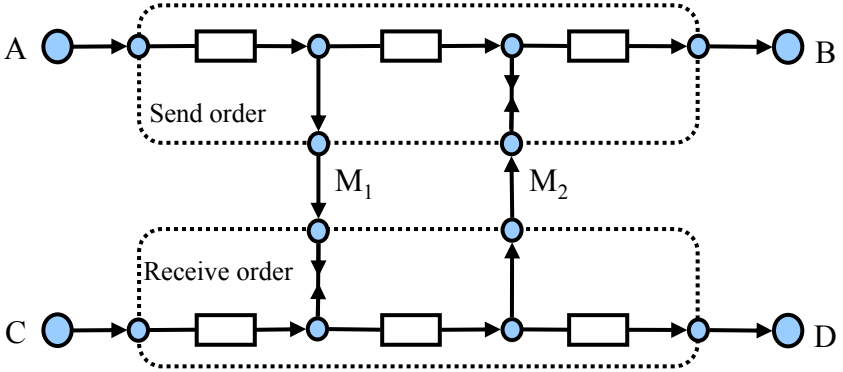
Event-based XOR decision

Complex gateways (e.g., m out of n choice) - repository of workflow patterns modeled with Reo http://homepages.cwi.nl/~proenca/webreo/home.htm

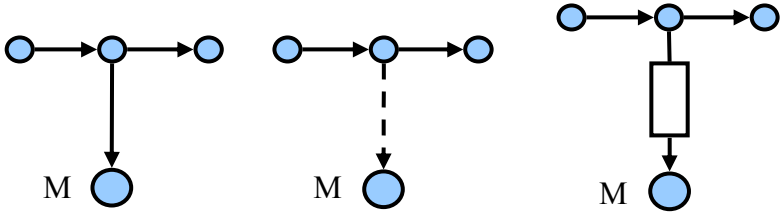
BPMN2Reo: tasks, events and messages



Message event

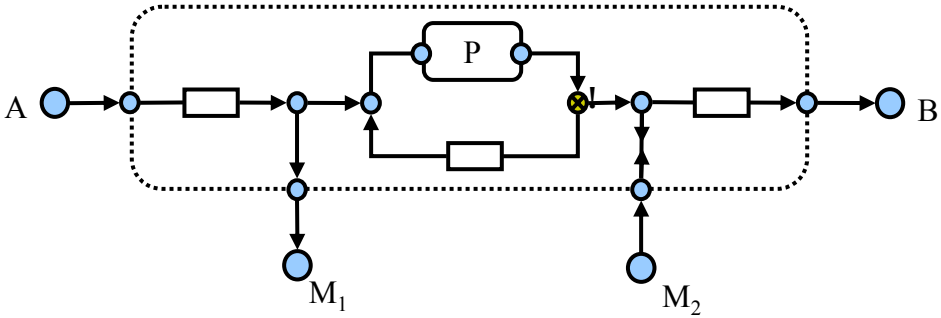


Synchronous message exchange



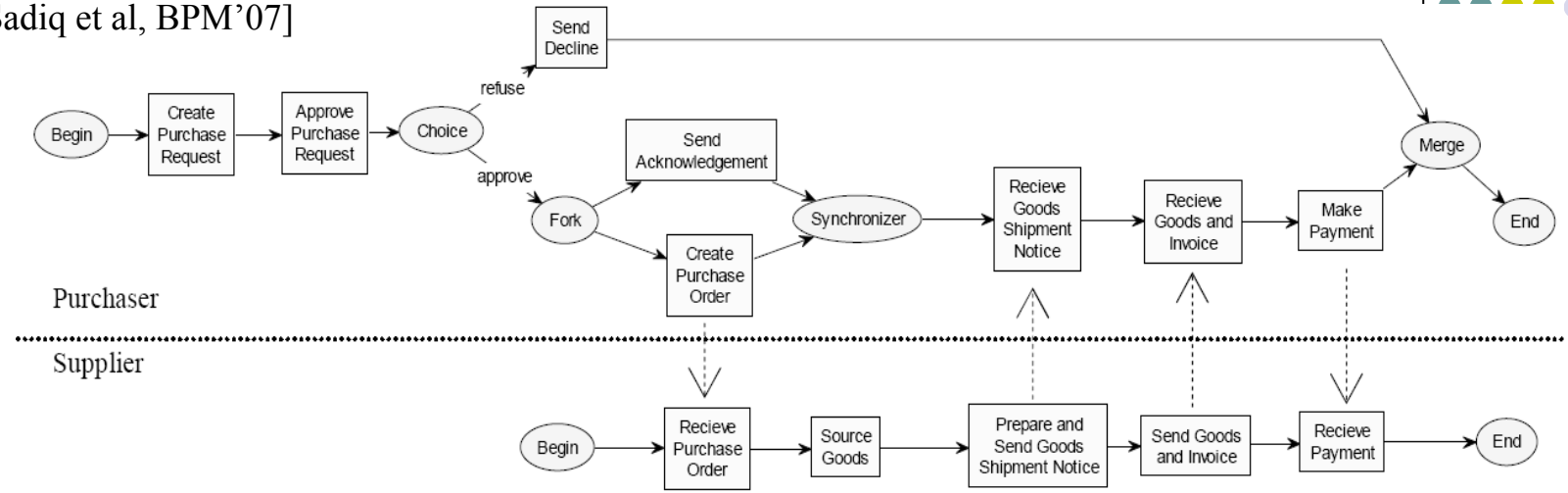
Blocking Non-blocking lossy Non-blocking waiting

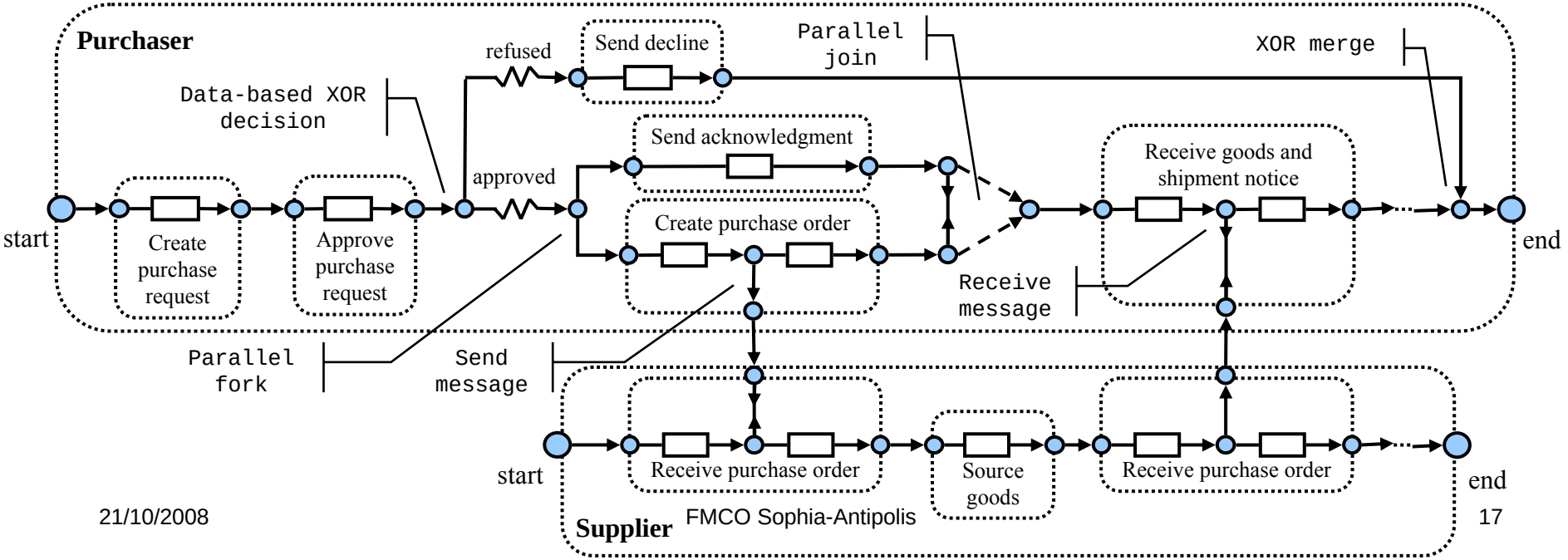
Outgoing messages



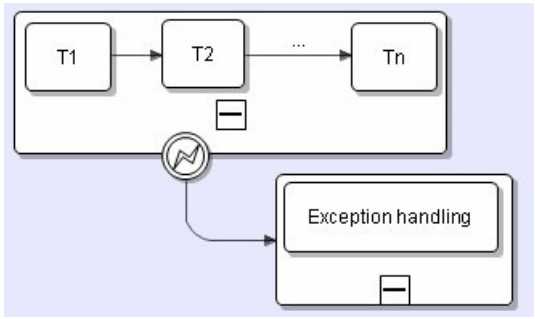
BPMN2Reo: Example

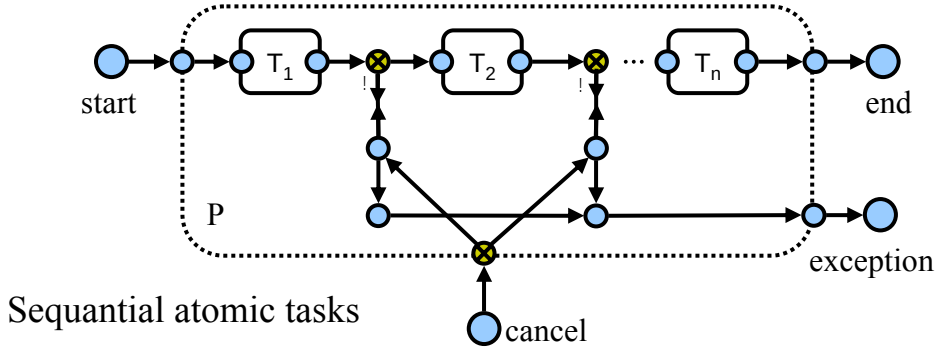
[Sadiq et al, BPM'07]



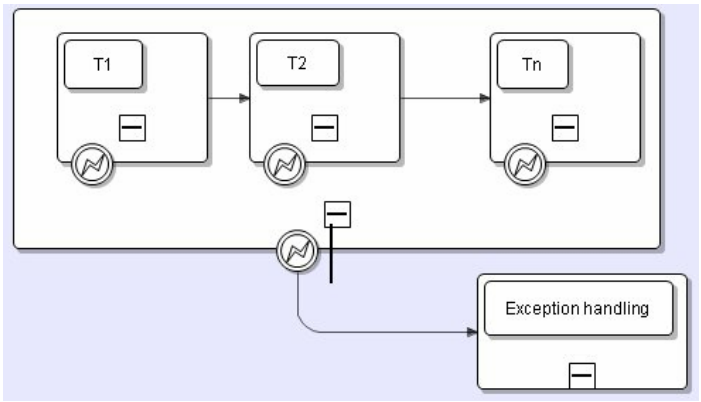


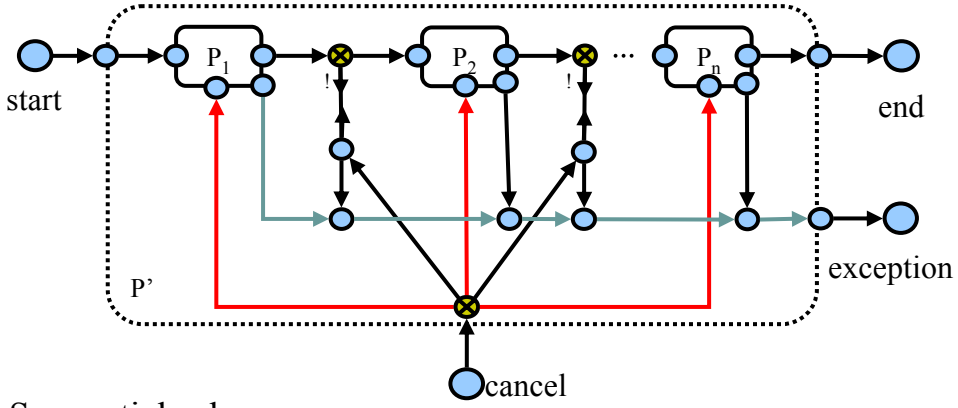
BPMN2Reo: Process termination and exception handling





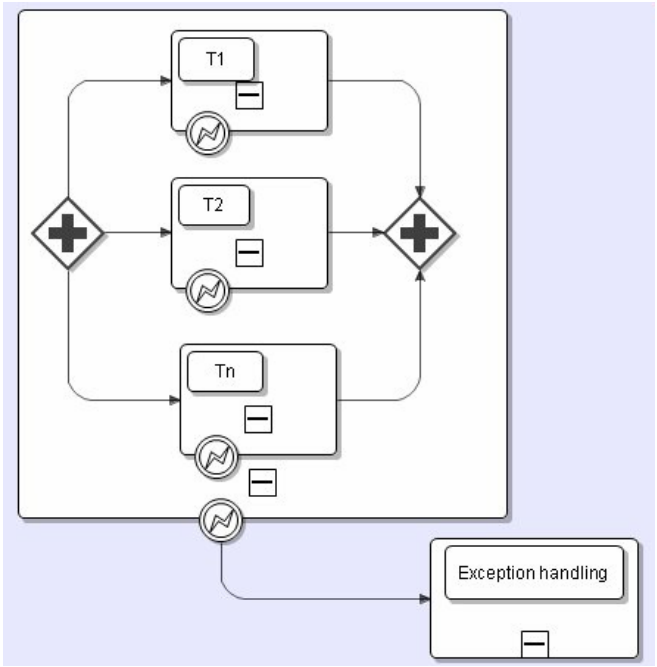
Sequantial atomic tasks

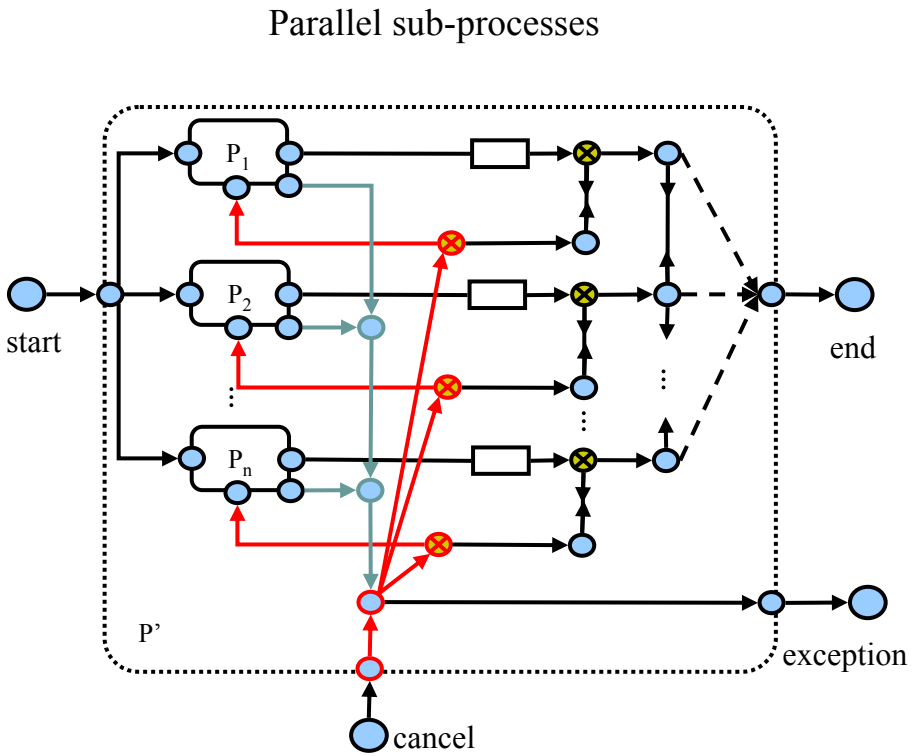




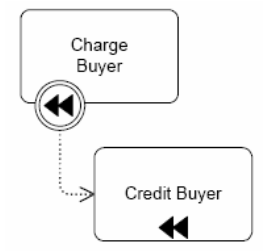
Sequantial sub-processes

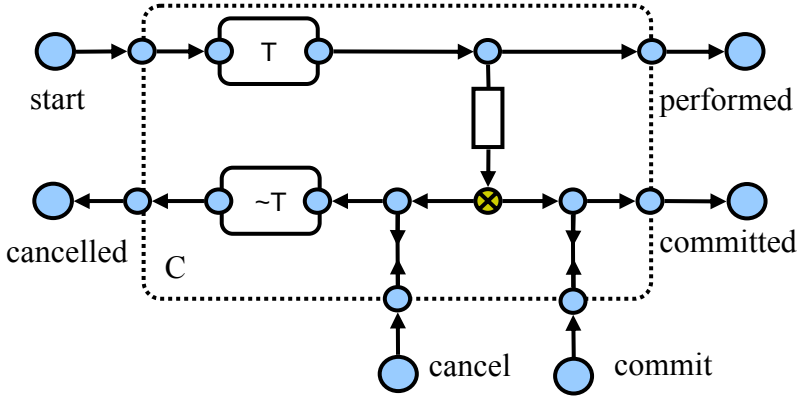
BPMN2Reo: Process termination and exception handling

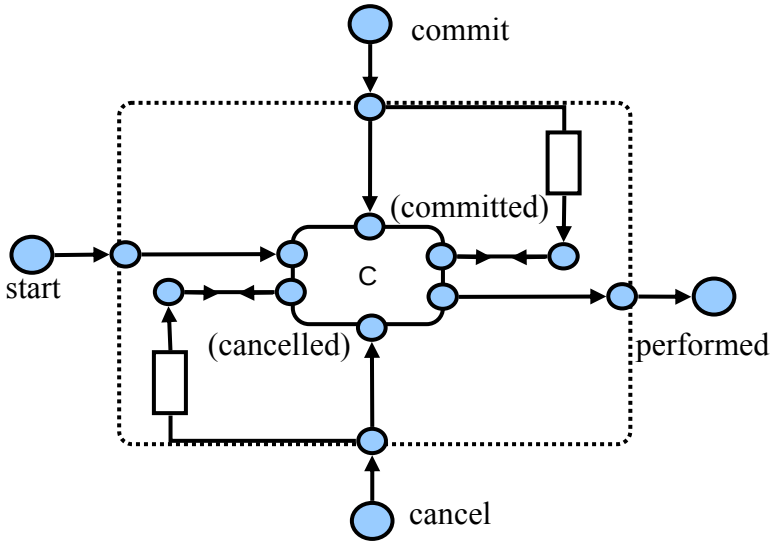


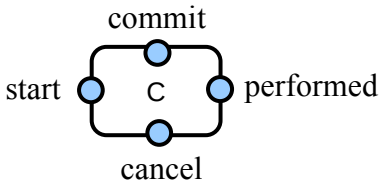


BPMN2Reo: Task compensation

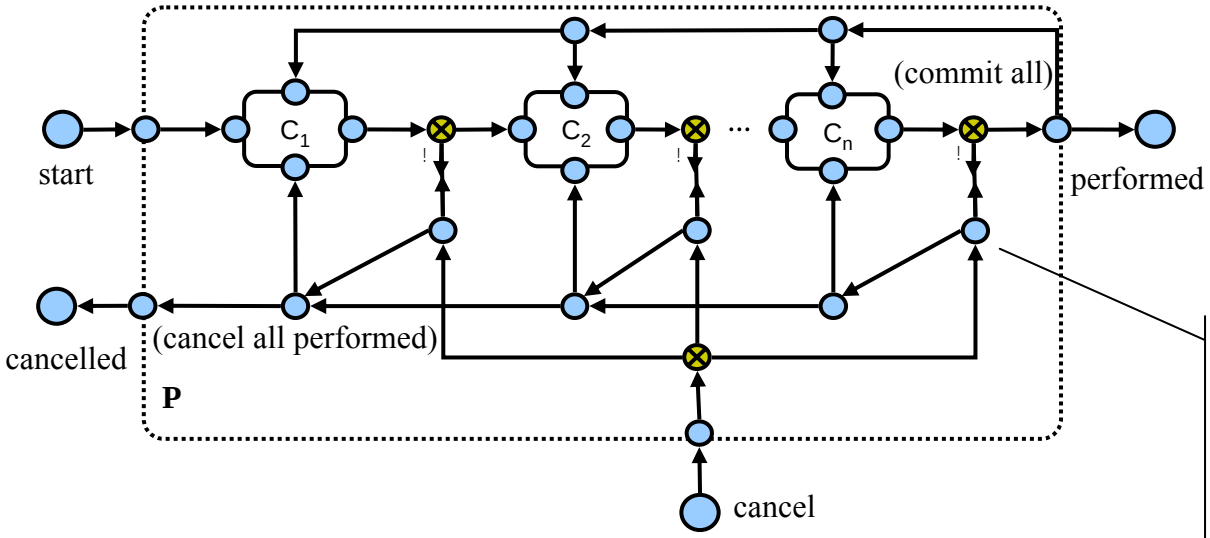








Modeling Long Running Business Transactions in Reo

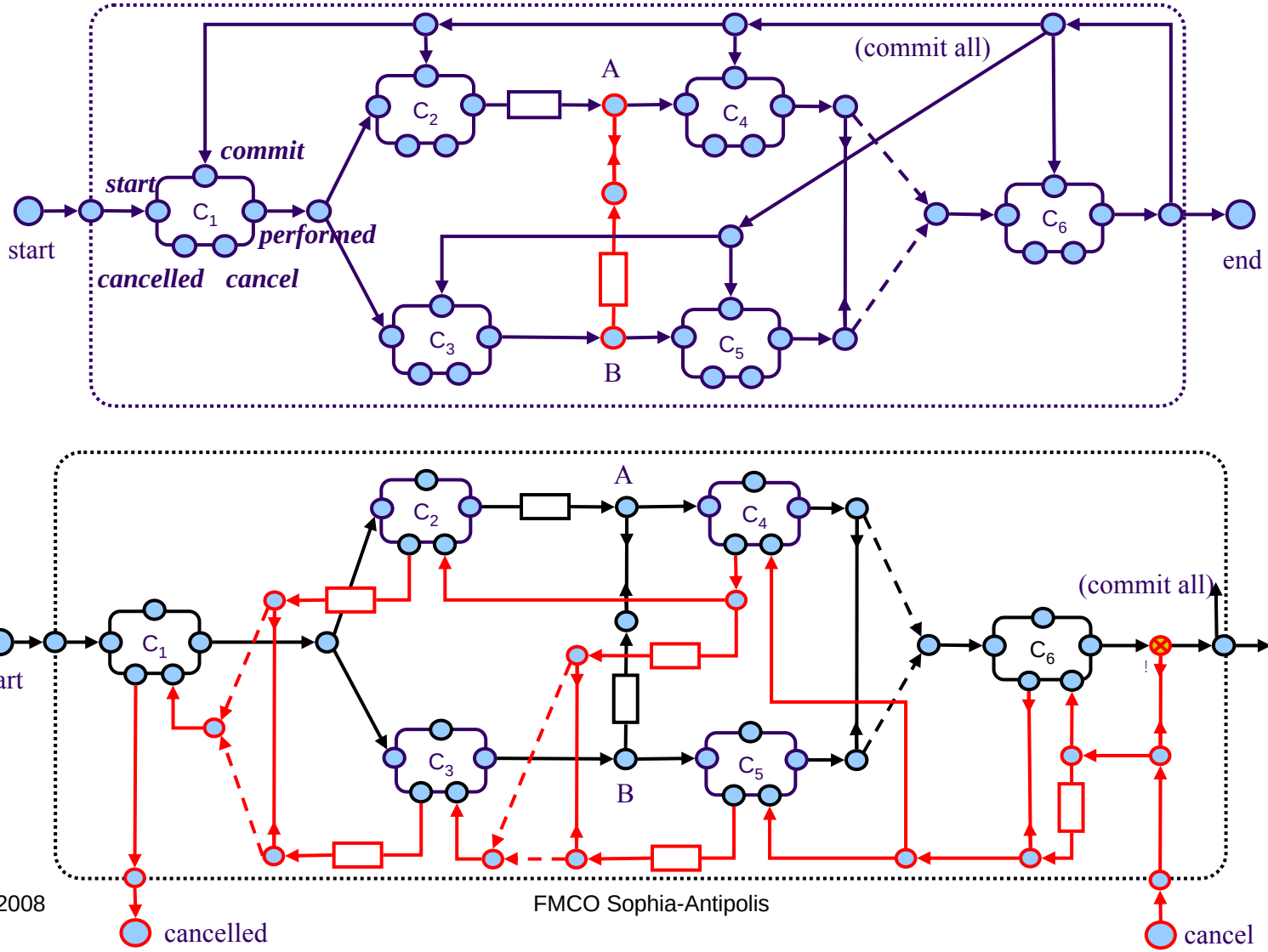


If a cancel message is received, the execution has to be stopped and all executed activities have to be compensated for

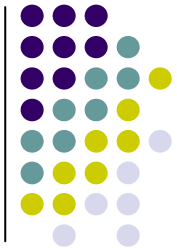
Encode in a CTL-like logic and automatically check common workflow properties like

- *Durability (*no more than one output is reached for any process run)
- *Eventuality (*an output is reached for any process run)
- *Atomicity (*all involved activities are either successfully completed or successfully canceled), etc.

Modeling Long Running Business Transactions in Reo

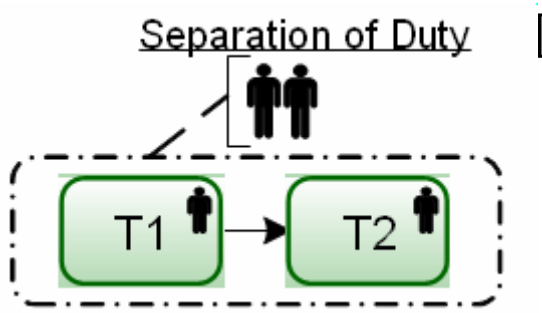


Compliance-aware Business Process Design

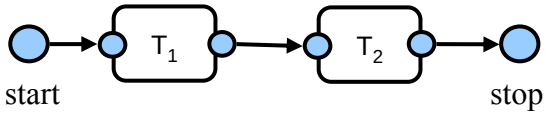


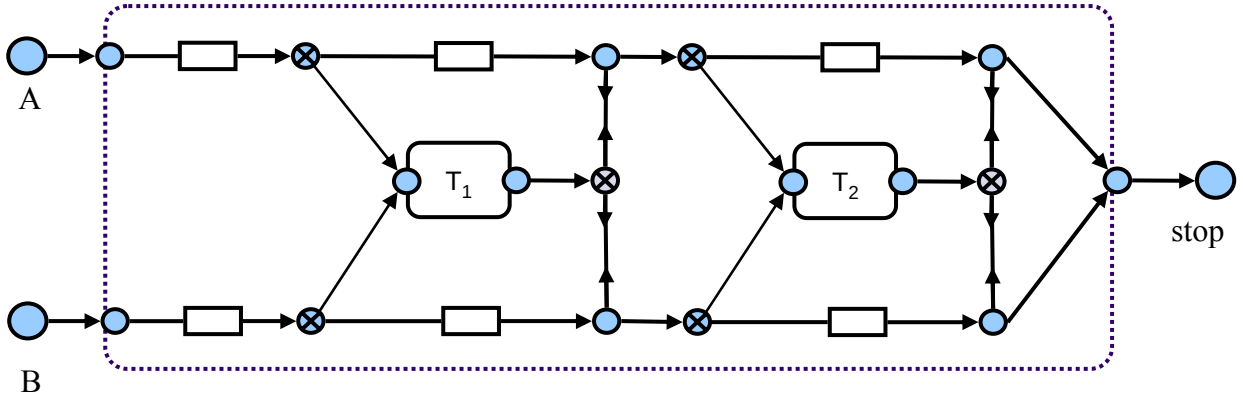
- Separation of Duty
  - One user cannot execute a whole process
  - E.g., four-eyes principle, “2 users must be involved in a process consisting of 4 sequential tasks”
- Approach
  - Constraints on task assignment to users expressed in GMT extensions (e.g., BPMN) or DSLs
    - C. Wolter and A. Schaad “Modeling of Task-Based Authorization Constraints in BPMN”, BPM’07, volume 4714 of LNCS, Springer, pp. 64–79

Enforcing Separation of Duty Constraints



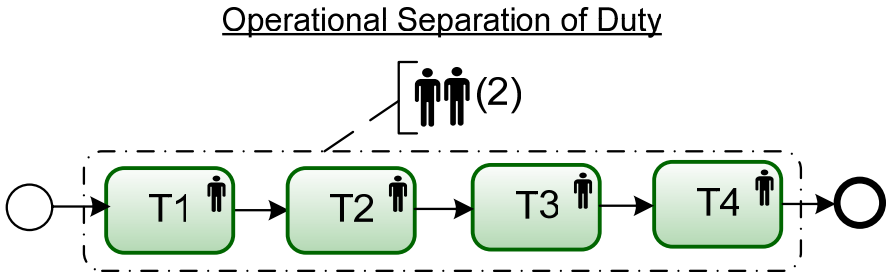
[Wolter & Schaad, BPM'07]



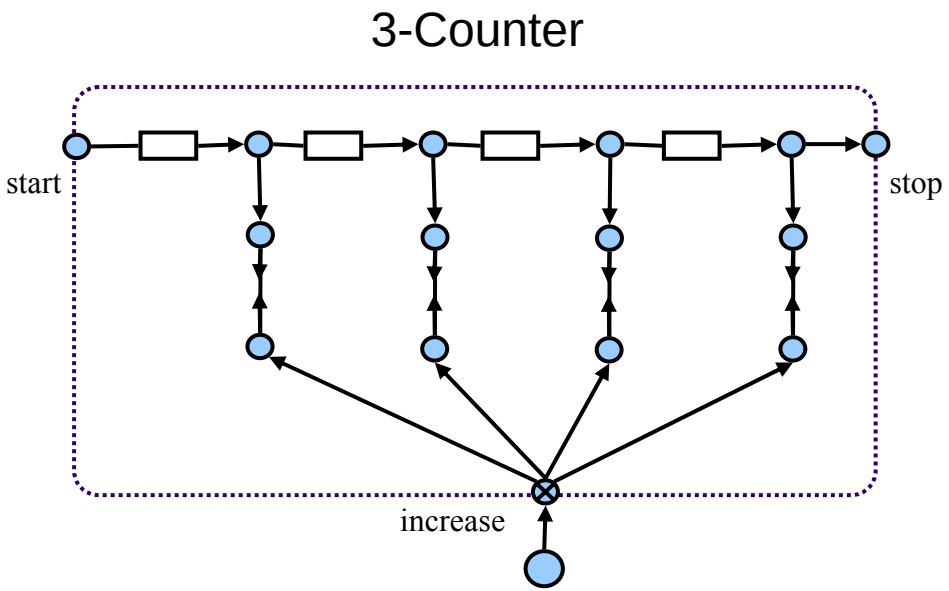


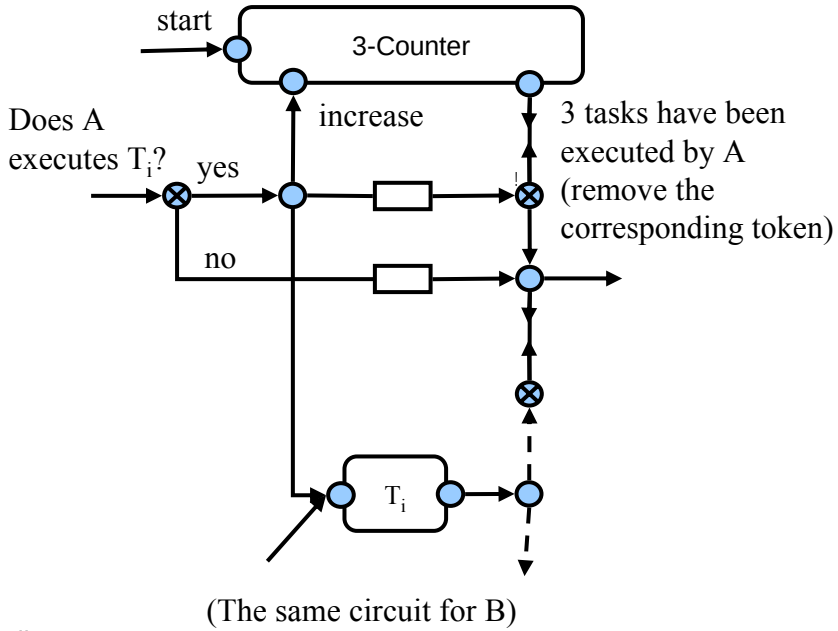
- Animation engine or model checking tools can be used to verify that tasks T_1 and T_2 are executed by different users
- Reo reconfiguration plug-in can be useful for process modification

Enforcing Separation of Duty Constraints



[Wolter & Schaad, BPM'07]





(The same circuit for B)

Related Work

- BPMN semantics
  - Dijkman, R.M., Dumas, M., Ouyang, C.: Formal semantics and analysis of BPMN process models. In: Information and Software Technology (IST). (2008)
  - Wong, P., Gibbons, J.: A process semantics for BPMN. Technical report, Queensland University of Technology (2007)
  - Wong, P., Gibbons, J.: A relative timed semantics for BPMN. Technical report, Queensland University of Technology (2007)
- BPEL semantics
  - Lohmann, N.: A feature-complete Petri net semantics for WS-BPEL 2.0. In: Proc. of the Int.Workshop on Web Services and Formal Methods. Volume 4937 of LNCS., Springer (2008) 77-91
  - 11. Lucchia, R., Mazzara, M.: A pi-calculus based semantics for WS-BPEL. Journal of Logic and Algebraic Programming 70(1) (2007) 96-118
- Petri-net semantics for web service composition
  - Lohmann, N.: A feature-complete Petri net semantics for WS-BPEL 2.0. In: Proc. of the Int.Workshop onWeb Services and Formal Methods. Volume 4937 of LNCS., Springer (2008) 77-91

Related Work

- Formal Methods for Compliance-aware Business Process Design
  - Liu, Y., Muller, S., Xu, K.: A static compliance-checking framework for business process models. IBM Systems Journal 46(2) (2007) 335-361
  - Ghose, A.K., Koliadis, G.: Auditing business process compliance. In: Proc. of the Int. Conf. on Service-Oriented Architectures (ICSOC'07). Volume 4749 of LNCS., Springer (2007) 169-180
  - Governatori, G., Milosevic, Z., Sadiq, S.: Compliance checking between business processes and business contracts. In: Proc. of the Int. Enterprize Distributed Object Computing Conf. (EDOC'06), IEEE Computer Society (2006) 221-232
  - Brunel, J., Cuppens, F., Cuppens, N., Sans, T., Bodeveix, J.P.: Security policy compliance with violation management. In: Proc. of the Workshop on Formal Methods in Security Engineering (FMSE'07), ACM Press (2007) 31-40
  - A. Awad, G. Decker and M. Weske, “Efficient Compliance Checking Using BPMN-Q and Temporal Logic”, Proc. of the Int. Conf. on Business Process Management (BPM), 2008
- COMPAS Deliverable 2.1 “State-of-the-art in the field of compliance languages”

Reo/Constraint automata and their applications in SOC

- Arbab, F.: Reo: A channel-based coordination model for component composition. Mathematical Structures in Computer Science 14(3) (2004) 329-366
- Baier, C., Sirjani, M., Arbab, F., Rutten, J.: Modeling component connectors in Reo by constraint automata. Science of Computer Programming 61 (2006) 75-113
- D. Clarke, D. Costa, and F. Arbab. Connector colouring i: Synchronisation and context dependency. *Electr. Notes Theor. Comput. Sci., 154(1):101-119, 2006.*
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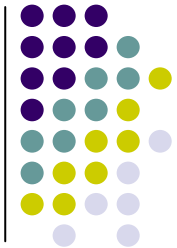
Conclusions and Future Work



- Conclusions
  - A formal behavioral model for business process / service composition description
  - Model-driven development – from high-level models to unambiguous executable models and their implementation
  - Processes are represented as Reo circuits or constraint automata
  - Compliance concerns are expressed as Reo circuits, constraint automata or logic formulae
- Future Work
  - Further investigation of compliance issues
  - Composition of processes from reusable compliant process fragments