Formal Methods For Web Service Process Modeling

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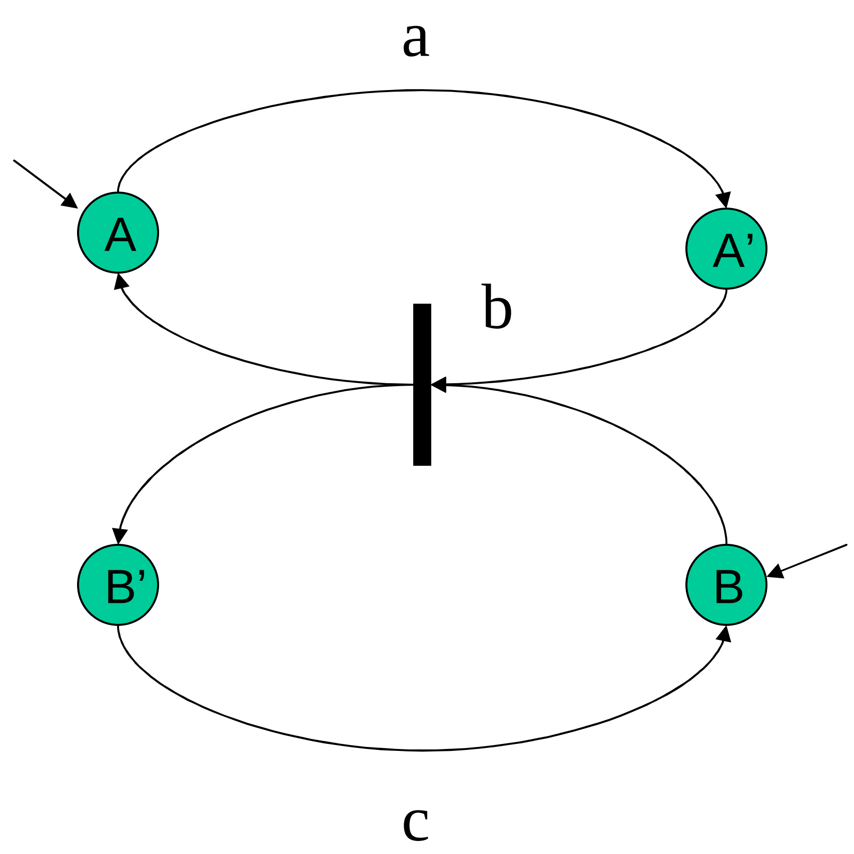
Modeling Web Service Processes with Petri Nets

The motivation of Petri nets

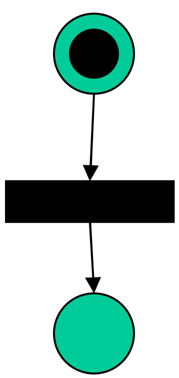


Petri nets

- **A marked place/transition net (P/T Net) is a tuple (*P, T, F, k, w, m₀*), where**

(P,T ,F) is a net with
- P is a finite set of places,
- T is a finite set of transitions, $(P \cap T = \emptyset)$
- $F \subseteq (P \times T) \cup (T \times P)$ is a finite set of arcs, the flow relation.

$k : P \rightarrow \{1, 2, 3, \ldots\} \cup \{\infty\}$ partial capacity of the places (default: ∞)
$w : F \rightarrow \{1, 2, 3, \ldots\}$ weight function (default:1)
$m_0 : P \rightarrow \{0, 1, 2, \ldots\}$ a marking satisfying $p \in P : k(p) = \infty \vee m_0(p) \leq k(p)$ (initial marking)



The occurrence rule

- **A transition *t* is enabled a marking *m* if**
  - **Every place** $\mathrm{p} \in^{\bullet} t$ **satisfies** $m(p) \geq w(p,t)$
  - **Every place** $\mathrm{p} \in t^{\bullet}$ **satisfies** $m(p) + w(t,p) \leq k(p)$
- **The occurrence of *t* leads to the successor marking *m'*, defined by**

$$m'(p) = \begin{cases} m(p) & \text{if } p \notin^{\bullet} t \text{ and } p \notin t^{\bullet} \\ m(p) - w(p,t) & \text{if } p \in^{\bullet} t \text{ and } p \notin t^{\bullet} \\ m(p) + w(p,t) & \text{if } p \notin^{\bullet} t \text{ and } p \in t^{\bullet} \\ m(p) - w(p,t) + w(t,p) & \text{if } p \in^{\bullet} t \text{ and } p \in t^{\bullet} \end{cases}$$

- **Notation**

$$m \xrightarrow{t} m' \qquad\qquad m[t\rangle m'$$

Occurrence sequences and reachability

- A finite sequence $\sigma = t_1 t_2 \ldots t_n$ of transitions is a ***finite occurrence sequence*** leading from m_0 to m_n if

$$\mathrm{m}_0 \xrightarrow{t_1} m_1 \xrightarrow{t_2} \ldots \xrightarrow{t_n} m_n$$

- A marking *m* is ***reachable*** (from m_0) if there is an occurrence sequence leading from m_o to *m*
- **Notation**: $[\mathrm{m}_0\rangle$ is the set of all reachable markings

- An infinite sequence $\sigma = t_1 t_2 t_3 \ldots$ is an ***infinite occurrence sequence*** enable at m_0 if

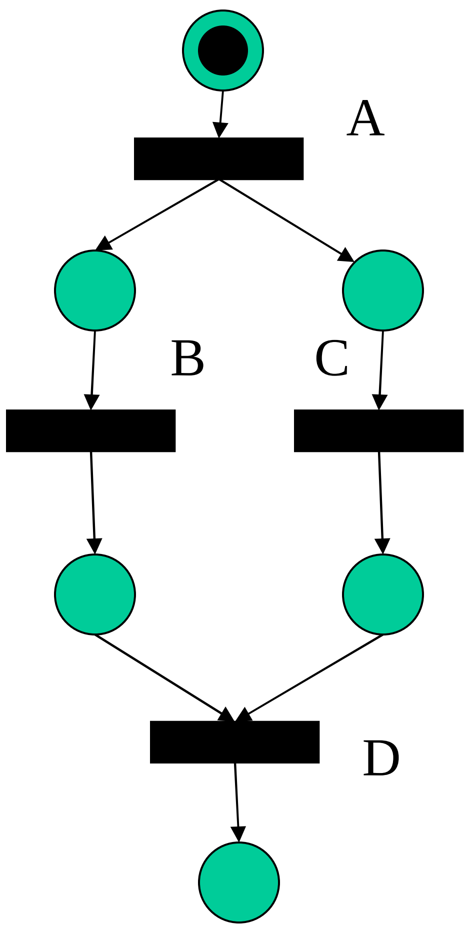
$$\mathrm{m}_0 \xrightarrow{t_1} m_1 \xrightarrow{t_2} m_2 \xrightarrow{t_3} \ldots$$

Behavioral Properties of Market p/t-nets

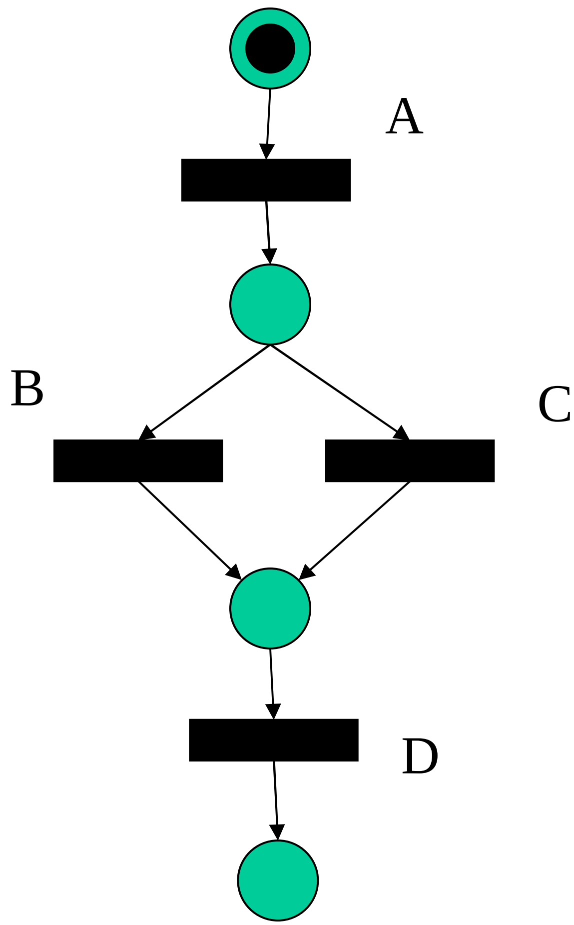
A marked p/t-net is

- **Terminating – if there is no infinite occurrence sequence**
- **Deadlock-free – if each reachable marking enables a transition**
- **Live – if each reachable marking enables an occurrence sequence containing all transitions**
- **Bounded – if, for each place *p*, there is a bound *b(s)* such that *m(s)<=b(s)* for every reachable marking *m***
- **1-safe – if *b(s)=1* is a bound for each place *p***
- **Reversible – if m_0 is reachable from each other reachable marking**

Petri Nets Blocks

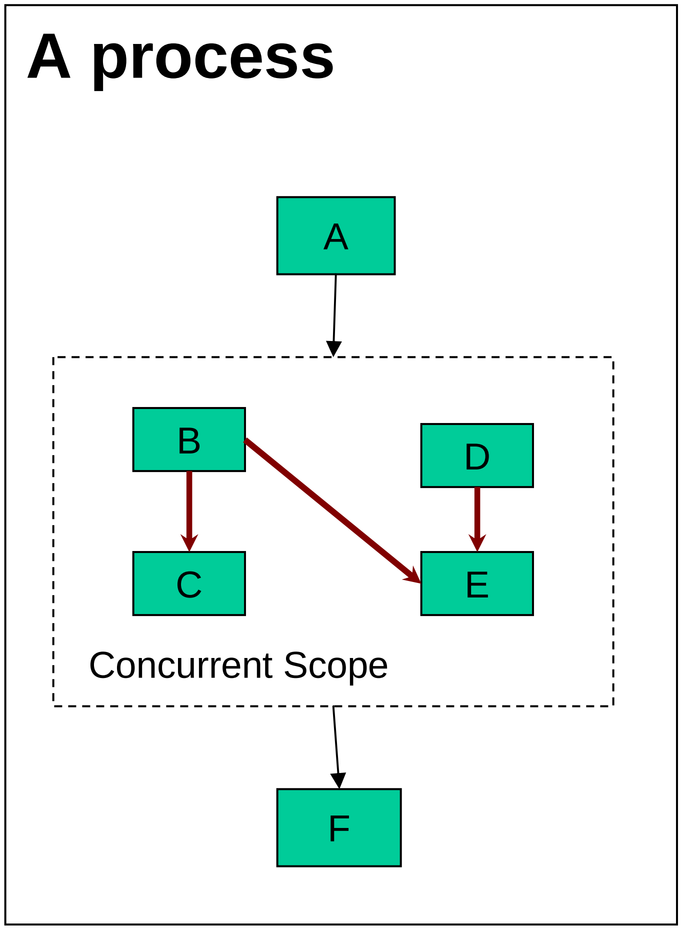


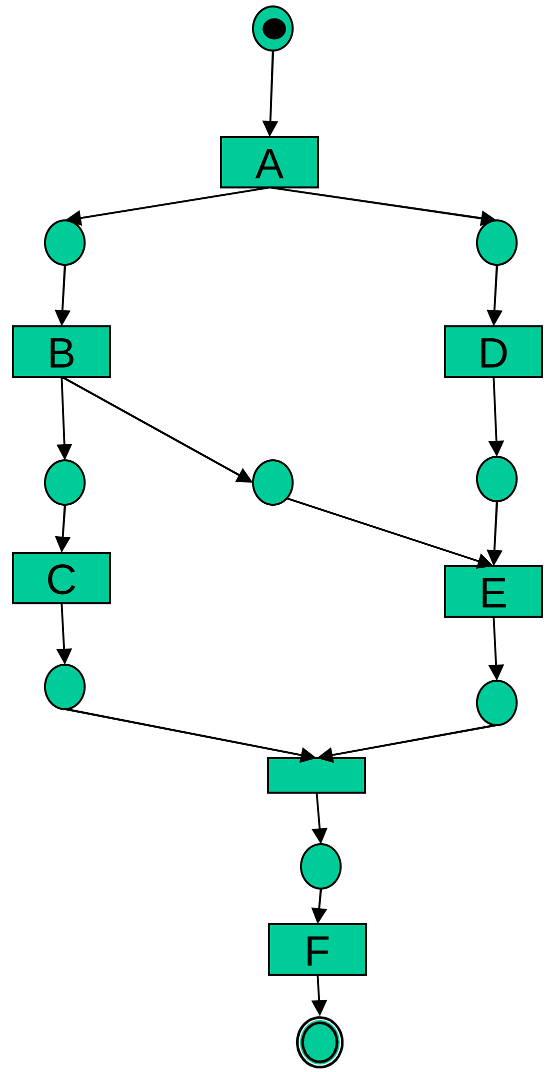
B parallels with C



B or C

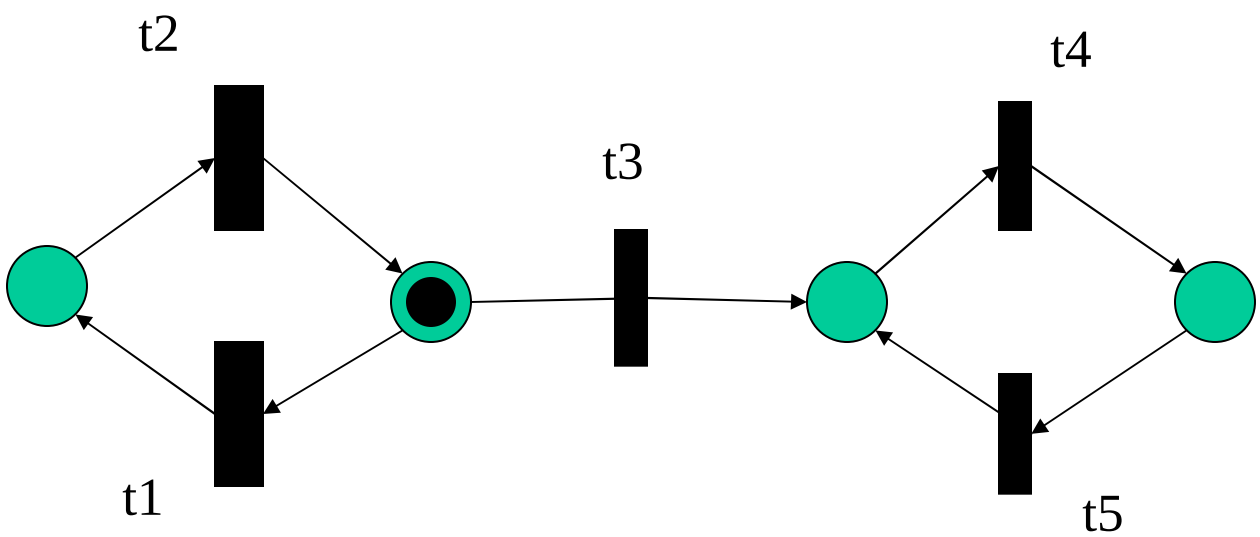
The Petri Net for the Example Process





Some Propositions about Petri Nets

- **No deadlock-free marked p/t-net is terminating**
- **Every live marked p/t-net is deadlock-free**
- **A marked p/t-net is live if and only if at no reachable marking a transition is dead**



Example: some transitions are dead at a reachable marking

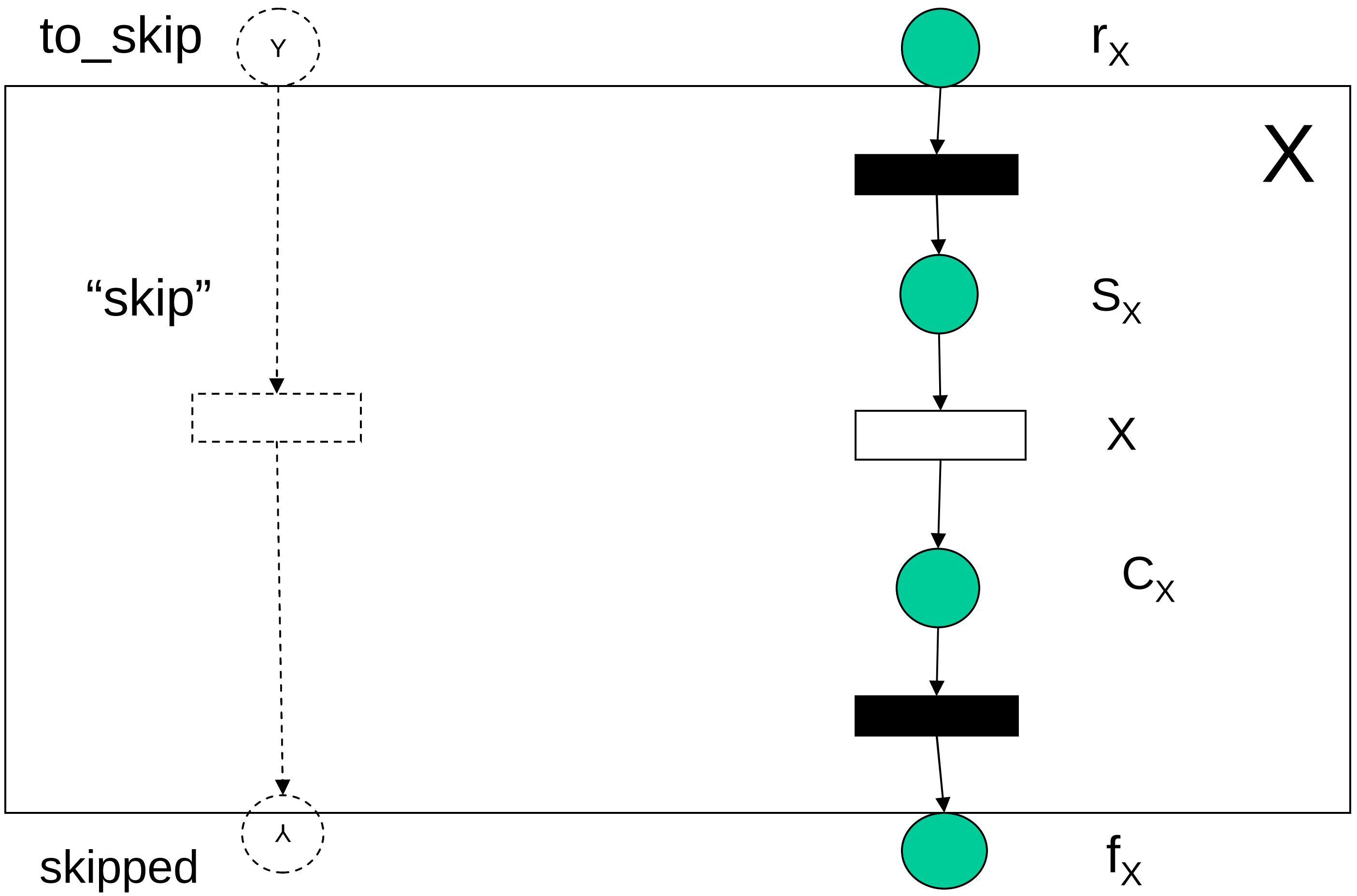
Properties of Business Processes

- A business process should
  - Terminate
  - A transition is in a finite sequence
  - 1-safe
  - Reversible
- Or, if you connect the Receive-Reply with a pseudo transition
  - Deadlock-free
  - Live
  - 1-safe
  - Reversible

Add parameters to Petri nets for BEPL activities

- **Associate variables with places**
- **Associate conditions with transitions**

The Petri Net for the Internal Behavior of an Activity [Aalst05]



Basic Analysis Techniques in Petri Nets

- **Linear-algebraic techniques**
  - The marking equation
  - Place invariants
  - Transition invariants
- **Structural techniques**
  - Siphons
  - Traps
  - The siphon/trap property
- **Restricted net classes**
  - State machines
  - Marked graphs
  - Free-choice nets
- **Causal Semantics**
  - Occurrence nets
  - Process nets