MULAN4SONAR – A Tutorial

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Agent vs. Organisation; Service vs. System

Agents

- local autonomy
- inteligence:
  goal-orientation, learning
- social awareness:
  cooperation, competition

Problems

- bounded rationality:
  sub-optimal solutions
- scaling problem for large agent populations

Organisations

- global coherence
- organisational learning,
  data mining
- teams

Solutions

- social structures:
  roles, protocols, norms
- reduction of complexity:
  interaction networks,
  e.g. hierarchies

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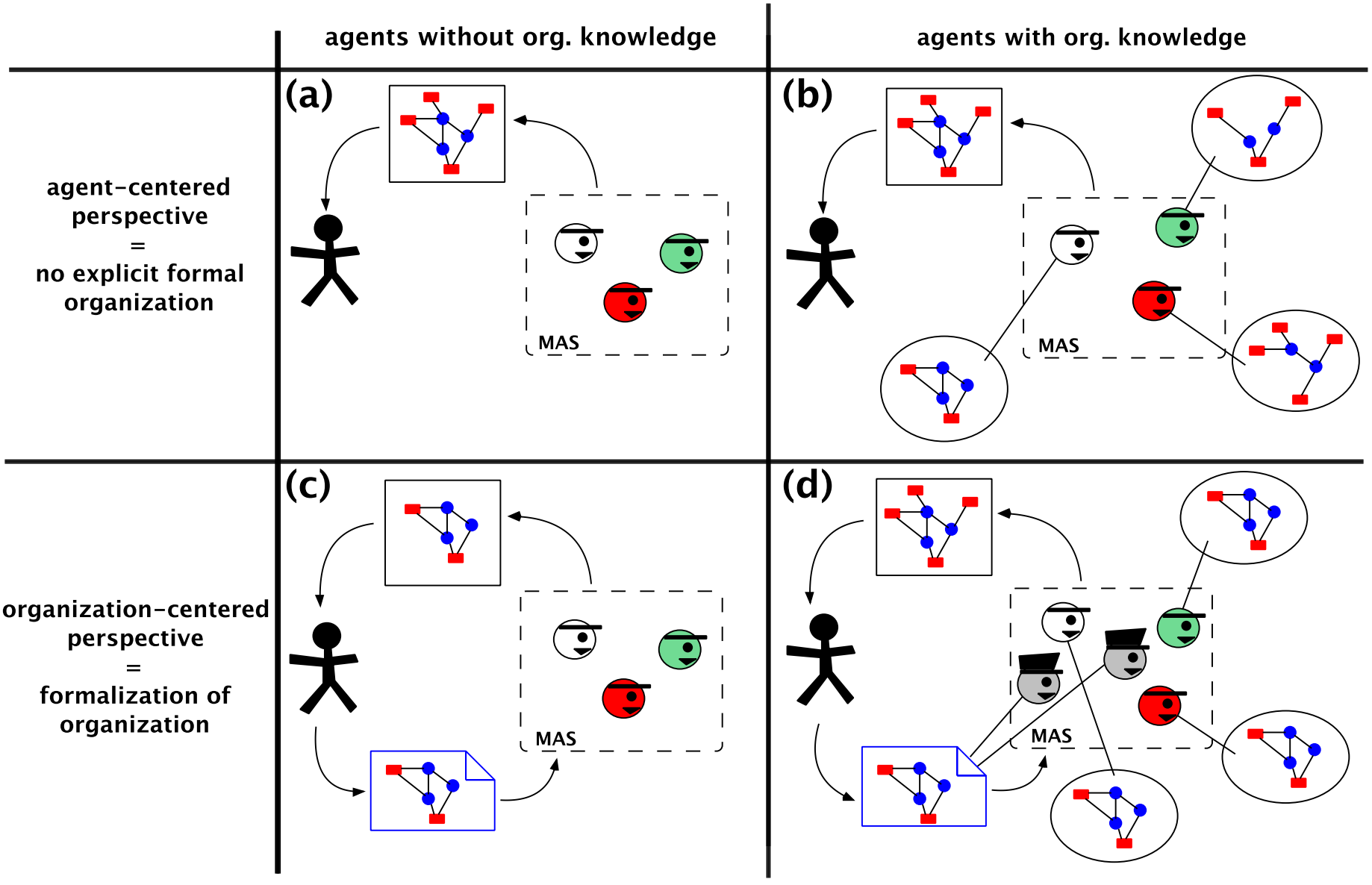
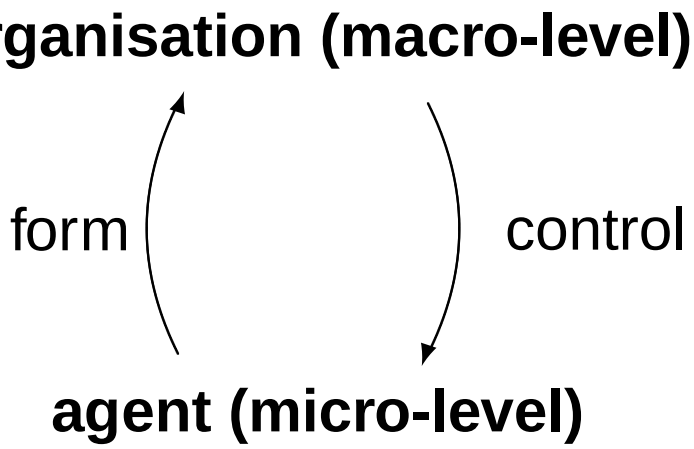
Matrix: Organisation Awareness



Duality of the Concept ’Organisation’

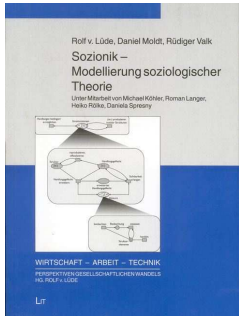
Cyclic dependencies of micro (agents) and macro (organisation):



Sociology: *middle-up-down* instead of *top-down*/*bottom-up*

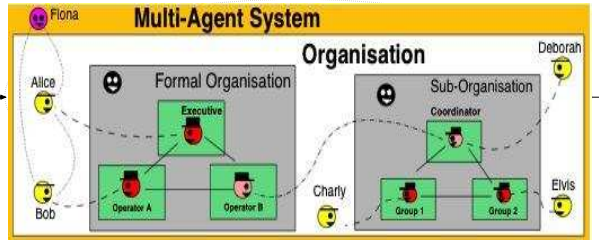
⇒ Organisations as modelling components and sw-artefacts

DFG-SPP Socionics:
Modells of Social Theories



Overview of SONAR Concepts

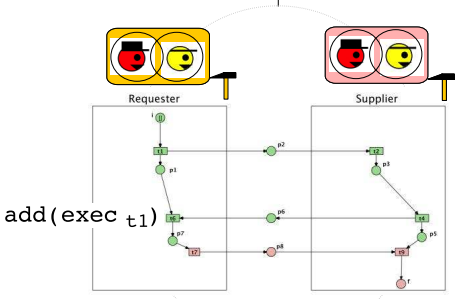
reorganise



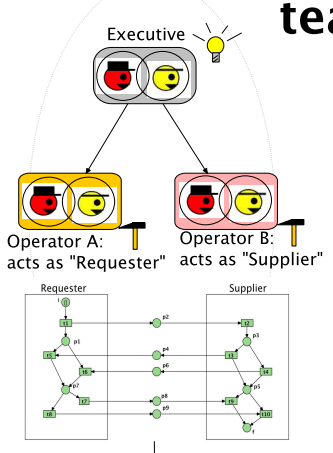
form team

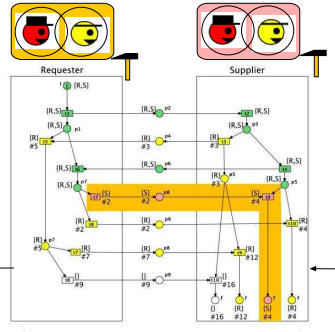
Organsiation-MAS

transformation



team





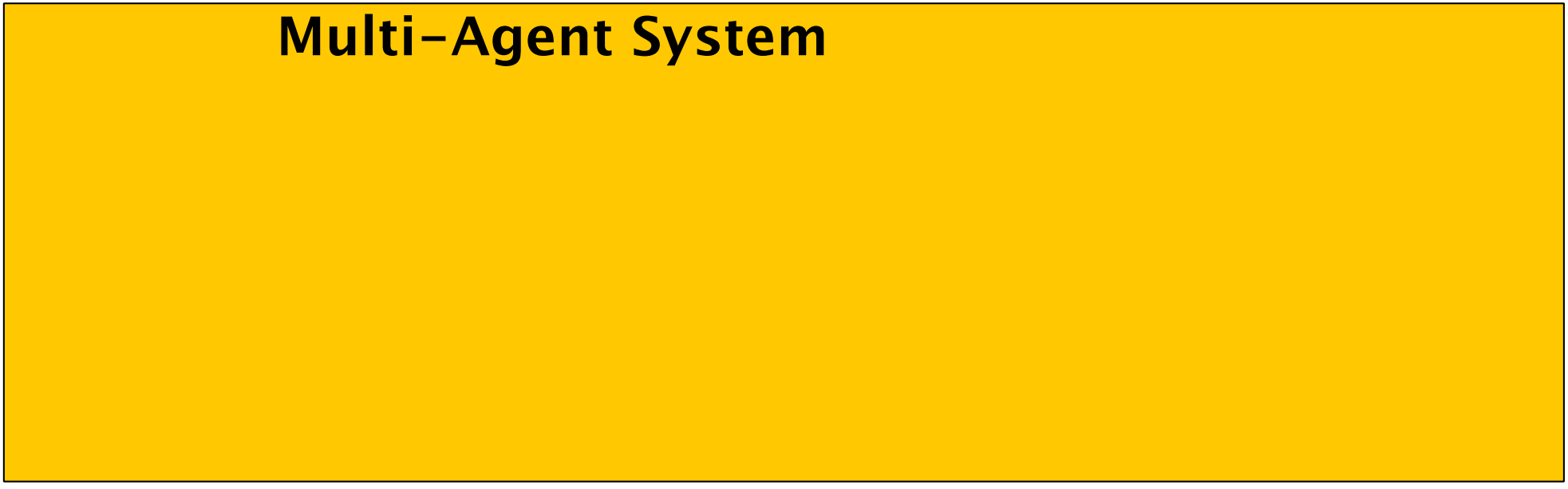
team plan

execute

negotiate

Outline

The MULAN4SONAR Organisation MAS



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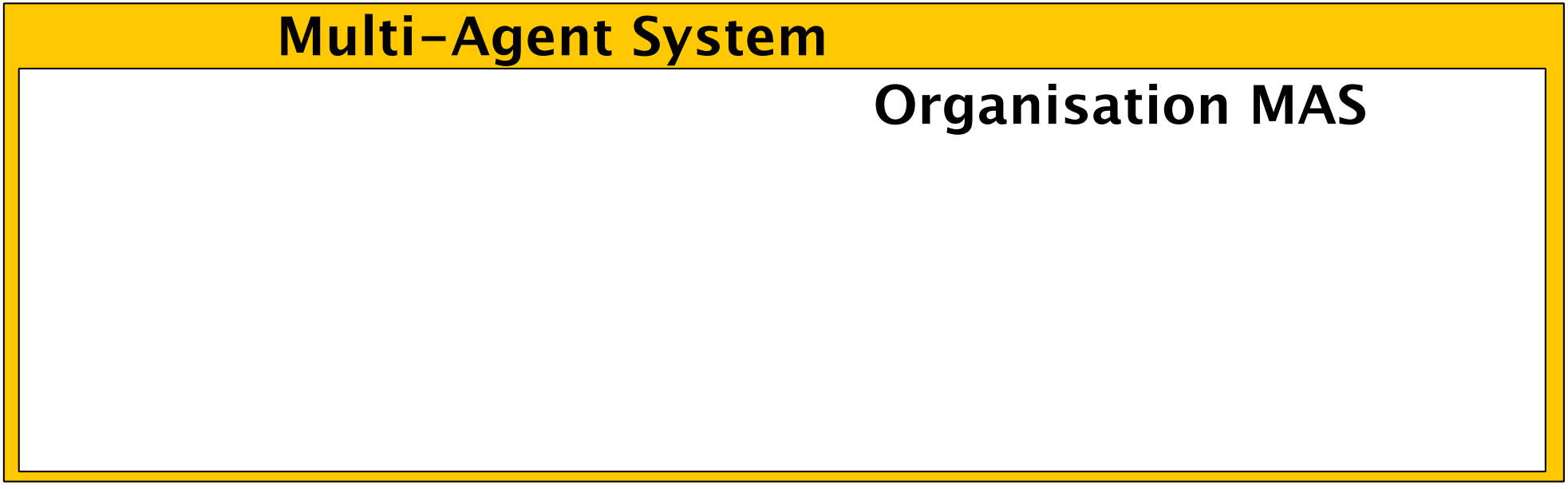

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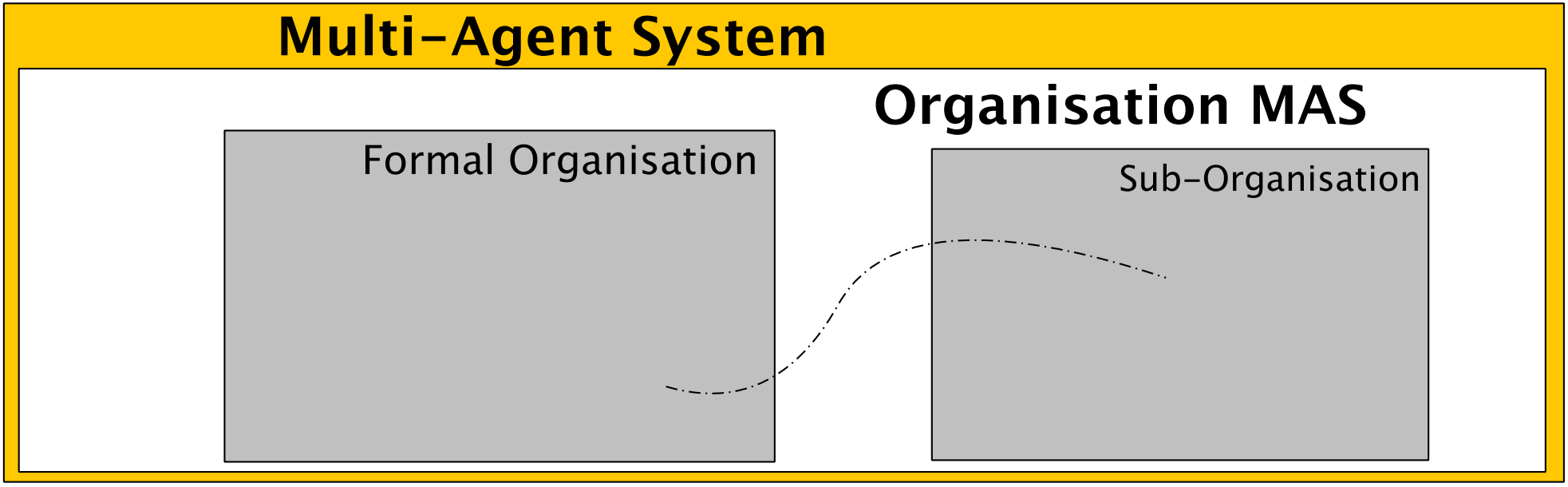

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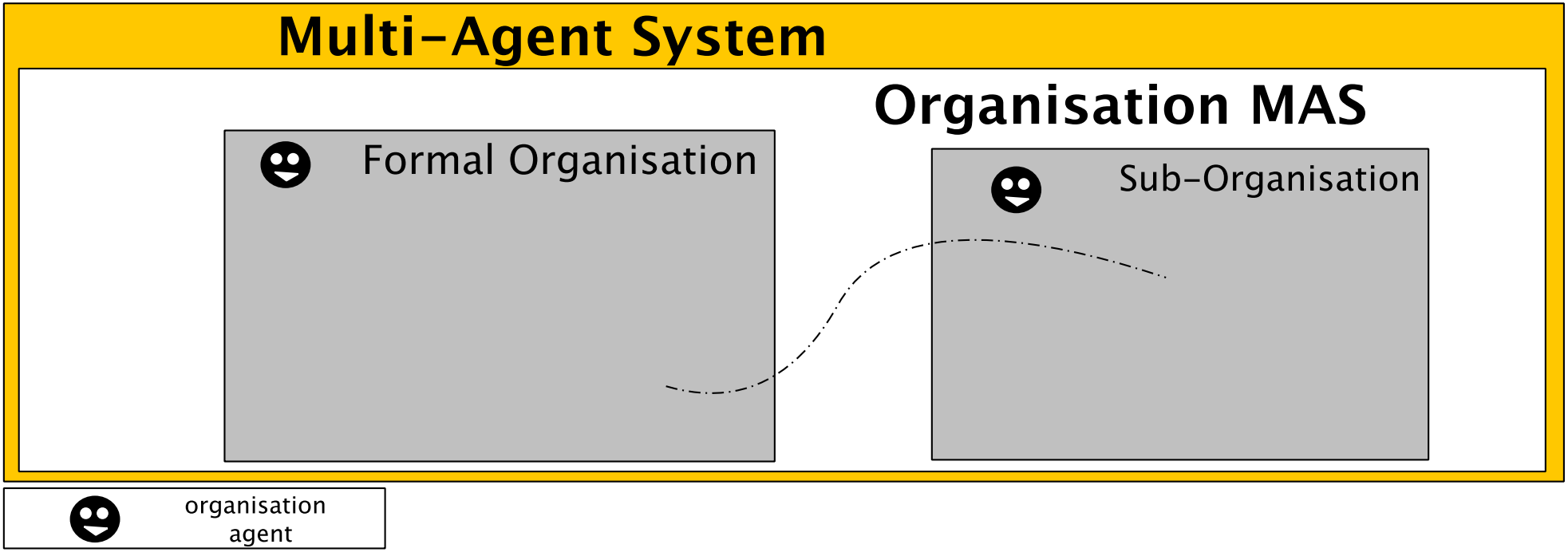

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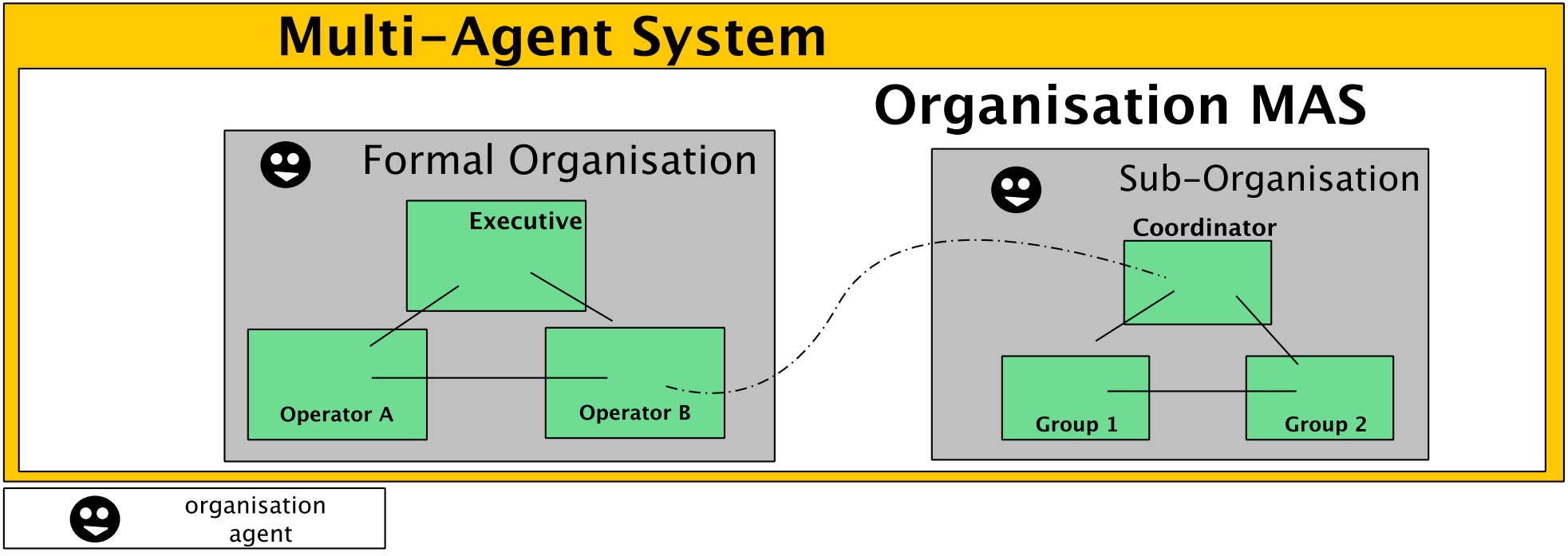

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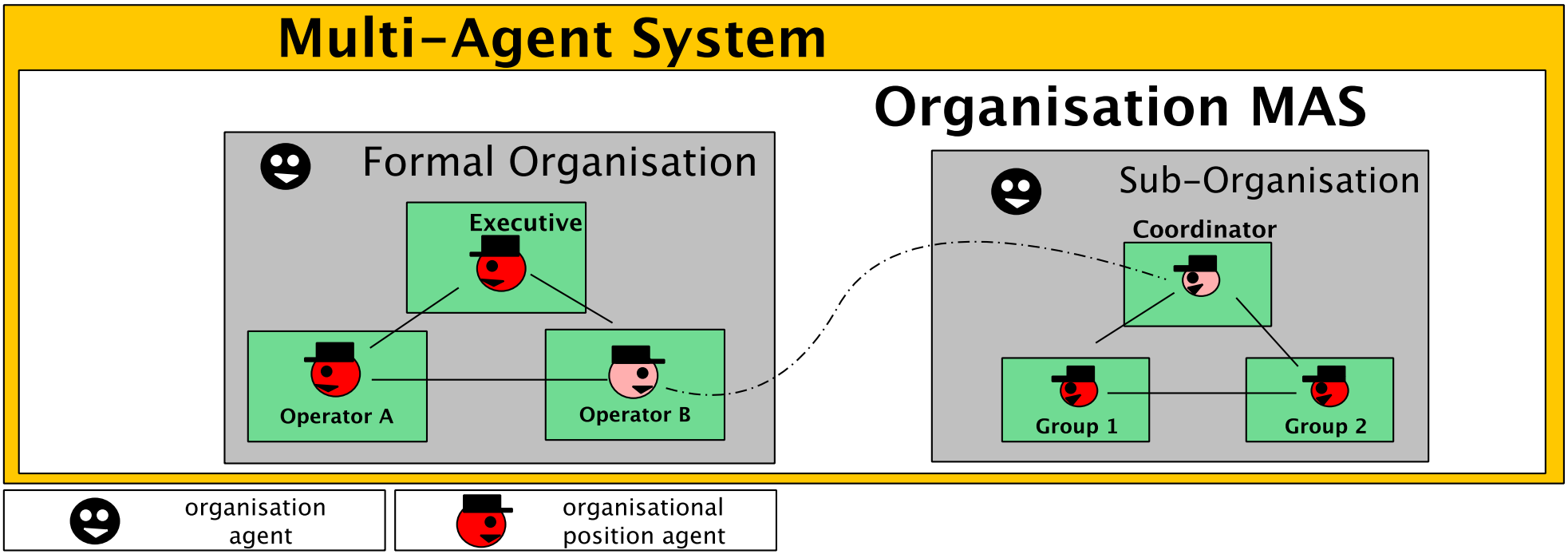

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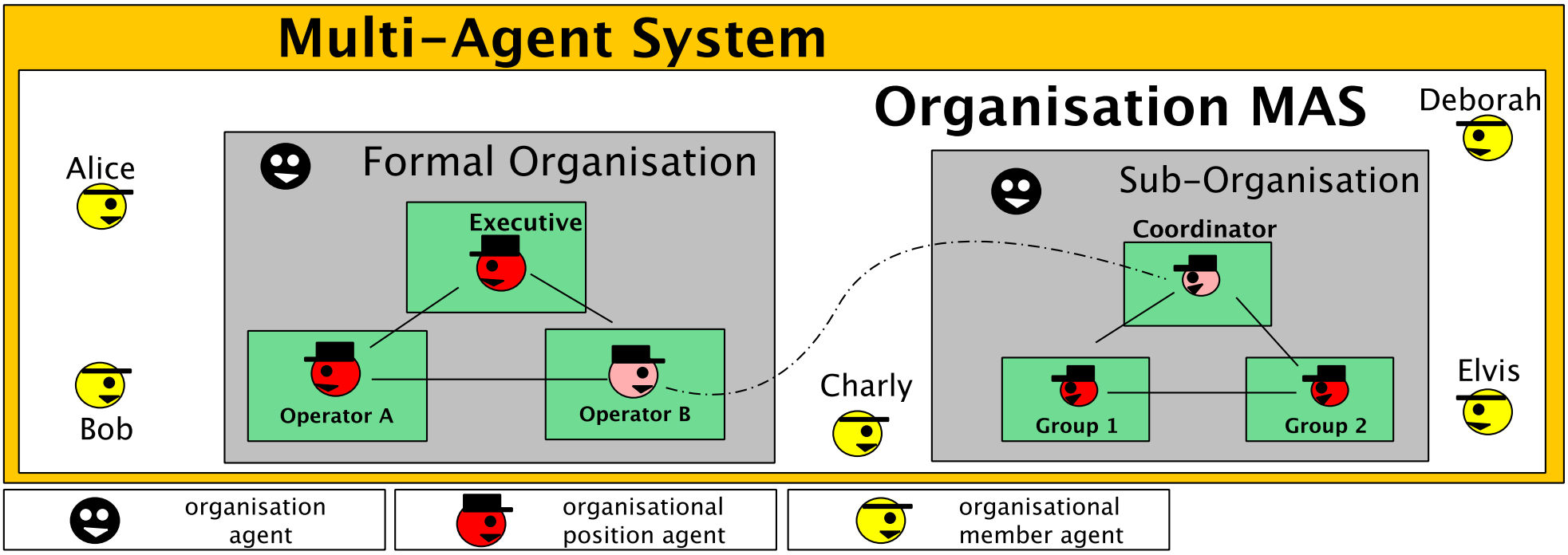

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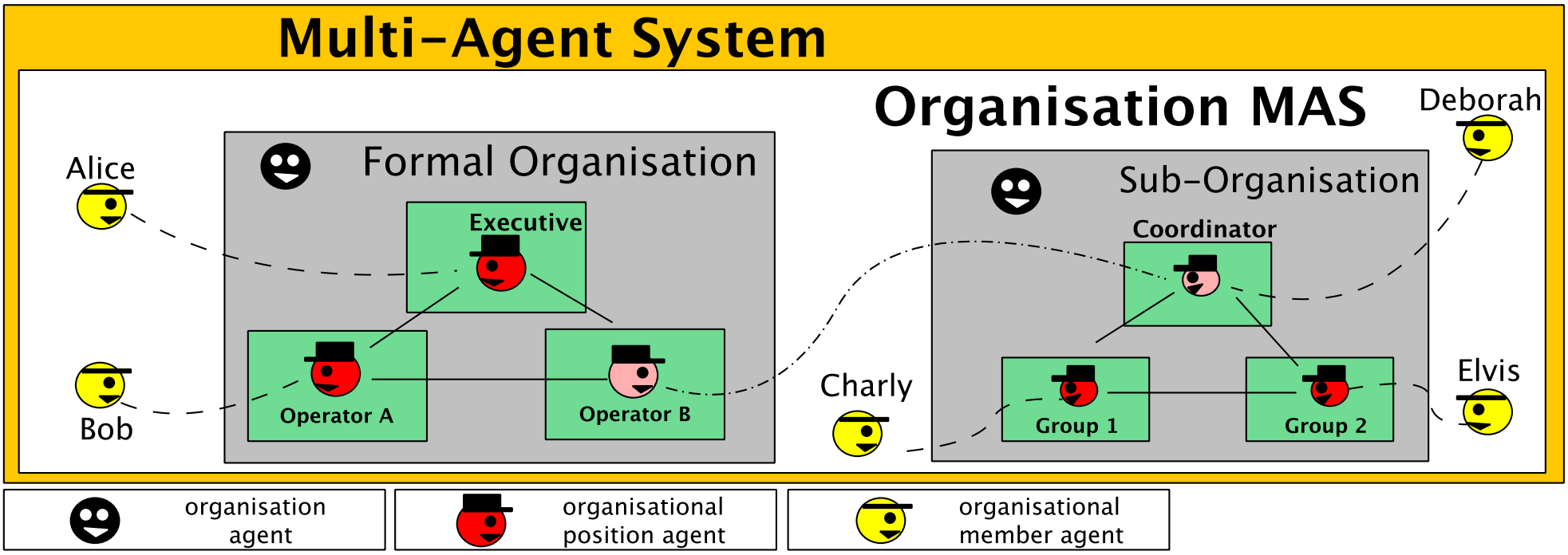

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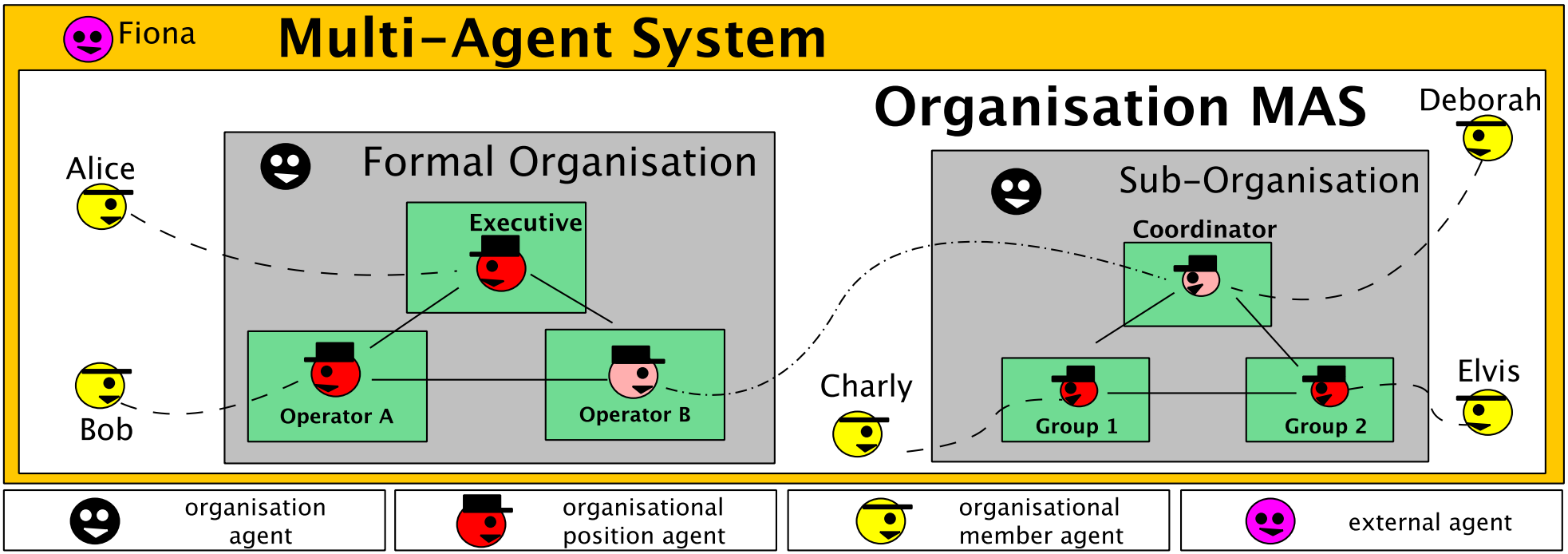

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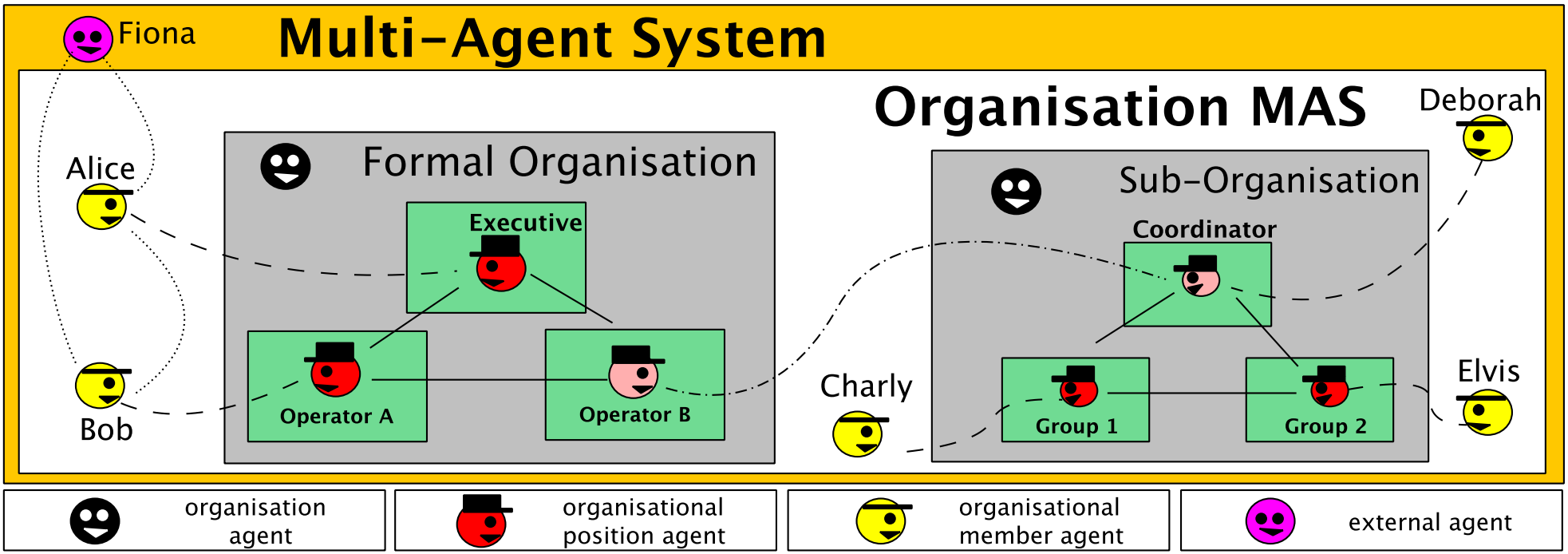

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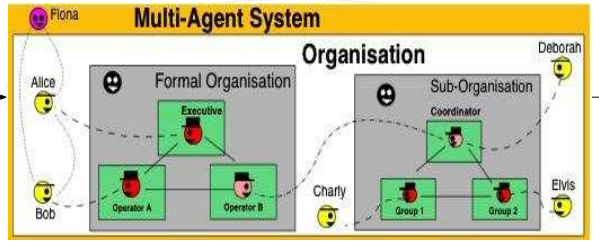

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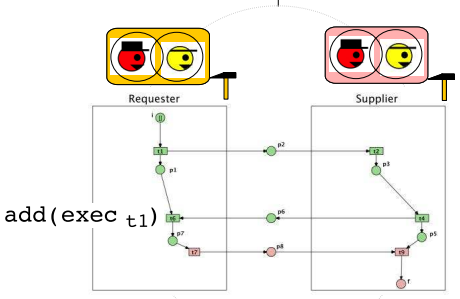

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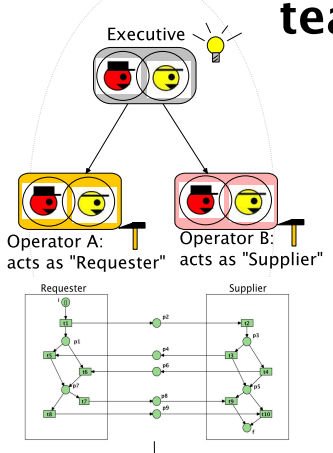

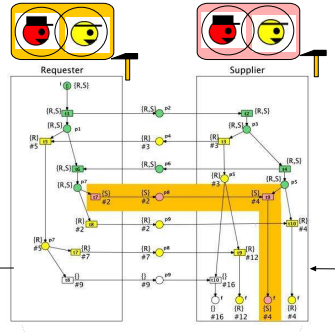

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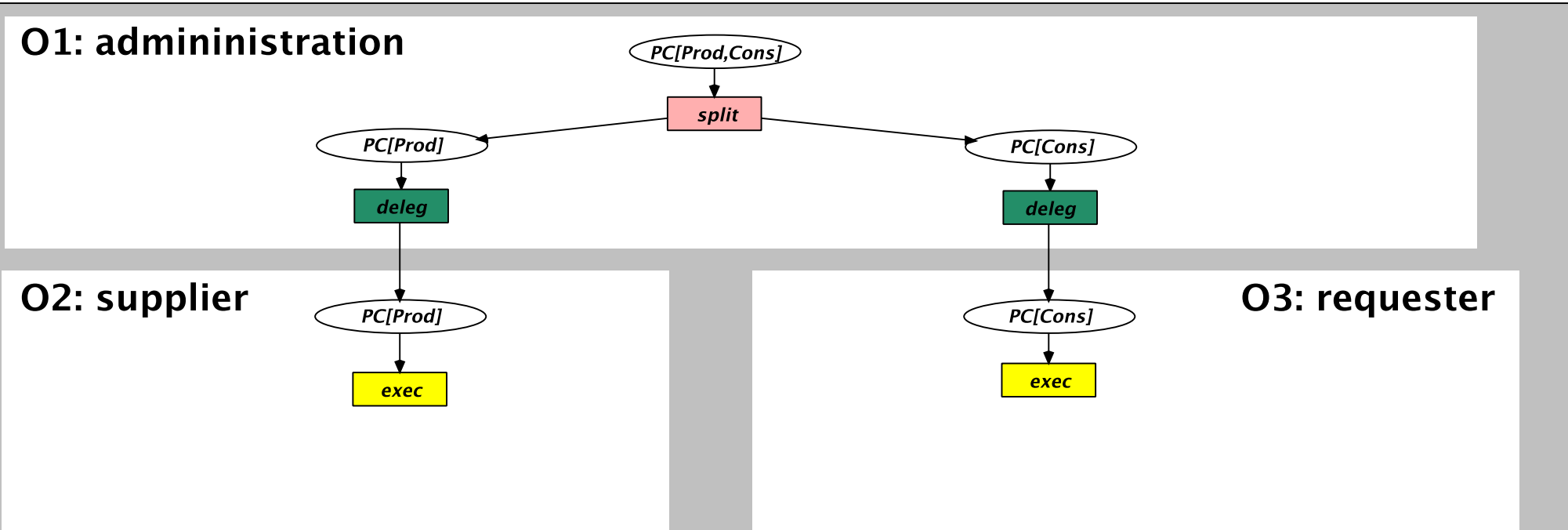
execute

negotiate

Outline

SONAR Organisation Models

- An **organisation** is a Petri net $N = (P, T, F)$.
- Places $\texttt{task}^{a}_{D[R]}$: Agent a has to implement the role R in the interaction D.
- Transitions: Implementation of tasks via ...
  1. delegation
  2. split
  3. refinement or
  4. execution



The SONAR Organisation Model

Let $\mathcal{T}$ be the set of all task implementations (i.e. delegations, split, refinement, and execution).

Definition

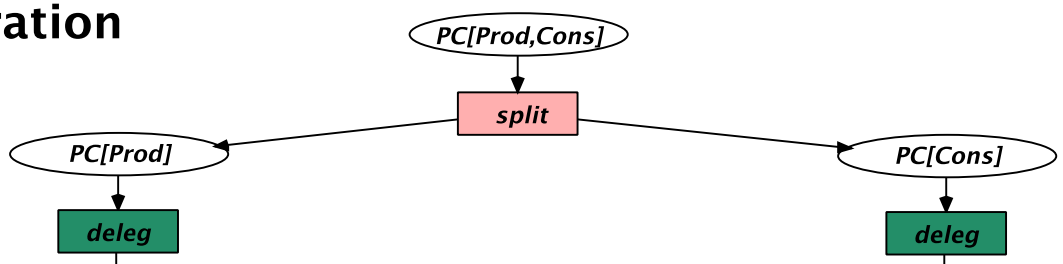
An **organisation** is a Petri net $N = (P, T, F)$ with

- $T \subseteq \mathcal{T}$,
- $P = {}^\bullet T \cup T^\bullet$, and
- $F = \mathcal{F} \cap (P \cup T)^2$.

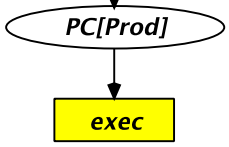
The places in $P^0 := \{p \in P \mid {}^\bullet p = \emptyset\}$ model those tasks that are generated by the environment.

Transformations on SONAR-Models

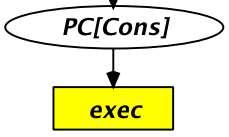
O1: admininistration



O2: supplier



O3: requester



O21

O22

O4

O31

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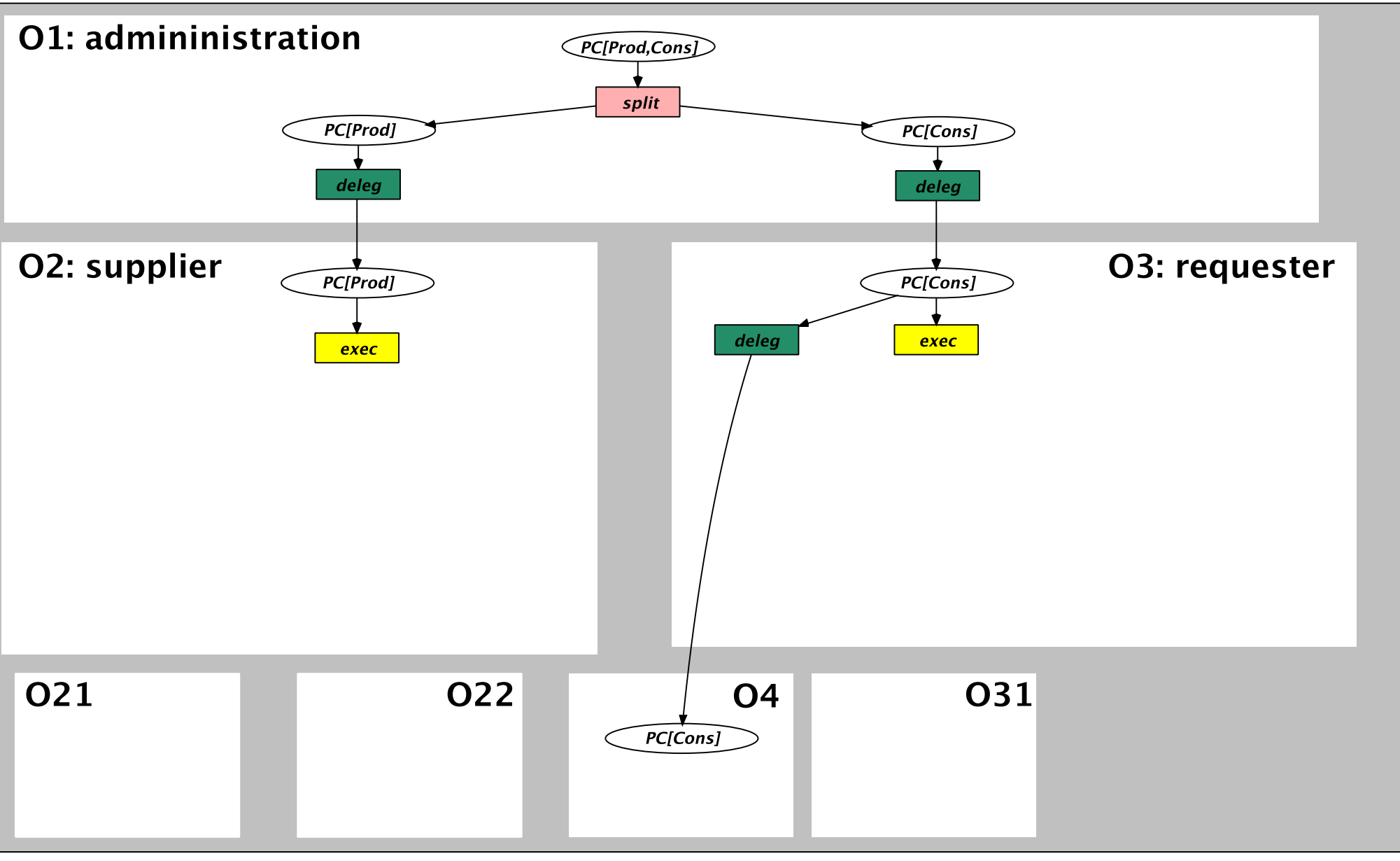

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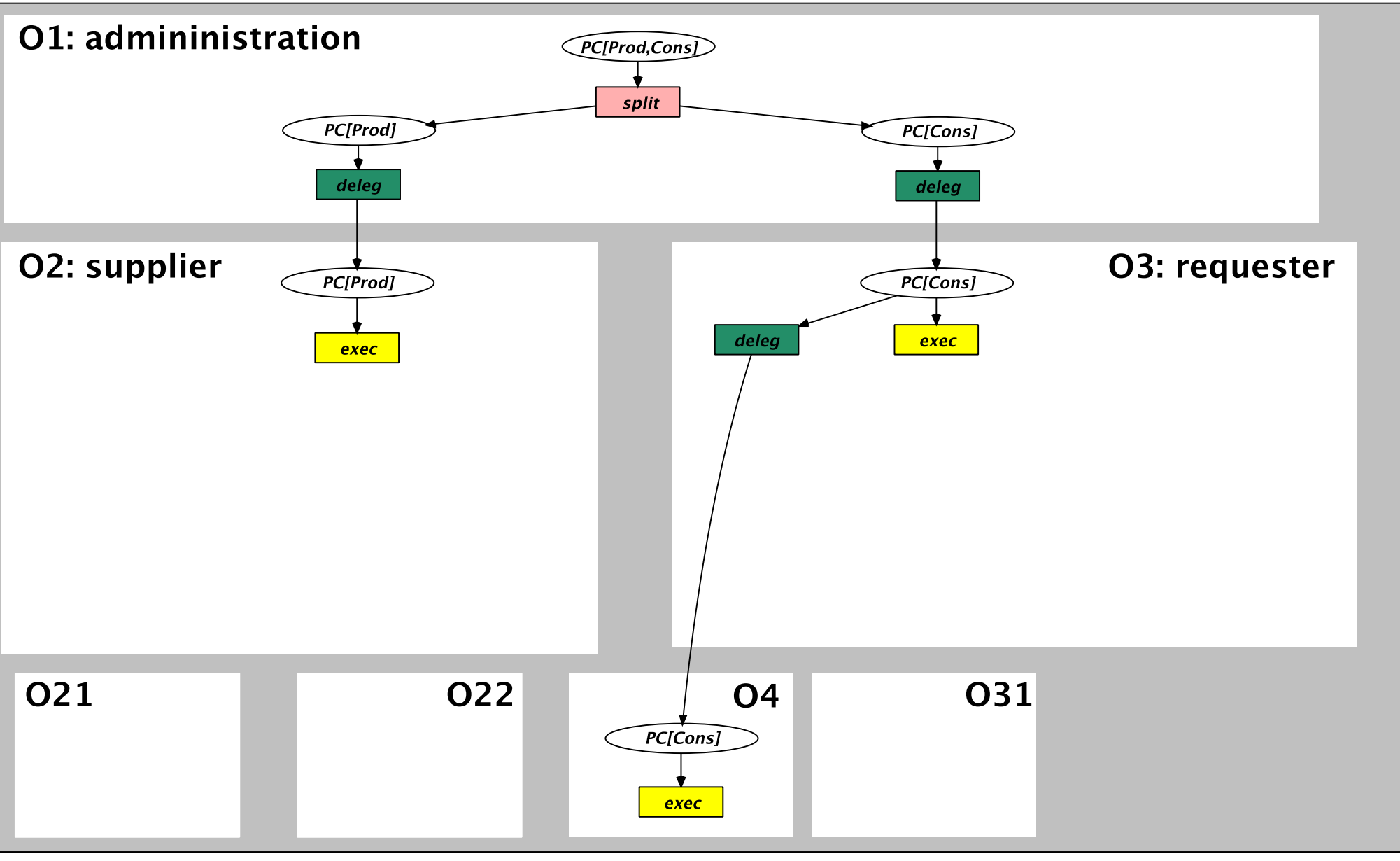

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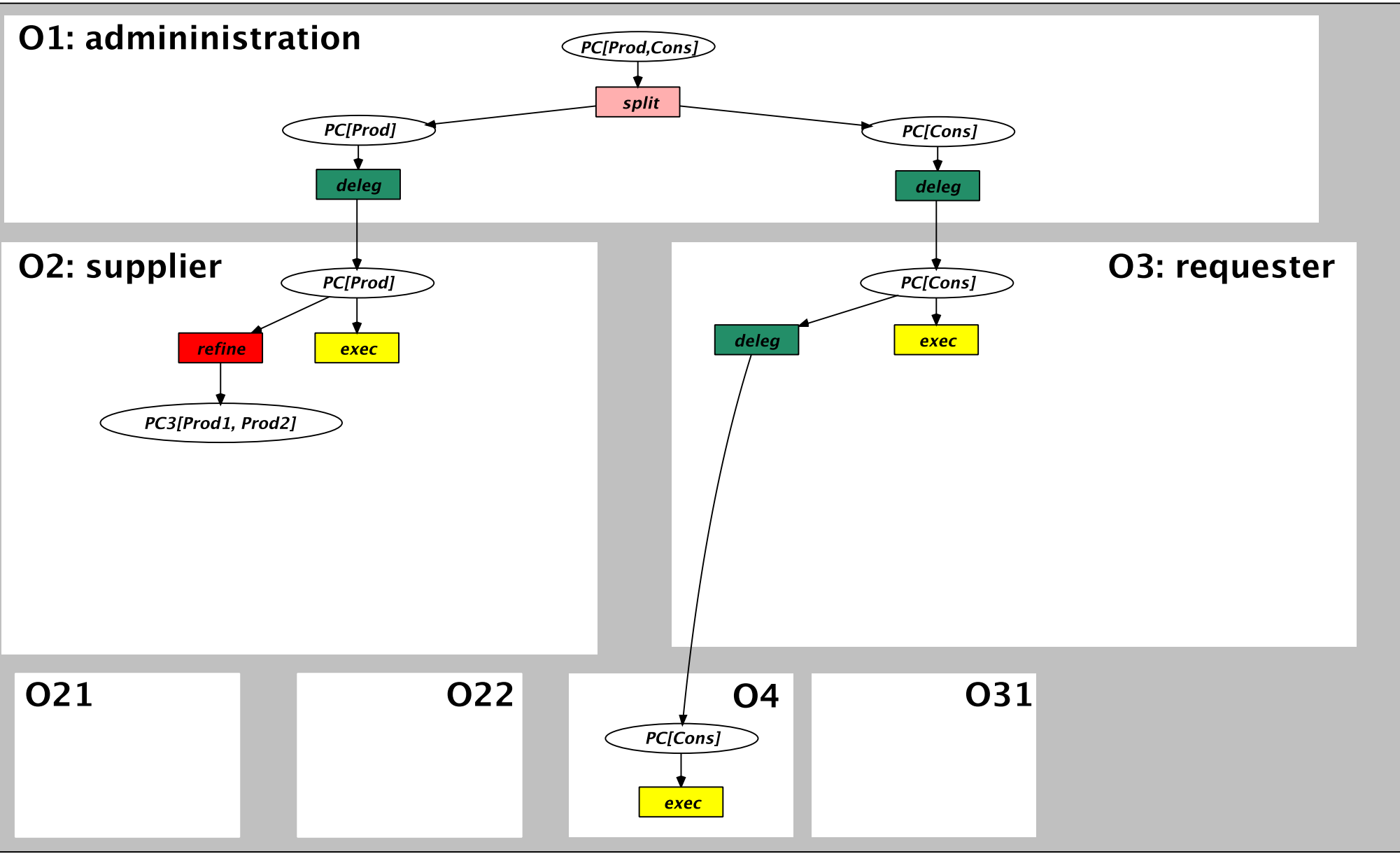

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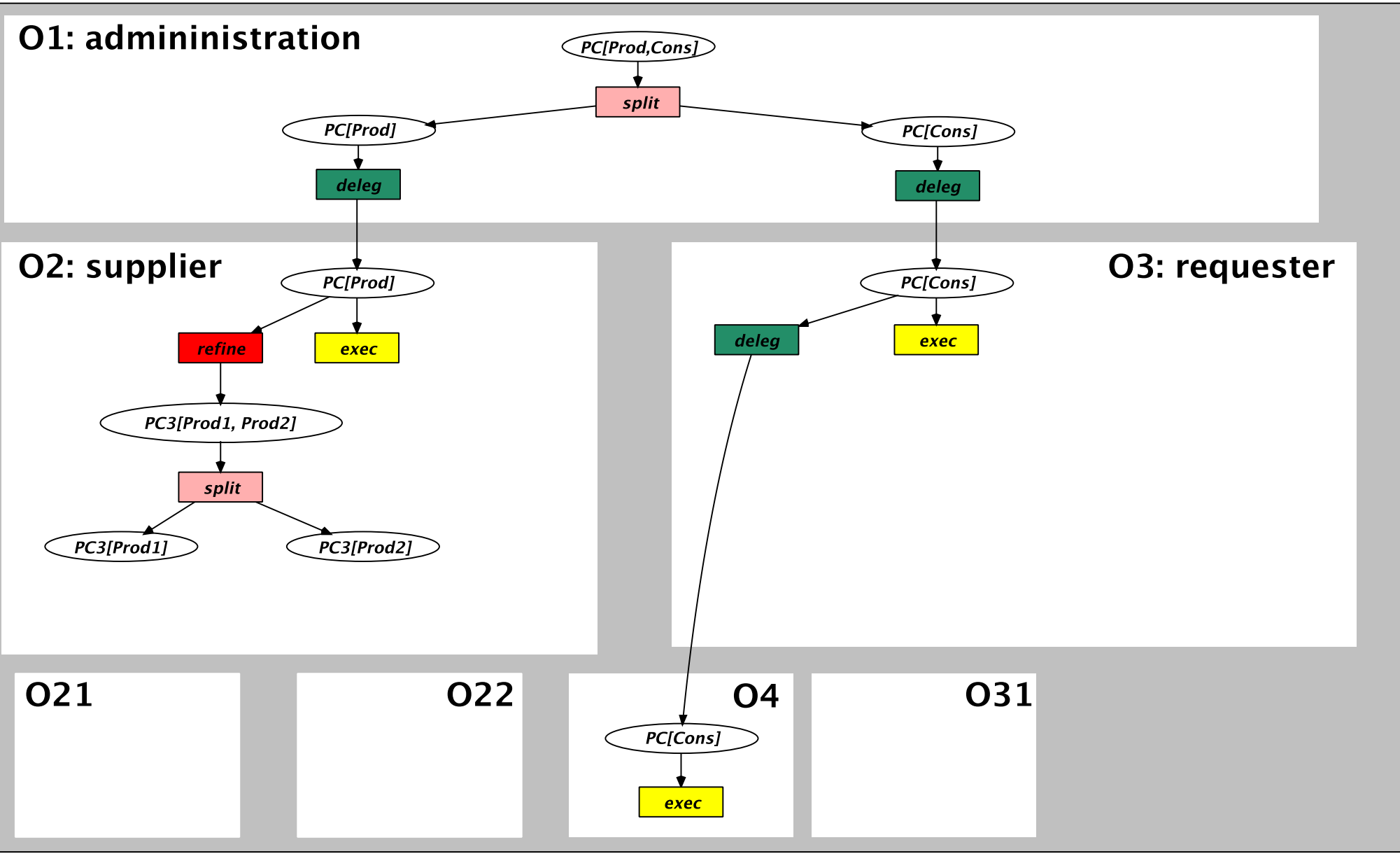

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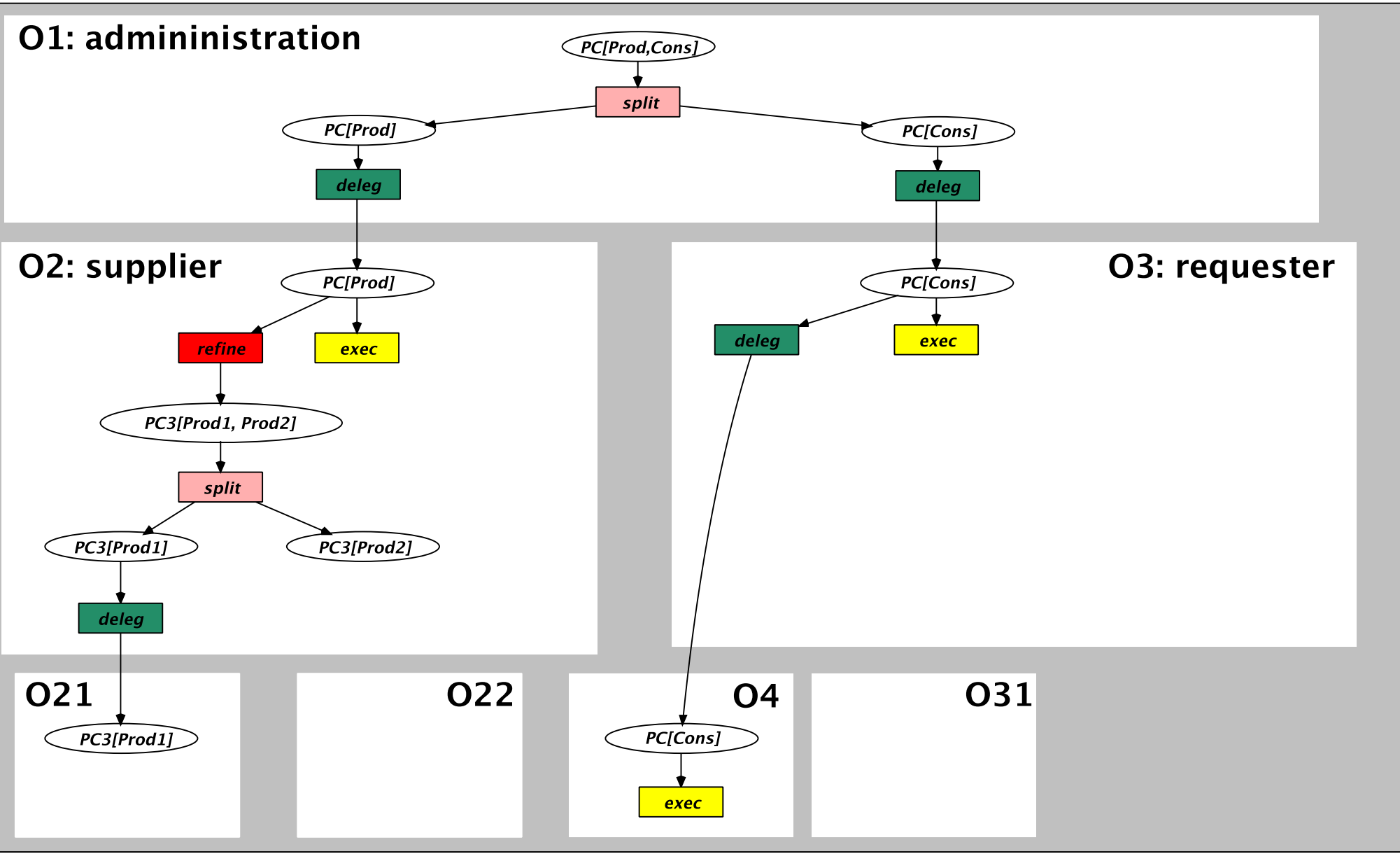

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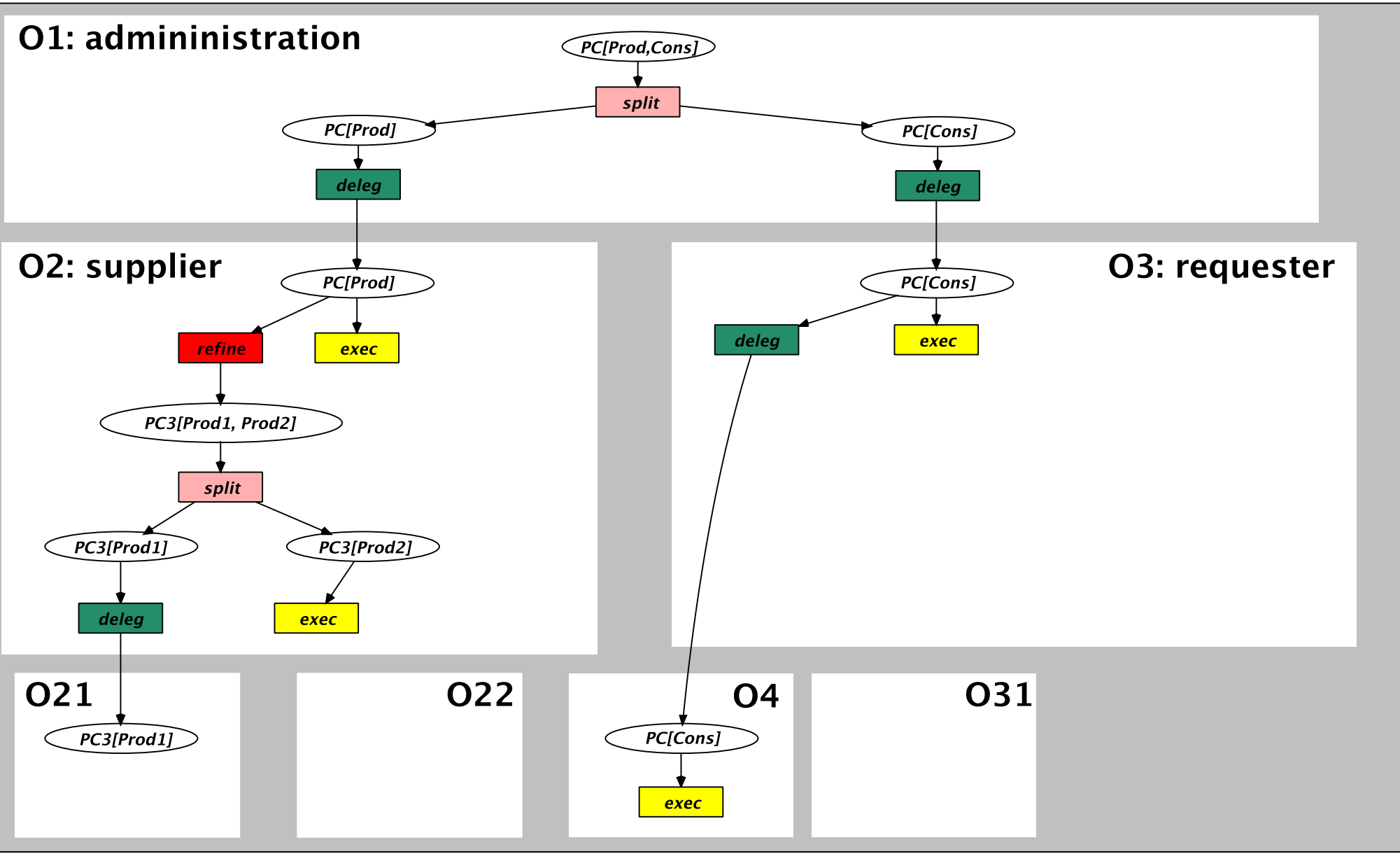

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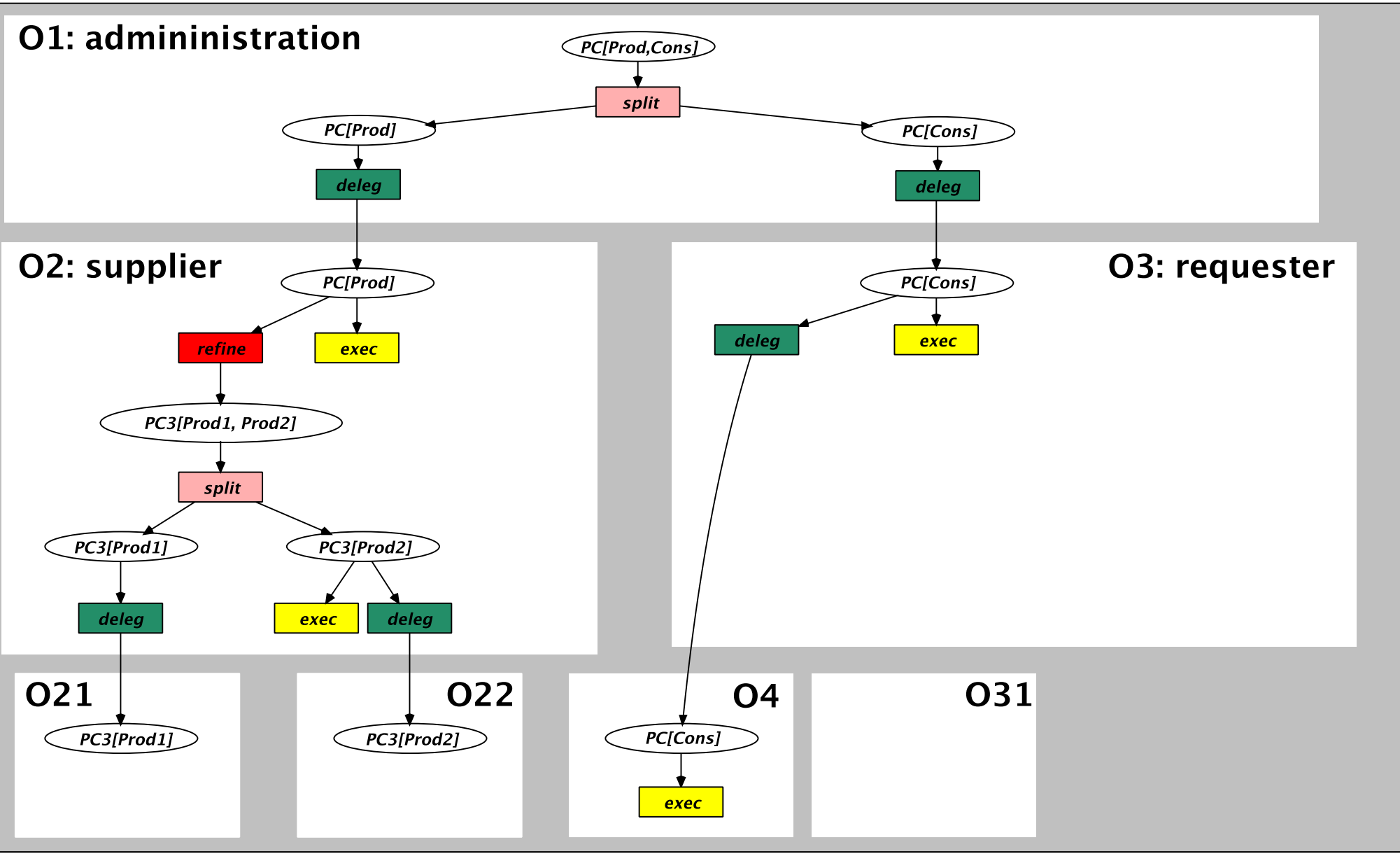

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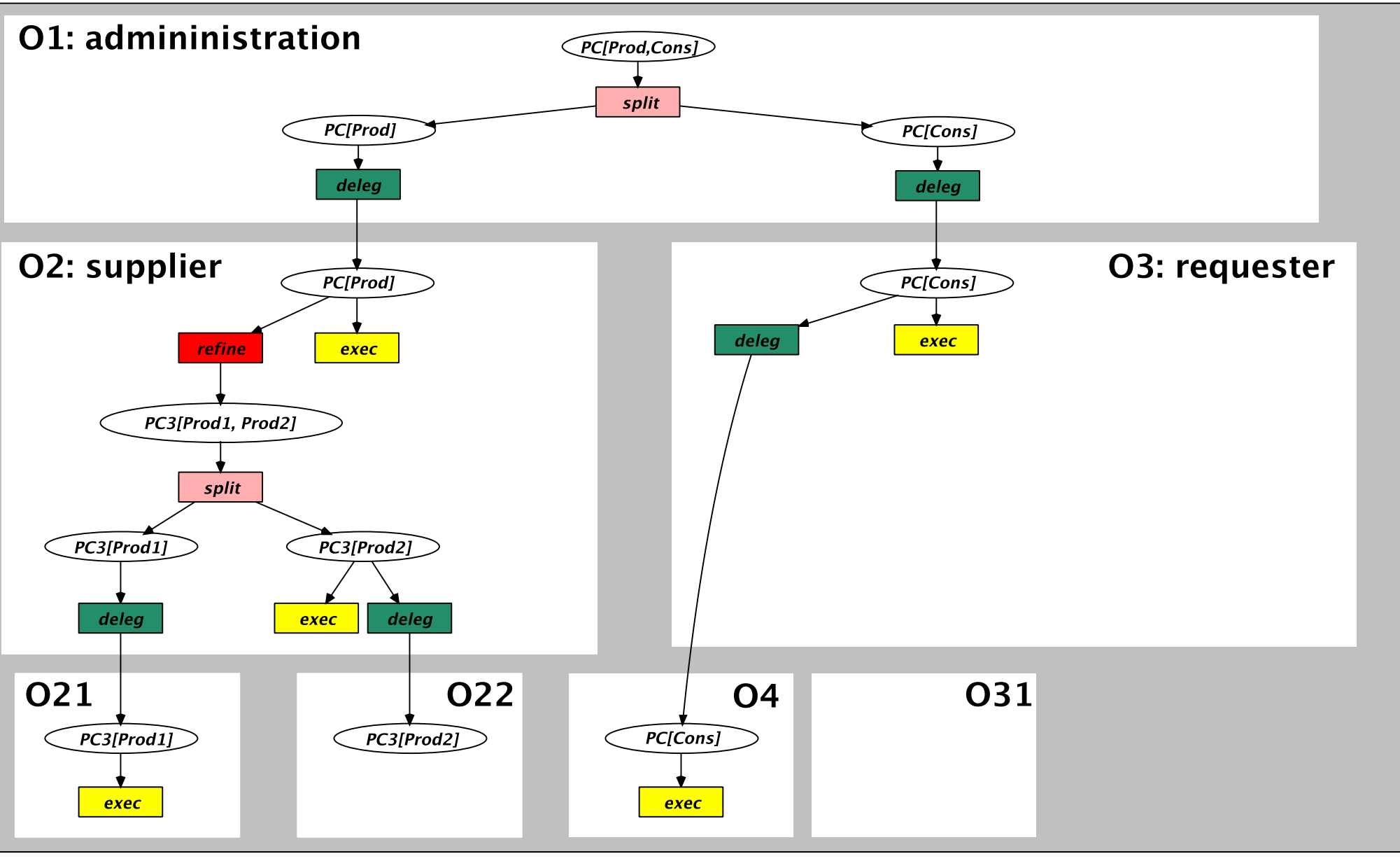

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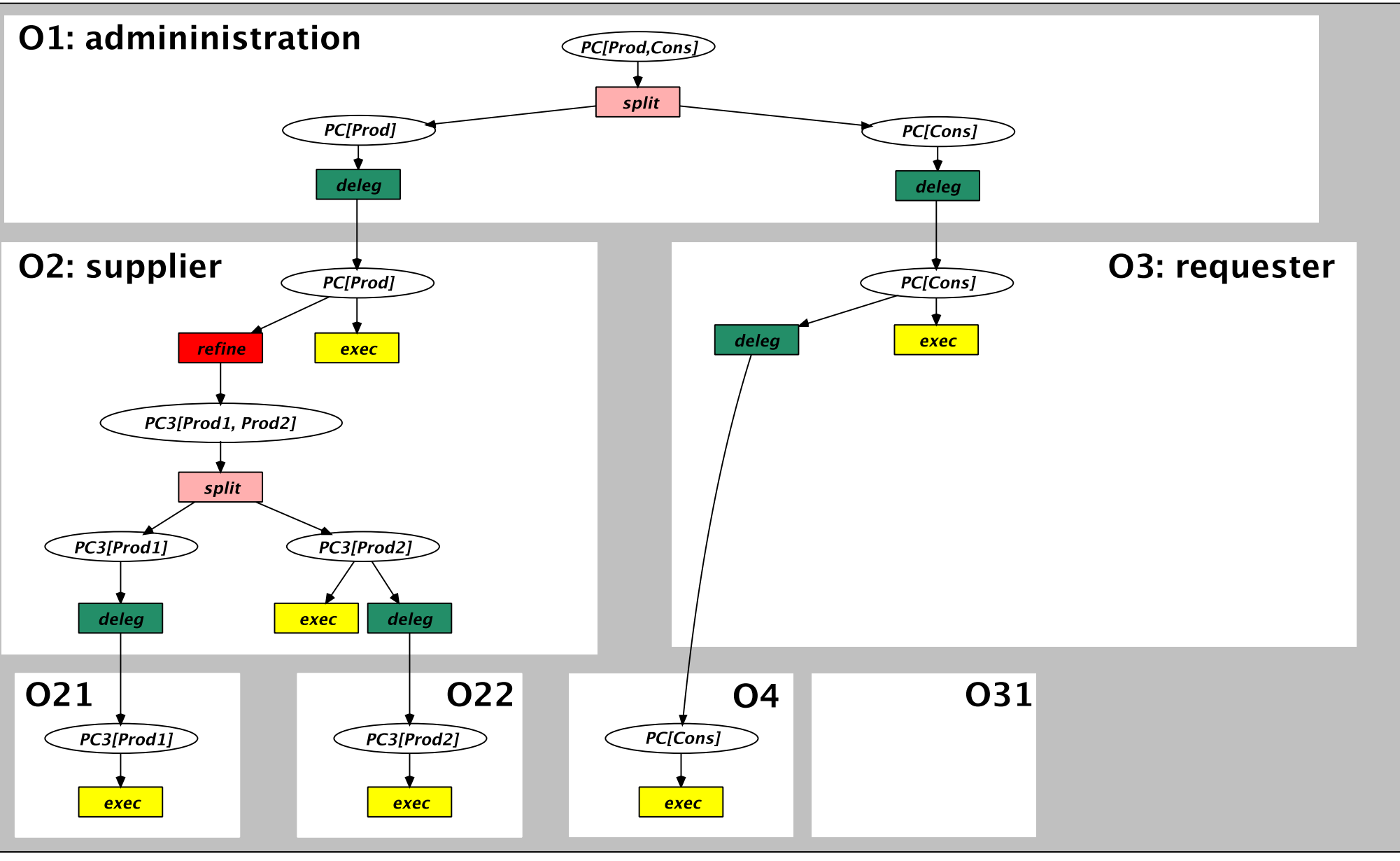

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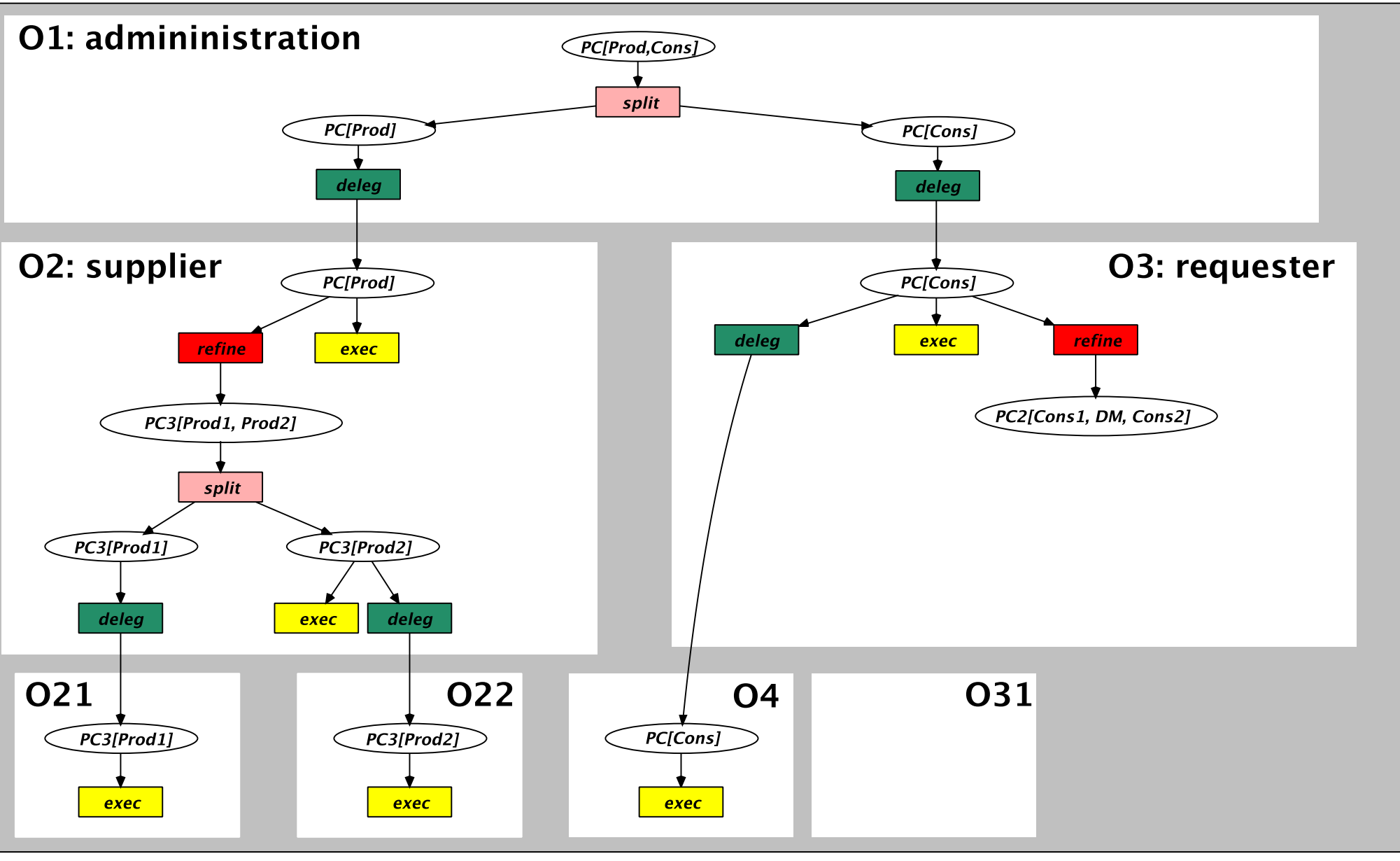

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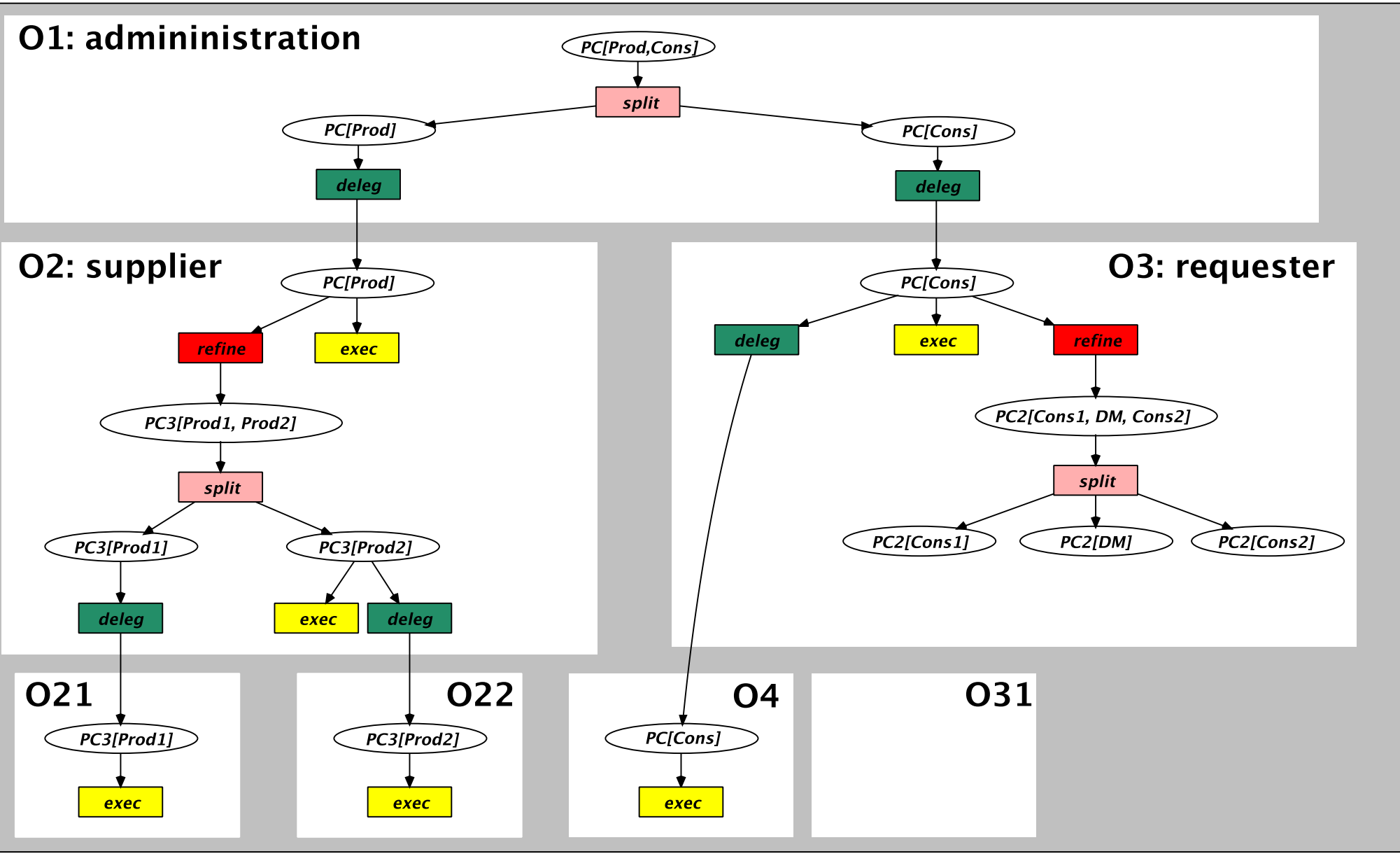

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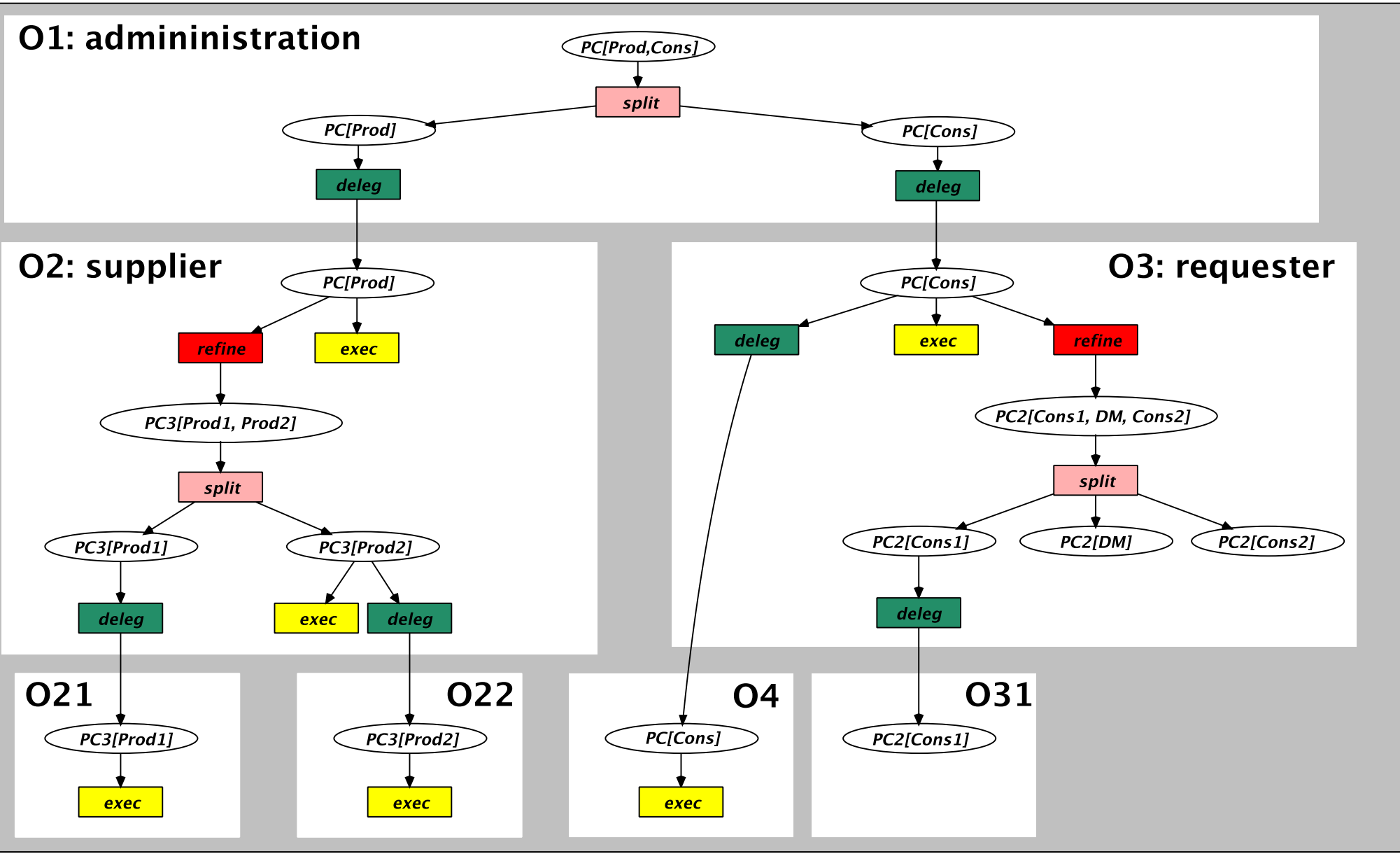

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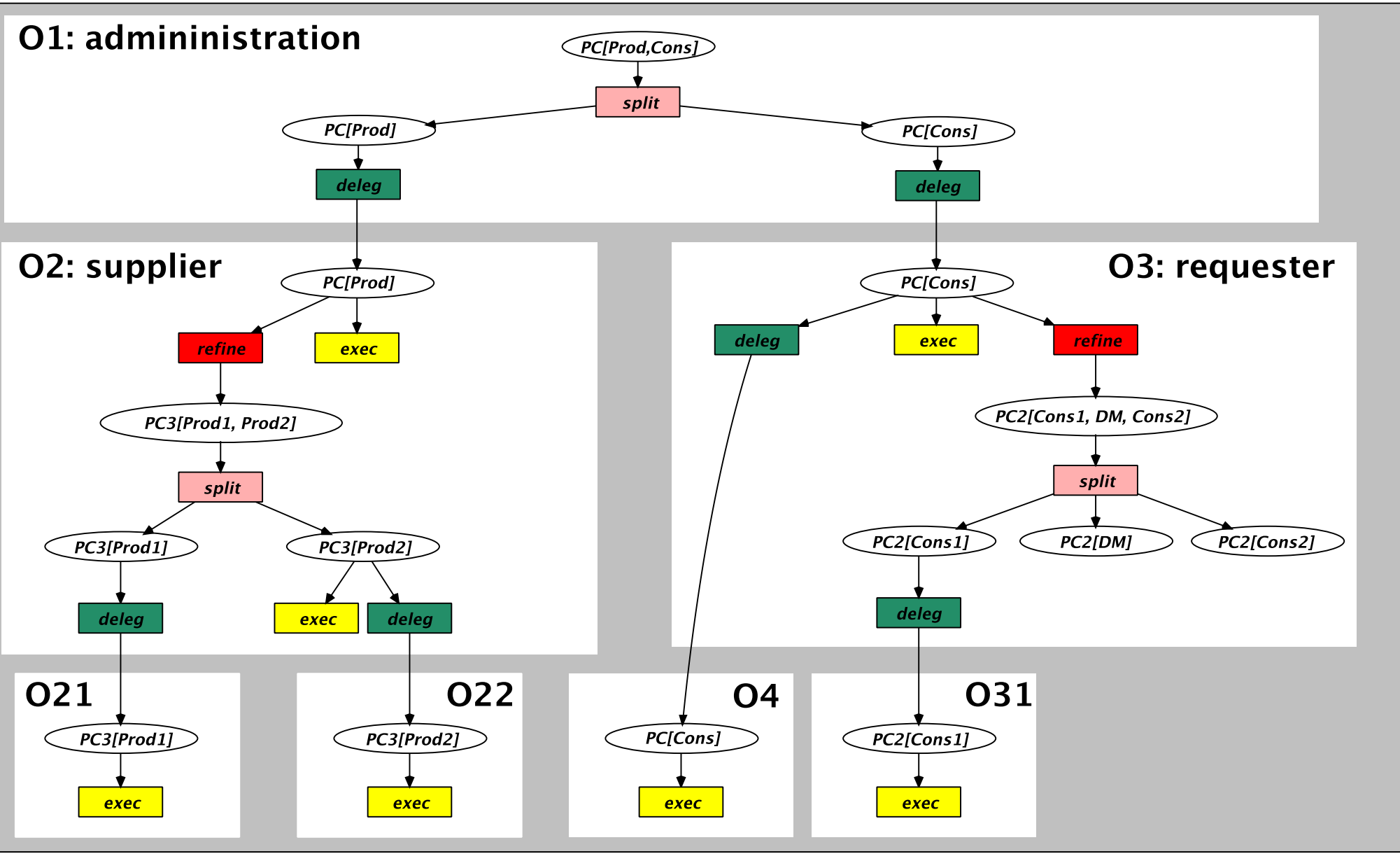

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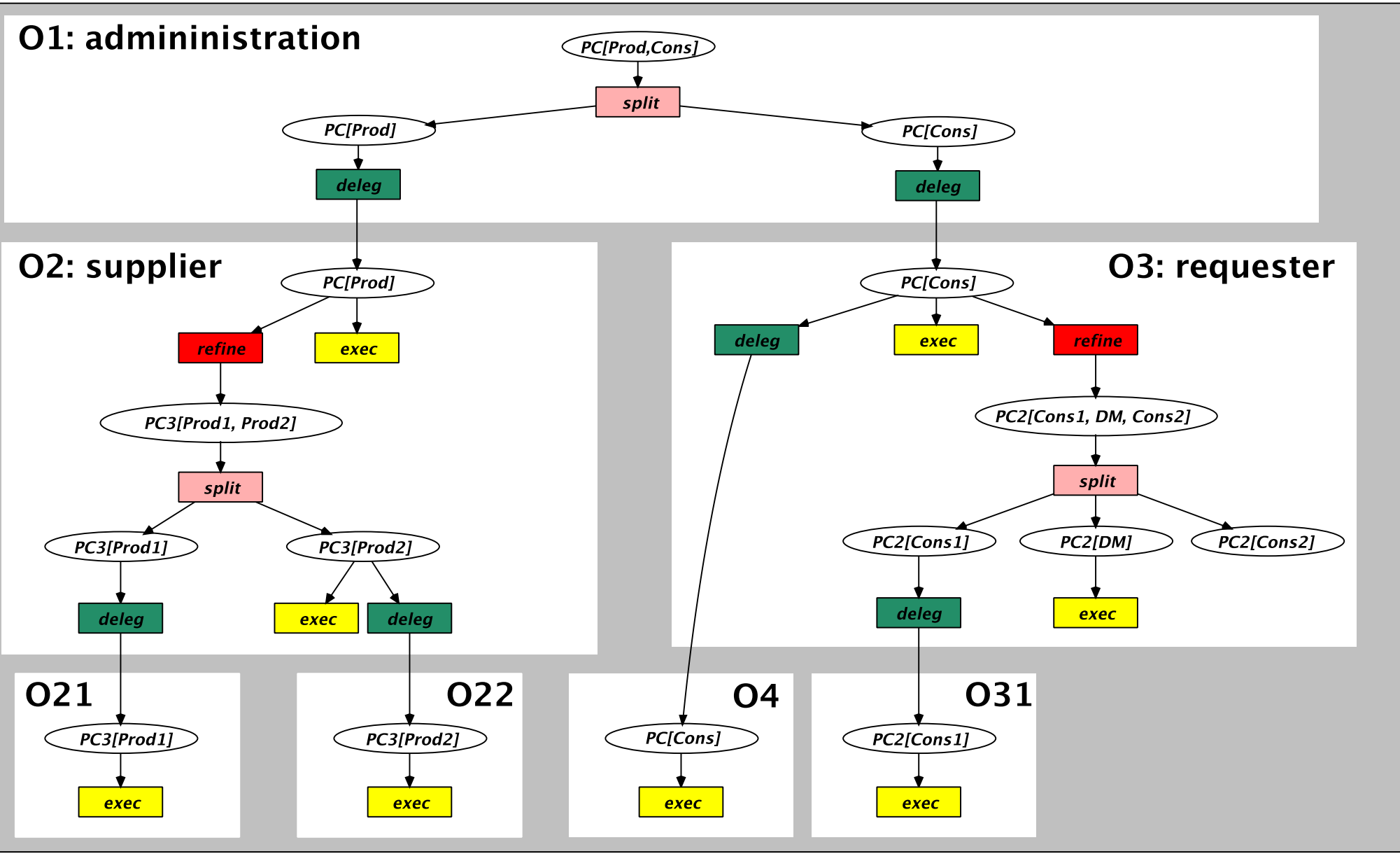

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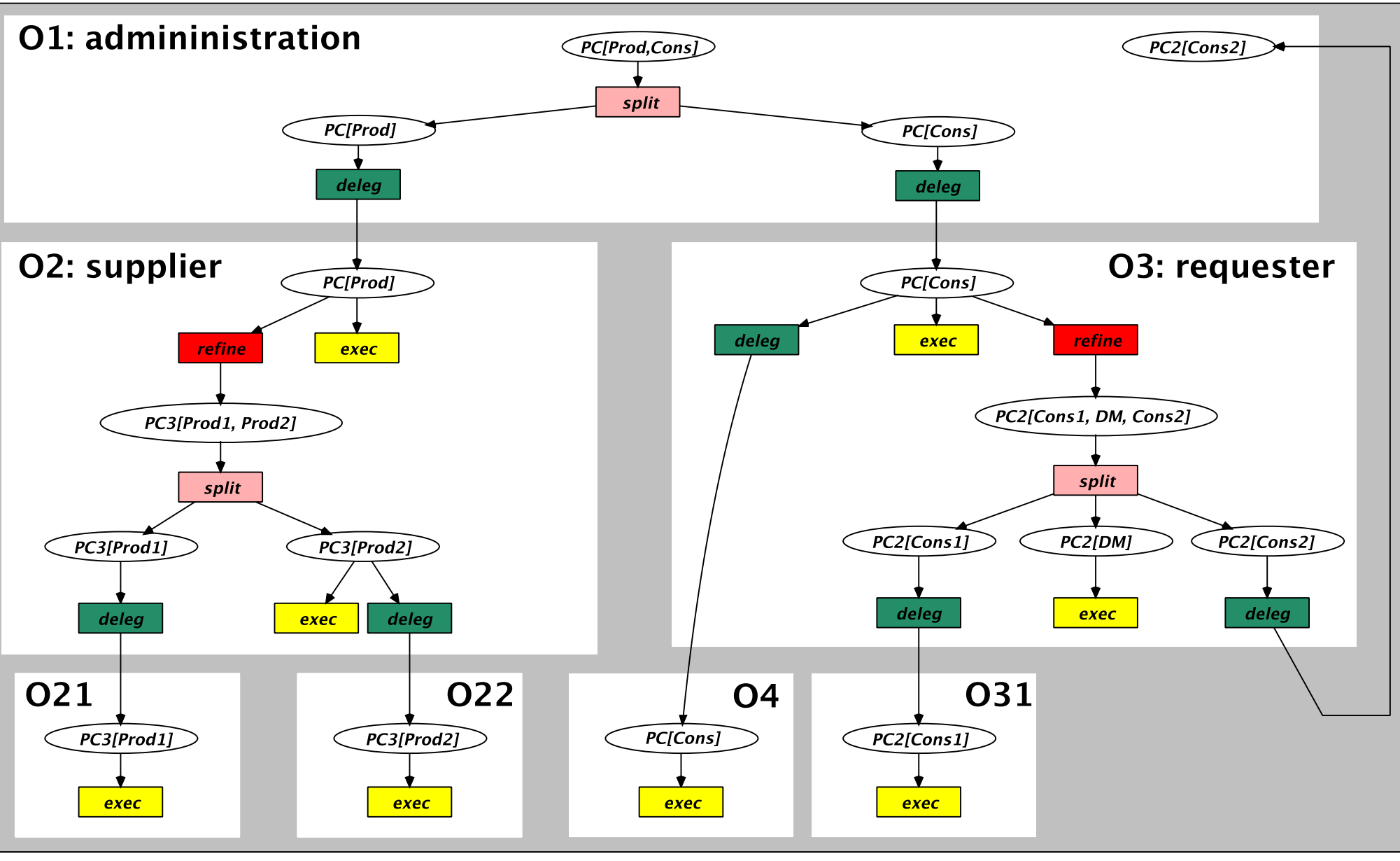

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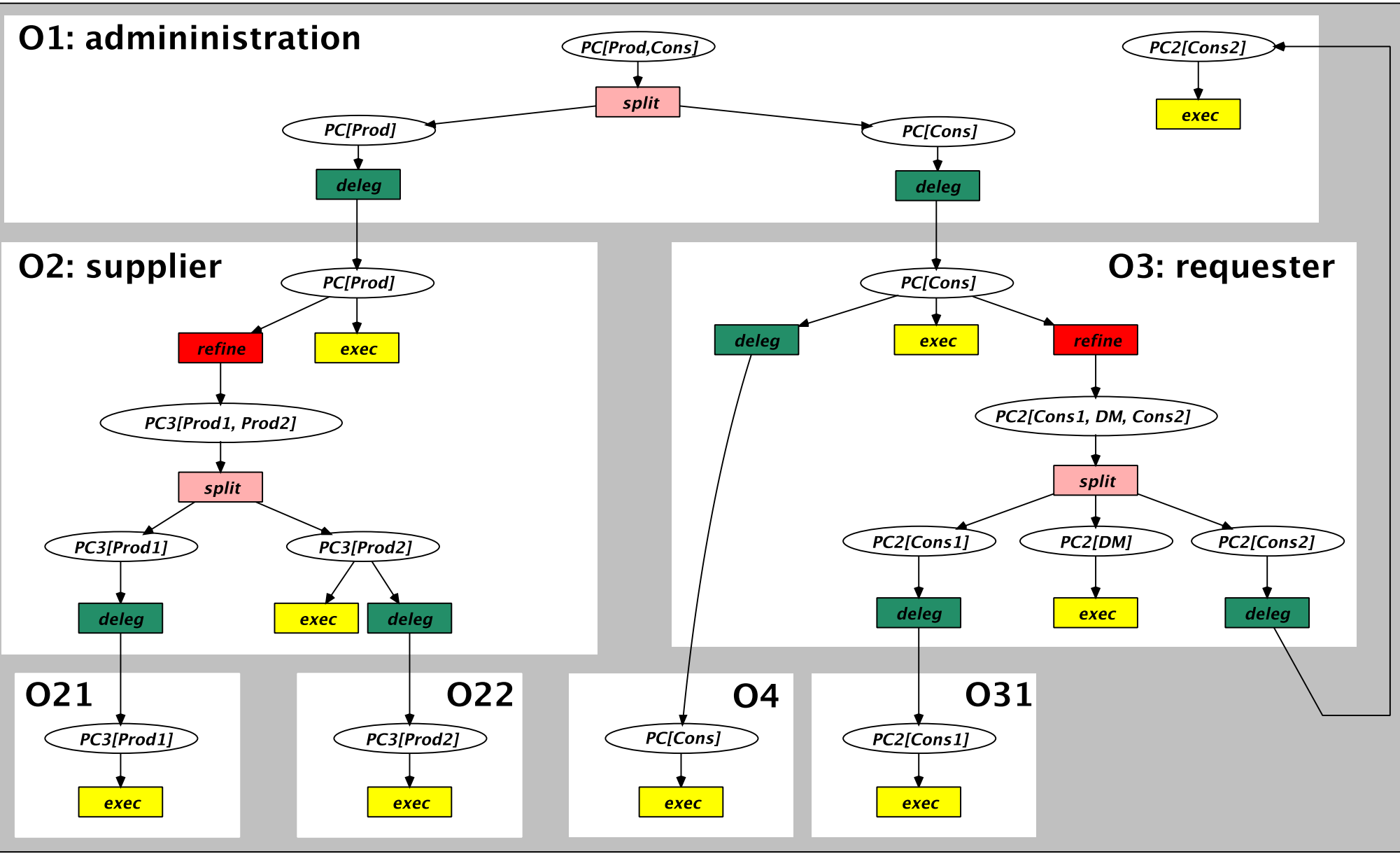
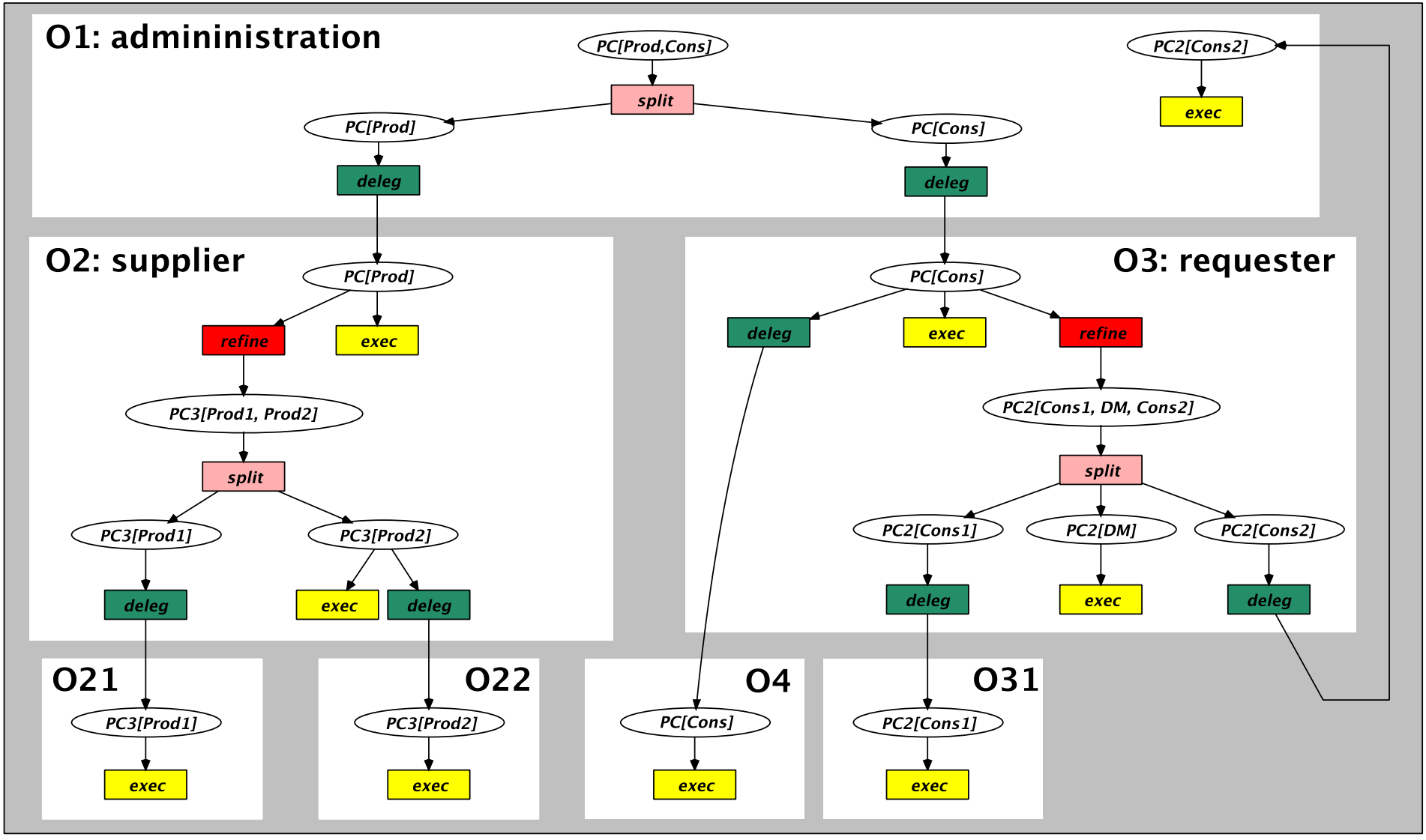


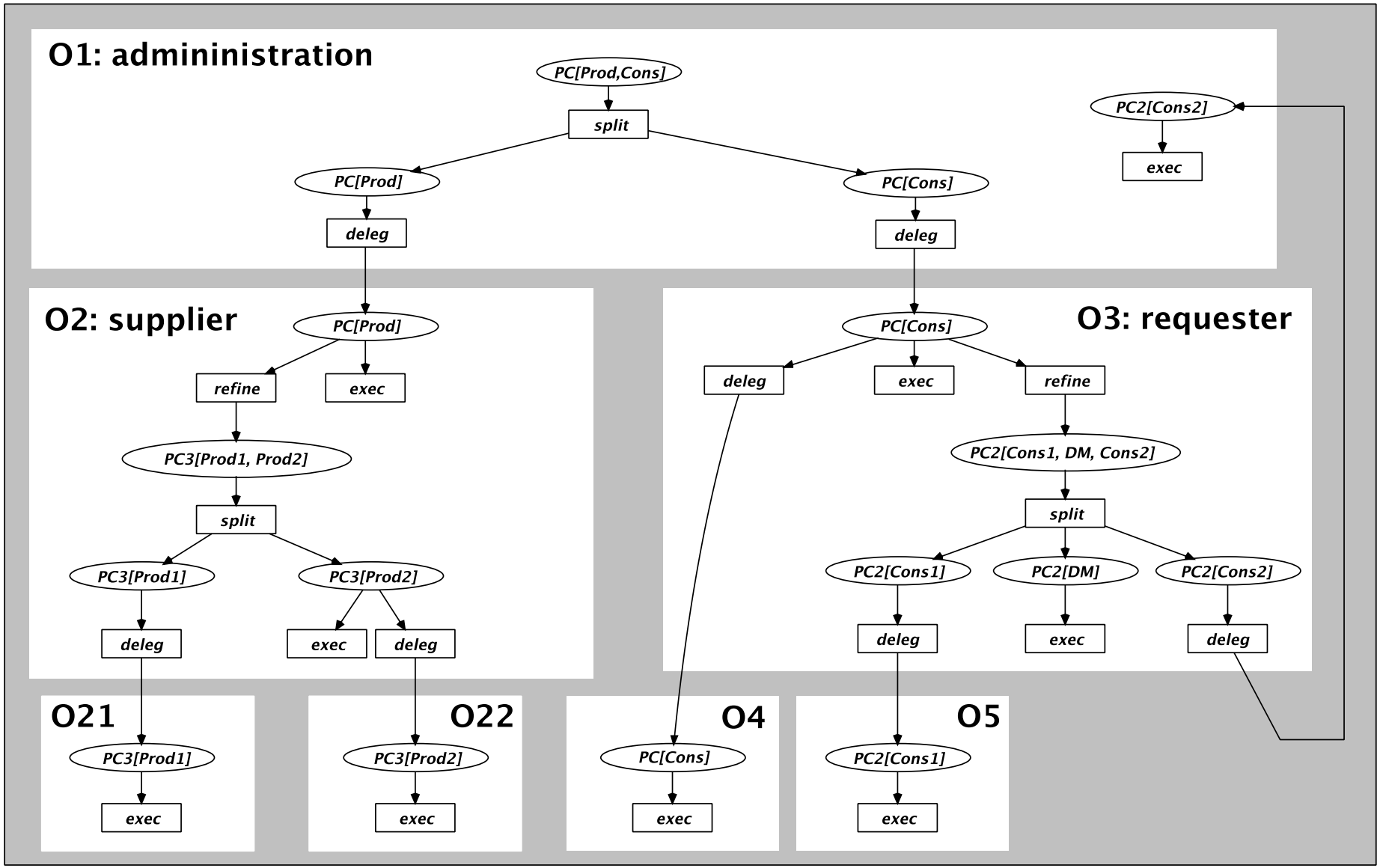
Example: SONAR-Model



Outline

Teamformation in SONAR

Team = Petri Net Process of the Organisation Net



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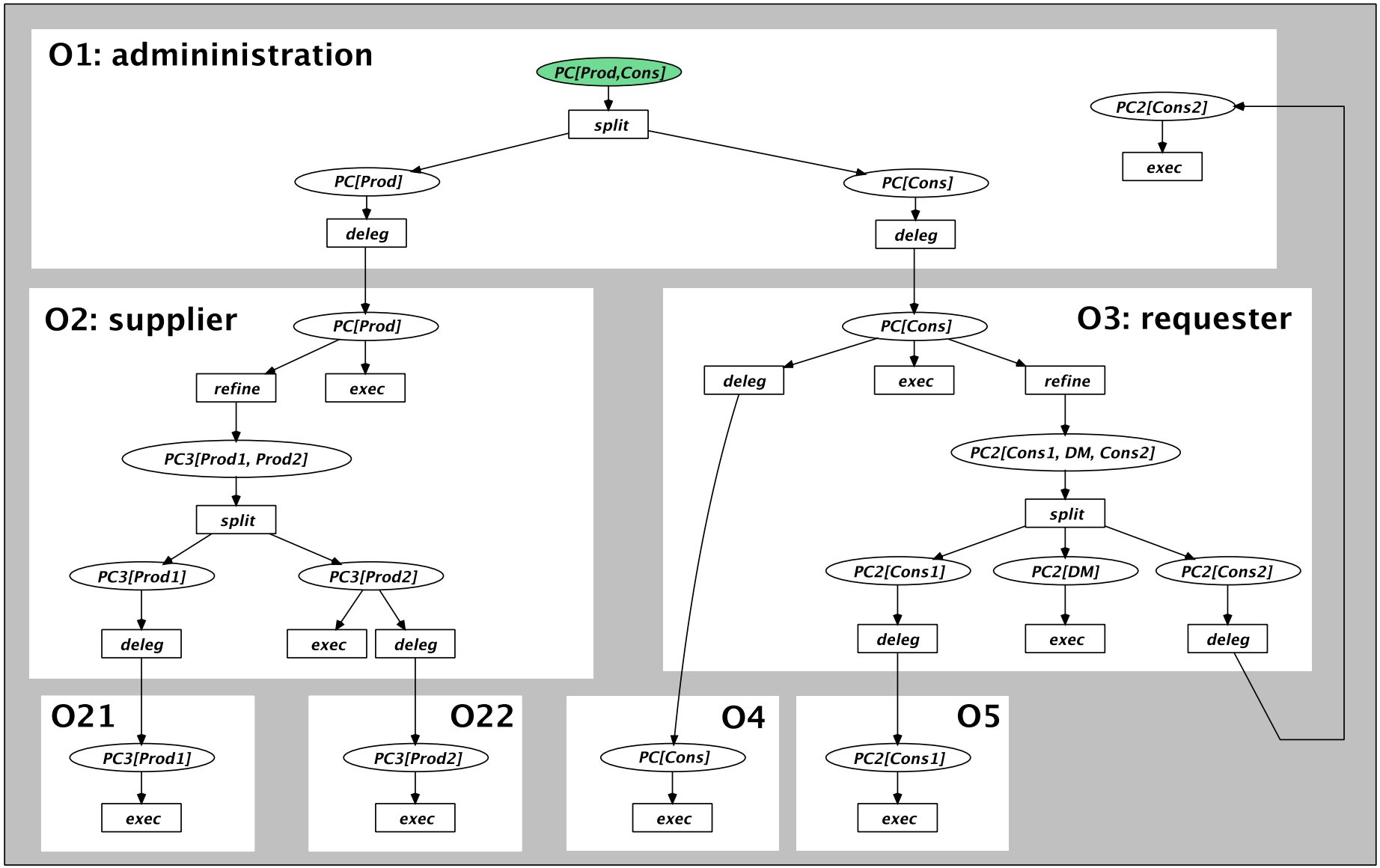

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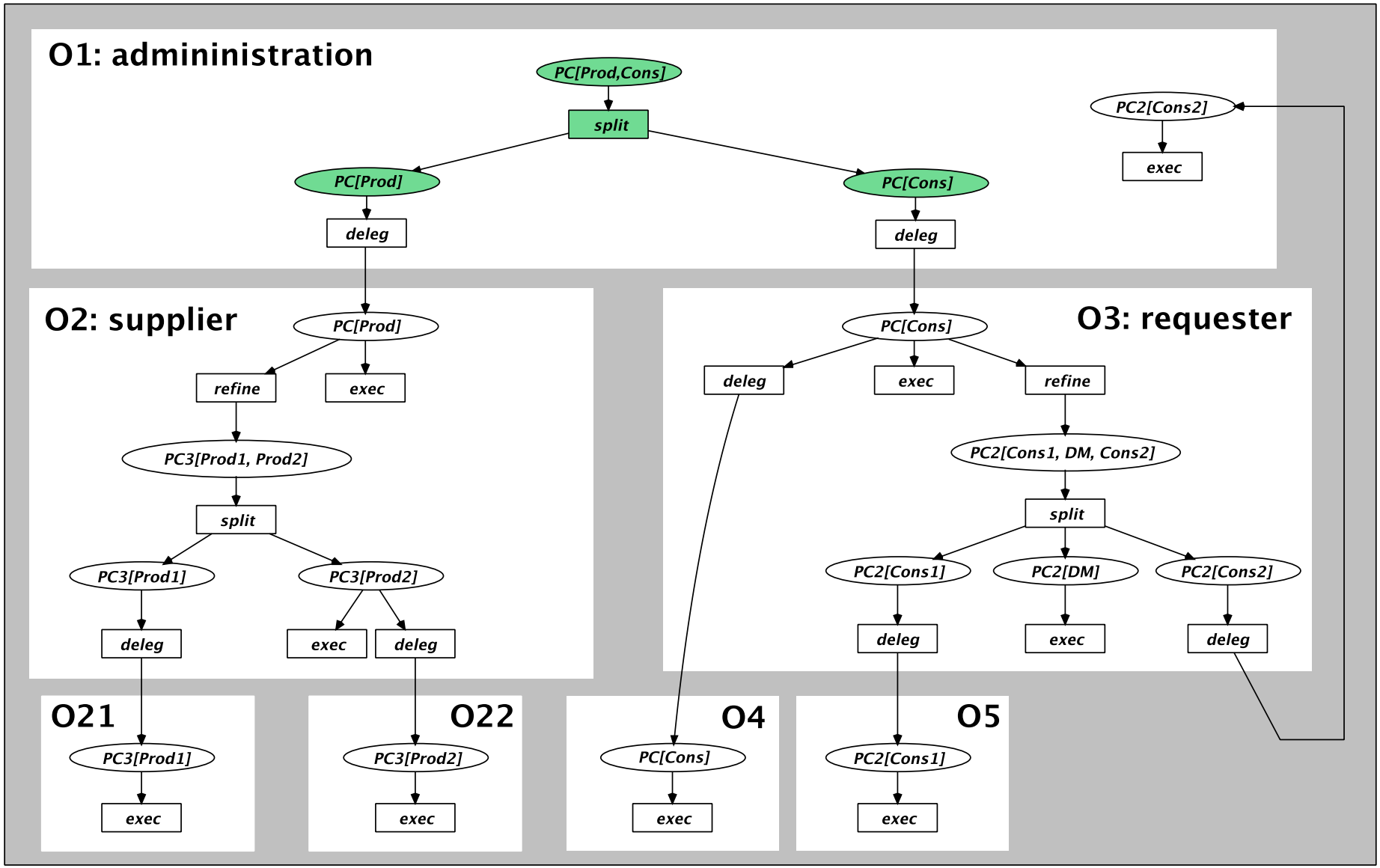

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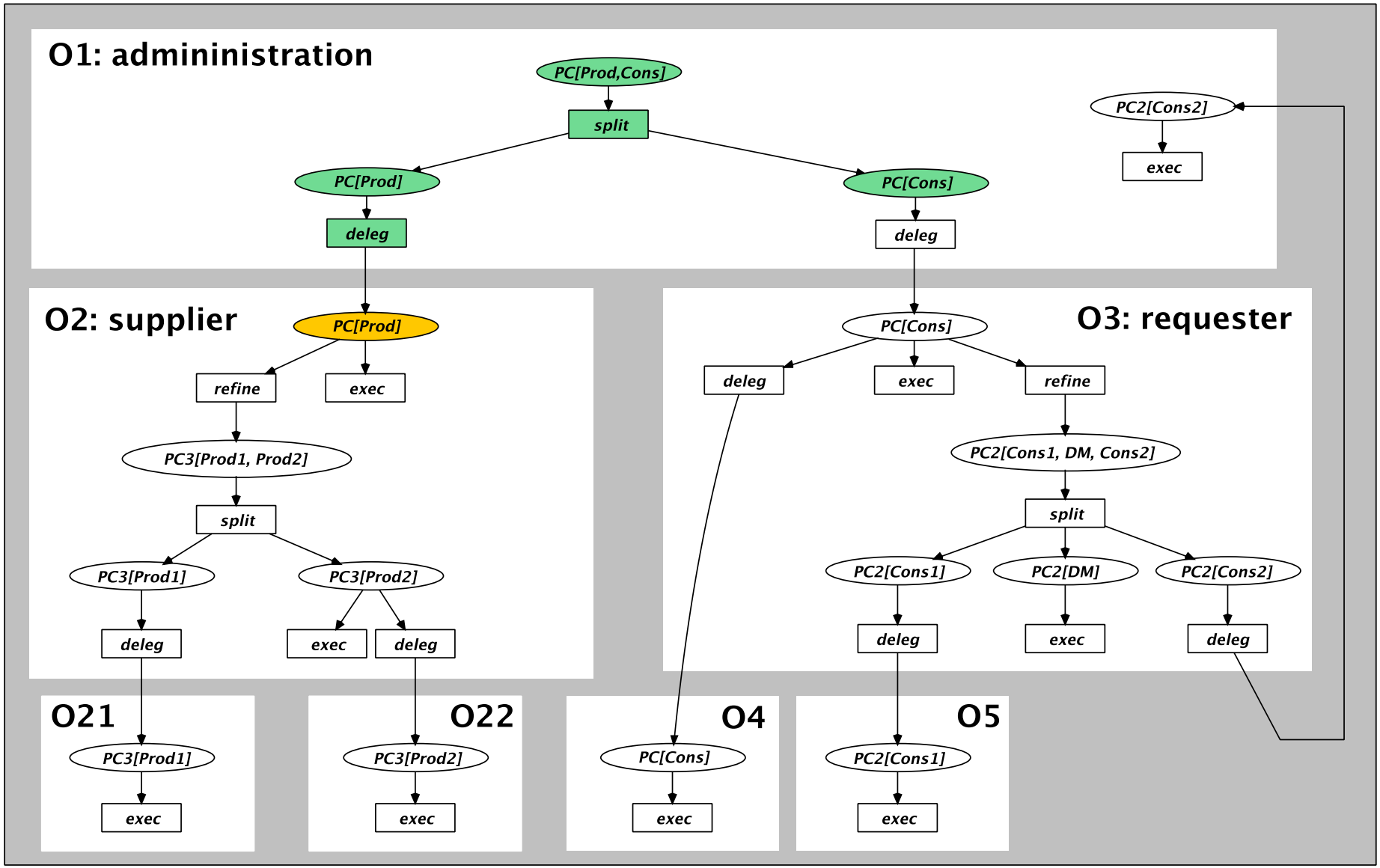

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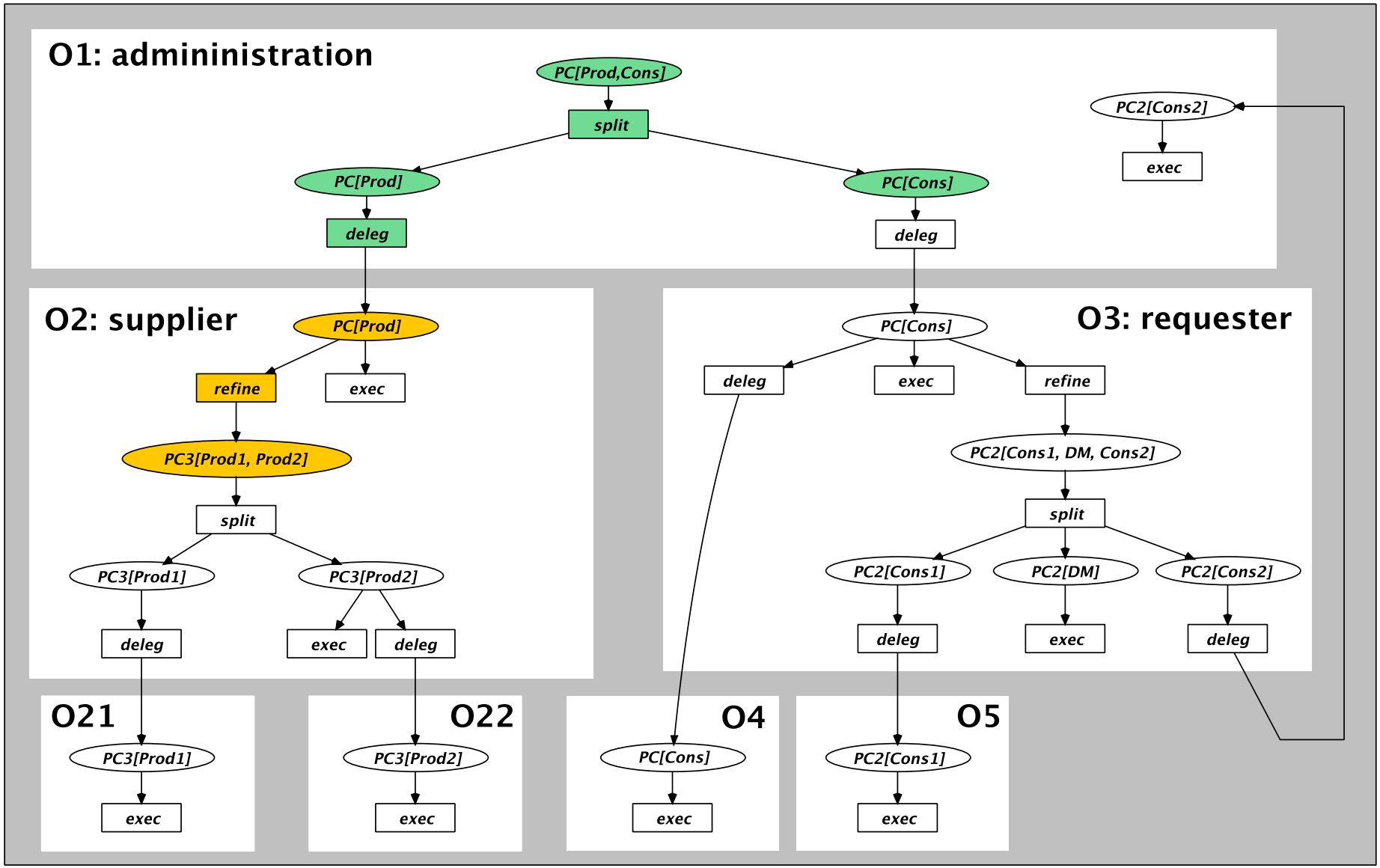

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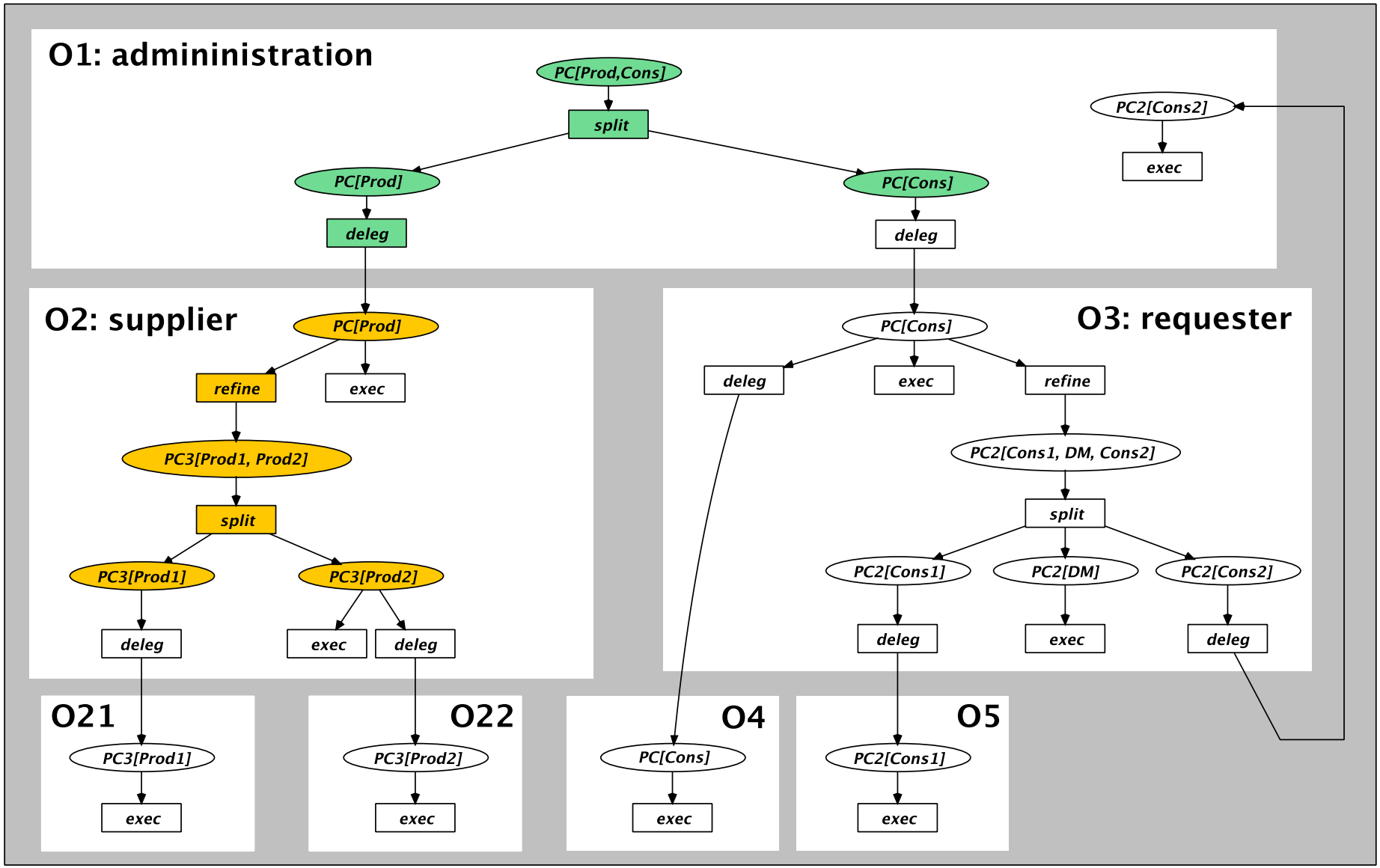

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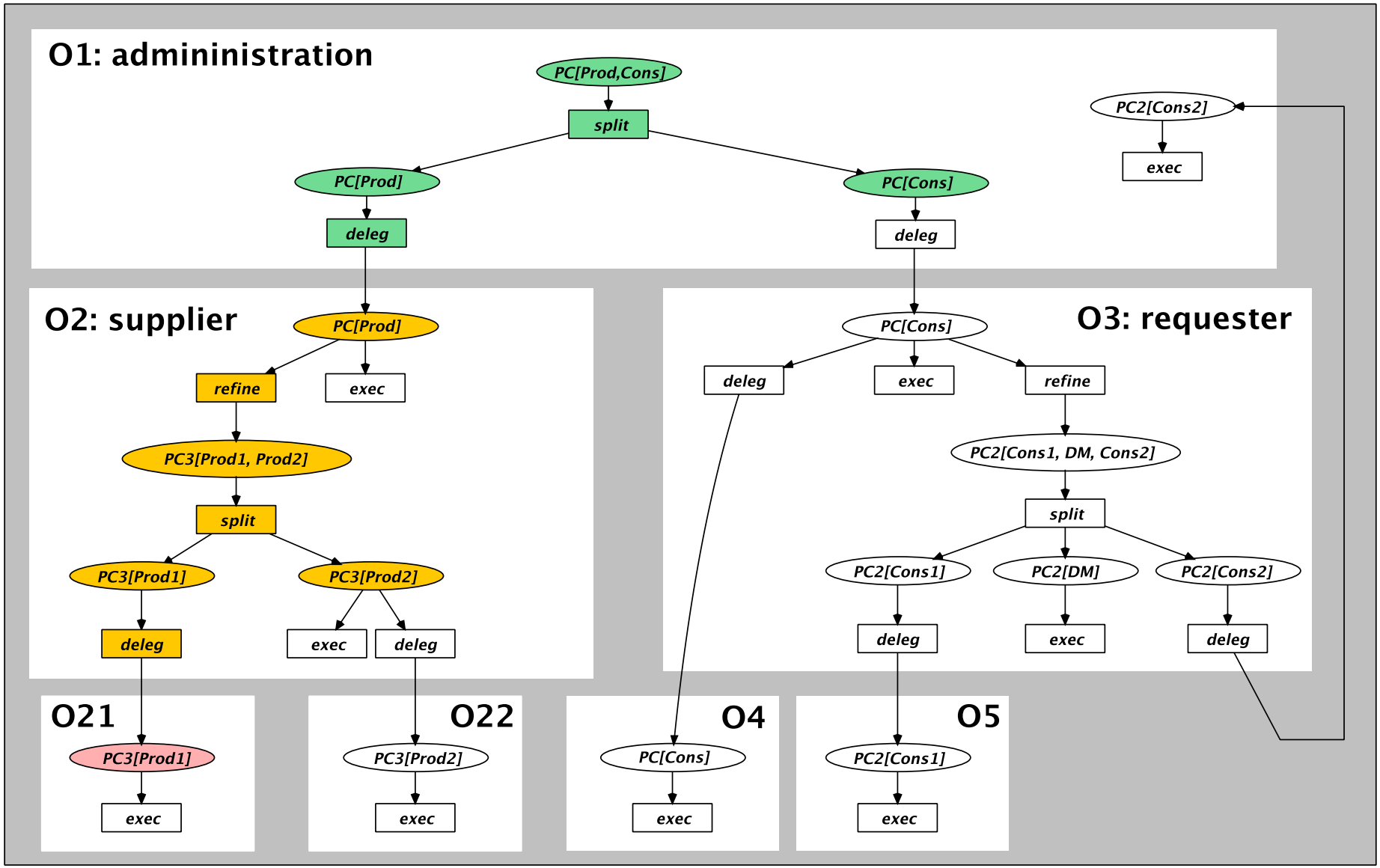

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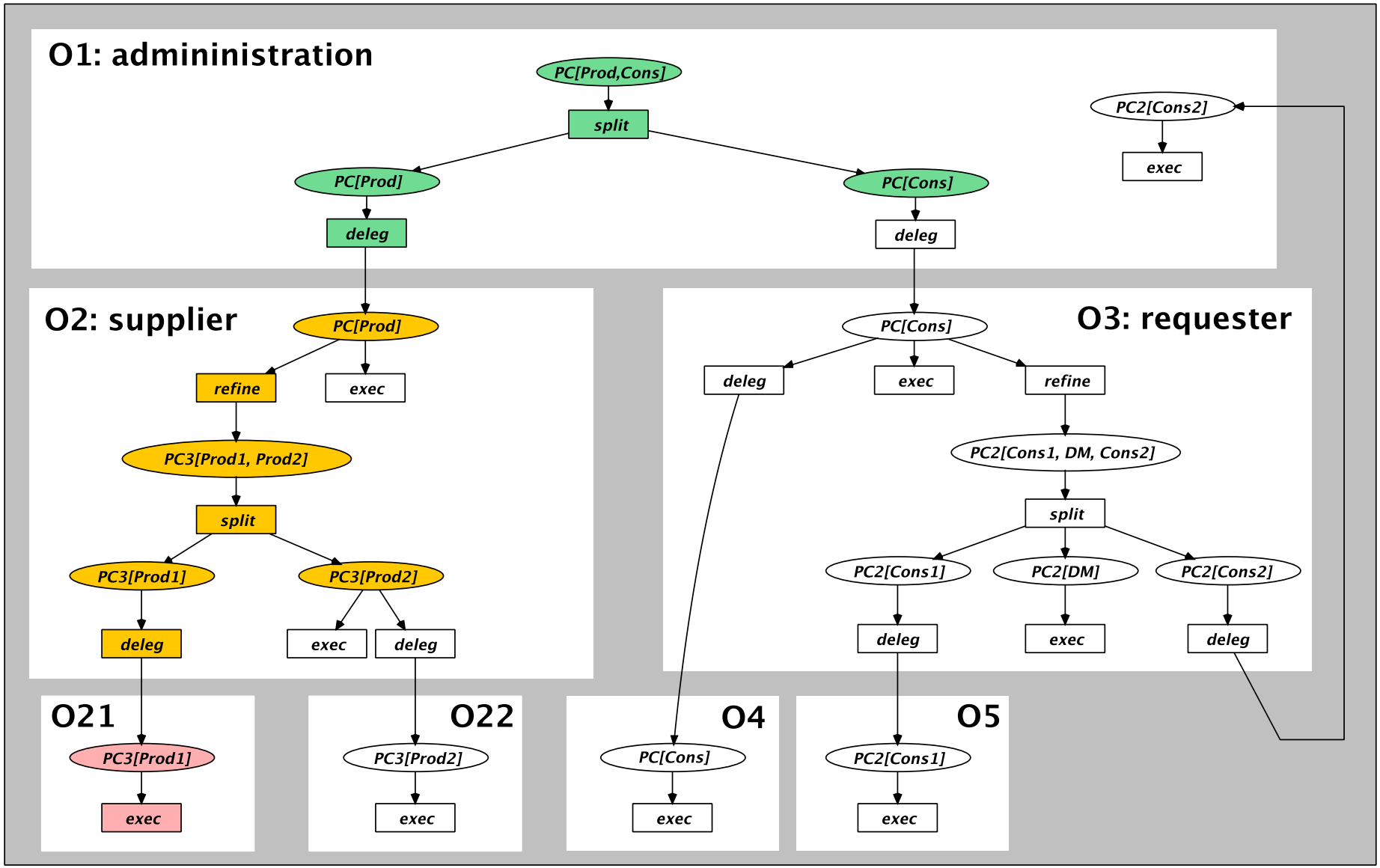

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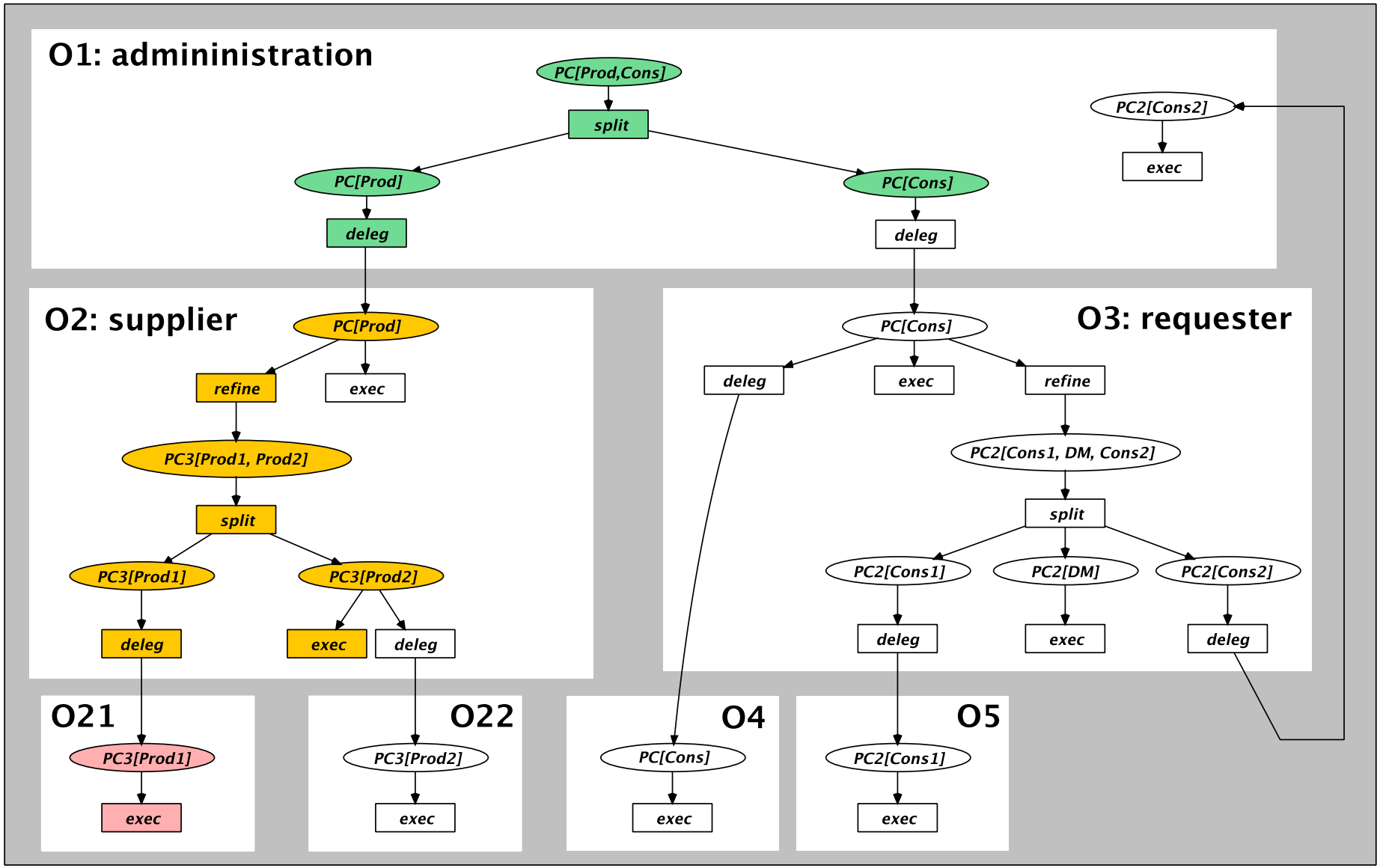

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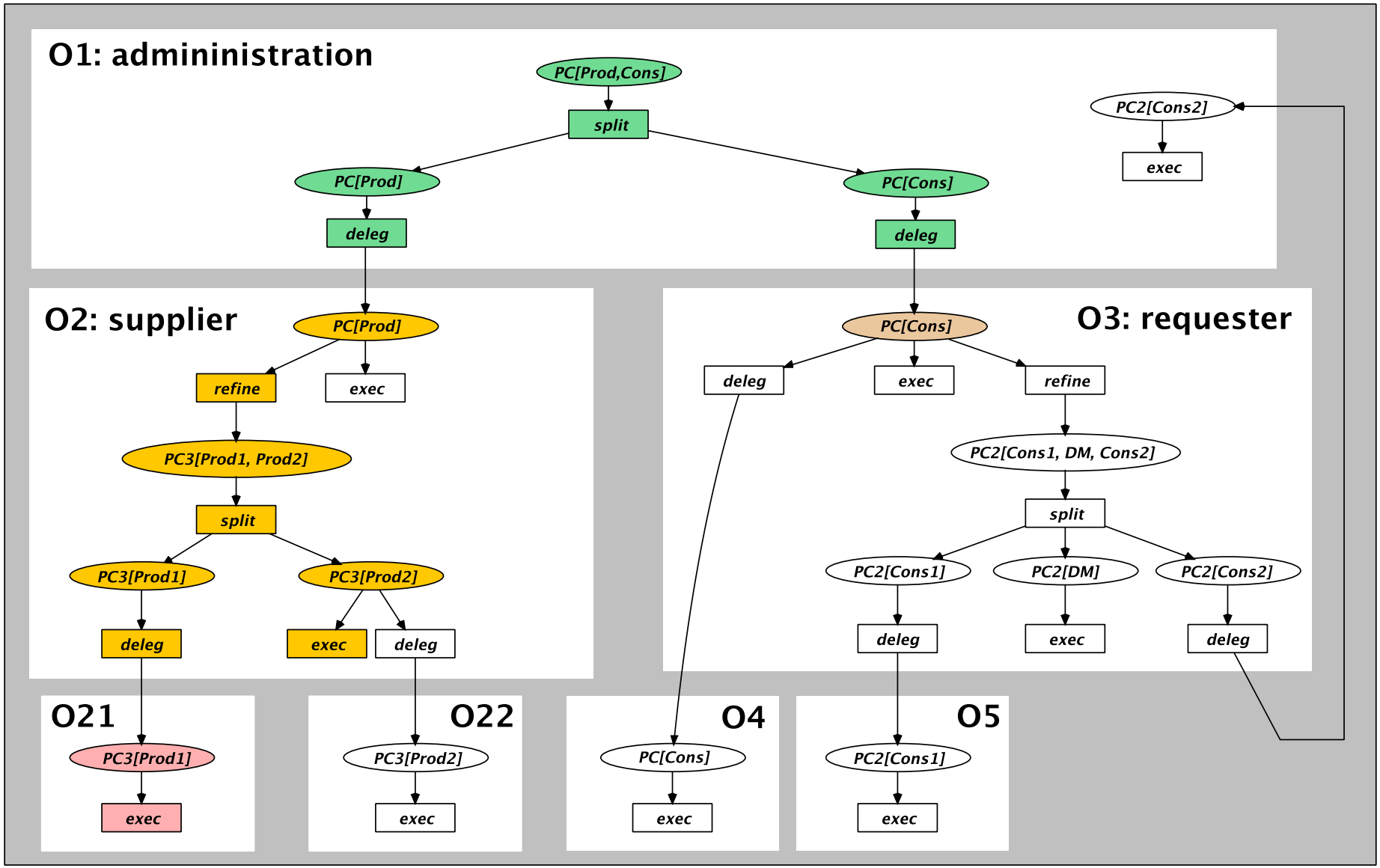

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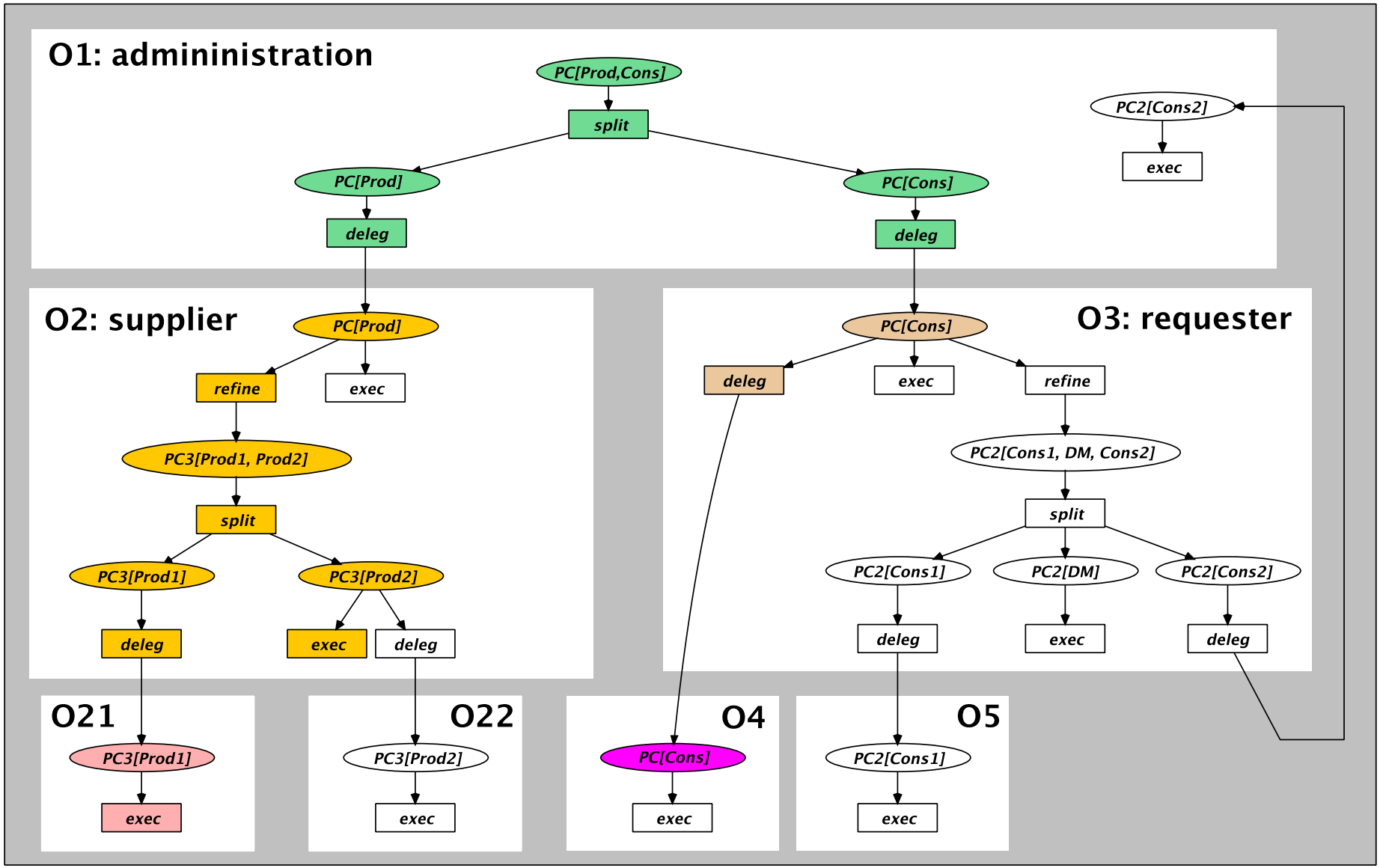

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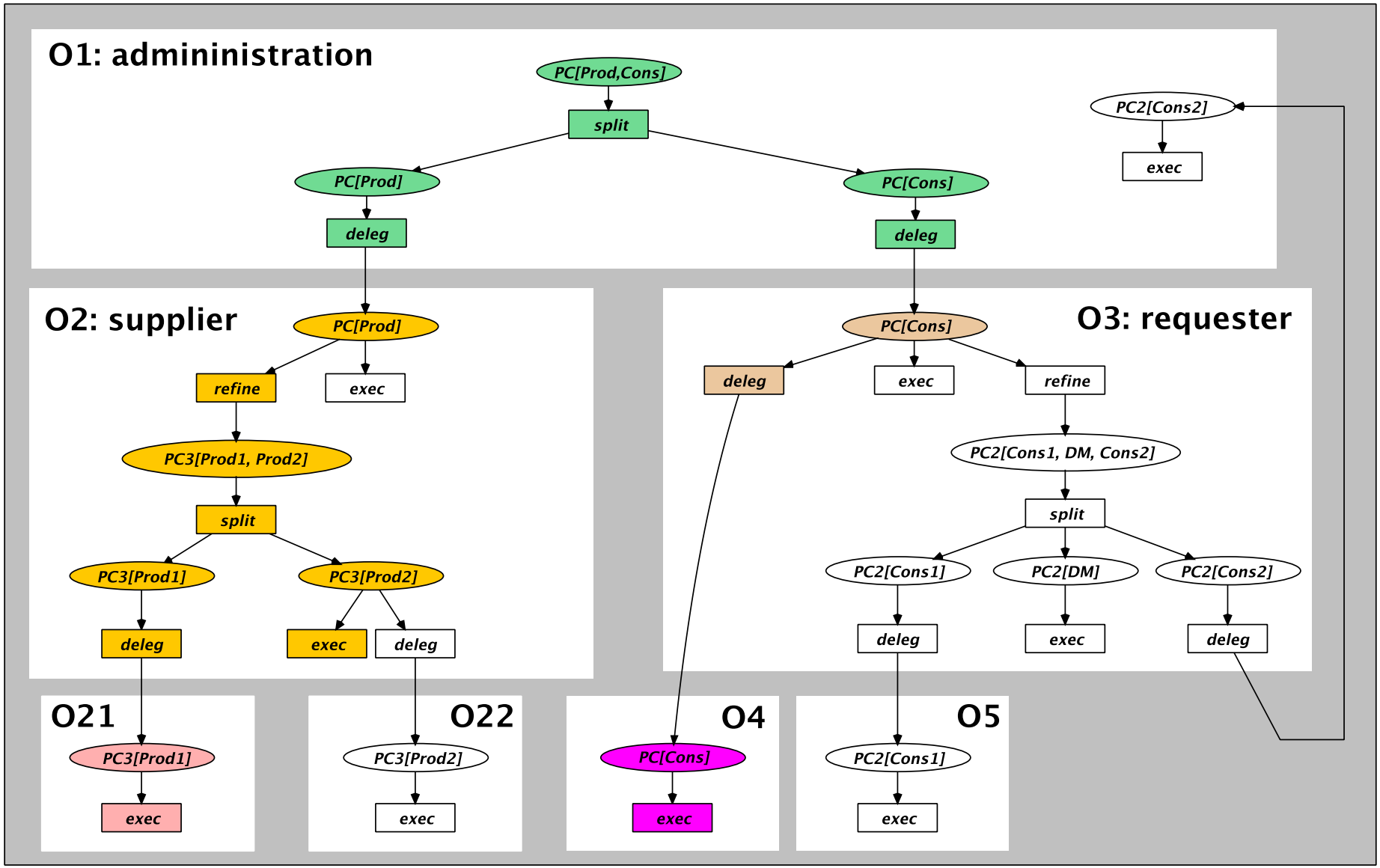
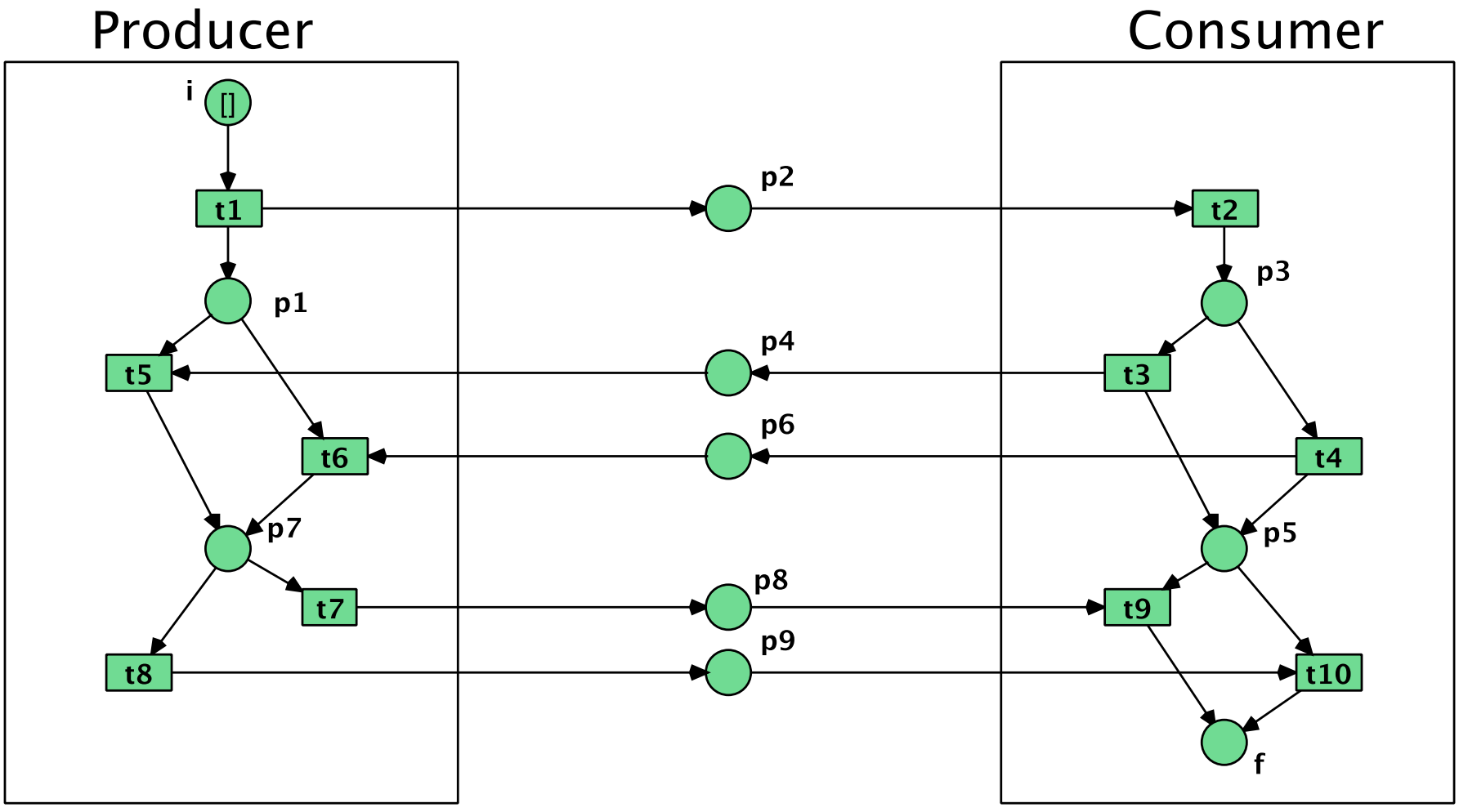


Outline

The Team's Interaction Protocol



Compute the **Unfolding** of the Interaction Protocol.

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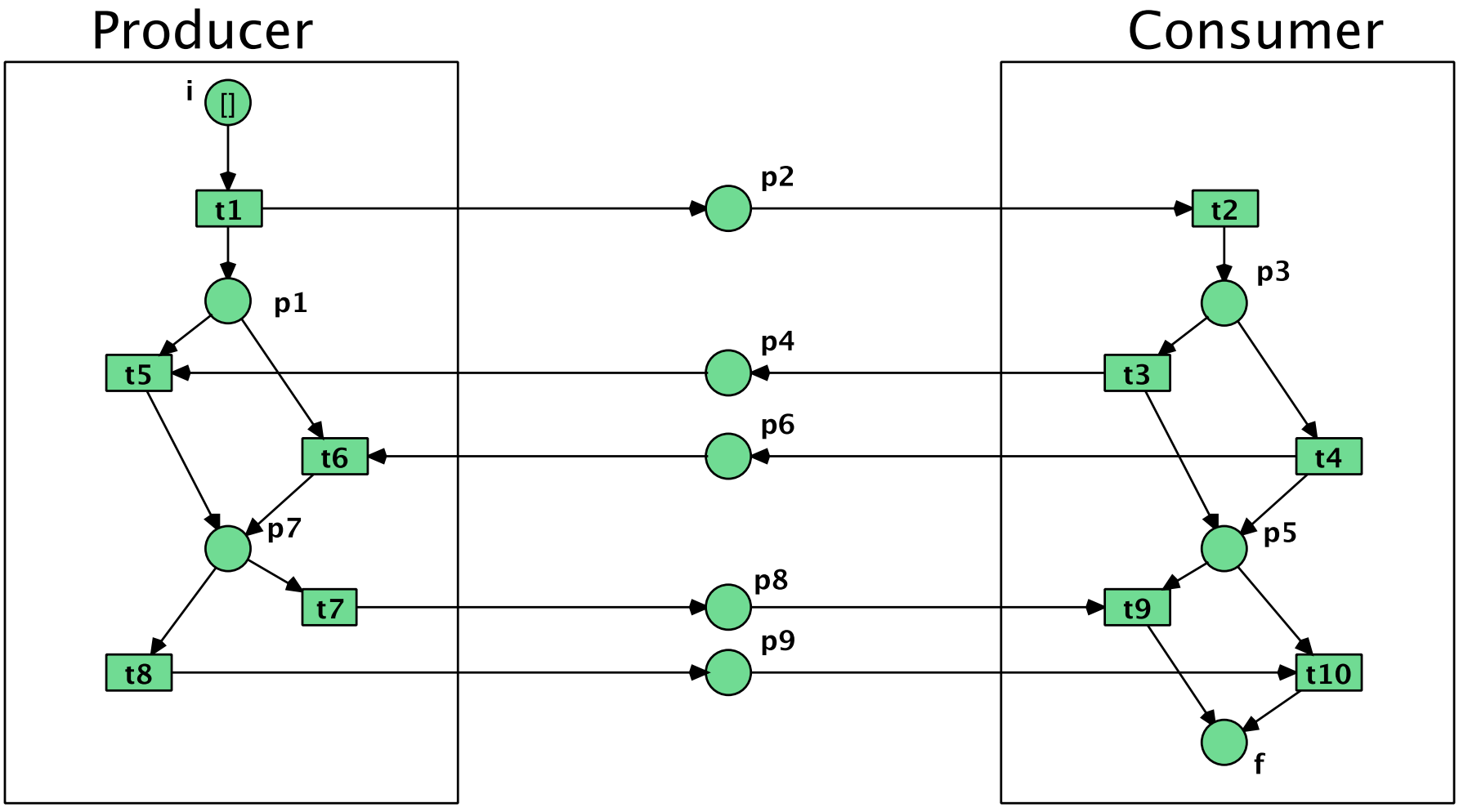

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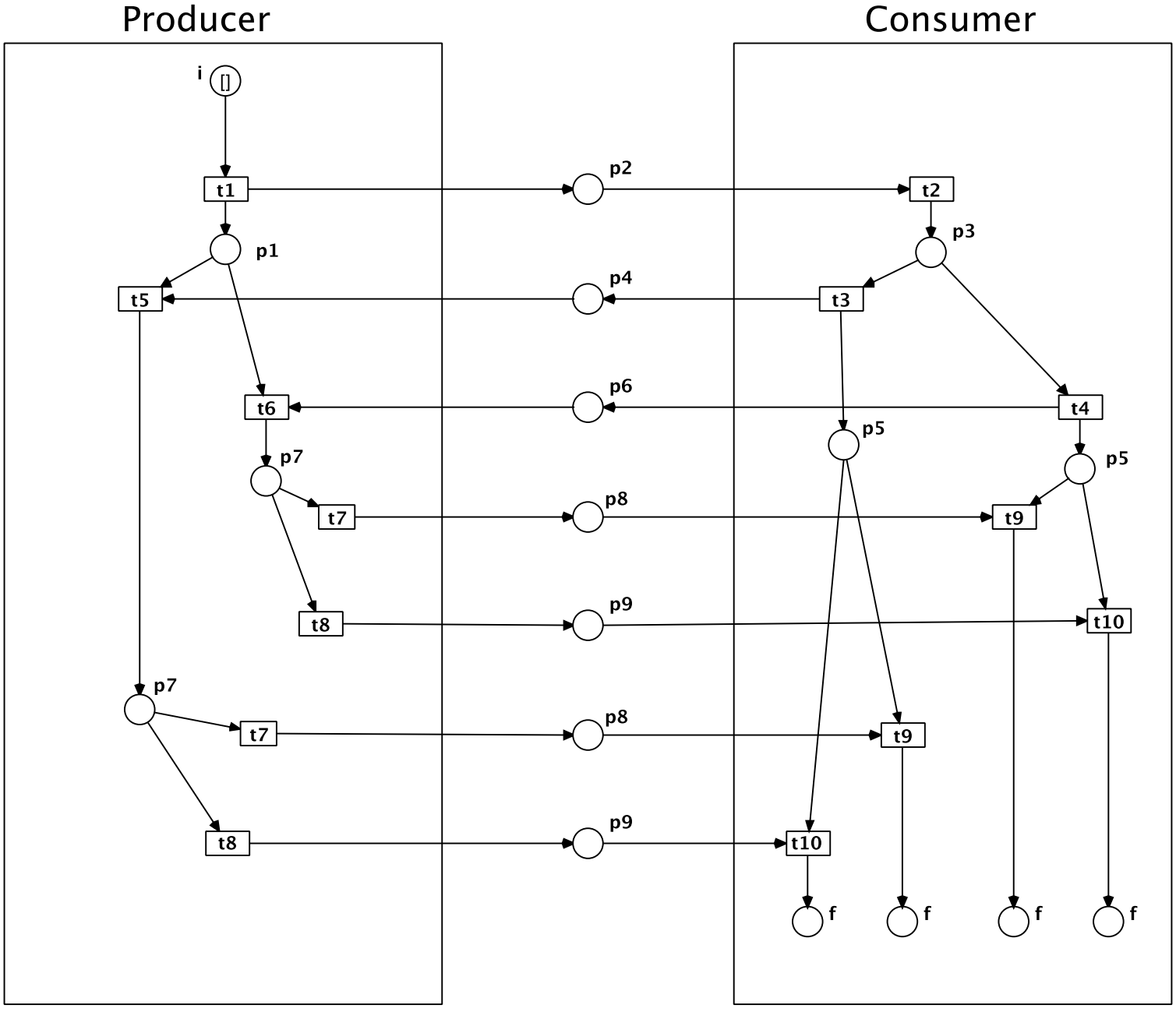
Negotiation in SONAR based on Unfoldings



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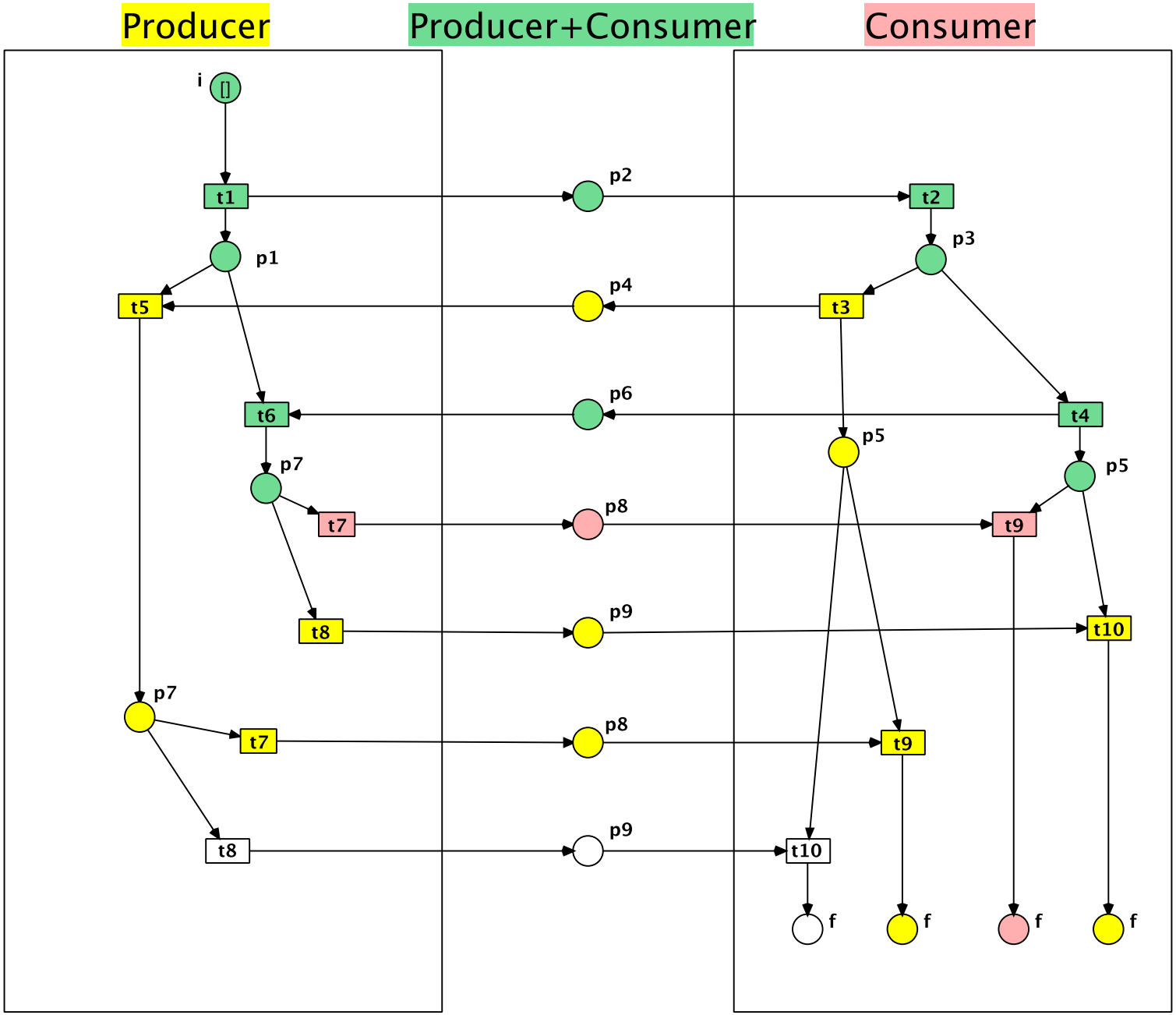

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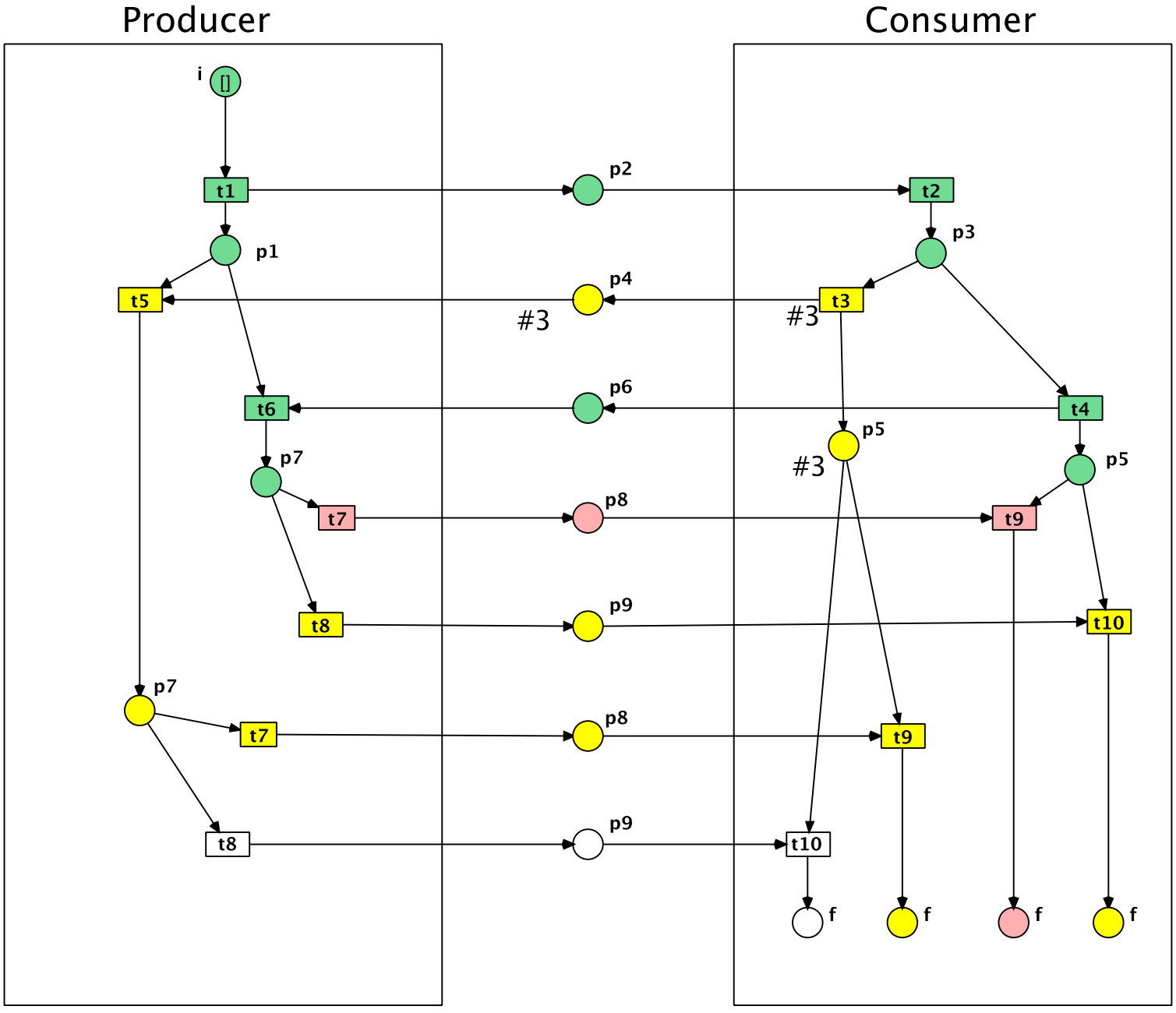

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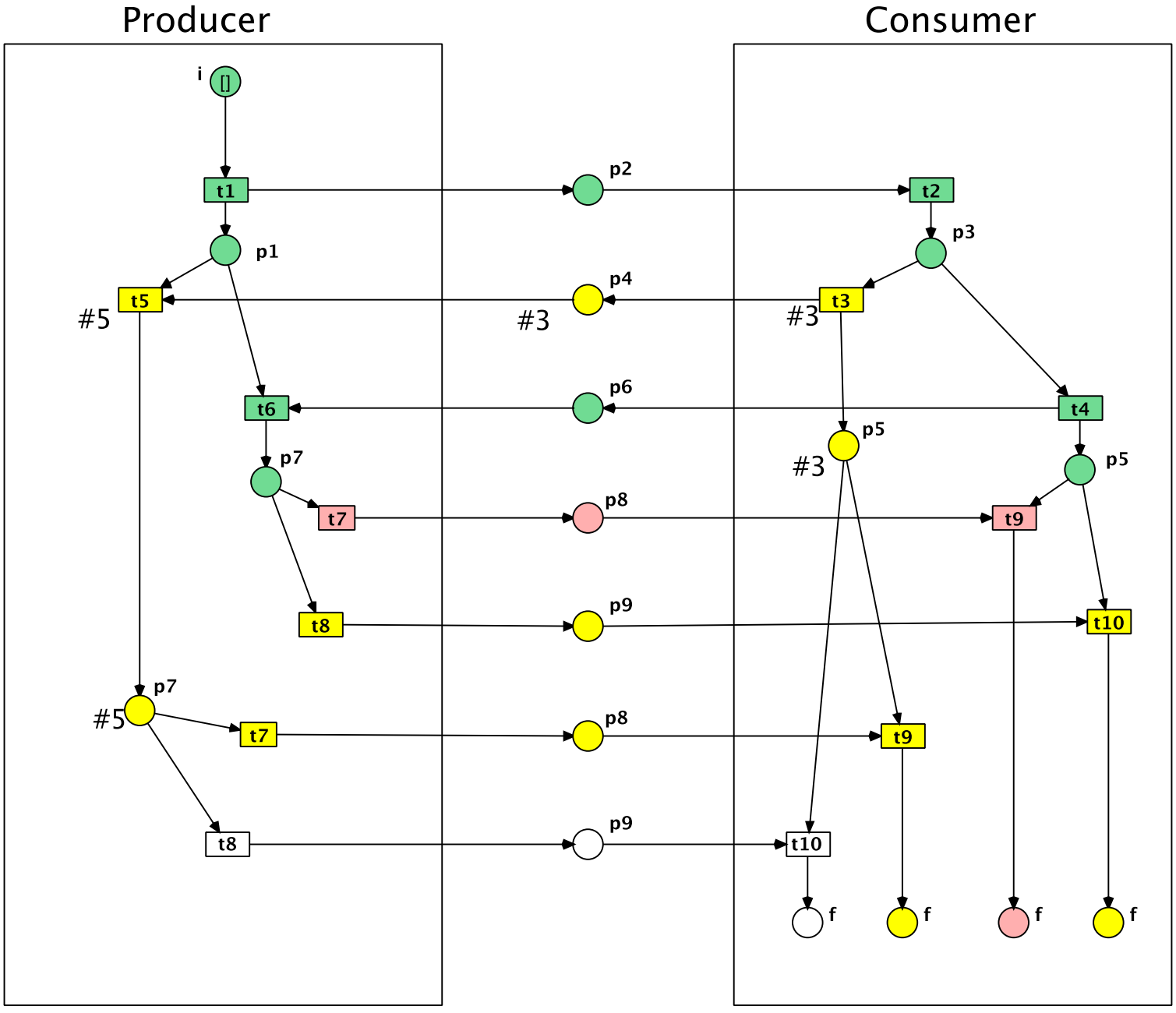

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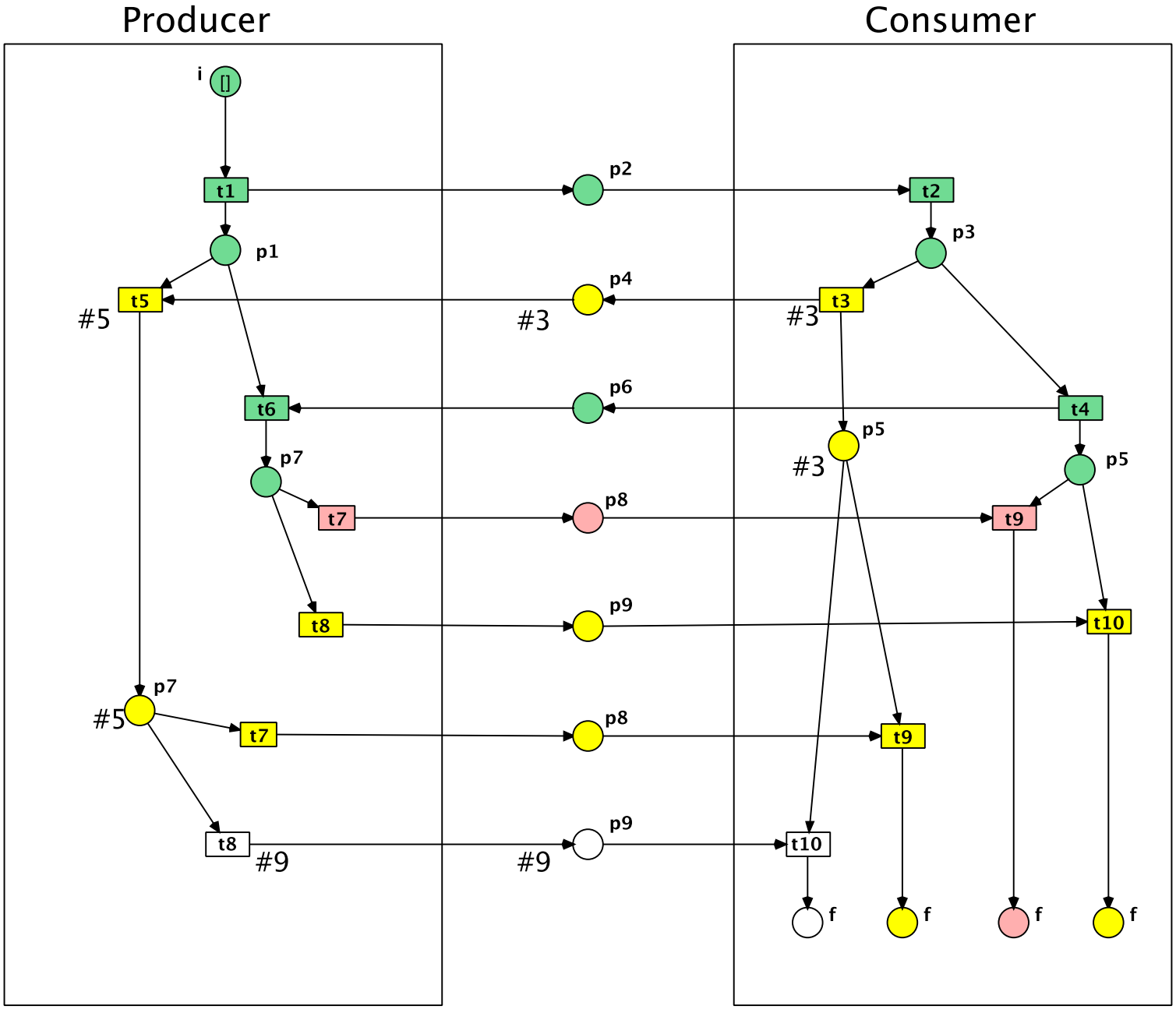

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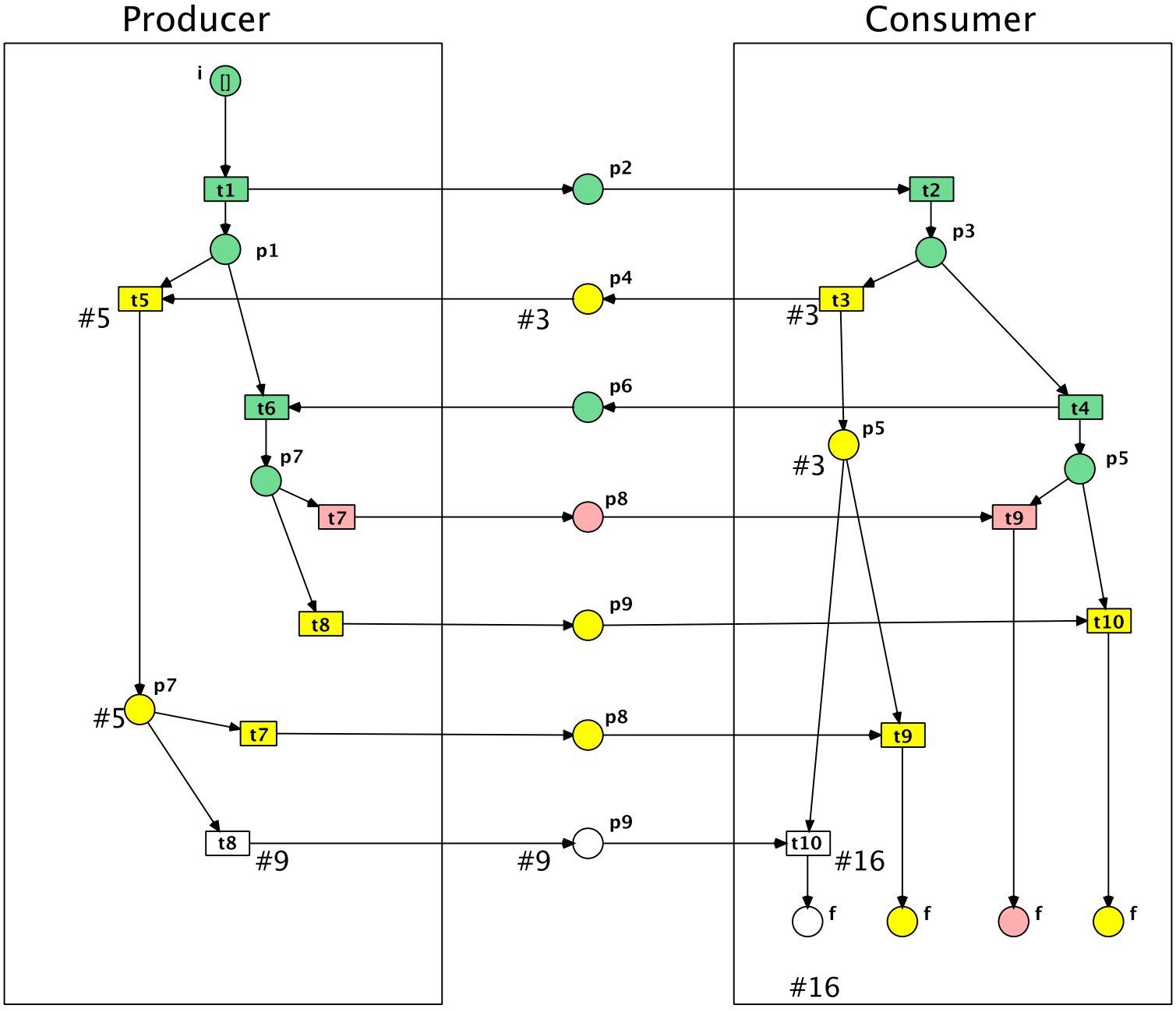

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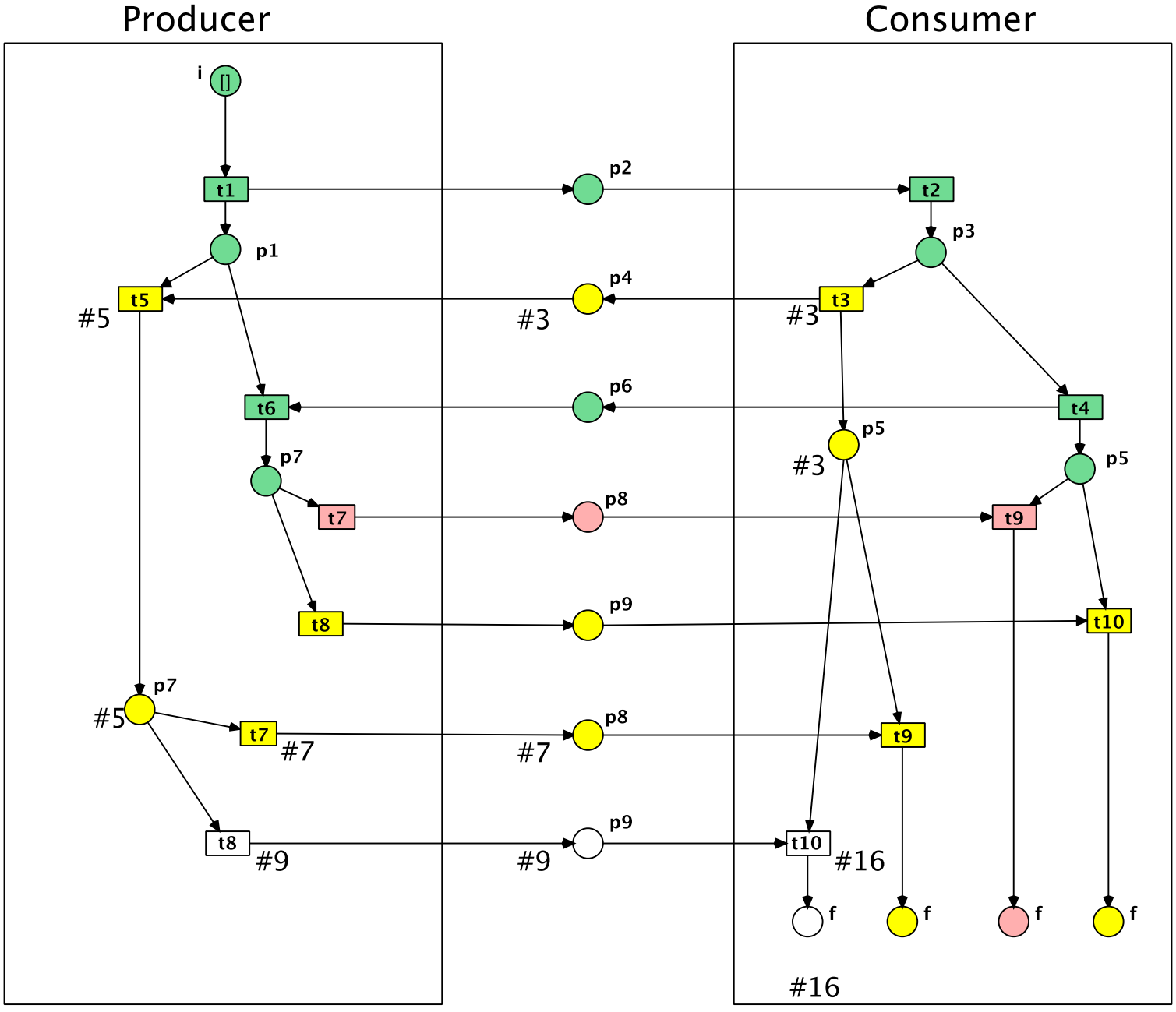

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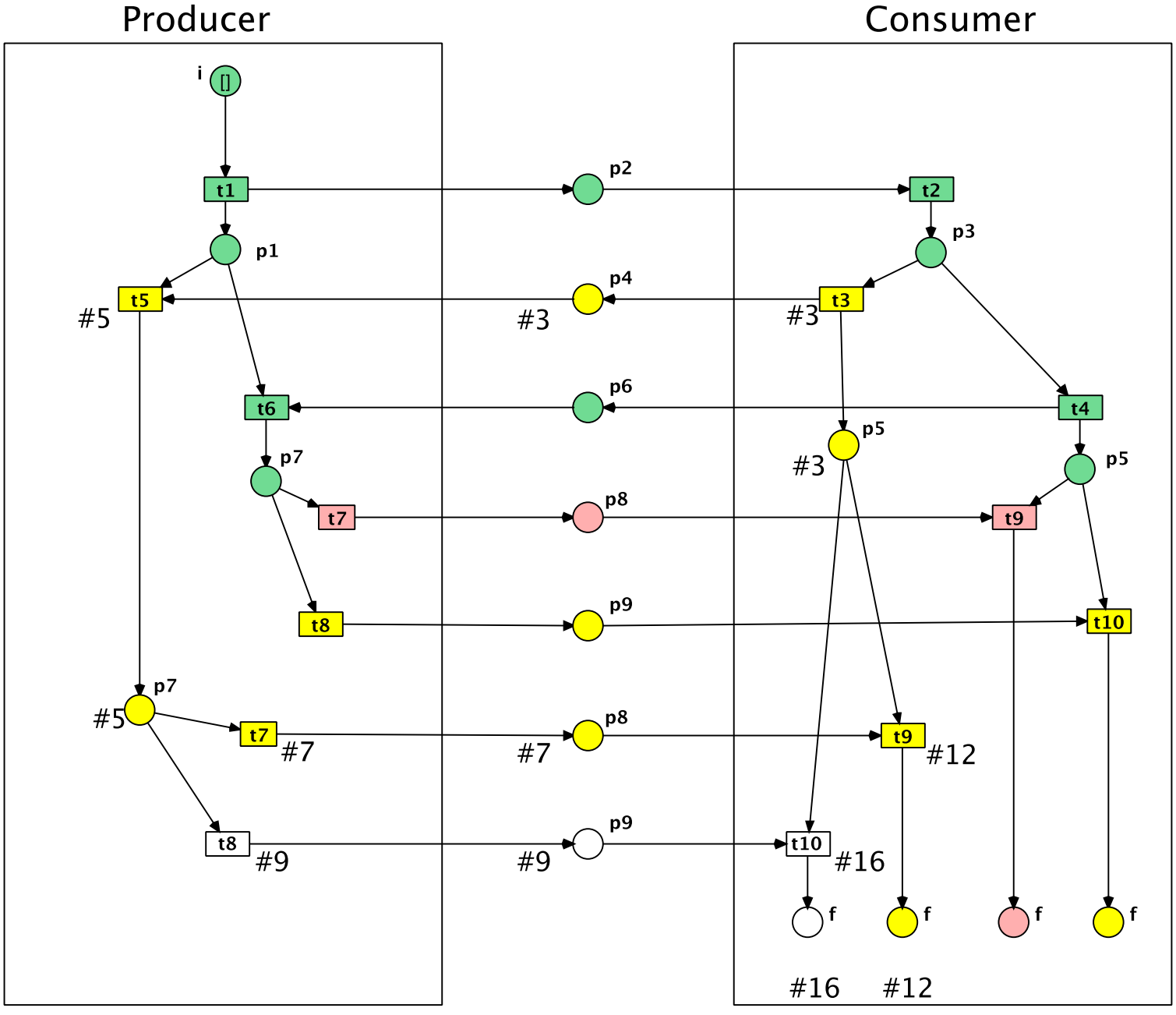

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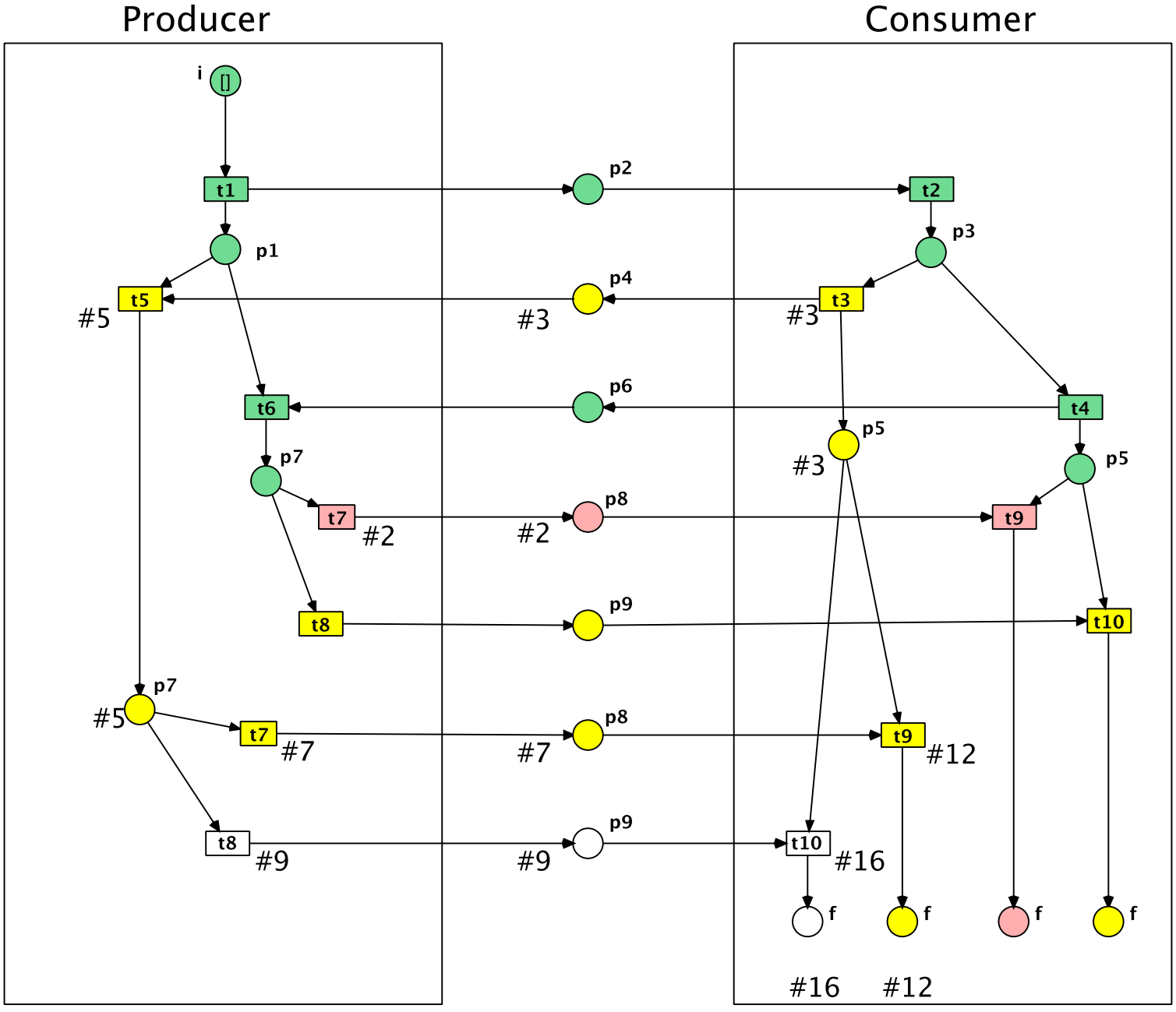

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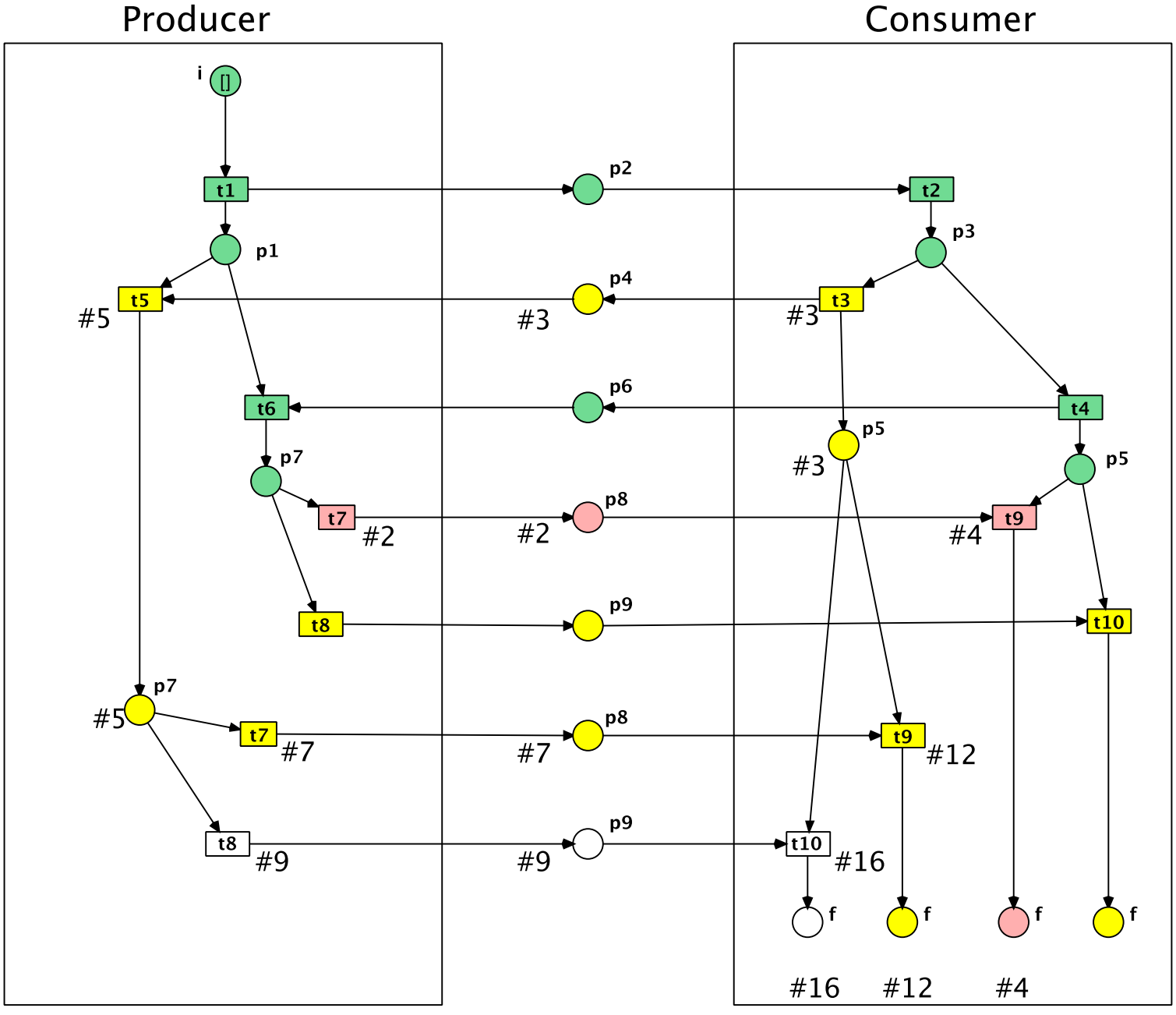

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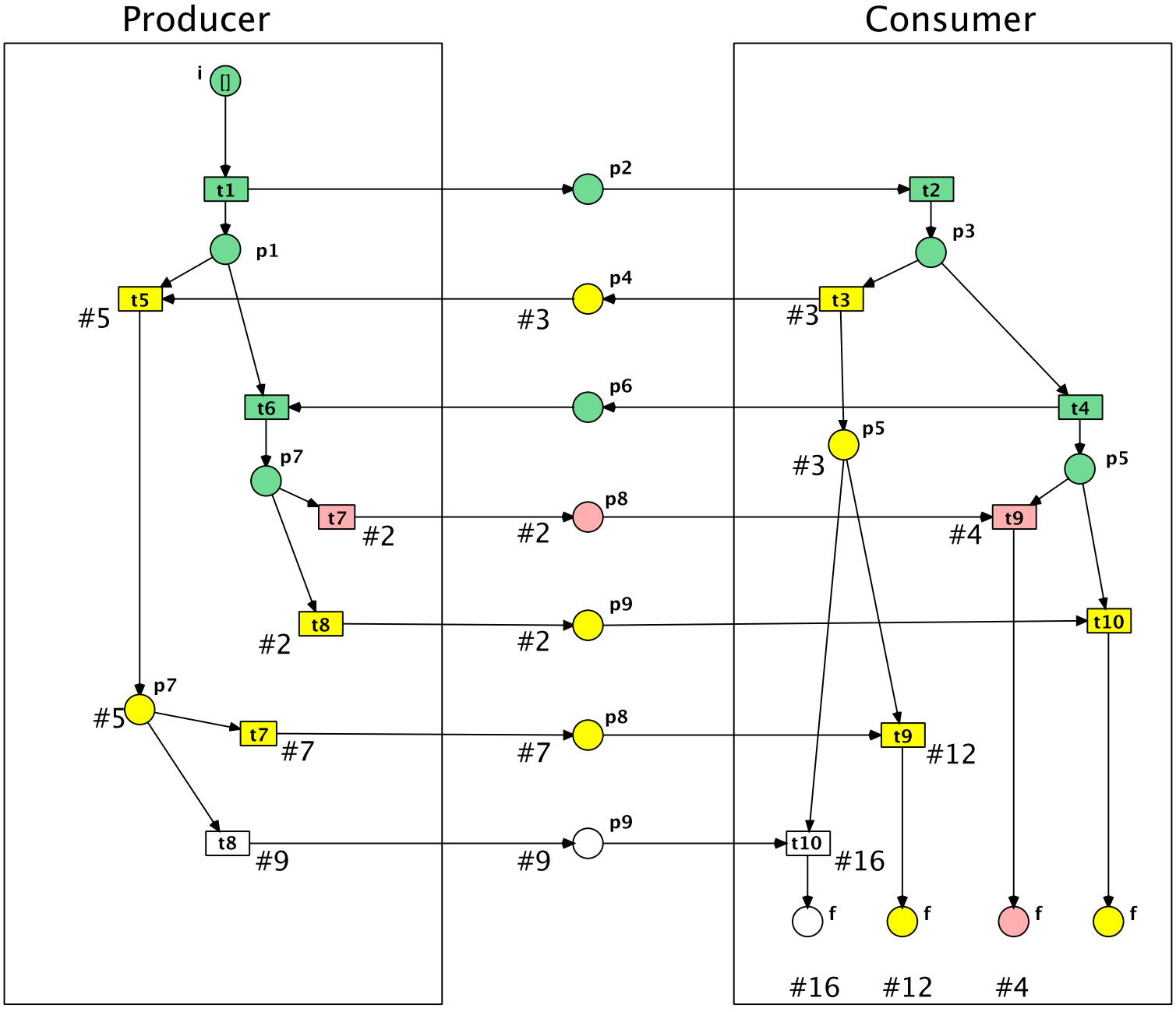

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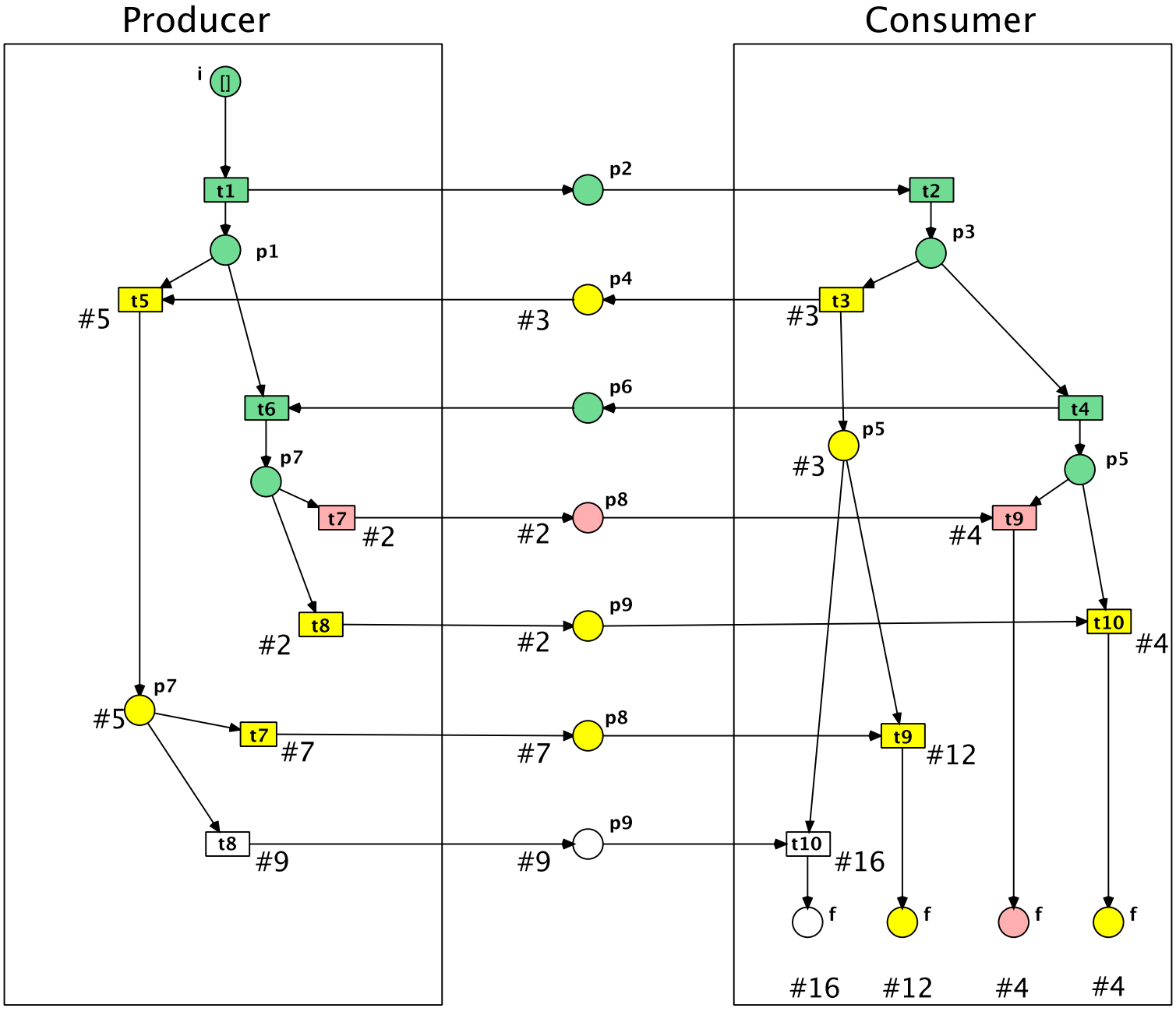

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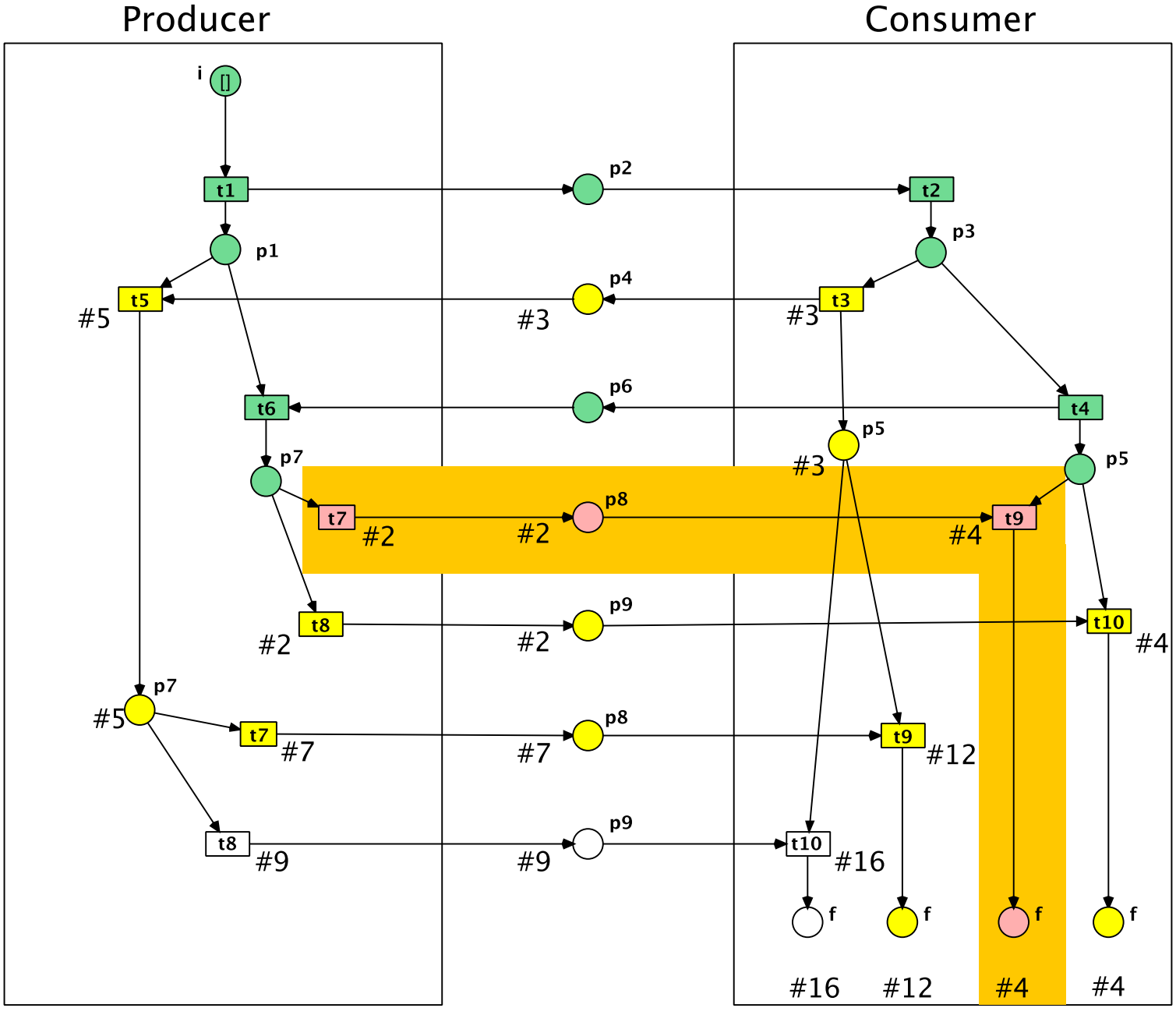

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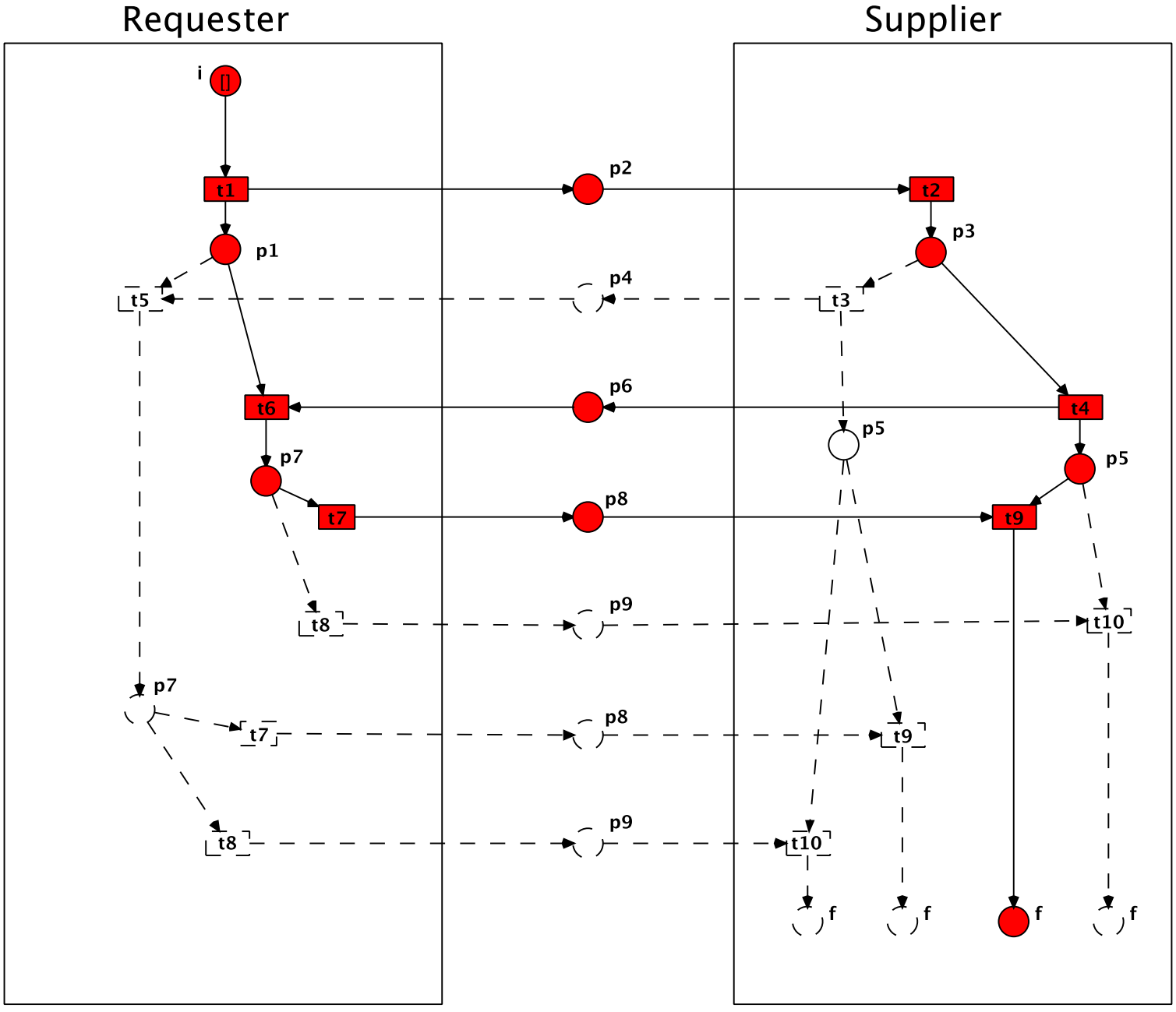
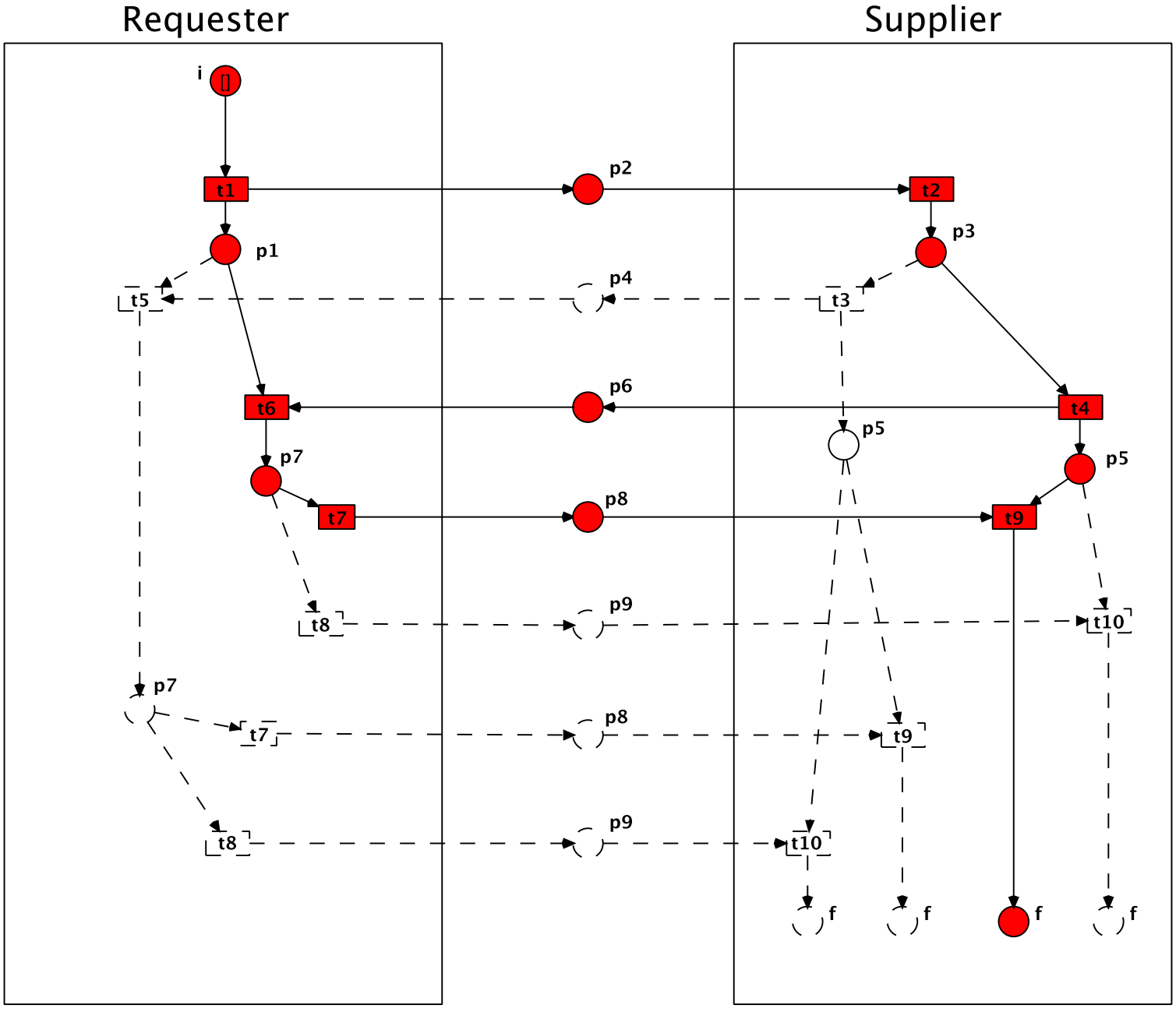
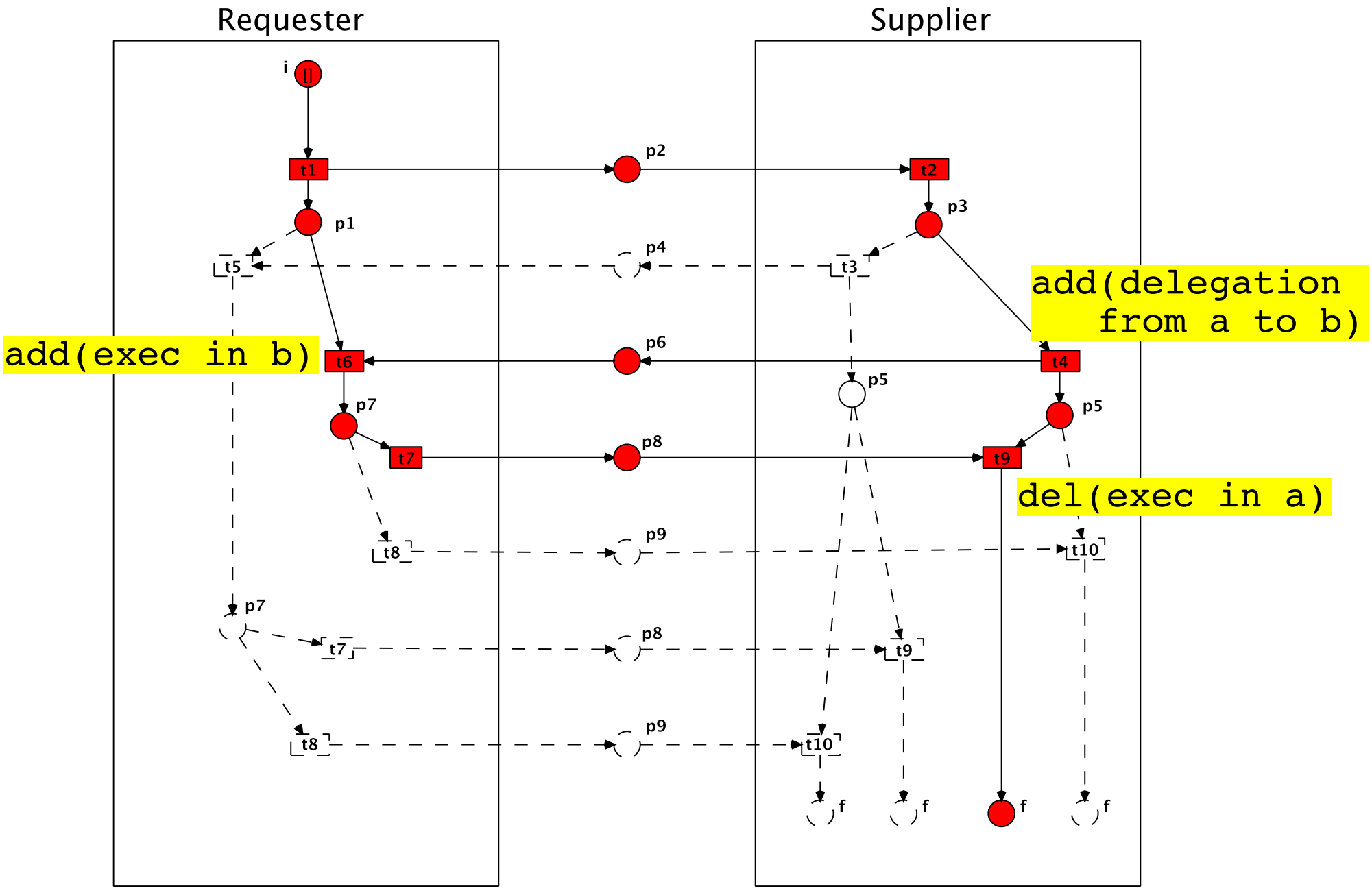


Outline

Execution of Plans in SONAR



Transformation τ induced by a SONAR Plan



Atomic Transformations of SONAR-Models

We allow two atomic transformations on organisations:

Definition

Define the operations $\mathtt{add}_t$ and $\mathtt{del}_t$ for each $t \in \mathcal{T}$ as:

$$\mathtt{add}_t(P,T,F) := \begin{cases} (P \cup t^\bullet, \quad T \cup \{t\}, \quad F \cup {}^\bullet t \times \{t\} \cup \{t\} \times t^\bullet) \\ \qquad\qquad \text{if } t \notin T \wedge {}^\bullet t \subseteq P \\ \text{undef.} \quad \text{otherwise} \end{cases}$$

$$\mathtt{del}_t(P,T,F) := \begin{cases} (P \setminus t^\bullet, \quad T \setminus \{t\}, \quad F \setminus ({}^\bullet t \times \{t\} \cup \{t\} \times t^\bullet)) \\ \qquad\qquad \text{if } t \in T \\ \text{undef.} \quad \text{otherwise} \end{cases}$$

Set of all atomic transformations: $ATF := \{\mathtt{add}_t, \mathtt{del}_t \mid t \in \mathcal{T}\}$.

Transformation: Reorganisation of the SONAR-Model

1. $\tau_1 =$ `add` *delegation* `from` O_3 `to` O_3
2. $\tau_2 =$ `add` *exec* `in` O_4
3. $\tau_3 =$ `del` *exec* `in` O_3

Question: Can we apply $\tau := \tau_1; \tau_2; \tau_3$ to the organisation?

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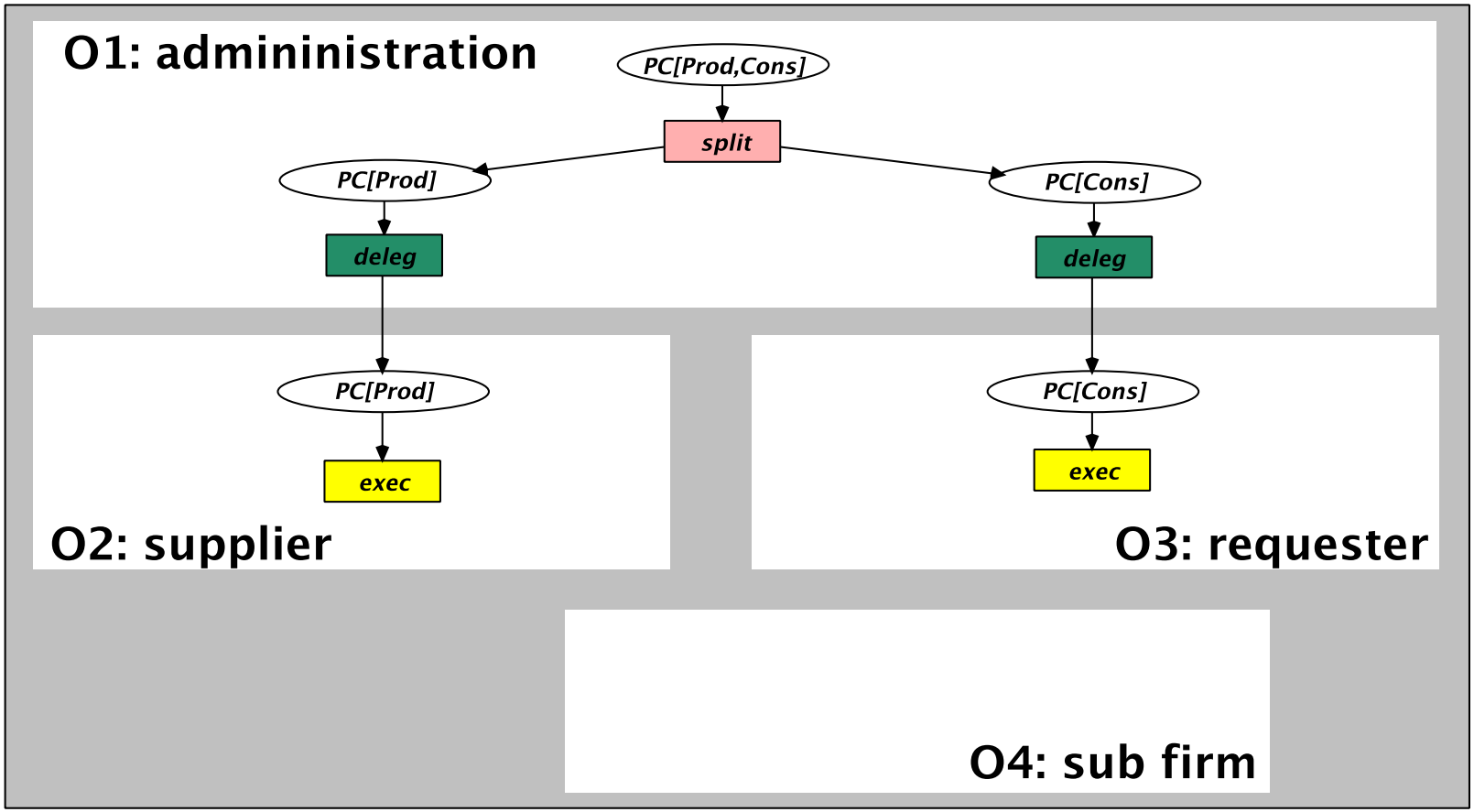

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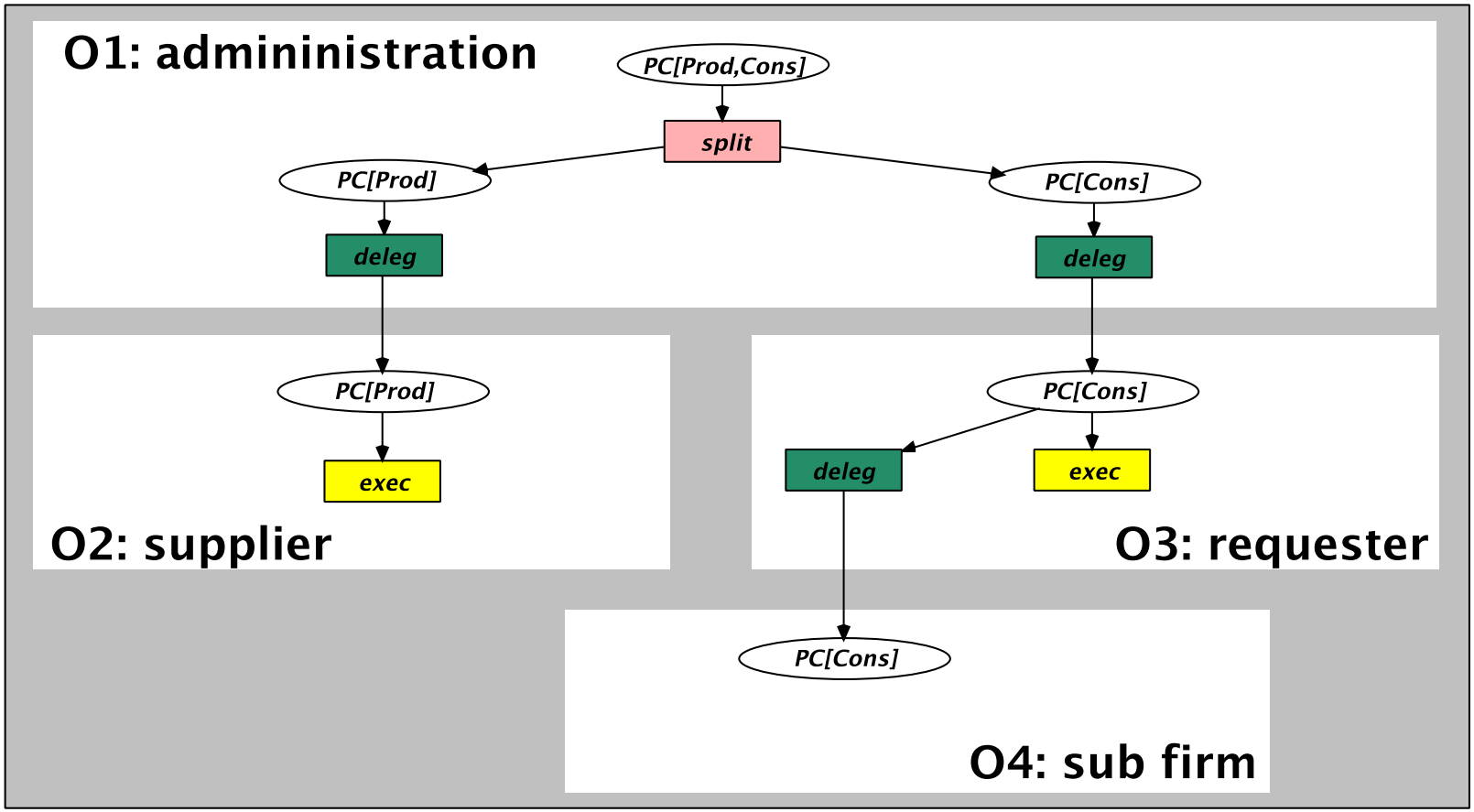

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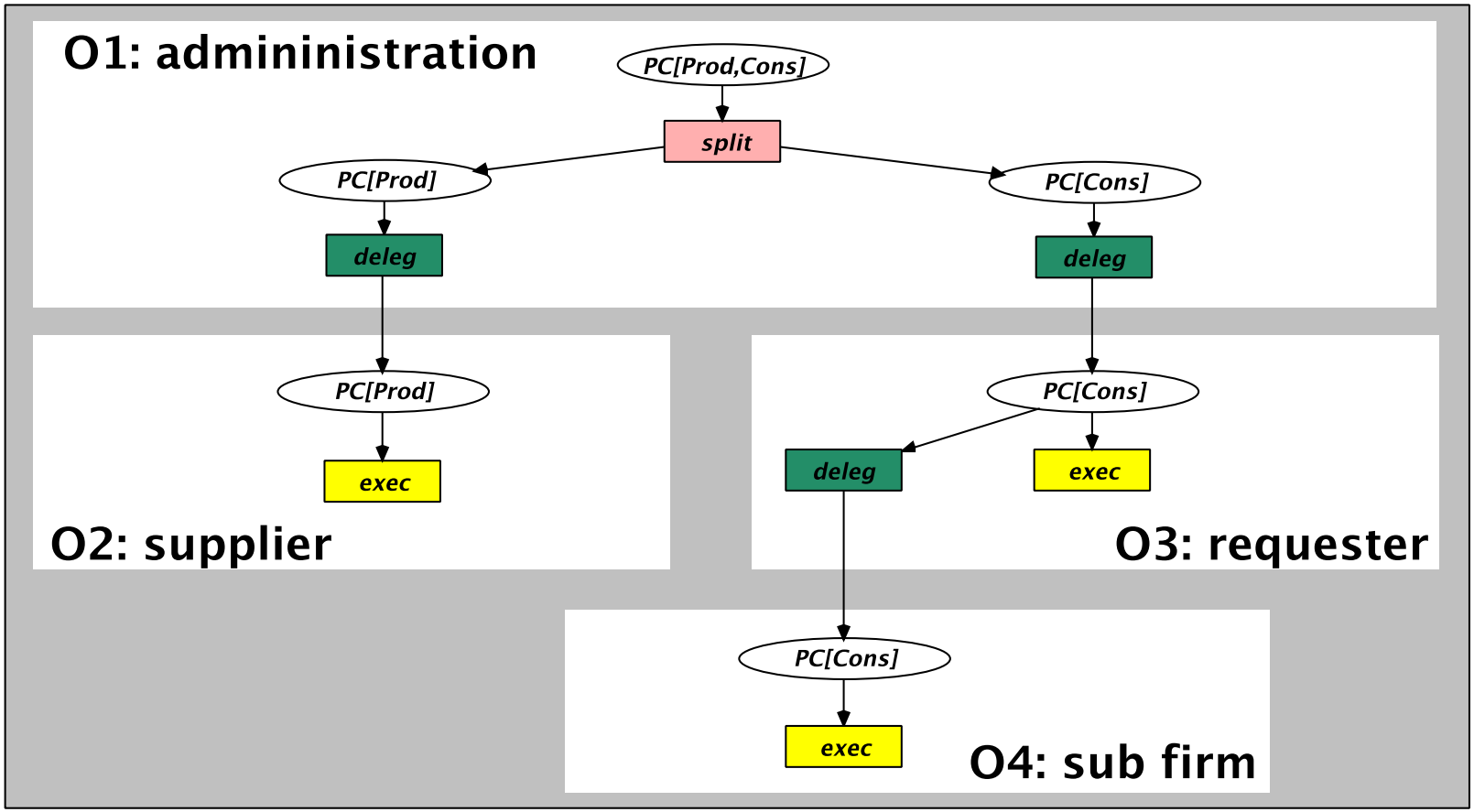

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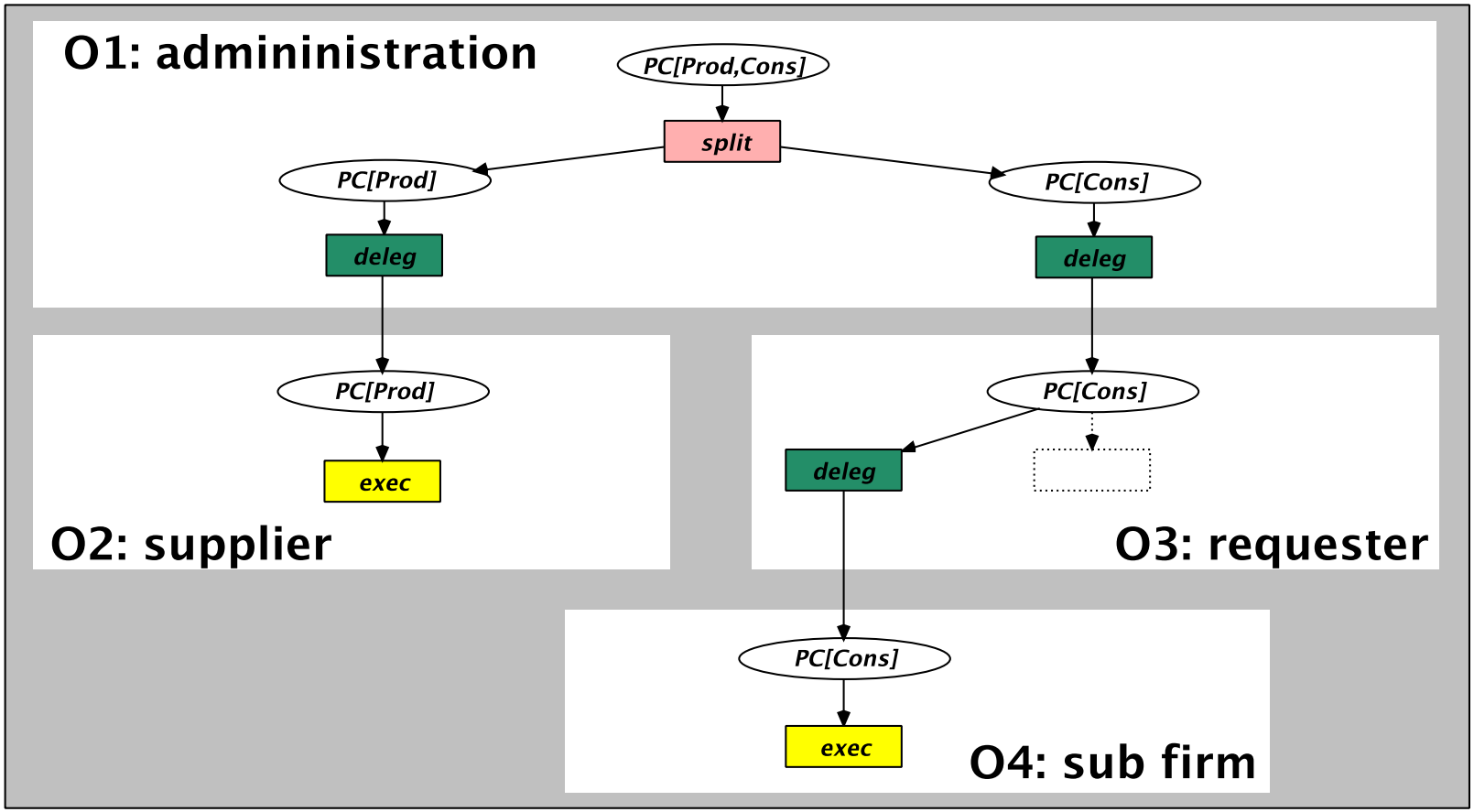

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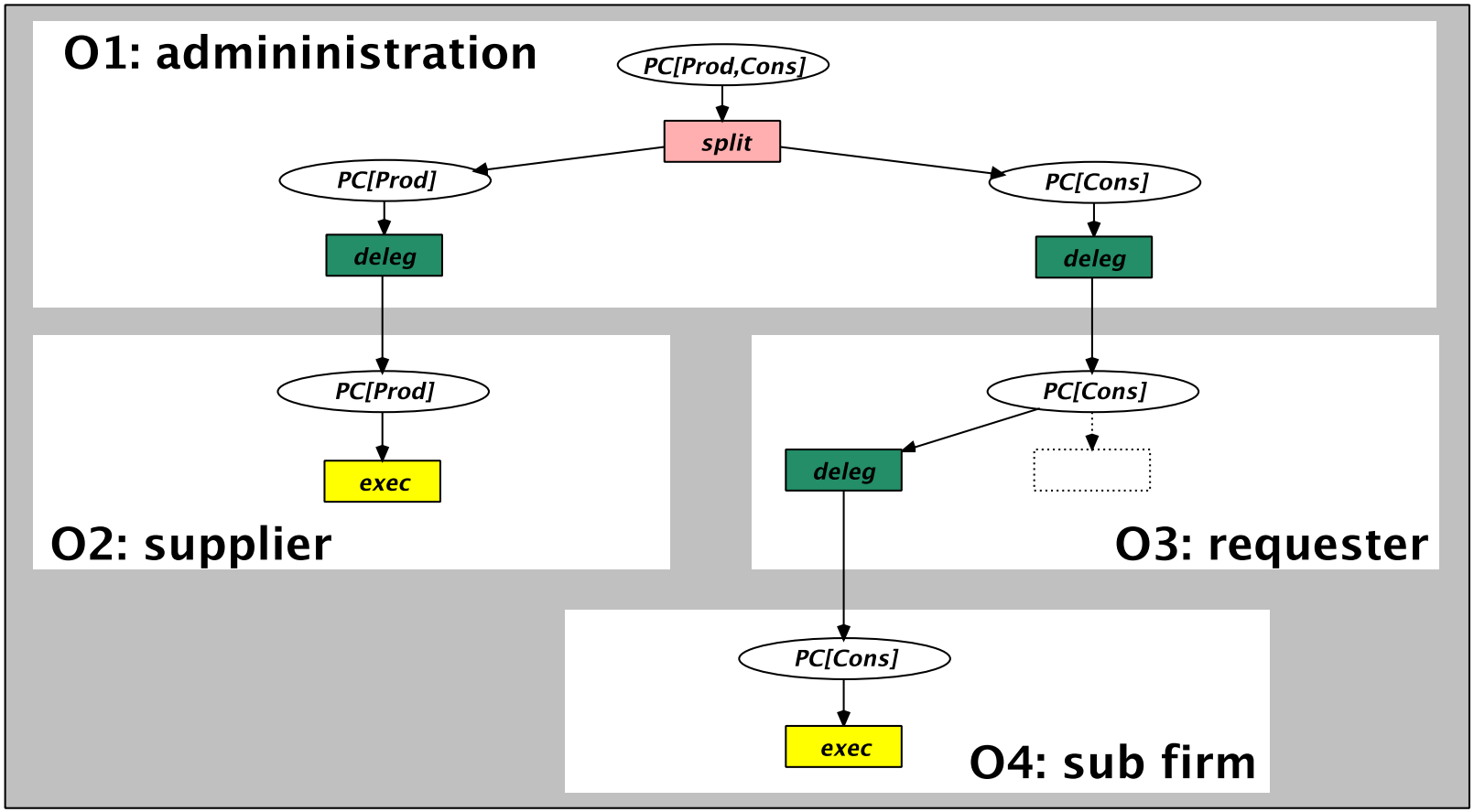
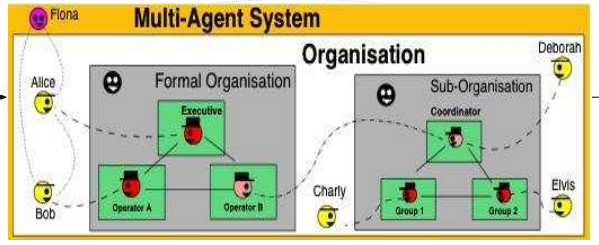


Summary: Overview of SONAR Concepts

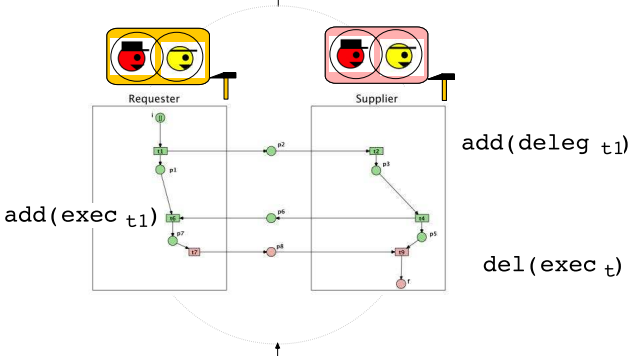
reorganise



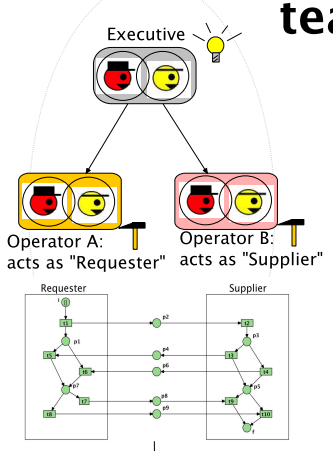
form team

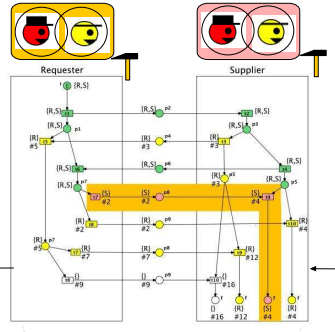
Organsiation-MAS

transformation



team





team plan

execute

negotiate

Outline

Problems

Problems:

- Can one ensure that the transformation (generated by a team plan) is applicable to the current organisation?
- Can one ensure that the resulting organisation is well formed?
- Can one guide the negotiation process that applicability is guaranteed?

Our approach in SONAR:

- Study the space of transformations.
- Here: Specify transformations as processes of a special Petri net, called the **meta organisation** $\hat{N}$.
  - A meta-marking $\hat{m}$ encodes an organisation net $N := N(\hat{m})$.
  - Each meta-transition $\hat{t}$ either activates or deactivates an implementation $t \in \mathcal{T}$.
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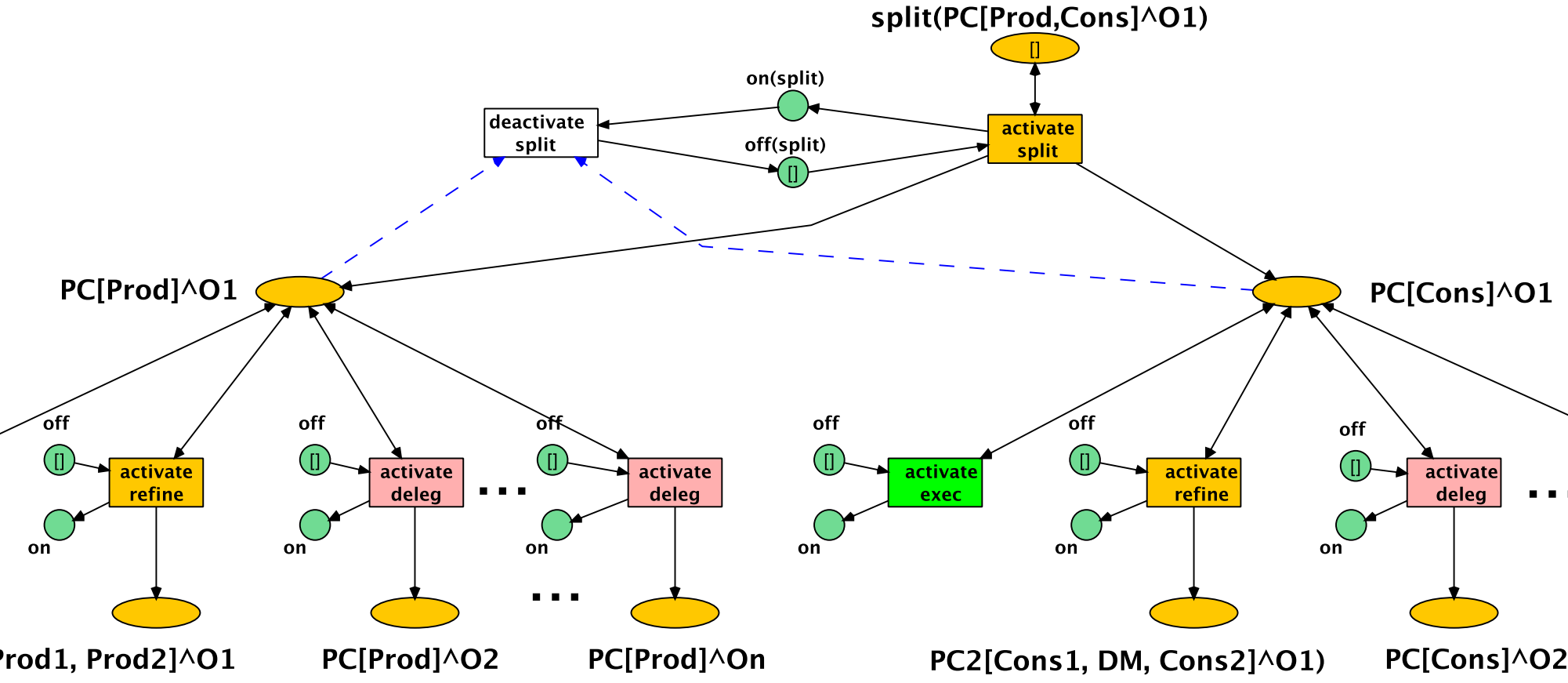
Meta Organisation: Example



Simulation

Define the isomorphism $h : (\hat{T} \cup \{\perp\})^* \to ATF^*$ as:

$h(\texttt{activate}_t) = \texttt{add}_t, \quad h(\texttt{deactivate}_t) = \texttt{del}_t, \quad \text{and} \quad h(\perp) = id.$

Theorem

Meta-Events are activated transformations:

$$\begin{array}{ccc} \hat{m} & \xrightarrow{\hat{t}} & \hat{m}' \\ \downarrow{\scriptstyle N(\cdot)} & & \downarrow{\scriptstyle N(\cdot)} \\ N = N(\hat{m}) & \xrightarrow{h(\hat{t})} & N' = N(\hat{m}') \end{array}$$

Application to Distributed Team Planning

- How can one guarantee that the transformation generated by the team plan is applicable to the organisation?
- Answer: We *synchronise* the team-protocol D with the meta-organisation $\hat{N}_{P^0}$.
- Define the *synchronous product* $D \otimes \hat{N}_{P^0}$.
  - A protocol transition t_D labelled with $\texttt{add}_t$ is synchronised with the meta-transition $\texttt{activate}_t$.
  - Them, t_D is activated only if the transformation $\texttt{add}_t$ is applicable to the current organisation.
- Negotiation constructs a partial plan for the product $(D \otimes \hat{N}_{P^0})$ – and not only for the team-protocol D.
- Then, each team plan for $(D \otimes \hat{N}_{P^0})$ generates an applicable transformation *by construction*.

Outline

Analysis of the Meta-Organisation

A **policy** Φ is a predicate on organisation nets N.

Validity of a policy Φ for the organisation N is denoted $N \models \Phi$.

Define the set of meta-markings that satisfy a policy Φ as:

$$SAT(\Phi) := \{\hat{m} \in RS(\hat{N}_{P^0}, \hat{m}_0) \mid N(\hat{m}) \models \Phi\}$$

Definition

The meta-organisation $\hat{N}$ *enforces* the policy Φ if $SAT(\Phi) = RS(\hat{N}_{P^0}, \hat{m}_0)$.

Assume, that the set of agents $\mathcal{A}$ and protocols $\mathcal{D}$ are finite sets.

Theorem

Given a meta-organisation $\hat{N}$, it can be checked (using standard model checking techniques), whether the policy is enforced.

Note, that whenever $\mathcal{A}$ and $\mathcal{D}$ are finite sets, then $\hat{N}$ and its state space are finite, too.

Analysis of the Meta-Organisation: Stability

But, in almost all cases a meta-organisation $\hat{N}$ does *not* enforce a policy Φ.

Usually, this is not problematic, since it is not necessary that each $N(\hat{m})$ satisfy Φ after each *step* of the team plan;

Instead: It is necessary that for each reachable meta-marking $\hat{m}$ we have the possibility to satisfy Φ again:

$$\forall \hat{m} \in RS(\hat{N}_{P^0}, \hat{m}_0) : \exists \hat{m}' \in RS(\hat{N}_{P^0}, \hat{m}) : \hat{m}' \in SAT(\Phi)$$

But, the answer is trivially “yes”, since each transformation can be undone (since $\hat{N}$ is revertible).

Therefore we exclude the $\texttt{deactivate}_t$ transitions from the analysis:

Definition

The meta-organisation $\hat{N}$ is **stable** w.r.t. the policy Φ if we have for $\hat{A} = \{\texttt{deactivate}_t \mid t \in \mathcal{T}\}$:

$$\forall \hat{m} \in RS(\hat{N}_{P^0} - \hat{A}, \hat{m}_0) : \exists \hat{m}' \in RS(\hat{N}_{P^0} - \hat{A}, \hat{m}) : \hat{m}' \in SAT(\Phi)$$

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Theorem

Given a meta-organisation $\hat{N}$, it can be checked using standard model checking techniques, whether a policy Φ is stable.

Proof.

Stability is a kind of *liveness property* and can be checked by computing the SCCs of the state space:
Check whether each terminal SCC contains an $\hat{m}$ that satisfies Φ. □

Outline