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26-2-2024

Lecture 7: concurrency viewpoint II

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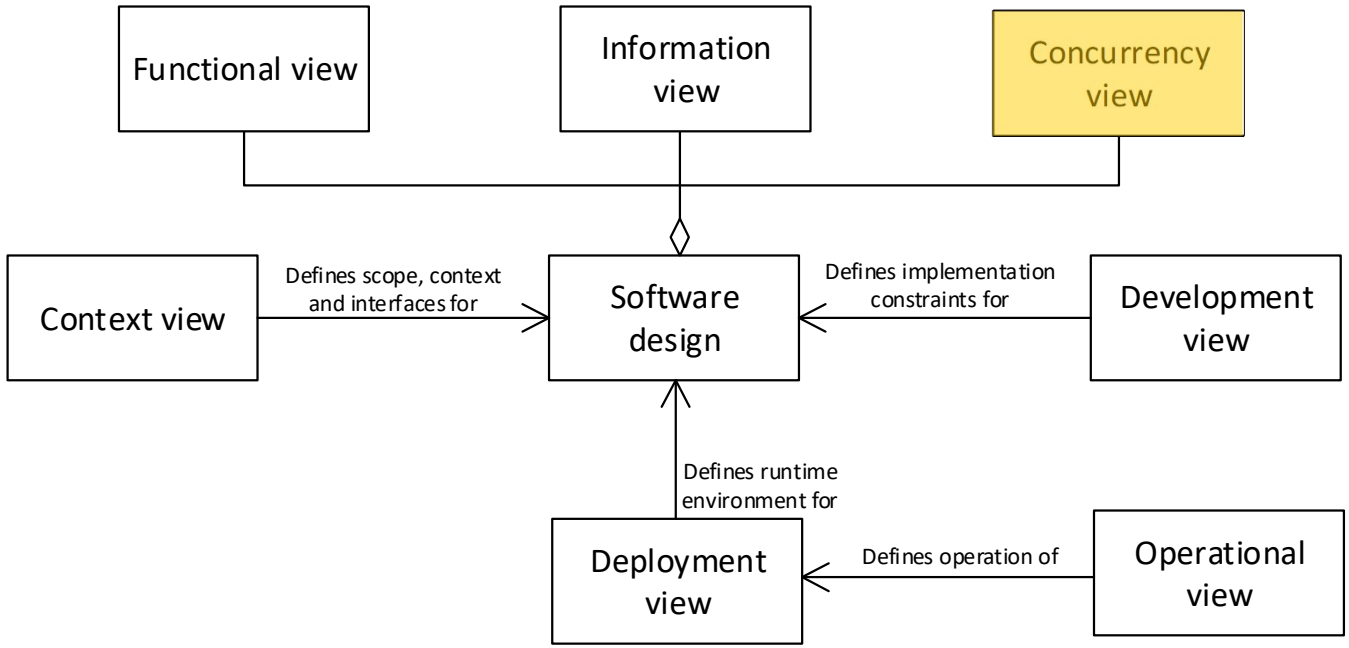
Viewpoint catalog



Viewpoint:

Collection of patterns, templates and conventions for constructing one type of view. It defines the stakeholders whose concerns are reflected in the viewpoint and the guidelines, principles, and template models for constructing its views

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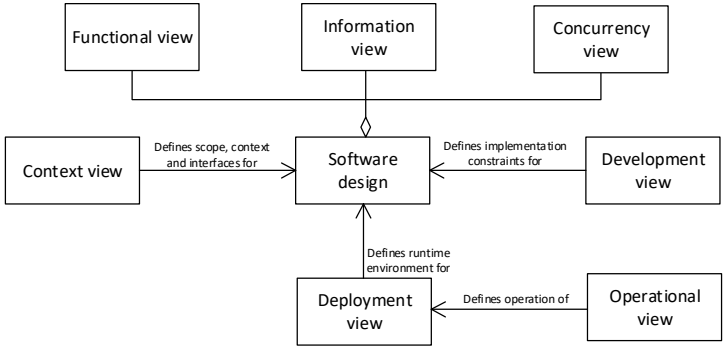
Concurrency view



- Concurrency view:
  - **Describes the concurrency structure of the system and maps functional elements to concurrency units to clearly identify the parts of the system that can execute concurrently and how this is coordinated and controlled**
- Concerns
  - **Task structure, mapping of functional elements to tasks,**
  - **Inter-process communication,**
  - **State management,**
  - **Synchronization and integrity,**
  - **Supporting scalability, task failure,**
  - **Startup and shutdown, re-entrancy**
- Models and views
  - **System level concurrency models**
  - **State models, protocol models**

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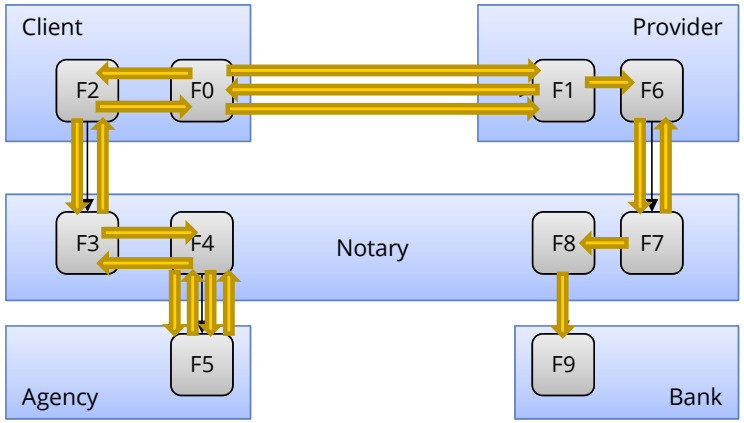
Logical model and scenarios



- Scenario is a sequence of function calls
- Formal definition:

  Given a logical model $(C, F, h, \rightarrow)$**,**
  a scenario is a partial order over the function calls,
  i.e., $\sigma \in (\rightarrow)^*$ **such that:**

  Functions can only start if being called before:

  $$\forall 1 < i < |\sigma| : \left(\exists 1 < j < i : \pi_3(\sigma(j)) = \pi_1(\sigma(i))\right)$$

Problem: scenarios can be conflicting!

Key:
F0: Request service
F1: Handle service request
F2: Request approval
F3: Receive approval request
F4: Validate client
F5: Do credibility check
F6: Request payment
F7: Check payment request
F8: Send payment
F9: Make payment

Given a set A, a sequence of length $n \in \mathbb{N}$ is a function $\sigma : \{1..n\} \rightarrow A$

- We write $\sigma = \langle a_1, \ldots, a_n \rangle$ if $\sigma(i) = a_i$ for all $1 \leq i \leq n$.
- We denote its length by $|\sigma|$
- If $n = 0$, we call it the empty sequence, and denote it with ϵ
- The set of all finite sequences over A is denoted by A^*

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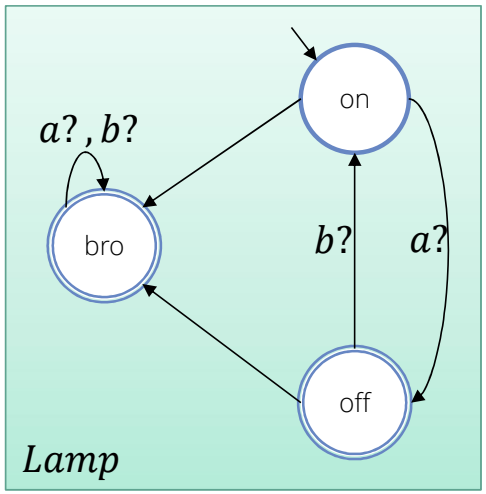
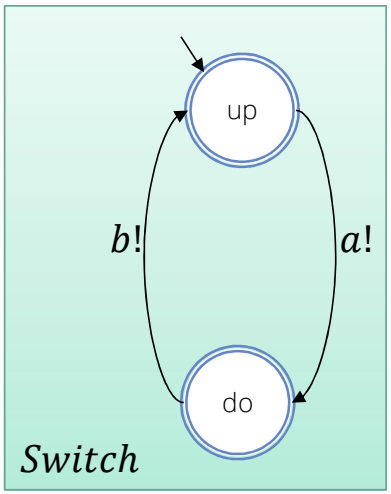
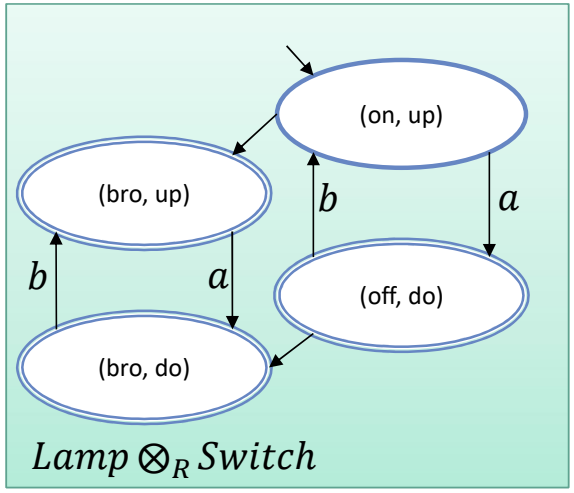
Composing interface automata







$R = \{a, b\}$

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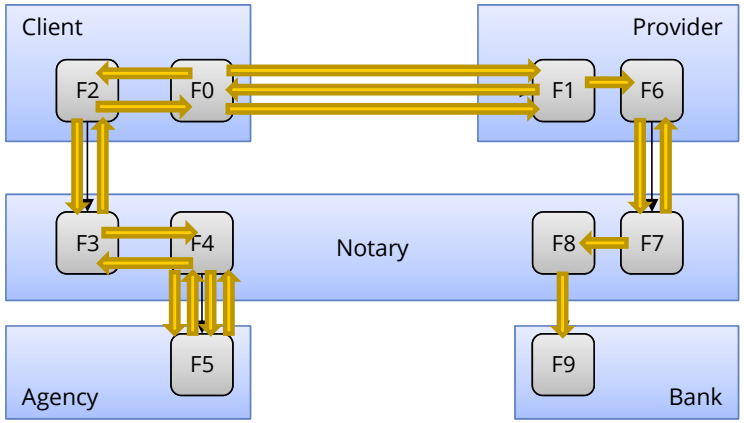
Communication mechanisms



- Synchronous communication
  You have to know in which state the other is!
- Asynchronous communication
  Send messages to the other, the state of the other is unknown!

Key:
F0: Request service
F1: Handle service request
F2: Request approval
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Petri nets

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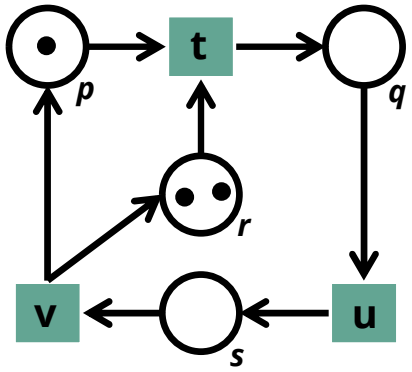
Petri nets: formal definition



$N = ((P, T, F), m_0)$ with:

$P = \{p, q, r, s\}$

$T = \{t, u, v\}$

$F = \{(p,t), (r,t), (t,q), (q,u)$
$(u,s), (s,v), (v,r), (v,p)\}$

$m_0 = [\, p,\ r^2 \,]$

(reads as: $[\, p^1,\ r^2, q^0, s^0]$)

- A Petri net is a 4-tuple N = $((P, T, F), m_0)$ with:

- P: a (finite) set of places
- T: a (finite) set of transitions
- P and T are disjoint ($P \cap T = \emptyset$)
- F is the flow relation that defines the arcs

$$F \subseteq (P \times T) \cup (T \times P)$$

- m_0 is the initial marking, gives the tokens per place

$$m_0 : P \rightarrow \mathbb{N}$$

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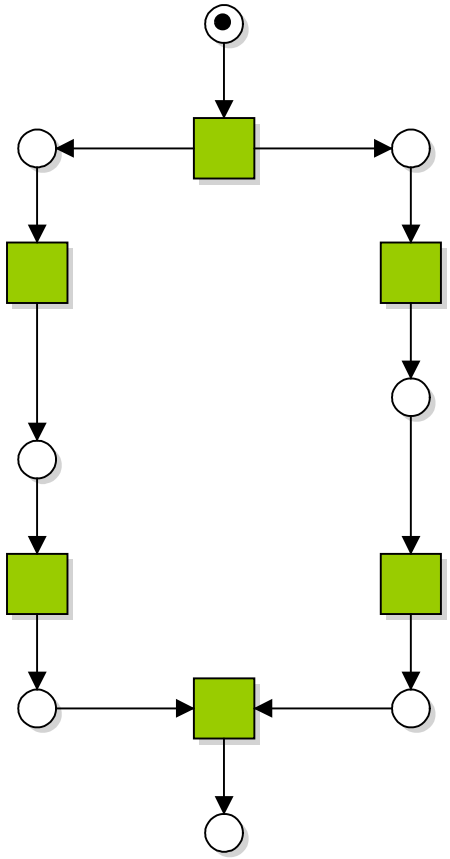
Petri nets and communication mechanisms



- Synchronous communication
  - **Transitions that consume from multiple places**
- Asynchronous communication
  - **Places resemble pools of messages to be handled**
  - **Random access of messages in these pools**

Both communication mechanisms in a single, **graphical** formalism!

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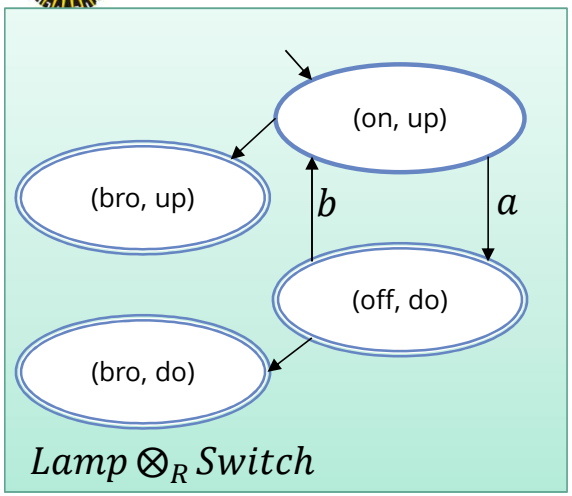
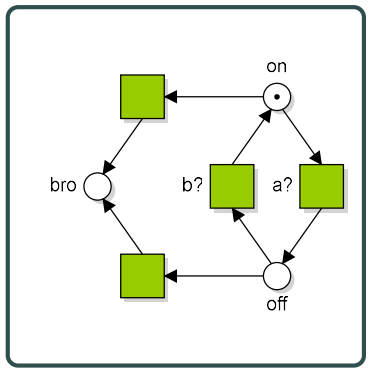
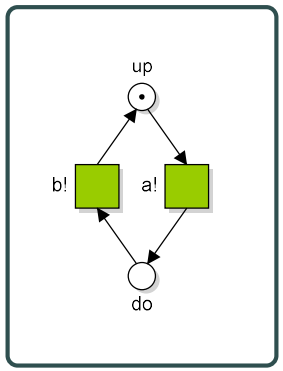
Back to our lamps: now as Petri nets

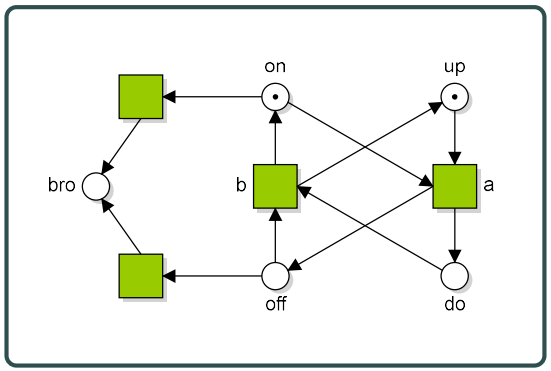




Lamp



Switch



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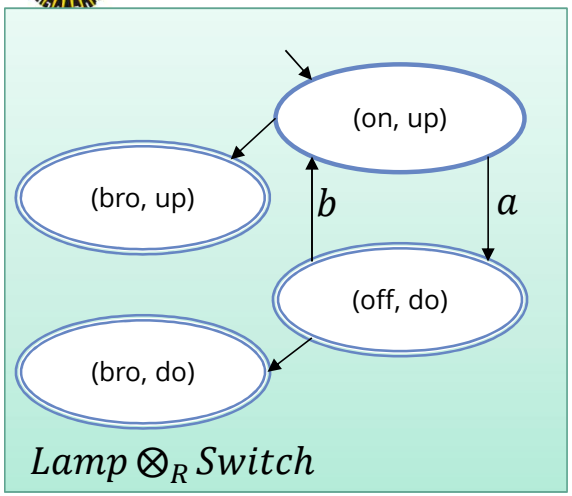
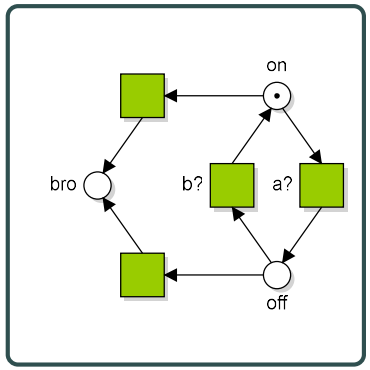
Back to our lamps: now as Petri nets





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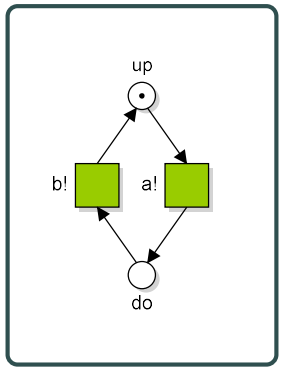

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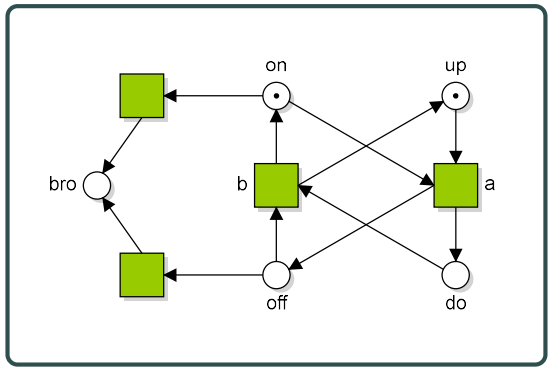

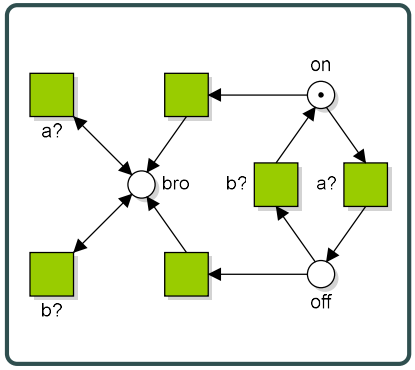

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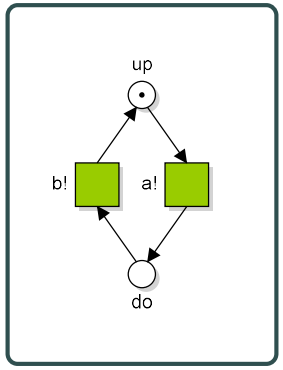

Switch

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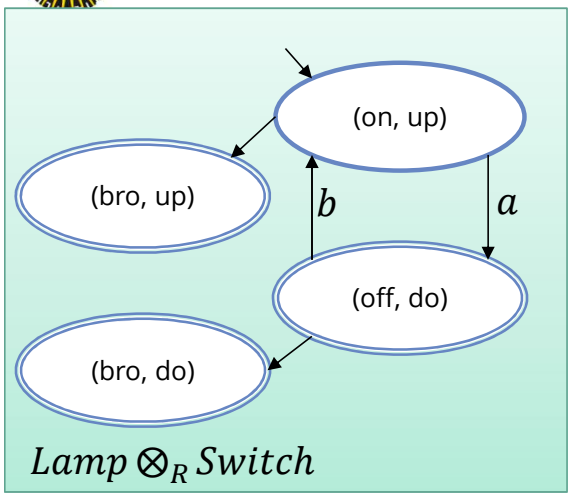
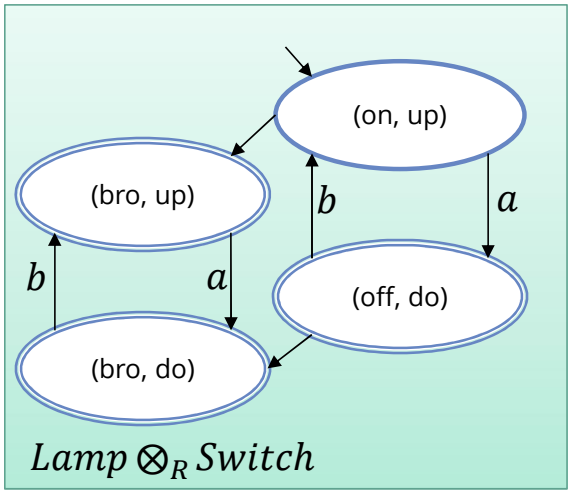
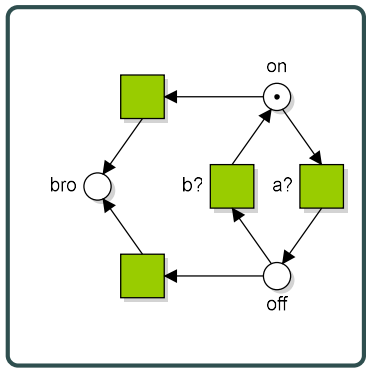
Back to our lamps: now as Petri nets
Synchronous communication







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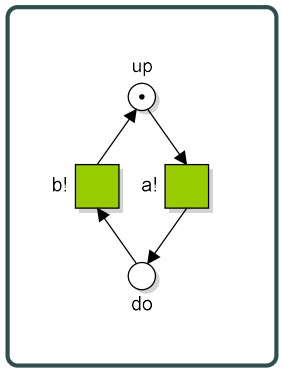

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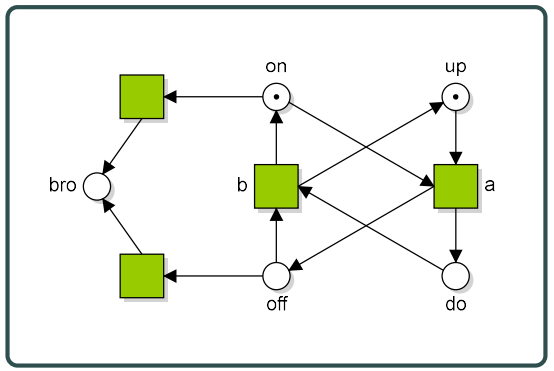

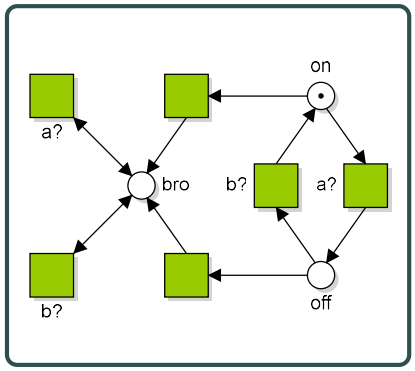

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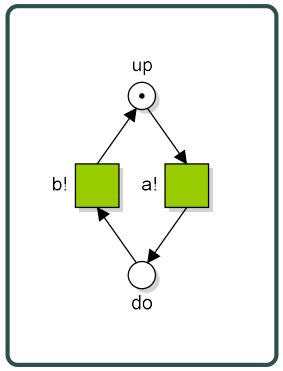

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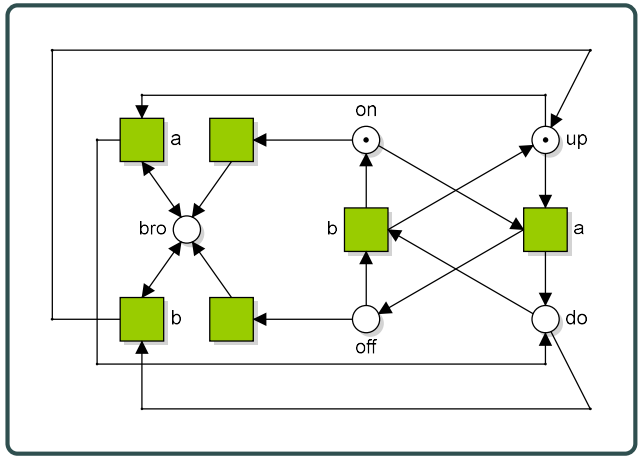

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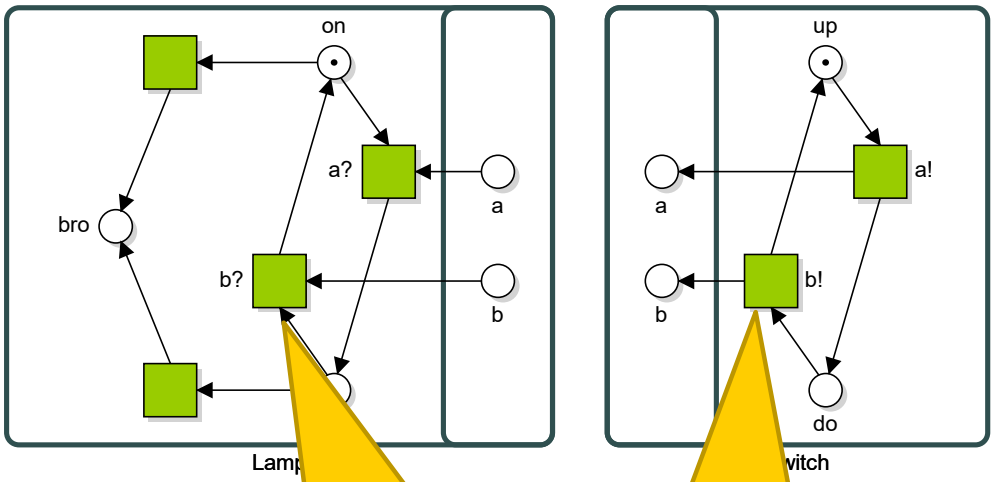
Back to our lamps: now as Petri nets
Asynchronous communication!



Transition receives a message by consuming a token from “message place” b

Transition sends a message by placing a token in the “message place” b

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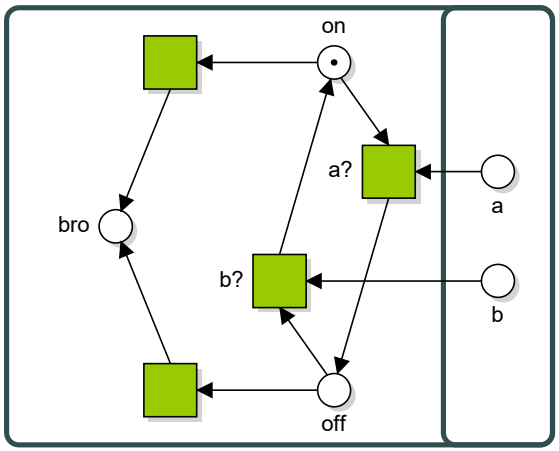
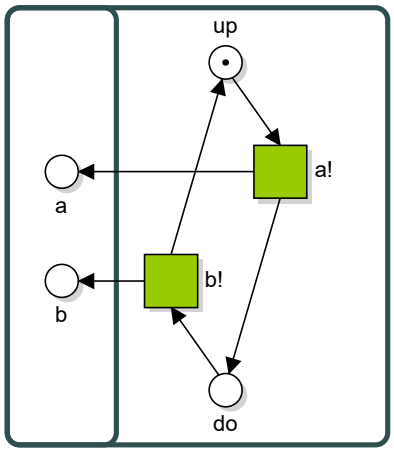
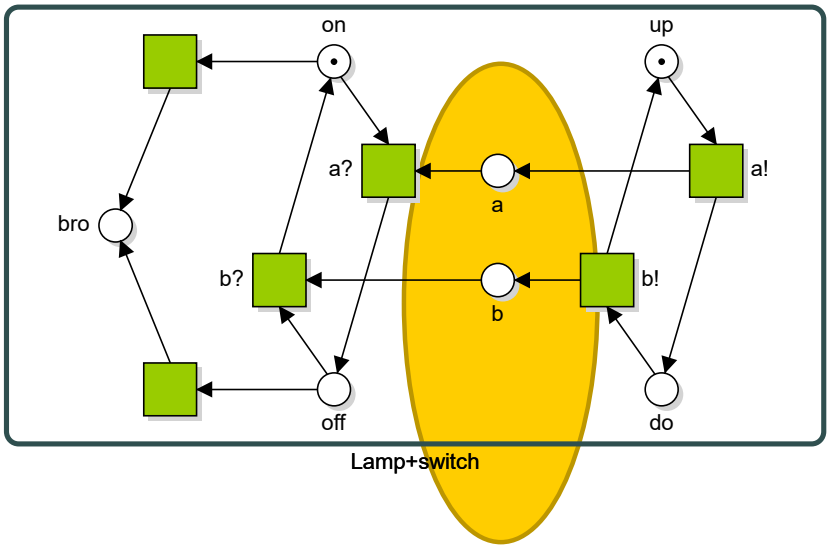
Back to our lamps: now as Petri nets
Asynchronous communication!



Lamp



Switch



Lamp+switch

Message buffers

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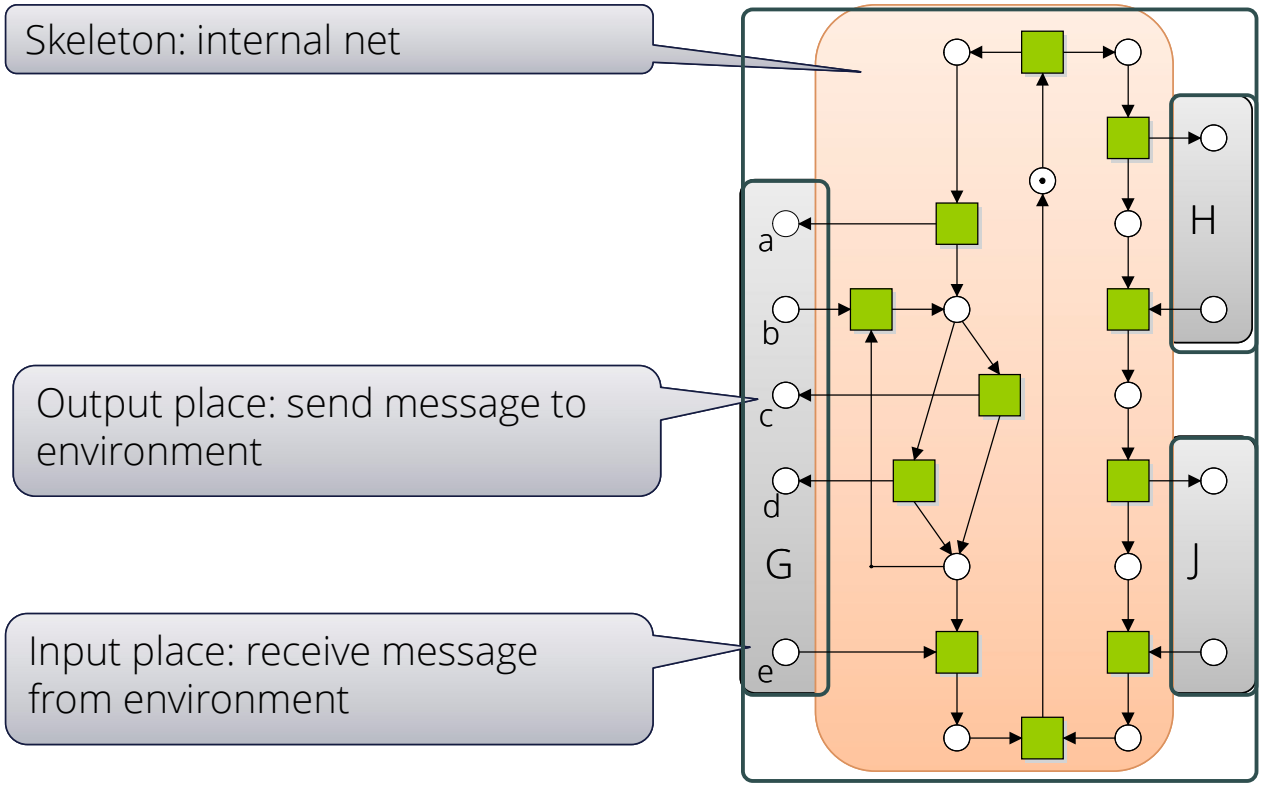
Open nets – asynchronous communication



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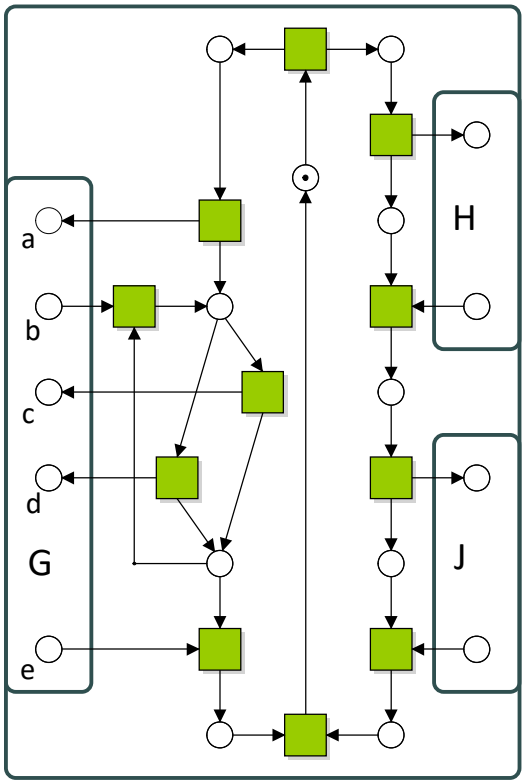
Open nets – verification

1. Stable state
   - **Each component is in rest**
   - **No tokens in the interface**
   - **Typically the initial marking**

Correctness:

1. Weakly terminating
   - **Always possible to reach a stable state**
2. Proper completion
   - **If a marking covers a stable state, it is a stable state.**

3. Defined on skeleton!



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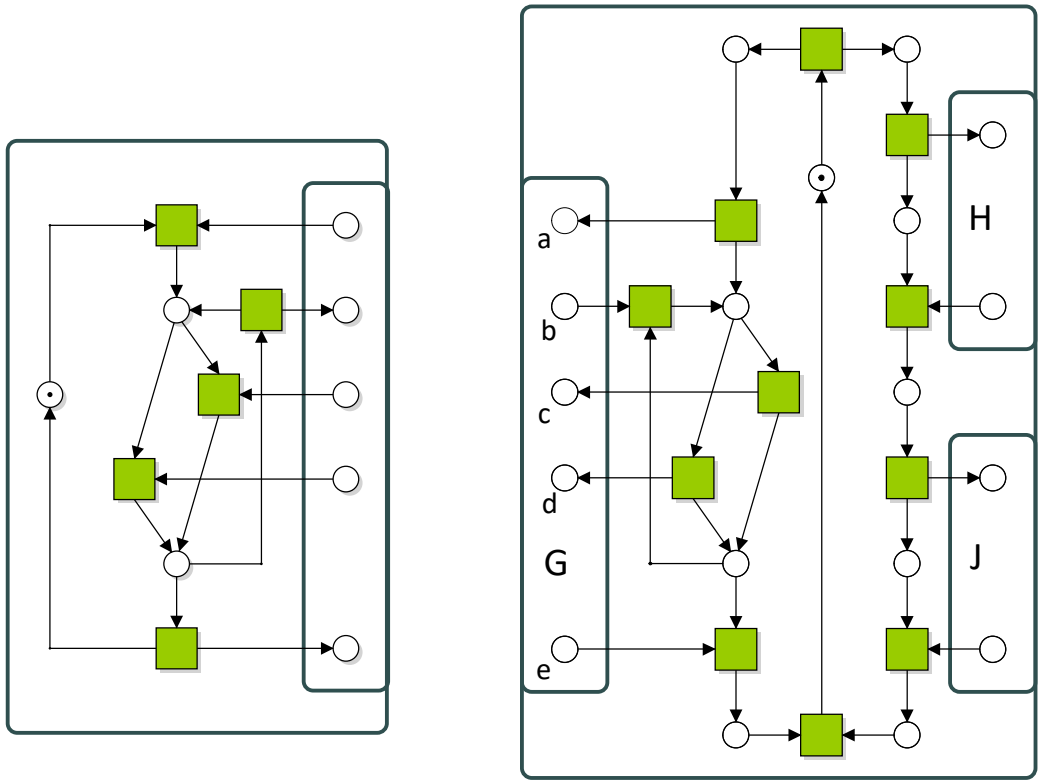
Open nets – composition



Composition:

- glue interface places with the same name
- Input place of the one should be output of the other

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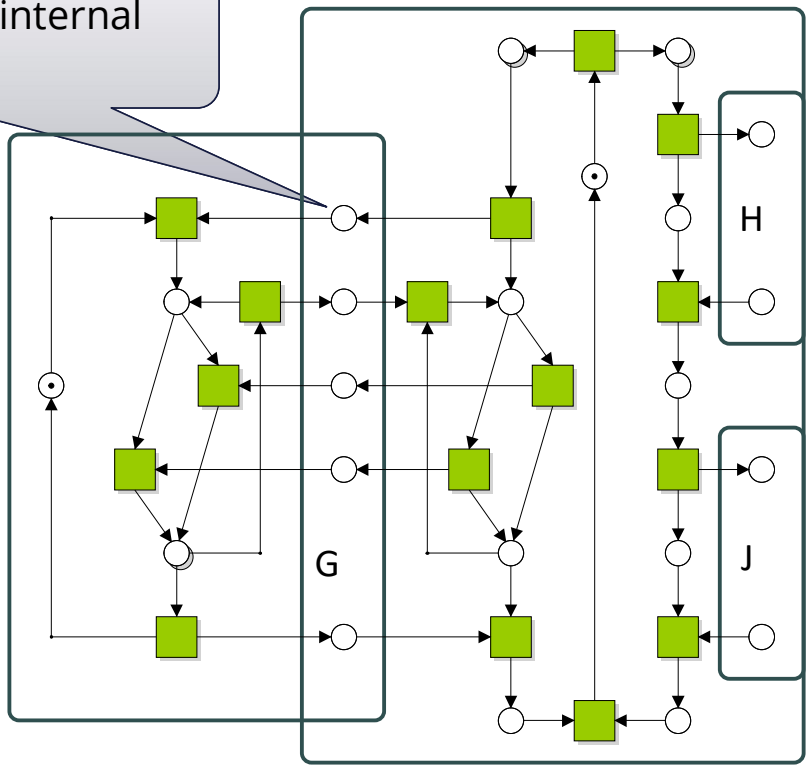
Open nets – composition

Glued places become internal places of the skeleton



Composition:

- glue interface places with the same name
- Input place of the one should be output of the other

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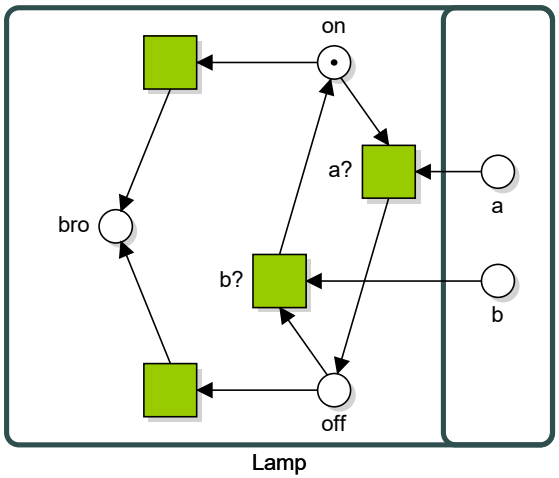
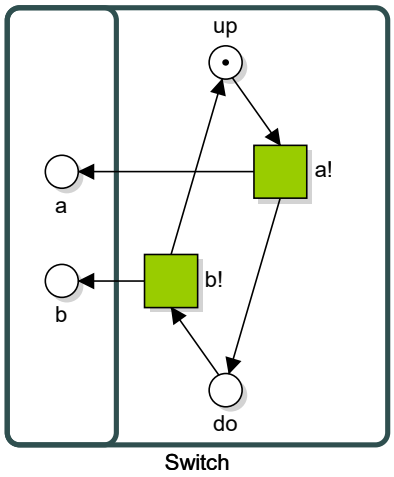
Remember our lamp?



Lamp



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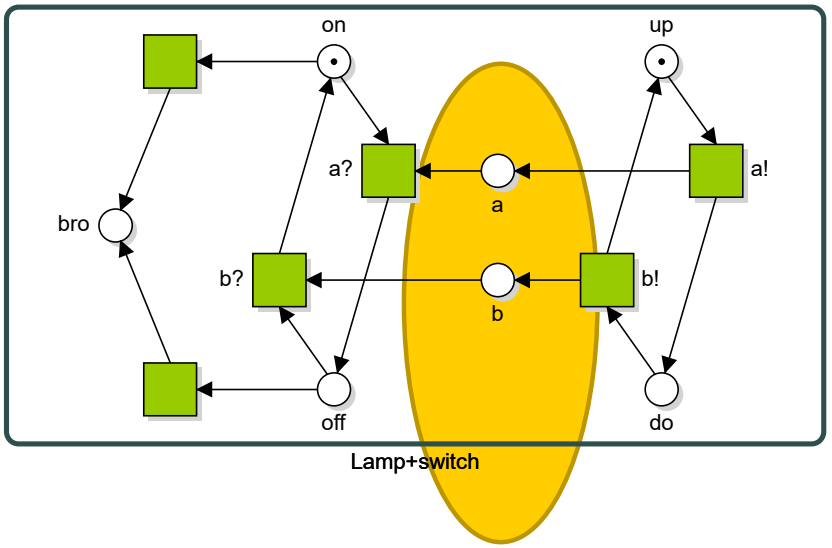

Lamp+switch

Message buffers

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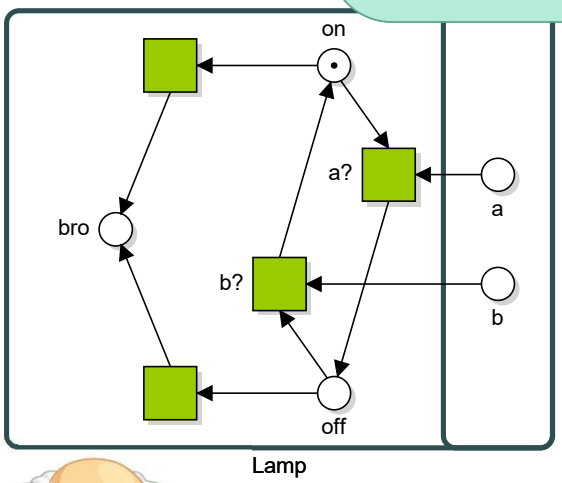
Correctness:

1. Weakly terminating
   Always possible to reach a stable state
2. Proper completion
   If a marking covers a stable state, it is a stable state.



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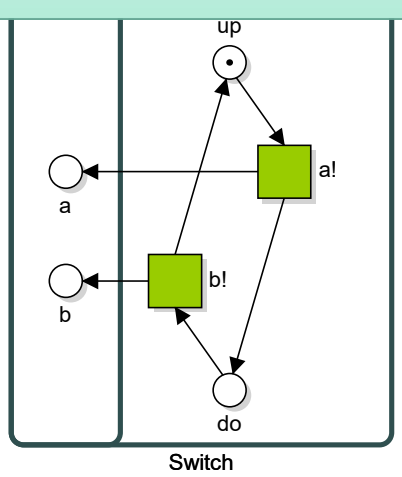

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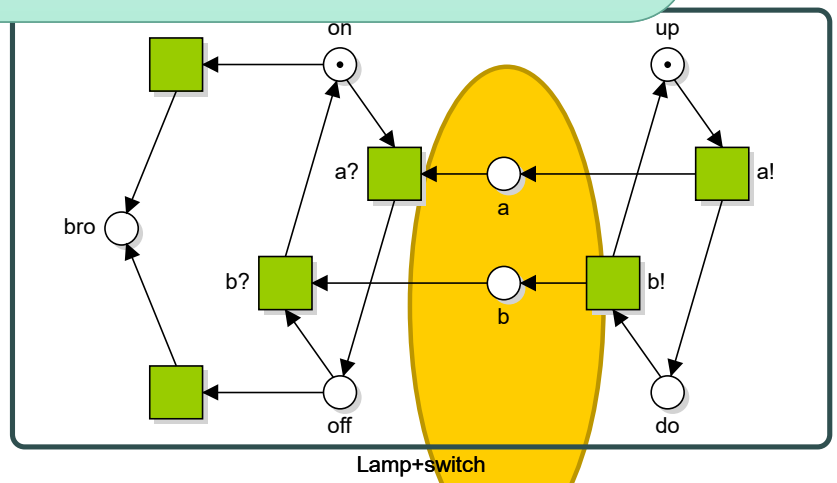

Lamp+switch

Message buffers

Is this net correct?

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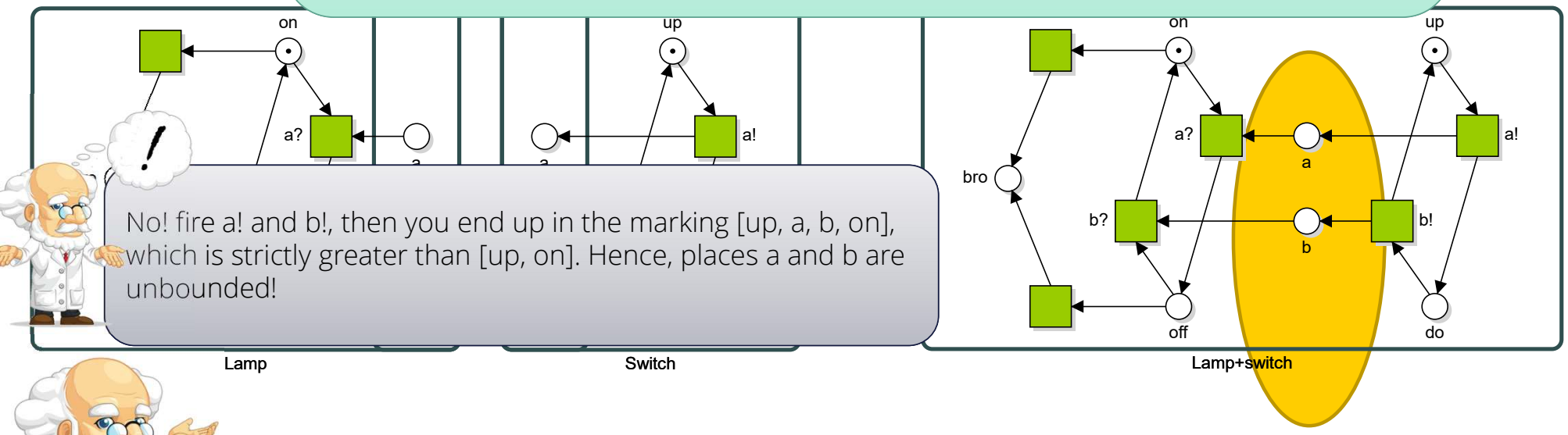
Correctness:

1. Weakly terminating
   Always possible to reach a stable state
2. Proper completion
   If a marking covers a stable state, it is a stable state.



No! fire a! and b!, then you end up in the marking [up, a, b, on], which is strictly greater than [up, on]. Hence, places a and b are unbounded!

Is this net correct?

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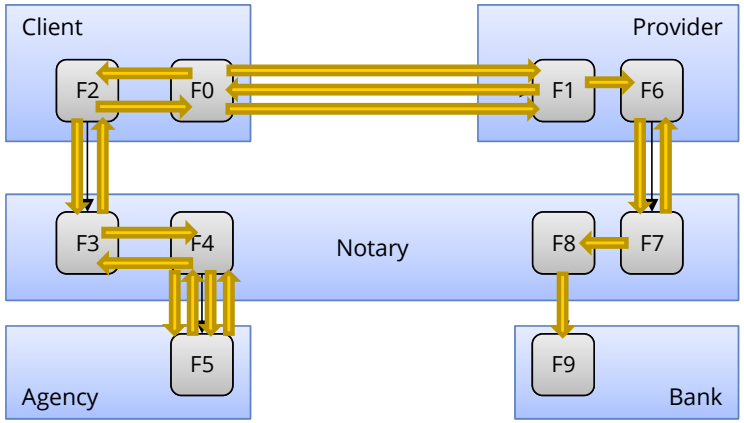
Create correct open nets for F0 and F1



- The client asks for permission. Upon receiving the permission, (s)he asks for a service of the provider, and either accepts or denies the offer received by the provider. Upon accepting, the provider offers the service, and regularly sends an invoice, which needs to be signed and returned by the client. Once denied, either (s)he stops, or (s)he asks for a better offer.
  In case the client does not receive permission, (s)he tries again.

Key:
F0: Request service
F1: Handle service request
F2: Request approval
F3: Receive approval request
F4: Validate client
F5: Do credibility check
F6: Request payment
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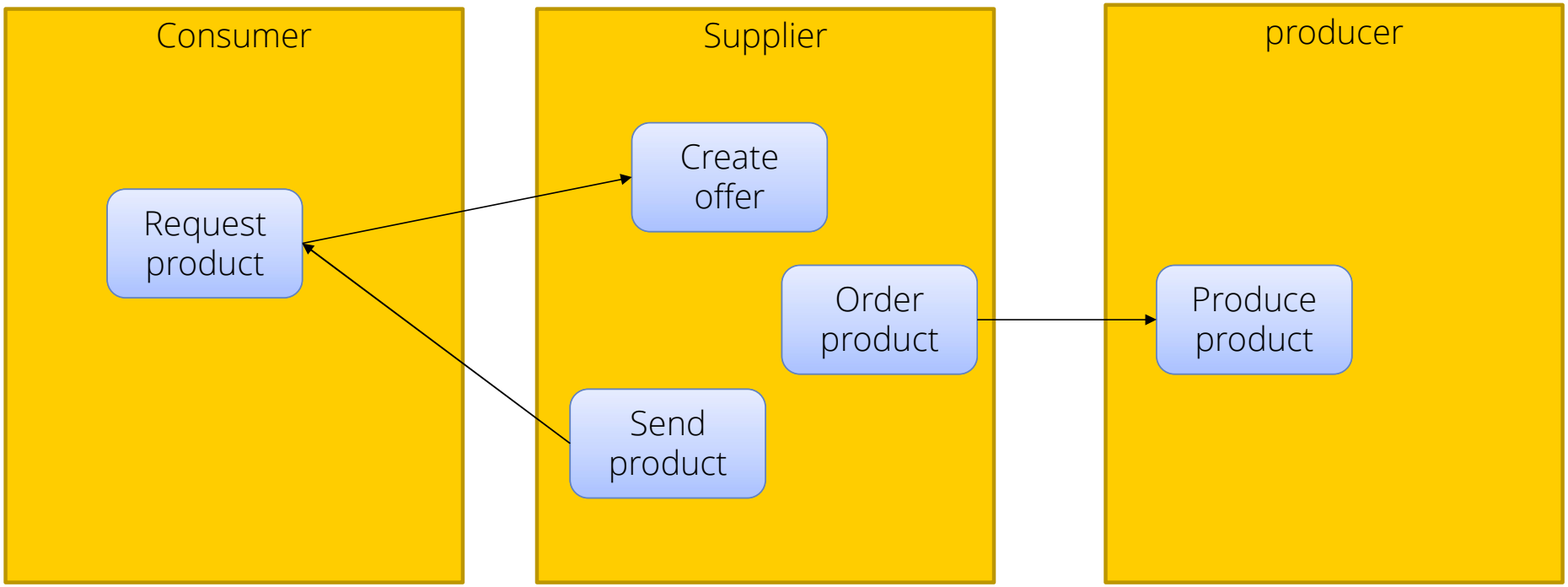
Modelling with Open nets
Step 1: create a logical model



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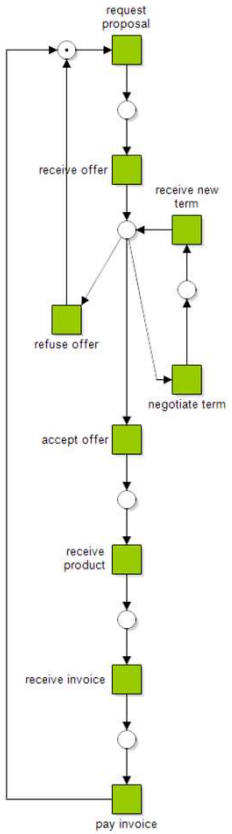
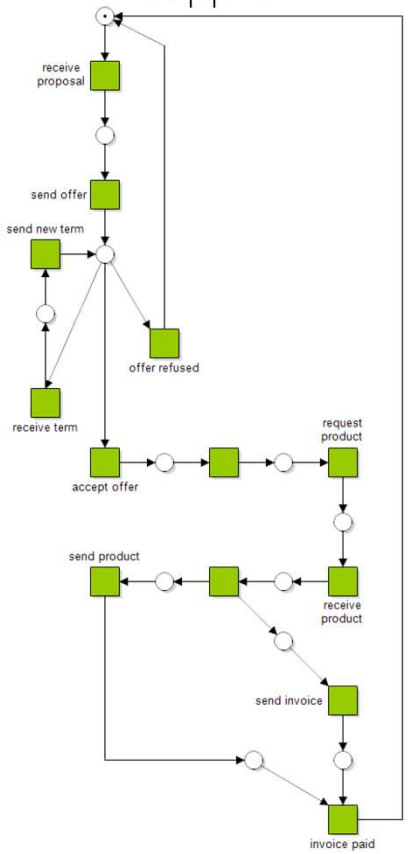
Modelling with Open nets
Step 2: create an open net for each module

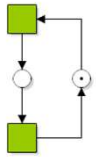
Consumer



Supplier



producer



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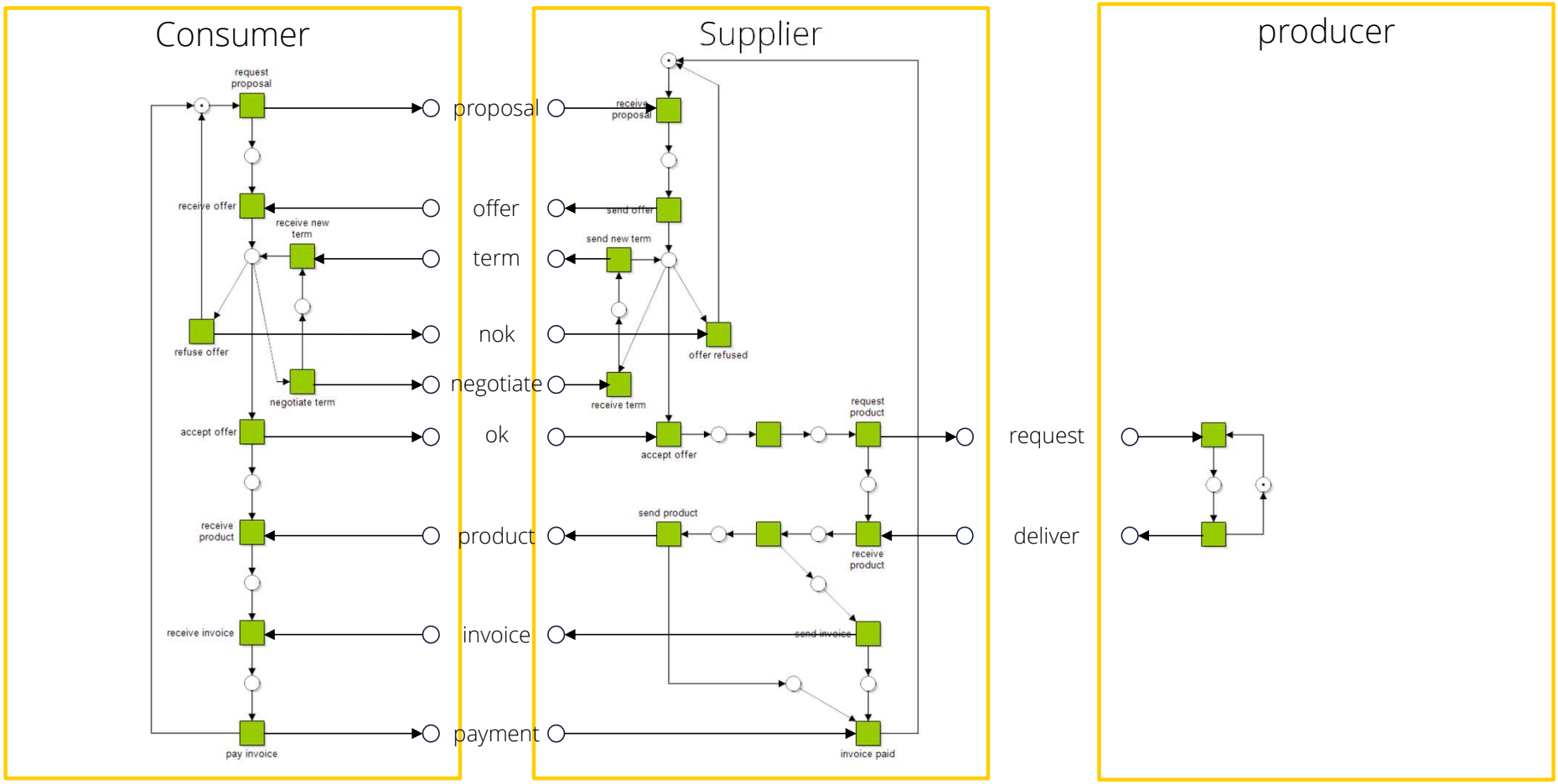
Modelling with Open nets
Step 3: define the interface places for the modules



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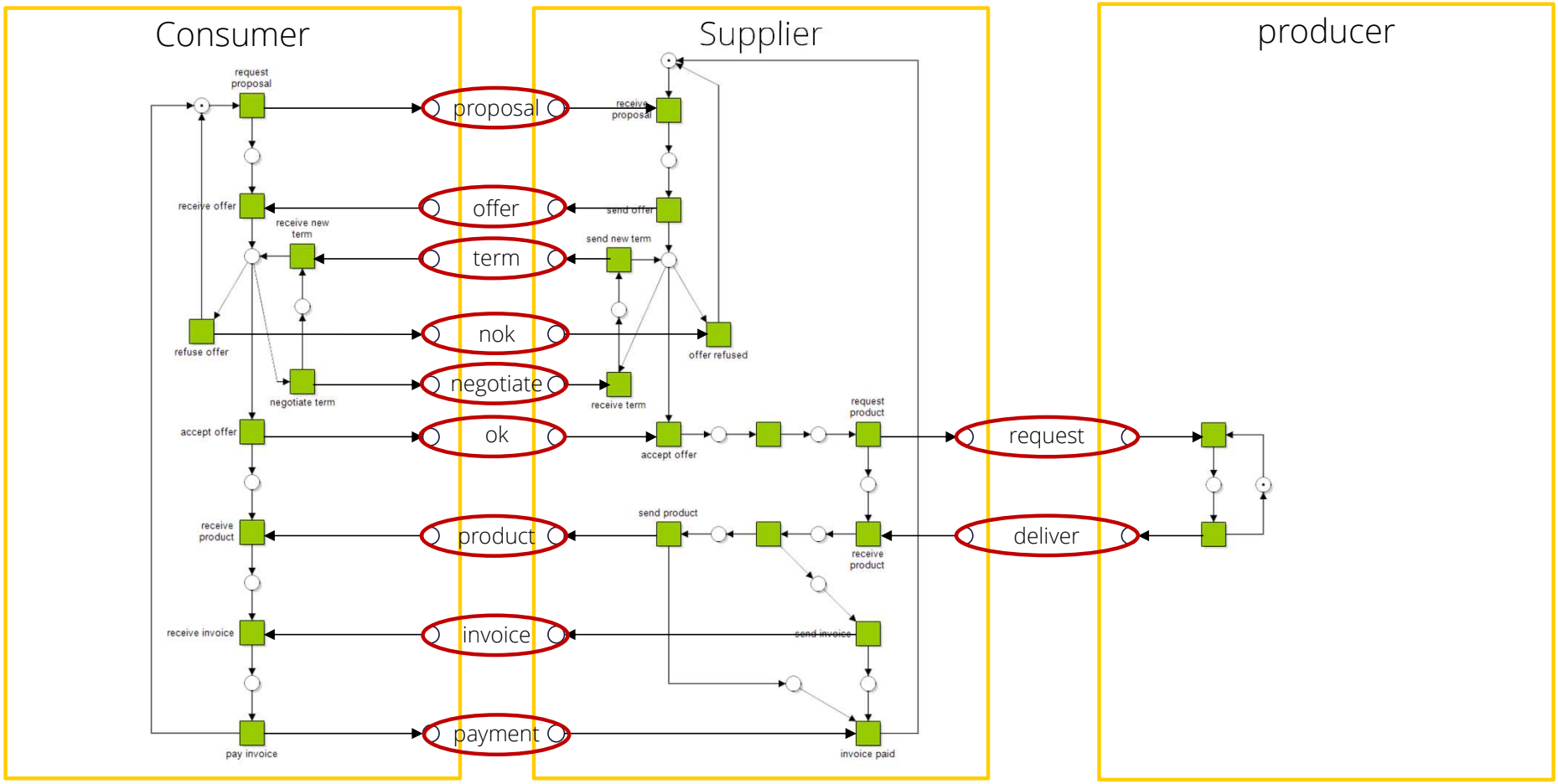
Modelling with Open nets
Step 4: compose the modules



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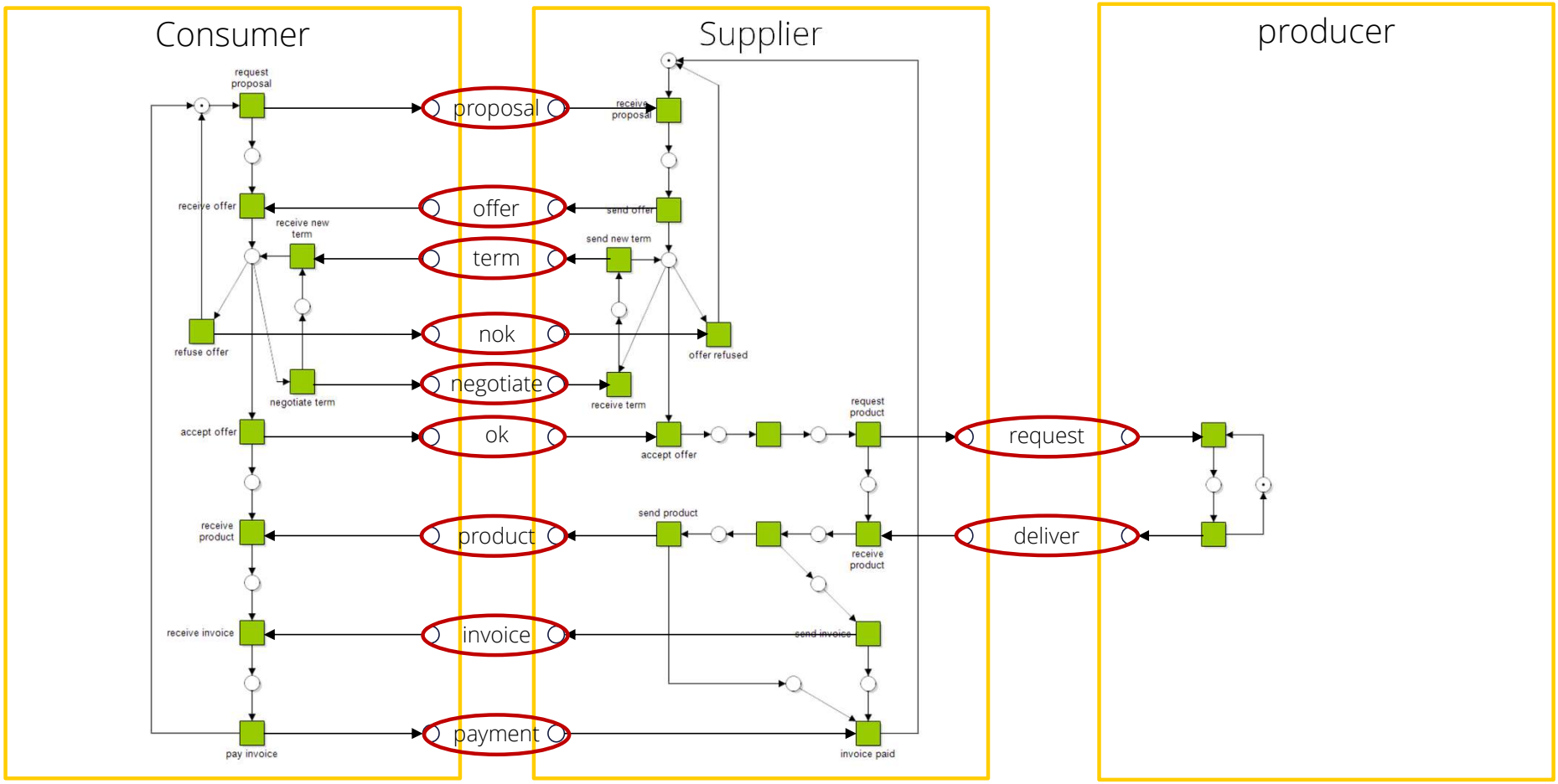
Modelling with Open nets
Step 5: analyze the model



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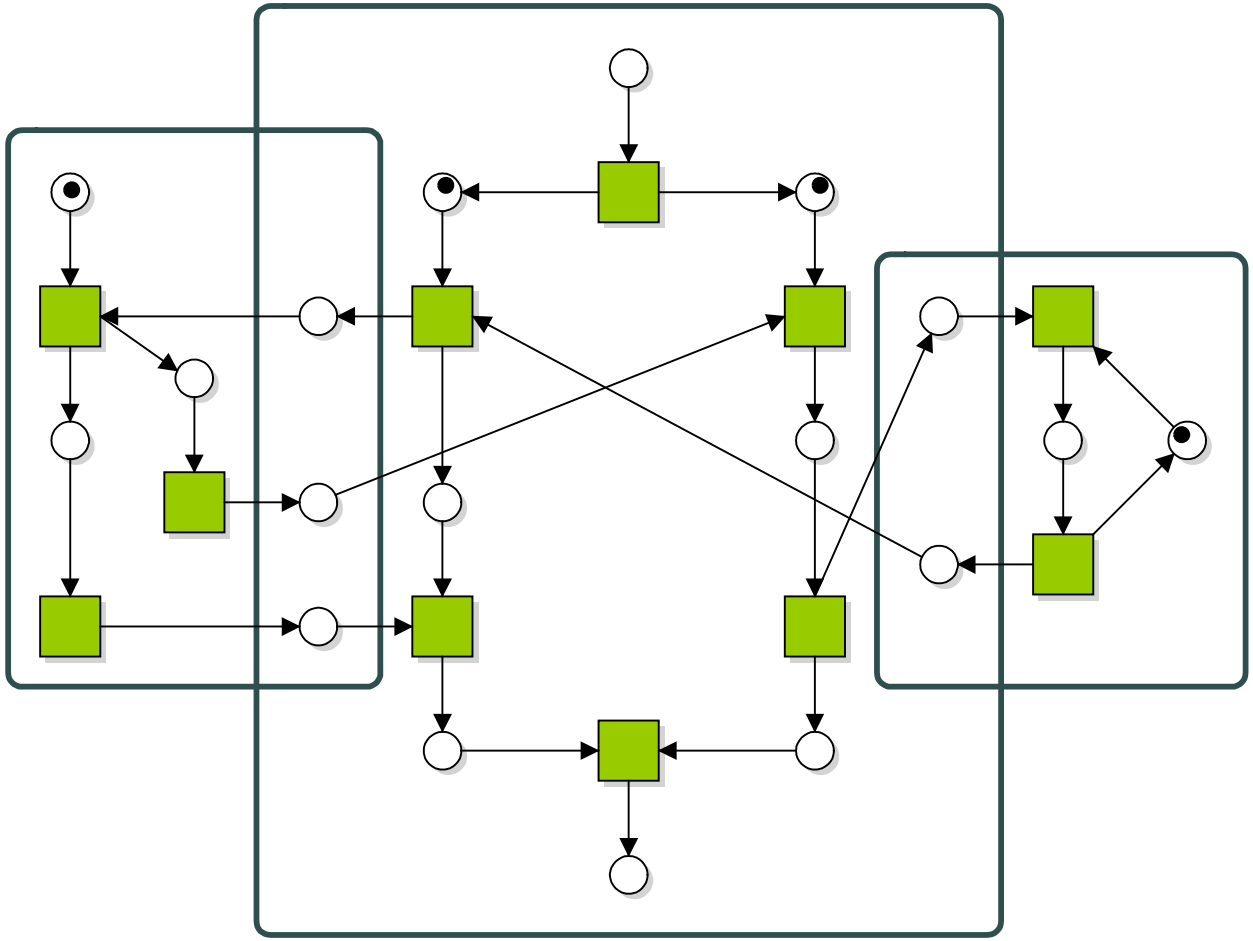
Correctness:

1. Weakly terminating
   Always possible to reach a stable state
2. Proper completion
   If a marking covers a stable state, it is a stable state.

How to check 3 components?



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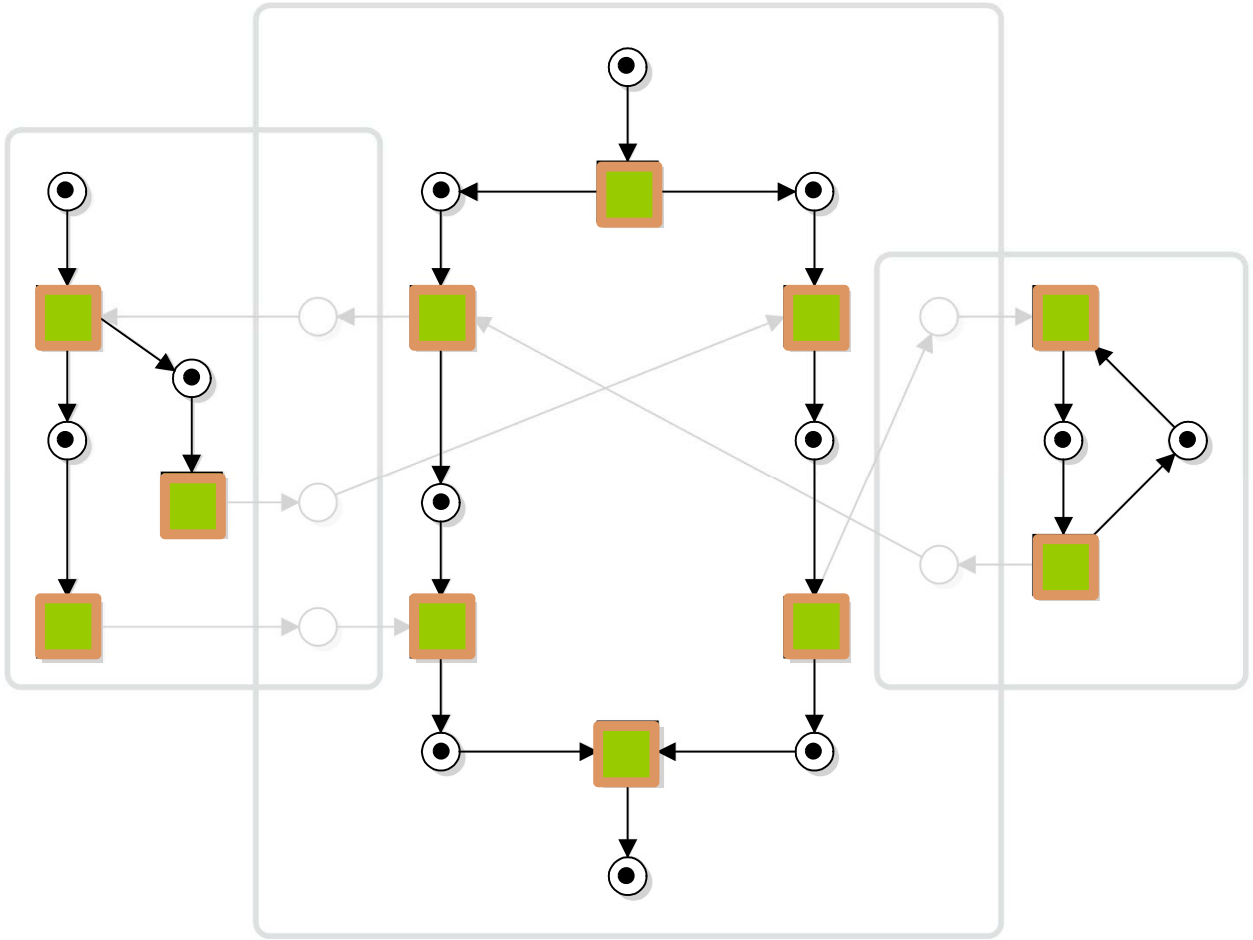

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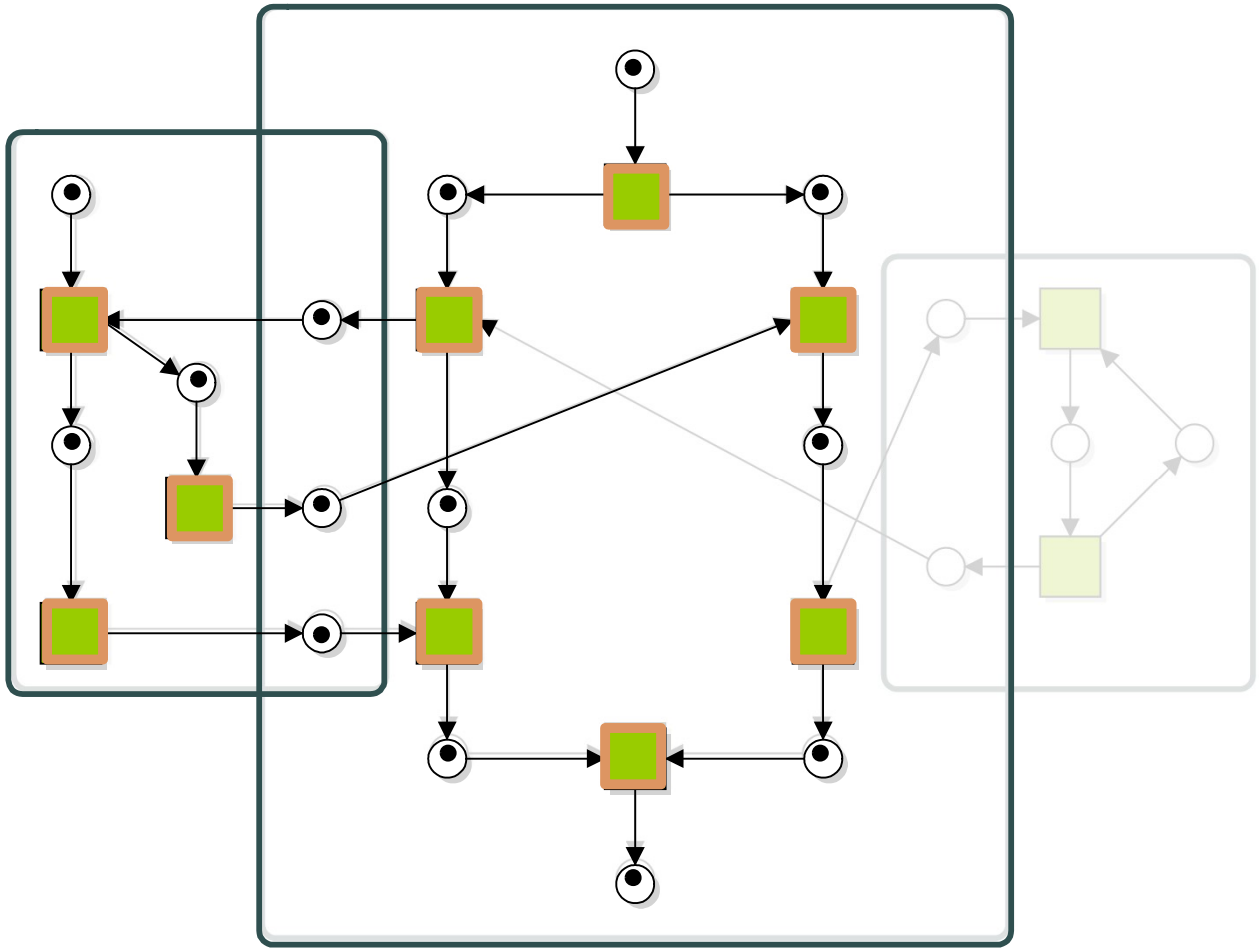

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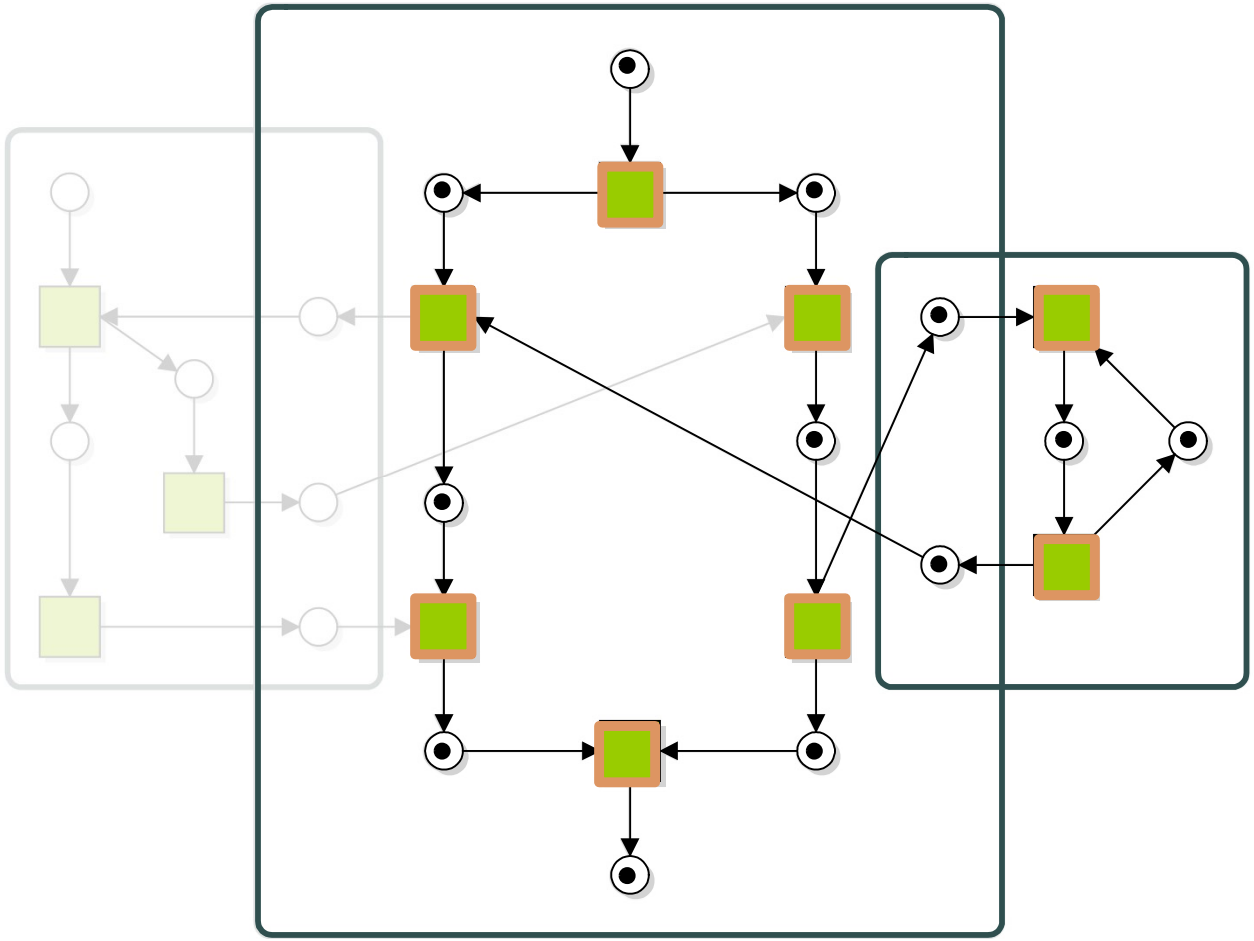

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Choreographies and their implementation

Correctness:

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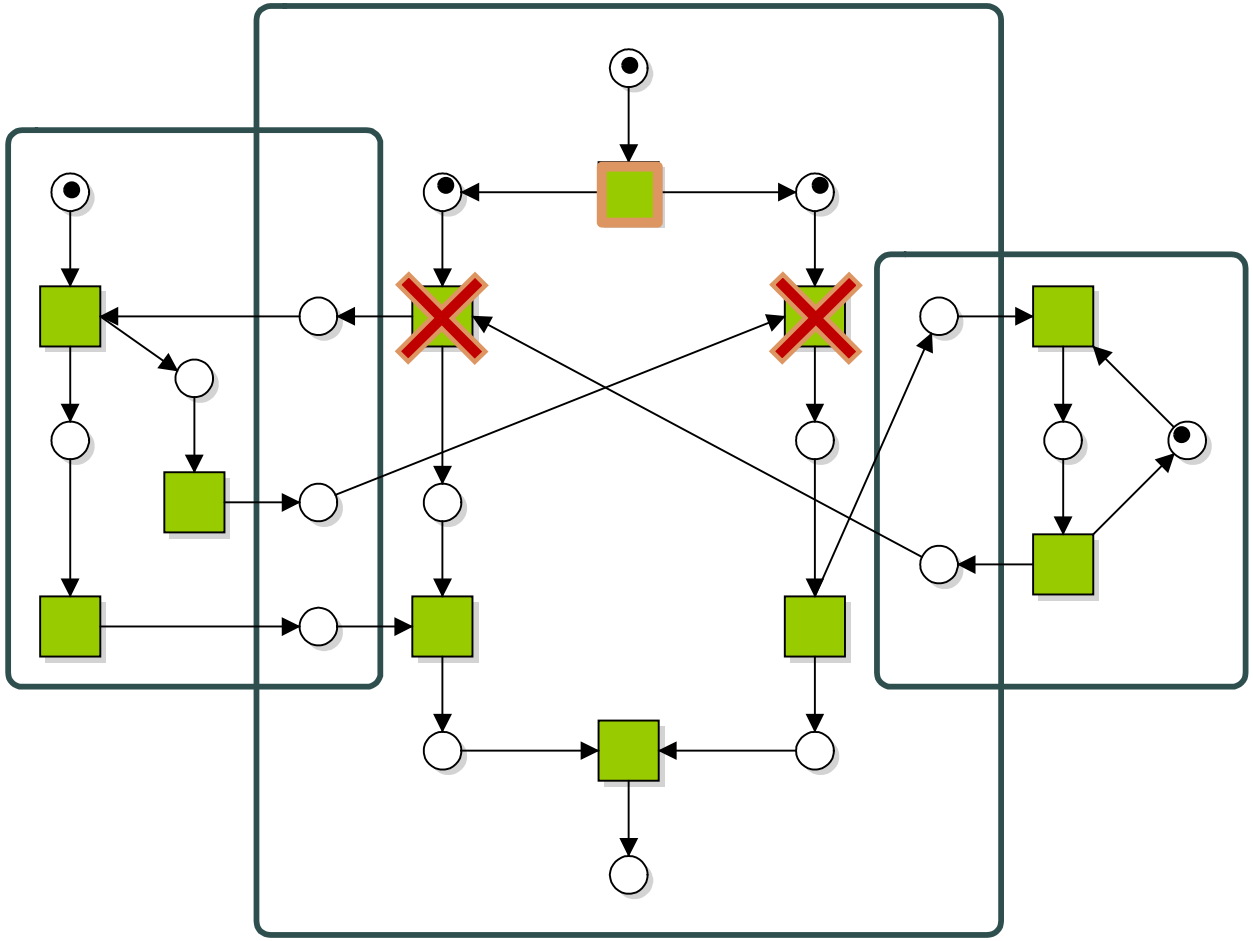
   If a marking covers a stable state, it is a stable state.



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How to check 3 components?

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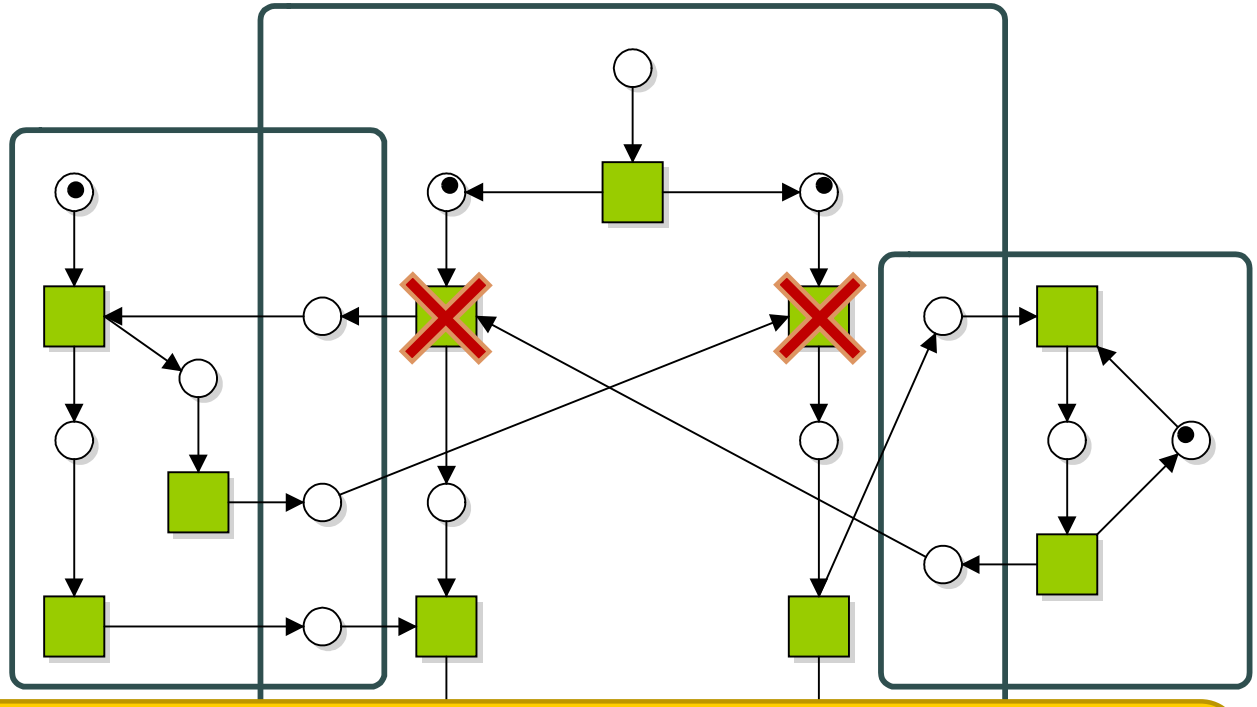

Correctness is not a sufficient condition to pairwise validate the component interactions

In general: this problem is **undecidable!**

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Choreographies: a different perspective on concurrency

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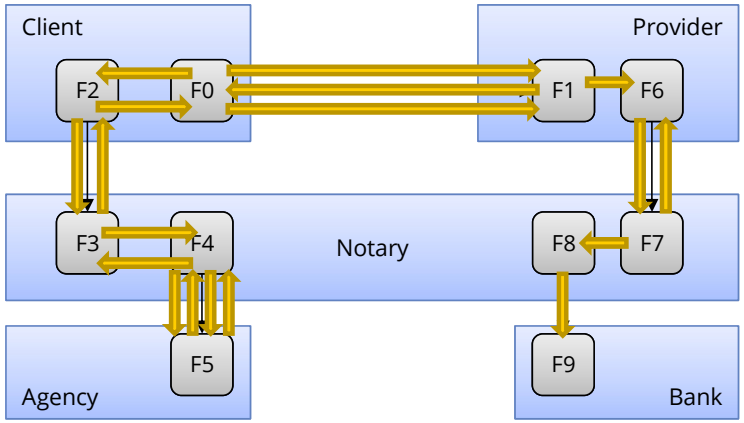
Logical model and scenarios



- Scenario is a sequence of function calls
- Formal definition:

  Given a logical model $(C, F, h, \rightarrow)$**,**
  a scenario is a partial order over the function calls,
  i.e., $\sigma \in (\rightarrow)^*$ **such that:**

  Functions can only start if being called before:

  $$\forall 1 < i < |\sigma| : \left(\exists 1 < j < i : \pi_3(\sigma(j)) = \pi_1(\sigma(i))\right)$$

Key:
F0: Request service
F1: Handle service request
F2: Request approval
F3: Receive approval request
F4: Validate client
F5: Do credibility check
F6: Request payment
F7: Check payment request
F8: Send payment
F9: Make payment

Given a set A, a sequence of length $n \in \mathbb{N}$ is a function $\sigma : \{1..n\} \rightarrow A$

- We write $\sigma = \langle a_1, \ldots, a_n \rangle$ if $\sigma(i) = a_i$ for all $1 \leq i \leq n$.
- We denote its length by $|\sigma|$
- If $n = 0$, we call it the empty sequence, and denote it with ϵ
- The set of all finite sequences over A is denoted by A^*

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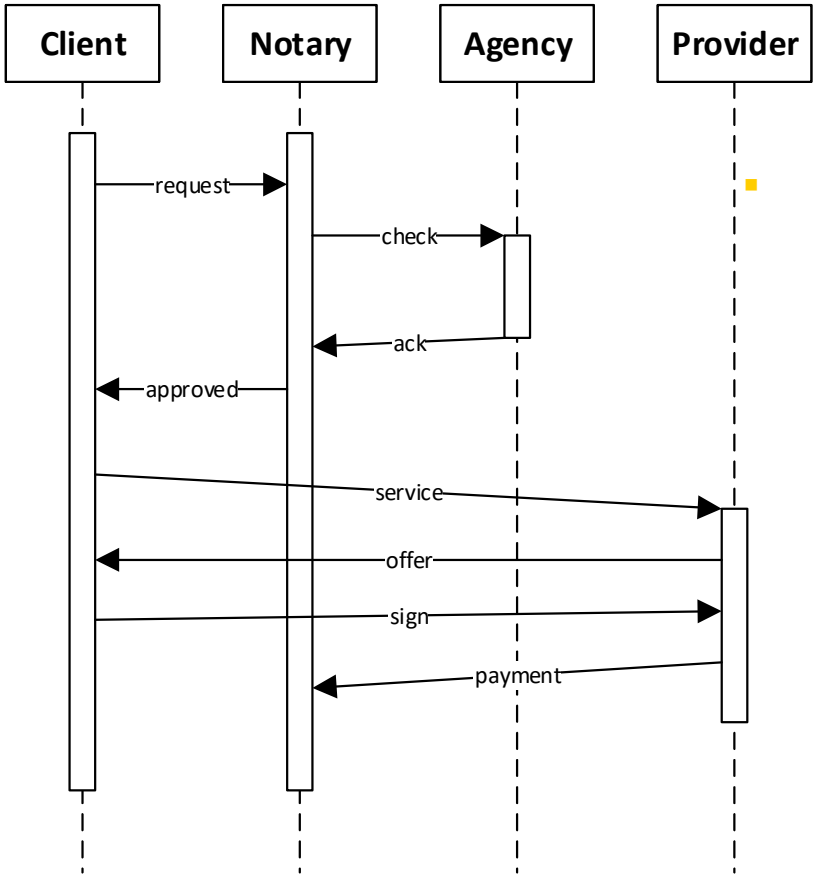
Sequence diagrams



Scenario is a sequence of function calls

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  Given a logical model $(C, F, h, \rightarrow)$**,**
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  Functions can only start if being called before:
  $\forall 1 < i < |\sigma| : \left(\exists 1 < j < i : \pi_3(\sigma(j)) = \pi_1(\sigma(i))\right)$

$\sigma =$ <(C,request, N) , (N,check, A) , (A,ack, N) , (N,approved, C) , (C, service, P) , (P, offer, C), (C, sign, P), (P, payment, N) >

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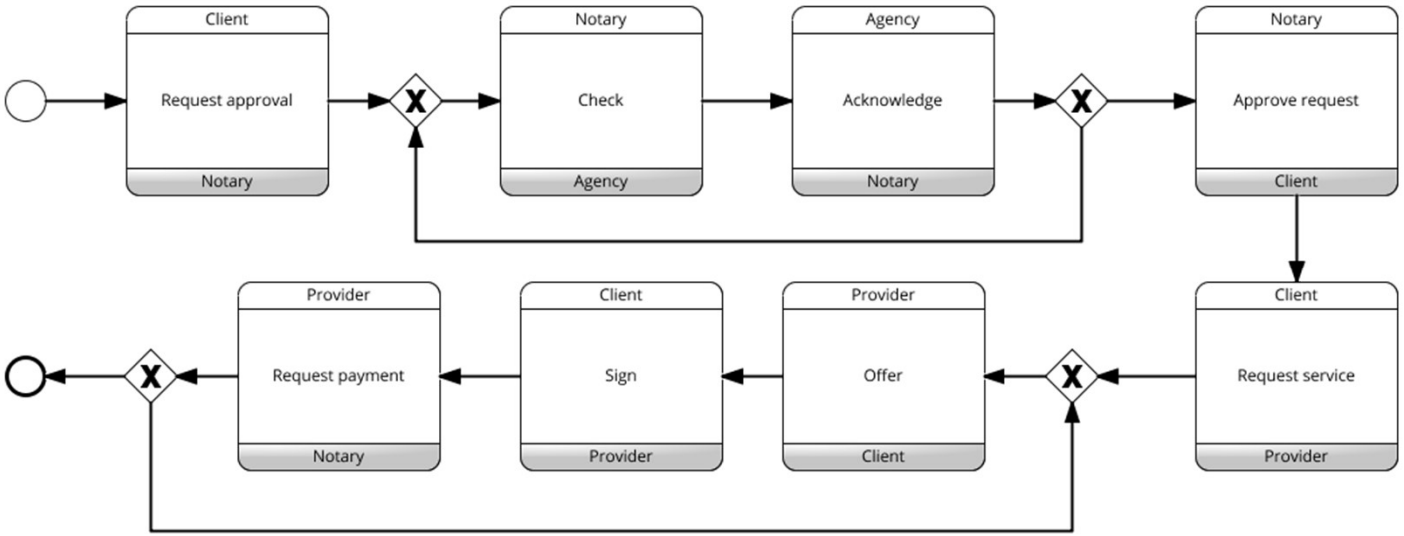
A choreography

- Models conversations
  - **A conversation is a sequence of message exchanges**
- A Choreography:
  - **All conversations that are allowed.**
  - **Based on BPMN**



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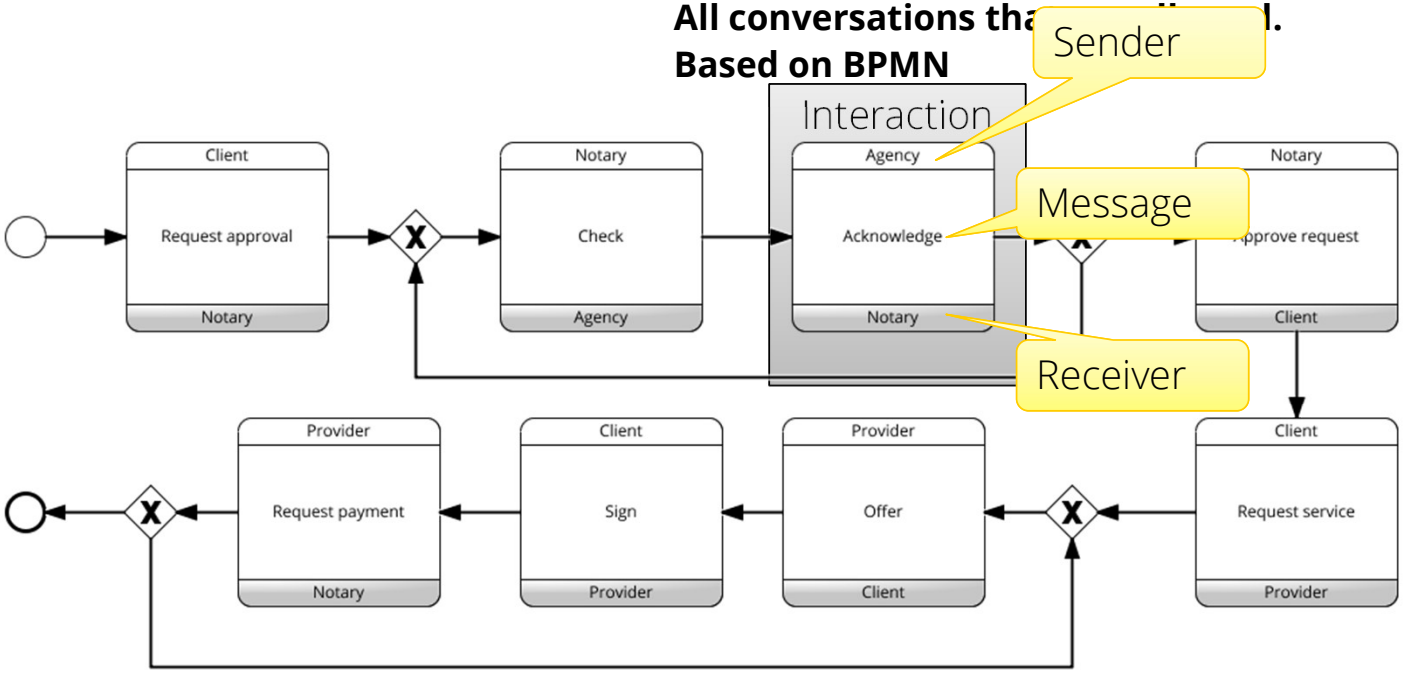
A choreography

- Models conversations
  - **A conversation is a sequence of message exchanges**
- A Choreography:
  - **All conversations tha[illegible]l.**
  - **Based on BPMN**



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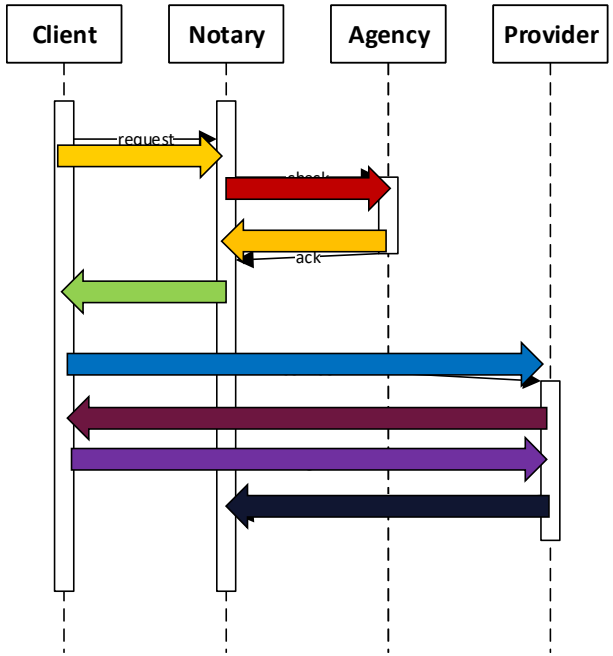
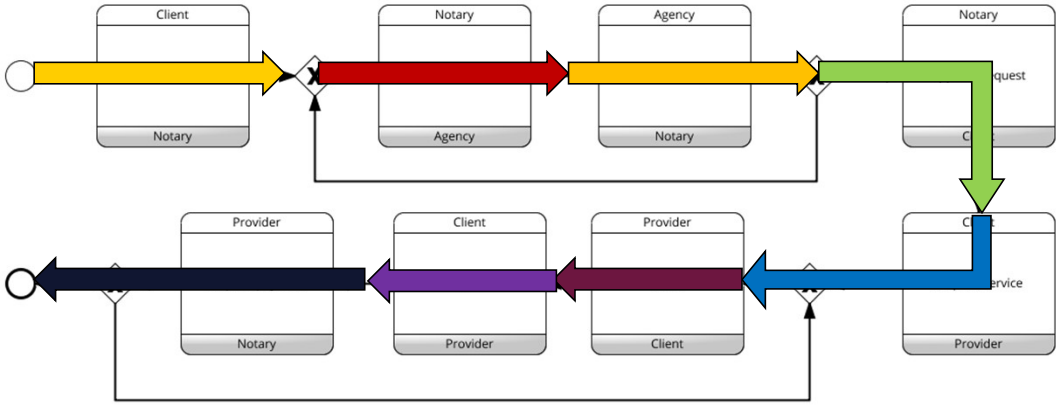


Choreographies and Message Sequence Charts

- A choreography describes all valid conversations



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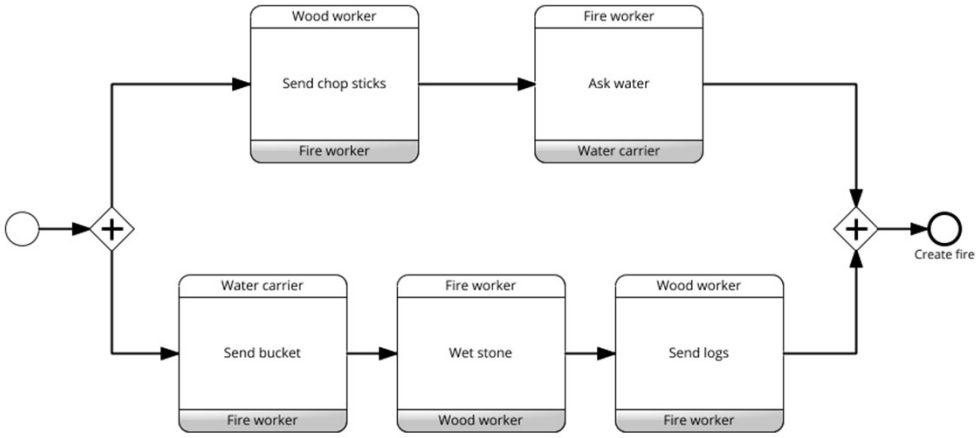
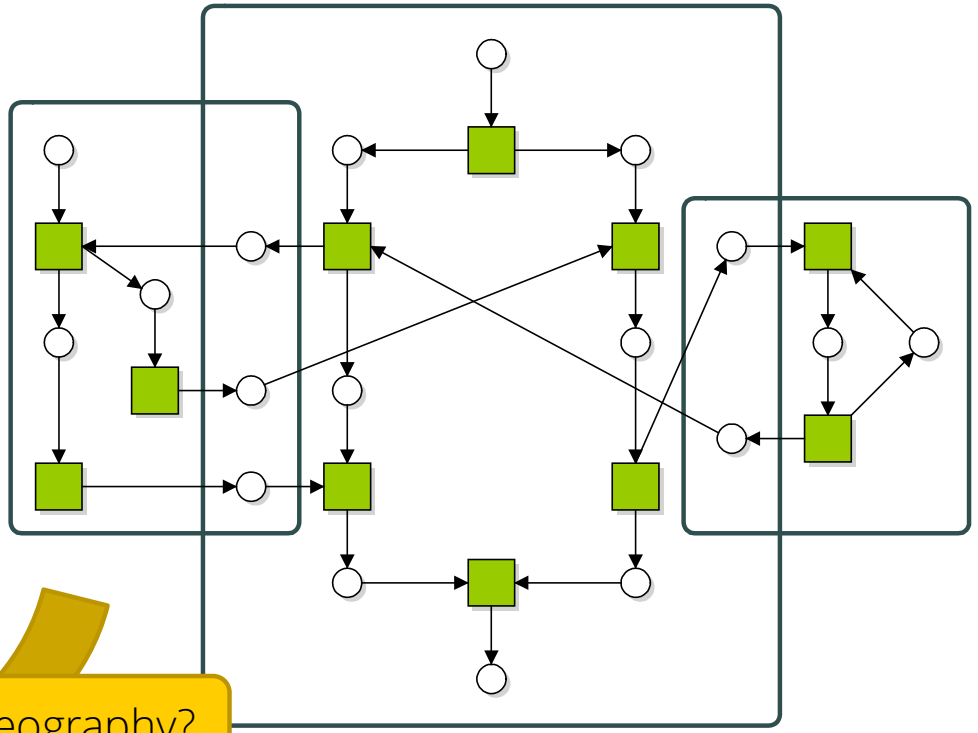
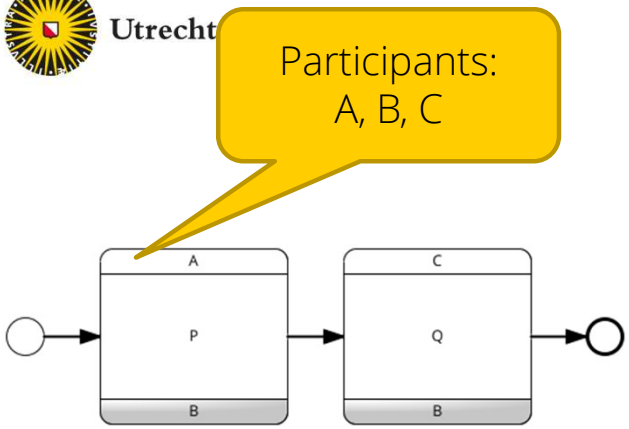
Back to our previous example...





Is this Petri net a realization of this choreography?

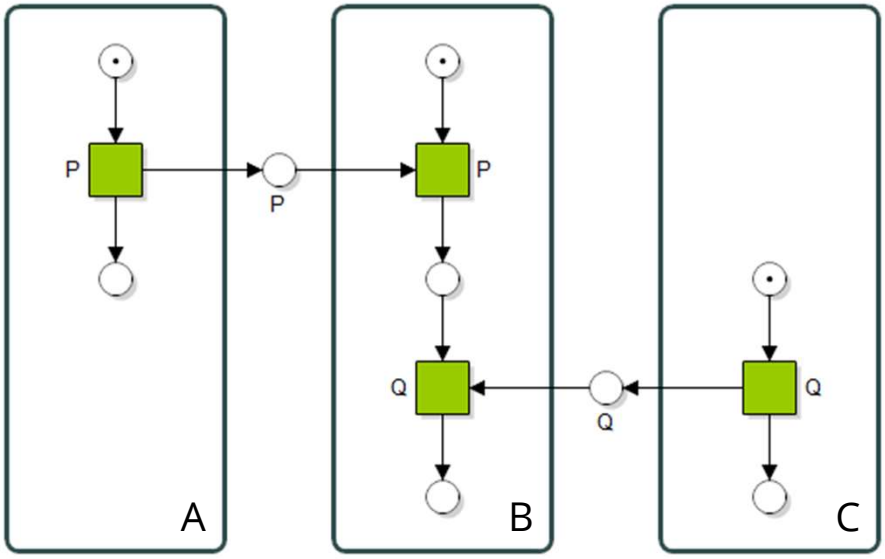
No! Actually: no choreography can be constructed with this PN as some realization!



Is every choreography "correct"? From choreography to Petri net

- Realizable:

  There exists an implementation "such that the set of conversations (possibly infinite!) the implementation supports is equal to the set of conversations in the choreography (possibly infinite!).



1: translate model to a Petri net "a la BPMN"
2: replicate net for each participant
3: create a place for each message
4: connect the participants to the messages

Sending participant produces token
Receiving participant consumes token

5: simplify the model using Murata rules

(Murata, 1989)

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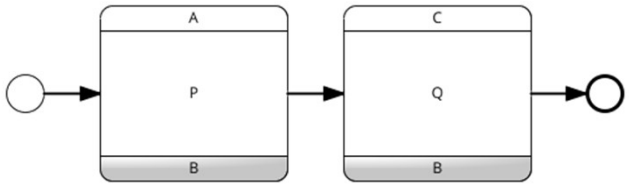
Is every choreography “correct”?



- Realizable:

  There exists an implementation “such that the set of conversations (possibly infinite!) the implementation supports is equal to the set of conversations in the choreography (possibly infinite!).

There may be many implementations that realize the same choreography!

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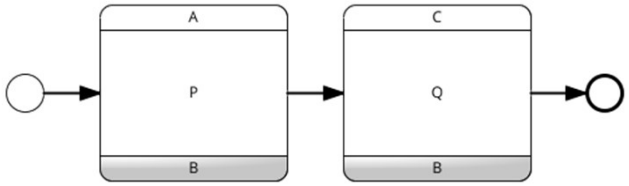
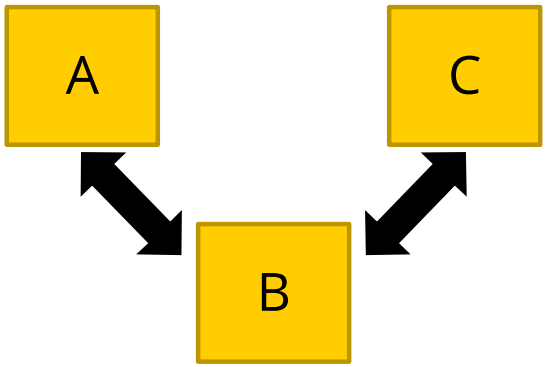
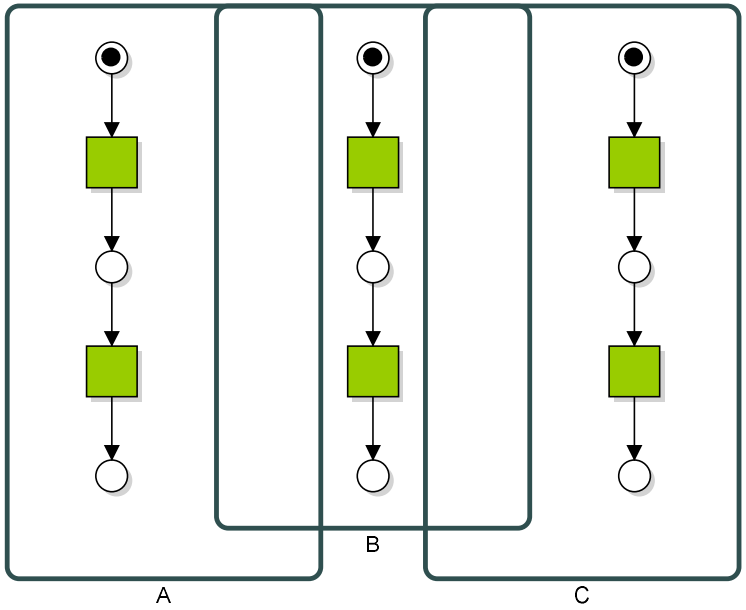
Is every choreography “correct”?







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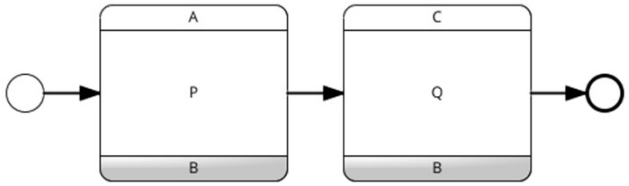
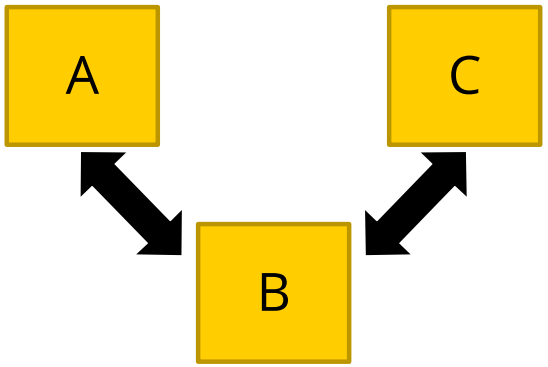
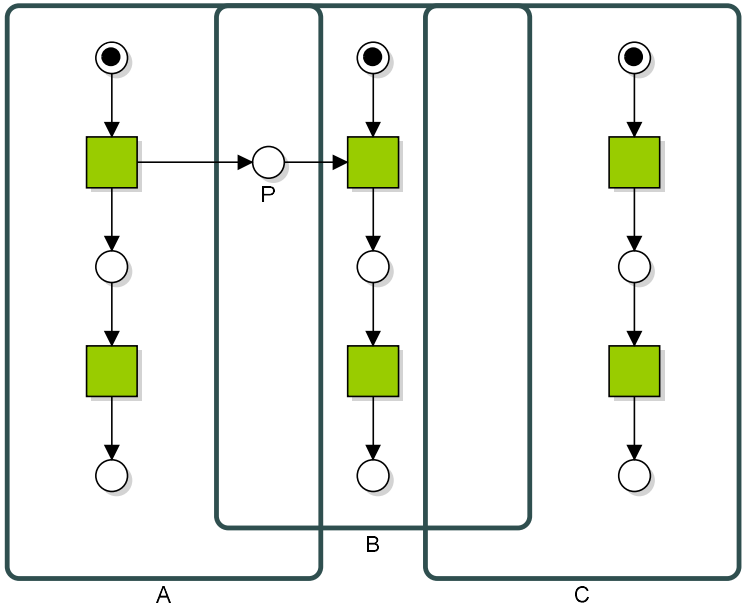
Is every choreography “correct”?







JMvdW2

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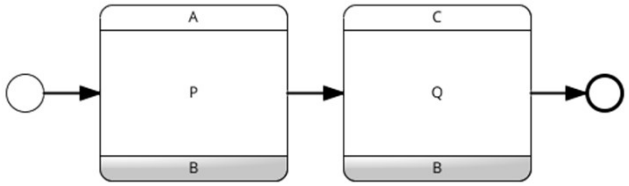
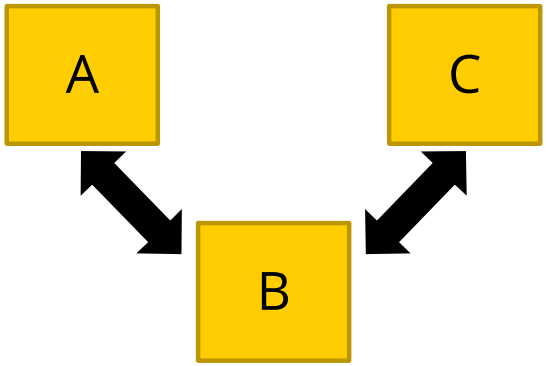
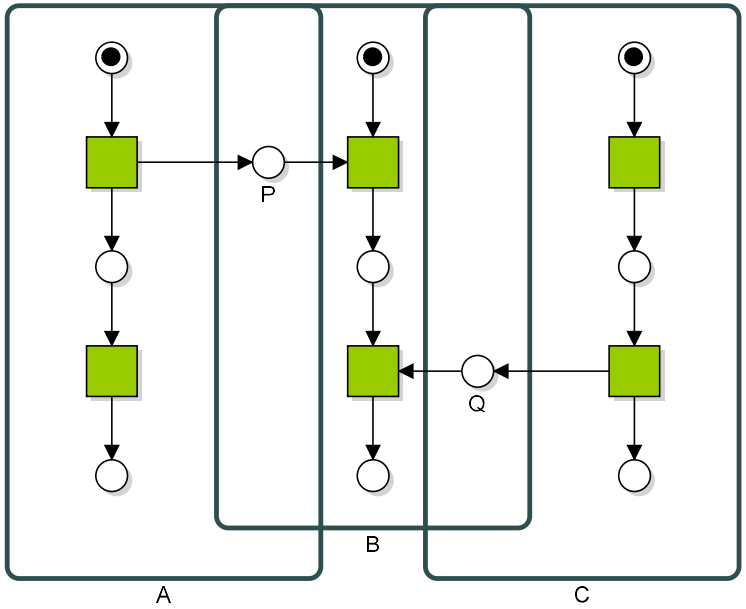
Is every choreography “correct”?







Slide 46

JMvdW2 Toevoegen blauwe en rode run (realiseerbaar en niet realiseerbaar)
Jan Martijn van der Werf; 21-10-2021

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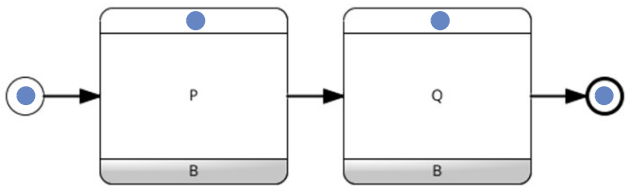
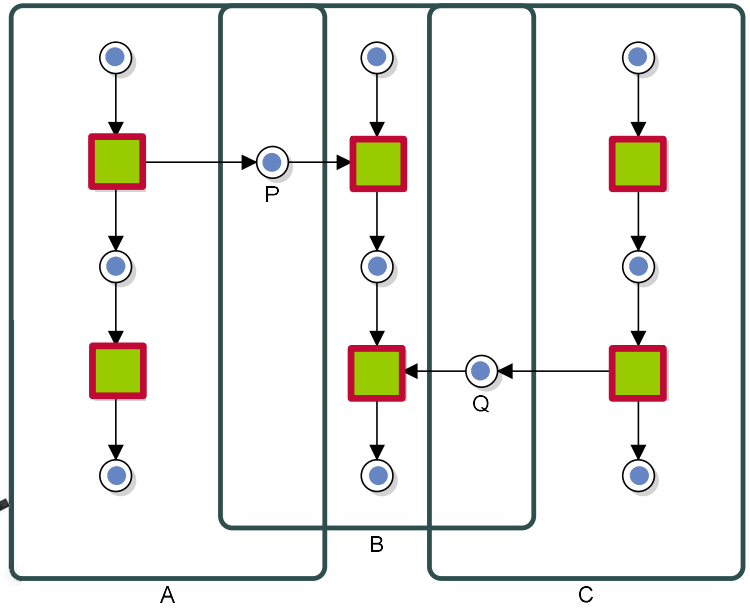
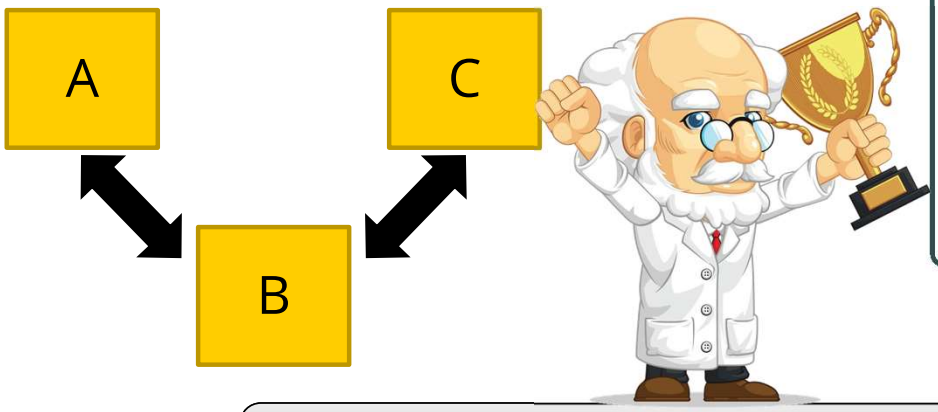
Is every choreography “correct”?







This is a run of the choreography realized by the system

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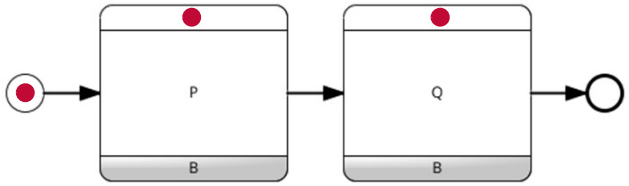
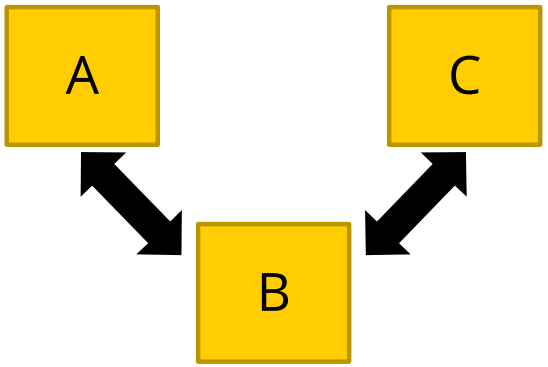
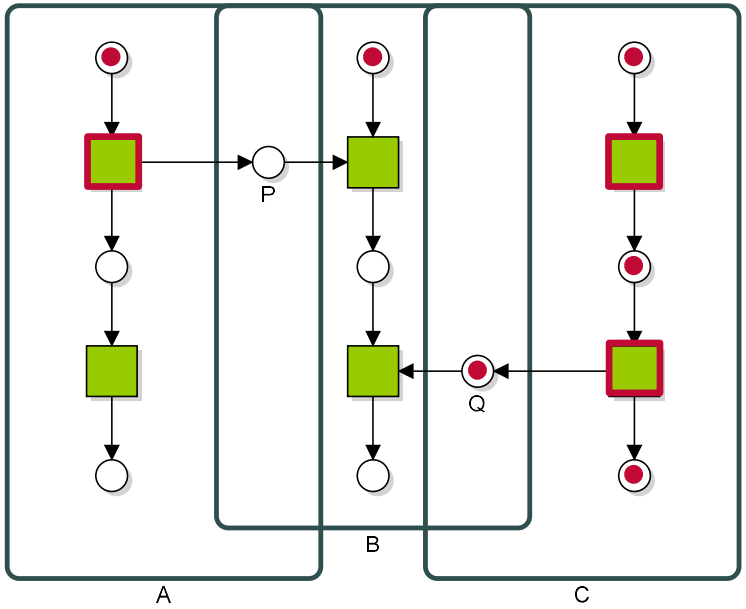
Is every choreography “correct”?







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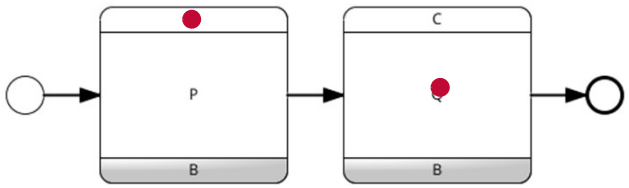
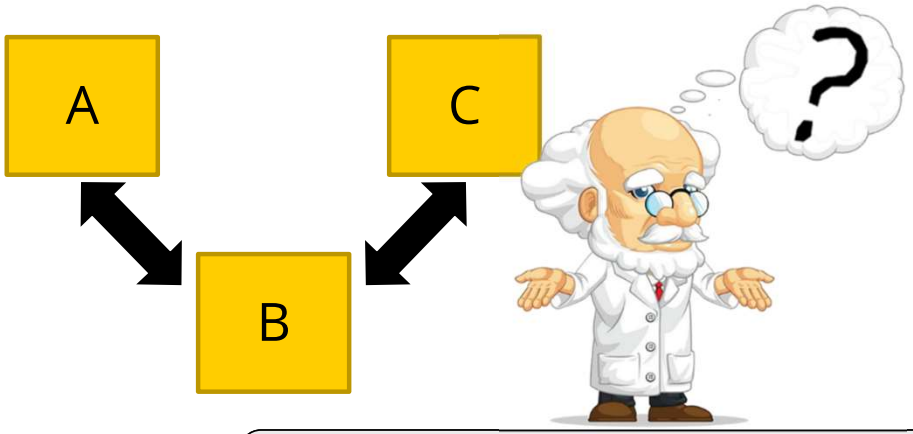
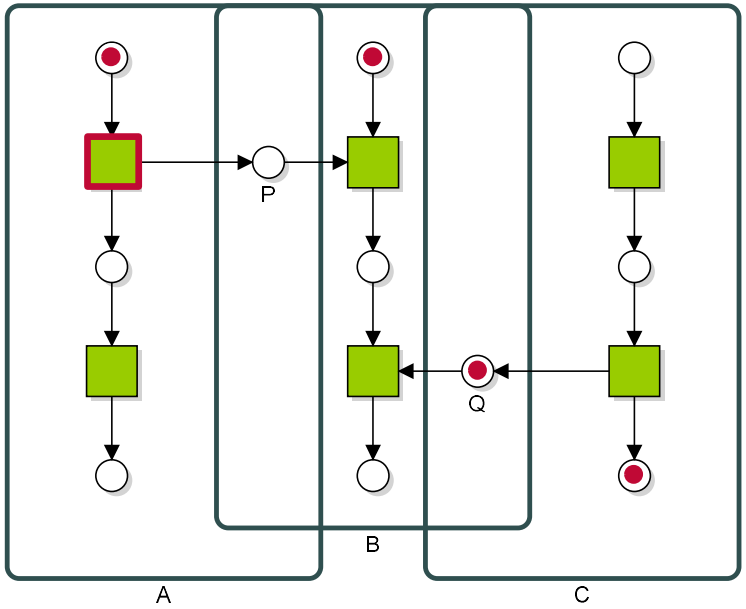
Is every choreography “correct”?







How does C know whether A sent its message?

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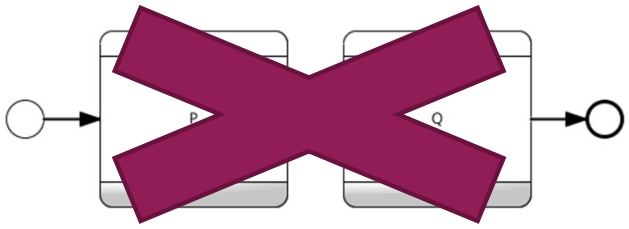
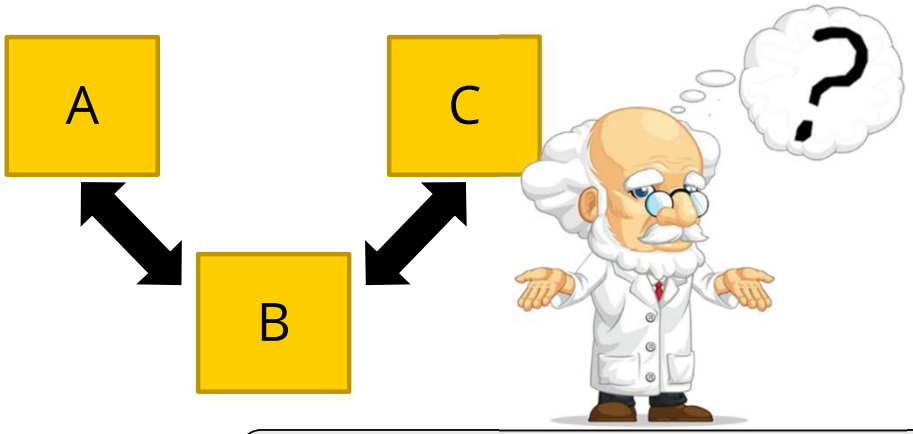
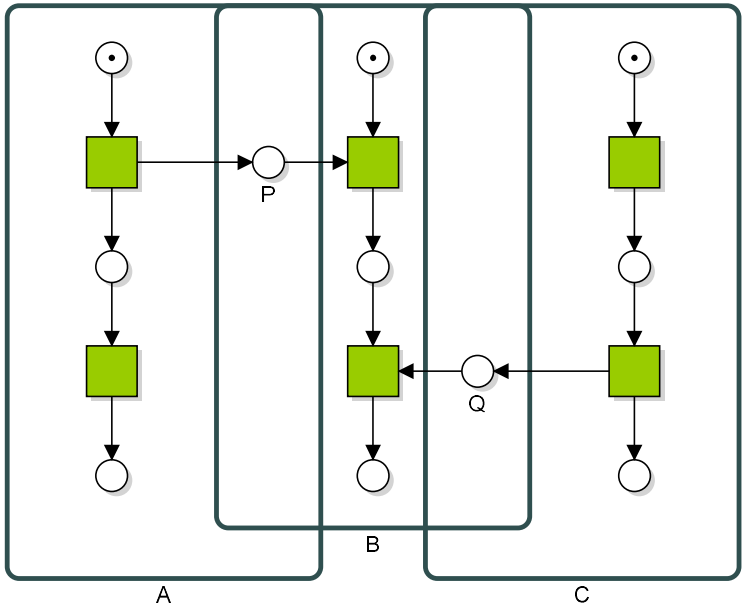
Is every choreography “correct”?







How does C know whether A sent its message?

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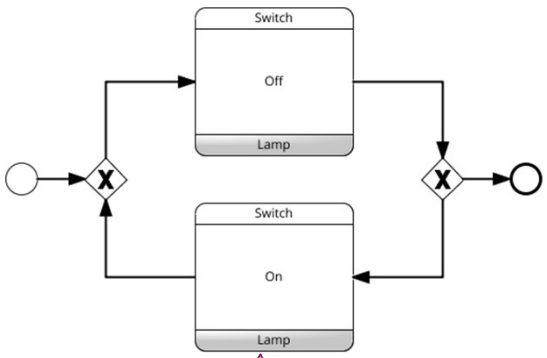
Rules on choreographies
A sufficient condition



Loop, but only 1 party sends

A choreography is correct if **all** of the following hold:

1. Only 2 parties involved
2. No parallelism! (sorry…)
3. Each choice should be made by one party only
4. Both parties send at least one message
5. In any loop, both parties should at least send one message

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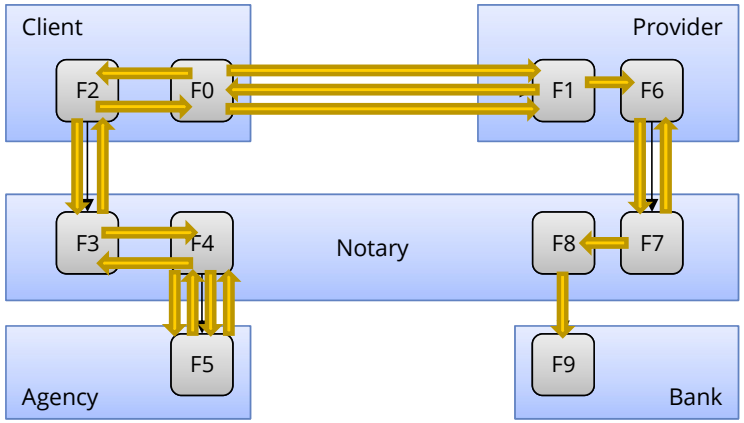
Define a Choreography for F0 and F1



- The client asks for permission. Upon receiving the permission, (s)he asks for a service of the provider, and either accepts or denies the offer received by the provider. Upon accepting, the provider offers the service, and regularly sends an invoice, which needs to be signed and returned by the client. Once denied, either (s)he stops, or (s)he asks for a better offer.
  In case the client does not receive permission, (s)he tries again.

Key:
F0: Request service
F1: Handle service request
F2: Request approval
F3: Receive approval request
F4: Validate client
F5: Do credibility check
F6: Request payment
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F8: Send payment
F9: Make payment

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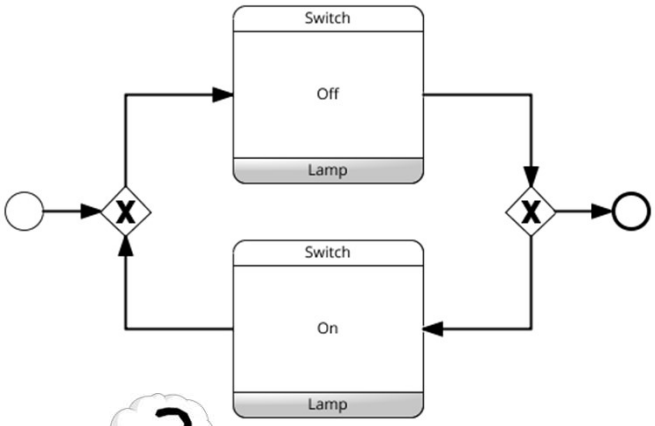
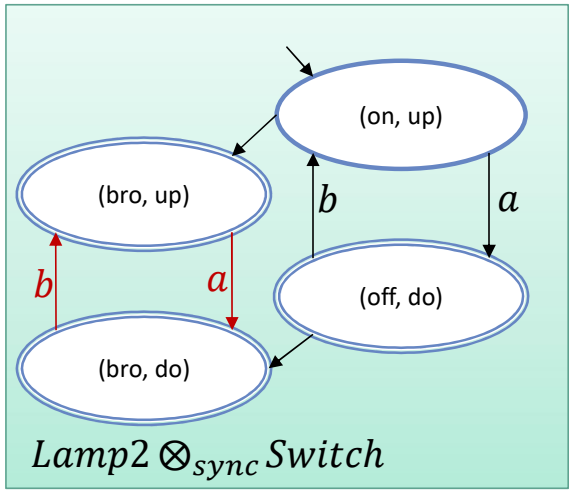
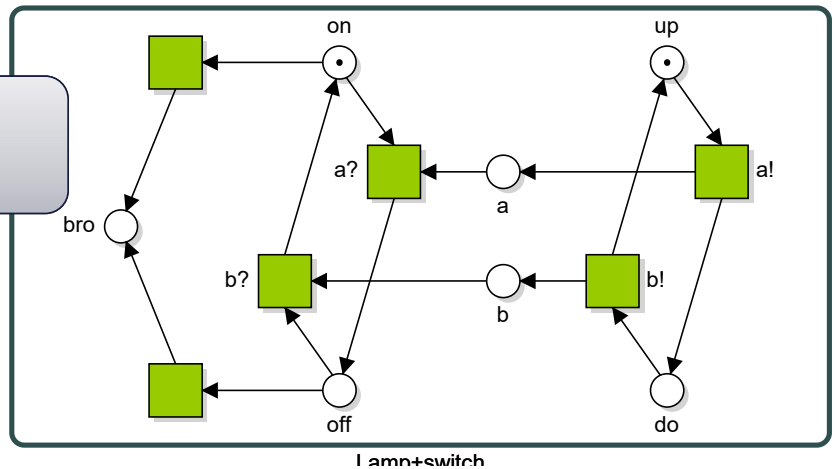
Realizability: asynchronous vs. synchronous





Which semantics do you choose? Why?

Realizable:
Synchronous : **yes**
Asynchronous : **no**



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Towards a construction method…

Research in progress

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How to model the containers?

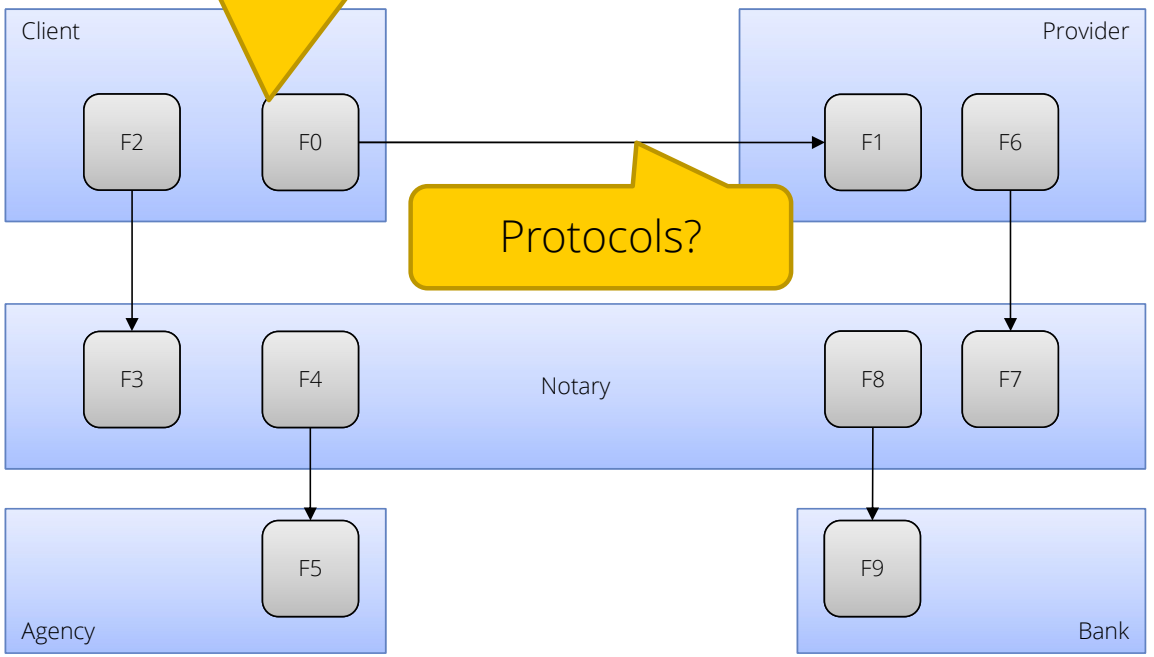
Allowed orders?

Internal dependencies?

Types of dependencies:
- Exclusion / choice
- Parallelism
- Loops

State diagrams?
- No parallelism

Petri nets?
- Feature == transition
- Places denote dependencies



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F6: Request payment
F7: Check payment request
F8: Send payment
F9: Make payment

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How to model the containers?

Types of dependencies:
- Exclusion / choice
- Parallelism
- Loops

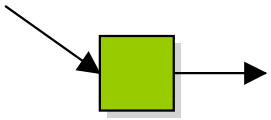
State diagrams?
- No parallelism

Petri nets?
- Feature == transition
- Places denote dependencies

Key:

F0: Request service
F1: Handle service request
F2: Request approval
F3: Receive approval request
F4: Validate client
F5: Do credibility check
F6: Request payment
F7: Check payment request
F8: Send payment
F9: Make payment

Function:



Dependency

Via places

Allowed order of functions?

Token game in Petri nets

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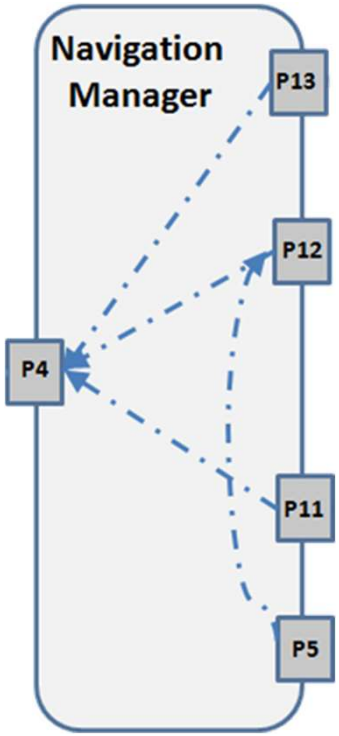
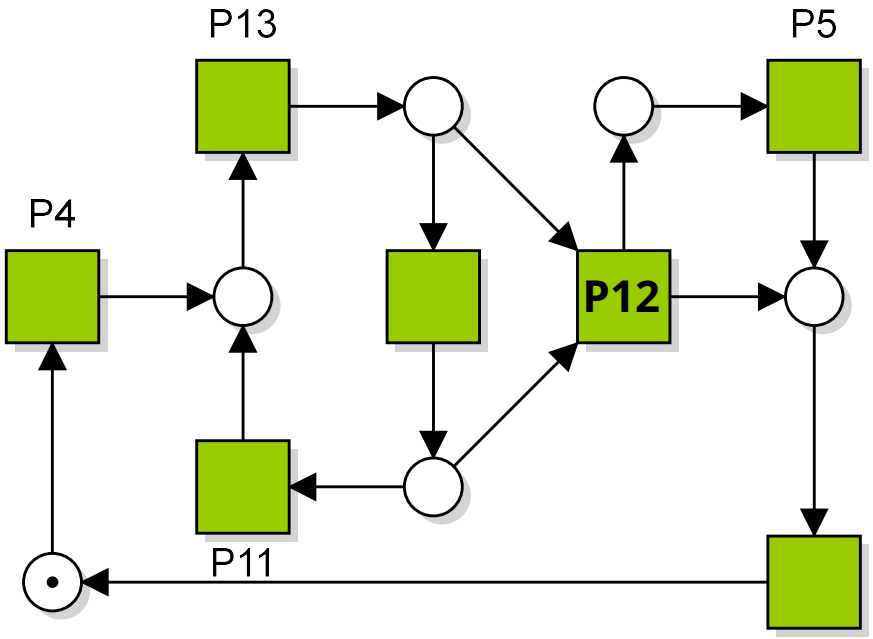
When is an internal specification correct?





Every function should always eventually be enabled?

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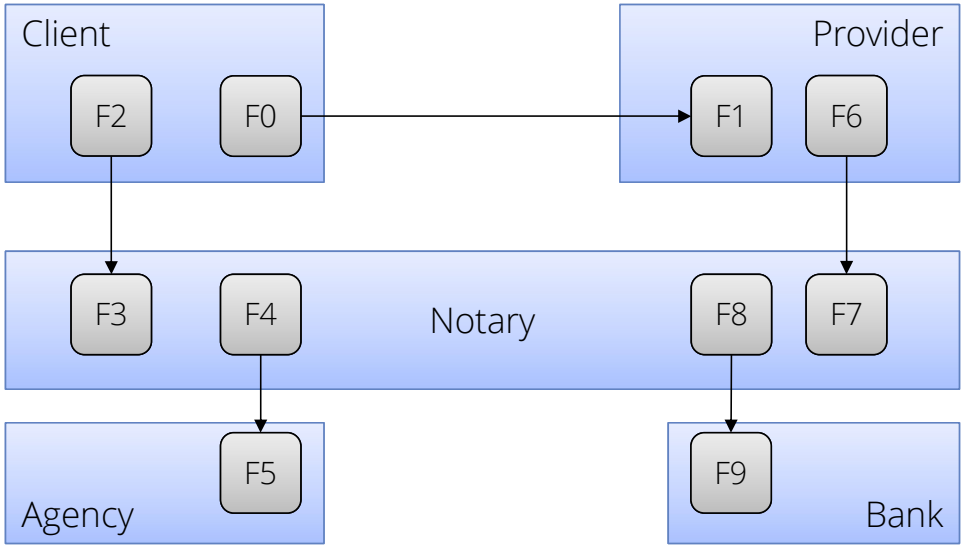
How to model the containers?



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Questions:

- ctions depend on another function?
- ctions may be called on their own?

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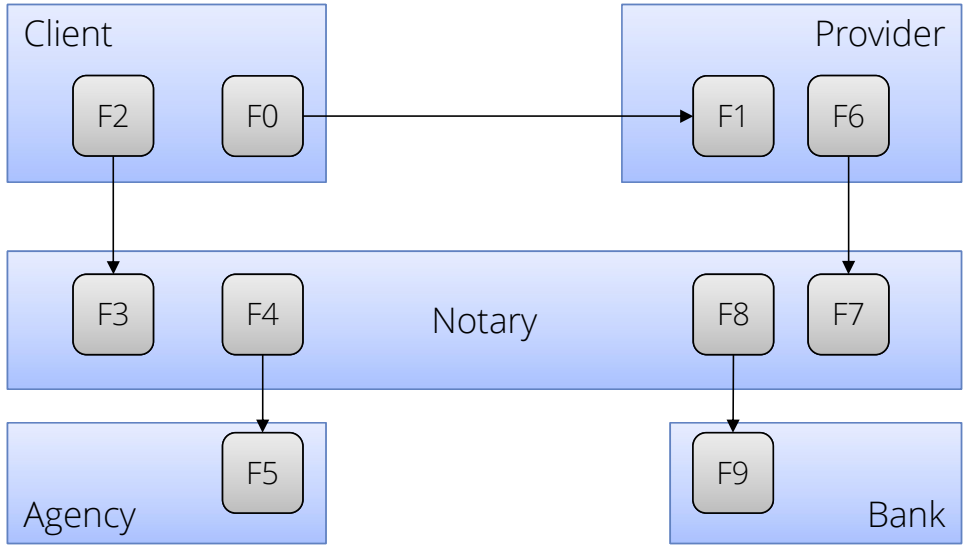
How to model the containers?



Questions:
1. Which functions depend on another function?
2. Which functions may be called on their own?

A function F is **independent** iff there are no functions that depend on F within the same container

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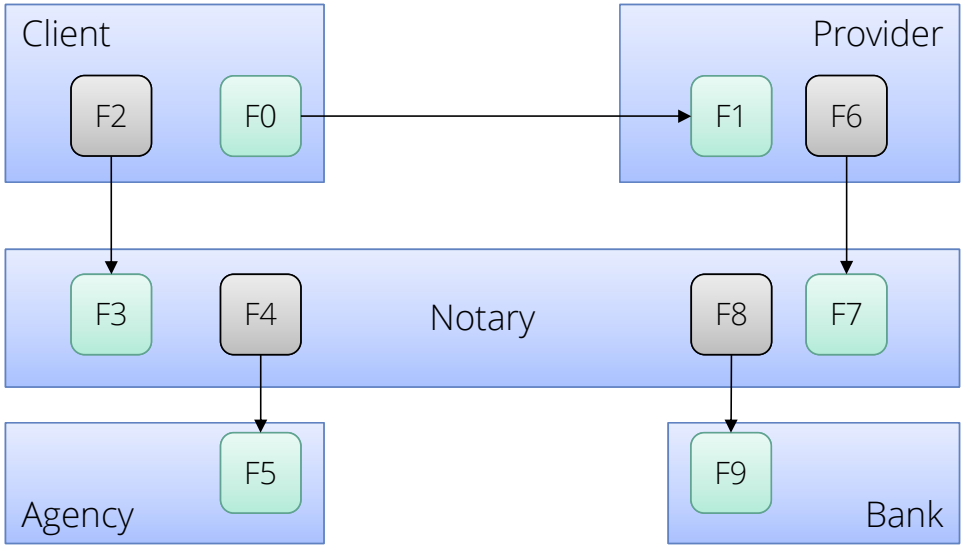
How to model the containers?



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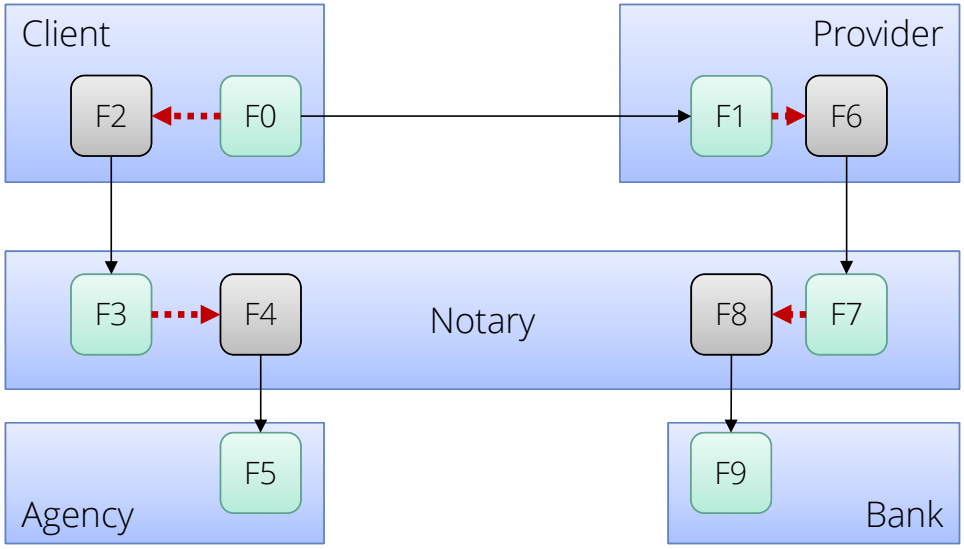
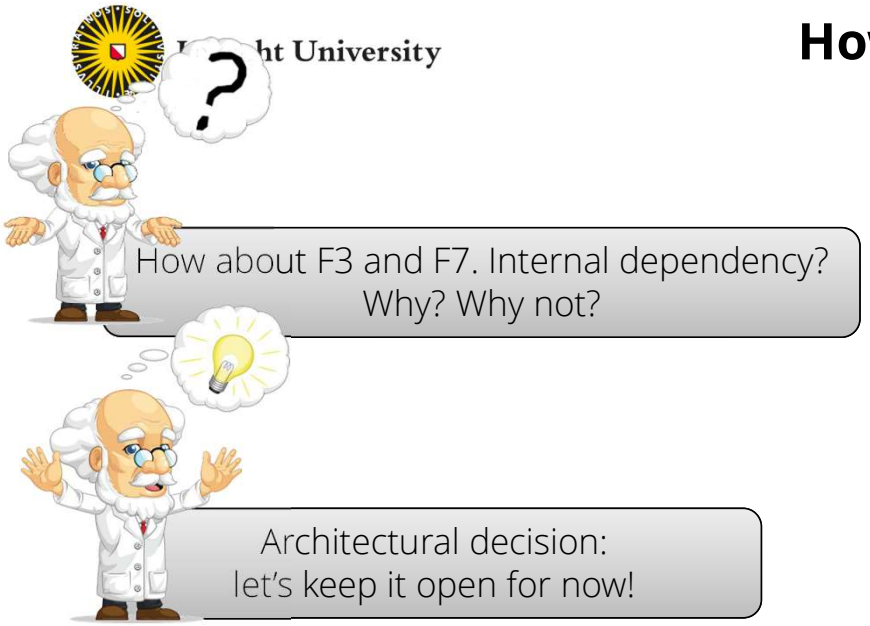


Two types of arrows in the logical model:

1. Function calls: between functions of **different** containers

2. Dependencies: "requires relation": A → B iff "A requires B to complete its function"

We use a dashed arrow for the requires relation!



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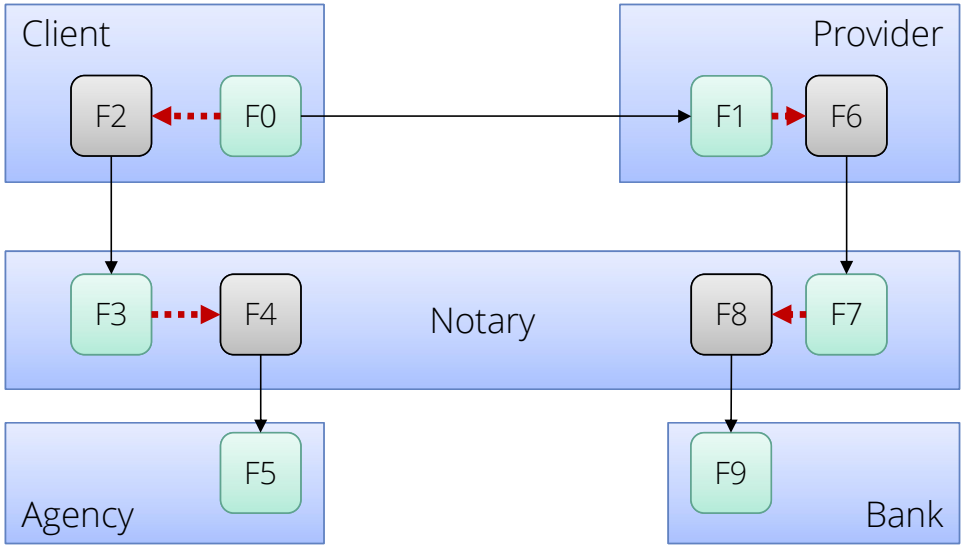

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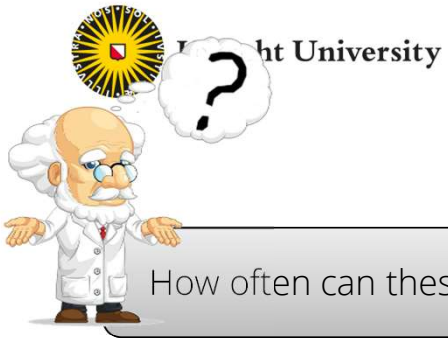

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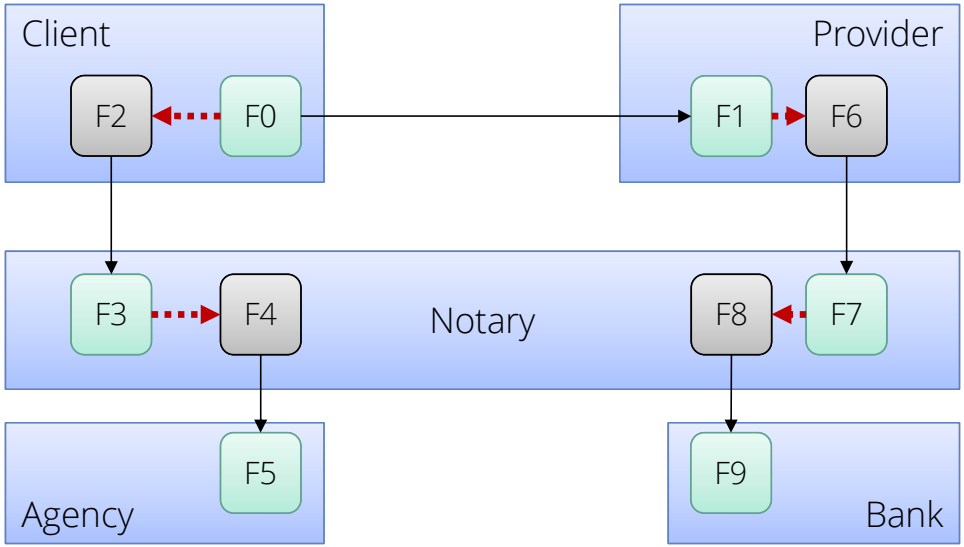

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We use a dashed arrow for the requires relation!

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Building a container net

- Each **independent** feature becomes a transition

- Questions your net should answer:

  Is it always possible to "restart" the module?
  Can the feature only be called once?

Refinement rules aid in building **correct** Petri nets!

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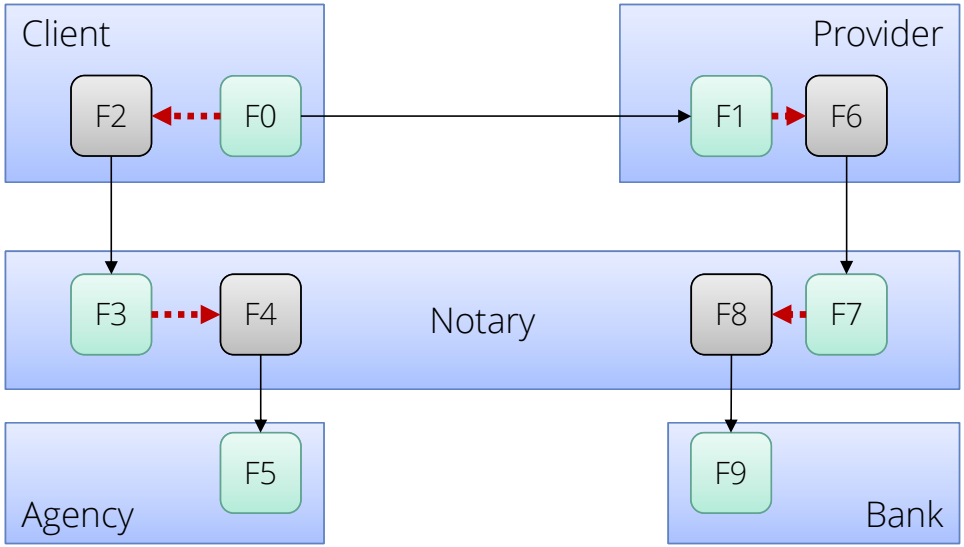
Transformation of LM into Petri nets



Rules of the transformation:

1. Dependencies between independent functions as **container nets**.

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Building a container net

- Each **independent** function becomes a transition
- Each container net starts with the following net:

- Stick to the Self-loop transition rule!

  Even the Jackson rules may introduce dead- and livelocks!

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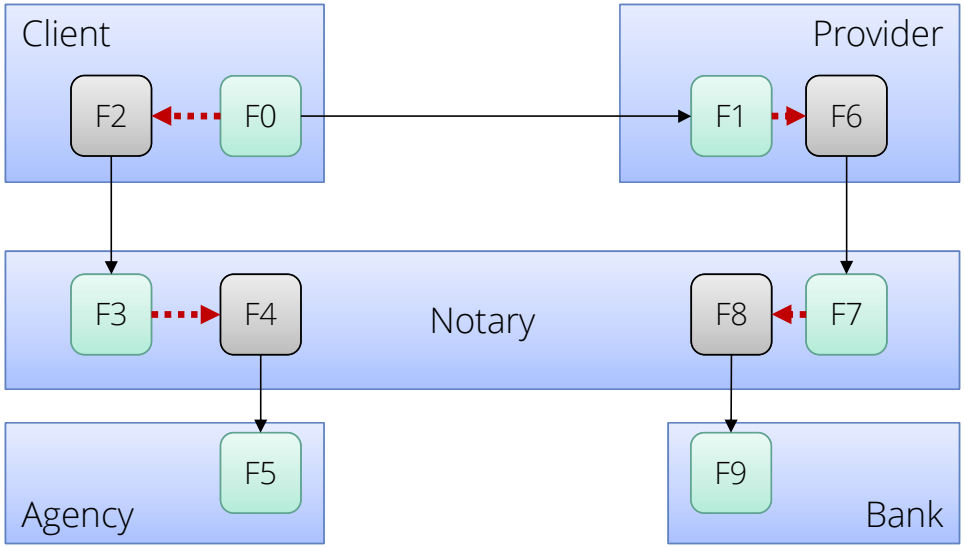
Transformation of LM into Petri nets



Rules of the transformation:

1. Dependencies between independent functions as **container nets**.

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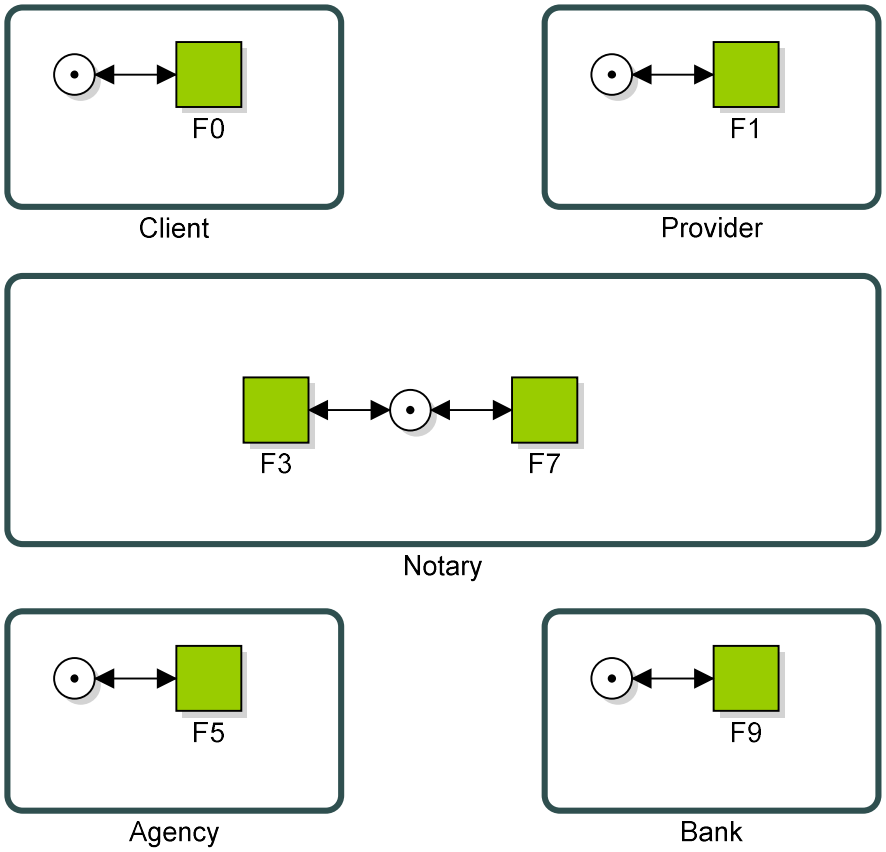
Step 1: create a “Flower model” with all independent functions



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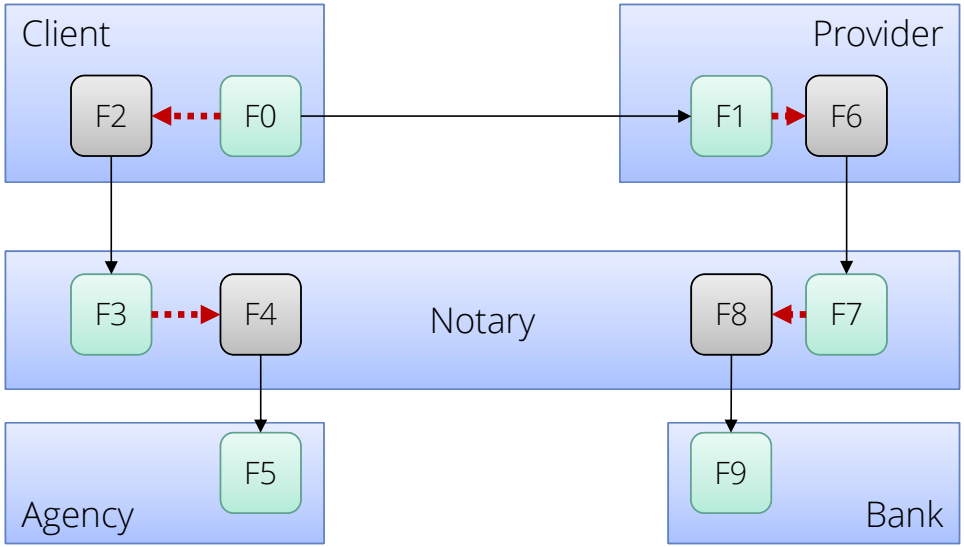
Transformation of LM into Petri nets



Rules of the transformation:

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2. Function calls are **protocol choreographies**.

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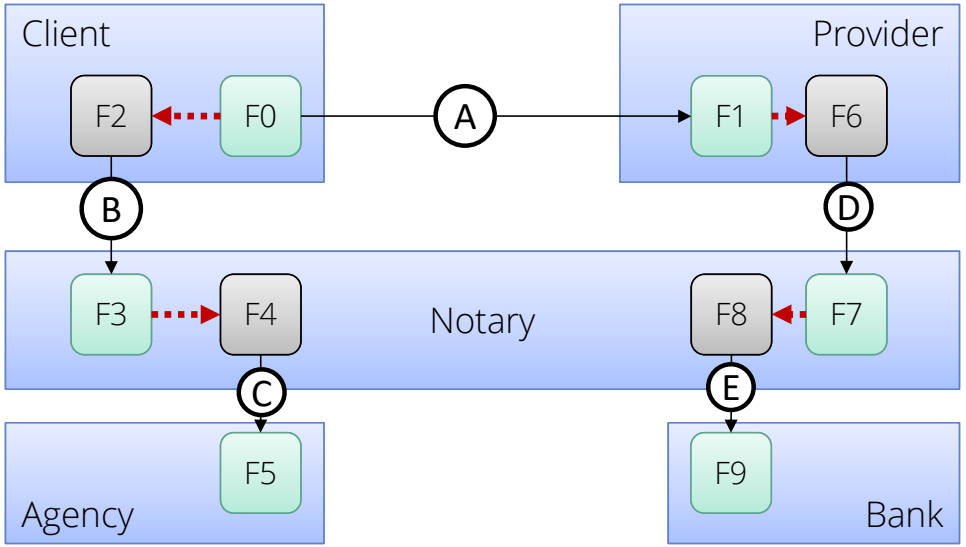
Transformation of LM into Petri nets



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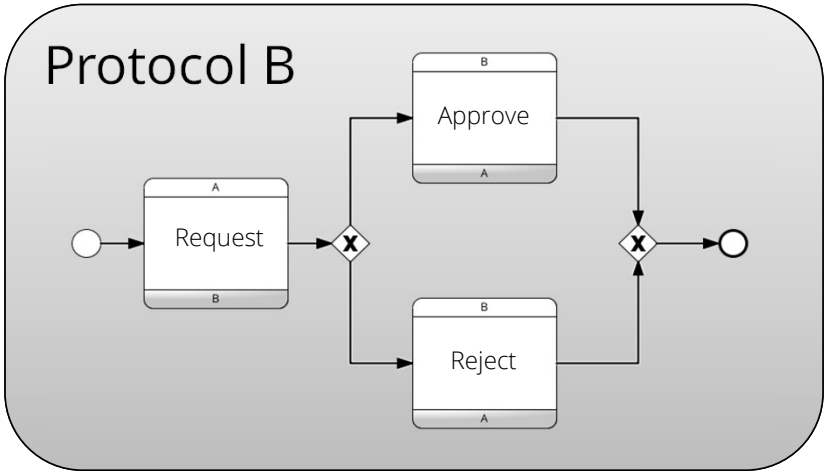
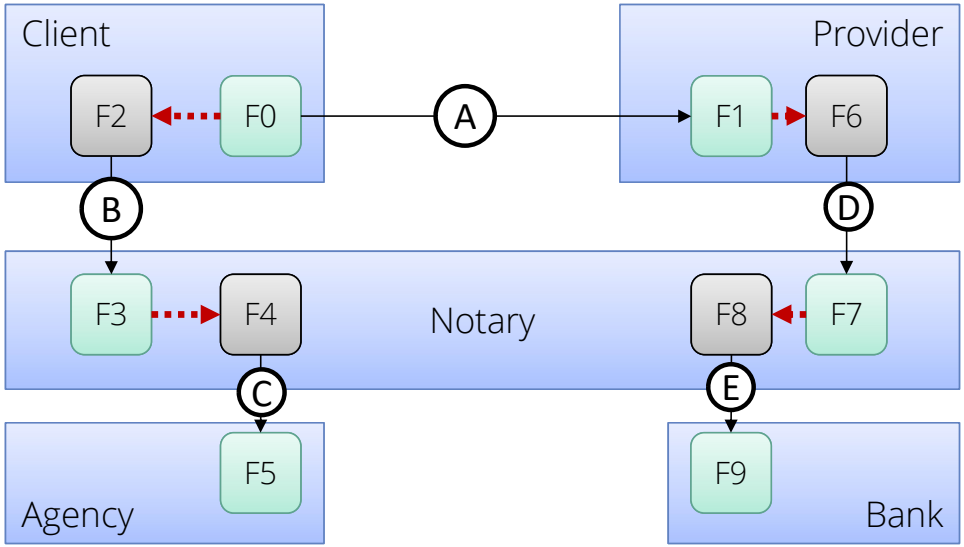
Transformation of LM into Petri nets





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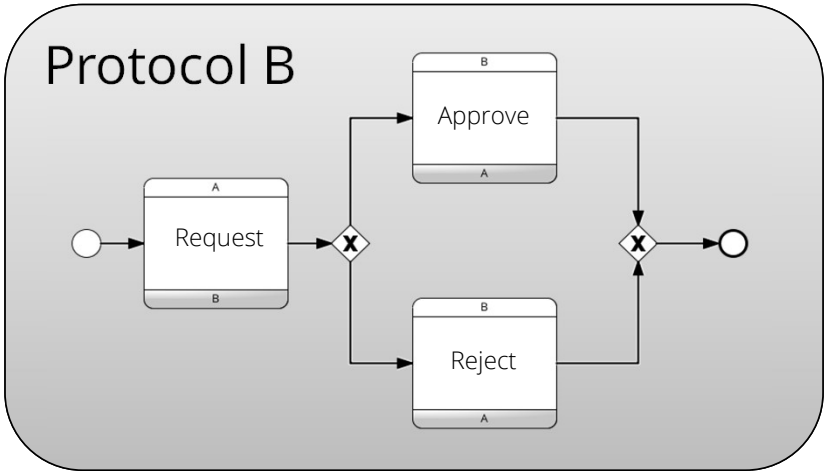
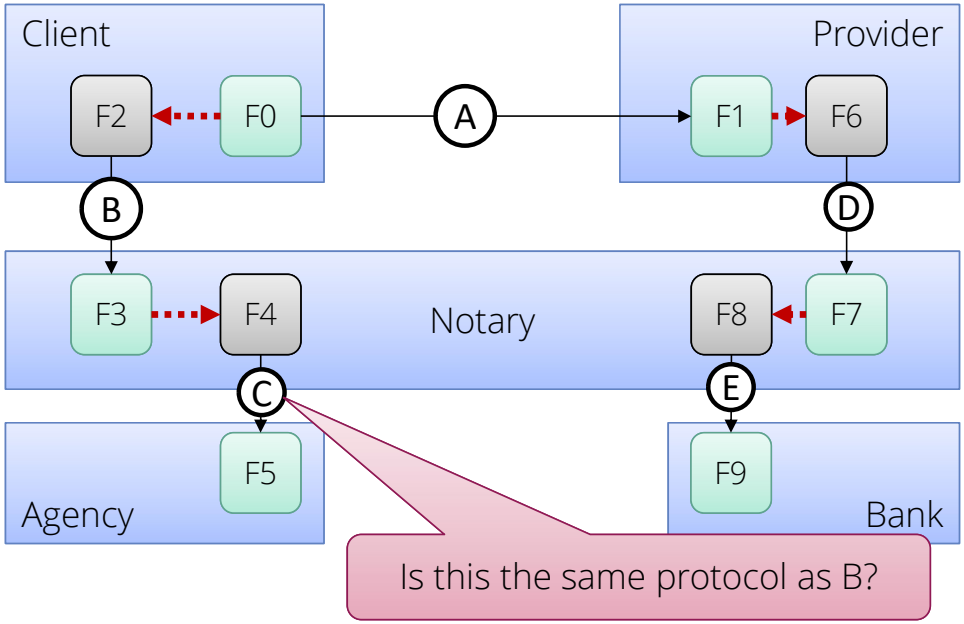
Transformation of LM into Petri nets





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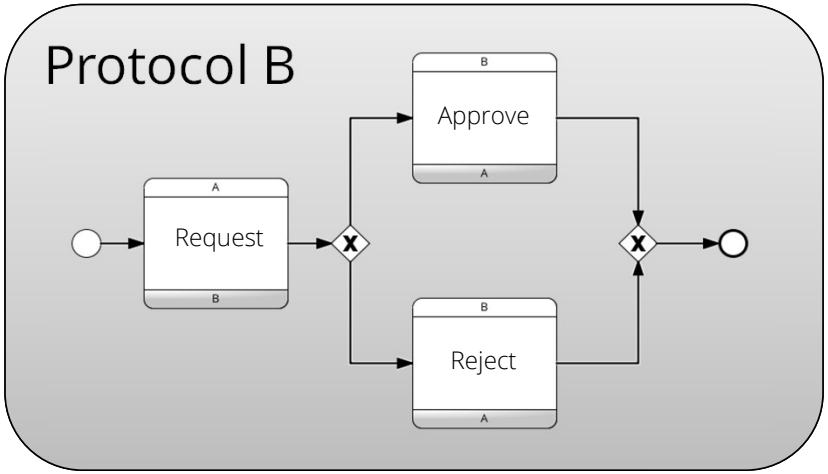
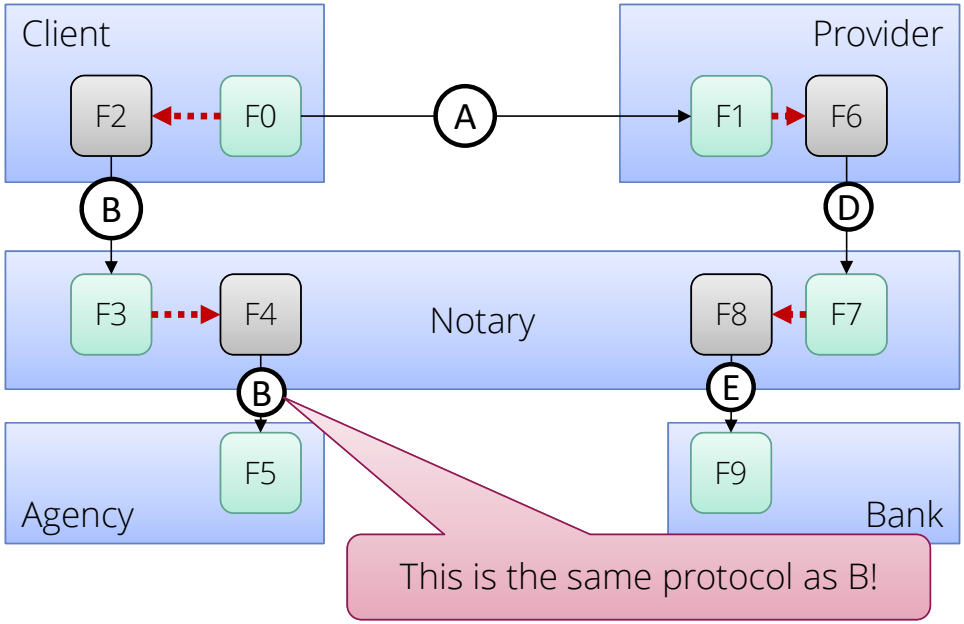
Transformation of LM into Petri nets





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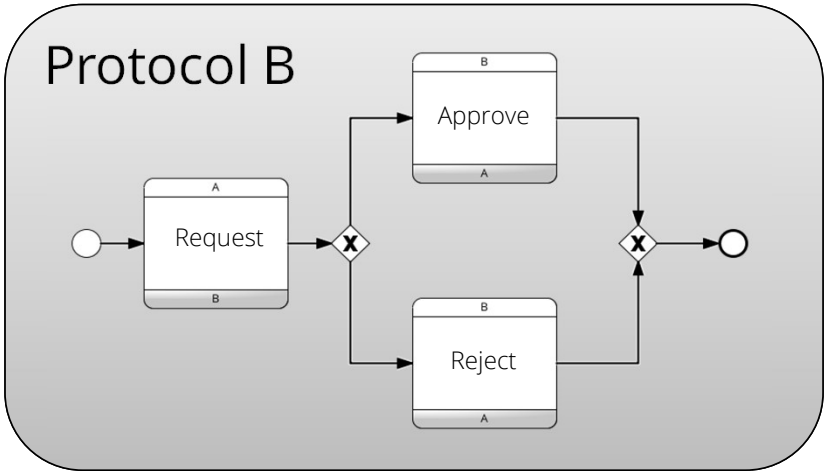

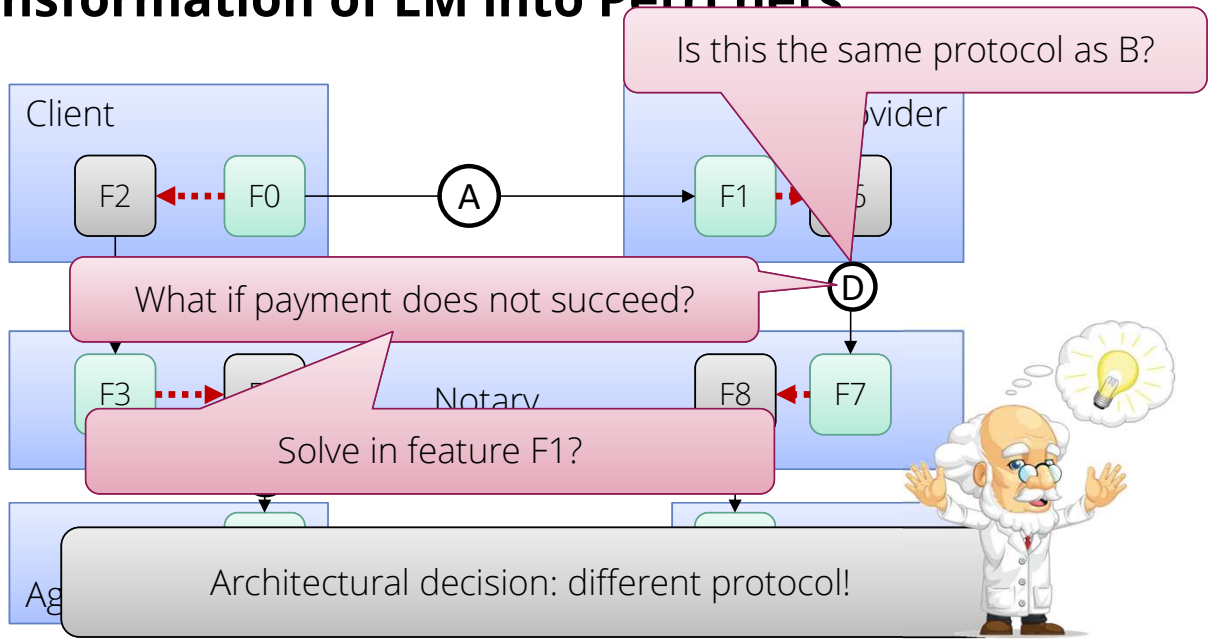

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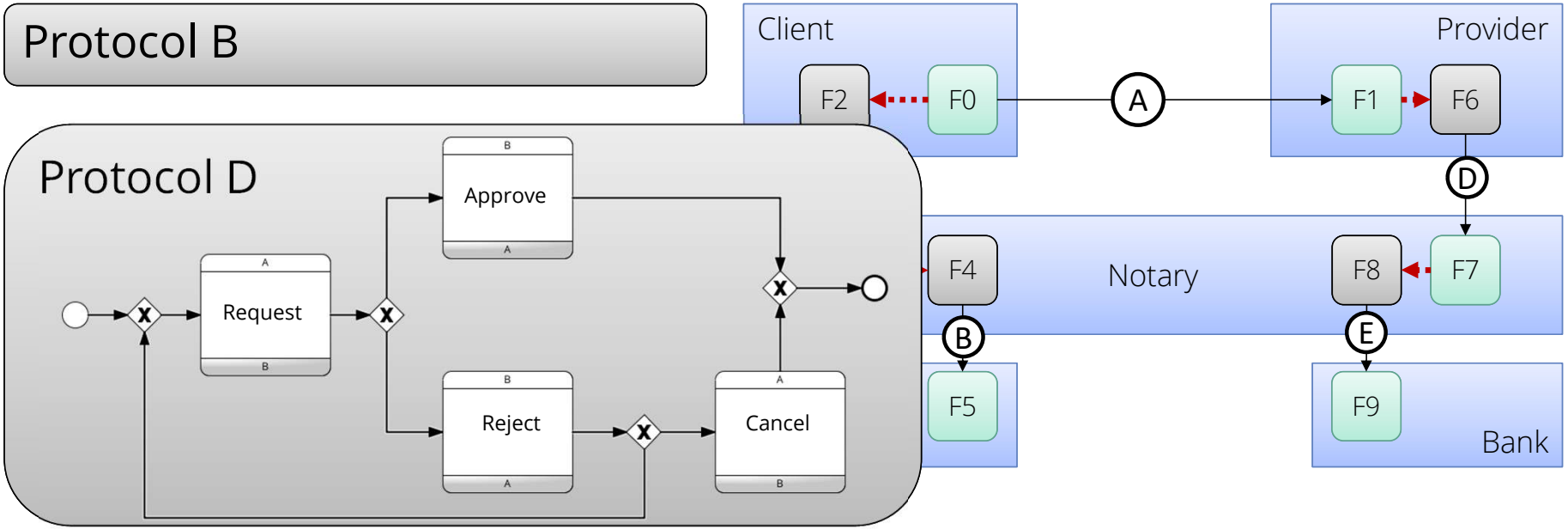
Transformation of LM into Petri nets



Rules of the transformation:

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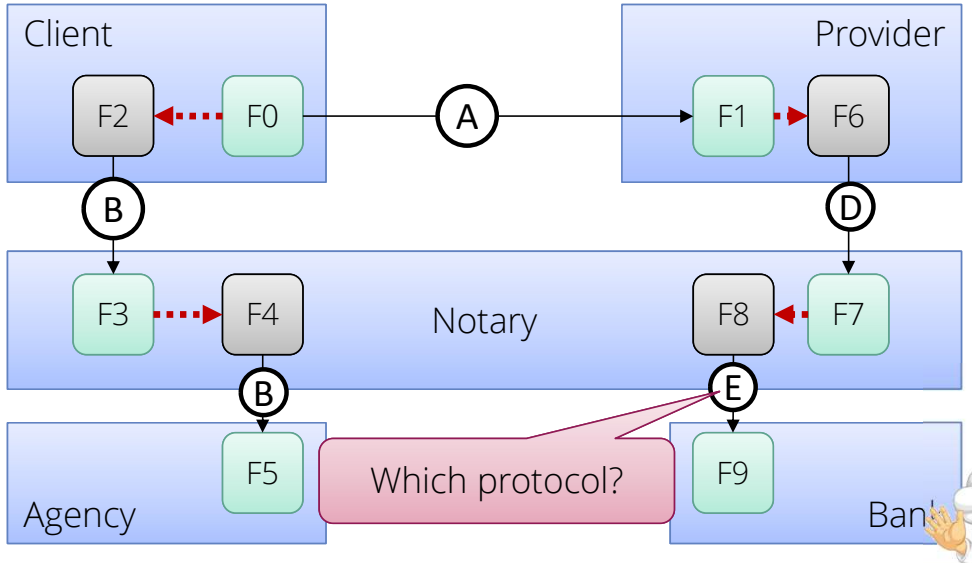
Transformation of LM into Petri nets

Protocol B

Protocol D



Architectural decision: Remove bank from the system!

Rules of the transformation:

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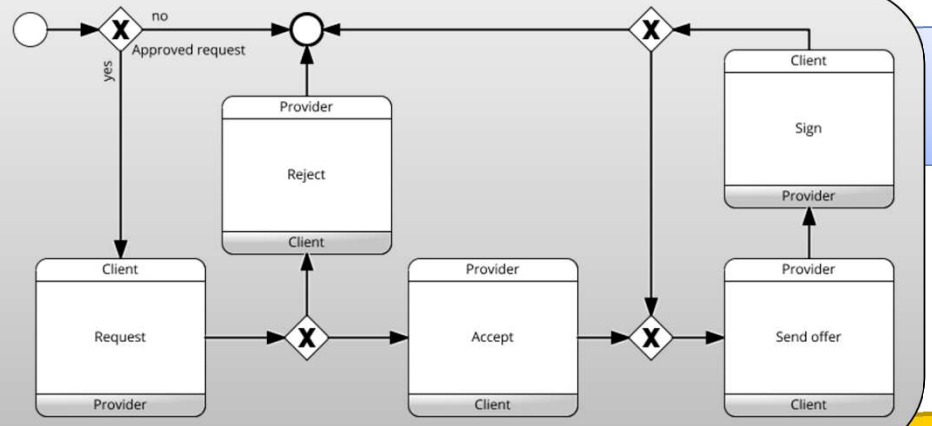
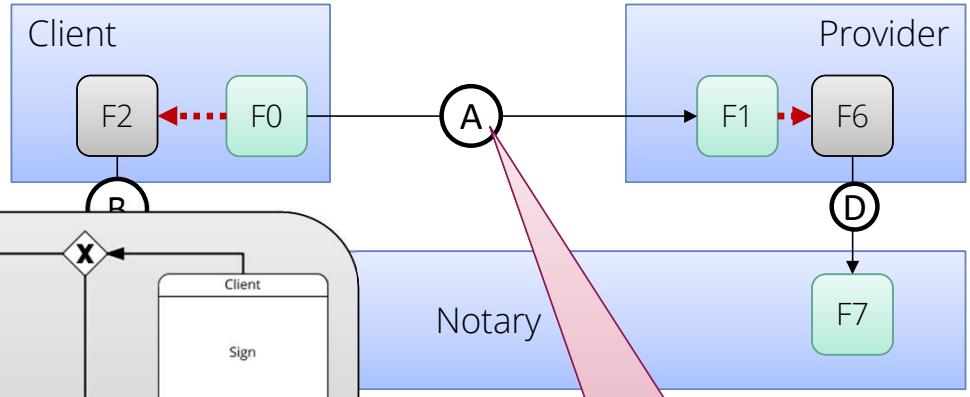
Transformation of LM into Petri nets

Protocol B

Protocol D

Protocol A





Which protocol?

What if function F2 fails?

Rules of the transformation:

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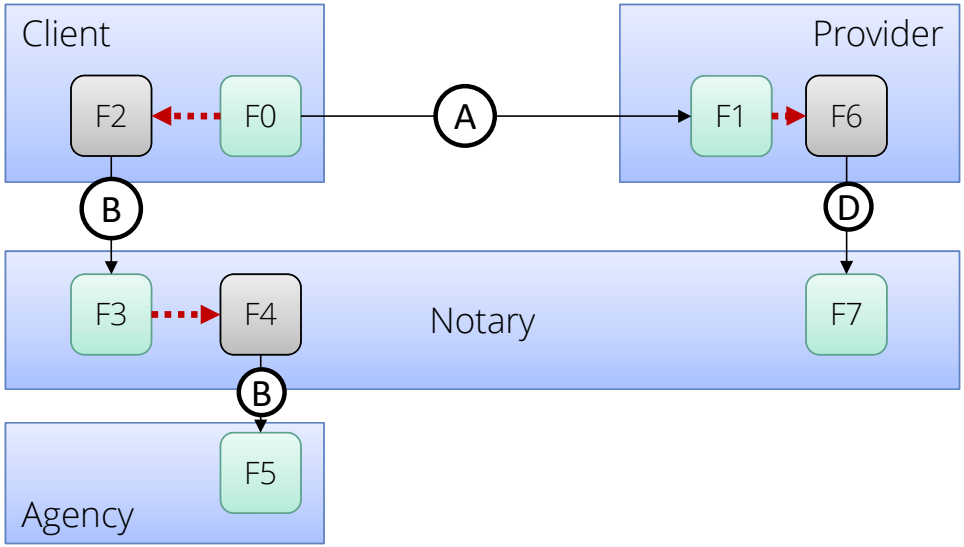
Transformation of LM into Petri nets

Protocol B

Protocol D

Protocol A



Rules of the transformation:

1. Dependencies between independent functions as **container nets**.
2. Function calls are **protocol choreographies**.
3. Transform each protocol choreography into a “protocol Petri net”
4. Refinement step: refine each function with its protocol part.

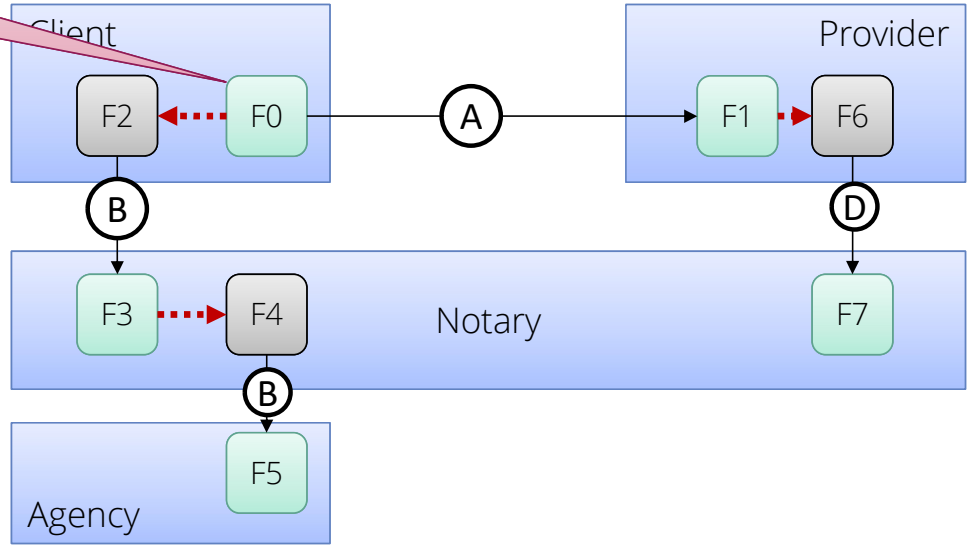
ansformation of LM into Petri nets

Select which place is refined in F0 for F2

Protocol B

Protocol D

Protocol A



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   For dependent functions: select the place in the protocol to refine

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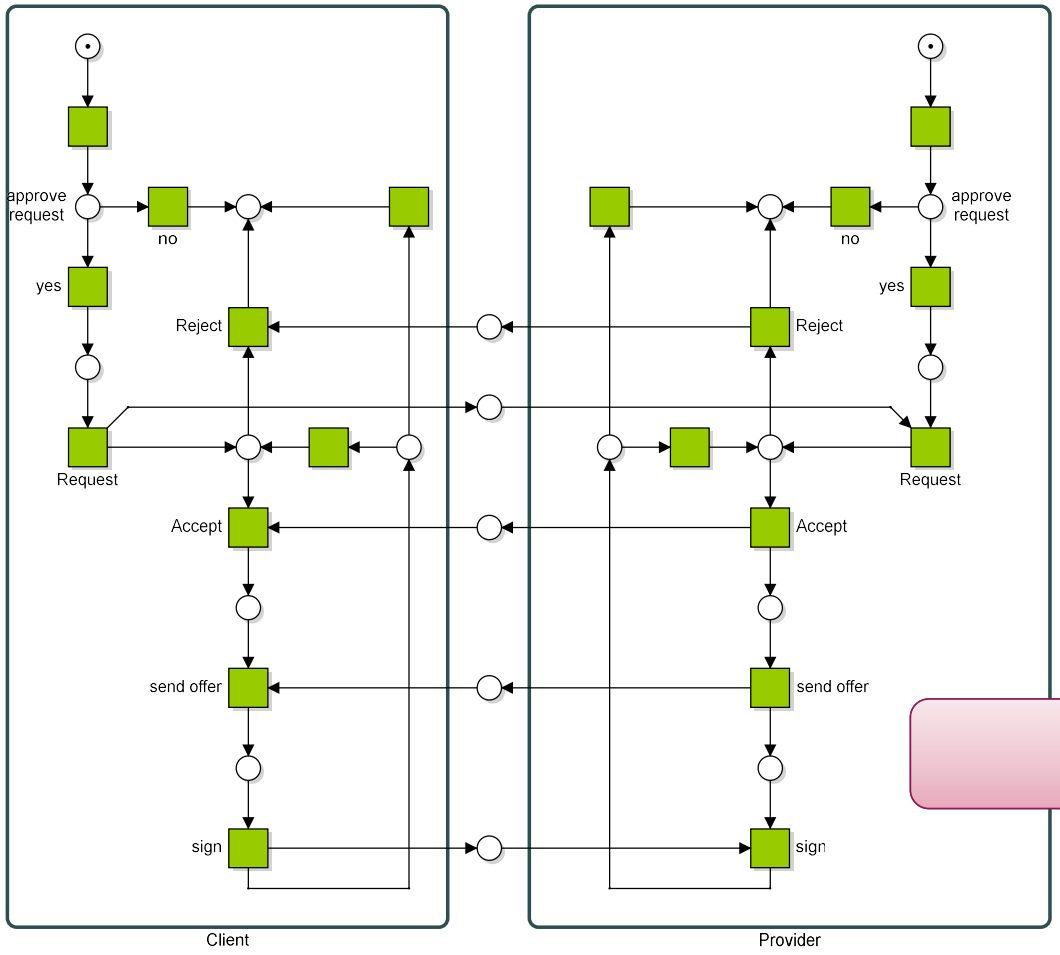
Protocol net for Protocol A



Not a correct protocol! Back to the drawing board!

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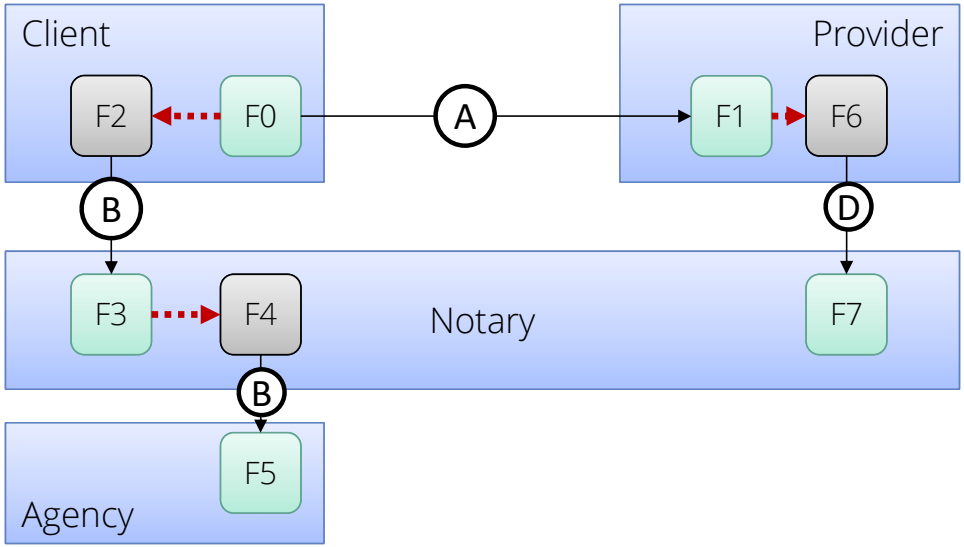
Transformation of LM into Petri nets

Protocol B

Protocol D

Protocol A



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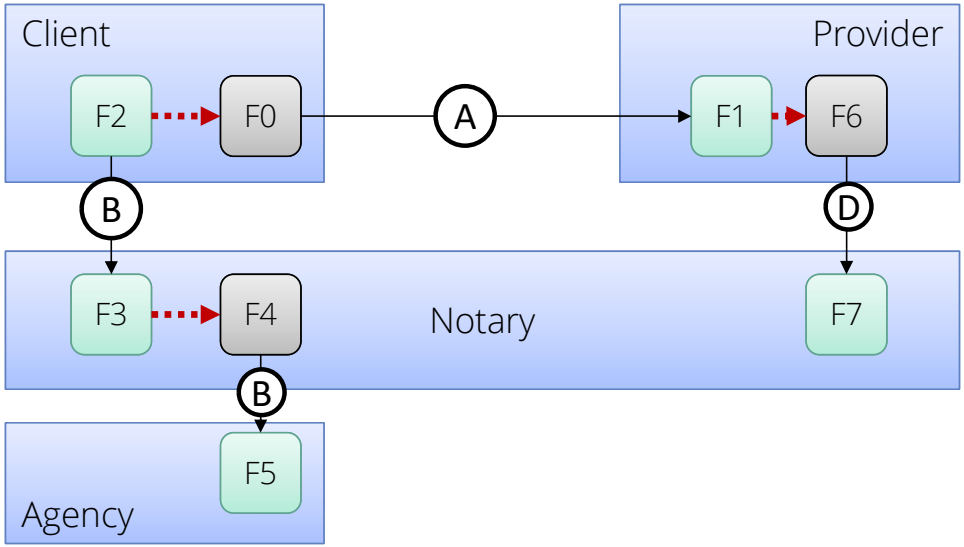
Transformation of LM into Petri nets

Protocol B

Protocol D

Protocol A



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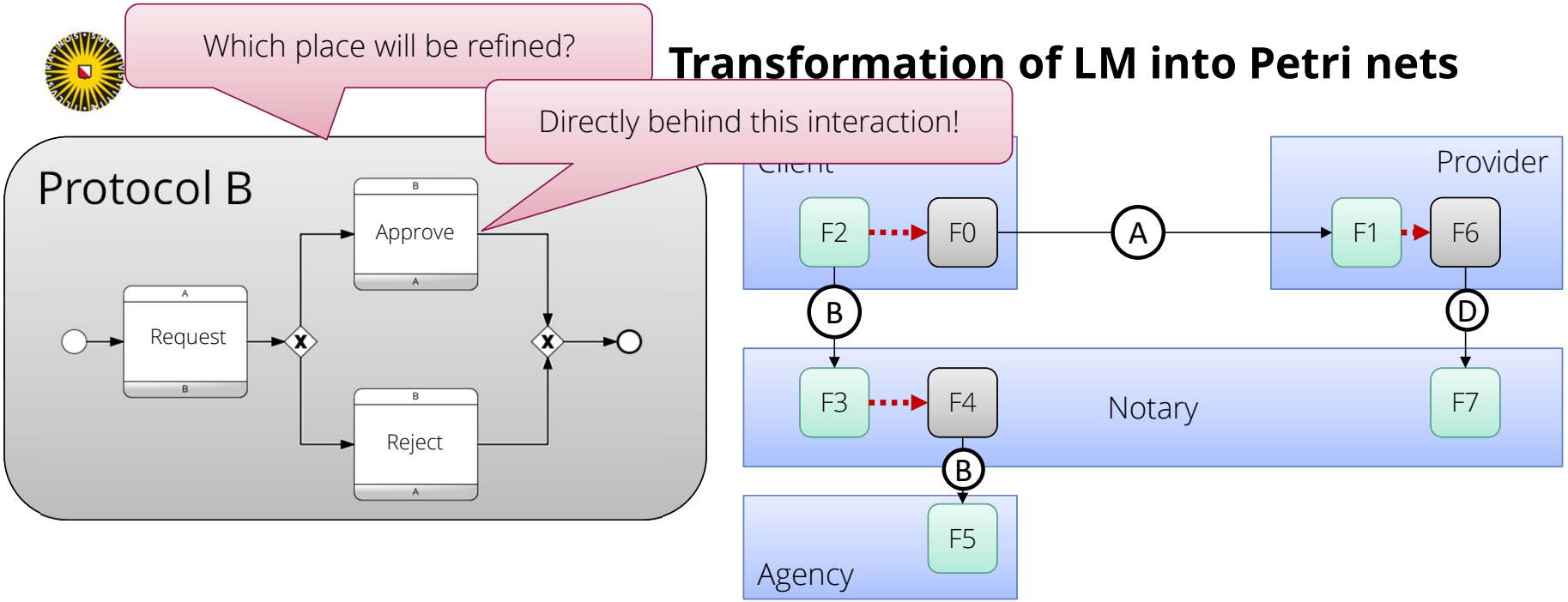
Transformation of LM into Petri nets



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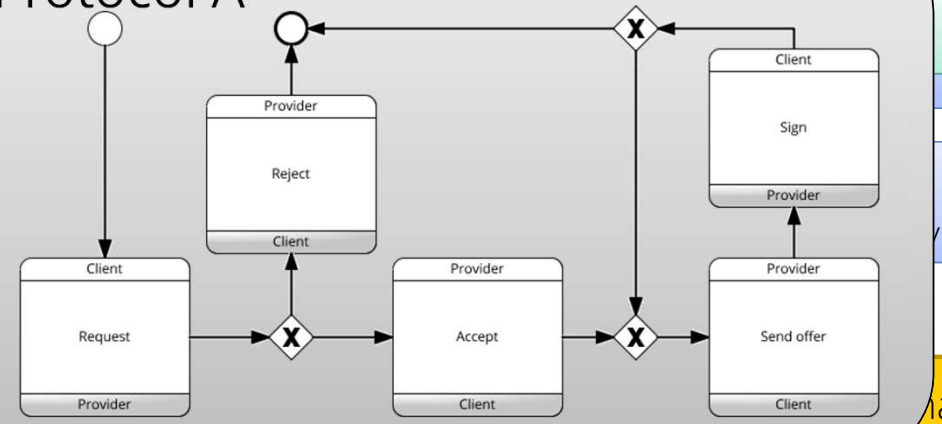
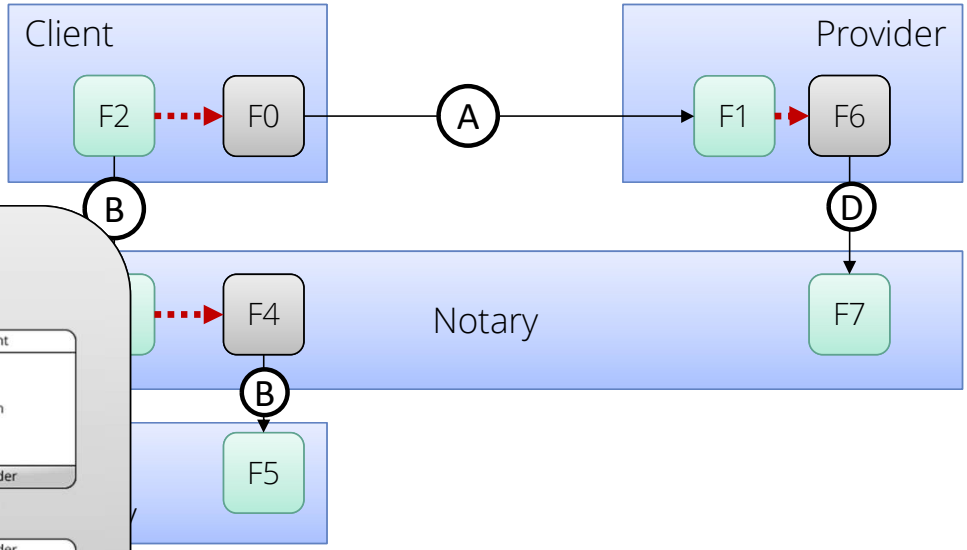
Transformation of LM into Petri nets

Protocol B

Protocol D

Protocol A





ıation:

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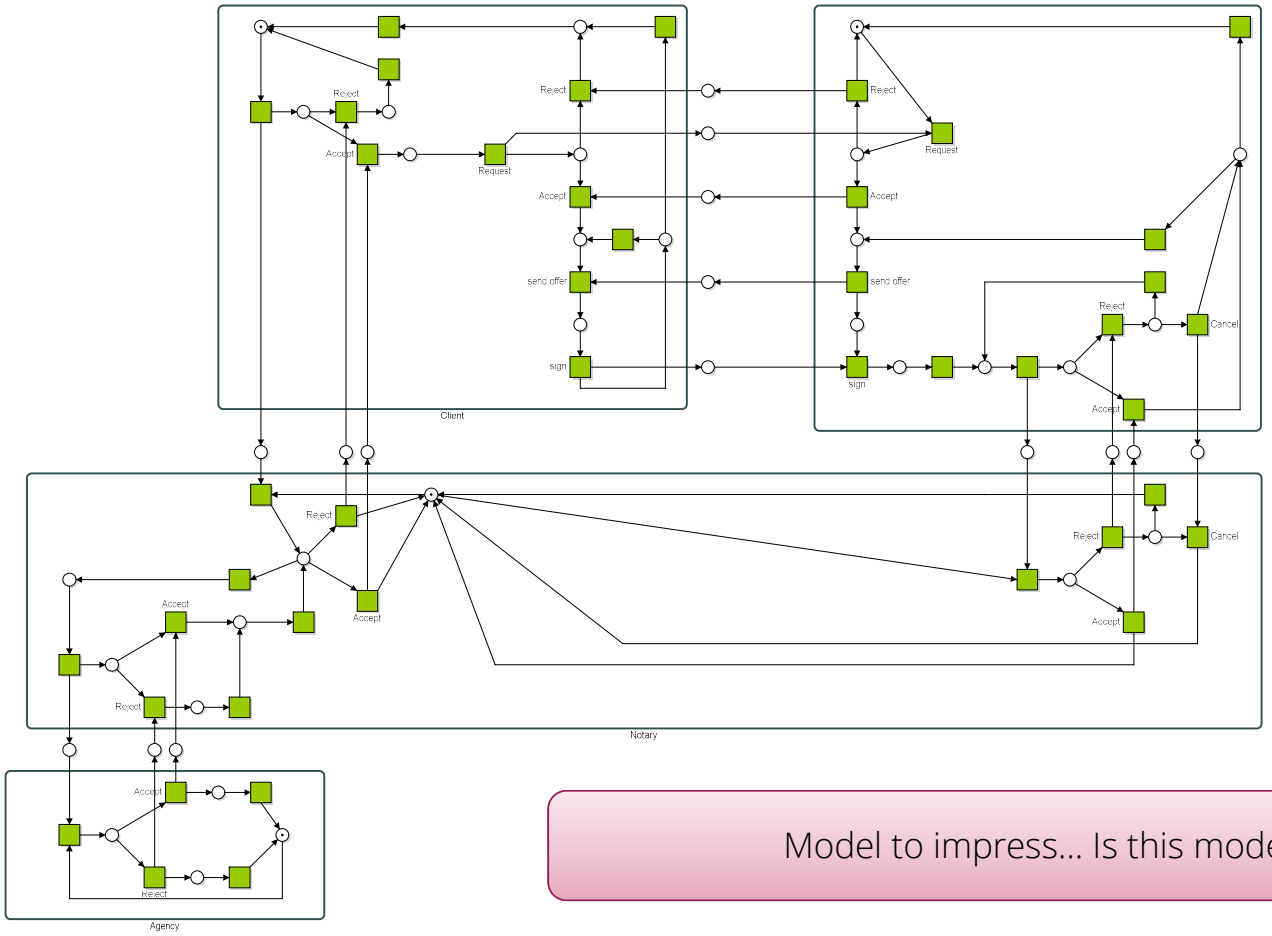
Resulting net



Model to impress... Is this model correct?

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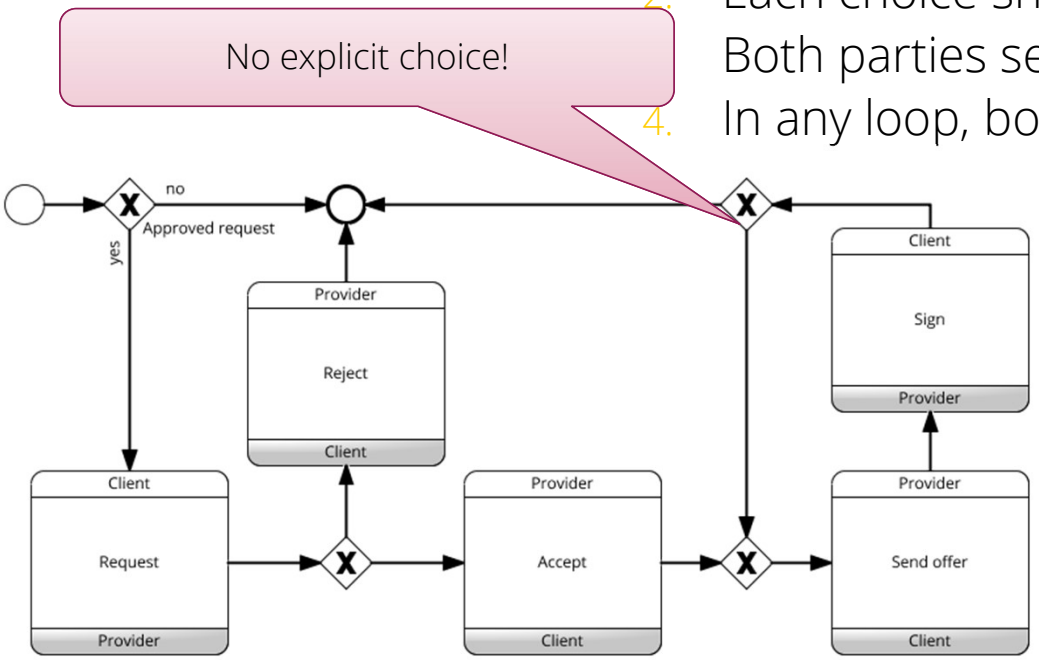
Rules on choreographies
A sufficient condition

A choreography is correct if **all** of the following hold:

1. No parallelism! (sorry…)
2. Each choice should be made by one party only
3. Both parties send at least one message
4. In any loop, both parties should at least send one message



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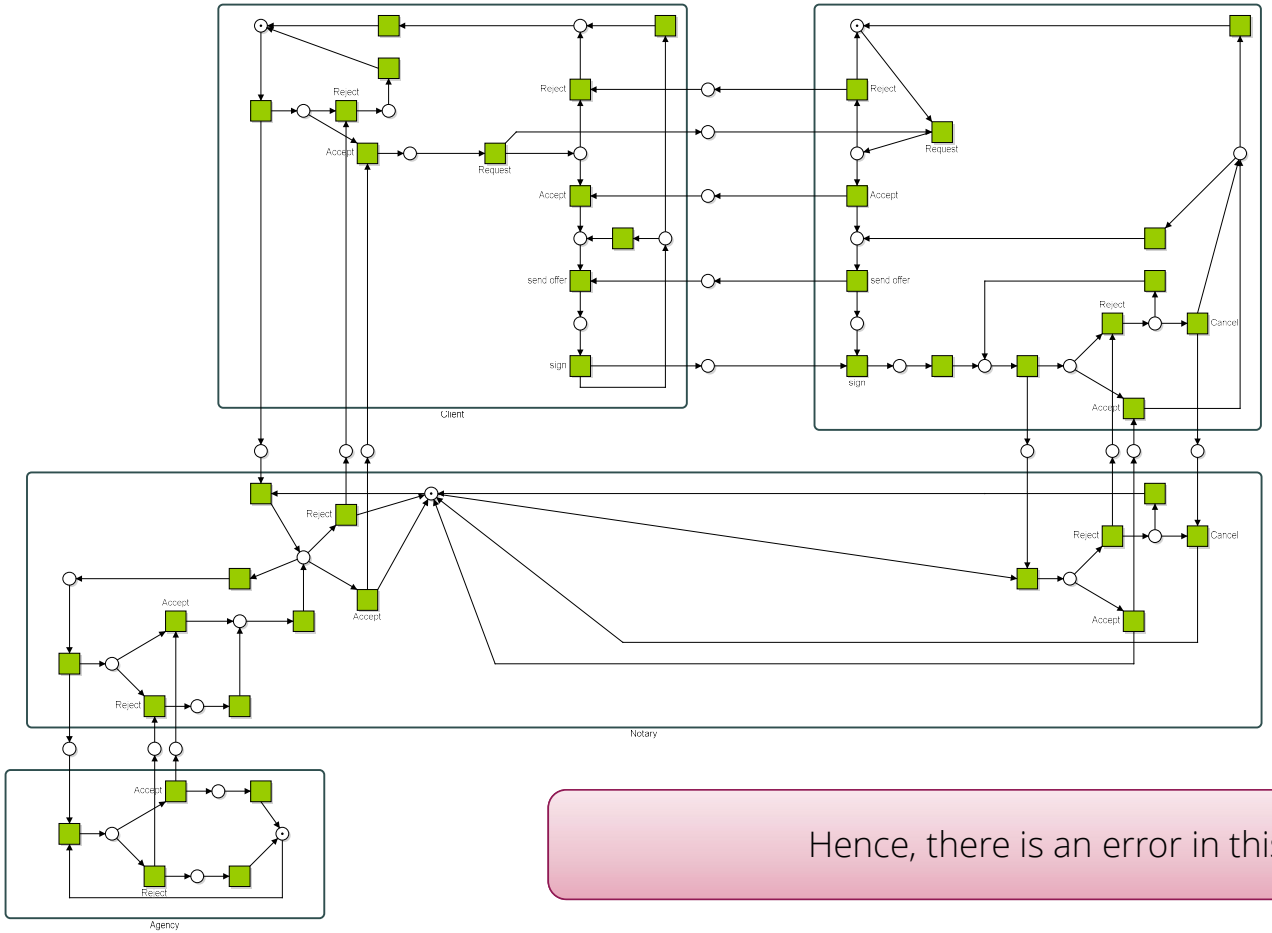
Resulting net



Hence, there is an error in this model!

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Is the model correct after repairing protocol A?

When is the composition correct?

- Protocols between two containers only
- Protocol choreography with before mentioned rules

- Acyclic high level picture (i.e., LM) should be acyclic!

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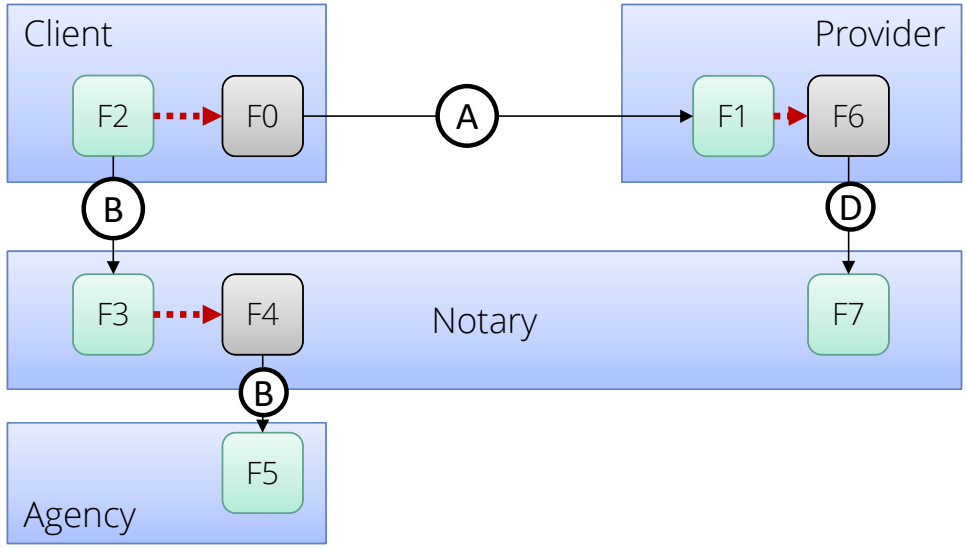
Transformation of LM into Petri nets

Protocol B

Protocol D

Protocol A



This logical model is acyclic

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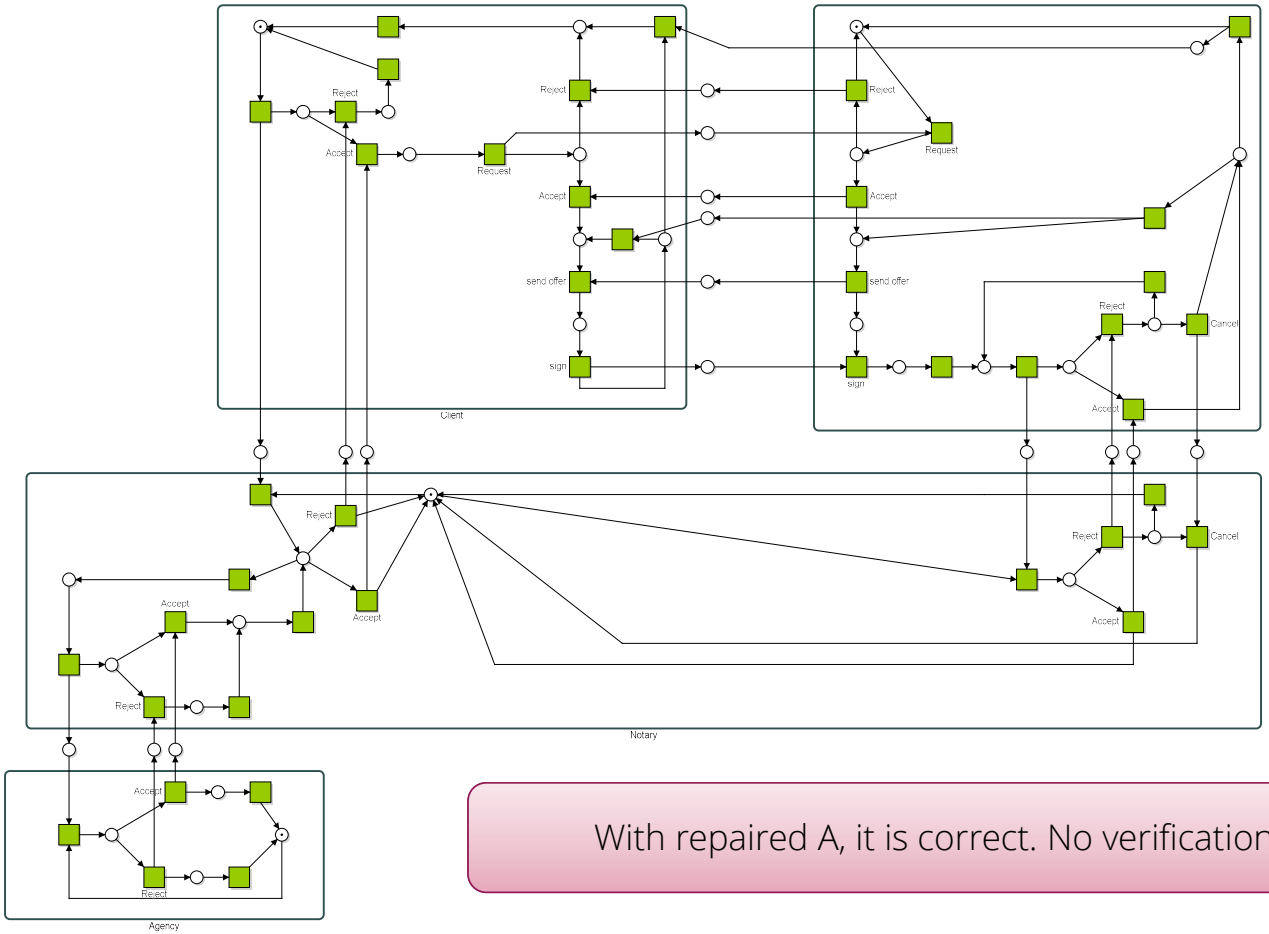
Resulting net



With repaired A, it is correct. No verification required ☺

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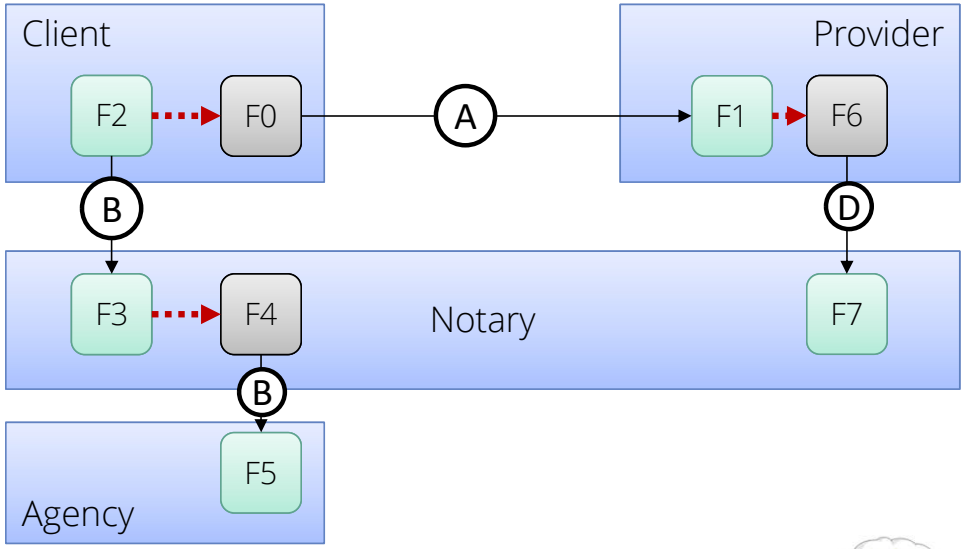
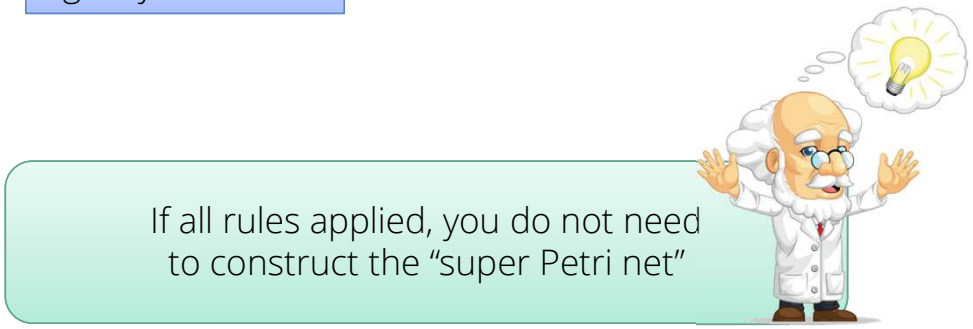
Dynamics in Architecture Documentation

Documentation

- **Logical model**
- **Container nets**
- **Protocol A**
- **Protocol B**
- **Protocol D**





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About the debates…

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Architecture debate

- Evaluation of your architecture, serves as feedback!
- A debate lasts 30 minutes:
  - **Team A presents for 15 minutes**
  - **Team B&C are contesting (provide arguments against)**
  - **Team D&E are defending (provide arguments in favor)**
  - **Team F takes notes for team A**
- Discussion on pros and cons
  - **Proper trade-offs?**
  - **How do the trade-offs influence the architecture?**
  - **What are the consequences of the choices?**
  - **How can the architecture be improved?**

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DISCLAIMER

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but no rights can be derived from its contents.