Methods for the specification and verification of business processes

MPB (6 cfu, 295AA)

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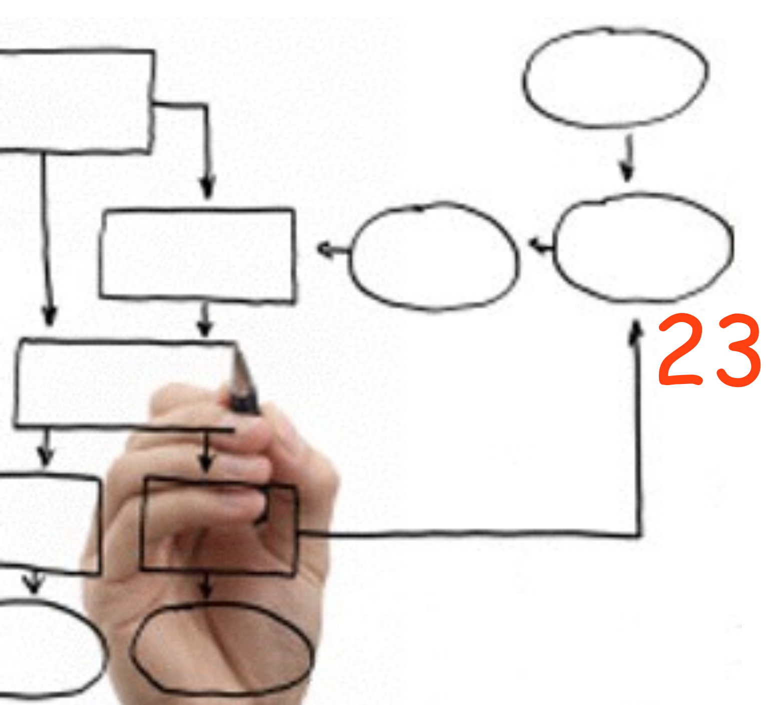

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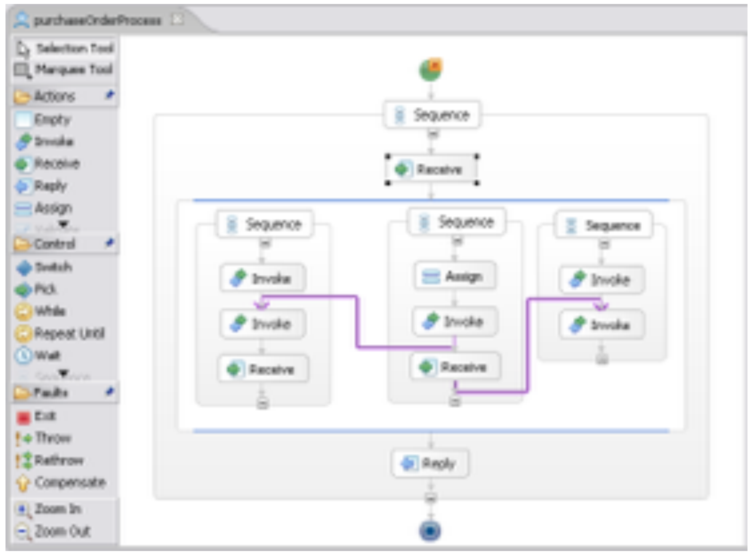
Object



We overview the key features of BPEL

Material inspired in part to Antonio Brogi's slides on Software Services: thanks!

Business process execution language

Also known as:
Web Services Business Process Execution Language
(**WS-BPEL**)
Business Process Execution Language for Web Services
(**BPEL4WS**)

a **standard executable language for the orchestration** of Web Service within business processes

it deals with import / export information, remote invocation, correlation, fault handling, compensation

Web services

Web services fix a standard for interoperability between heterogeneous, loosely coupled, remote software applications (separately developed, running on different platforms) over (not only) the HTTP protocol

Informally:
web services are for software
what web sites are for human

WS basics

Services must be made available on the web
(need a server)

Services must be advertised over the web
(need some repositories)

Service repositories must be queried
(need service description)

Services must be invoked
(need standard communication format)

XMLification

WSFL, BPEL, ...	Service composition
UDDI	Service discovery
	Service publication
WSDL	Service description
SOAP	XML based messaging
HTTP, HTTPS, SMTP	Network

Birth of BPEL

IBM was pushing for a standard called WSFL

Microsoft was pushing for a technology called XLANG

Intalio was pushing for BPML

IBM and Microsoft merged their efforts and pushed together for BPEL (a hybrid WSFL+XLANG) and BPEL was soon widely adopted

Life of BPEL

BPEL4WS 1.0 (2002) by BEA, IBM, Microsoft

SAP + Siebel joined the effort
BPEL 1.1 (2003)
submitted to OASIS

Adobe + HP + NEC + Oracle + Sun + many more joined
WS-BPEL 2.0 (2005)

The problem with BPEL

BPEL is not a graphical language

BPEL is an XML dialect

Machines like XML,
human beings not necessarily…

A typical BPEL tutorial

Turn to page 4 of any BPEL tutorial
(the first couple of pages are just a verbal introduction)
and you find the first small example...

... of about two pages of formatted XML code

```xml
<process name="purchaseOrderProcess" targetNamespace="http://example.com/ws-bp/purchase" xmlns="http://docs.oasis-open.org/wsbpel/2.0/process/executable" xmlns:lns="http://manufacturing.org/wsdl/purchase">

   <documentation xml:lang="EN">
      A simple example of a WS-BPEL process for handling a purchase order.
   </documentation>

   <partnerLinks>
      <partnerLink name="purchasing" partnerLinkType="lns:purchasingLT" myRole="purchaseService" />
      <partnerLink name="invoicing" partnerLinkType="lns:invoicingLT" myRole="invoiceRequester" partnerRole="invoiceService" />
      <partnerLink name="shipping" partnerLinkType="lns:shippingLT" myRole="shippingRequester" partnerRole="shippingService" />
      <partnerLink name="scheduling" partnerLinkType="lns:schedulingLT" partnerRole="schedulingService" />
   </partnerLinks>

   <variables>
      <variable name="PO" messageType="lns:POMessage" />
      <variable name="Invoice" messageType="lns:InvMessage" />
      <variable name="shippingRequest" messageType="lns:shippingRequestMessage" />
      <variable name="shippingInfo" messageType="lns:shippingInfoMessage" />
      <variable name="shippingSchedule" messageType="lns:scheduleMessage" />
   </variables>

   <faultHandlers>
      <catch faultName="lns:cannotCompleteOrder" faultVariable="POFault" faultMessageType="lns:orderFaultType">
         <reply partnerLink="purchasing" portType="lns:purchaseOrderPT" operation="sendPurchaseOrder" variable="POFault" faultName="cannotCompleteOrder" />
      </catch>
   </faultHandlers>

   <sequence>
      <receive partnerLink="purchasing" portType="lns:purchaseOrderPT" operation="sendPurchaseOrder" variable="PO" createInstance="yes">
         <documentation>Receive Purchase Order</documentation>
      </receive>

      <flow>
         <documentation>
            A parallel flow to handle shipping, invoicing and scheduling
         </documentation>
         <links>
            <link name="ship-to-invoice" />
            <link name="ship-to-scheduling" />
         </links>
         <sequence>
            <assign>
               <copy>
                  <from>$PO.customerInfo</from>
                  <to>$shippingRequest.customerInfo</to>
               </copy>
            </assign>
            <invoke partnerLink="shipping" portType="lns:shippingPT" operation="requestShipping" inputVariable="shippingRequest" outputVariable="shippingInfo">
               <documentation>Decide On Shipper</documentation>
               <sources>
                  <source linkName="ship-to-invoice" />
               </sources>
            </invoke>
            <receive partnerLink="shipping" portType="lns:shippingCallbackPT" operation="sendSchedule" variable="shippingSchedule">
               <documentation>Arrange Logistics</documentation>
               <sources>
                  <source linkName="ship-to-scheduling" />
               </sources>
            </receive>
         </sequence>
         <sequence>
            <invoke partnerLink="invoicing" portType="lns:computePricePT" operation="initiatePriceCalculation" inputVariable="PO">
               <documentation>
                  Initial Price Calculation
               </documentation>
            </invoke>
            <invoke partnerLink="invoicing" portType="lns:computePricePT" operation="sendShippingPrice" inputVariable="shippingInfo">
               <documentation>
                  Complete Price Calculation
               </documentation>
               <targets>
                  <target linkName="ship-to-invoice" />
               </targets>
            </invoke>
            <receive partnerLink="invoicing" portType="lns:invoiceCallbackPT" operation="sendInvoice" variable="Invoice" />
         </sequence>
         <sequence>
            <invoke partnerLink="scheduling" portType="lns:schedulingPT" operation="requestProductionScheduling" inputVariable="PO">
               <documentation>
                  Initiate Production Scheduling
               </documentation>
            </invoke>
            <invoke partnerLink="scheduling" portType="lns:schedulingPT" operation="sendShippingSchedule" inputVariable="shippingSchedule">
               <documentation>
                  Complete Production Scheduling
               </documentation>
               <targets>
                  <target linkName="ship-to-scheduling" />
               </targets>
            </invoke>
         </sequence>
      </flow>
      <reply partnerLink="purchasing" portType="lns:purchaseOrderPT" operation="sendPurchaseOrder" variable="Invoice">
         <documentation>Invoice Processing</documentation>
      </reply>
   </sequence>
</process>
```

```
    </faultHandlers>

    <sequence>
       <receive partnerLink="purchasing" portType="lns:purchaseOrderPT"
operation="sendPurchaseOrder" variable="PO" createInstance="yes">
          <documentation>Receive Purchase Order</documentation>
       </receive>

       <flow>
          <documentation>
             A parallel flow to handle shipping, invoicing and scheduling
          </documentation>
          <links>
             <link name="ship-to-invoice" />
             <link name="ship-to-scheduling" />
          </links>
          <sequence>
             <assign>
                <copy>
                   <from>$PO.customerInfo</from>
                   <to>$shippingRequest.customerInfo</to>
                </copy>
```

Learning the syntax

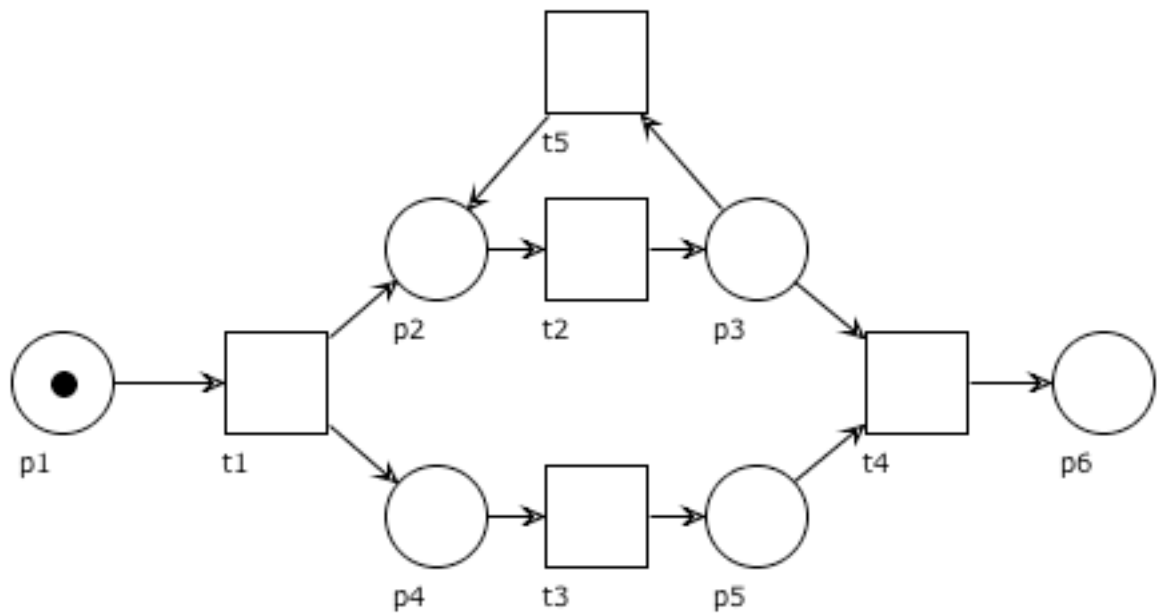
Learning BPEL by looking at XML documents

is like

learning Petri nets by looking at PNML documents

or similar to

learning Java by looking at the bytecode




```xml
    </place>
    <place id="p4">
      <name>
        <text>p4</text>
        <graphics>
          <offset x="180" y="320"/>
        </graphics>
      </name>
      <graphics>
        <position x="180" y="280"/>
        <dimension x="40" y="40"/>
      </graphics>
    </place>
    <place id="p3">
      <name>
        <text>p3</text>
        <graphics>
```


```xml
<?xml version="1.0" encoding="UTF-8"?><pnml>
  <net type="http://www.informatik.hu-berlin.de/top/pntd/ptNetb" id="noID">
    <place id="p6">
      <name>
        <text>p6</text>
        <graphics>
          <offset x="430" y="270"/>
        </graphics>
      </name>
      <graphics>
        <position x="430" y="230"/>
        <dimension x="40" y="40"/>
      </graphics>
    </place>
    <place id="p5">
      <name>
        <text>p5</text>
        <graphics>
          <offset x="300" y="320"/>
        </graphics>
      </name>
      <graphics>
        <position x="300" y="280"/>
        <dimension x="40" y="40"/>
      </graphics>
    </place>
    <place id="p4">
      <name>
        <text>p4</text>
        <graphics>
          <offset x="180" y="320"/>
        </graphics>
      </name>
      <graphics>
        <position x="180" y="280"/>
        <dimension x="40" y="40"/>
      </graphics>
    </place>
    <place id="p3">
      <name>
        <text>p3</text>
        <graphics>
          <offset x="300" y="220"/>
        </graphics>
      </name>
      <graphics>
        <position x="300" y="180"/>
        <dimension x="40" y="40"/>
      </graphics>
    </place>
    <place id="p2">
      <name>
        <text>p2</text>
        <graphics>
          <offset x="180" y="220"/>
        </graphics>
      </name>
      <graphics>
        <position x="180" y="180"/>
        <dimension x="40" y="40"/>
      </graphics>
    </place>
    <place id="p1">
      <name>
        <text>p1</text>
        <graphics>
          <offset x="40" y="270"/>
        </graphics>
      </name>
      <graphics>
        <position x="40" y="230"/>
        <dimension x="40" y="40"/>
      </graphics>
      <initialMarking>
        <text>1</text>
      </initialMarking>
    </place>
    <transition id="t3">
      <name>
        <text>t3</text>
        <graphics>
          <offset x="240" y="320"/>
        </graphics>
      </name>
      <graphics>
        <position x="240" y="280"/>
        <dimension x="40" y="40"/>
      </graphics>
      <toolspecific tool="WoPeD" version="1.0">
        <time>0</time>
        <timeUnit>1</timeUnit>
        <orientation>1</orientation>
      </toolspecific>
    </transition>
    <transition id="t2">
      <name>
        <text>t2</text>
        <graphics>
          <offset x="240" y="220"/>
        </graphics>
      </name>
      <graphics>
        <position x="240" y="180"/>
        <dimension x="40" y="40"/>
      </graphics>
      <toolspecific tool="WoPeD" version="1.0">
        <time>0</time>
        <timeUnit>1</timeUnit>
        <orientation>1</orientation>
      </toolspecific>
    </transition>
    <transition id="t1">
      <name>
        <text>t1</text>
        <graphics>
          <offset x="120" y="270"/>
        </graphics>
      </name>
      <graphics>
        <position x="120" y="230"/>
        <dimension x="40" y="40"/>
      </graphics>
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        <time>0</time>
        <timeUnit>1</timeUnit>
        <orientation>1</orientation>
      </toolspecific>
    </transition>
    <transition id="t4">
      <name>
        <text>t4</text>
        <graphics>
          <offset x="360" y="270"/>
        </graphics>
      </name>
      <graphics>
        <position x="360" y="230"/>
        <dimension x="40" y="40"/>
      </graphics>
      <toolspecific tool="WoPeD" version="1.0">
        <time>0</time>
        <timeUnit>1</timeUnit>
        <orientation>1</orientation>
      </toolspecific>
    </transition>
    <transition id="t5">
      <name>
        <text>t5</text>
        <graphics>
          <offset x="240" y="150"/>
        </graphics>
      </name>
      <graphics>
        <position x="240" y="110"/>
        <dimension x="40" y="40"/>
      </graphics>
      <toolspecific tool="WoPeD" version="1.0">
        <time>0</time>
        <timeUnit>1</timeUnit>
        <orientation>1</orientation>
      </toolspecific>
    </transition>
    <arc id="a9" source="t1" target="p4">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a17" source="p3" target="t4">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a14" source="p5" target="t4">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a21" source="p3" target="t5">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a13" source="t3" target="p5">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a10" source="p4" target="t3">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a24" source="t5" target="p2">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a1" source="p1" target="t1">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a2" source="t1" target="p2">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a5" source="p2" target="t2">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a6" source="t2" target="p3">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <arc id="a18" source="t4" target="p6">
      <inscription>
        <text>1</text>
      </inscription>
      <graphics/>
      <toolspecific tool="WoPeD" version="1.0">
        <probability>1.0</probability>
        <displayProbabilityOn>false</displayProbabilityOn>
        <displayProbabilityPosition x="500.0" y="0.0"/>
      </toolspecific>
    </arc>
    <toolspecific tool="WoPeD" version="1.0">
      <bounds>
        <position x="11" y="33"/>
        <dimension x="755" y="490"/>
      </bounds>
      <treeWidth>2</treeWidth>
      <verticalLayout>false</verticalLayout>
      <resources/>
      <simulations/>
      <partnerLinks/>
      <variables/>
    </toolspecific>
  </net>
</pnml>
```

Forget XML

BPEL is designed to work with WSDL documents
of the services required by the process

A process can itself be exposed as a service
which needs its own WSDL document

let us forget that WSDL documents are written in XML
we regard them as abstract interface descriptions

BPEL guidelines

Structured control vs free flow

BPEL4WS should provide
both **structured** (hierarchical)
and **graph-like** control regimes,
and allow their usage to be blended
as seamlessly as possible.

About data handling

BPEL4WS provides **limited data handling** functions that are sufficient for the simple manipulation of data that is needed to define process relevant data and control flow.

WSDL

Service

A service can be thought of as a container
for a set of (logically related) operations
that are made available via web-based protocols

Roughly: a remote object

PortType / Interface

The **`<portType>`** element,
renamed to **`<interface>`** in WSDL 2.0,
defines a web service,
the operations that can be performed,
and the messages that are used to perform the operation.

Roughly: the type of a remote object

i.e., a remote (abstract) class

Operation

Each operation can be thought of as
a method or function call in some programming language.

Four kinds of operations
(one-way, request-response, notification, solicit-response)
Three kinds of parameters/arguments
(input, output, fault)
(not all combinations allowed)

Roughly: a remote (abstract) method

Port / Endpoint

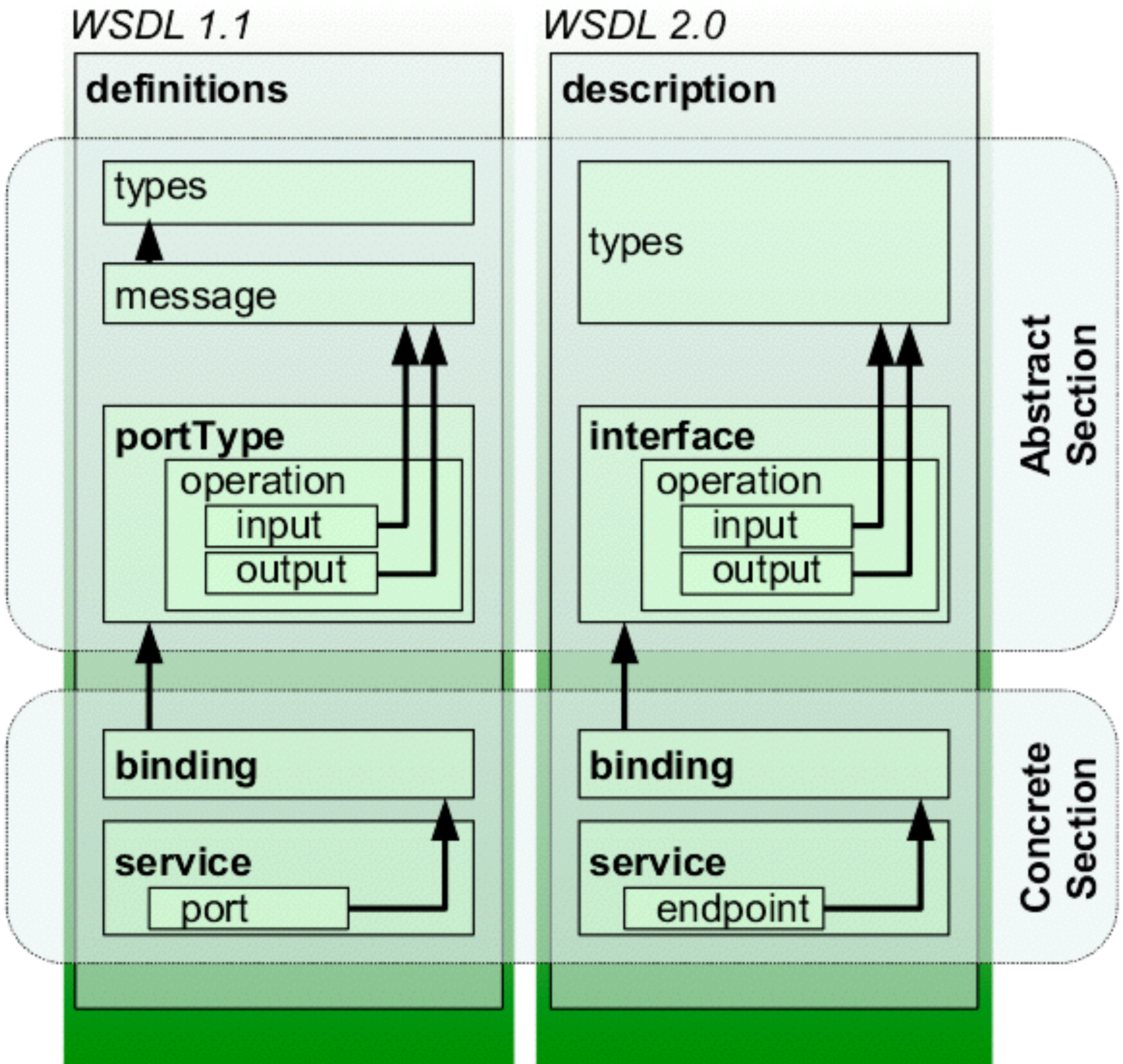
The **`<port>`** element,
renamed to **`<endpoint>`** in WSDL 2.0,
declares the address of a web service.

It typically involves a **name**, a **binding** and a **URL**

Binding

The binding specifies the interface as well as the SOAP binding style (message format) and SOAP transport protocol (http / smtp).

WSDL (from wikipedia)



```
<!--create a port type with one operation -->
<wsdl:portType name="purchaseType">
    <wsdl:operation name="purchaseOperation">
        <wsdl:input name="tns:purchaseMessage"/>
    </wsdl:operation>
</wsdl:portType>
```

```
<!-- Adding a message that has two addresses -->
<wsdl:message name="purchaseMessage">
    <wsdl:part name="productCode" element="tns:scannerType"/>
</wsdl:message>
```

```
        <xsd:complexType name="scannerType">
            <xsd:all>
                <xsd:element name="upc" type="upcType"/>
                <xsd:element name="isbn" type="isbnType"/>
            </xsd:all>
        </xsd:complexType>
```

UPC = Universal Product Code

```
        <xsd:simpleType name="upcType">
            <xsd:restriction base="xsd:string">
                <xsd:pattern value="[0-9]{12}"/>
            </xsd:restriction>
        </xsd:simpleType>
        <xsd:simpleType name="isbnType">
            <xsd:restriction base="xsd:string">
                <xsd:pattern value="([0-9]- ){10}"/>
            </xsd:restriction>
        </xsd:simpleType>
```

ISBN = International Standard Book Number

```
<!--Bind the message to SOAP over  HTTP -->
<wsdl:binding name="purchaseBinding" type="tns:purchaseType">
    <soap:binding style="document"
          transport="http://schemas.xmlsoap.org/soap/http"/>
    <wsdl:operation name="tns:purchaseOperation">
        <wsdl:input>
             <soap:body use="literal"/>
        </wsdl:input>
    </wsdl:operation>
</wsdl:binding>
```

```
<service name="Purchase_Service">
    <documentation>Purchase service,
                   offering purchase of ISBN or UPC based matterials
                   to the world!</documentation>
    <port binding="tns:purchaseBinding" name="Purchase_ServicePort">
        <soap:address
   location="http://www.fluidimagination.com:8080/soap/servlet/rpcrouter"/>
    </port>
</service>
```

BPEL ingredients

BPEL ingredients

Data flow
(scoped variables)

Partner links and Message correlation

Message flow
(one-way, request-response, notify, solicit-response)

Control flow
(structured activities and synchronization links)

Handling events, faults, compensations

Variable assignment

Variables can be defined (within a local scope)

The activity **`<assign>`** can be used to copy data (messages, part of messages, service references) between variables

```
<assign>
     <copy>
          <from variable="PO" part="customerInfo"/>
          <to variable="shippingRequest" part="customerInfo"/>
     </copy>
</assign>
```

Stateless services, stateful processes

When a message for (WS-BPEL) service arrives,
it must be delivered either to a new
or to an existing instance of the process

Stateful business processes are instantiated to act
according to interaction history

Messages should not only be delivered to the correct port,
but also to the correct instance of the business process
that provides that port

Message correlation

Message correlation is the way to tie together messages coming from different communications

A correlation set is a set of properties such that all messages having the same values of all properties are part of the same interaction

The partner that first fixes the values of the properties in the correlation set is the **initiator** of the exchange, the other partners are called the **followers**

Message flow

Basic activities are available
to send and receive messages to partners

Activity **`<invoke>`**: asynchronous (one-way) or synchronous (request-response)

Activity **`<receive>`**: a request from a partner to execute one of the (WSDL) operations implemented by the process

Activity **`<reply>`**: to return the result of a **`<receive>`**d synchronous request-response operation

Partner Link

A partner is a service that the process invokes,
or a client that invokes the process

A BPEL process interacts with a partner using a
`<partnerLink>` a (typed) connector
that the process offers to/requires from its partner
(to be declared in the BPEL document)

```
<partnerLinks>
    <partnerLink name="shipping"
                 partnerLinkType="lns:shippingLT"
                 myRole="shippingRequester"
                 partnerRole="shippingService"/>
    ...
</partnerLinks>
```

Invoke

Needed information: the **<partnerLink>**, the WSDL **<portType>** of the service to be invoked, and the name and parameters of the **<operation>**

```
<invoke partnerLink="shipping"
        portType="lns:shippingPT"
        operation="requestShipping"
        inputVariable="shippingRequest"
        outputVariable="shippingInfo">
        <source linkName="ship-to-invoice"/>
</invoke>
```

Receive

Needed information: the **<partnerLink>**, the WSDL **<portType>** of the exposed service, and a **<variable>** where to copy the parameters of the **<operation>**

```
<receive partnerLink="purchasing"
         portType="lns:purchaseOrderPT"
         operation="sendPurchaseOrder"
         variable="PO">
</receive>
```

Reply

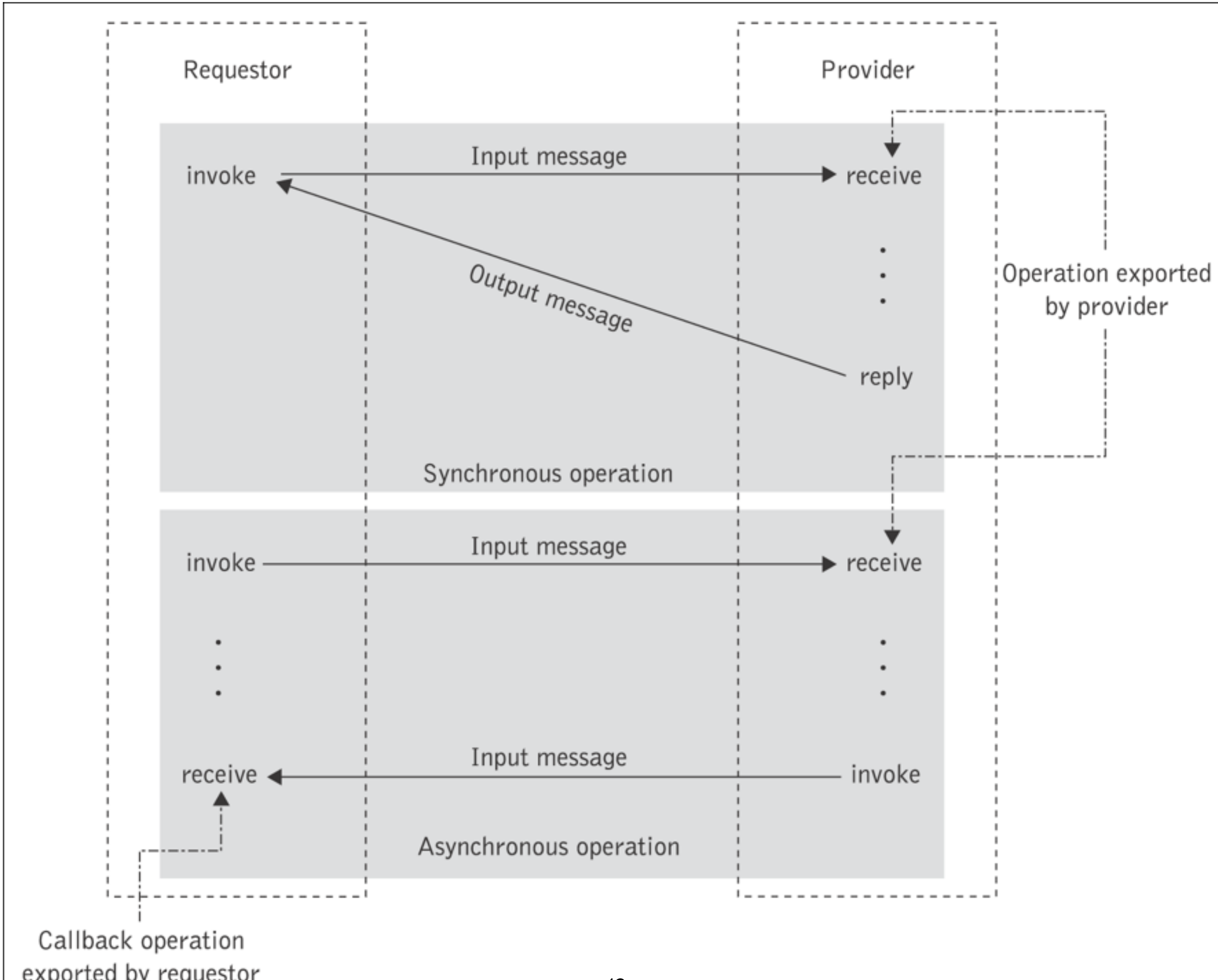
A process can **<reply>** to a message it **<receive>**d

```
<reply partnerLink="purchasing"
       portType="lns:purchaseOrderPT"
       operation="sendPurchaseOrder"
       variable="Invoice" />
```

Asynchronous operations do not use **<reply>**

If a reply must be sent,

<invoke> is used to call back a client operation


Requestor
Provider
invoke
Input message
receive
Output message
reply
Operation exported
by provider
Synchronous operation
invoke
Input message
receive
receive
Input message
invoke
Asynchronous operation
Callback operation
exported by requestor

Structured activities

<sequence> for specifying sequential compositions

only one branch
is selected

<switch> for (local) internal choices
(ordered list of conditional **<case>** branches,
possibly ended by an **<otherwise>** branch)

<pick> for (global) external choices
(set of event handlers of the form event → activity,
<onMessage> arrival of a message or **<onAlarm>** timer)

<flow> for parallel composition

<while> for iterations (guards are XPath expressions)

Control links

Control links are a non-structural element
that introduces control dependencies between activities

Each link carry a predicate, called “**transition condition**”

An activity can be the **source** of many links
(when the activity completes,
the transition conditions of all links are evaluated)

An activity can be the **target** of many links
(it waits for the boolean evaluation of the transition
conditions of incoming links and apply a “**join condition**”)

Link

A `<link>` expresses synchronisation dependencies among activities in a process

Each `<link>` has a name, one source activity, one target activity, and it may be associated with a **transition condition** (a predicate to be evaluated when the source activity ends)

Join condition

Any activity that is the target of one or more links
may have an explicit **<joinCondition>**,
(a predicate on the status values of the incoming links,
to be evaluated once all such values have been determined)

otherwise, the **implicit join condition** is the **OR**

If the **<joinCondition>** evaluates to:

TRUE the activity can be executed,

FALSE a **<joinFailure>** fault may be thrown
(depending on the **<suppressJoinFailure>** flag

Join condition failure

If the attribute `suppressJoinFailure` is set to `no`,
a join failure needs to be thrown,
which triggers a standard fault handling procedure

If the attribute `suppressJoinFailure` is set to `yes`,
the activity will not be performed,
will end up in the “finished” state,
(the processing of any following activity will not be affected)
and the status of all outgoing links will be set to `false`.
This is known as **dead path elimination**
(the false link status is propagated transitively along the paths formed by control links, until a join condition is reached that evaluates to true)

Scope

A scope provides fault and compensation handling capabilities to the activities nested within it

A **`<scope>`** activity consists of:
a, possibly structured, primary activity,

a set of (optional) fault handlers,

a single (optional) compensation handlers,

a set of (optional) event handlers
(executed concurrently with the process,
they enable a scope to react to messages and alarm events)

Faults

BPEL defines three kinds of faults:

application faults (also **service faults**)
generated by invoked services

process-defined faults
generated by a `<throw>` activity

system faults
generated by the process engine, such as join failures

"it is never possible to run more than one fault handler for the same scope, under any circumstances"

Formal Semantics and Analysis of Control Flow in WS-BPEL

(Revised Version)

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Formal semantics of control flow in BPEL

Motivation

BPEL specification:
rigorous XML syntax
English prose semantics (of apparent clarity)

Consequences:
inconsistencies, ambiguities, incompleteness

try to google for "WS BPEL issues list", e.g.

Issue 32 Link Semantics in Event Handlers (resolved)
Issue 39 Inconsistent syntax for query attribute values in spec examples (resolved)

...

Issue 42 Need for Formalism (resolved) YES

Approaches

Promela (SPIN)

Process algebras

Abstract State Machines

Automata

Weakest preconditions / strongest postconditions

Axiomatic semantics

Petri nets

Goal

Unveil ambiguities in BPEL specification
(reported to BPEL standardization committee)

Complete formalization of all control-flow constructs

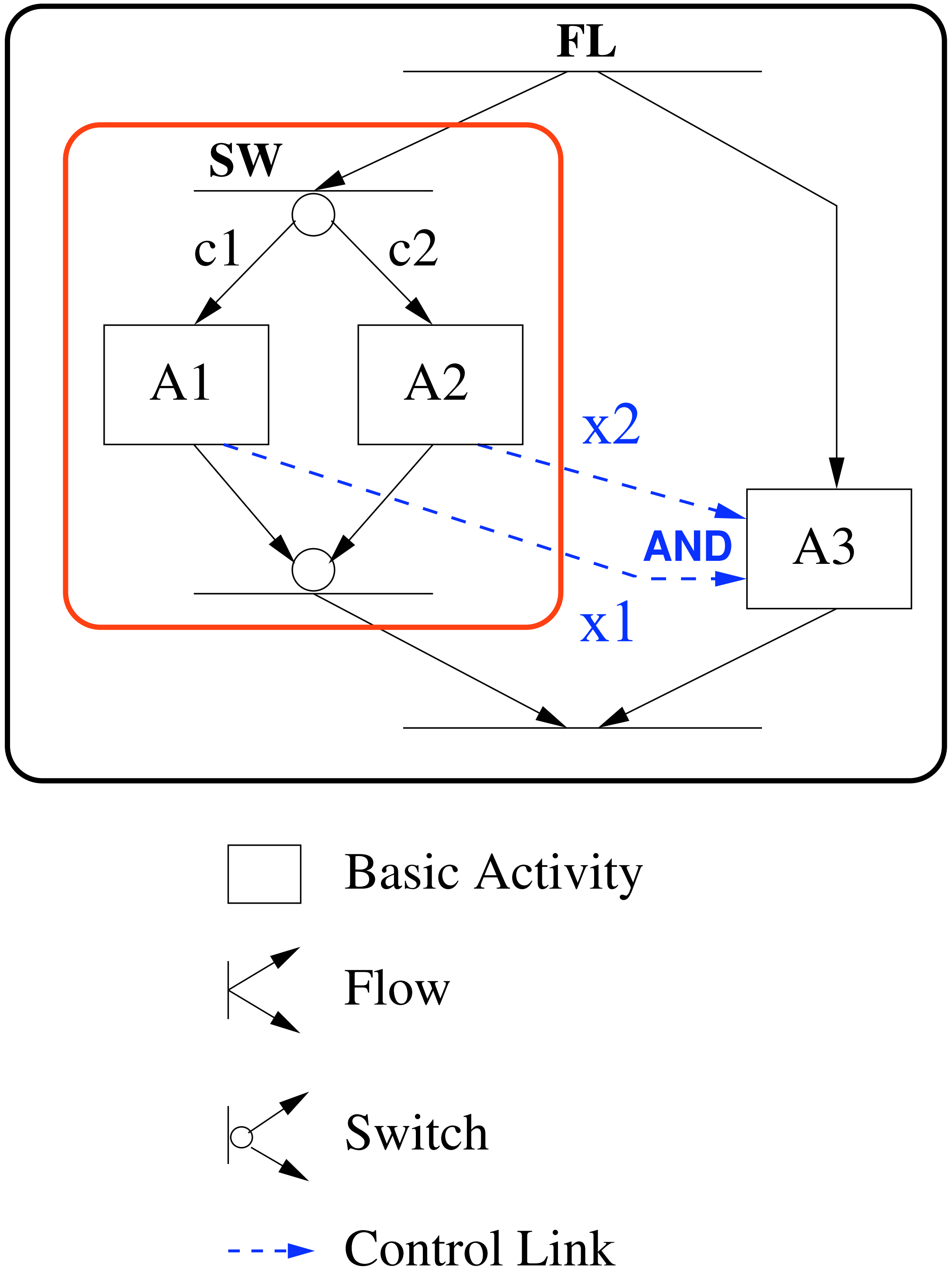
Checking for unreachable activities

Checking for potential conflicting message receipt actions

Determining which messages can be eventually consumed

Example: BPEL with unreachable activity

```
<process name="unreachableTask"
   targetNamespace="http://samples.otn.com"
   suppressJoinFailure="yes"
   xmlns:tns="http://samples.otn.com"
   xmlns:services="http://services.otn.com"
   xmlns="http://schemas.xmlsoap.org/ws/2003/03/business-process/">
  <flow name="FL" suppressJoinFailure="yes">
  <links>
    <link name="x1"/>
    <link name="x2"/>
  </links>
  <switch name="SW">
    <case>
      <invoke name="A1">
       <sources>  <source linkName="x1"/>   </sources>
      </invoke>
    </case>
    <otherwise>
      <invoke name="A2">
       <sources>  <source linkName="x2"/>   </sources>
      </invoke>
    </otherwise>
  </switch>
  <invoke name = "A3">
   <targets>
    <joinCondition>
      bpws:getLinkStatus('x1') and bpws:getLinkStatus('x2')
    </joinCondition>
    <target linkName="x1"/>
    <target linkName="x2"/>
   </targets>
  </invoke>
  </flow>
</process>
```



Basic activity X

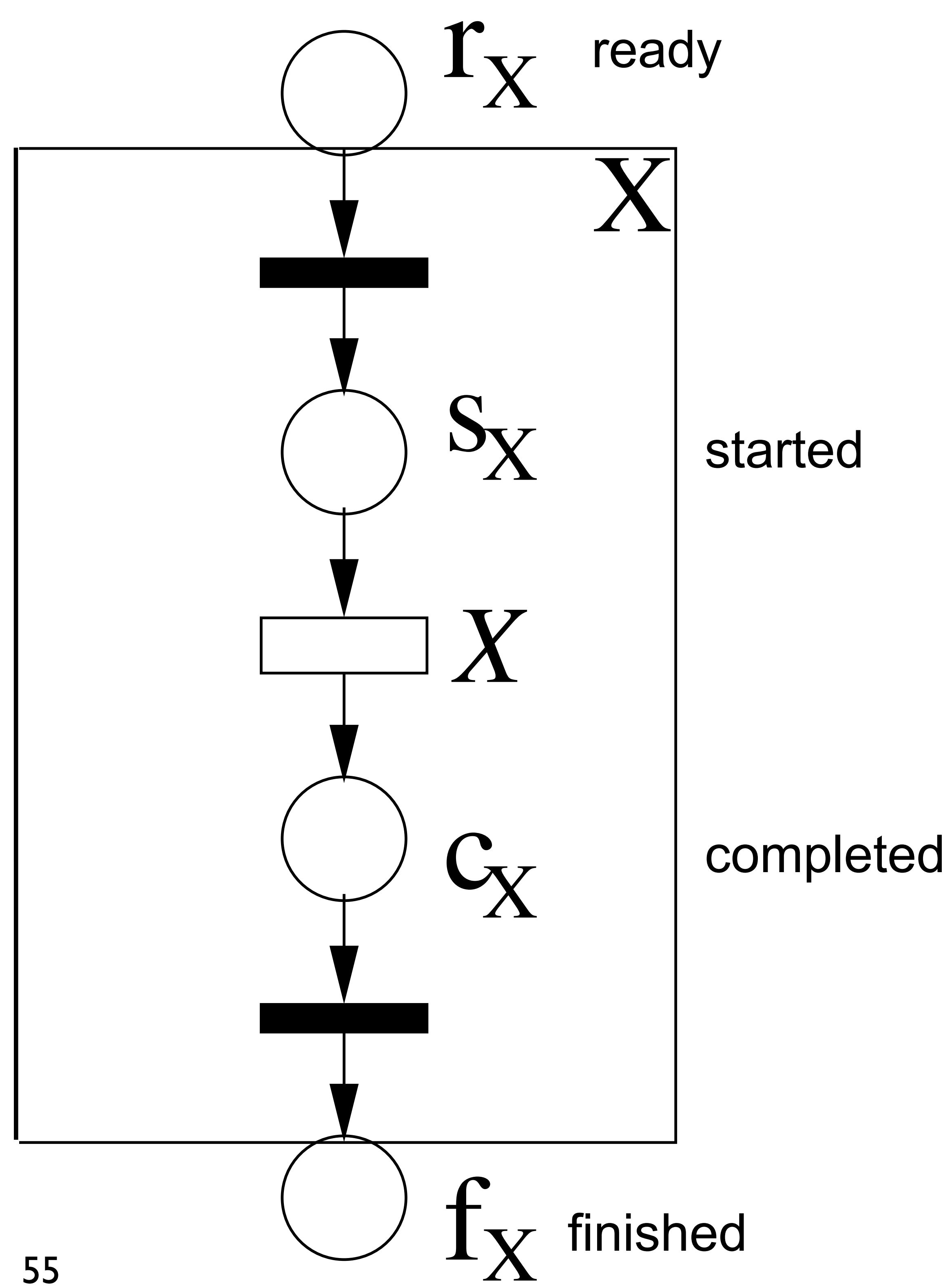
The activity can be

<assign>

<invoke>

<receive>

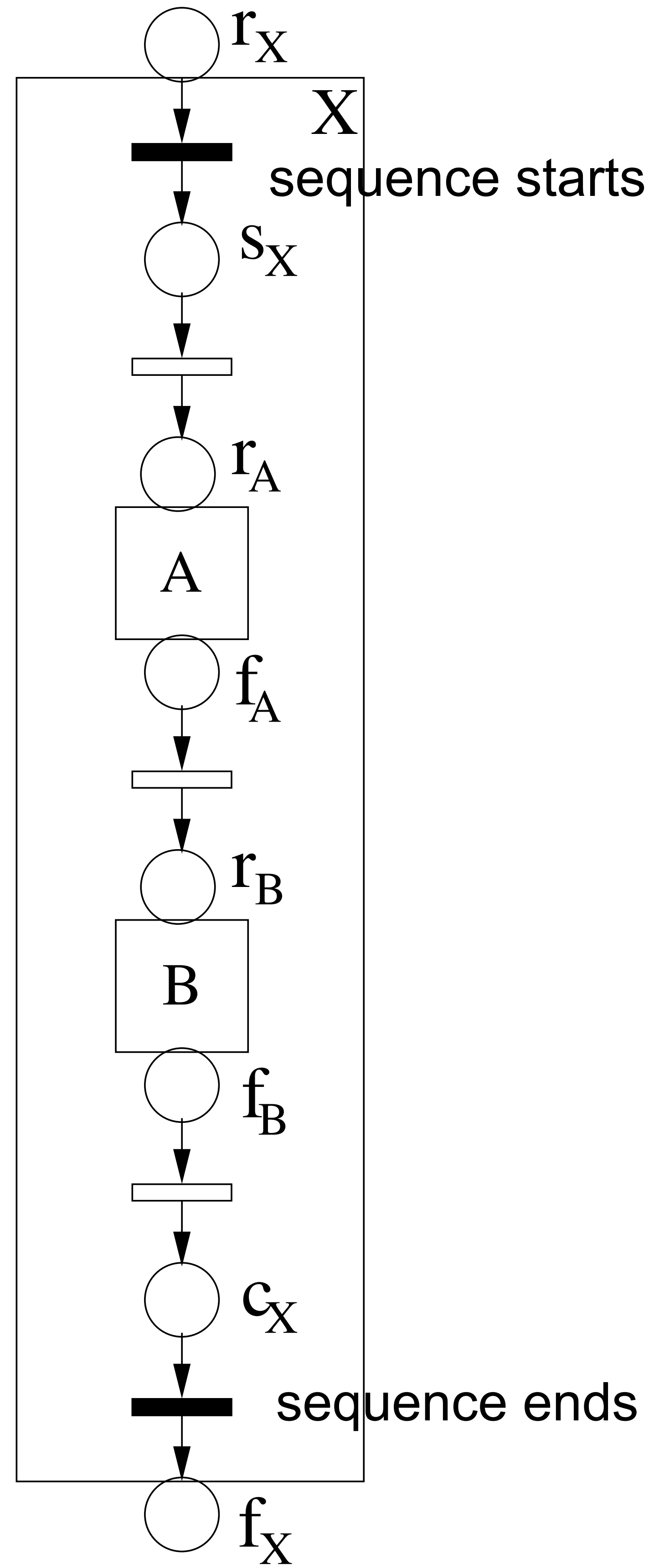
<reply>



Sequence A;B

We show the binary version, but it can be generalized to an arbitrary number of activities

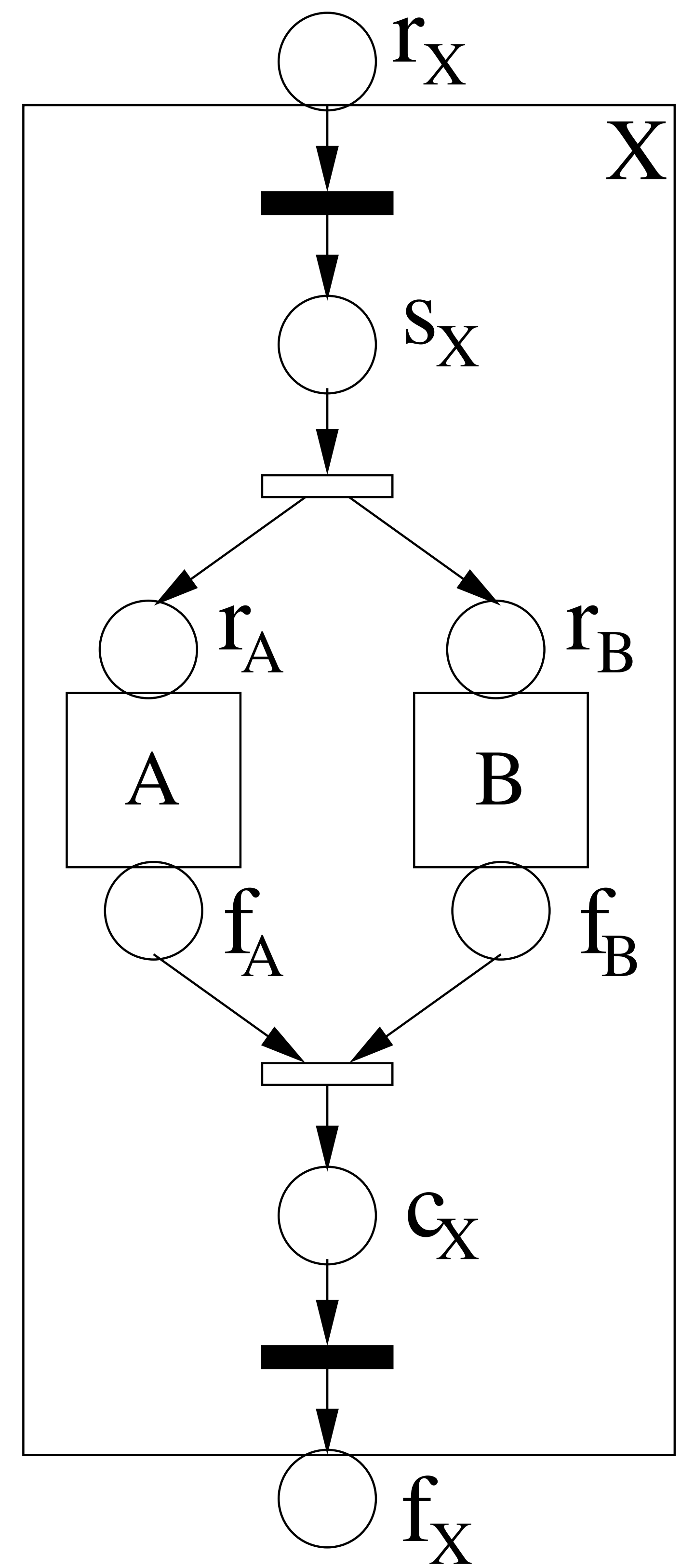
<sequence
name="X">
activity A
activity B
</sequence>



Flow A|B

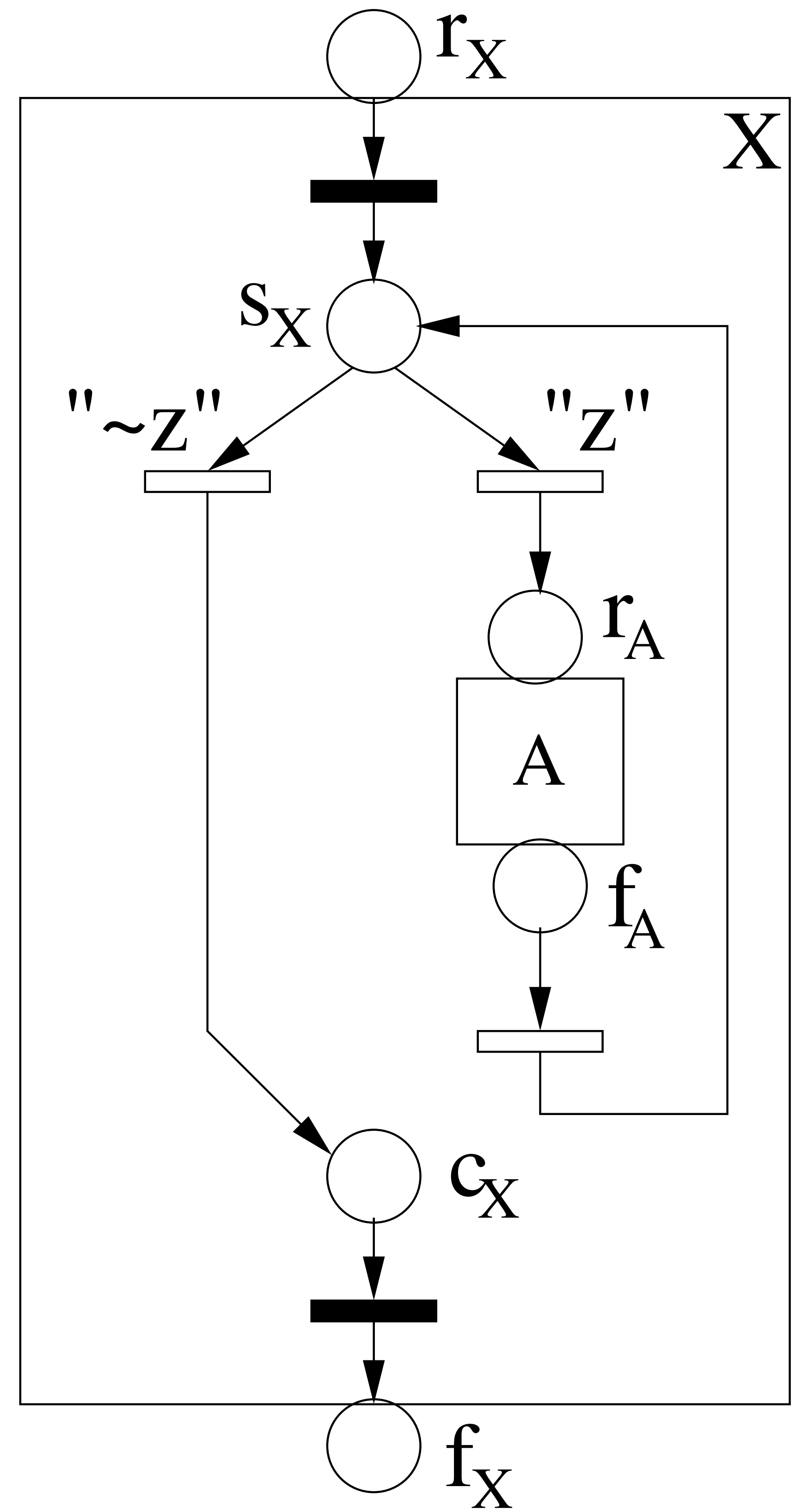
We show the binary version, but it can be generalized to an arbitrary number of activities

<flow
  name="X">
   activity A
   activity B
</flow>



While z do A

<while name="X">
<condition>
z
</condition>
activity A
</while>



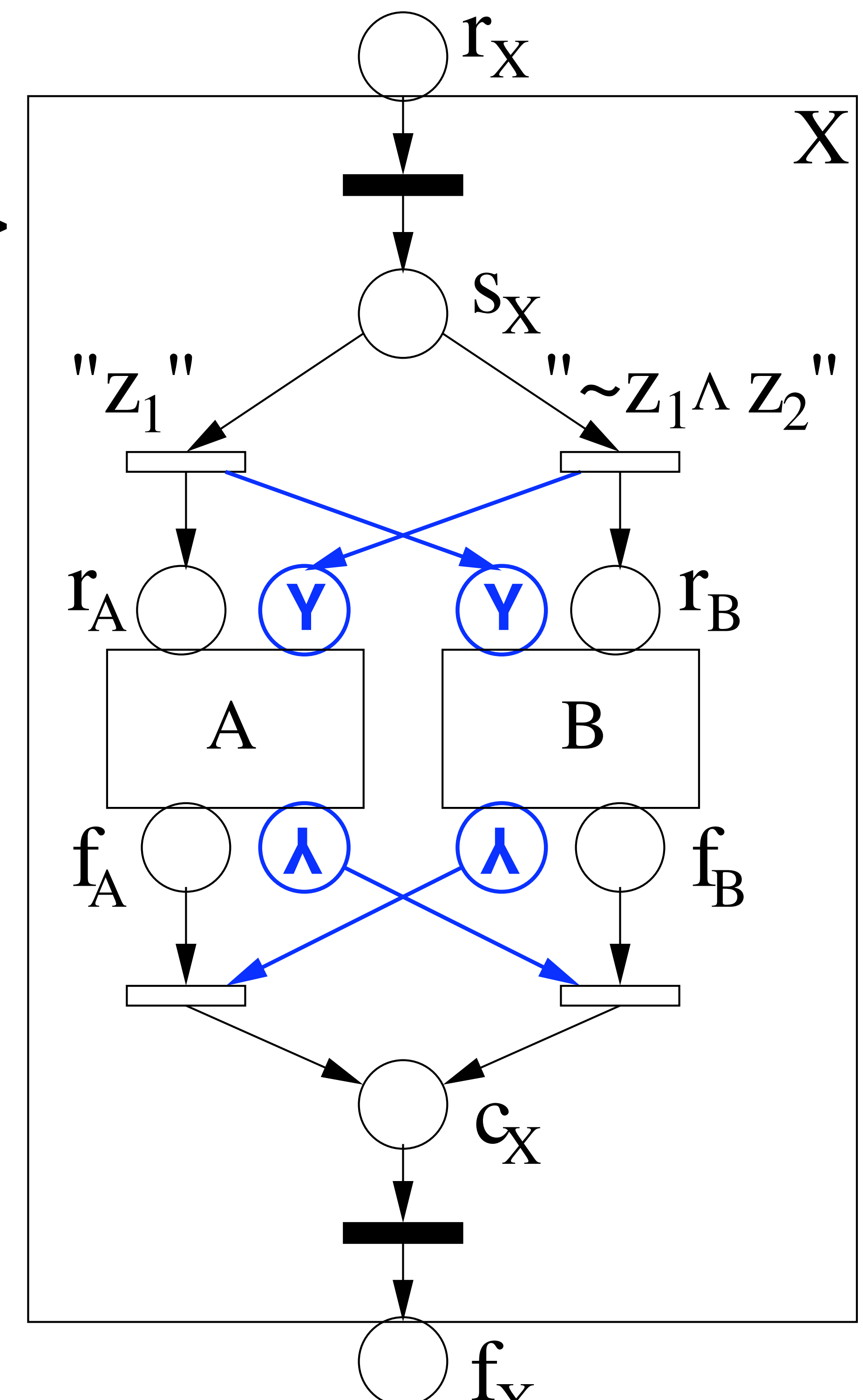
Switch (z_1)A,(z_2)B

We show the binary version, but it can be generalized to an arbitrary number of activities

In blue:
alternative flow to skip activities (to deal with links and dead-path elim.)

Y ⅄
are just decorations

```
<switch name="X">
  <case>
    <condition>
        z1
    </condition>
    activity A
  </case>
  <case>
    <condition>
        z2
    </condition>
    activity B
  </case>
</switch>
```



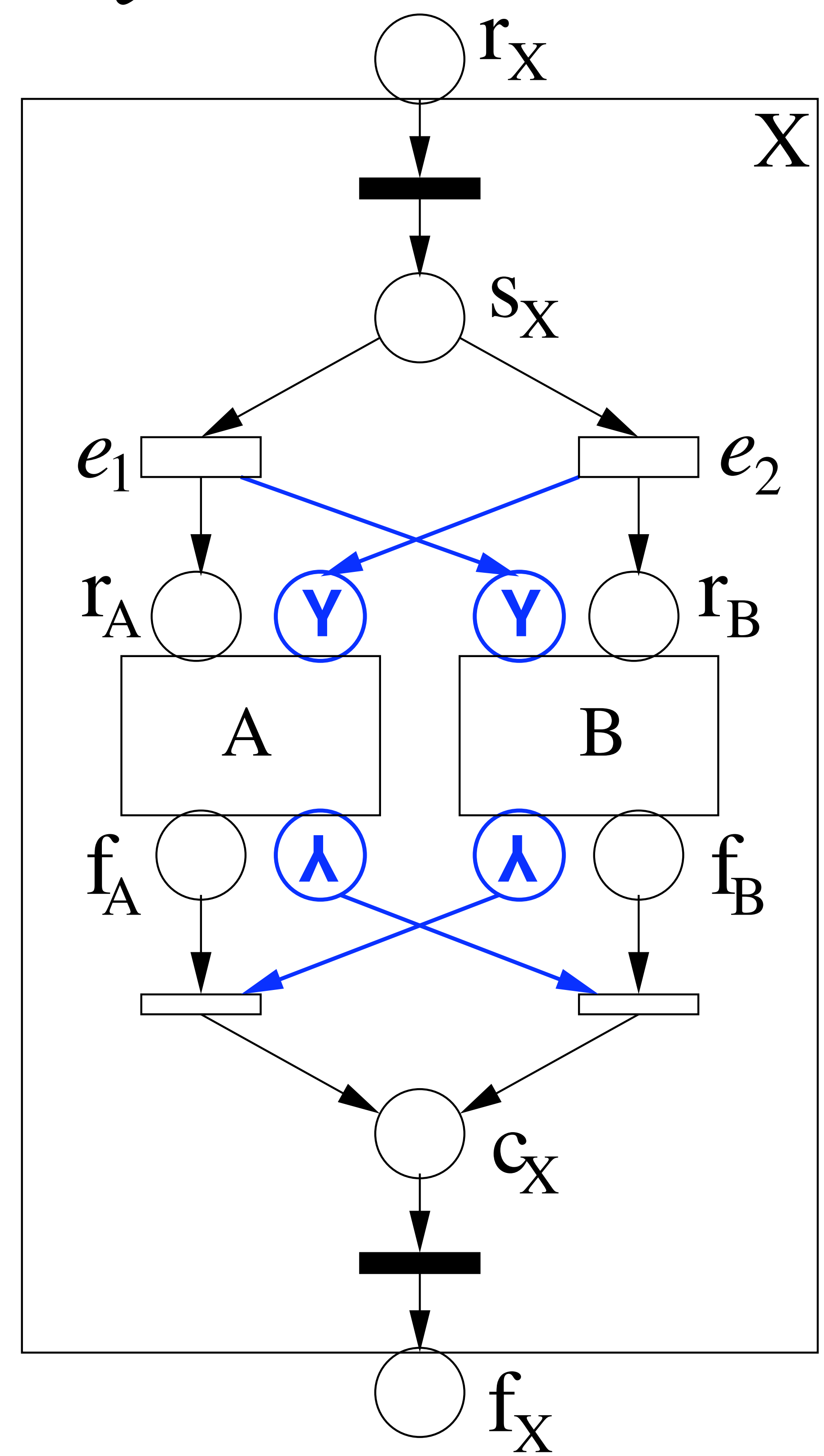
Pick $(e_1)A,(e_2)B$

We show the binary version, but it can be generalized to an arbitrary number of activities

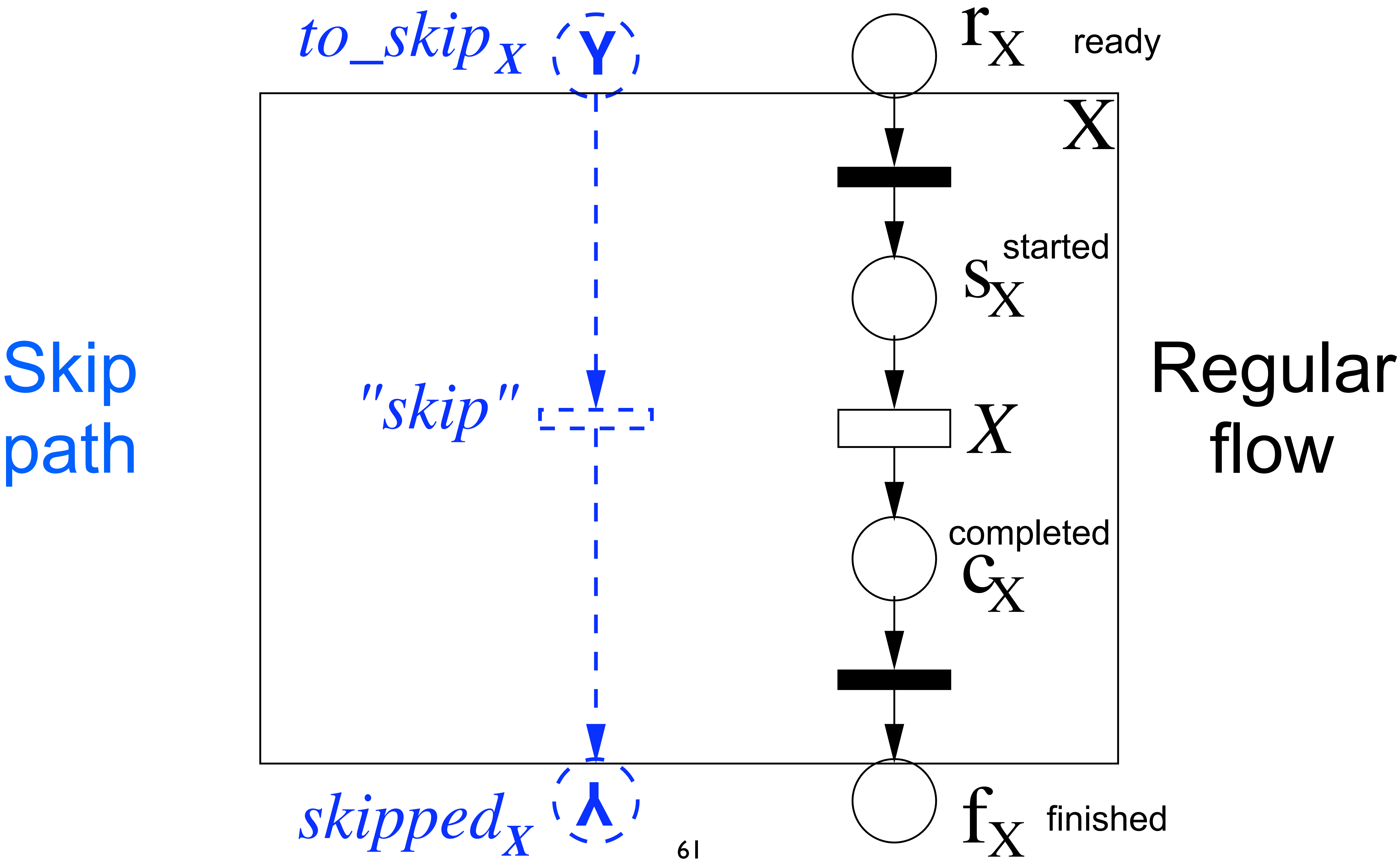
In blue:
alternative flow to skip activities (to deal with links and dead-path elim.)

Y ⅄
are just decorations

```
<pick name="X">
  <onMessage e1>
      activity A
  </onMessage>
  <onAlarm  e2>
      activity B
  </onAlarm>
</pick>
```



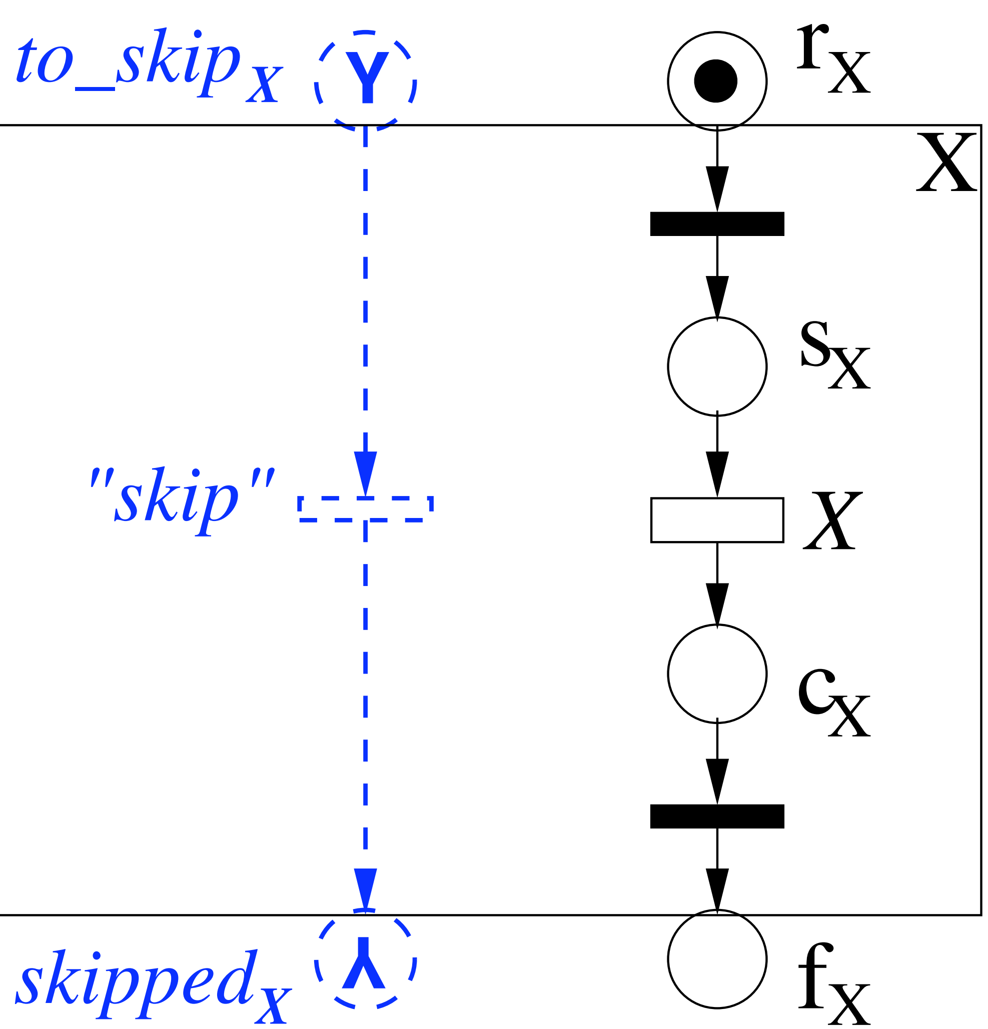
Basic activity + skip



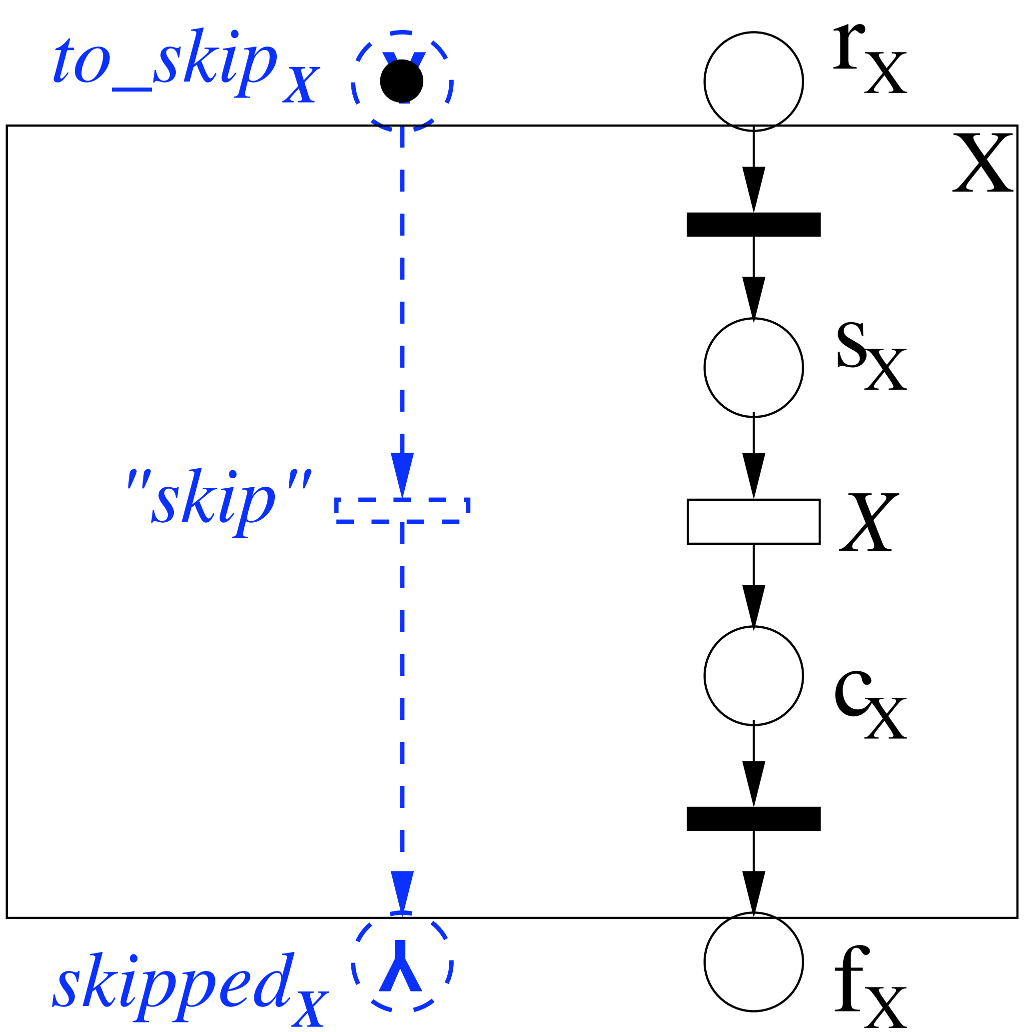
Basic activity + skip

The token arrives
either here...

... or here



normal behaviour

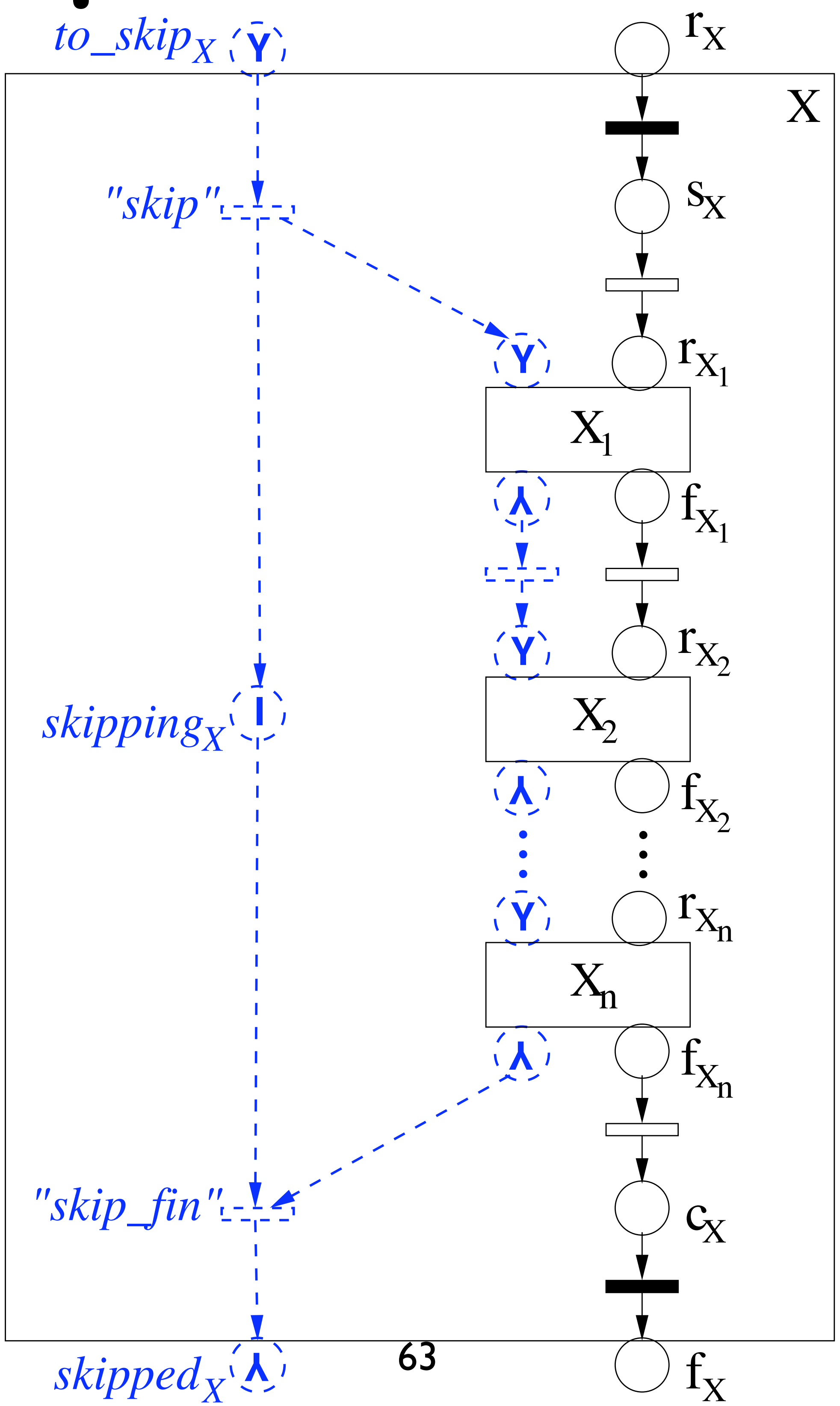


skipping behaviour

(but not both)

Sequence + skip

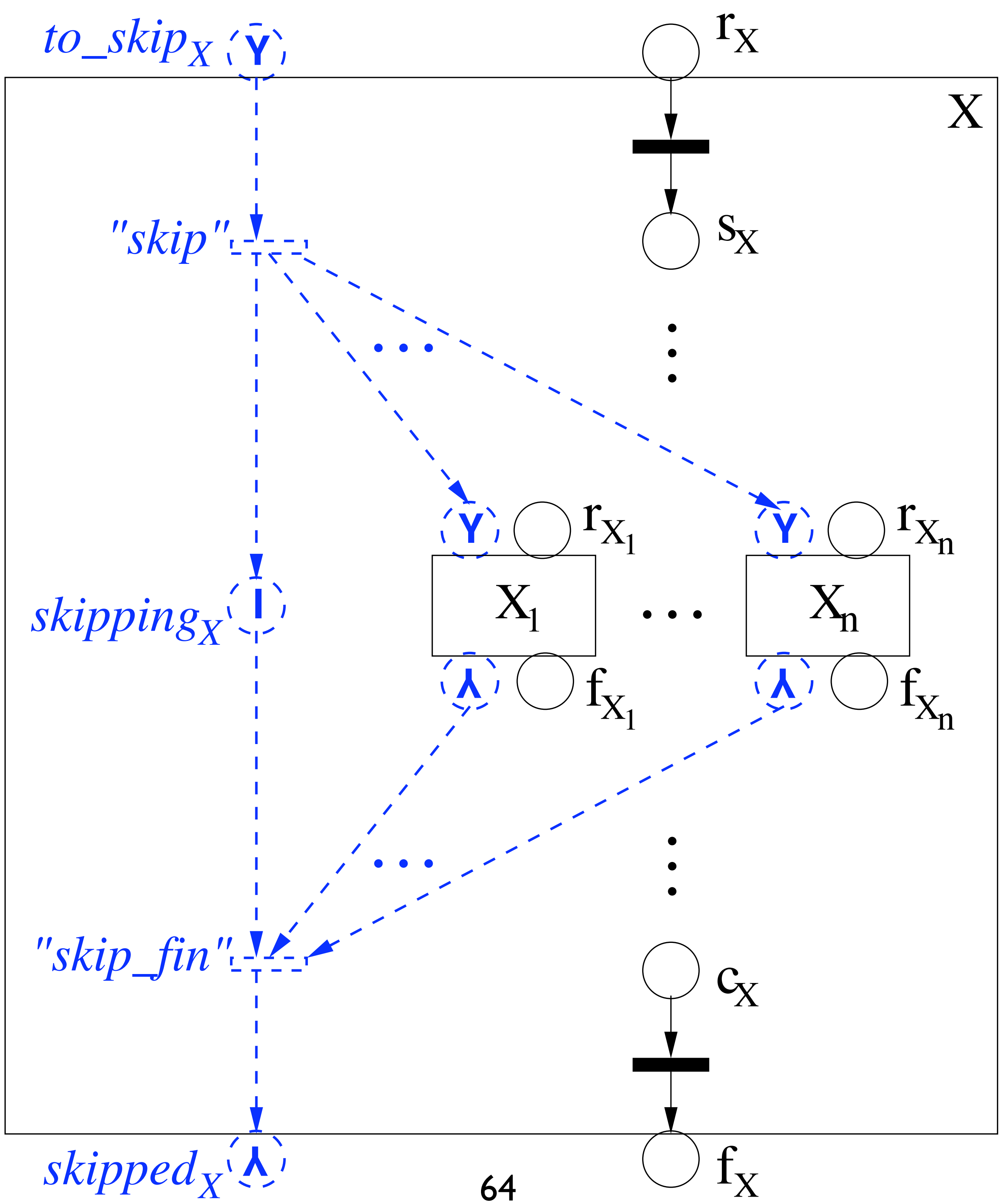
Skip path



Regular flow

Non-sequence + skip

Skip path

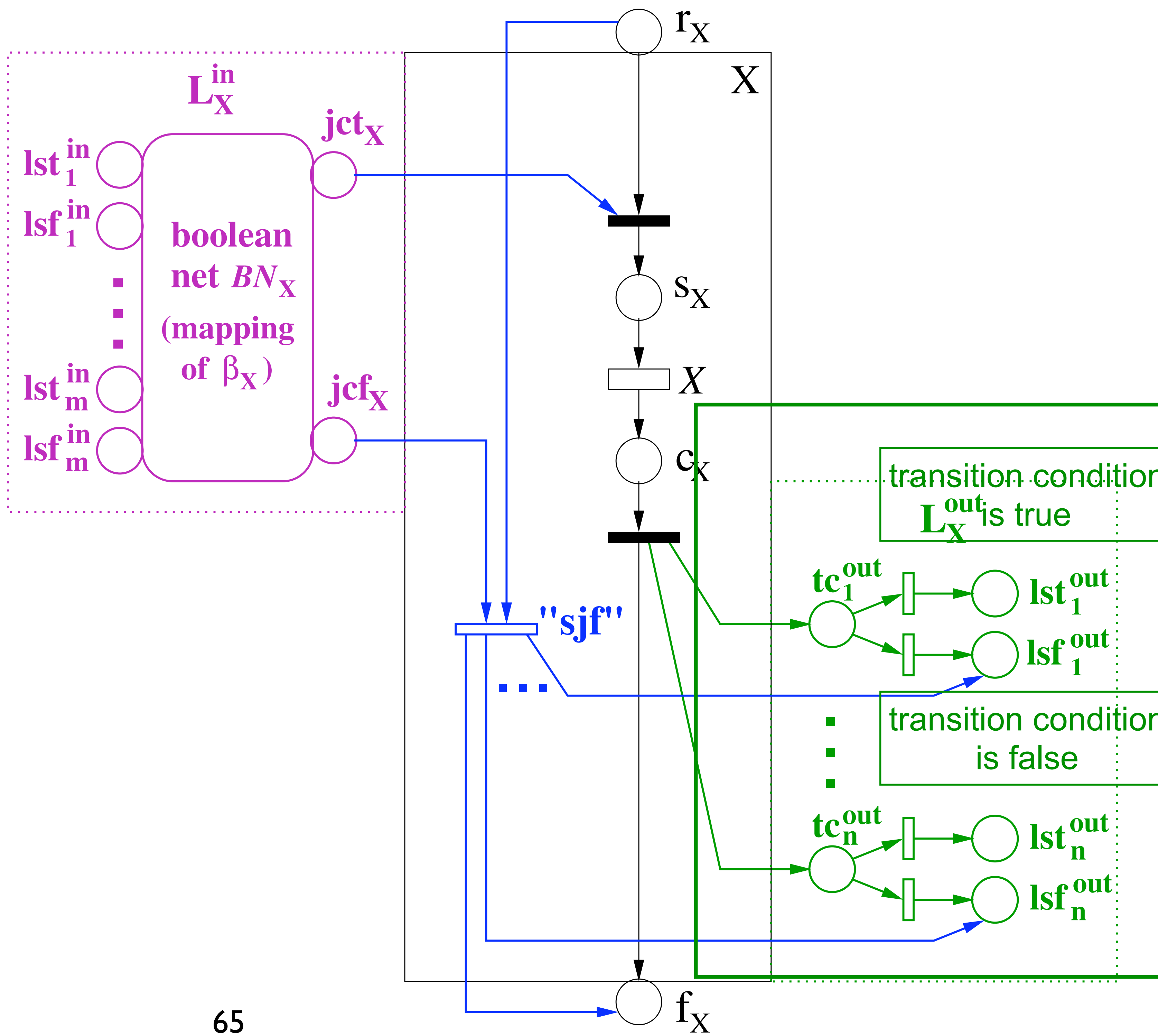


Regular flow

Basic activity with control links: normal behaviour

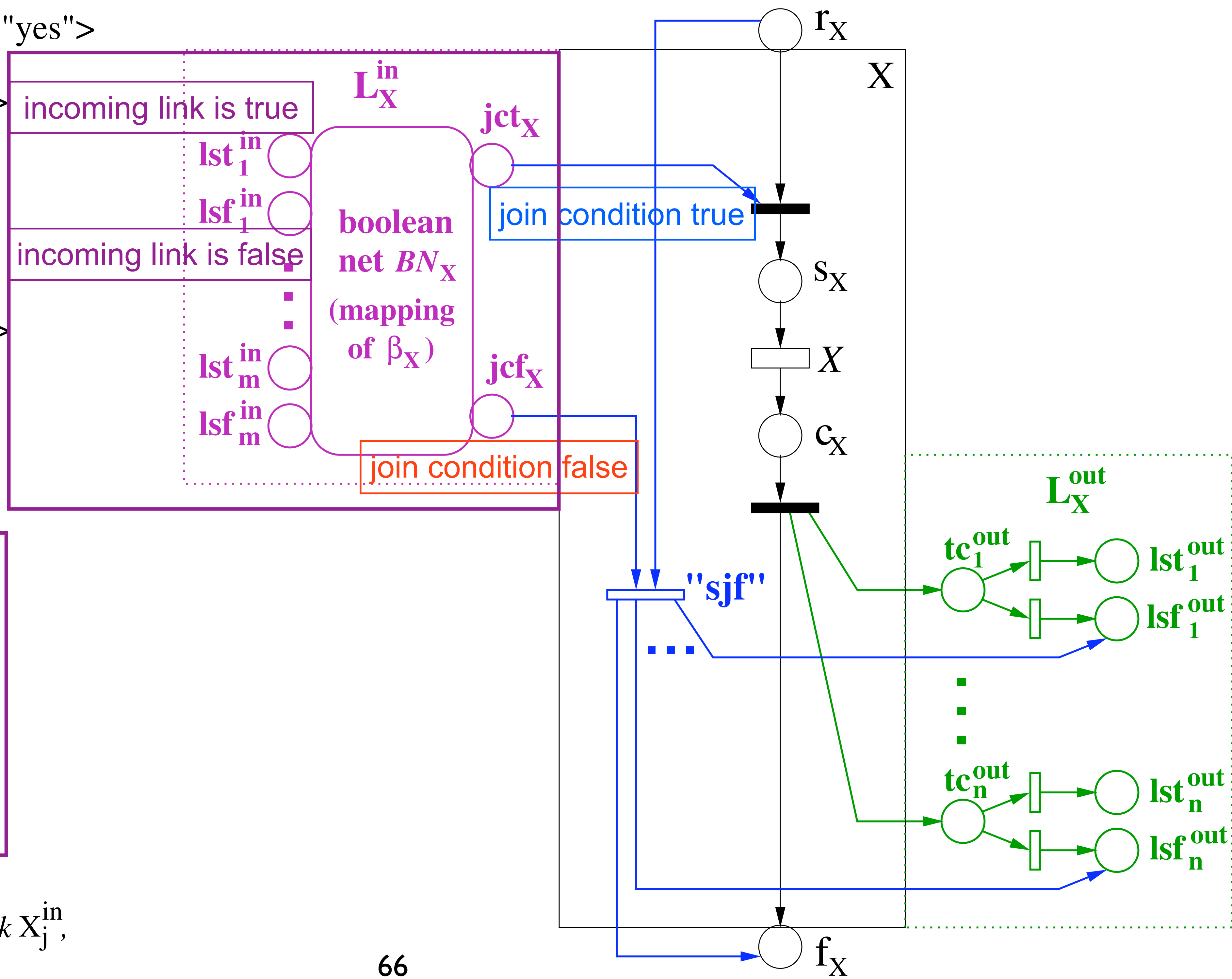
<activityX suppressJoinFailure="yes">
<sources>
<source linkname="X_1^{out}">
<transitionCondition>
tc_1^{out}
</transitionCondition>
</source>
⋮
<source linkname="X_n^{out}">
<transitionCondition>
tc_n^{out}
</transitionCondition>
</source>
</sources>
<targets>
<joinCondition>
$\beta_X\,(ls_1^{in}, \ldots, ls_m^{in})$
</joinCondition>
<target linkname="X_1^{in}">
⋮
<target linkname="X_m^{in}">
</targets>
</activityX>

[note] ls_j^{in} *is the status of control link* X_j^{in}, *where j=1, 2, ... , m.*



Basic activity with control links: normal behaviour

<activityX suppressJoinFailure="yes">
<sources>
<source linkname="X^{out}_{1}">
<transitionCondition>
tc^{out}_{1}
</transitionCondition>
</source>
⋮
<source linkname="X^{out}_{n}">
<transitionCondition>
tc^{out}_{n}
</transitionCondition>
</source>
</sources>
<targets>
<joinCondition>
$\beta_X(ls^{in}_1, \ldots, ls^{in}_m)$
</joinCondition>
<target linkname="X^{in}_{1}">
⋮
<target linkname="X^{in}_{m}">
</targets>
</activityX>

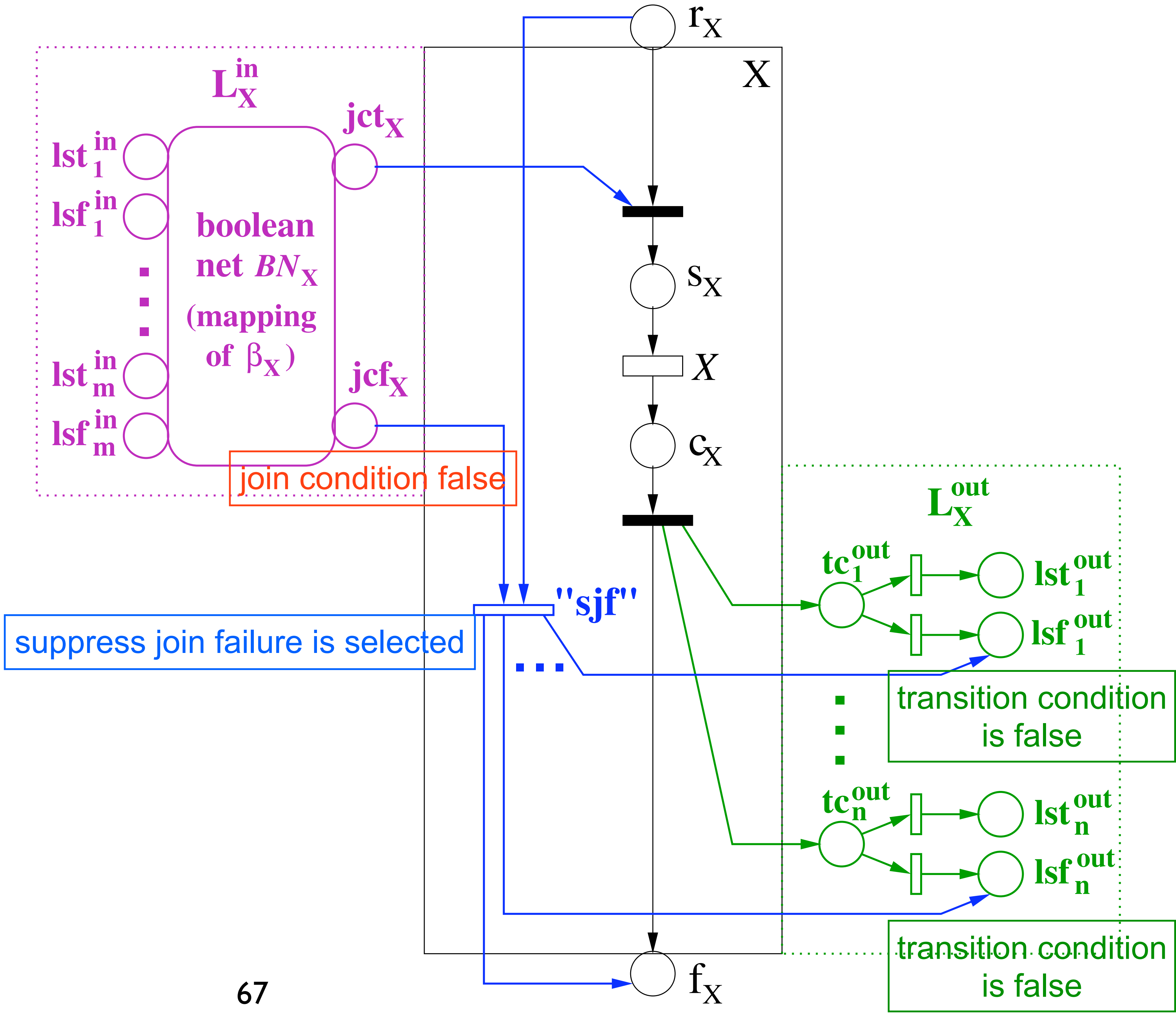


[note] ls^{in}_j *is the status of control link* X^{in}_j, *where j=1, 2, ... , m.*

Basic activity with control links: normal behaviour

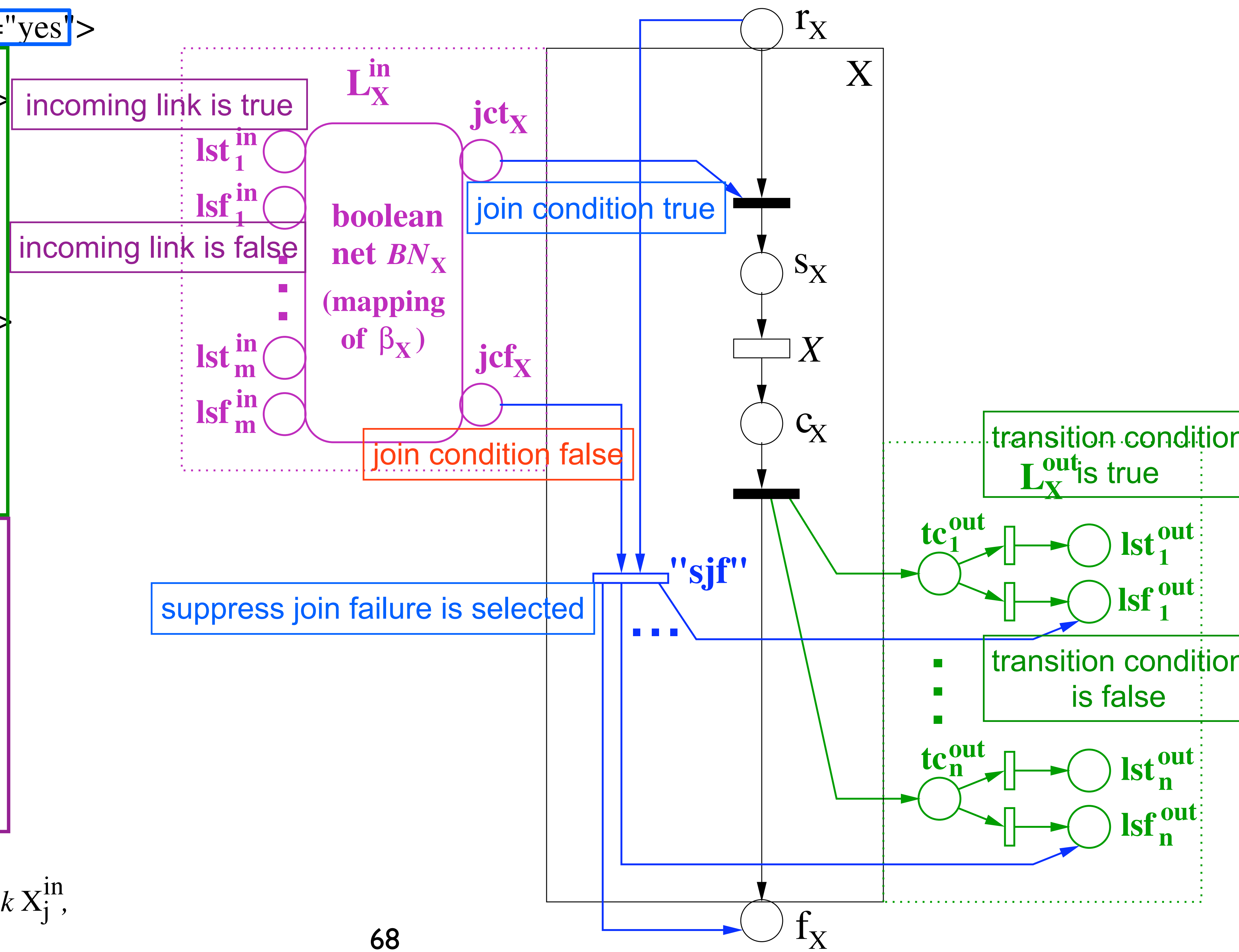
<activityX suppressJoinFailure="yes">
<sources>
<source linkname="X_1^{out}">
<transitionCondition>
tc_1^{out}
</transitionCondition>
</source>
⋮
<source linkname="X_n^{out}">
<transitionCondition>
tc_n^{out}
</transitionCondition>
</source>
</sources>
<targets>
<joinCondition>
$\beta_X(ls_1^{in}, \ldots , ls_m^{in})$
</joinCondition>
<target linkname="X_1^{in}">
⋮
<target linkname="X_m^{in}">
</targets>
</activityX>

[note] ls_j^{in} *is the status of control link* X_j^{in}, *where j=1, 2, ... , m.*



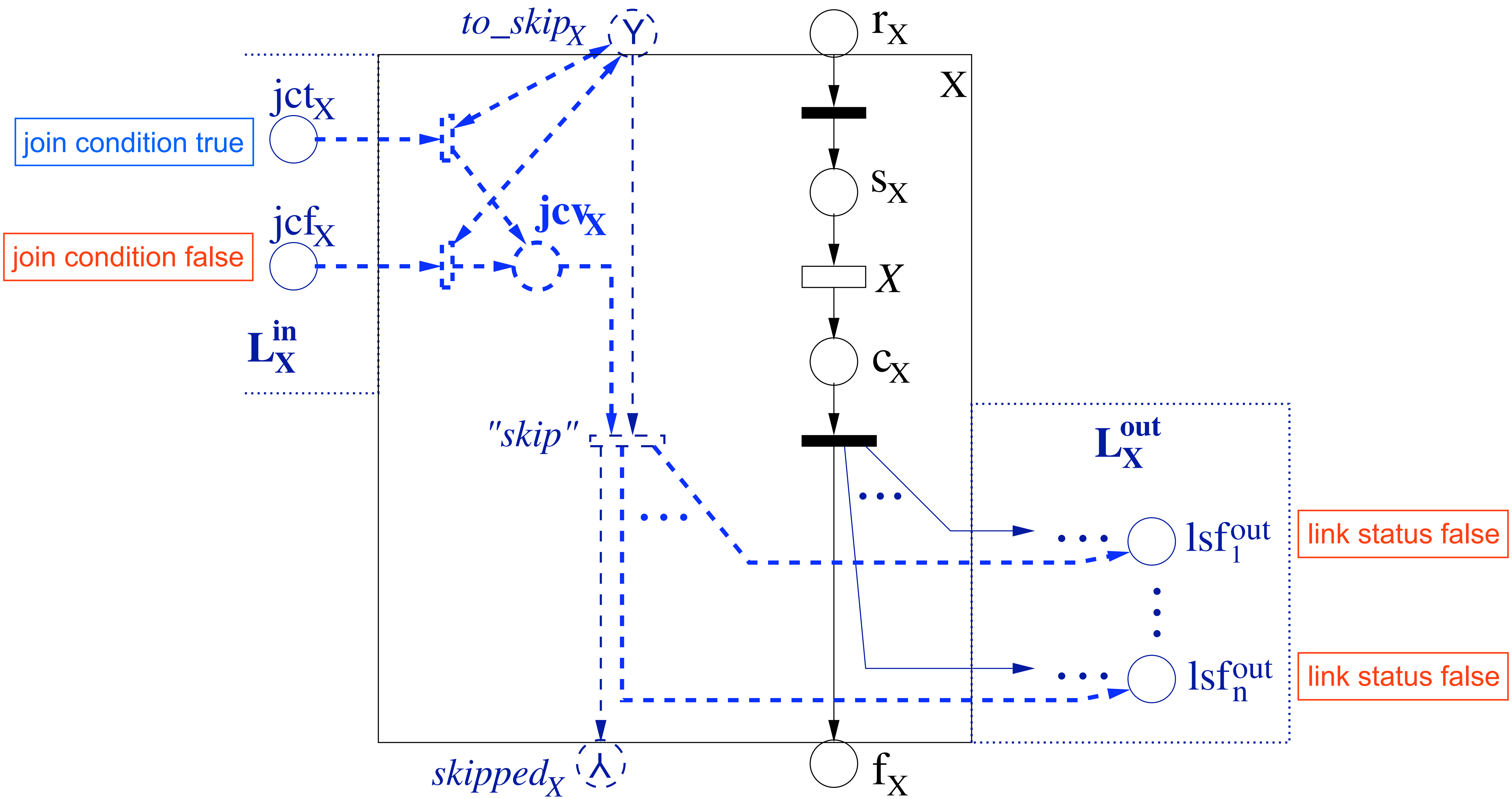
Basic activity with control links: normal behaviour

<activityX suppressJoinFailure="yes">
<sources>
<source linkname="X_1^{out}">
<transitionCondition>
tc_1^{out}
</transitionCondition>
</source>
⋮
<source linkname="X_n^{out}">
<transitionCondition>
tc_n^{out}
</transitionCondition>
</source>
</sources>
<targets>
<joinCondition>
$\beta_X(ls_1^{in}, \ldots, ls_m^{in})$
</joinCondition>
<target linkname="X_1^{in}">
⋮
<target linkname="X_m^{in}">
</targets>
</activityX>

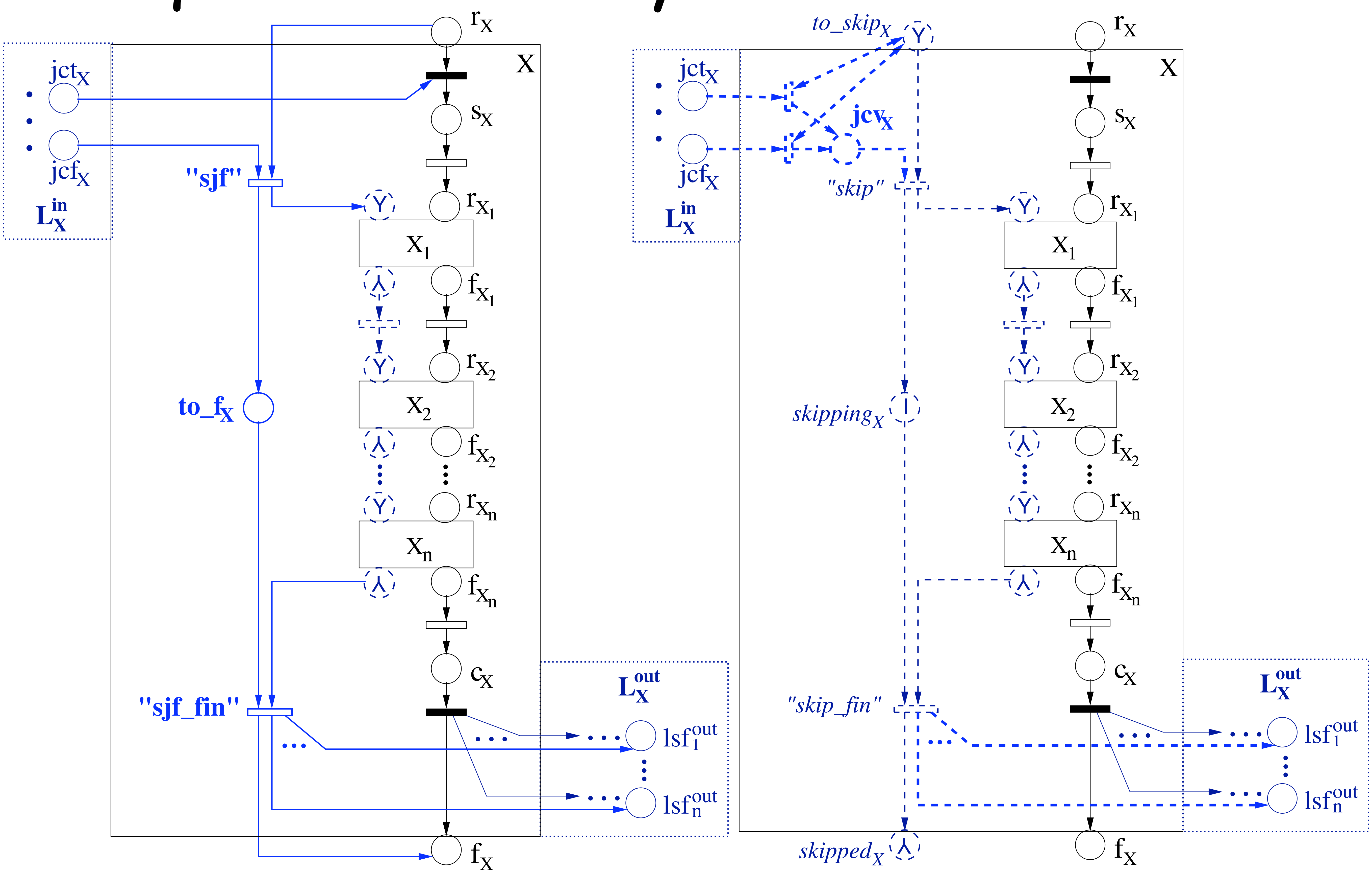


[note] ls_j^{in} *is the status of control link* X_j^{in}, *where j=1, 2, ... , m.*

Basic activity with control links: skipping behaviour



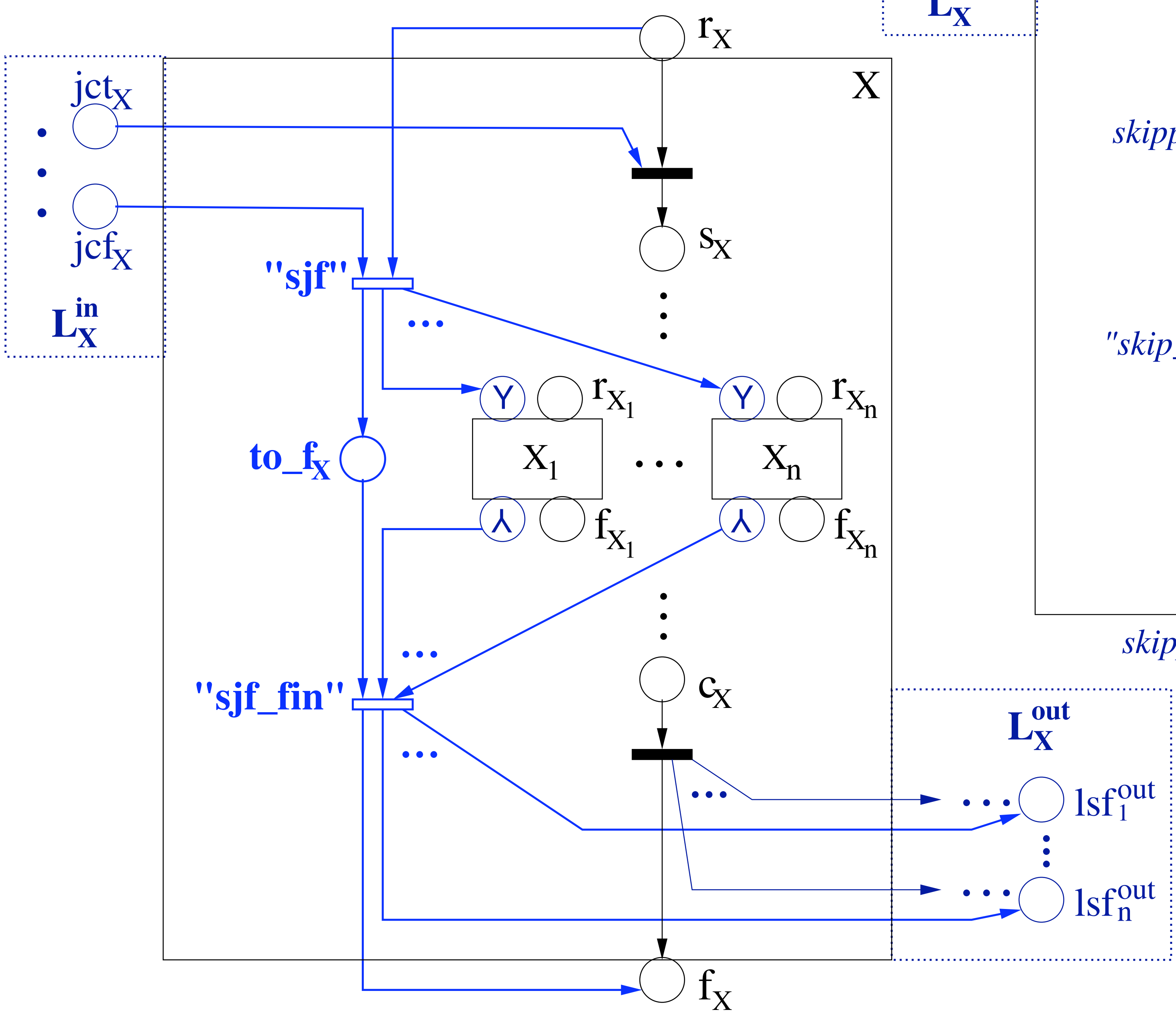
Sequence activity with control links



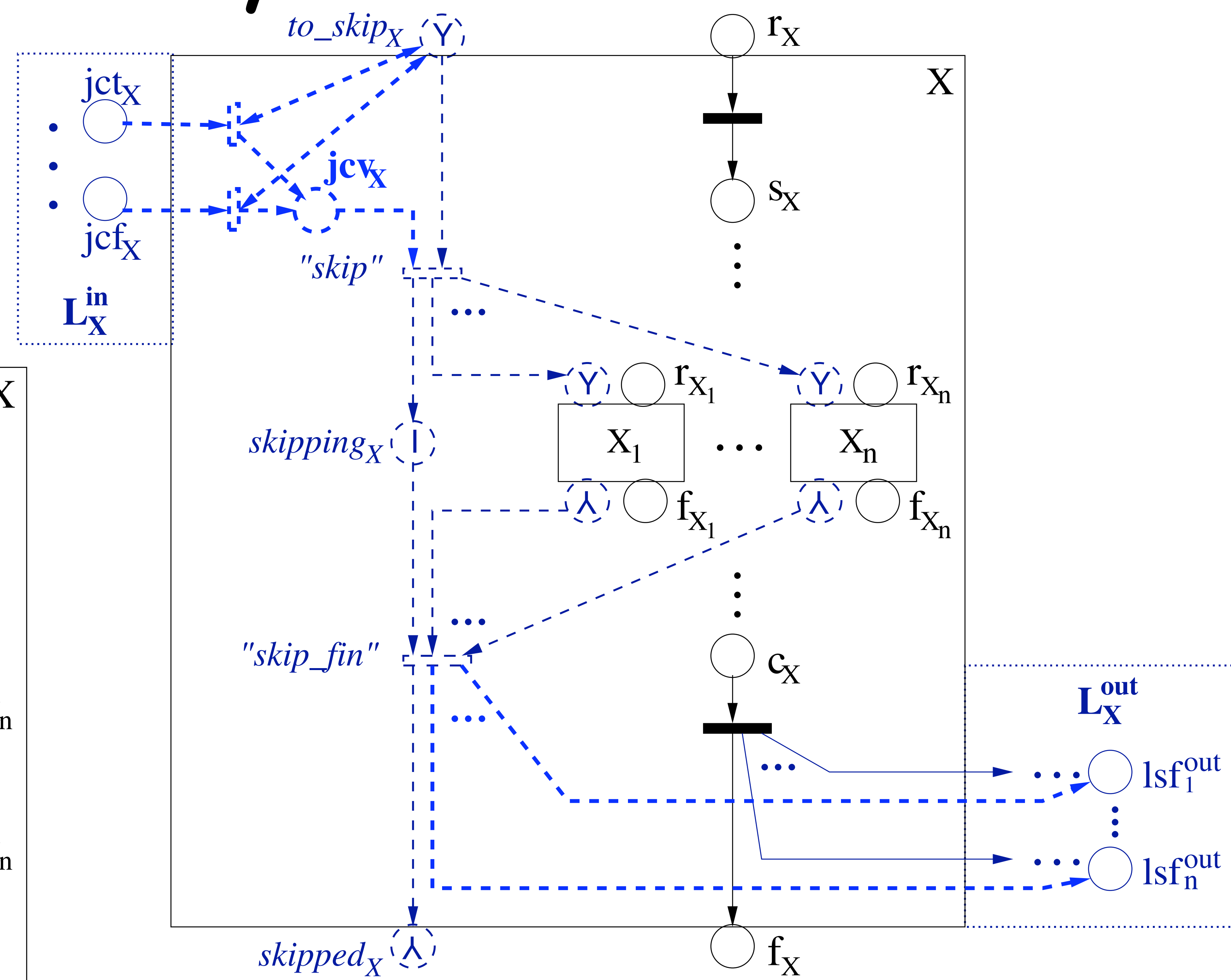
(a) normal behaviour

(b) skipping behaviour

Non-sequence activity with control links

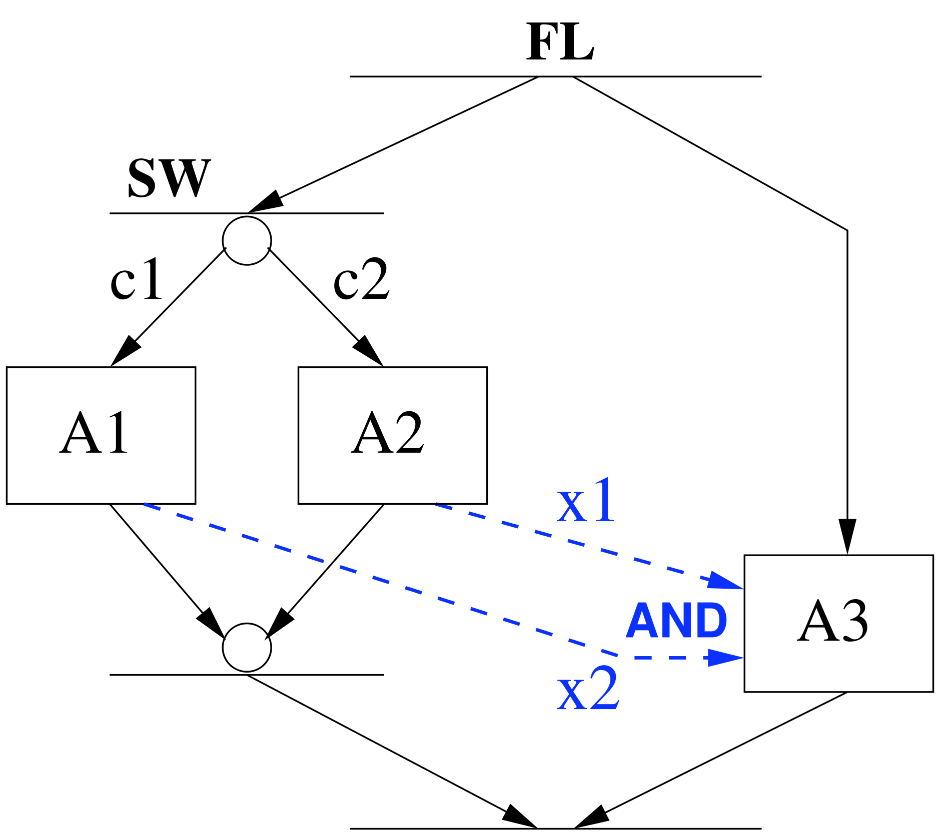


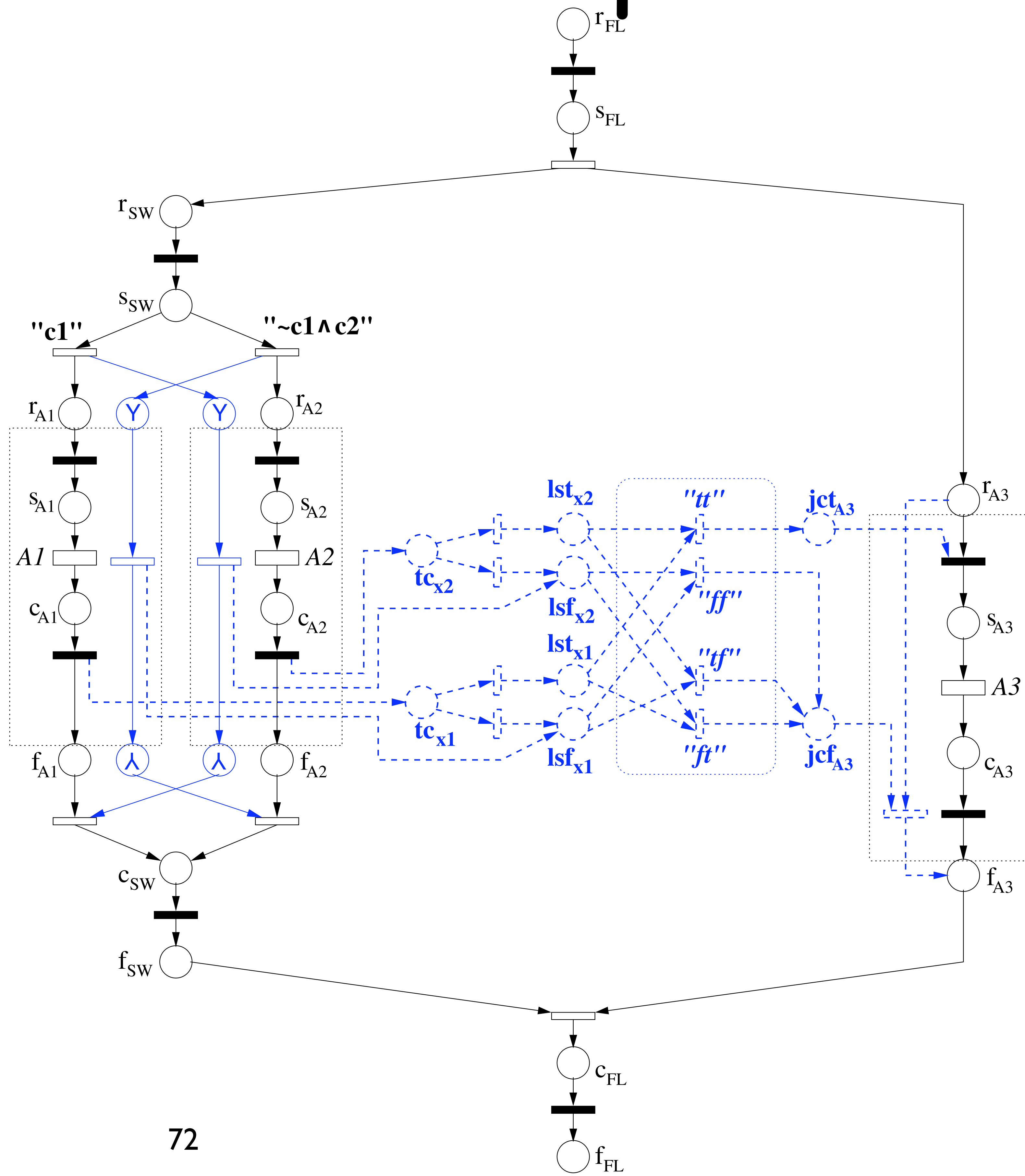
(a) normal behaviour



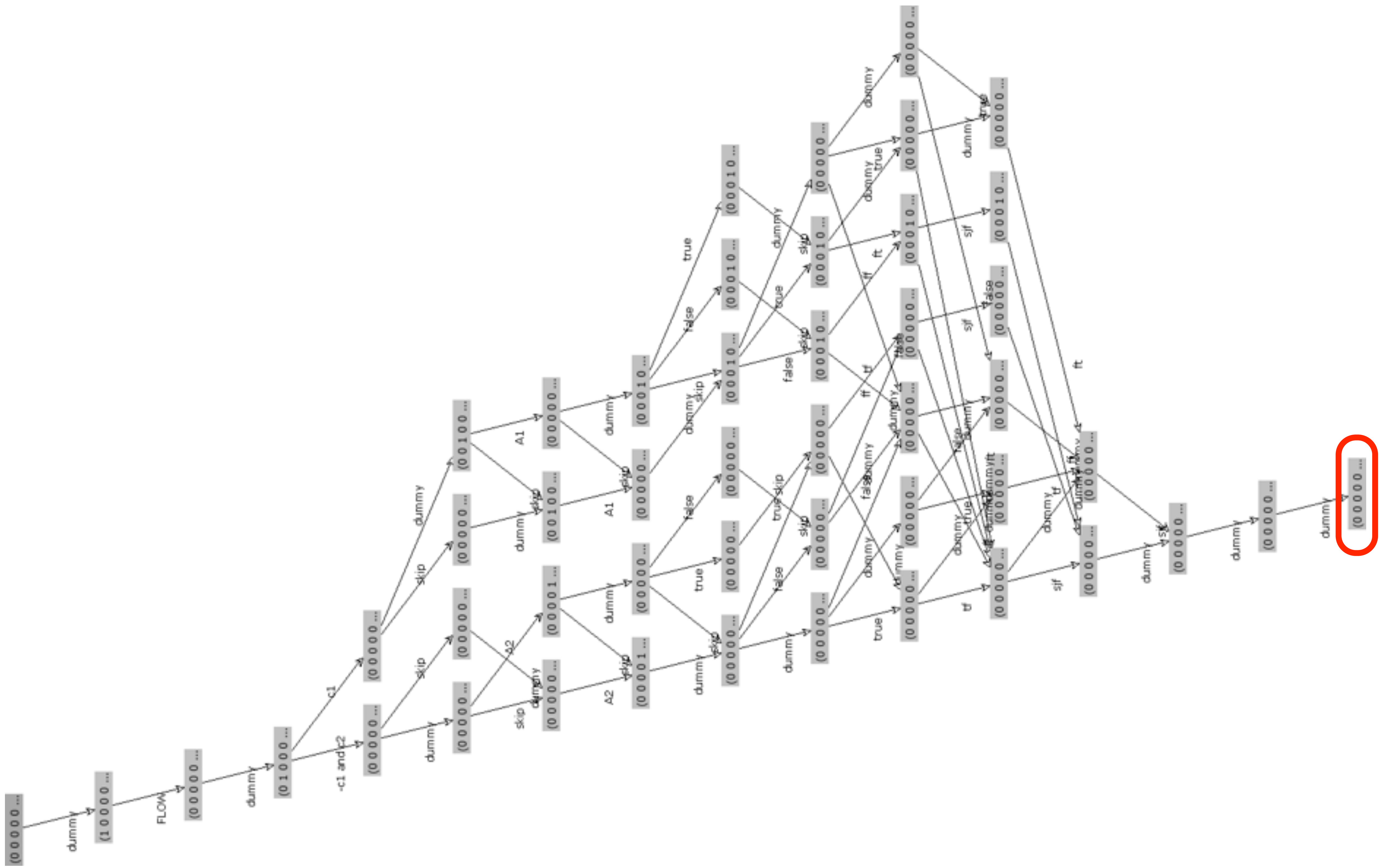
(b) skipping behaviour

The previous example

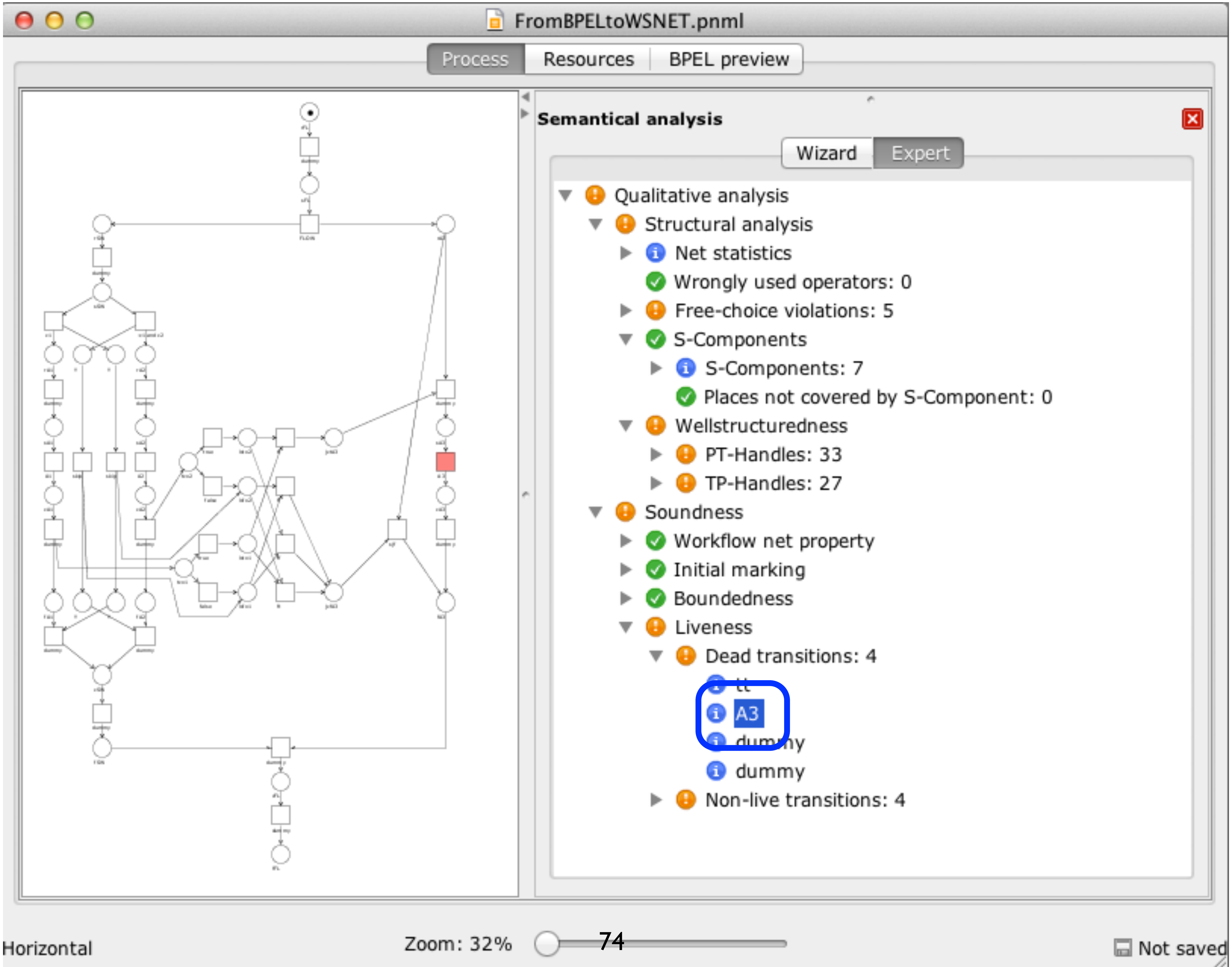




The previous example



The previous example

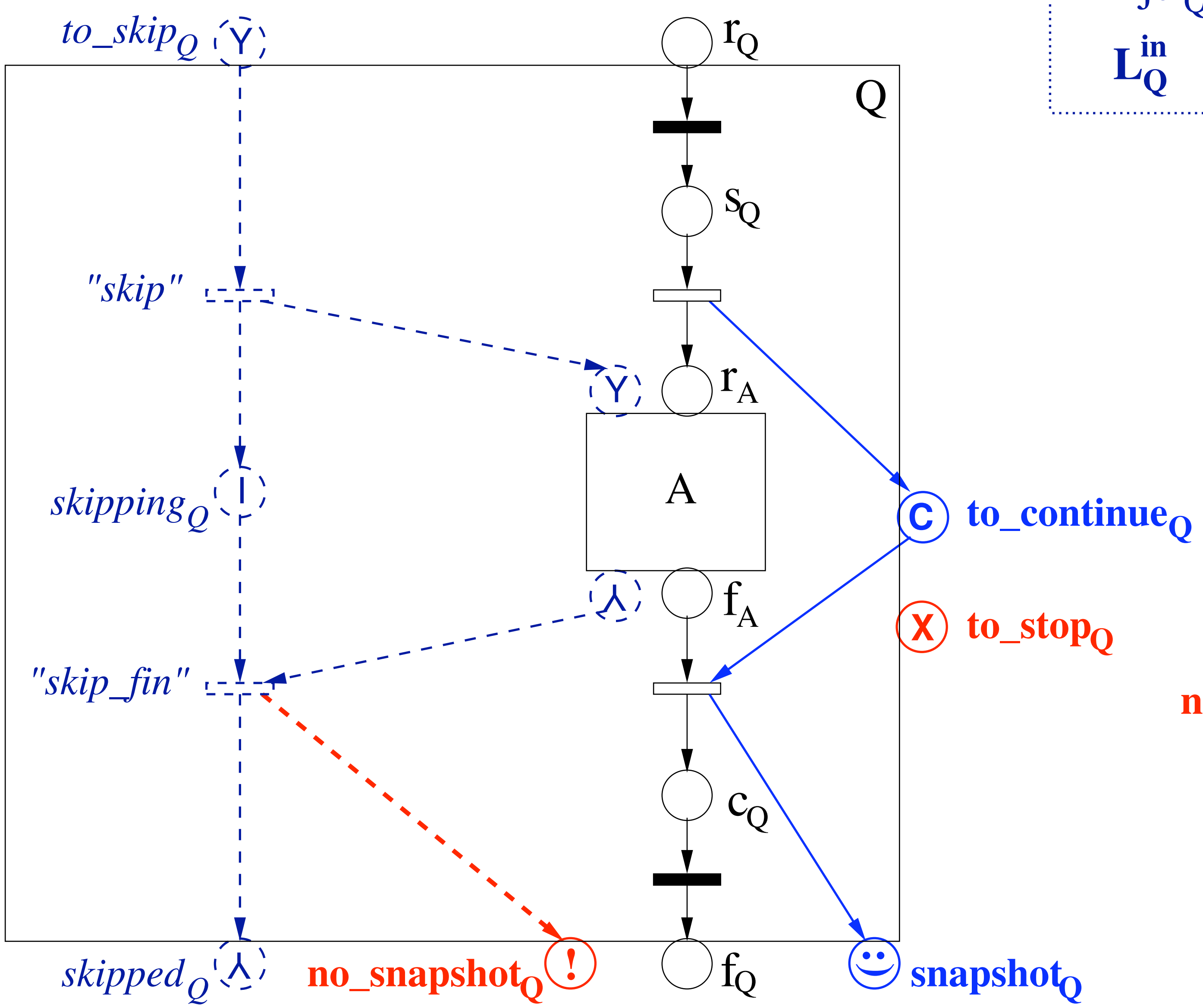


Scope

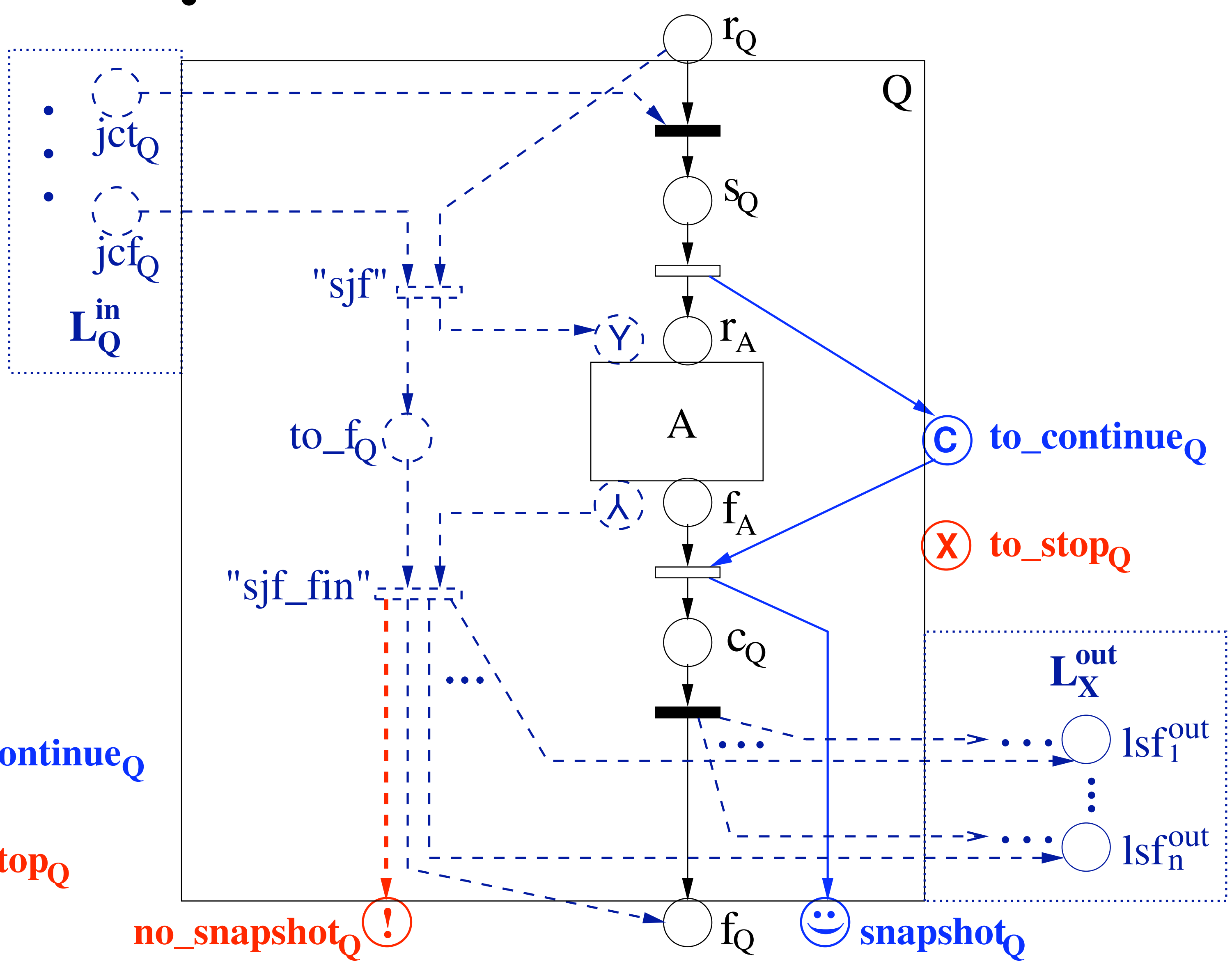
Remind that a scope has a primary activity, and optionally:
a set of fault handlers,
a set of event handlers, and
one compensation handler.

To deal with them, four “flags” are attached to a scope:
`to_continue` (no exception, execution is in progress)
`to_stop` (an error occurred, activities need to stop)
`snapshot` (successfully completed, uncompensated)
`no_snapshot` (no compensation needed)

Scope



(a) skipping behaviour



(b) suppressing join failure

Full translation

The interested reader can find out
more details in the paper by Ouyang *et al.*
and play with the **BPEL2PNML** tool available at
http://www.win.tue.nl/~hverbeek/doku.php?id=projects:prom:plug-ins:conversion:bpel2tpn

An alternative translation is given in the paper
``Transforming BPEL to Petri Nets'' by Hinz, Schmidt, Stahl,
supported by the **BPEL2oWFN** tool available at
http://www.gnu.org/software/bpel2owfn/

The two translations are compared in
``Comparing and Evaluating Petri Net Semantics for BPEL''
by Lohmann, Verbeek, Ouyang, Stahl, van der Aalst