Programming Web Services with Choreography

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This Talk In One Slide

- **Choreography and Web Services (07)**
  - A model for Choreography
  - Session Types
  - Global Calculus
  - About End-Point Projection (EPP)
- **Interactional Exceptions and Choreography (08&workinprogress)**
  - Session Types and Exceptions
  - Extension of the Global Calculus
  - About End-Point Projection (EPP)

Choreography?

- Choreography as a way of describing communication-based systems focusing on global message flows
- Idea from WS-CDL, the *Web Services Choreography Description Language*
- XML-based description language
- Developed by W3C (since 2003) in collaboration with private companies Pi4Tech, Adobe, Oracle, Sun, etc.
- π-calculus experts invited since 2004 (R. Milner and us)

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Joint with K. Honda & N. Yoshida

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Choreography? (2)

- Choreography as a way of describing communication-based systems focusing on global message flows

  1. Entities have a common goal
  2. No single point of control
  3. Only describe **communications**

"Dancers dance following a global scenario without a single point of control", WS-CDL working group

Example: End Points

ALICE

send Bob<“Hello”>;
receive (z)

Example: End Points

ALICE

send Bob<“Hello”>;
receive (z)

BOB

receive (x)
send Carl<“Hello”>;

Example: End Points

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BOB

receive (x)
send Carl<“Hello”>;

CARL

receive (y)
send Alice<“Hello”>;

Example: End Points

ALICE

send Bob<“Hello”>;
receive (z)

BOB

receive (x)
send Carl<“Hello”>;

CARL

receive (y)
send Alice<“Hello”>;

What happens in this system?

- Alice writes to Bob, then
- Bob writes to Carl, then
- Carl writes to Alice

Example: Choreography

Alice → Bob <“Hello”, x> .

Bob → Carl <“Hello”, y> .

Carl → Alice <“Hello”, z>

Example: comparison

ALICE

send Bob<"Hello">;
receive (z)

BOB

receive (x)
send Carl<"Hello">;

CARL

receive (y)
send Alice<"Hello">;

Alice → Bob <"Hello", x> .
Bob → Carl <"Hello", y> .
Carl → Alice <"Hello", z>

Why Choreography?

- *Useful* at design stage
- *Abstraction* of a system for formal reasoning
- *Monitoring*

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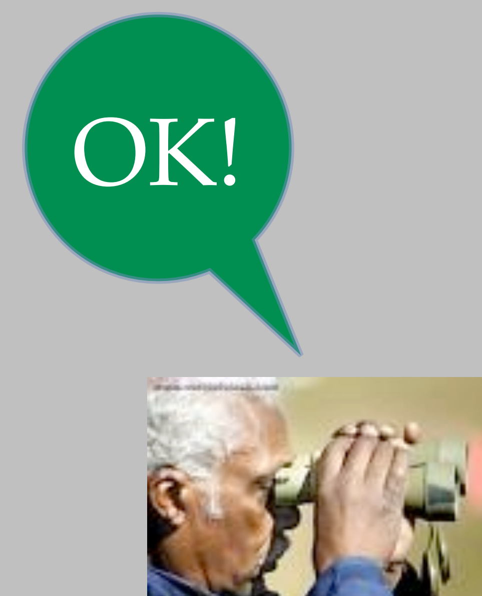
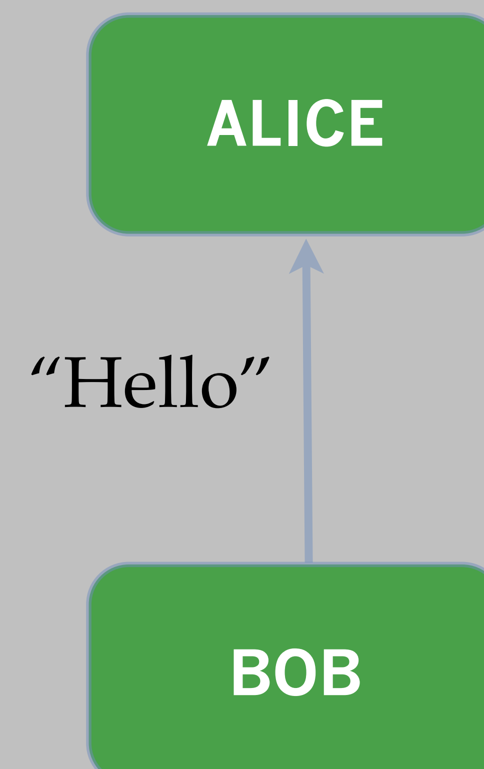




Why Choreography?

- *Useful* at design stage
- *Abstraction* of a system for formal reasoning
- *Monitoring*

What???
&^%#@

Alice → Bob <“Hello”, x> .
Bob → Carl <“Hello”, y> .
Carl → Alice <“Hello”, z>

“Cheat Carl”

ALICE

BOB

Why Choreography?

- *Useful* at design stage
- *Abstraction* of a system for formal reasoning
- *Monitoring*
- ...

Observation & Question

1. Choreography, ***nice***

2. End-point, directly gives implementation of communication primitives

Observation & Question

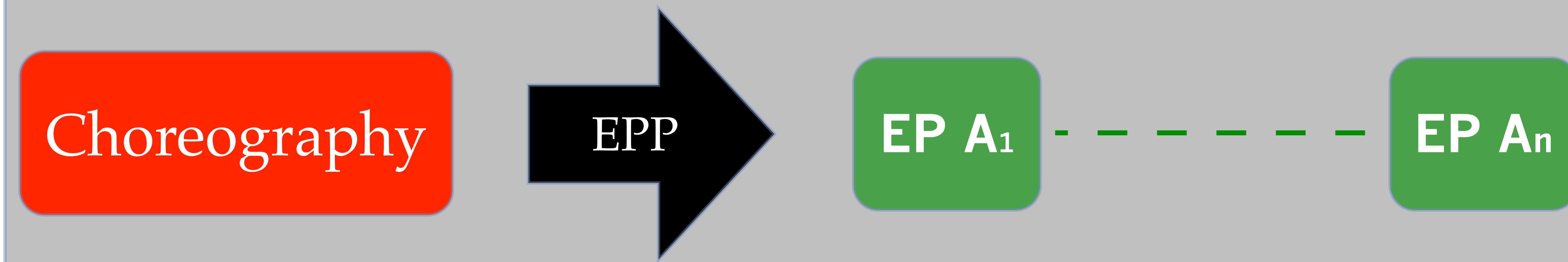
1. Choreography, ***nice***

2. End-point, directly gives implementation of communication primitives

QUESTION

- Can we formally relate 1. and 2.?
  - ➡ Can we define an automated mapping from 1. to 2.?

A possible solution with sessions [ESOP07]



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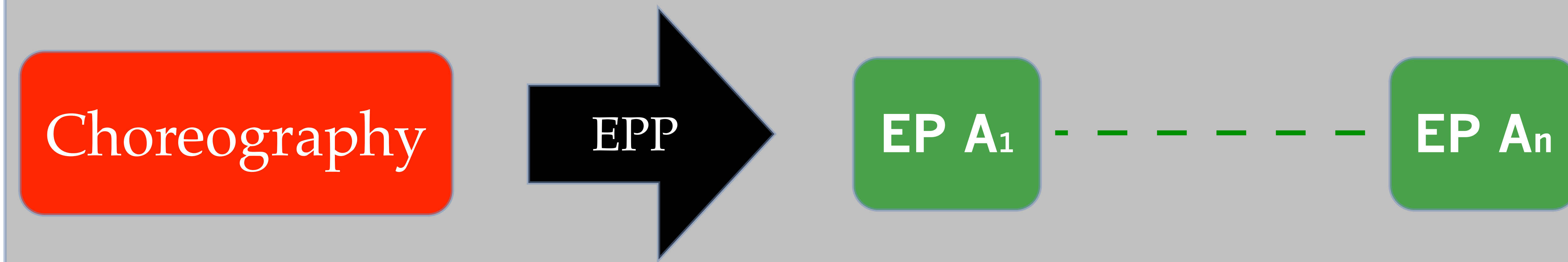

- Define two models (process algebras):
  - Global Calculus (GC);
  - End-point Calculus (EPC);

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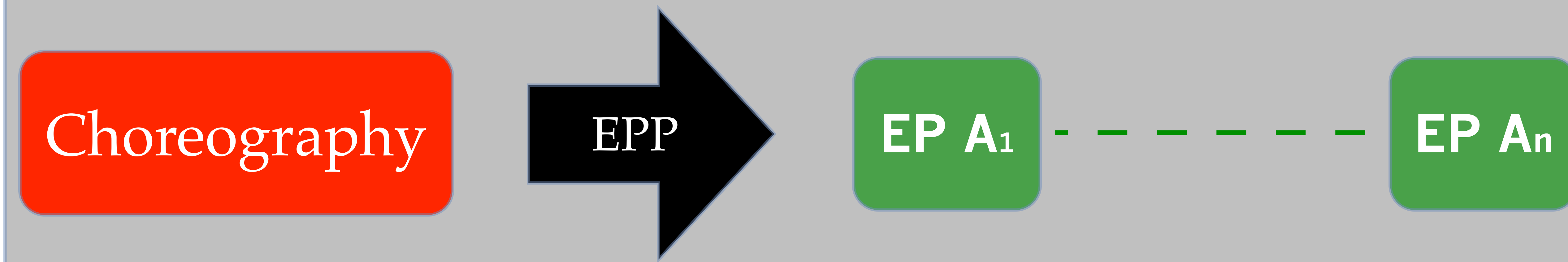

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- Define an *efficient* mapping (EPP) from GC to EPC

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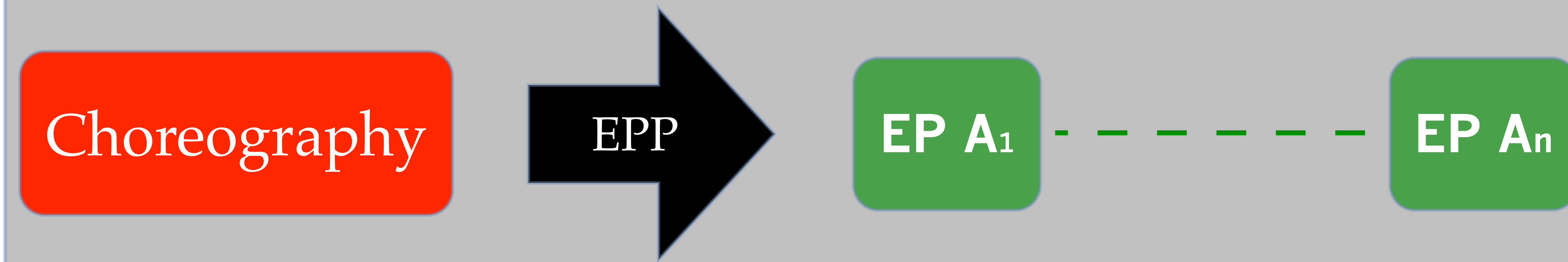

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- Define an *efficient* mapping (EPP) from GC to EPC

- EPP theorem: is EPP always correct?

Related Work

- **Q. Zongyan et al. [WWW07]**
  CCS-like approach (similar to ours), no sessions
- **Bultan et al.**
  (Communicating) Finite State Automata
- **BIP, REO**
- **MSC, Protocol Narrations, etc.**

Sessions (Types) in two slides...

Channel-based communication:

- two types of channels
  - service channels: ch,... (e.g. services, public channels)
  - session channels: s,t,...(e.g. session id's)
- participants invoke shared channels and
- then they communicate over session channels (s)

Sessions (Types) in two slides... (2)

- Each service channel ch has a type α:
    - ch@B : α
- "ch is located at B and is used as α"
- α specifies the direction and the type of each message sent in a session (e.g. over s)
- !(int).?(bool) + !(real).!(real).?(bool)

Service Channel Principle

A service (ch) is **always available in many copies**

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Service Channel Principle

A service (ch) is **always available in many copies**

Alice → **Bob** ch(...) .
Bob → **Carl** <"Hello", y> .
...
Carl → **Bob** ch (...). ...

Global Calculus

$I ::=$	$A \to B : ch(s).\ I$	(init)
$\mid$	$A \to B : s<op, e, y>.\ I$	(com)
$\mid$	if $e@A$ then I_1 else I_2	(cond)
$\mid$	$I_1 + I_2$	(sum)
$\mid$	$I_1 \mid I_2$	(par)
$\mid$	$rec\ X.\ I$	(rec)
$\mid$	X	(recVar)
$\mid$	$(\nu s)\ I$	(res)

Global Calculus

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	| (νs) I	(res)

Global Calculus

$I ::= A \rightarrow B : ch(s).\ I$ (init)

$\mid A \rightarrow B : s\langle op, e, y\rangle.\ I$ (com)

$\mid$ if $e@A$ then I_1 else I_2 (cond)

$\mid I_1 + I_2$ (sum)

$\mid I_1 \mid I_2$ (par)

$\mid \text{rec } X.\ I$ (rec)

$\mid X$ (recVar)

$\mid (\nu s)\ I$ (res)

Global Calculus

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Global Calculus

I ::=	$A \rightarrow B$: ch(s). I	(init)
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|	(νs) I	(res)

Global Calculus

I ::=	$A \rightarrow B : ch(s).\ I$	(init)
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|	rec $X.\ I$	(rec)
|	X	(recVar)
|	$(\nu s)\ I$	(res)

(causality) semantics

$$I \longrightarrow I'$$

- communication happens in the system;
- the system becomes I’

$$A \rightarrow B : ch(s).\ I \quad \rightarrow (\nu s)\ I$$

$$A \rightarrow B : s\langle op, e, y\rangle.\ I \quad \rightarrow I$$

(causality) semantics

$$I \longrightarrow I'$$

- communication happens in the system;
- the system becomes I'

$$A \to B : ch(s).\ I \quad \to (\nu s)\ I$$

$$A \to B : s\langle op, e, y\rangle.\ I \quad \to I[e/y]$$

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(causality) semantics

$$(\sigma, I) \quad \rightarrow \quad (\sigma', I')$$

- communication happens in the system;
- the system becomes I'

$$(\sigma,\ A \rightarrow B : ch(s).\ I) \rightarrow (\sigma,\ (\nu s)\ I)$$

$$(\sigma,\ A \rightarrow B : s<op,\ e,y>.\ I) \rightarrow (\sigma@B[y = \sigma(e)@A],\ I)$$

An Example

$$
\begin{aligned}
&\textbf{Buyer} \rightarrow \textbf{Seller} : \textbf{ch1}(s) \,.\\
&\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \mathrm{QuoteReq},\ \mathit{product},\ x \rangle \,.\\
&\textbf{Seller} \rightarrow \textbf{Buyer} : s\langle \mathrm{QuoteRes},\ \mathit{quote},\ y \rangle \,.\\
&\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \mathrm{QuoteAcc},\ \mathit{creditcard},\ z \rangle \,.\\
&\textbf{Seller} \rightarrow \textbf{Shipper} : \textbf{ch2}(r) \,.\\
&\textbf{Seller} \rightarrow \textbf{Shipper} : r\langle \mathrm{ShipReq},\ z,\ x \rangle \,.\\
&\textbf{Shipper} \rightarrow \textbf{Seller} : r\langle \mathrm{ShipConf} \rangle \,.\\
&\textbf{Seller} \rightarrow \textbf{Buyer} : s\langle \mathrm{OrderConf} \rangle \,.\, \mathbf{0}
\end{aligned}
$$

An Example (2)

$\textbf{Buyer} \rightarrow \textbf{Seller} : \textbf{ch1}(s)\,.$

$\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteReq},\ \mathit{product},\ x \rangle\,.$

$\textbf{Seller} \rightarrow \textbf{Buyer} : s\langle \text{QuoteRes},\ \mathit{quote},\ y \rangle\,.$

$\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteAcc},\ \mathit{creditcard},\ z \rangle\,.$

$\textbf{Seller} \rightarrow \textbf{Shipper} : \textbf{ch2}(r)\,.$

$\cdots \text{(as before)} \cdots$

$+$

$\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteNoGood} \rangle\,.\,\mathbf{0}$

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An Example (3)

$$\textbf{Buyer} \rightarrow \textbf{Seller} : \textbf{ch1}(s) \,.$$
$$\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteReq}, \ \textit{product}, \ x \rangle \,.$$
$$\textbf{Seller} \rightarrow \textbf{Buyer} : s\langle \text{QuoteRes}, \ \textit{quote}, \ y \rangle \,.$$

if reasonable(y)@*Buyer* **then**

$$\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteAcc}, \ \textit{creditcard}, \ z \rangle \,.$$
$$\textbf{Seller} \rightarrow \textbf{Shipper} : \textbf{ch2}(r) \,.$$
$\cdots$ (as before) $\cdots$

else

$$\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteNoGood} \rangle \,.\, \mathbf{0}$$

An Example (4)

$$\textbf{Buyer} \rightarrow \textbf{Seller} : \textbf{ch1}(s) .$$
$$\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteReq},\ \mathit{product},\ x\rangle .$$
$$\textbf{rec X} . \textbf{Seller} \rightarrow \textbf{Buyer} : s\langle \text{QuoteRes},\ \mathit{quote},\ y\rangle .$$

$$\textbf{if}\ \text{reasonable}(y)@\mathit{Buyer}\ \textbf{then}$$

$$\quad \textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteAcc},\ \mathit{creditcard},\ z\rangle .$$
$$\quad \textbf{Seller} \rightarrow \textbf{Shipper} : \textbf{ch2}(r) .$$
$$\quad \cdots \text{(as before)} \cdots$$

$$\textbf{else}$$

$$\quad \textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteNoGood}\rangle . \textbf{X}$$

End-Point Calculus

P::=	$*ch\ (s)\ .\ P$	(serv)
|	$ch\ !\ (s)\ .\ P$	(req)
|	$s\ ?\ (\ op_1(x_1).P_1\ + \ldots +\ op_n(x_n).P_n\ )$	(in)
|	$s\ !\ op$<e>. P	(out)
|	$P_1 \oplus P_2$	(oplus)
|	$P_1 \mid P_2$	(par)
|	if e then P_1 else P_2	(cond)
|	rec X. P | X | (νs) P	(other)

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End-Point Calculus

P::=	*ch (s) . P	(serv)
	| ch ! (s) . P	(req)
	| s ? ($op_1(x_1).P_1$ + ... + $op_n(x_n).P_n$)	(in)
	| s ! op<e>. P	(out)
	| $P_1 \oplus P_2$	(oplus)
	| P_1 | P_2	(par)
	| if e then P_1 else P_2	(cond)
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End-Point Calculus

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How does EPP work?

For each session (service) and Seller:

$$
\begin{aligned}
&\textbf{Buyer} \rightarrow \textbf{Seller} : \textbf{ch1}(s)\,.\\
&\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \text{QuoteReq},\ \textit{product},\ x\rangle\,.\\
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&\textbf{Seller} \rightarrow \textbf{Shipper} : \textbf{ch2}(r)\,.\\
&\textbf{Seller} \rightarrow \textbf{Shipper} : r\langle \text{ShipReq},\ z,\ x\rangle\,.\\
&\textbf{Shipper} \rightarrow \textbf{Seller} : r\langle \text{ShipConf}\rangle\,.\\
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\end{aligned}
$$

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For each session (service) and Seller:

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$$

How does EPP work?

For each session (service) and Seller:

Buyer → Seller : ch1(*s*) .
Buyer → Seller : *s*⟨QuoteRe
Seller → Buyer : *s*⟨QuoteRe
Buyer → Seller : *s*⟨QuoteAc
Seller → Shipper : ch2(*r*) .
Seller → Shipper : *r*⟨ShipRe
Shipper → Seller : *r*⟨ShipCo
Seller → Buyer : *s*⟨OrderCo

<u>SELLER</u>

***ch1(s).**
s ? QuoteReq(x).
s ! QuoteRes<*quote*>.
s ? QuoteAcc(z).
ch2!(r).
r ! ShipReq<z>.
r ? ShipConf.
s ! OrderConf

How does EPP work?

and for Buyer...

$$\begin{array}{l}
\textbf{Buyer} \rightarrow \textbf{Seller} : \textbf{ch1}(s) \,. \\
\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \mathrm{QuoteReq},\ \mathit{product},\ x \rangle \,. \\
\textbf{Seller} \rightarrow \textbf{Buyer} : s\langle \mathrm{QuoteRes},\ \mathit{quote},\ y \rangle \,. \\
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\textbf{Shipper} \rightarrow \textbf{Seller} : r\langle \mathrm{ShipConf} \rangle \,. \\
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How does EPP work?

and for Buyer...

$$
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\textbf{Buyer} \rightarrow \textbf{Seller} : s\langle \mathsf{QuoteAcc},\ creditcard,\ z \rangle . \\
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\textbf{Seller} \rightarrow \textbf{Buyer} : s\langle \mathsf{OrderConf} \rangle . \mathbf{0}
\end{array}
$$

How does EPP work?

and for Buyer...

Buyer → Seller : ch1(*s*) .
Buyer → Seller : *s*⟨QuoteRe
Seller → Buyer : *s*⟨QuoteRe
Buyer → Seller : *s*⟨QuoteAc
Seller → Shipper : ch2(*r*) .
Seller → Shipper : *r*⟨ShipRe
Shipper → Seller : *r*⟨ShipCo
Seller → Buyer : *s*⟨OrderCo

BUYER

ch1!(s).
s!QuoteReq<*product*>.
s?QuoteRes(y).
s!QuoteAcc<*creditcard*>.
s?OrderConf

How does EPP work? (2)

- Careful with participant with multiple services

$$\textbf{Buyer} \rightarrow \textbf{Seller} : \textbf{ch1}(s).$$
$$\textbf{Seller} \rightarrow \textbf{Buyer} : s\langle \mathsf{op}_1,\ e_1,\ x\rangle.$$
$$\textbf{Buyer} \rightarrow \textbf{Seller} : \textbf{ch2}(t).$$
$$\textbf{Seller} \rightarrow \textbf{Buyer} : t\langle \mathsf{op}_2,\ e_2,\ y\rangle.$$
$$\ldots$$
$$\textbf{Buyer2} \rightarrow \textbf{Seller} : \textbf{ch2}(t).$$
$$\textbf{Seller} \rightarrow \textbf{Buyer2} : t\langle \mathsf{op}_3,\ e_3,\ y\rangle.$$

How does EPP work? (2)

- Careful with participant with multiple services

$\mathsf{Buyer} \to \mathsf{Seller} : \mathsf{ch1}(s)\,.$
$\mathsf{Seller} \to \mathsf{Buyer} : s\langle \mathsf{op}_1,\ e_1,\ x\rangle\,.$
$\mathsf{Buyer} \to \mathsf{Seller} : \mathsf{ch2}(t)\,.$
$\mathsf{Seller} \to \mathsf{Buyer} : t\langle \mathsf{op}_2,\ e_2,\ y\rangle\,.$
...
$\mathsf{Buyer2} \to \mathsf{Seller} : \mathsf{ch2}(t)\,.$
$\mathsf{Seller} \to \mathsf{Buyer2} : t\langle \mathsf{op}_3,\ e_3,\ y\rangle\,.$

SELLER

$*\mathbf{ch1(s)}.$
$\mathbf{s\ !\ op_1<e_1>.}$ } *thread*

|

$*\mathbf{ch2!(r)}.$
$\mathbf{r\ !\ op_2<e_2>.}$
$\oplus$
$\mathbf{r\ !\ op_3<e_3>.}$ } *thread*

How does EPP work? (2)

- Careful with participant with multiple services

$\textsf{Buyer} \rightarrow \textsf{Seller} : \textsf{ch1}(s)\,.$
$\textsf{Seller} \rightarrow \textsf{Buyer} : s\langle \textsf{op}_1,\ e_1,\ x\rangle\,.$
$\textsf{Buyer} \rightarrow \textsf{Seller} : \textsf{ch2}(t)\,.$
$\textsf{Seller} \rightarrow \textsf{Buyer} : t\langle \textsf{op}_2,\ e_2,\ y\rangle\,.$
...

SELLER

***ch1(s).**
s ! op$_1$<e$_1$>. } *thread*

e$_2$>. } *thread*

e$_3$>.

NOTE.

The EPP guarantees that actions happen in the right order.

This is not always feasible!!!

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Three principles

Three principles for correct EPP:

- **Connectedness**. A causality principle.
- **Well-Threadedness**. A local causality principle related to services.
- **Coherence**. Consistent behaviour of the same service over a global description.

This properties can be (in)validated algorithmically

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This properties can be (in)validated algorithmically

Connectedness

Good...	*Bad...*
1. $A \to B : \mathbf{b}(s)$.	a. $A \to B : \mathbf{b}(s)$.
2. $A \to B : s\langle \text{go} \rangle$.	b. $A \to B : s\langle \text{go} \rangle$.
3. $B \to C : \mathbf{c}(t) \ldots$	c. $C \to D : t\langle \text{hello} \rangle \ldots$

- b. is "disconnected" from c.
- we must synchronise either A or B with either C or D
- connectedness: in $A \to B \ldots . C \to D \ldots$ we have $B = C$.

In general, $\{A, B\} \cap \{C, D\} \neq \emptyset$ – not difficult

Coherence

if x@**A then**

$A \rightarrow B : \mathbf{b}(s_1, s_2)$.

$A \rightarrow B : s_1\langle \text{go} \rangle$.

$B \rightarrow A : s_2\langle \text{ok} \rangle . \mathbf{0}$

else

$A \rightarrow B : \mathbf{b}(s_1, s_2)$.

$A \rightarrow B : s_1\langle \text{stop} \rangle$.

$B \rightarrow A : s_2\langle \text{no} \rangle . \mathbf{0}$

if-branch.

$! \mathbf{b}(s_1, s_2) . s_1 \triangleright \text{go} . s_2 \triangleleft \text{ok} . \mathbf{0}$

else-branch.

$! \mathbf{b}(s_1, s_2) . s_1 \triangleright \text{stop} . s_2 \triangleleft \text{no} . \mathbf{0}$

merging the two.

$$! \mathbf{b}(s_1, s_2) . s_1 \triangleright \begin{bmatrix} \text{go} . s_2 \triangleleft \text{ok} . \mathbf{0} + \\ \text{stop} . s_2 \triangleleft \text{no} . \mathbf{0} \end{bmatrix}$$

We project each branch onto **B** and merge the results.

Coherence (bad case)

if x@**A then**

$A \longrightarrow B : \mathbf{b}(s_1, s_2)\,.$

$A \longrightarrow B : s_1\langle \mathrm{go}\rangle\,.$

$B \longrightarrow A : s_2\langle \mathrm{ok}\rangle\,.\,\mathbf{0}$

else

$A \longrightarrow B : \mathbf{b}(s_1, s_2)\,.$

$A \longrightarrow B : s_1\langle \mathrm{go}\rangle\,.$

$B \longrightarrow A : s_2\langle \mathrm{no}\rangle\,.\,\mathbf{0}$

EPP Theorem

The end point projection is:

- Type preserving
- $I \rightarrow I'$ implies $EPP(I) \rightarrow EPP(I')$
- $EPP(I) \rightarrow R$ implies $I \rightarrow I'$ and $EPP(I') \sim R$
- Barb preserving

whenever I is well-typed, connected, well-threaded and coherent

Exceptions

- **Interactional Exceptions and Choreography (08&workinprogress)**
  - Session Types and Exceptions
  - Extension of the Global Calculus
  - About End-Point Projection (EPP)

Exceptions, Literally...

- "An Exception is a person or thing that is excluded from a general statement or does not follow a rule" (Mac Dictionary)
- "Exception (handling) is a programming language construct or computer hardware mechanism designed to handle the occurrence of some condition that changes the normal flow of execution." (Wikipedia)

Exceptions, Literally...

- “An Exception is a person or thing that is excluded from a general statement or does not follow a rule” (Mac Dictionary)

- “Exception (handling) is a programming language construct or computer hardware mechanism designed to handle the occurrence of some condition that changes the normal flow of execution.” (Wikipedia)

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Exceptions, in General

try { /* Default Code */ }

catch { /* Handler Code */ }

If an exception is thrown by the default code then the handler is executed.

Exceptions are thrown with a special command **throw**

Exceptions and Choreography

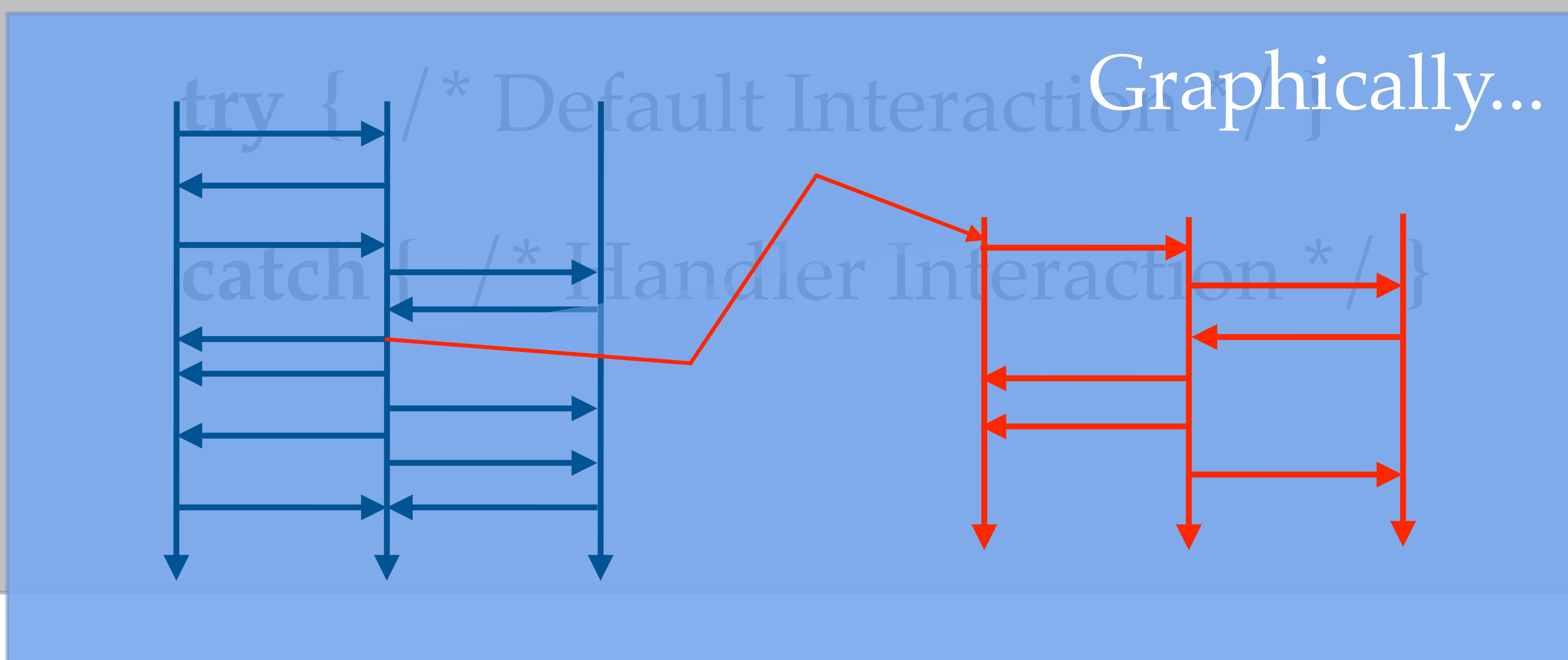
What if apply the exception (compensation) idea to *choreography*?

try { /* Default Interaction */ }

catch { /* Handler Interaction */ }

Exceptions and Choreography

What if apply the exception (compensation) idea to *choreography*?



A Simple Financial Protocol

1. $\texttt{Buyer} \rightarrow \texttt{Seller} \; : \; \mathbf{chSeller}(s) \; [s,$

2. $\mathbf{rec}\ X\ .\ \texttt{Seller} \rightarrow \texttt{Buyer} : s\langle \texttt{update}, \mathit{quote}, y \rangle\ .$
3. $\mathbf{if}\ (y < 100)@\texttt{Buyer}\ \mathbf{then}\ \mathbf{throw}\ \mathbf{else}\ X,$

} default

4. $\texttt{Seller} \rightarrow \texttt{Buyer} : s\langle \texttt{conf}, \mathit{cnum}, x \rangle\ .$
5. $\texttt{Buyer} \rightarrow \texttt{Seller} : s\langle \texttt{data}, \mathit{credit}, x \rangle\ ]$

} handler

A Financial Protocol with Broker

1. $\mathtt{Buyer} \rightarrow \mathtt{Broker} \; : \; \mathbf{chBroker}(s) \; [s,$

2. $\mathtt{Buyer} \rightarrow \mathtt{Broker} : s\langle \mathtt{identify}, id, x\rangle \,.$
3. $\mathbf{if}\ \mathtt{bad}(x)@\mathtt{Broker}\ \mathbf{then\ throw}$
4. $\mathbf{else}\ \mathtt{Broker} \rightarrow \mathtt{Seller} \; : \; \mathbf{chSeller}(t)[(s,t),\ \mathbf{rec}\ X\,.$
5. $\mathtt{Seller} \rightarrow \mathtt{Broker} : t\langle \mathtt{update}, quote, y\rangle \,.$
6. $\mathtt{Broker} \rightarrow \mathtt{Buyer} : s\langle \mathtt{update}, 1.1 * y, y\rangle \,.$
7. $\mathbf{if}\ (y < 100)@\mathtt{Buyer}\ \mathbf{then\ throw\ else}\ X,$

(lines 5–7: default)

8. $\mathtt{Seller} \rightarrow \mathtt{Broker} : t\langle \mathtt{conf}, cnum, x\rangle \,.$
9. $\mathtt{Broker} \rightarrow \mathtt{Buyer} : s\langle \mathtt{conf}, x, x\rangle \,.$
10. $\mathtt{Buyer} \rightarrow \mathtt{Broker} : s\langle \mathtt{data}, credit, x\rangle \,.$
11. $\mathtt{Broker} \rightarrow \mathtt{Seller} : t\langle \mathtt{data}, x, x\rangle],$

(lines 8–11: handler)

(lines 2–11: default)

12. $\mathtt{Broker} \rightarrow \mathtt{Buyer} : s\langle \mathtt{reject}, reason, x\rangle \;]$ (handler)

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A Financial Protocol with Broker

1. $\texttt{Buyer} \to \texttt{Broker} \ : \ \mathbf{chBroker}(s) \ [s,$
2. $\texttt{Buyer} \to \texttt{Broker} : s\langle \texttt{identify}, id, x\rangle \, .$
3. $\mathbf{if} \ \texttt{bad}(x)@\texttt{Broker} \ \mathbf{then\ throw}$
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12. ~~$\texttt{Broker} \to \texttt{Buyer} : s\langle \texttt{reject}, reason, x\rangle \ ]$~~

(Lines 5–7: default; lines 8–11: handler; lines 2–11: default; line 12: handler)

Global Calculus Extension

$$
\begin{array}{lllr|lr}
I, J ::= & A \rightarrow B \,\mathbf{:}\, a(s)[\tilde{t}, I, J] & & \text{(init)} & \mid \; \mathbf{0} & \text{(inaction)} \\
\mid & A \rightarrow B : s\langle \mathsf{op}, e, y\rangle \,\mathbf{.}\, I & & \text{(com)} & \mid \; I \mid J & \text{(par)} \\
\mid & \mathbf{throw} & & \text{(throw)} & \mid \; I + J & \text{(sum)} \\
\mid & \mathbf{if}\ e@A\ \mathbf{then}\ I\ \mathbf{else}\ J & & \text{(cond)} & \mid \; X & \text{(recVar)} \\
\mid & \mathbf{rec}\ X \,\mathbf{.}\, I & & \text{(rec)} & &
\end{array}
$$

End-Points?

$P ::=$	$!c(\kappa)[P,Q]$	(service)	$\mid \overline{c}(\lambda)[\tilde{\kappa},P,Q]$	(request)
	$\mid \kappa?\Sigma_i \mathsf{op}_i\langle x_i\rangle.P_i$	(input)	$\mid \kappa!\mathsf{op}\langle e\rangle\,.\,P$	(output)
	$\mid P \mid Q$	(par)	$\mid \textbf{if}\ e\ \textbf{then}\ P\ \textbf{else}\ P$	(cond)
	$\mid \mathbf{0}$	(inact)	$\mid P \oplus Q$	(choice)
	$\mid X$	(termVar)	$\mid \textbf{rec}\ X\,.\,P$	(recursion)
	$\mid \textbf{throw}$	(throw)		

$$N ::= \quad A[\ P\ ]_\sigma \mid \quad N_1 \mid\mid N_2 \mid \quad \epsilon$$

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Sunday, October 4, 2009

EPP?

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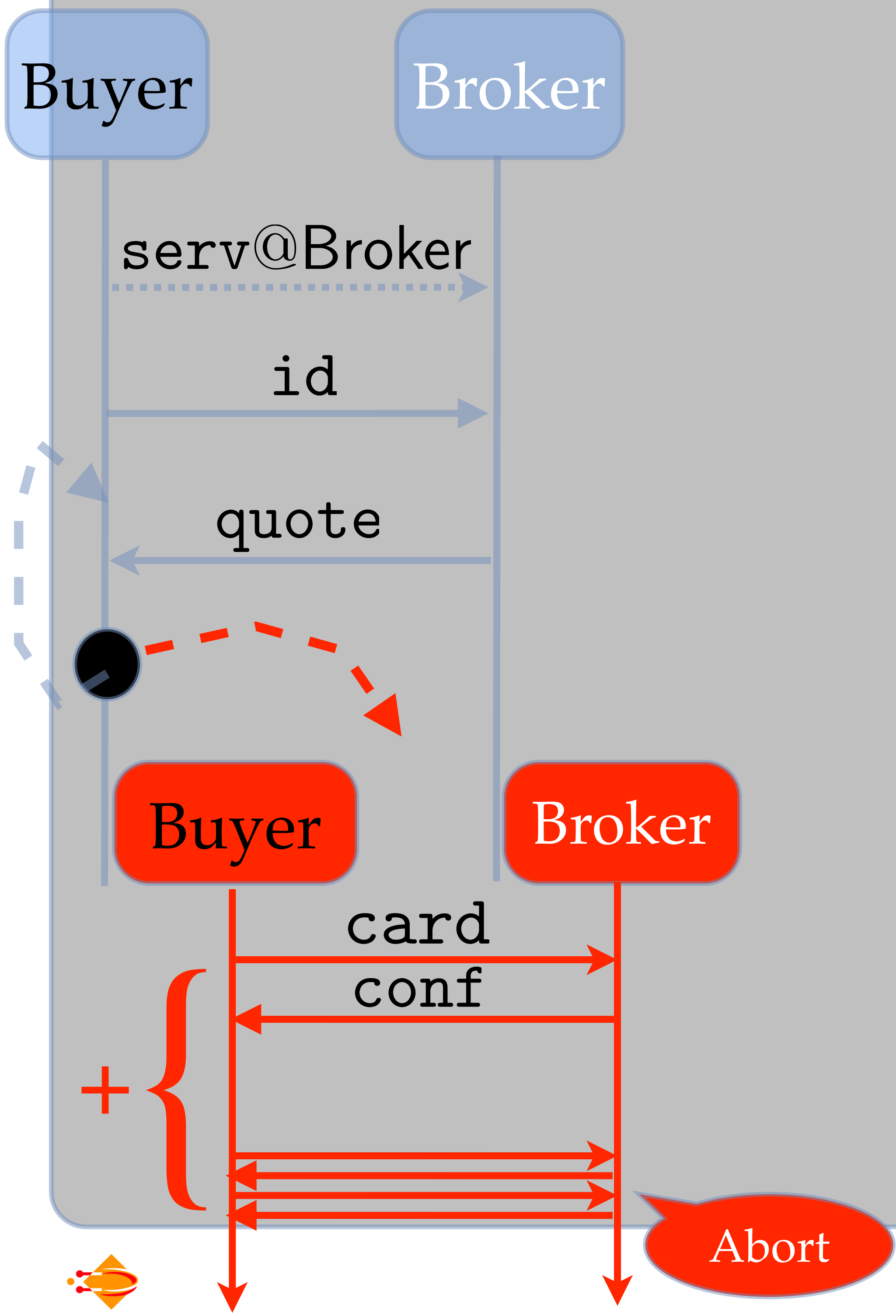
EPP? (Buyer)

$$\overline{\textbf{chBroker}}(s^+)[s^+,$$

$$s^+!\texttt{identify}\langle id\rangle\,.\,\textbf{rec}\ X\,.\,s^+?\texttt{update}(y)\,.\,\textbf{if}\ (y < 100)\ \textbf{then throw else}\ X,$$

$$\mathsf{merge}(s^+?\mathsf{conf}(x)\,.\,s^+!\mathsf{data}\langle credit\rangle,\ s^+?\mathsf{reject}(x)\,.\,P)\ ]$$

EPP? (Buyer)



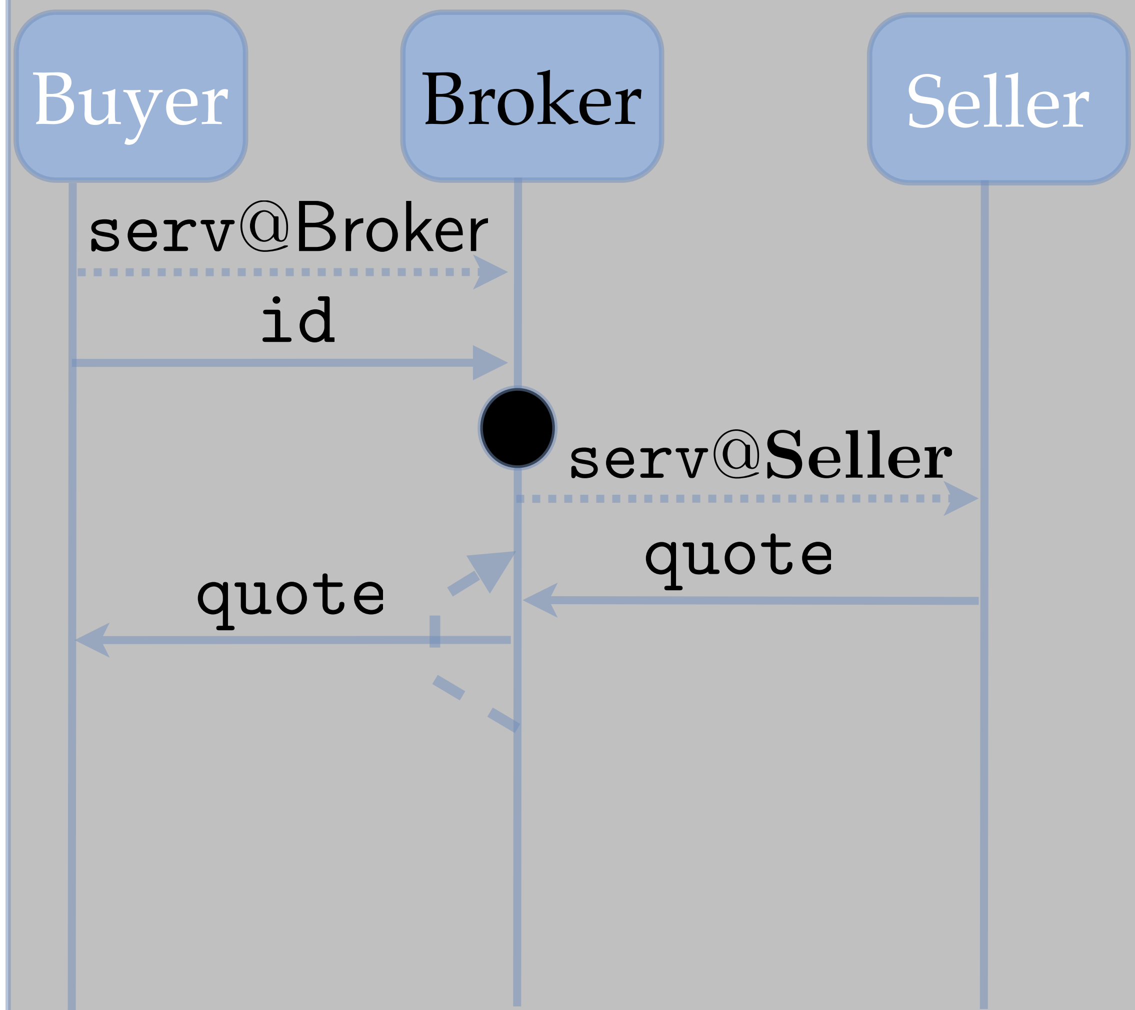
Buyer

$$
\begin{array}{l}
\textbf{invoke}\ \texttt{serv@Broker}(t);\\
\quad \textbf{try}\ \{\\
\qquad t!\langle \texttt{id}\rangle.\\
\qquad \mu X.\\
\qquad t?(y).\\
\qquad \textbf{if}\ (ok(y))\ \textbf{then throw else}\ X\\
\quad \}\\
\quad \textbf{catch}\ \{\\
\qquad l_1\ :\ t!\langle \texttt{card}\rangle.\ t?(y)\\
\qquad l_2\ :\ P_{\texttt{abort}}\\
\quad \}
\end{array}
$$

EPP? (Broker)

$$
\left.
\begin{array}{l}
*\mathbf{chBroker}(s^-)[\\
\quad \left.\begin{array}{l}
s^-?\mathsf{identify}(x)\,.\,\mathbf{if}\ \mathtt{bad}(x)\ \mathbf{then\ throw} \\
\mathbf{else}\ \overline{\mathbf{chSeller}}\,(t^+)[(s^-,t^+), \\
\quad \mathbf{rec}\ X\,.\ t^+?\mathtt{update}(y)\,.\,s^-!\mathtt{update}\langle y+10\%\rangle\,.\,X \quad \}\ \text{default} \\
\quad t^+?\mathtt{conf}(x)\,.\,s^-!\mathtt{conf}\langle x\rangle\,.\,s^-?\mathtt{data}(x)\,.\,t^+!\mathtt{data}\langle x\rangle], \quad \}\ \text{handler}
\end{array}\right\}\ \text{default} \\
\quad s^-!\mathtt{reject}\langle \mathit{reason}\rangle\,.\,\mathcal{A}\ ] \quad \}\ \text{handler}
\end{array}
\right.
$$

EPP? (Broker)

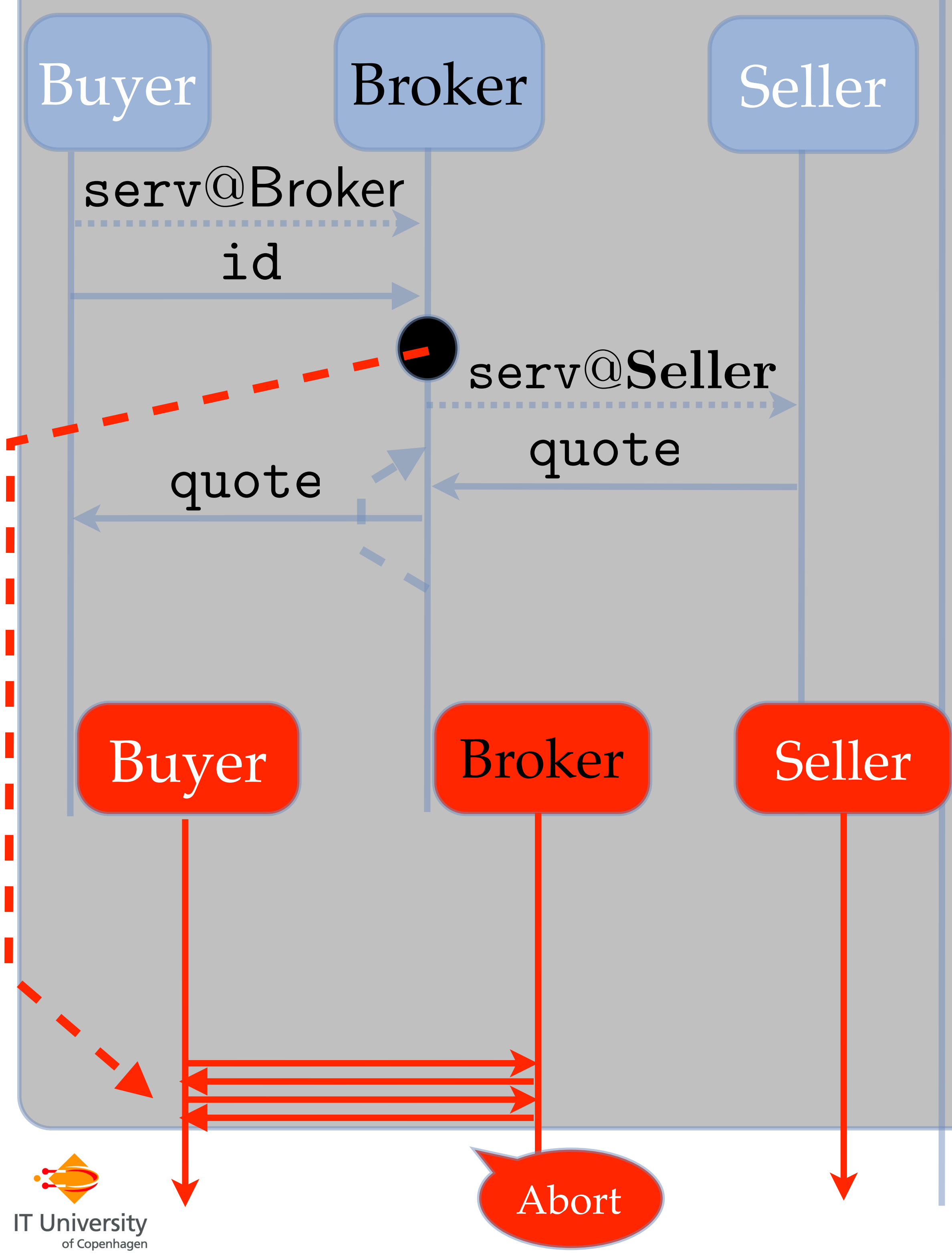


<u>Broker</u>

service serv(t) {
try (t) {
$t?(x)$.
if bad(x) **then throw else**
invoke serv@Seller(s);
try (t, s) {
$\mu X.\ s?(x).\ t!\langle x + 10\%\rangle.\ X$
catch $\{\ t \triangleright l_1.\ \ldots$fwd$\ldots\ \}$

catch $\{\ t \triangleright l_2.\ P'_{\texttt{abort}}\ \}$
}

EPP? (Broker)



Broker

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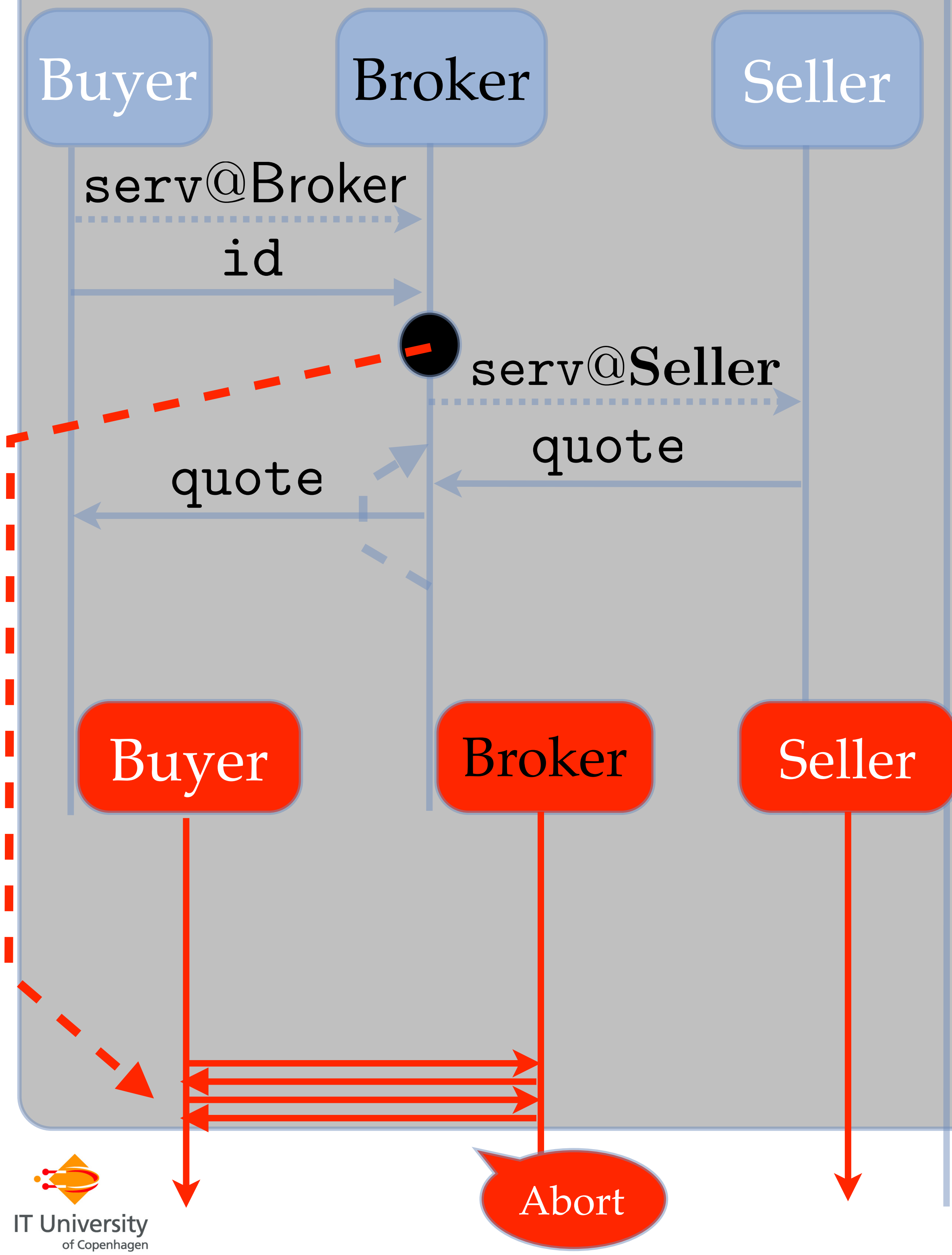
catch $\{\ t \rhd l_1.\ \ldots$fwd$\ldots\ \}$

catch $\{\ t \rhd l_2.\ P'_{\texttt{abort}}\ \}$

}

EPP? (Broker)



Broker

service serv(t) {

try (t) {

$t?(x).$

if bad(x) **then throw else**

invoke serv@Seller(s);

try (t, s) {

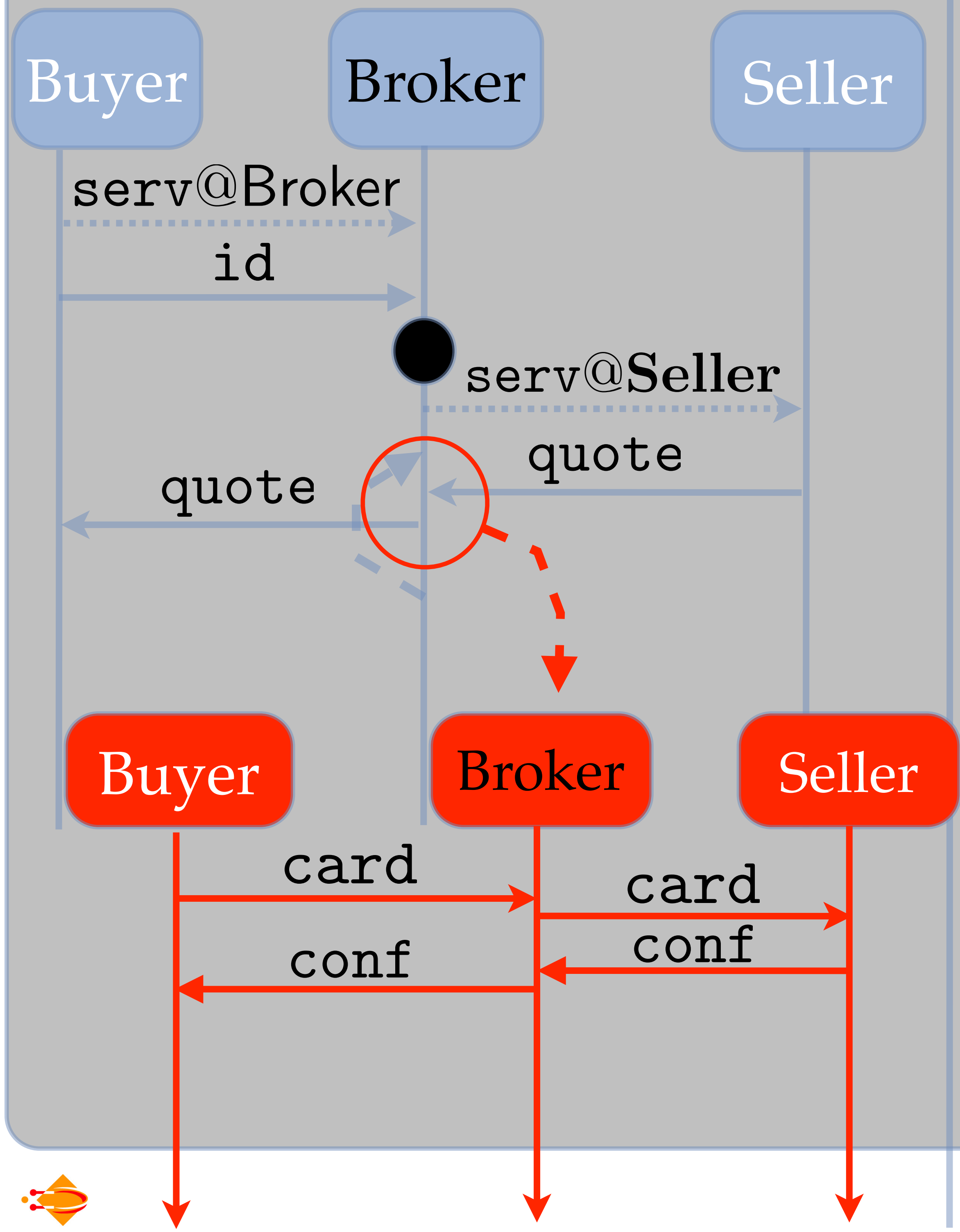
$\mu X.\ s?(x).\ t!\langle x + 10\% \rangle.\ X$

catch $\{\ t \triangleright l_1.\ \ldots \mathrm{fwd} \ldots\ \}$

catch $\{\ t \triangleright l_2.\ P'_{\texttt{abort}}\ \}$

}

EPP? (Broker)



Broker

service serv(t) $\{$

try (t) $\{$

$t?(x).$

if bad(x) **then throw else**

invoke serv@Seller(s);

try (t, s) $\{$

$\mu X.\ s?(x).\ t!\langle x + 10\% \rangle.\ X$

catch $\{\ t \triangleright l_1.\ \ldots \text{fwd} \ldots\ \}$

~~**catch** $\{\ t \triangleright l_2.\ P'_{\texttt{abort}}\ \}$~~

$\}$

EPP? (Seller)

$$*\mathbf{chSeller}(t^-)[\ \mathbf{rec}\ X\,.\,t^-!\mathsf{update}\langle quote\rangle\,.\,X,\ \ t^-!\mathsf{conf}\langle cnum\rangle\,.\,t^-?\mathsf{data}(x)\ ]$$

Other Stuff on Choreography

- Choreography as a Session Type (Multiparty Session Types) [@POPL08] [Yoshida et al. @CONCUR08, ESOP09]
- Choreography and Strand Spaces (Security) [PLACES09, ICE09 - jointly with J.Guttman]
- Scribble, a language based on choreography and session types (Pi4Tech, K. Honda, R. Hu)
- ...

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Work in Progress

- **Logic** for choreography and Partial Specification
- **Annotated** Multiparty Session Types
- **Secure EPP** for Choreography

- Global View Extraction (Inverse of EPP)

An open question?

An open question?

- How do you do it? Still an open problem (in general)...
- Allows for **round-trip engineering** (reuse&de-coupling)
    - code ⇒ choreography (change) ⇒ code

Thank you

Well-Threadedness

$A \rightarrow B : \mathbf{b}(s) .$
$A \rightarrow B : s\langle \mathrm{go} \rangle .$
$B \rightarrow C : \mathbf{c}(t) .$
$C \rightarrow A : \mathbf{a}(r) .$
$A \rightarrow C : r\langle \mathrm{hi} \rangle .$
$C \rightarrow B : t\langle \mathrm{acc} \rangle .$
$B \rightarrow A : s\langle \mathrm{ok} \rangle .$
$\ldots$

$$\mathbf{A} \left[\begin{array}{l} \overline{\mathbf{b}}(\nu s) . s \lhd \mathrm{go} . s \rhd \mathrm{ok} . \ldots \mid \\ !\mathbf{a}(r) . r \lhd \mathrm{hi} . \ldots \end{array} \right]$$

$$\mathbf{B} \left[\begin{array}{l} !\mathbf{b}(s) . s \rhd \mathrm{go} . \\ \quad \overline{\mathbf{c}}(\nu t) . t \rhd \mathrm{acc} . s \lhd \mathrm{ok} . \ldots \end{array} \right]$$

$$\mathbf{C} \left[!\mathbf{c}(t) . \overline{\mathbf{a}}(\nu r) . r \rhd \mathrm{hi} . t \lhd \mathrm{acc} . \ldots \right]$$

Well-Threadedness (2)

Bad...

$\mathsf{A} \rightarrow \mathsf{B} : \mathbf{b}(s).$
$\mathsf{A} \rightarrow \mathsf{B} : s\langle \mathrm{go} \rangle.$
$\mathsf{B} \rightarrow \mathsf{C} : \mathbf{c}(t).$
$\mathsf{C} \rightarrow \mathsf{A} : \mathbf{a}(r).$
$\mathsf{A} \rightarrow \mathsf{C} : r\langle \mathrm{hi} \rangle.$
$\mathsf{C} \rightarrow \mathsf{A} : r\langle \mathrm{hi} \rangle.$
$\mathsf{A} \rightarrow \mathsf{B} : s\langle \mathrm{hello} \rangle.$
$\ldots$

Good...

$\mathsf{A} \rightarrow \mathsf{B} : \mathbf{b}(s).$
$\mathsf{A} \rightarrow \mathsf{B} : s\langle \mathrm{go} \rangle.$
$\mathsf{B} \rightarrow \mathsf{C} : \mathbf{c}(t).$
$\mathsf{C} \rightarrow \mathsf{A} : \mathbf{a}(r).$
$\mathsf{A} \rightarrow \mathsf{C} : r\langle \mathrm{hi} \rangle.$
$\mathsf{C} \rightarrow \mathsf{B} : t\langle \mathrm{acc} \rangle.$
$\mathsf{B} \rightarrow \mathsf{A} : s\langle \mathrm{ok} \rangle.$
$\ldots$

Well-Threadedness (3)

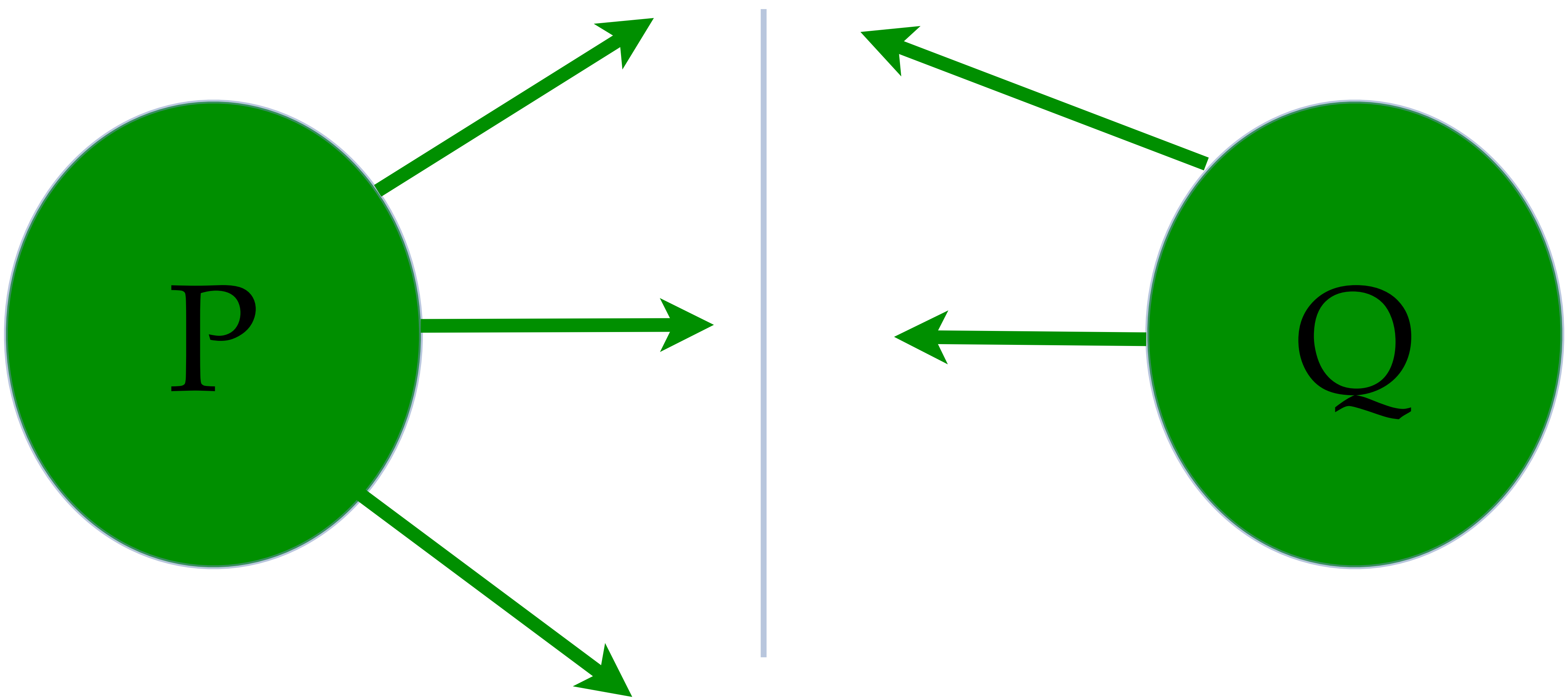
$$\begin{array}{l}
A \longrightarrow B : \mathbf{b}(s). \\
A \longrightarrow B : s\langle \mathrm{go} \rangle. \\
B \longrightarrow C : \mathbf{c}(t). \\
C \longrightarrow A : \mathbf{a}(r). \\
A \longrightarrow C : r\langle \mathrm{hi} \rangle. \\
C \longrightarrow A : r\langle \mathrm{hi} \rangle. \\
A \longrightarrow B : s\langle \mathrm{hello} \rangle. \\
\dots
\end{array}$$

$$\mathbf{A} \left[\begin{array}{l} \overline{\mathbf{b}}(s).\ s \triangleleft \mathrm{go}.\ \underline{s \triangleleft \mathrm{hello}}.P \\ !\mathbf{a}(r).\ r \triangleleft \mathrm{hi}.\ r \triangleright \mathrm{hi}.P' \end{array} \right]$$

$$\mathbf{B} \left[\begin{array}{l} !\mathbf{b}(s).\ s \triangleright \mathrm{go}. \\ \qquad \overline{\mathbf{c}}(t).\ \underline{s \triangleright \mathrm{hello}}.Q \end{array} \right]$$

$$\mathbf{C} \left[!\mathbf{c}(t).\ \overline{\mathbf{a}}(r).\ r \triangleright \mathrm{hi}.\ r \triangleleft \mathrm{hi}.S \right]$$

Parallel



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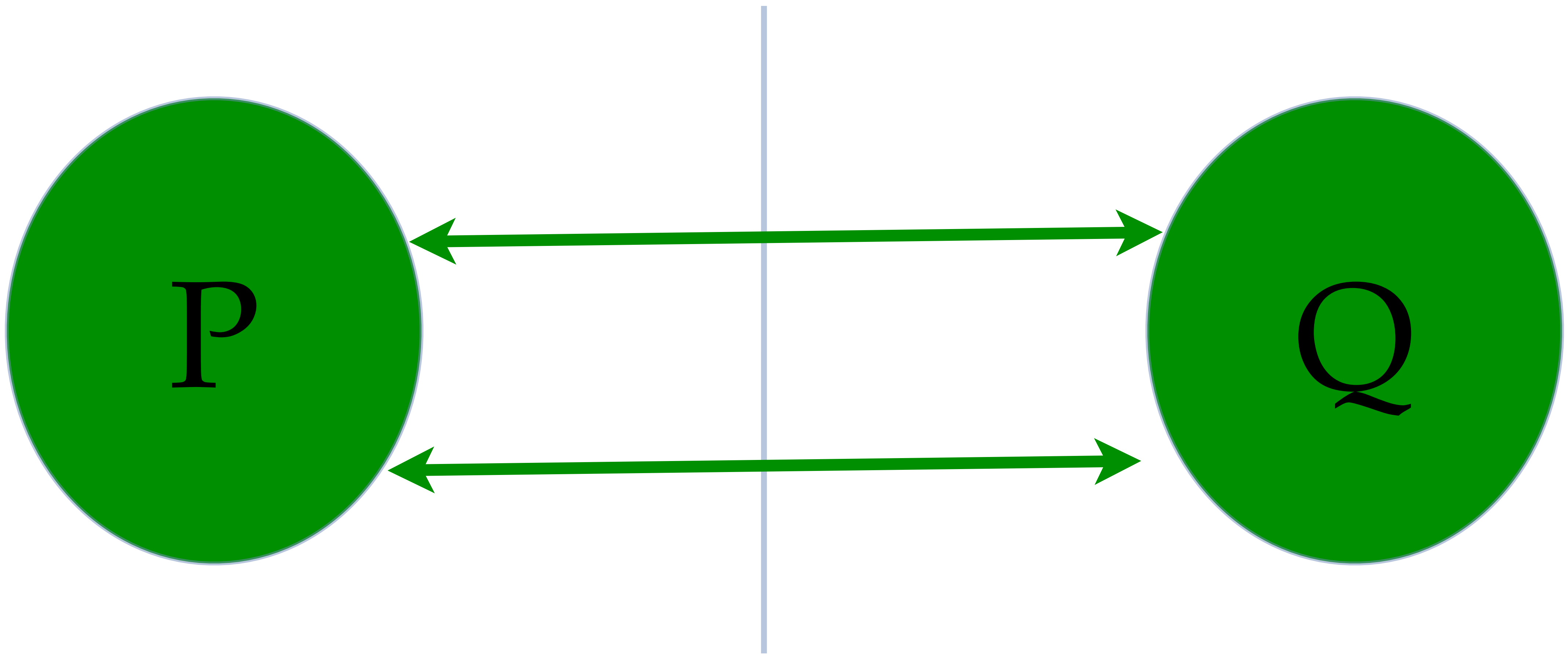
Parallel



Parallel