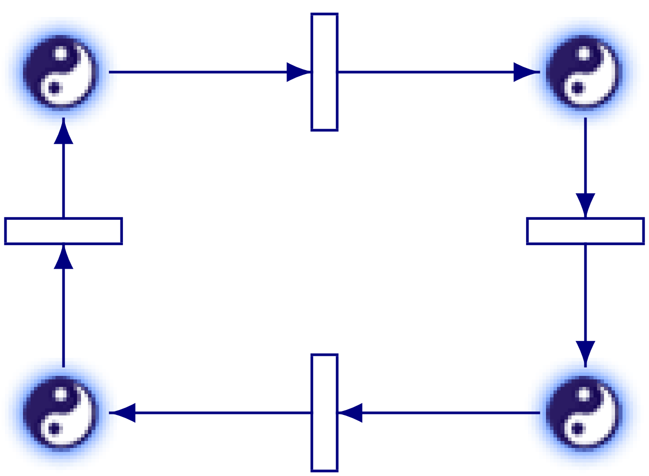
The Tao of PEPA nets

Stephen Gilmore

Joint work with

Jane Hillston, Leïla Kloul and Marina Ribaudo

13th August 2003



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Several formalisms exist to analyse security in mobile code systems (Secure Ambients, Spi-calculus) but what about the performance analysis of such systems?

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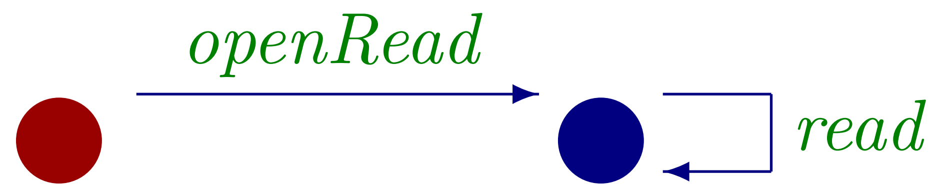

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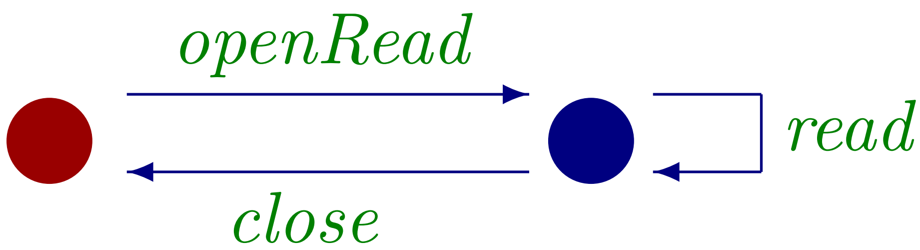

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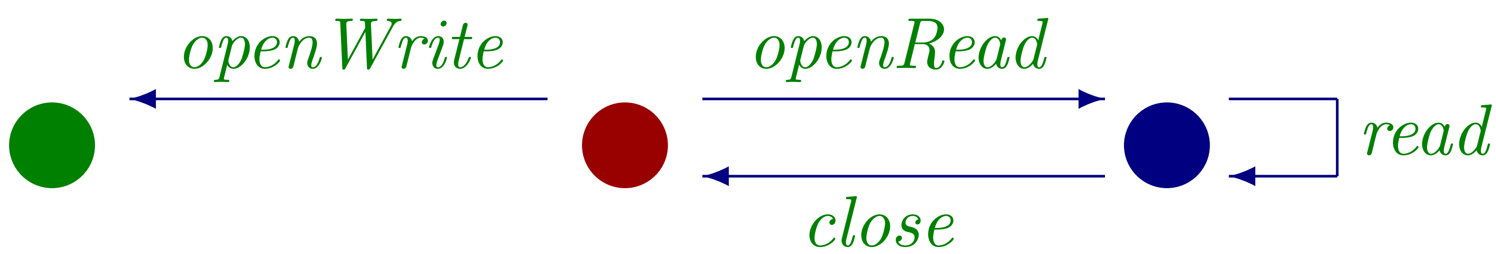

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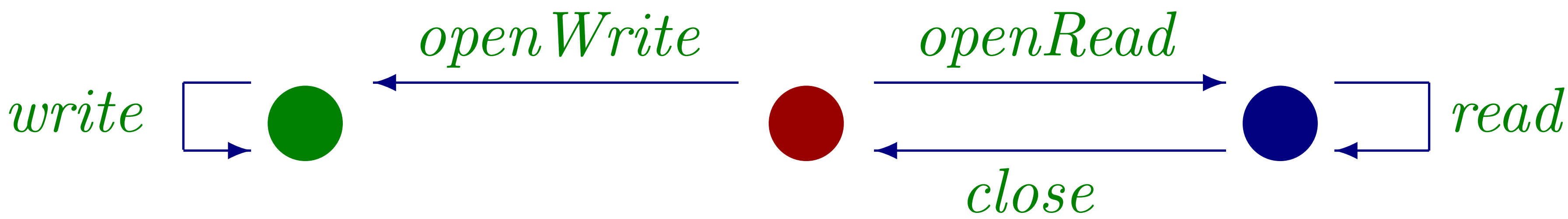

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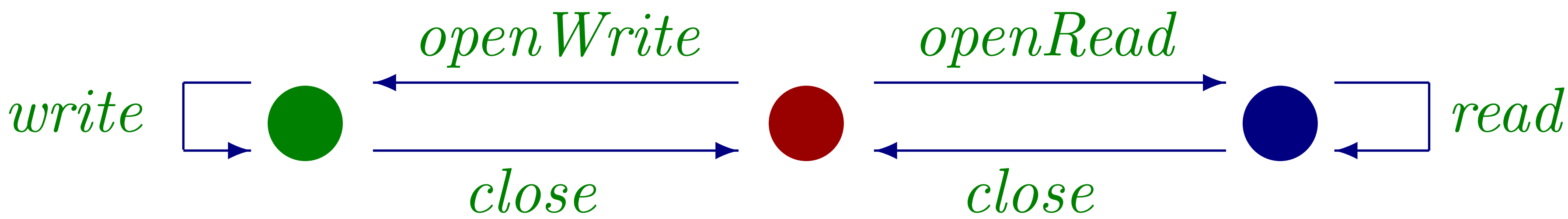

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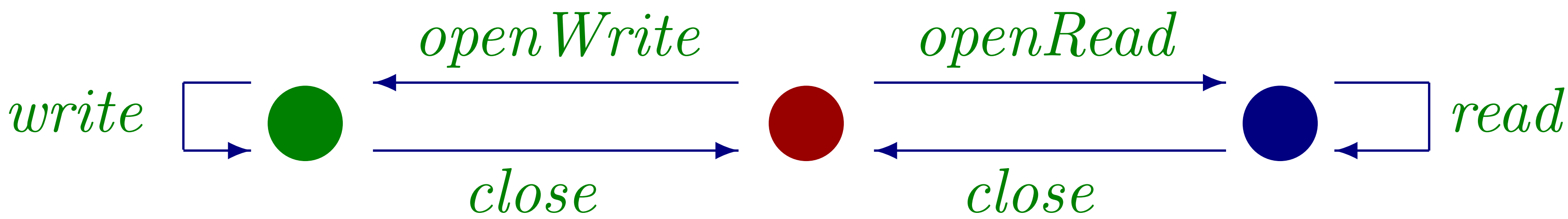

We can express this as a PEPA component.

$$
\begin{aligned}
File &\stackrel{def}{=} (openRead, r_o).InStream \\
&\quad + (openWrite, r_o).OutStream \\
InStream &\stackrel{def}{=} (read, r_r).InStream + (close, r_c).File \\
OutStream &\stackrel{def}{=} (write, r_w).OutStream + (close, r_c).File
\end{aligned}
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Contexts and cells

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A typical context might be the following:

$$File[\_] \underset{L}{\bowtie} FileReader$$

where the synchronisation set L in this case is $\vec{\mathcal{A}}(File)$, the complete action type set of the component, ($openRead$, $read$, $close$, ...).

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Part of a PEPA net which models the passage of instant messages is shown below.

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An instant message IM can be moved by the **transmit** firing. In moving it changes state to a $File$ derivative, which can be read by the $FileReader$.

Semantics: Enabling Set

An enabling set is a set of (token, place) pairs.

A transition t has an enabling set of firing type α, $\mathrm{ES}(t, \alpha)$, if for each input place $\mathbf{P}_i$ of t there is an element $(T, \mathbf{P}_i)$ in $\mathrm{ES}(t, \alpha)$ such that T is a token in the current marking of $\mathbf{P}_i$, which has a one-step α-derivative, T'.

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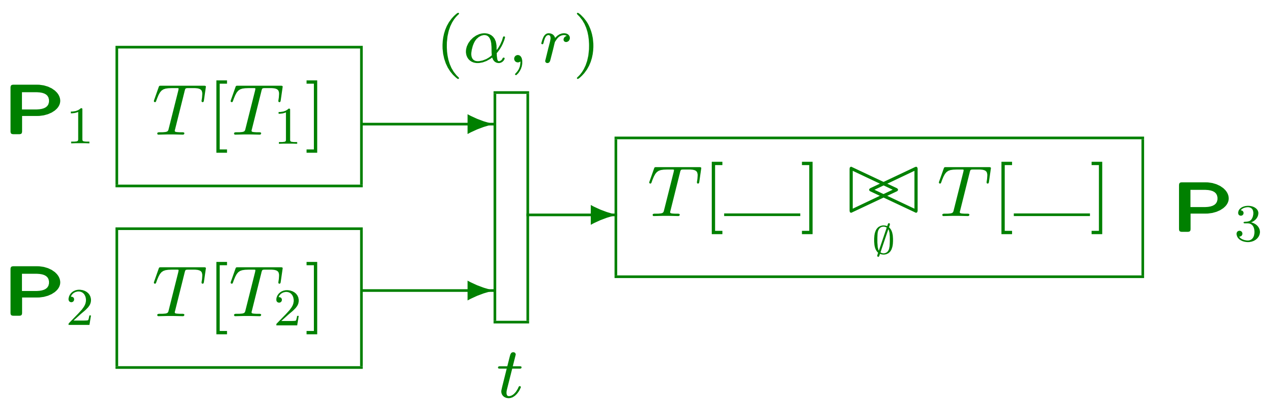

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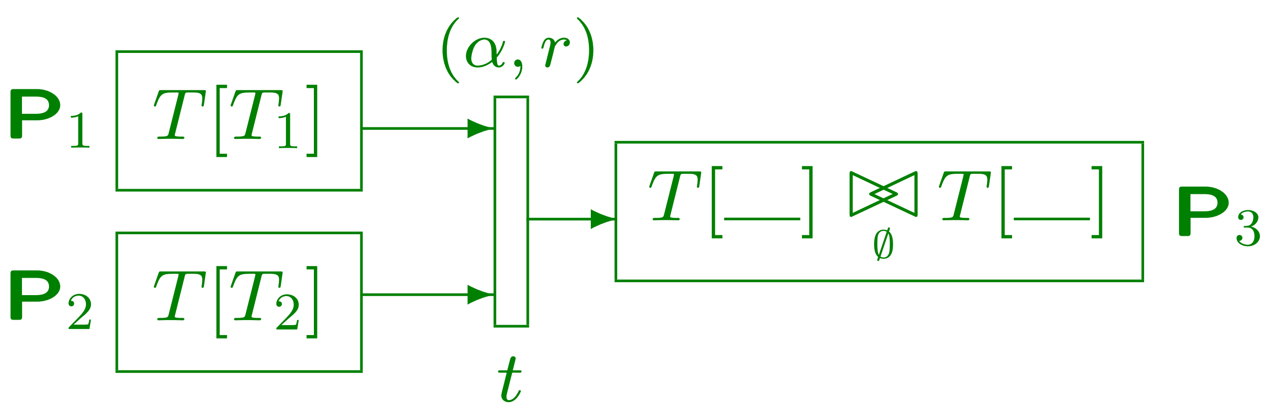

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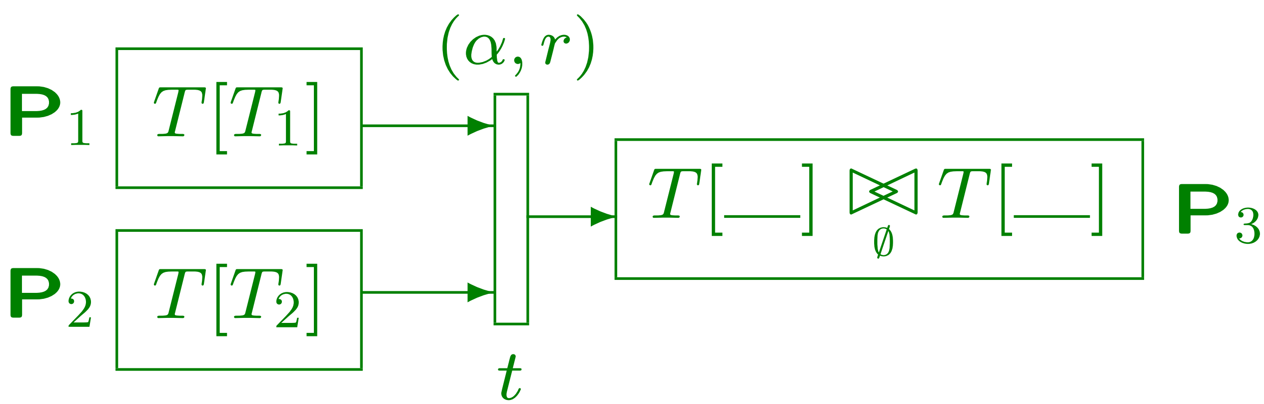

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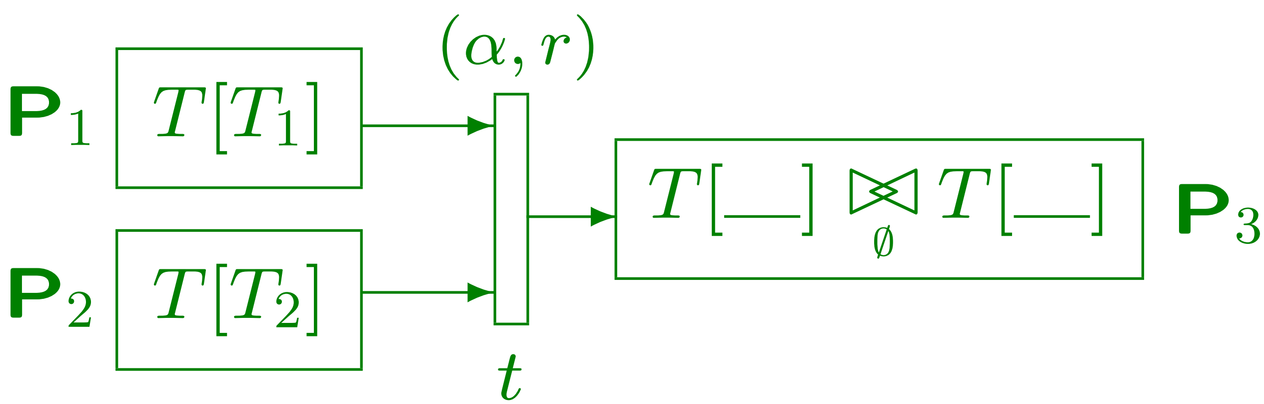

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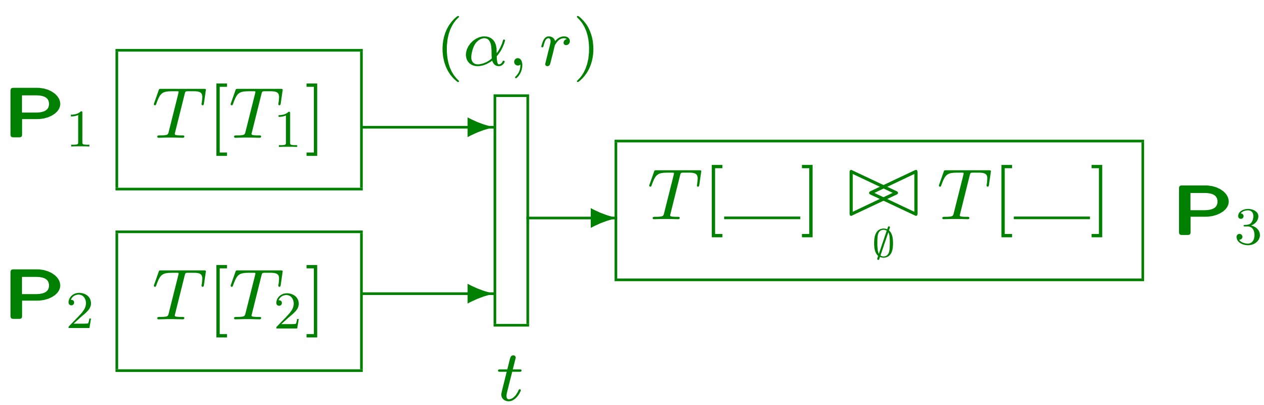

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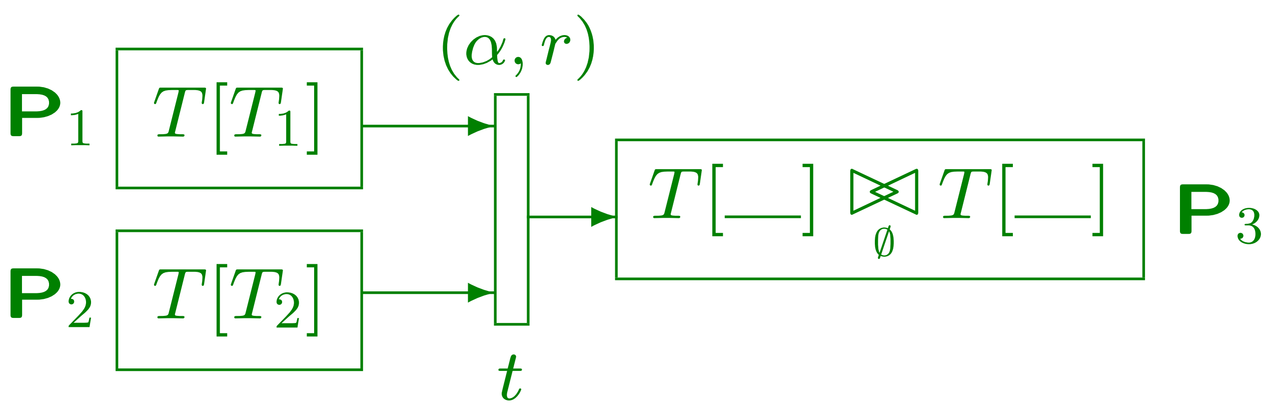

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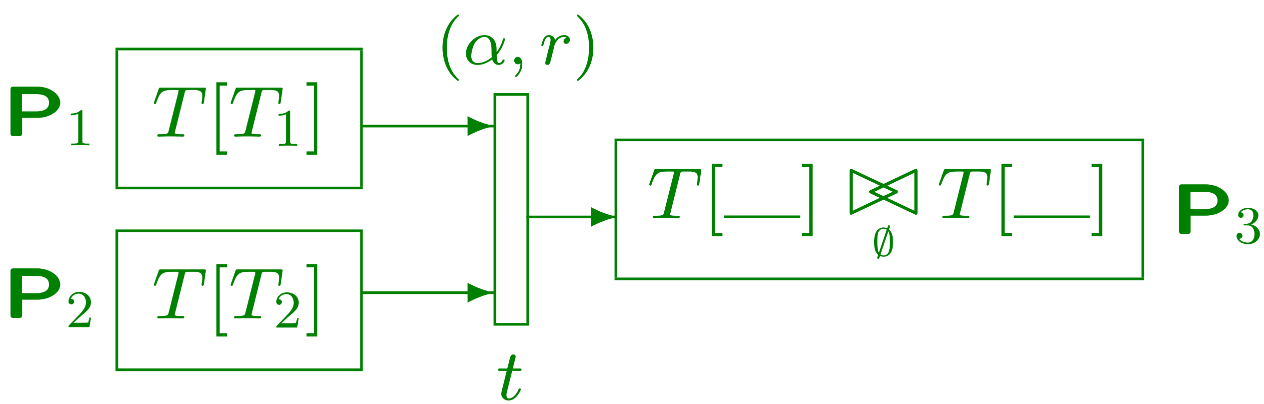

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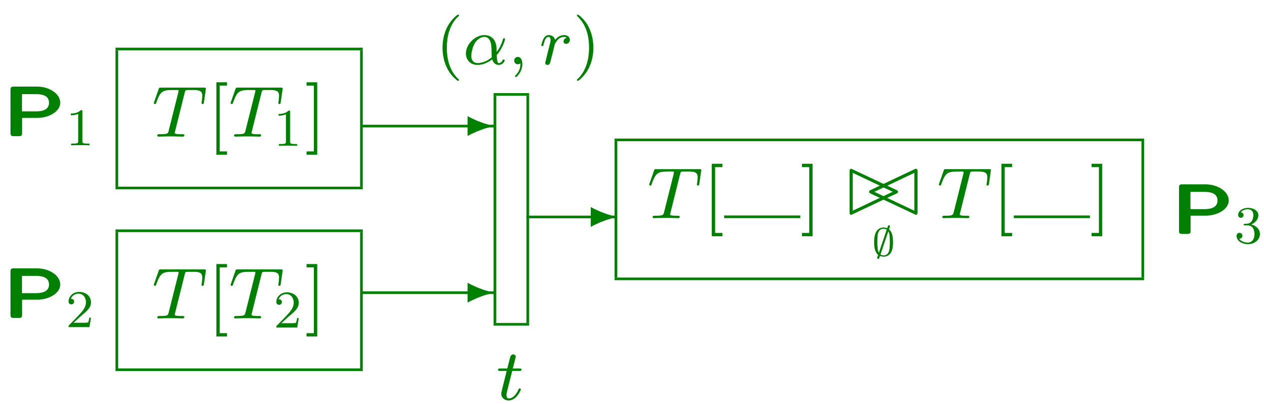

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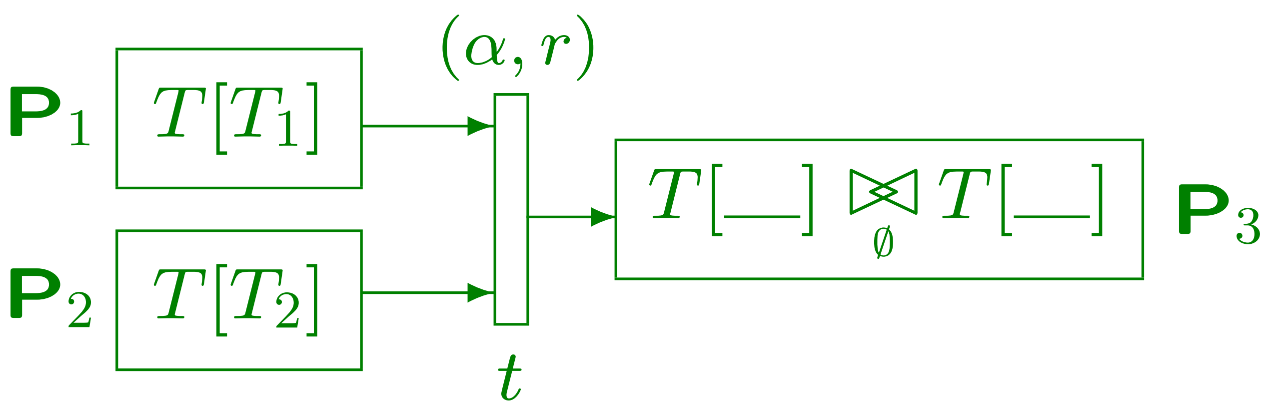

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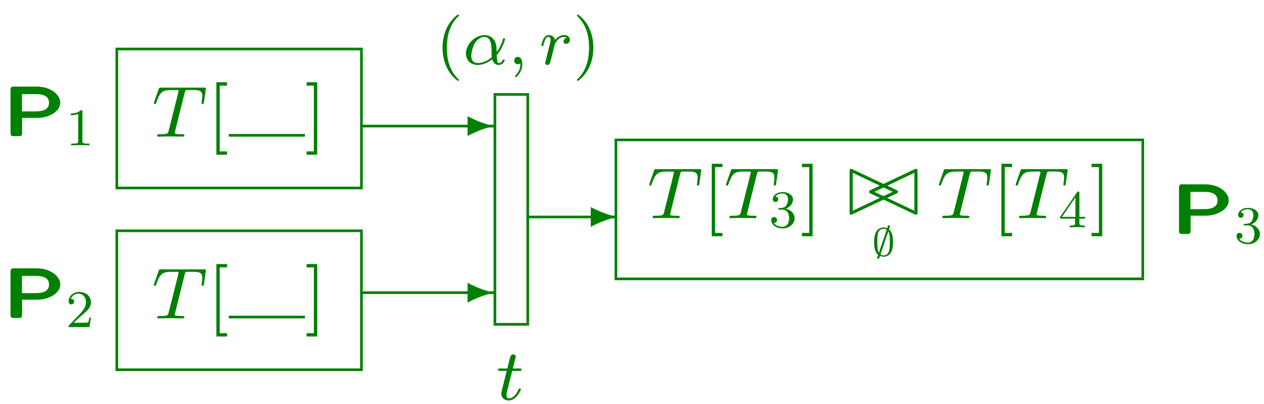

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Analysing PEPA nets

In the PEPA nets notation we have a modelling language which allows us to express performance models of mobile object systems.

The benefit of making such a model comes from the fact that we can gain insights into the system under study through the analysis of the model.

The state space of the model is typically too large to allow us to consider every state individually.

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We introduce the PML_ν logic by means of a two-level grammar which separates the specification of place formulae and token formulae from the specification of transition and firing activities.

Behaviour at the transition and firing level is captured by formulae of a sub-logic, PML_μ.

PML$_\mu$

Based on probabilistic modal logic [Larsen & Skou].

$$\phi \quad ::= \quad \texttt{tt} \quad | \quad \neg\phi \quad | \quad \phi_1 \wedge \phi_2 \quad | \quad \nabla_\alpha \quad | \quad \langle\alpha\rangle_\rho \phi$$

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P \models_\mu \langle\alpha\rangle_\rho\phi & \text{iff} & P \stackrel{(\alpha,\lambda)}{\Longrightarrow} S \text{ for some } \lambda \geq \rho, \\
 & & \text{and for all } P' \in S, P' \models_\mu \phi.
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$\mathbf{PML}_\nu$

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PML$_\nu$

$$\psi \quad ::= \quad \phi \quad | \quad \neg\psi \quad | \quad \psi_1 \wedge \psi_2 \quad | \quad P_i[\phi] \quad | \quad P_i \# T_i \sim n$$

where $\sim \, = \{=, \neq, <, \leq, >, \geq\}$.

$$M \models_\nu \phi \quad \text{iff} \quad M \models_\mu \phi$$

$$M \models_\nu \neg\psi \quad \text{iff} \quad M \not\models_\nu \psi$$

$$M \models_\nu \psi_1 \wedge \psi_2 \quad \text{iff} \quad M \models_\nu \psi_1 \wedge M \models_\nu \psi_2$$

PML$_\nu$

$$\psi \quad ::= \quad \phi \quad | \quad \neg\psi \quad | \quad \psi_1 \wedge \psi_2 \quad | \quad P_i[\phi] \quad | \quad P_i\#T_i \sim n$$

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$M \models_\nu \phi$	iff	$M \models_\mu \phi$
$M \models_\nu \neg\psi$	iff	$M \not\models_\nu \psi$
$M \models_\nu \psi_1 \wedge \psi_2$	iff	$M \models_\nu \psi_1 \wedge M \models_\nu \psi_2$
$M \models_\nu P_i[\phi]$	iff	$M_i \models_\mu \phi$

PML$_\nu$

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$$\begin{array}{lll}
M \models_\nu \phi & \text{iff} & M \models_\mu \phi \\
M \models_\nu \neg\psi & \text{iff} & M \not\models_\nu \psi \\
M \models_\nu \psi_1 \wedge \psi_2 & \text{iff} & M \models_\nu \psi_1 \wedge M \models_\nu \psi_2 \\
M \models_\nu P_i[\phi] & \text{iff} & M_i \models_\mu \phi \\
M \models_\nu P_i\#T_i \sim n & \text{iff} & \mathrm{tokens}(M_i, T_i) \sim n.
\end{array}$$

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M \models_\nu P_i[\phi] & \text{iff} & M_i \models_\mu \phi \\
M \models_\nu P_i\#T_i \sim n & \text{iff} & \mathrm{tokens}(M_i, T_i) \sim n.
\end{array}$$

$$\mathrm{tokens}(P, T_i) = \mathrm{tokens}(T[\_], T_i) = 0,$$
$$\mathrm{tokens}(T[T_i], T_i) = 1, \qquad \mathrm{tokens}(T[T_j], T_i) = 0 \text{ if } T_j \neq T_i$$
$$\mathrm{tokens}(P \underset{L}{\bowtie} Q, T_i) = \mathrm{tokens}(P, T_i) + \mathrm{tokens}(Q, T_i)$$

Example: Secure Web service

We provide a model of a secure Web service.

Web service requests are sent in encrypted form between the client and the service.

A gatekeeper process runs on the machine at the firewall.

Messages are decrypted and either forwarded on to the server or bounced back to the client.

Inside the firewall messages are exchanged as cleartext but outside the firewall communication is always encrypted.

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Tokens

$$
\begin{aligned}
SoapMessage \quad &\stackrel{def}{=} \quad (send_{clr}, r_{sc}).SentClearMessage \\
&+ \quad (encrypt, r_e).EncryptedMsg \\
&+ \quad (parse, r_p).DOMtree
\end{aligned}
$$

Tokens

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\begin{aligned}
SoapMessage &\stackrel{def}{=} (send_{clr}, r_{sc}).SentClearMessage \\
&+ (encrypt, r_e).EncryptedMsg \\
&+ (parse, r_p).DOMtree \\
SentClearMessage &\stackrel{def}{=} (\mathbf{copyClear}, \top).SoapMessage
\end{aligned}
$$

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&+ (encrypt, r_e).EncryptedMsg \\
&+ (parse, r_p).DOMtree
\end{aligned}
$$

$$
SentClearMessage \stackrel{def}{=} (\mathbf{copyClear}, \top).SoapMessage
$$

$$
\begin{aligned}
EncryptedMsg &\stackrel{def}{=} (decrypt, r_d).SoapMessage \\
&+ (send_{enc}, r_{se}).SentEncMessage
\end{aligned}
$$

Tokens

$$
\begin{aligned}
SoapMessage &\stackrel{def}{=} (send_{clr}, r_{sc}).SentClearMessage \\
&+ (encrypt, r_e).EncryptedMsg \\
&+ (parse, r_p).DOMtree \\
SentClearMessage &\stackrel{def}{=} (\mathbf{copyClear}, \top).SoapMessage \\
EncryptedMsg &\stackrel{def}{=} (decrypt, r_d).SoapMessage \\
&+ (send_{enc}, r_{se}).SentEncMessage \\
SentEncMessage &\stackrel{def}{=} (\mathbf{copyEncrypted}, \top).EncryptedMsg
\end{aligned}
$$

Tokens

$$
\begin{array}{rcl}
SoapMessage & \stackrel{def}{=} & (send_{clr}, r_{sc}).SentClearMessage \\
 & + & (encrypt, r_e).EncryptedMsg \\
 & + & (parse, r_p).DOMtree \\
 & & \\
SentClearMessage & \stackrel{def}{=} & (\mathbf{copyClear}, \top).SoapMessage \\
 & & \\
EncryptedMsg & \stackrel{def}{=} & (decrypt, r_d).SoapMessage \\
 & + & (send_{enc}, r_{se}).SentEncMessage \\
 & & \\
SentEncMessage & \stackrel{def}{=} & (\mathbf{copyEncrypted}, \top).EncryptedMsg \\
 & & \\
DOMtree & \stackrel{def}{=} & (read, r_r).DOMtree \\
 & + & (modify, r_m).DOMtree \\
 & + & (export, r_x).SoapMessage
\end{array}
$$

Static components

$$
\begin{aligned}
User &\stackrel{def}{=} \\
&\quad (encrypt, \top).(send_{enc}, \top).User \\
&+ (decrypt, \top).(parse, \top).(read, \top).(modify, \top).(export, \top).User
\end{aligned}
$$

Static components

$$
\begin{aligned}
&User \stackrel{def}{=} \\
&\quad (encrypt, \top).(send_{enc}, \top).User \\
&+ (decrypt, \top).(parse, \top).(read, \top).(modify, \top).(export, \top).User
\end{aligned}
$$

$$
\begin{aligned}
&GateKeeper \stackrel{def}{=} \\
&\quad (decrypt, \top).(send_{clr}, \top).GateKeeper \\
&+ (decrypt, \top).(encrypt, \top).(send_{enc}, \top).GateKeeper \\
&+ (encrypt, \top).(send_{enc}, \top).GateKeeper
\end{aligned}
$$

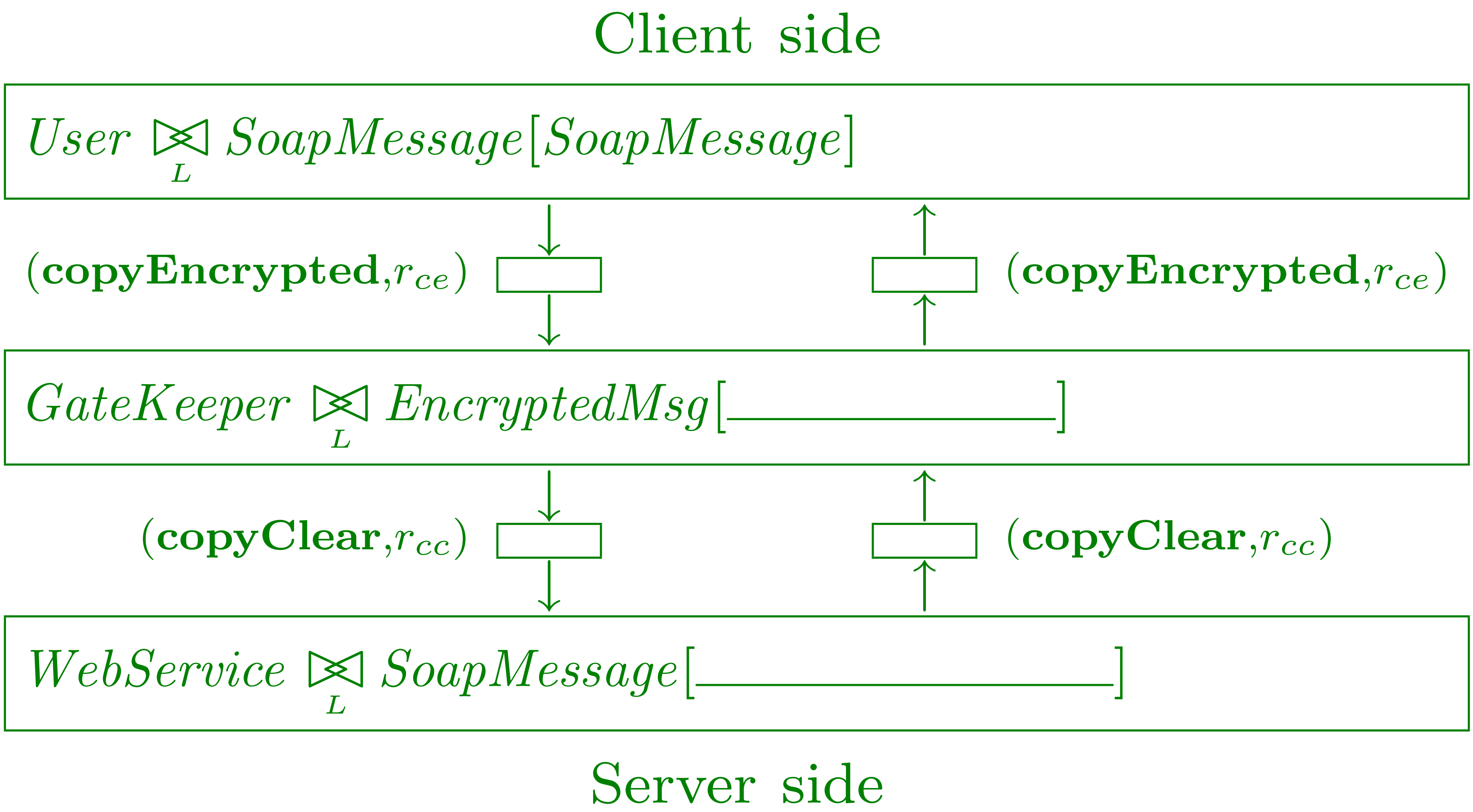
Static components

$$
\begin{aligned}
&User \stackrel{def}{=} \\
&\quad (encrypt, \top).(send_{enc}, \top).User \\
&+ (decrypt, \top).(parse, \top).(read, \top).(modify, \top).(export, \top).User
\end{aligned}
$$

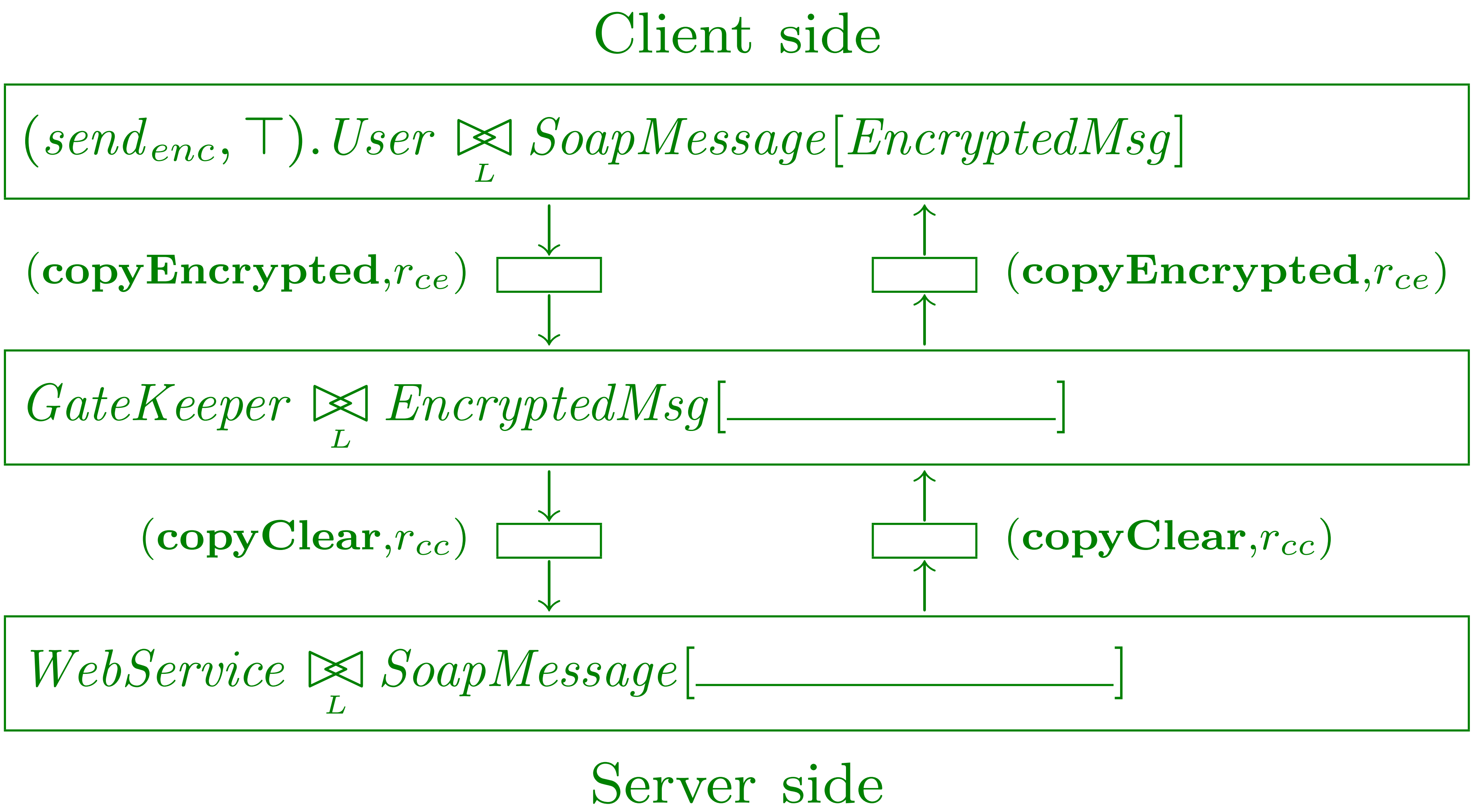
$$
\begin{aligned}
&GateKeeper \stackrel{def}{=} \\
&\quad (decrypt, \top).(send_{clr}, \top).GateKeeper \\
&+ (decrypt, \top).(encrypt, \top).(send_{enc}, \top).GateKeeper \\
&+ (encrypt, \top).(send_{enc}, \top).GateKeeper
\end{aligned}
$$

$$
\begin{aligned}
&WebService \stackrel{def}{=} (parse, \top).(read, \top). \\
&\qquad (modify, \top).(export, \top).(send_{clr}, \top).WebService
\end{aligned}
$$

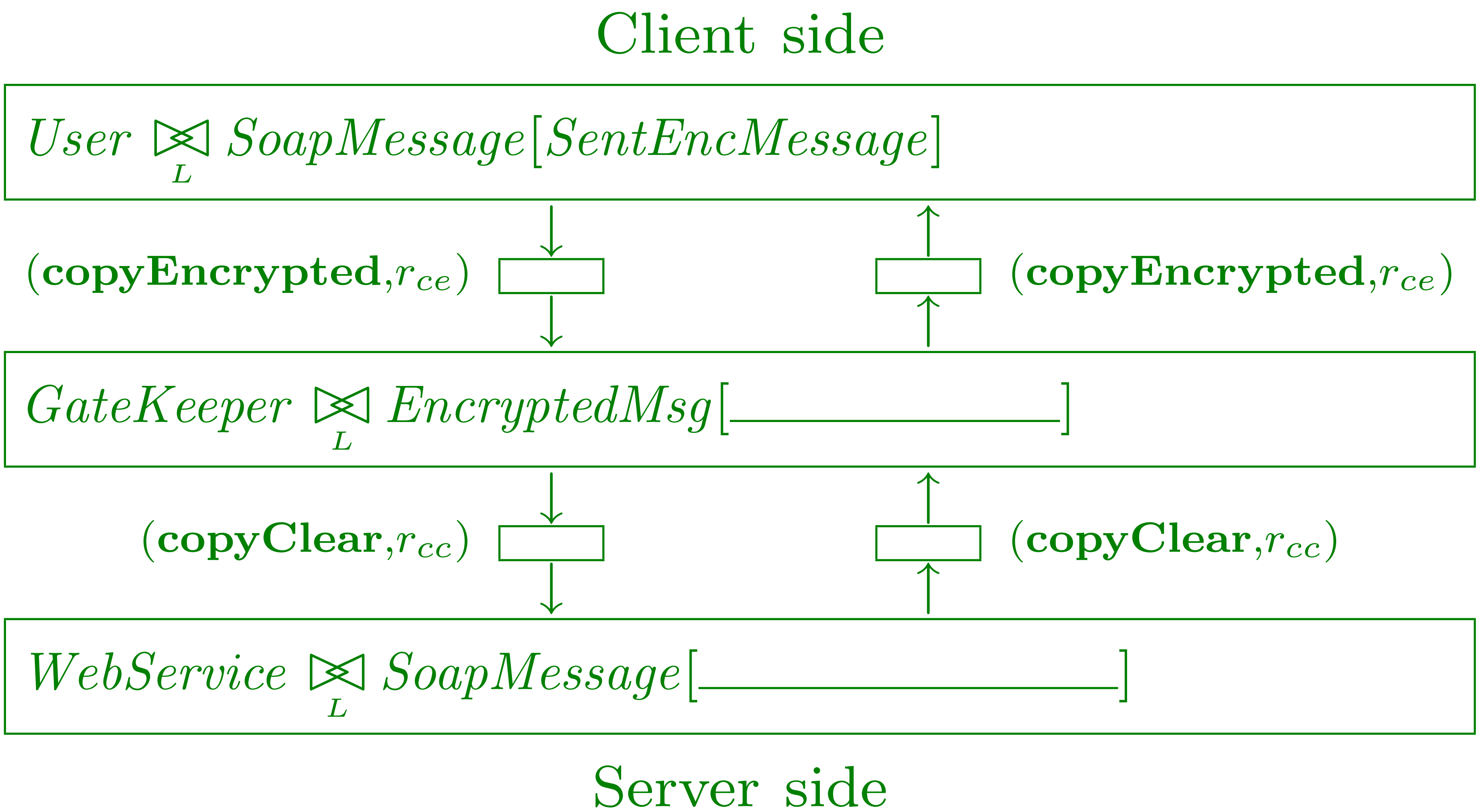
PEPA net


Client side
$User \bowtie_{L} SoapMessage[SoapMessage]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_{L} EncryptedMsg[\_\_\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[\_\_\_]$
Server side

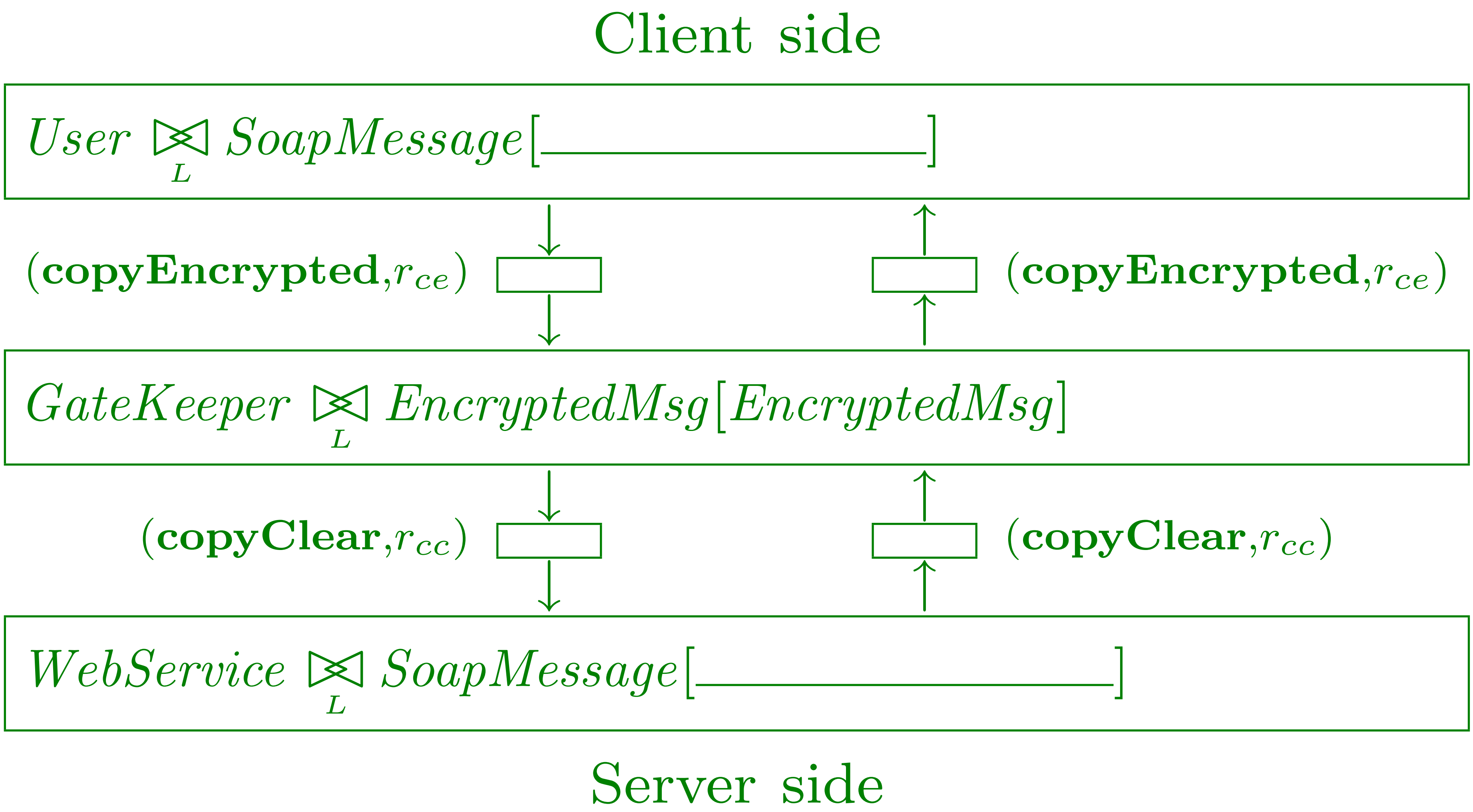
PEPA net


Client side
$(send_{enc}, \top).User \bowtie_{L} SoapMessage[EncryptedMsg]$
(**copyEncrypted**,r_{ce})
(**copyEncrypted**,r_{ce})
$GateKeeper \bowtie_{L} EncryptedMsg[\_\_\_]$
(**copyClear**,r_{cc})
(**copyClear**,r_{cc})
$WebService \bowtie_{L} SoapMessage[\_\_\_]$
Server side

PEPA net

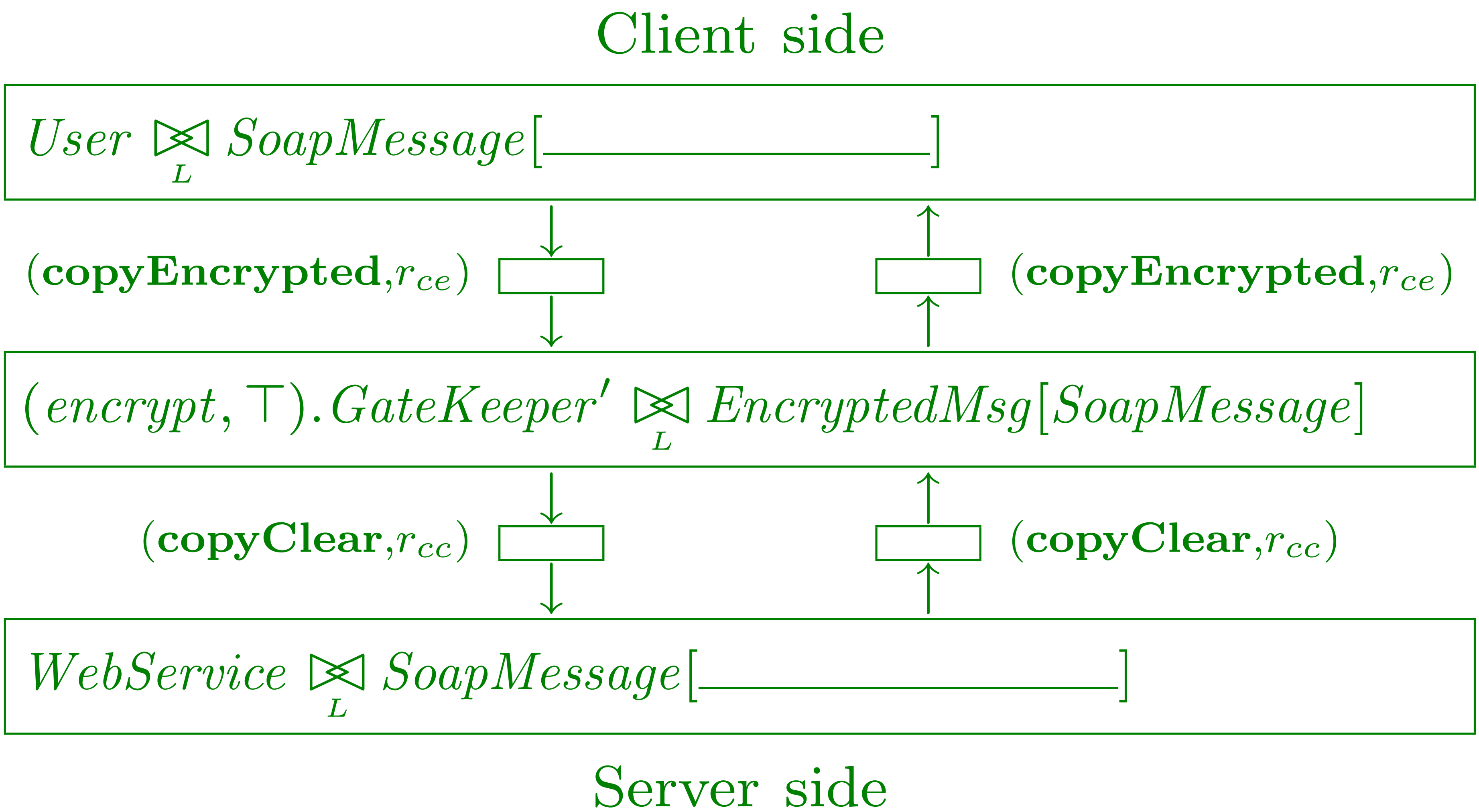

Client side
$User \bowtie_{L} SoapMessage[SentEncMessage]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_{L} EncryptedMsg[\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[\_]$
Server side

PEPA net

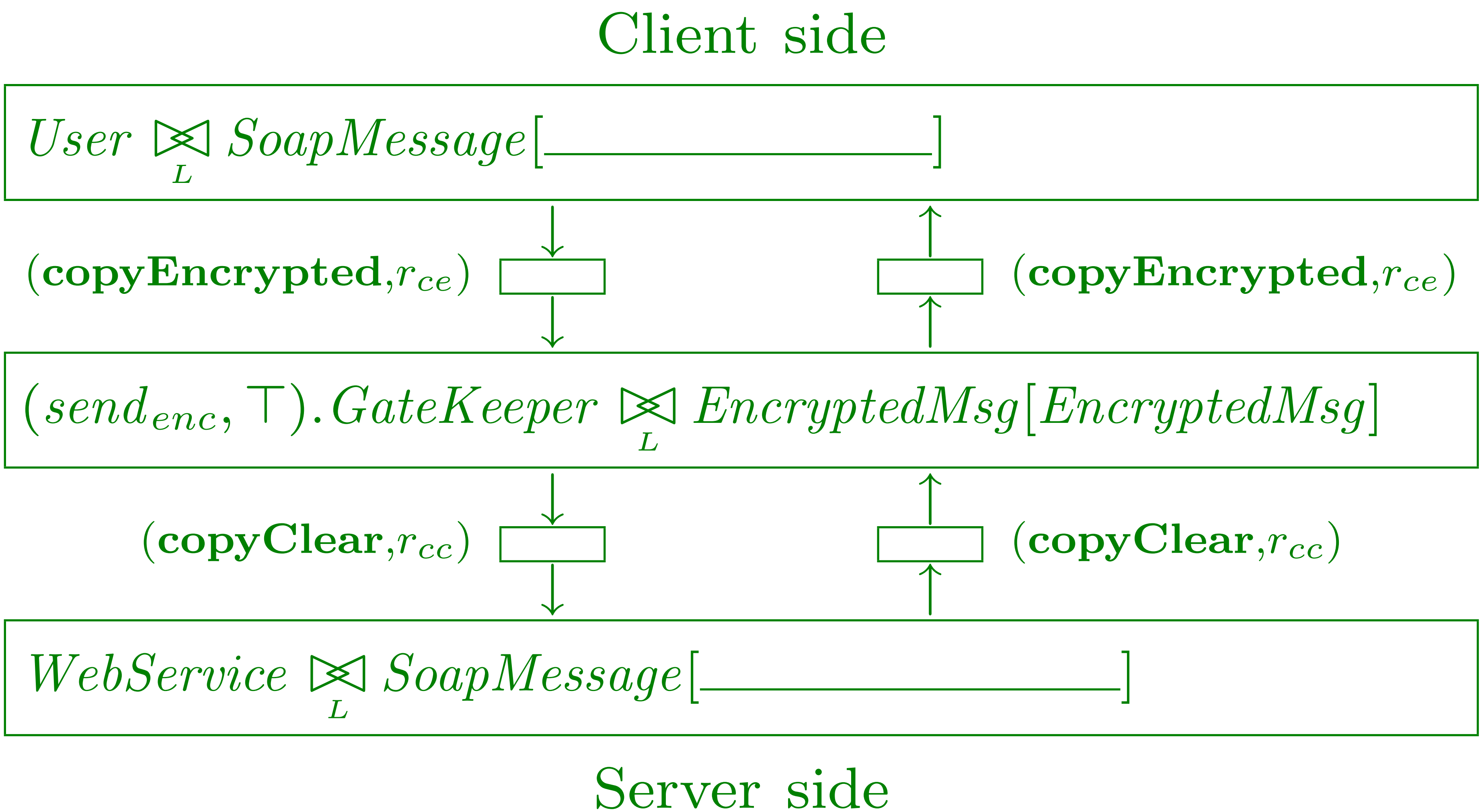


Client side
$User \underset{L}{\bowtie} SoapMessage[\_\_\_]$
(**copyEncrypted**,r_{ce})
(**copyEncrypted**,r_{ce})
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[EncryptedMsg]$
(**copyClear**,r_{cc})
(**copyClear**,r_{cc})
$WebService \underset{L}{\bowtie} SoapMessage[\_\_\_]$
Server side

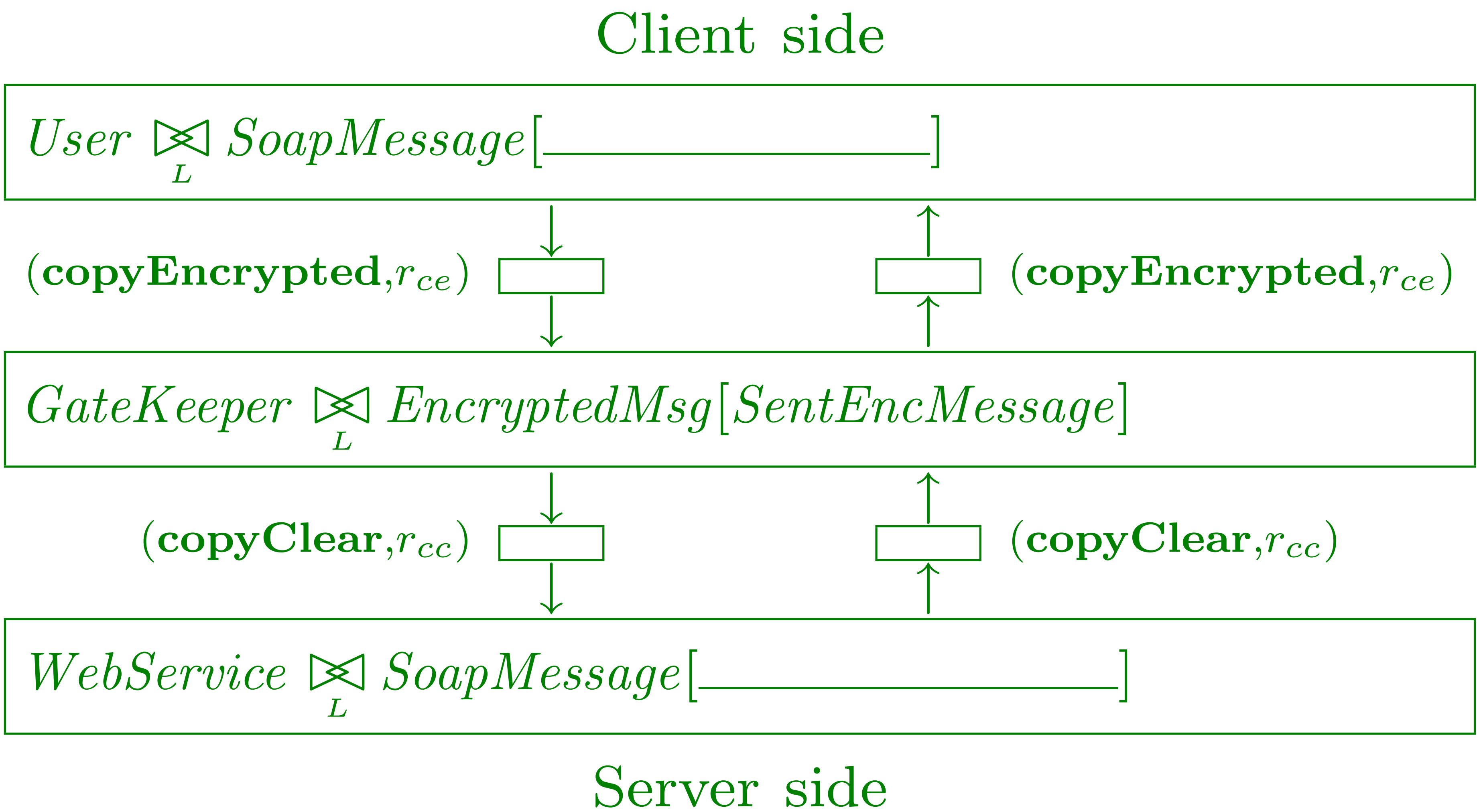
PEPA net


Client side
$User \bowtie_L SoapMessage[\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$(encrypt, \top).GateKeeper' \bowtie_L EncryptedMsg[SoapMessage]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_L SoapMessage[\_\_\_]$
Server side

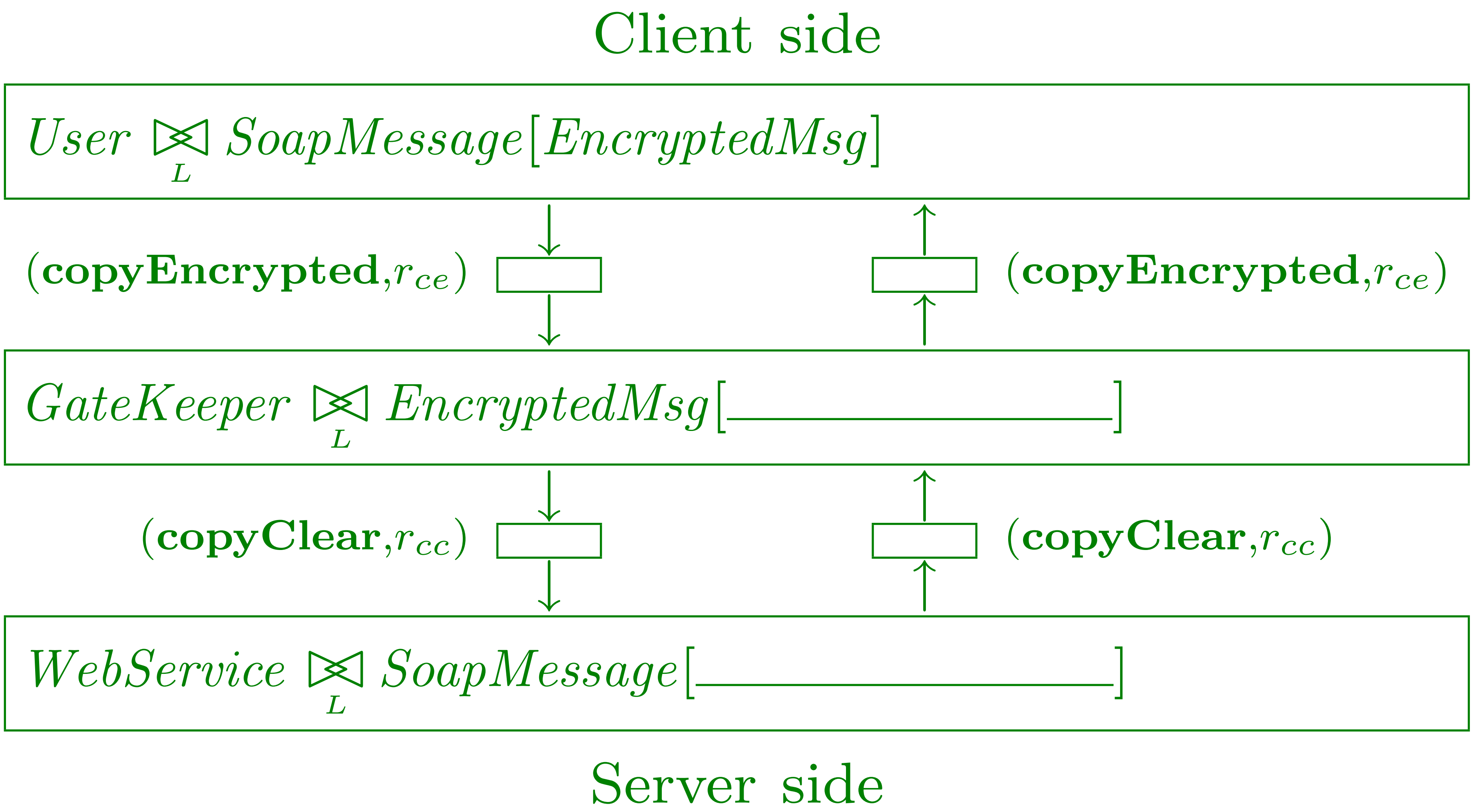
PEPA net


Client side
$User \bowtie_{L} SoapMessage[\underline{\qquad\qquad\qquad}]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$(send_{enc}, \top).GateKeeper \bowtie_{L} EncryptedMsg[EncryptedMsg]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[\underline{\qquad\qquad\qquad}]$
Server side

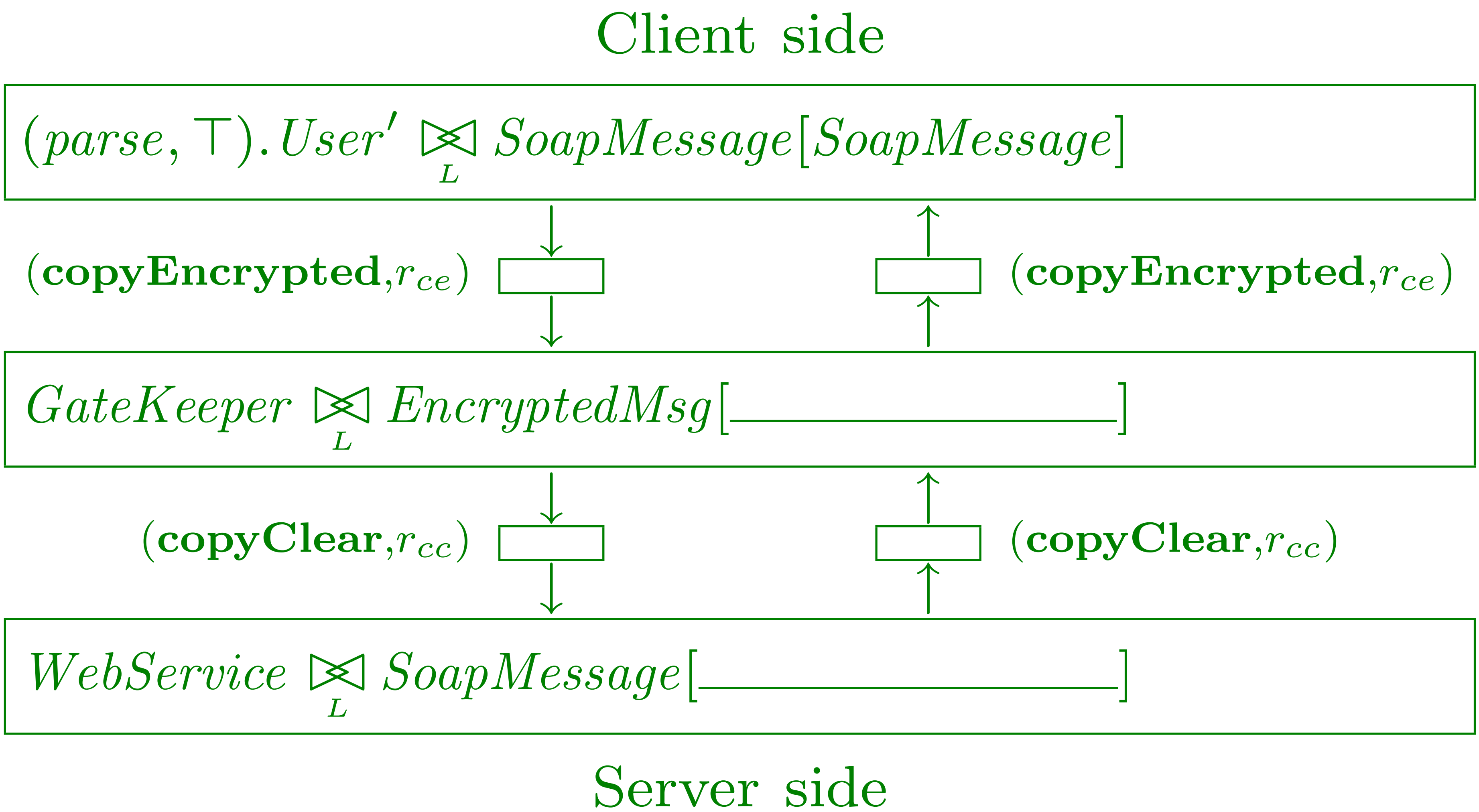
PEPA net


Client side
$User \bowtie_{L} SoapMessage[\_\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_{L} EncryptedMsg[SentEncMessage]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[\_\_\_\_]$
Server side

PEPA net

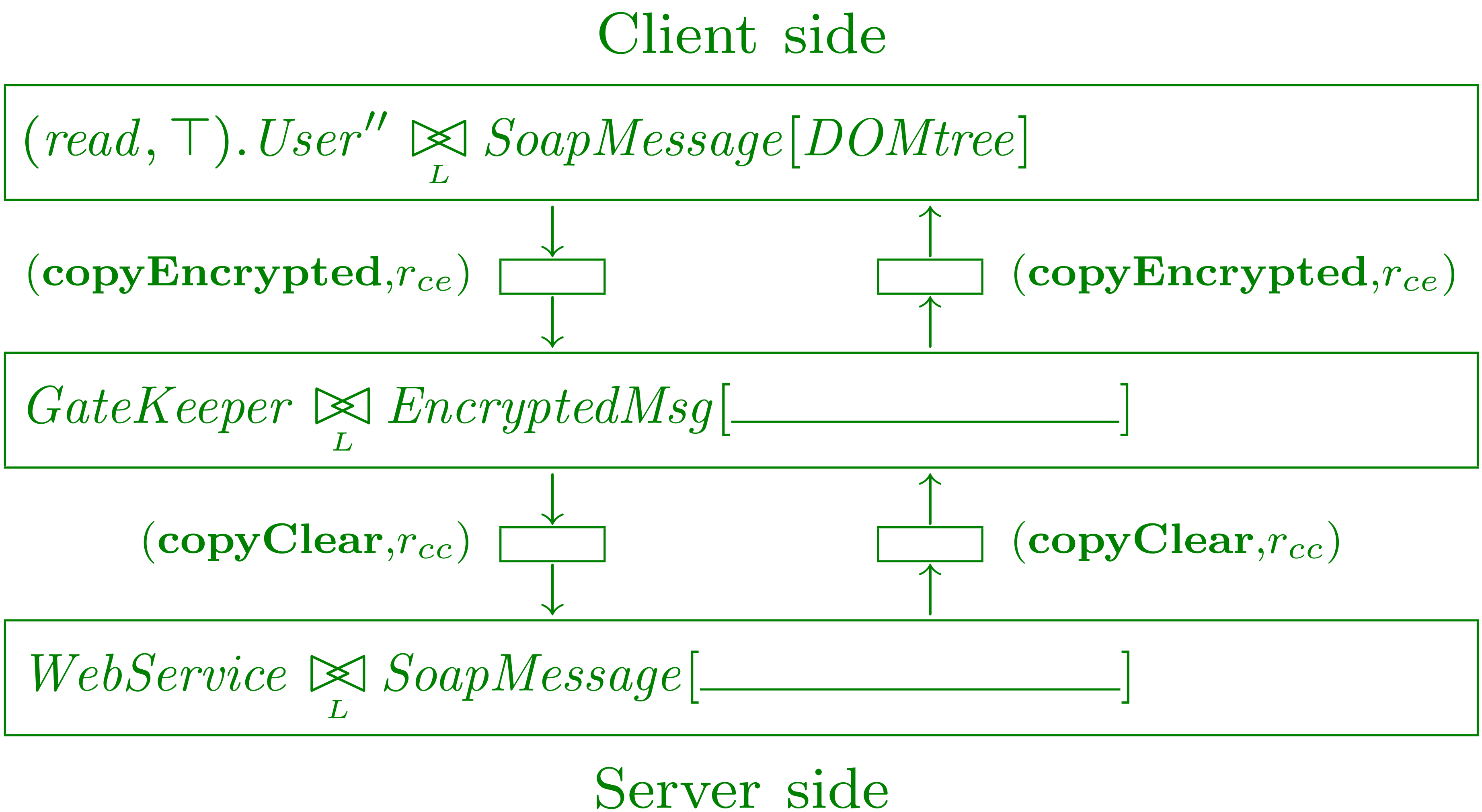

Client side
$User \bowtie_{L} SoapMessage[EncryptedMsg]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_{L} EncryptedMsg[\_\_\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[\_\_\_]$
Server side

PEPA net

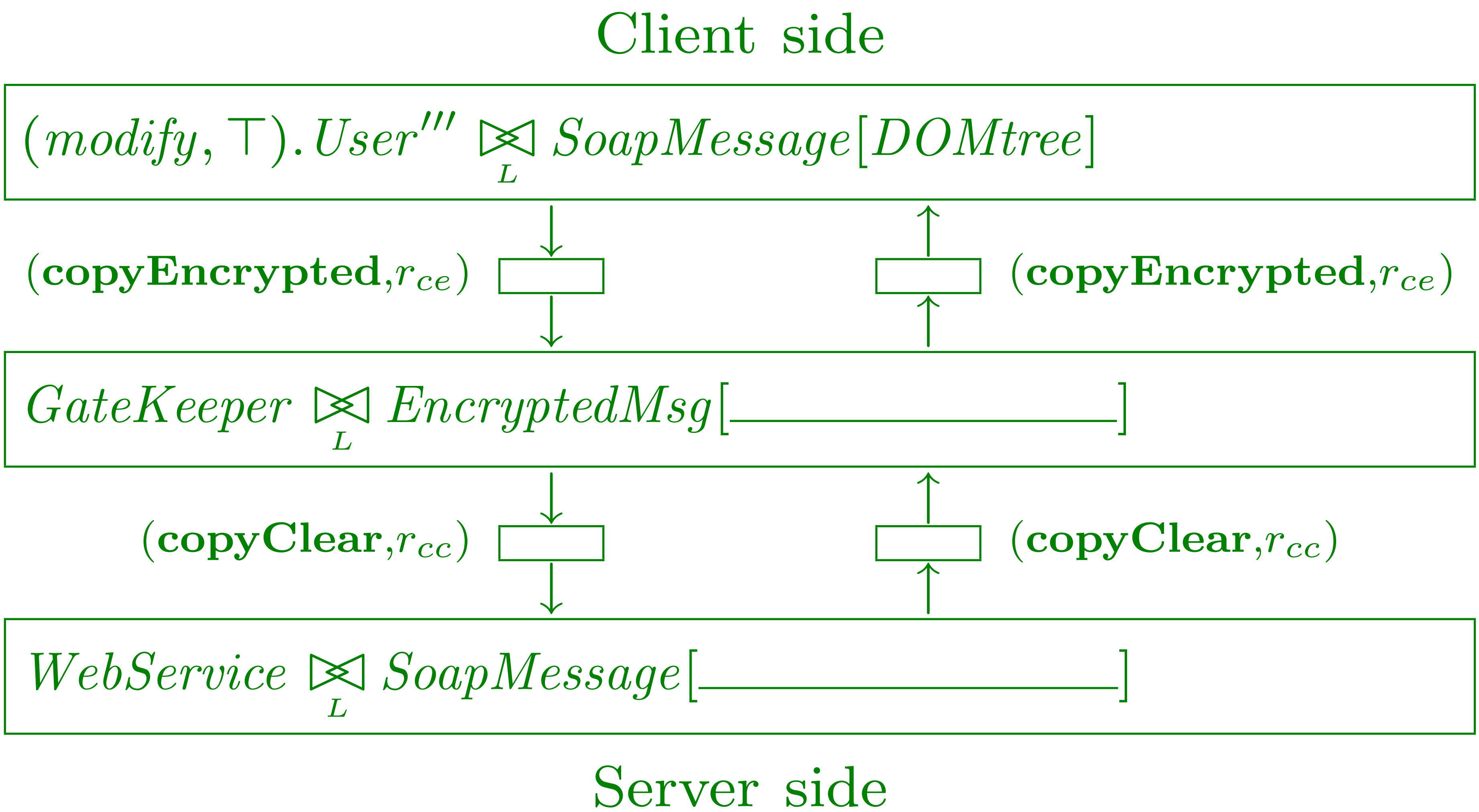


Client side
$(parse, \top).User' \bowtie_{L} SoapMessage[SoapMessage]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_{L} EncryptedMsg[\_\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[\_\_]$
Server side

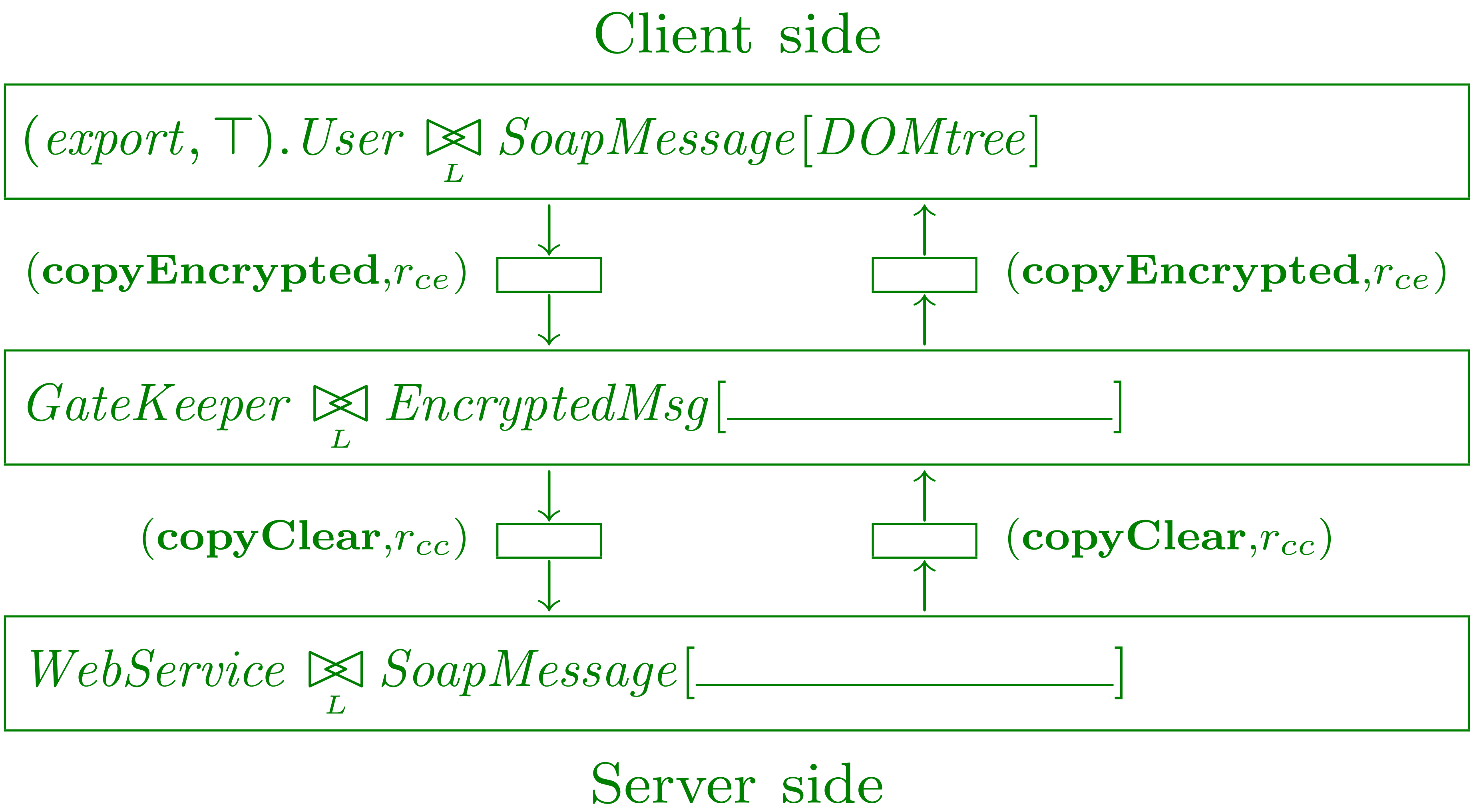
PEPA net


Client side
$(read, \top).User'' \bowtie_L SoapMessage[DOMtree]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_L EncryptedMsg[\_\_\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_L SoapMessage[\_\_\_]$
Server side

PEPA net

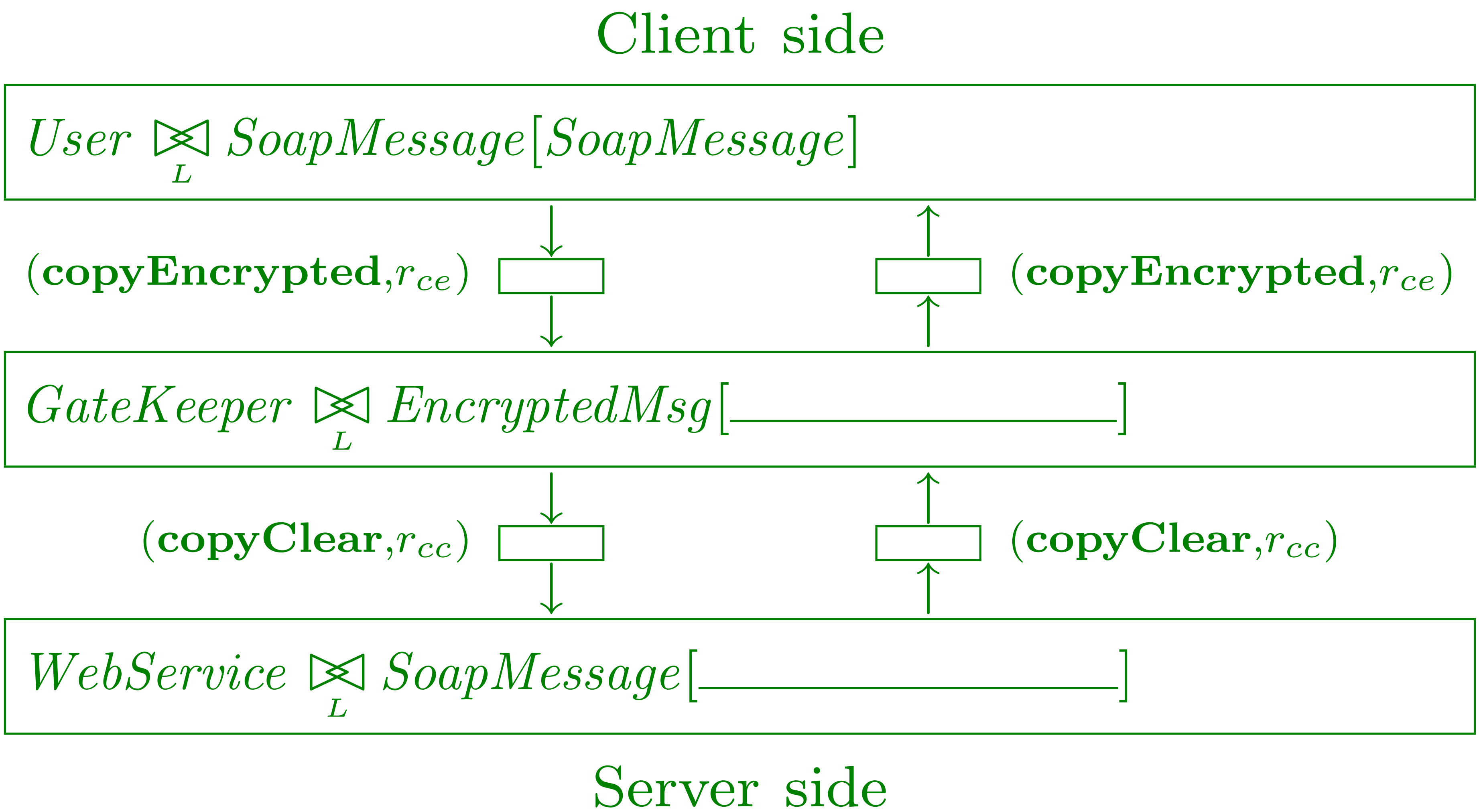

Client side
$(modify, \top).User''' \underset{L}{\bowtie} SoapMessage[DOMtree]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[\_\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \underset{L}{\bowtie} SoapMessage[\_\_]$
Server side

PEPA net

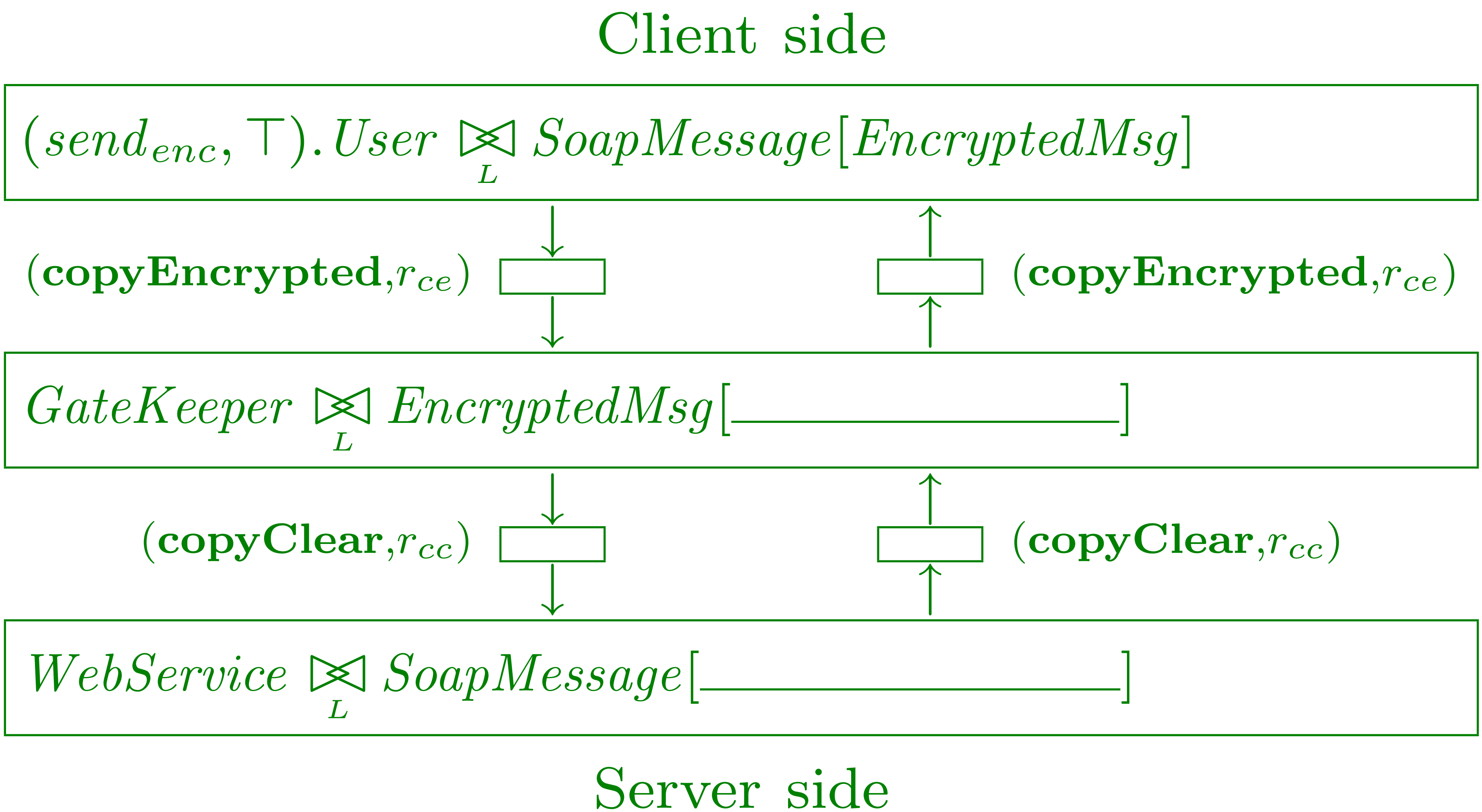


Client side
$(export, \top).User \underset{L}{\bowtie} SoapMessage[DOMtree]$
(**copyEncrypted**,r_{ce})
(**copyEncrypted**,r_{ce})
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[\_\_\_]$
(**copyClear**,r_{cc})
(**copyClear**,r_{cc})
$WebService \underset{L}{\bowtie} SoapMessage[\_\_\_]$
Server side

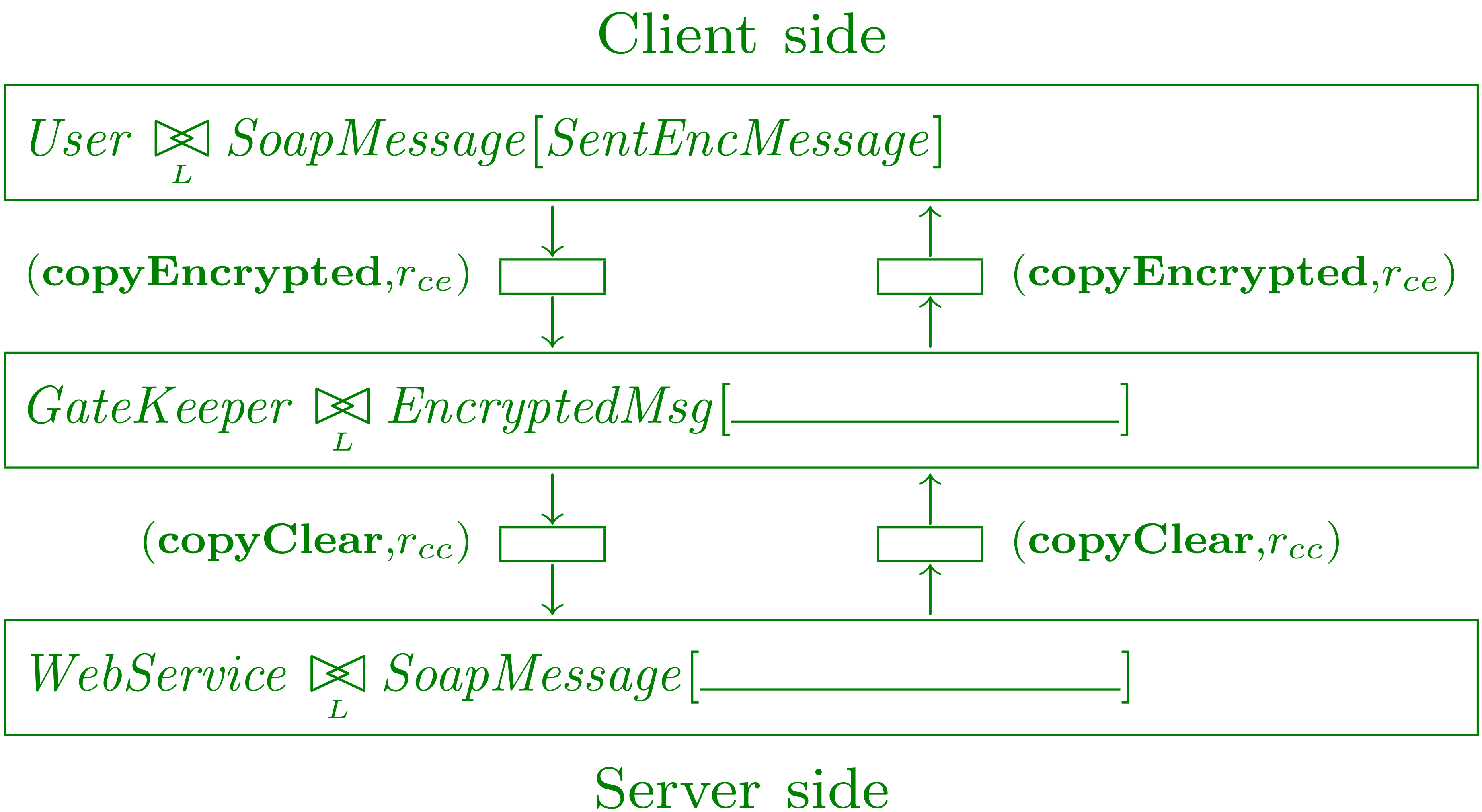
PEPA net


Client side
$User \underset{L}{\bowtie} SoapMessage[SoapMessage]$
$(\textbf{copyEncrypted}, r_{ce})$
$(\textbf{copyEncrypted}, r_{ce})$
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[\_\_]$
$(\textbf{copyClear}, r_{cc})$
$(\textbf{copyClear}, r_{cc})$
$WebService \underset{L}{\bowtie} SoapMessage[\_\_]$
Server side

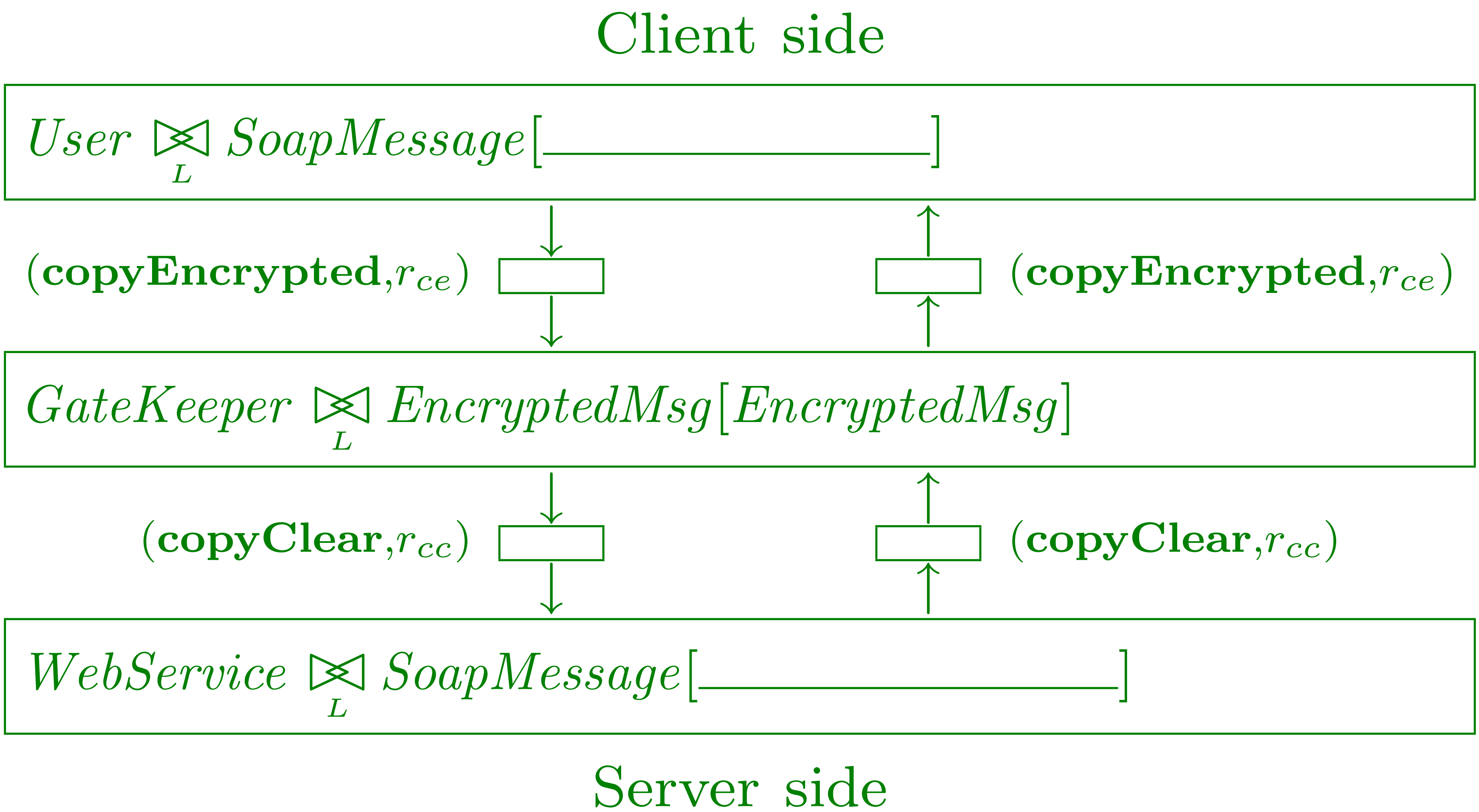
PEPA net


Client side
$(send_{enc}, \top).User \bowtie_L SoapMessage[EncryptedMsg]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_L EncryptedMsg[\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_L SoapMessage[\_]$
Server side

PEPA net


Client side
$User \underset{L}{\bowtie} SoapMessage[SentEncMessage]$
(**copyEncrypted**,r_{ce})
(**copyEncrypted**,r_{ce})
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[\_\_\_]$
(**copyClear**,r_{cc})
(**copyClear**,r_{cc})
$WebService \underset{L}{\bowtie} SoapMessage[\_\_\_]$
Server side

PEPA net



Client side
$User \bowtie_{L} SoapMessage[\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_{L} EncryptedMsg[EncryptedMsg]$
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$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[\_\_\_]$
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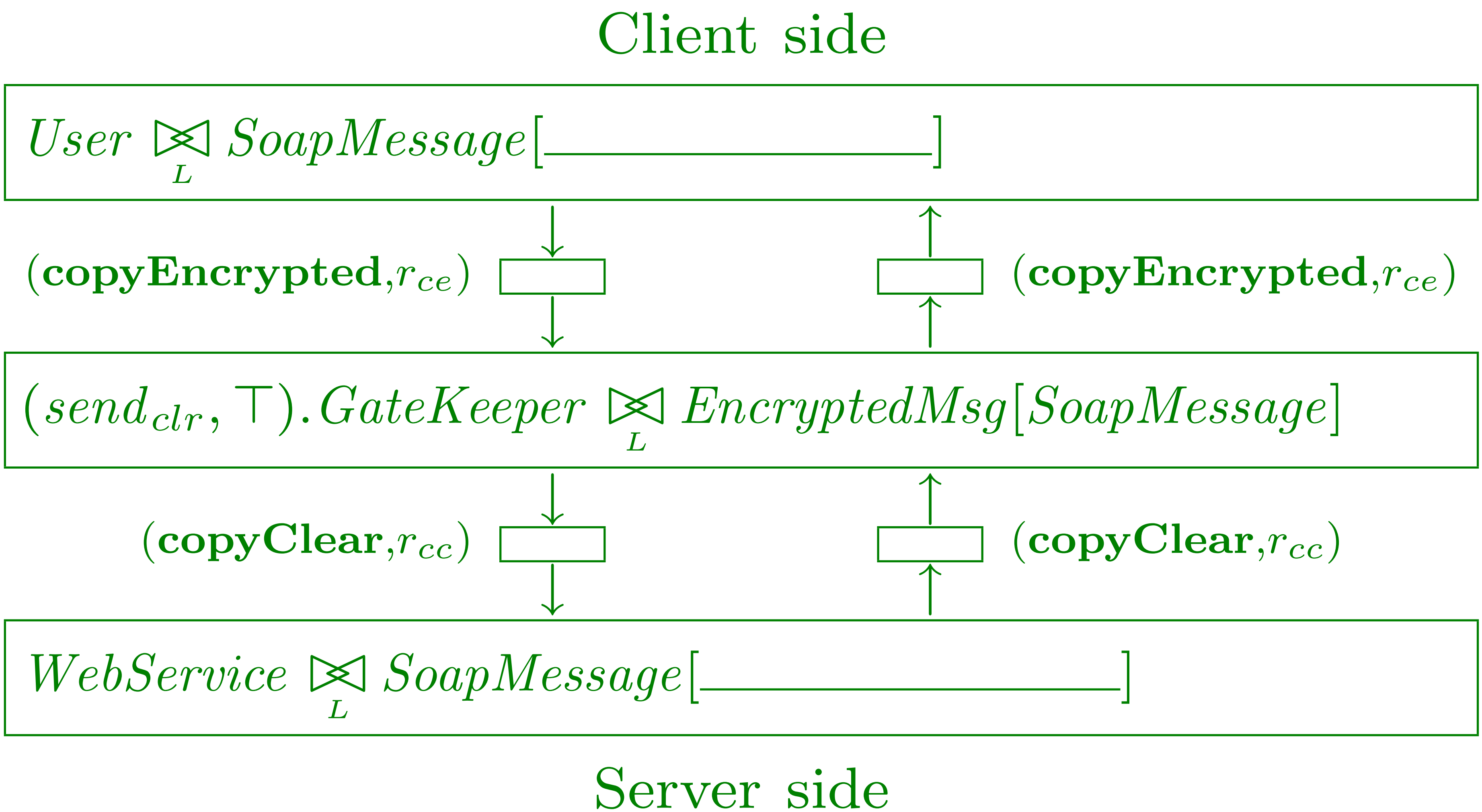
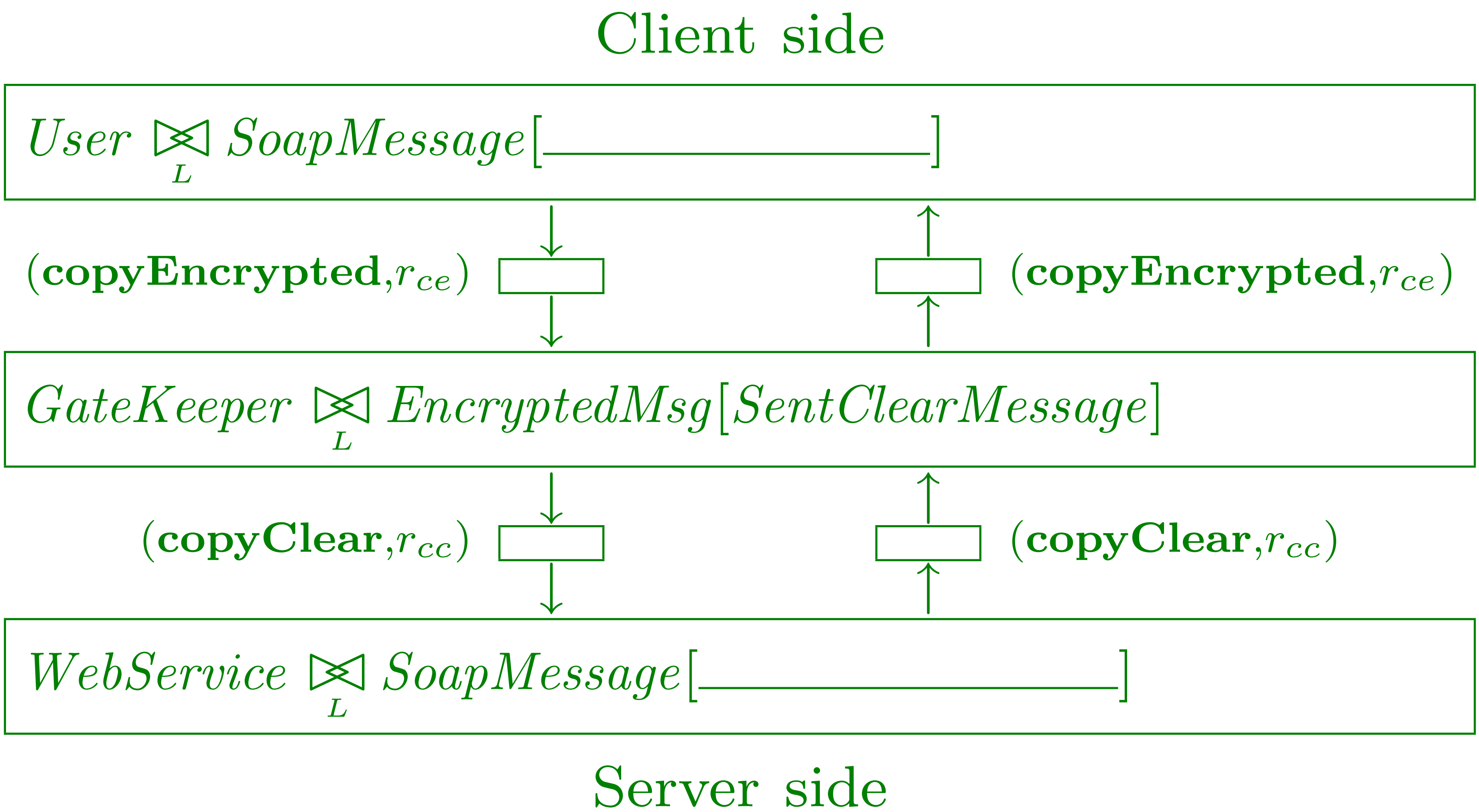
PEPA net

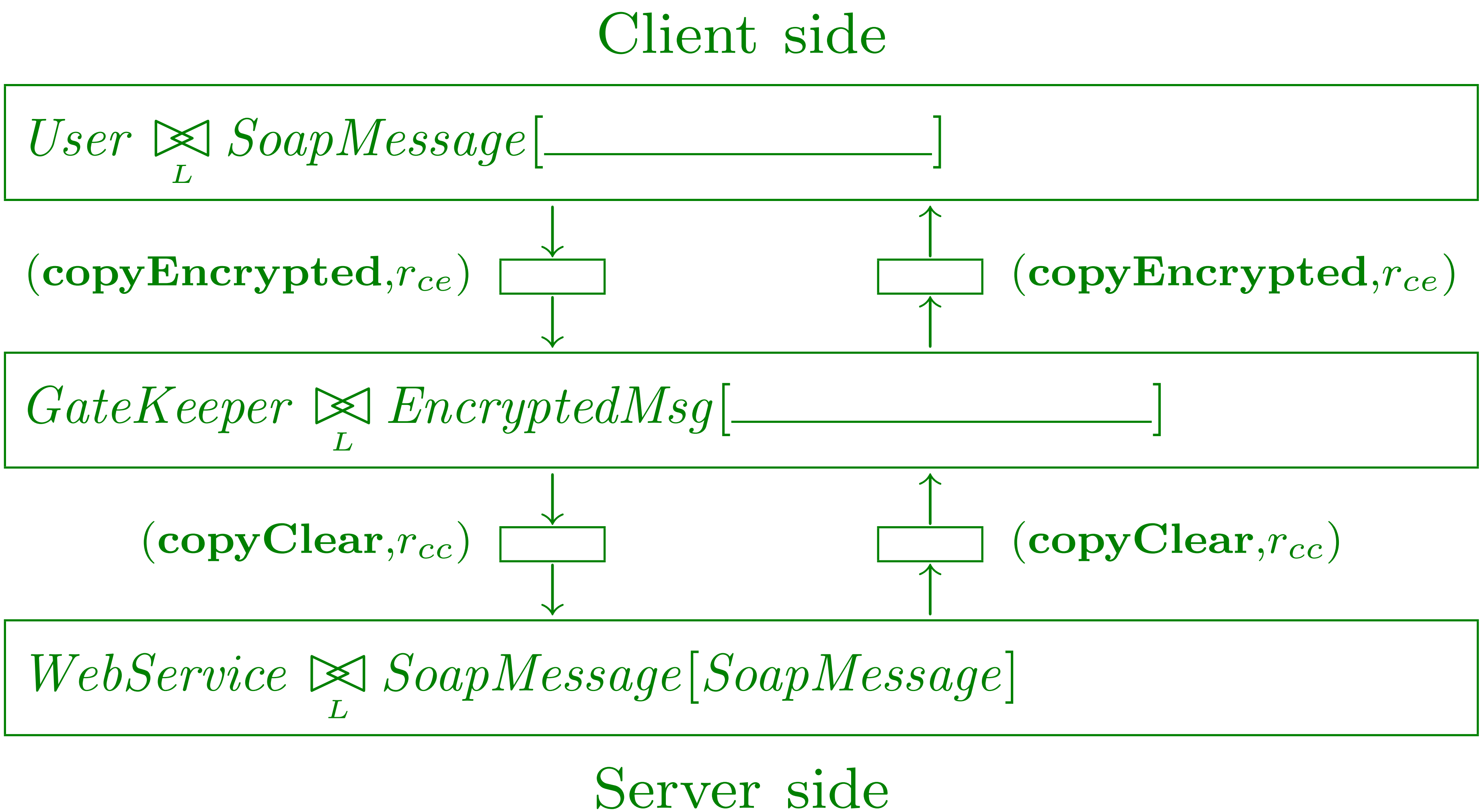

Client side
$User \underset{L}{\bowtie} SoapMessage[\_\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$(send_{clr}, \top).GateKeeper \underset{L}{\bowtie} EncryptedMsg[SoapMessage]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \underset{L}{\bowtie} SoapMessage[\_\_\_\_]$
Server side

PEPA net

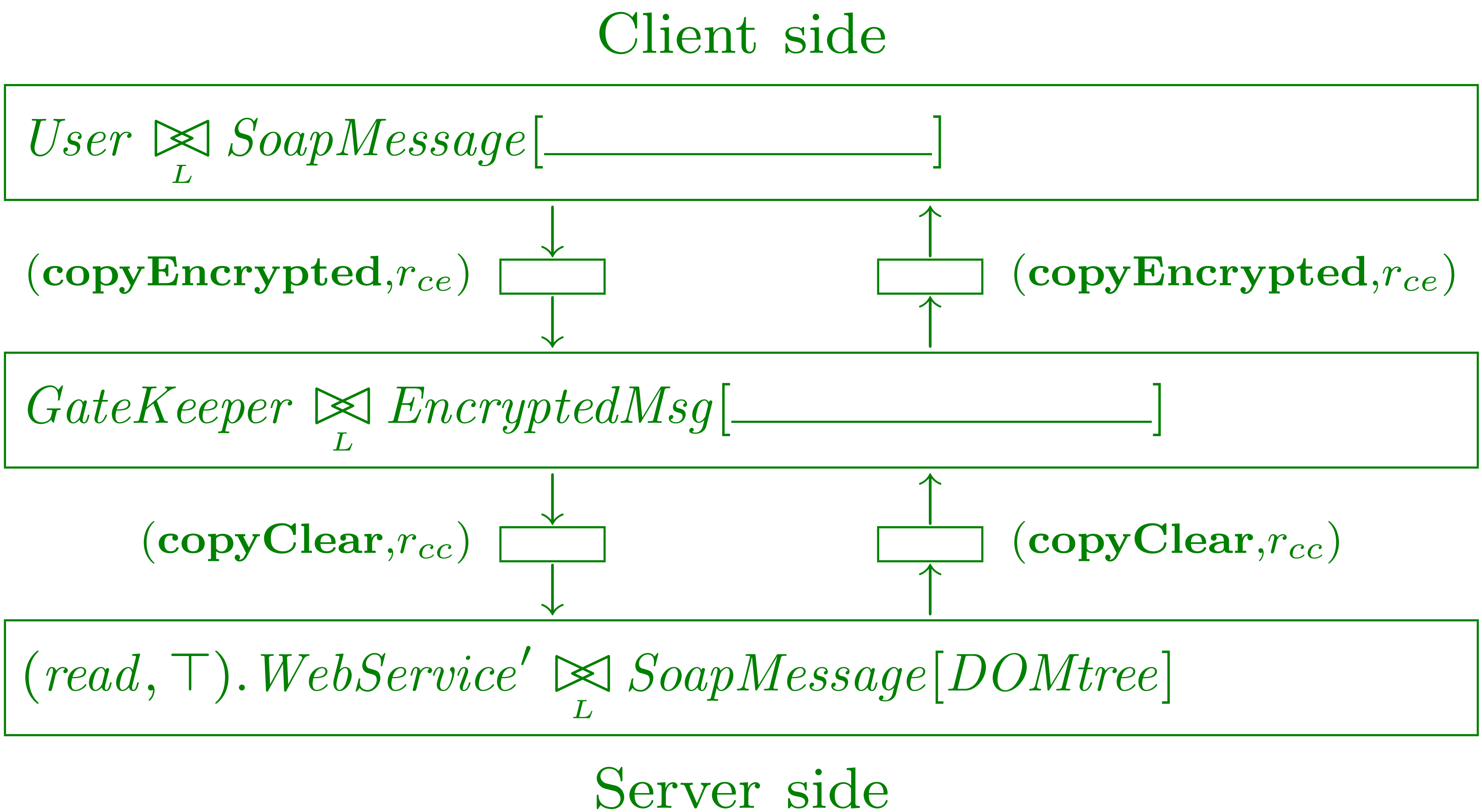


Client side
$User \underset{L}{\bowtie} SoapMessage[\_\_\_\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[SentClearMessage]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \underset{L}{\bowtie} SoapMessage[\_\_\_\_\_\_]$
Server side

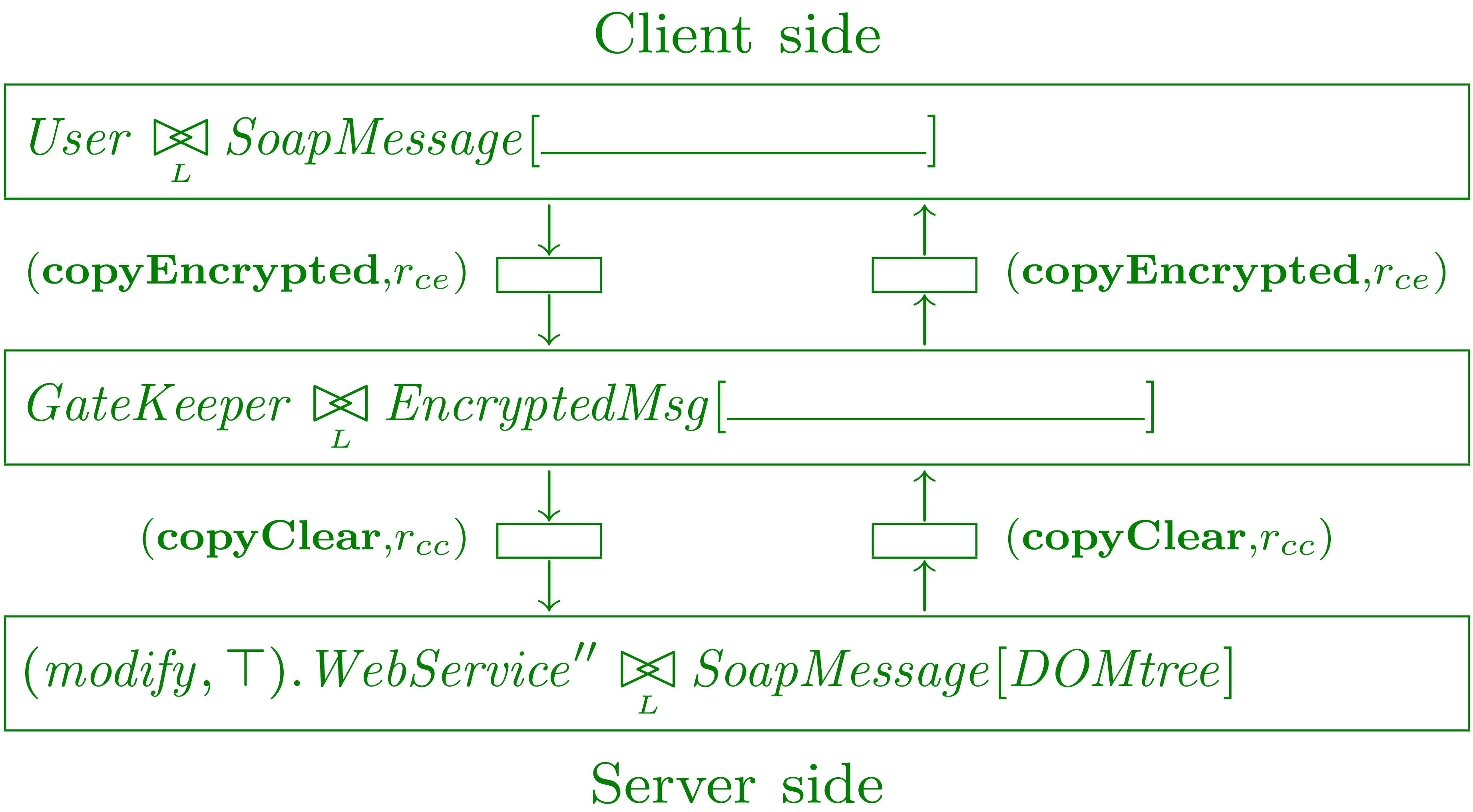
PEPA net


Client side
$User \bowtie_{L} SoapMessage[\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_{L} EncryptedMsg[\_\_\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[SoapMessage]$
Server side

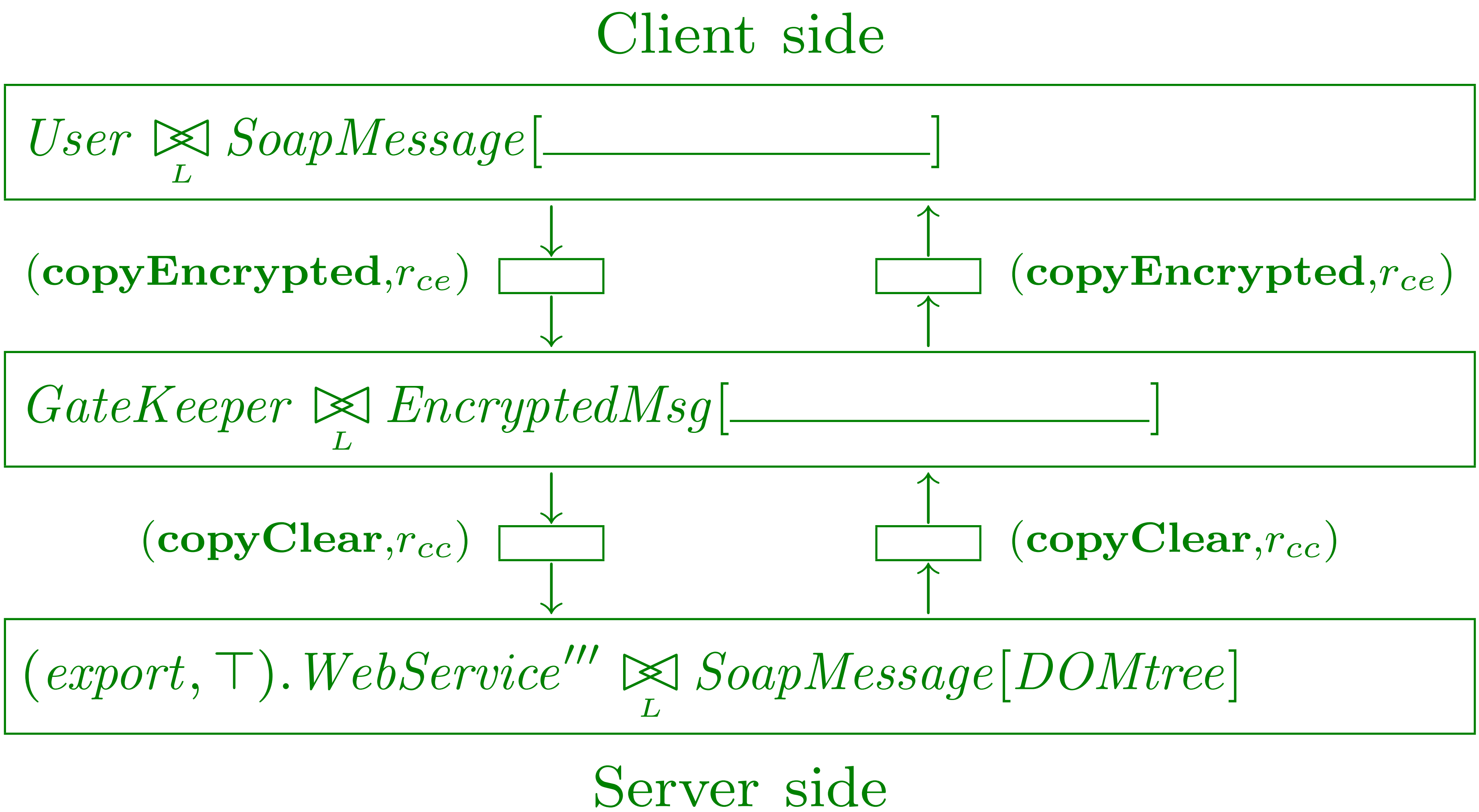
PEPA net


Client side
$User \bowtie_L SoapMessage[\_\_\_]$
(**copyEncrypted**,r_{ce})
(**copyEncrypted**,r_{ce})
$GateKeeper \bowtie_L EncryptedMsg[\_\_\_]$
(**copyClear**,r_{cc})
(**copyClear**,r_{cc})
$(read, \top).WebService' \bowtie_L SoapMessage[DOMtree]$
Server side

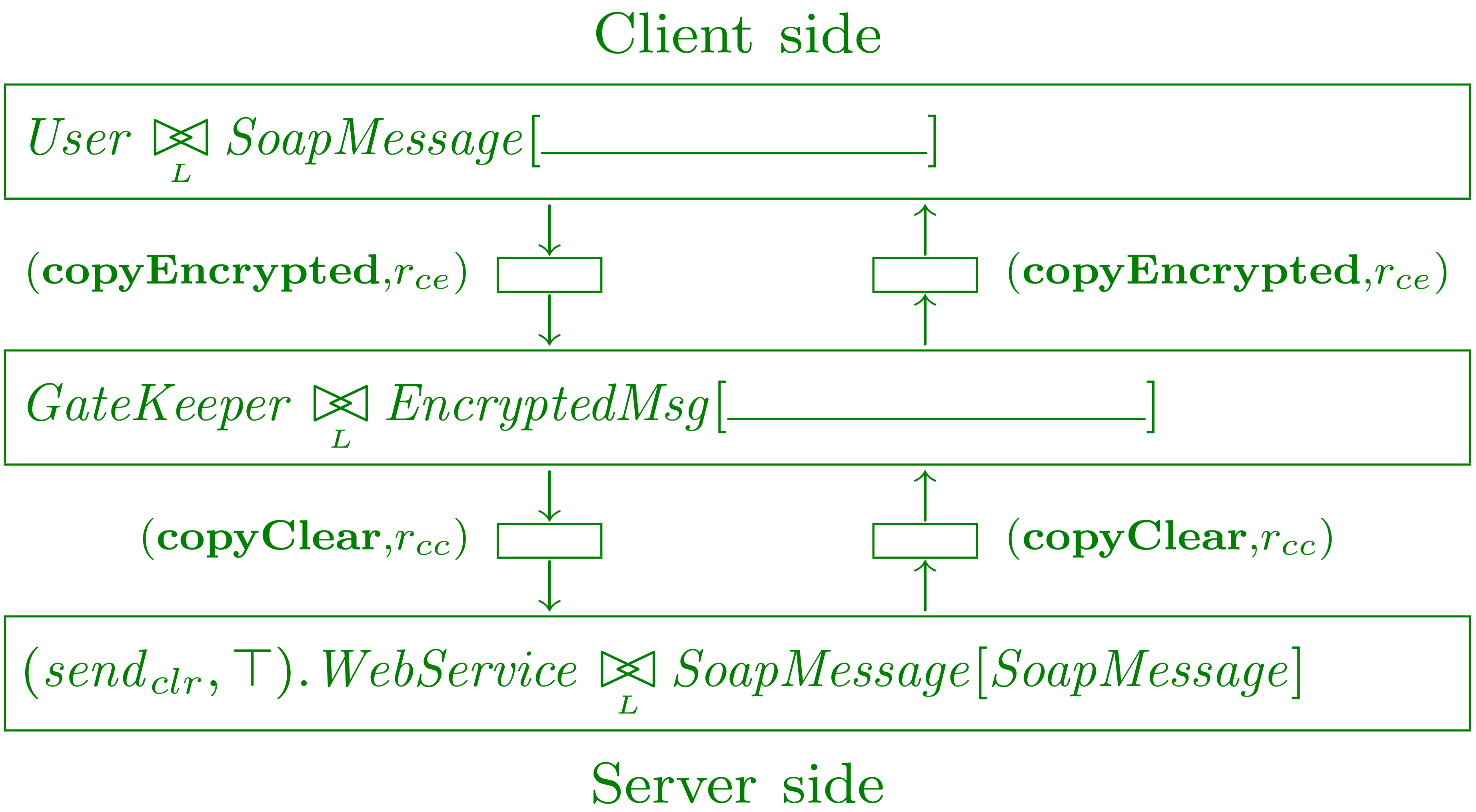
PEPA net


Client side
$User \underset{L}{\bowtie} SoapMessage[\_\_\_\_\_\_\_\_]$
$(\textbf{copyEncrypted}, r_{ce})$
$(\textbf{copyEncrypted}, r_{ce})$
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[\_\_\_\_\_\_\_\_]$
$(\textbf{copyClear}, r_{cc})$
$(\textbf{copyClear}, r_{cc})$
$(modify, \top).WebService'' \underset{L}{\bowtie} SoapMessage[DOMtree]$
Server side

PEPA net

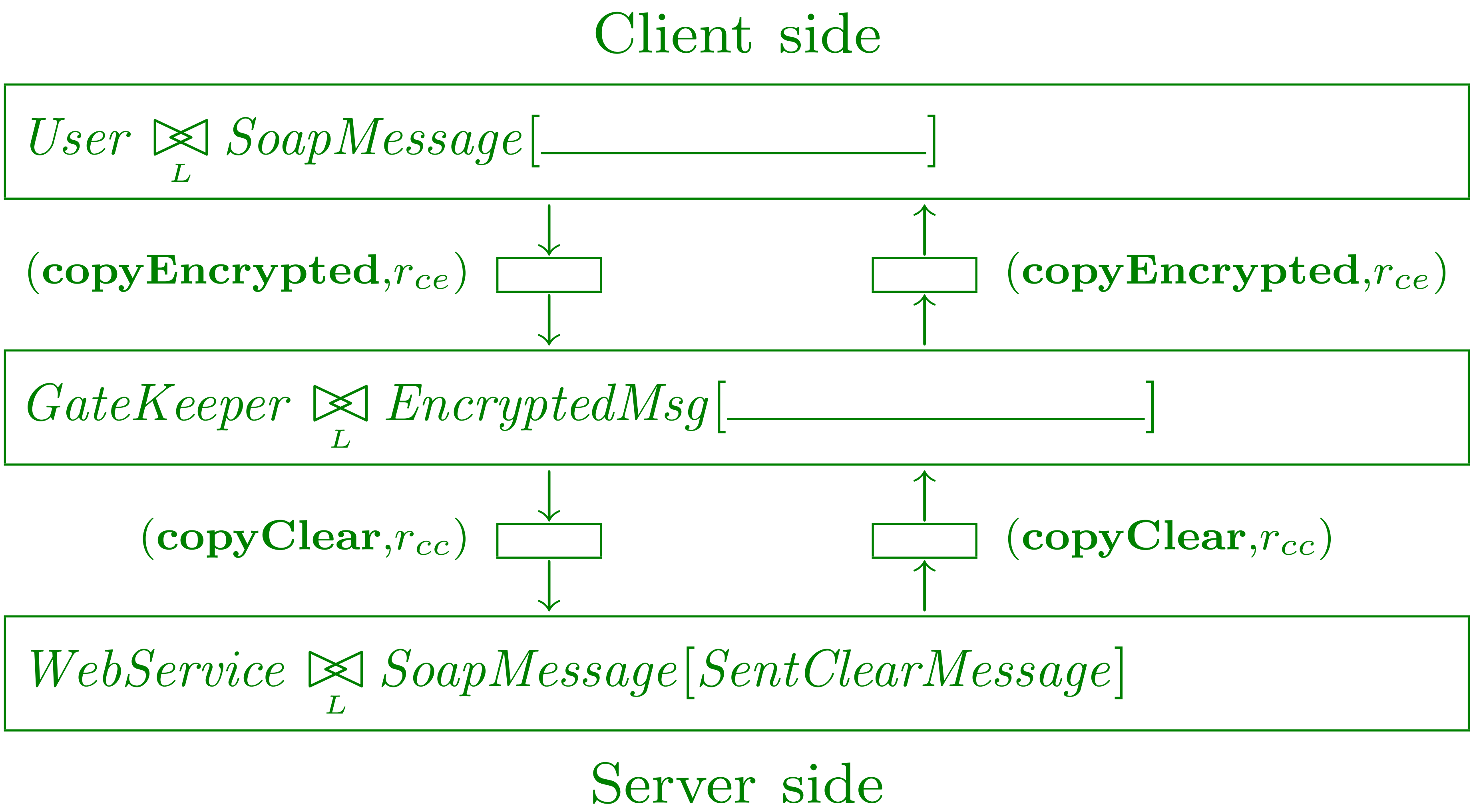

Client side
$User \underset{L}{\bowtie} SoapMessage[\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[\_\_\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$(export, \top).WebService''' \underset{L}{\bowtie} SoapMessage[DOMtree]$
Server side

PEPA net

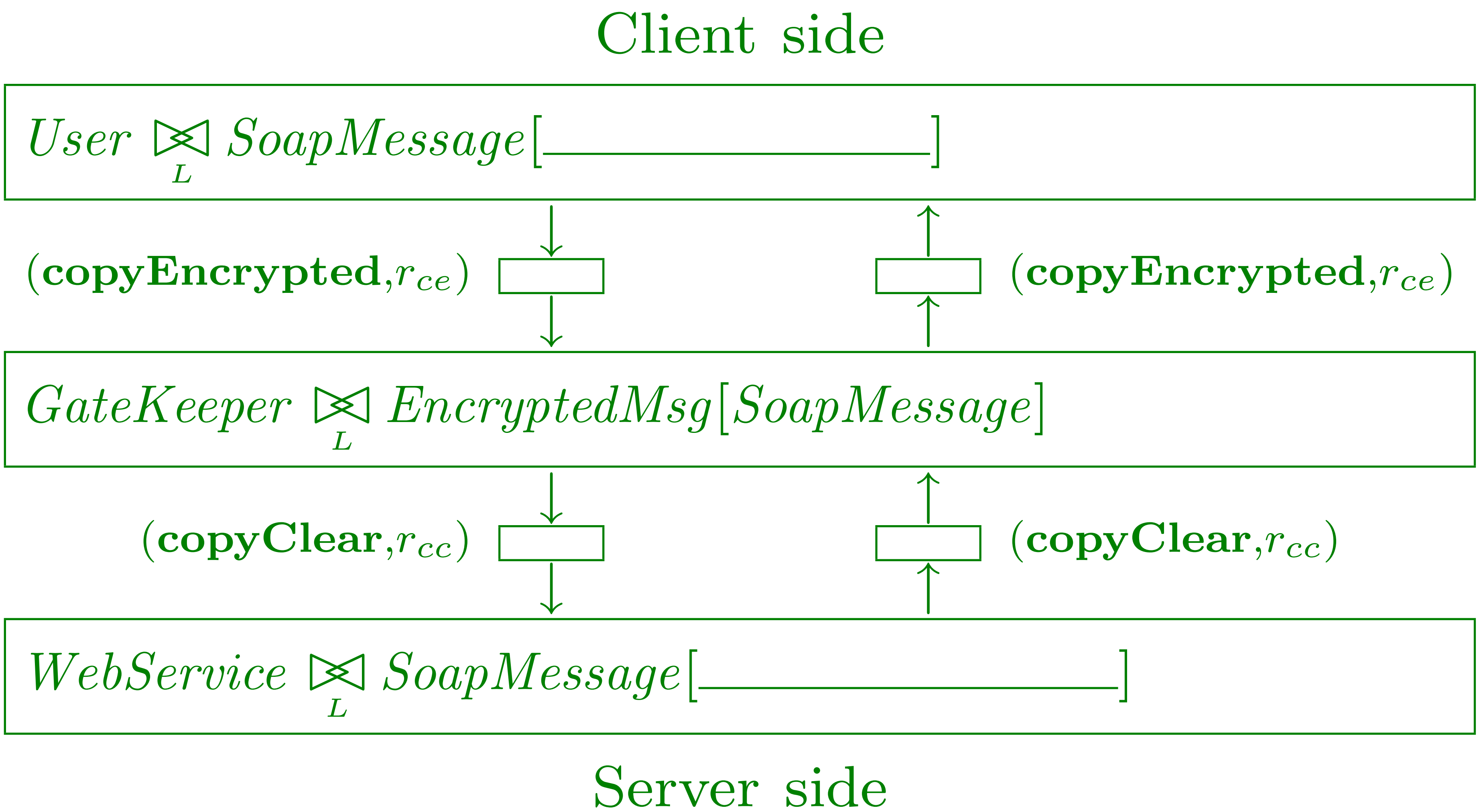


Client side
$User \bowtie_L SoapMessage[\_\_]$
(**copyEncrypted**,r_{ce})
(**copyEncrypted**,r_{ce})
$GateKeeper \bowtie_L EncryptedMsg[\_\_]$
(**copyClear**,r_{cc})
(**copyClear**,r_{cc})
$(send_{clr}, \top).WebService \bowtie_L SoapMessage[SoapMessage]$
Server side

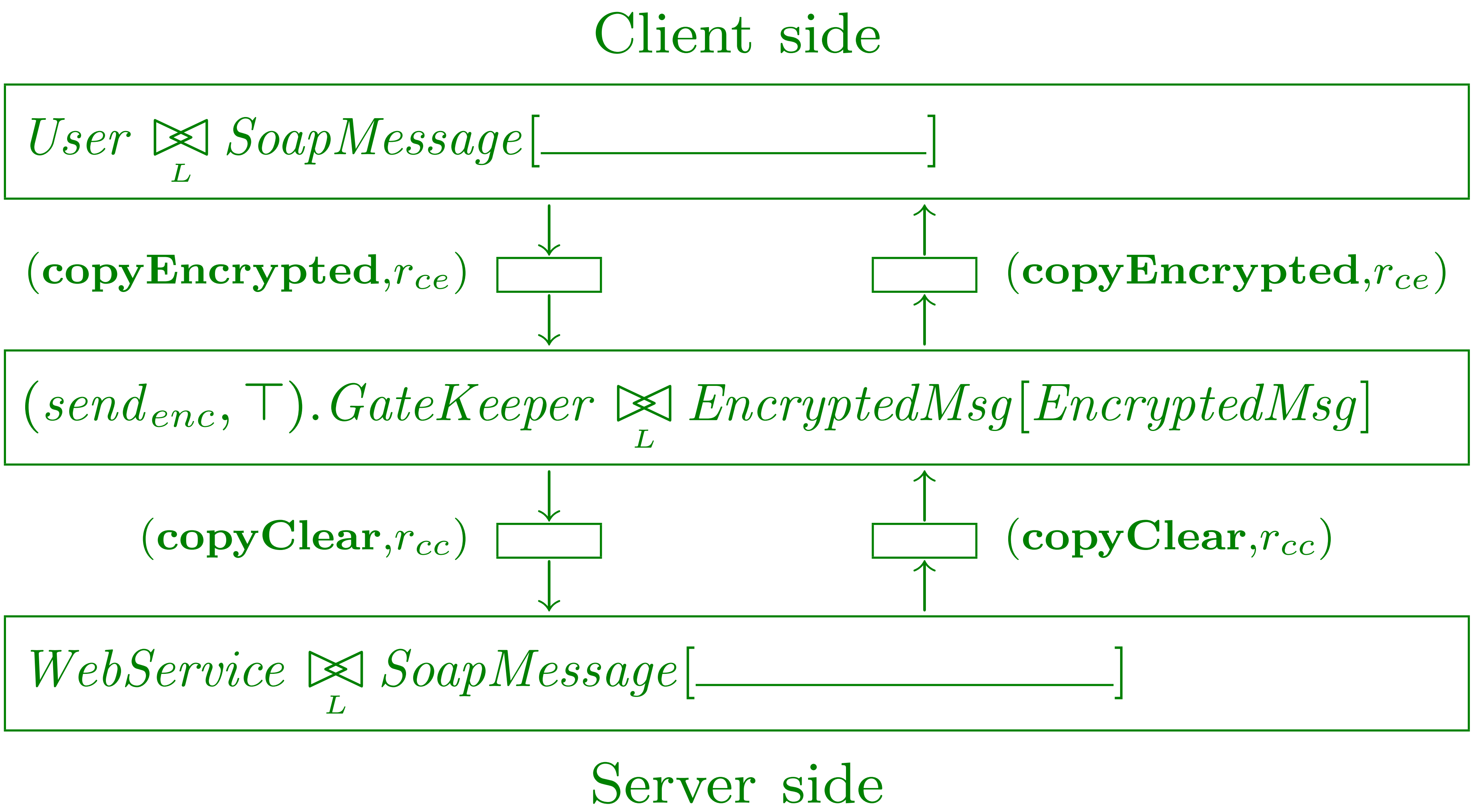
PEPA net


Client side
$User \underset{L}{\bowtie} SoapMessage[\_\_\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[\_\_\_\_\_]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \underset{L}{\bowtie} SoapMessage[SentClearMessage]$
Server side

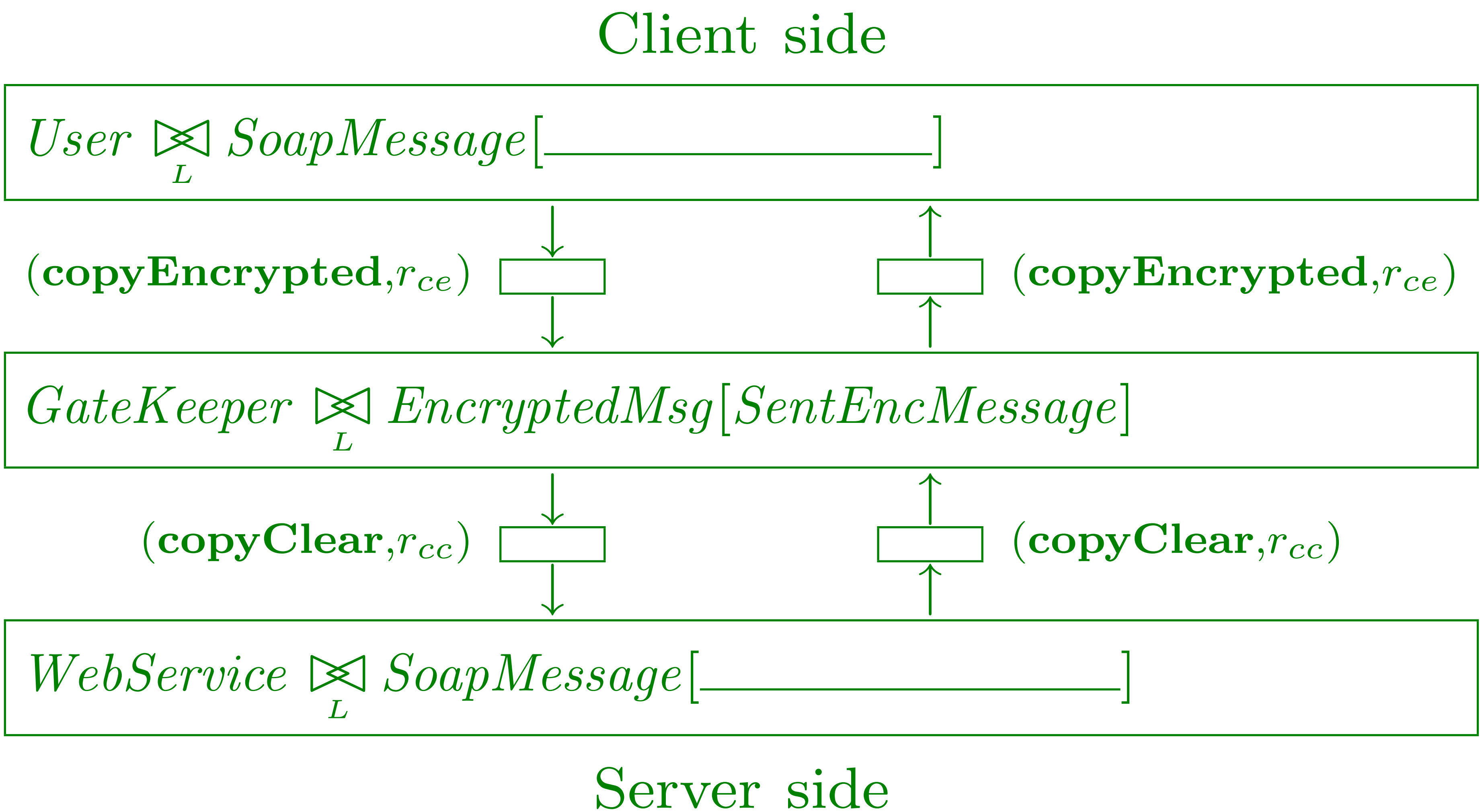
PEPA net


Client side
$User \bowtie_{L} SoapMessage[\_\_\_]$
$(\textbf{copyEncrypted}, r_{ce})$
$(\textbf{copyEncrypted}, r_{ce})$
$GateKeeper \bowtie_{L} EncryptedMsg[SoapMessage]$
$(\textbf{copyClear}, r_{cc})$
$(\textbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[\_\_\_]$
Server side

PEPA net

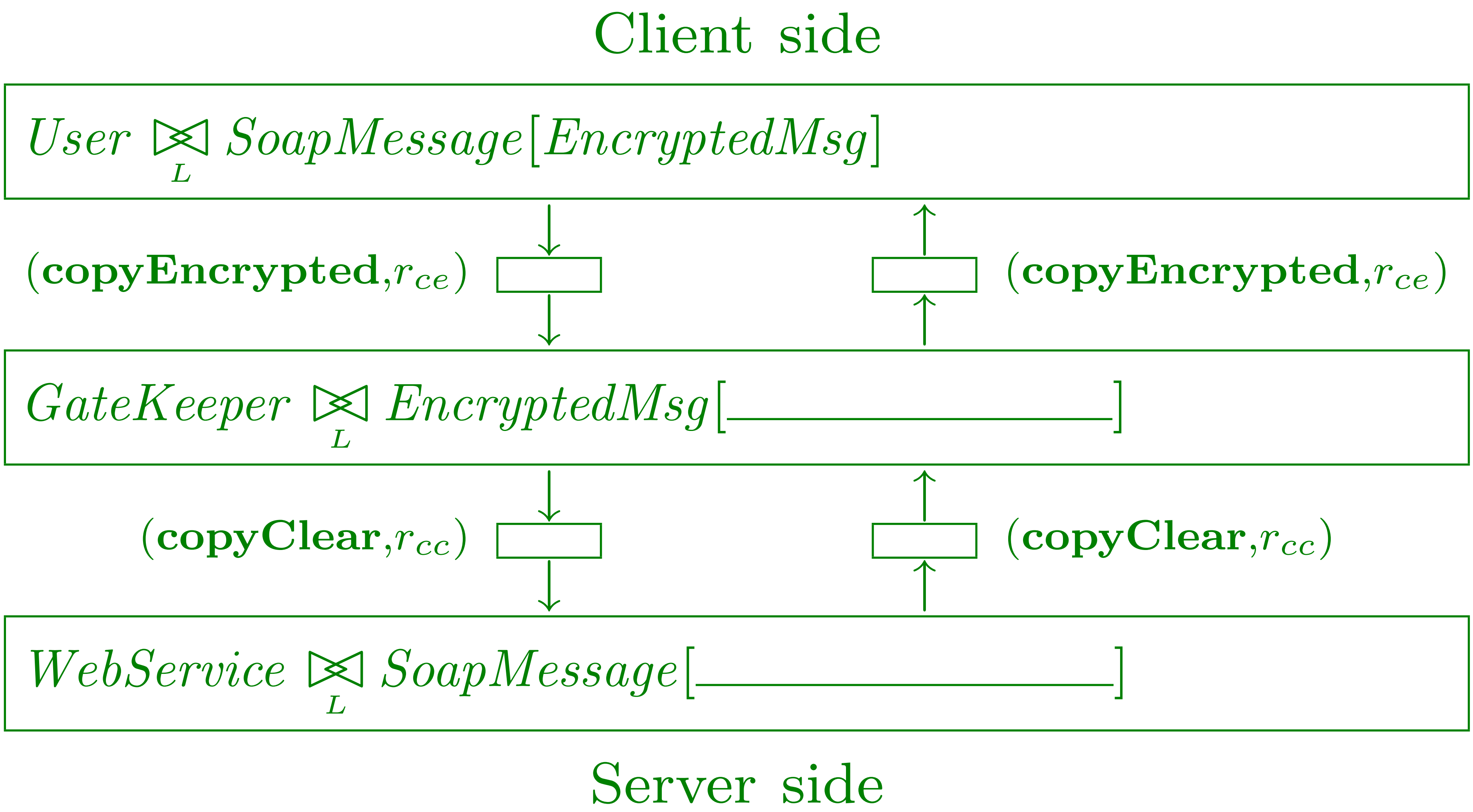

Client side
$User \bowtie_{L} SoapMessage[\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$(send_{enc}, \top).GateKeeper \bowtie_{L} EncryptedMsg[EncryptedMsg]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \bowtie_{L} SoapMessage[\_\_\_]$
Server side

PEPA net



Client side
$User \underset{L}{\bowtie} SoapMessage[\_\_\_]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[SentEncMessage]$
$(\mathbf{copyClear}, r_{cc})$
$(\mathbf{copyClear}, r_{cc})$
$WebService \underset{L}{\bowtie} SoapMessage[\_\_\_]$
Server side

PEPA net


Client side
$User \underset{L}{\bowtie} SoapMessage[EncryptedMsg]$
$(\mathbf{copyEncrypted}, r_{ce})$
$(\mathbf{copyEncrypted}, r_{ce})$
$GateKeeper \underset{L}{\bowtie} EncryptedMsg[\_\_\_]$
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Expressing performance measures using PML$_\nu$

Probability that the user has an unread reply:

$$Client[\Delta_{decrypt} \vee \Delta_{parse}]$$

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Service time distribution at the server side:

Start when $Server\#SoapMessage = 1$

Stop when $Firewall\#SentEncMessage = 1$

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We can derive a CTMC directly from a PEPA net using the PEPA Workbench for PEPA nets.

An alternative is to compile a PEPA net to an equivalent PEPA model and then use one of the PEPA tools.

Compiling PEPA nets to PEPA

The PEPA net compiler compiles a PEPA net to a PEPA model. Activities are renamed to enforce the PEPA net idiom that components at different places cannot synchronise on transitions.

The given net and the generated PEPA model produce isomorphic CTMCs (but via different labelled transition systems).

The renaming of activities is systematic so that it is possible to recover the transition system of the PEPA net from the transition system of the PEPA model.

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Alternatives: Möbius, PRISM.

Conclusions

PEPA nets are a high-level modelling language addressing the performance aspects of the design of modern software systems.

Unlike a Petri net, tokens are programmable components, allowing direct modelling of stateful objects.

Evaluation contexts at the places of the net allow the modeller to represent different areas of computation.

Tools exist which support the PEPA nets language.

Future work

It is possible that the PEPA nets language could be extended, necessitating extensions to the existing tool support.

One possibility would be to add a type system which ensures a consistent interface for tokens.

It is possible that the PML$_\nu$ logic should be extended or revised.

Undertaking real-world examples and case studies is a good way to drive this process.

end of slide show