A Theory of System Behaviour in the presence of Node and Link Failure

CONCUR, August 2005.

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Starting Point: $D\pi$

$$P \mid (\nu\, n)Q \mid R$$

Starting Point: $D\pi$

$$l[[P]] \mid (\nu k)(k[[Q]] \mid l[[R]])$$

Starting Point: $D\pi$

Processes

$$P, Q \quad ::= \quad a!\langle v\rangle.P \quad | \; a?(x).P \quad | \; *P$$
$$| \quad \text{if } v = u \text{ then } P \text{ else } Q$$
$$| \quad \textbf{stop} \quad | \; P|Q \quad | \; (\nu a)P$$
$$| \quad \text{go } l.P \quad (\textit{migration})$$

Systems

$$N, M \quad ::= \quad l[\![P]\!] \quad (\textit{located process})$$
$$| \quad (\nu\, n)N \quad (\textit{network scoping})$$
$$| \quad N|M \quad (\textit{parallel systems})$$

Starting Point: $D\pi$

(r-comm)

$$l[\![a!\langle n\rangle.P]\!] \mid l[\![a?(x).Q]\!] \longrightarrow l[\![P]\!] \mid l[\![Q\{^{n}/_{x}\}]\!]$$

(r-go)

$$l[\![\text{go } k.P]\!] \longrightarrow k[\![P]\!]$$

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Motivating Example (1)

$$\text{server} \Leftarrow (\nu\, \mathit{data}) \left(\begin{array}{l} l[\![\mathit{req}?(x_1, x_2).\mathit{data}!\langle x_1, x_2\rangle]\!] \\ \\ \mid l[\![\mathit{data}?(y_1, y_2).y_2!\langle \mathbf{lookup}(y_1)\rangle]\!] \end{array} \right)$$

$$\text{serverLoc} \Leftarrow (\nu\, \mathit{data}) \left(\begin{array}{l} l[\![\mathit{req}?(x_1, x_2).\text{go}\, k_1.\mathit{data}!\langle x_1, x_2\rangle]\!] \\ \\ \mid k_1[\![\mathit{data}?(y_1, y_2).\text{go}\, l.y_2!\langle \mathbf{lookup}(y_1)\rangle]\!] \end{array} \right)$$

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Motivating Example (1)

$$\mathsf{serverLnk} \Leftarrow (\nu\, \mathit{data})\left(\begin{array}{l} l\left[\!\left[\mathit{req}?(x_1, x_2).(\nu \mathit{sync})\left(\begin{array}{l} \text{go } k_1.\mathit{data}!\langle x_1, \mathit{sync}\rangle \\ \mid \text{go } k_2, k_1.\mathit{data}!\langle x_1, \mathit{sync}\rangle \\ \mid \mathit{sync}?(z).x_2!\langle z\rangle \end{array}\right)\right]\!\right] \\ \\ \mid k_1\left[\!\left[\mathit{data}?(y_1, y_2).\left(\begin{array}{l} \text{go } l.y_2!\langle \mathbf{lookup}(y_1)\rangle \\ \mid \text{go } k_2, l.y_2!\langle \mathbf{lookup}(y_1)\rangle \end{array}\right)\right]\!\right] \end{array}\right)$$

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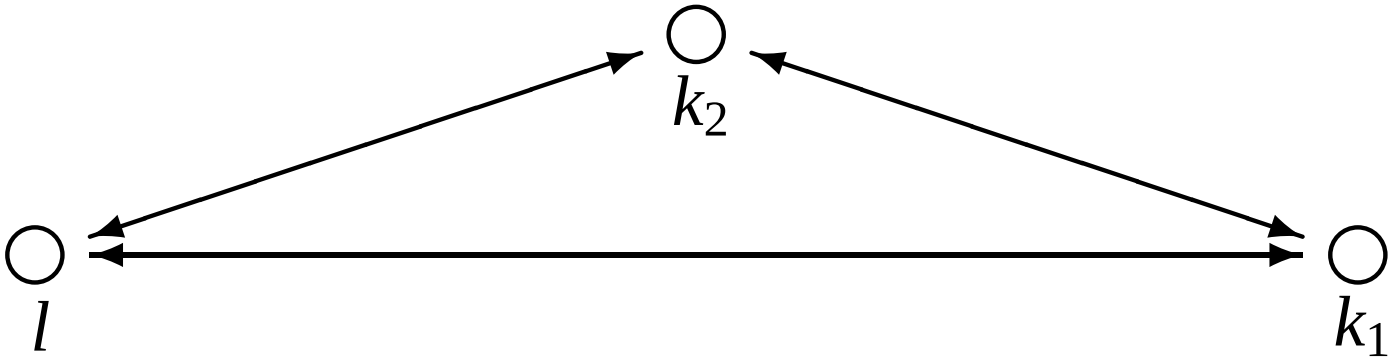
The Underlying Network



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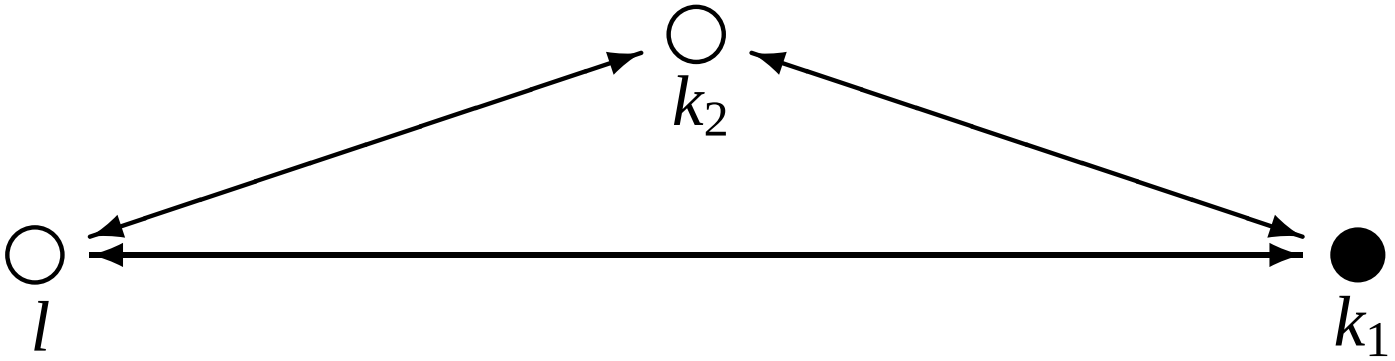

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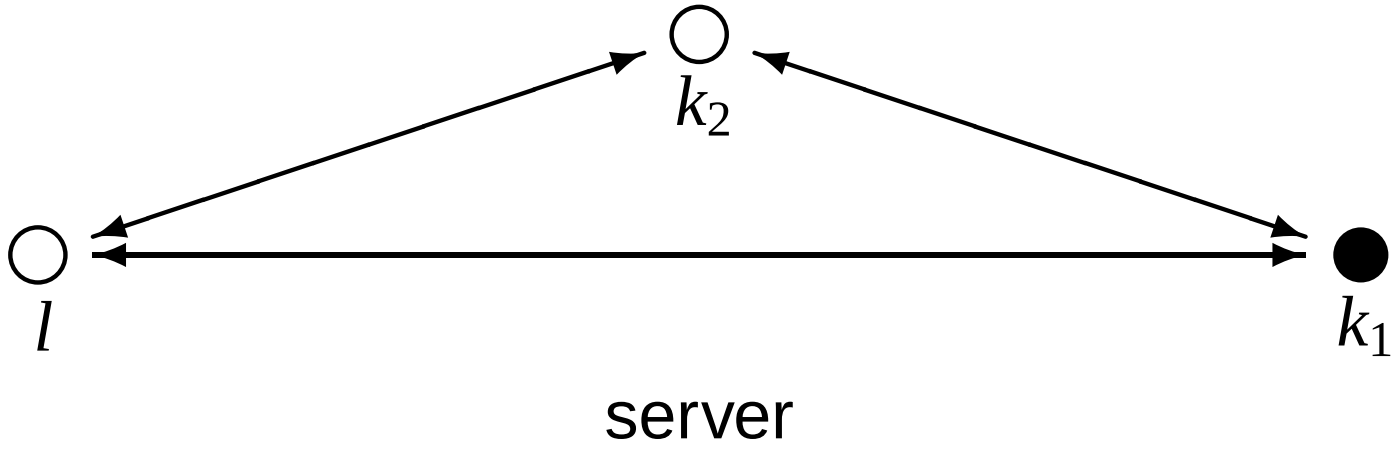

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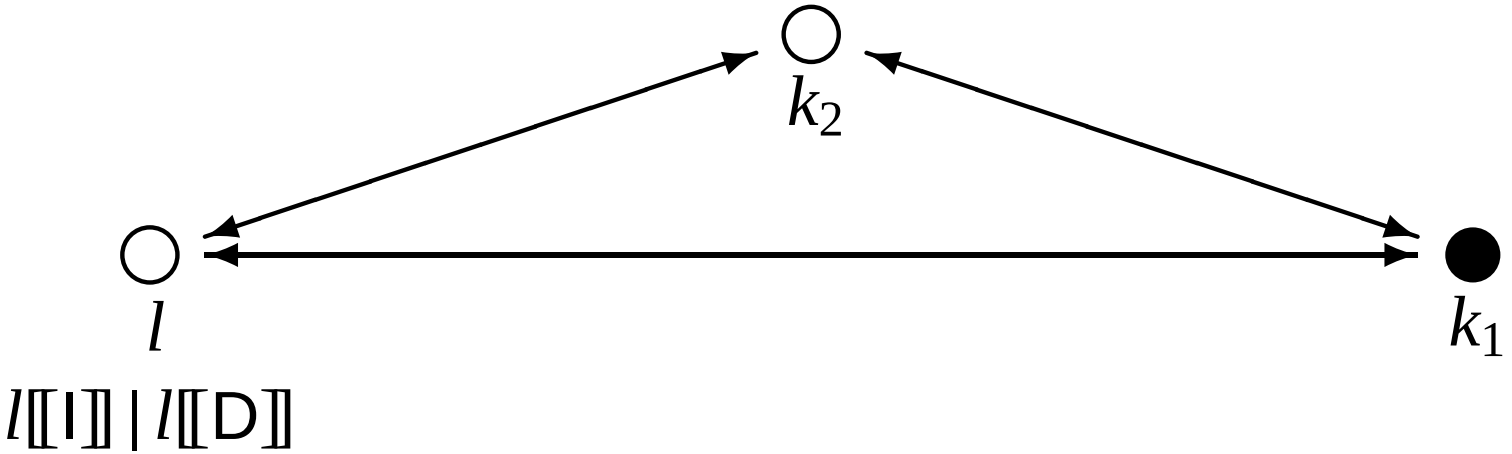

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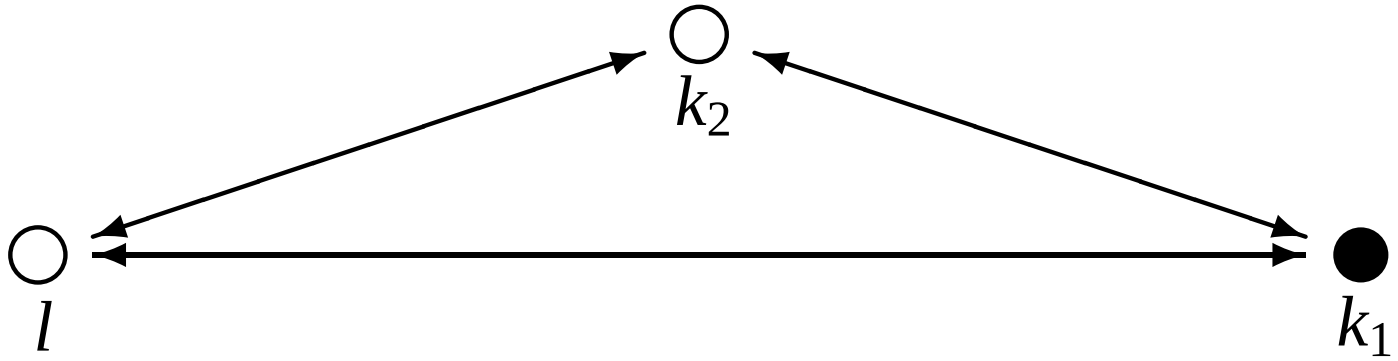

serverLoc

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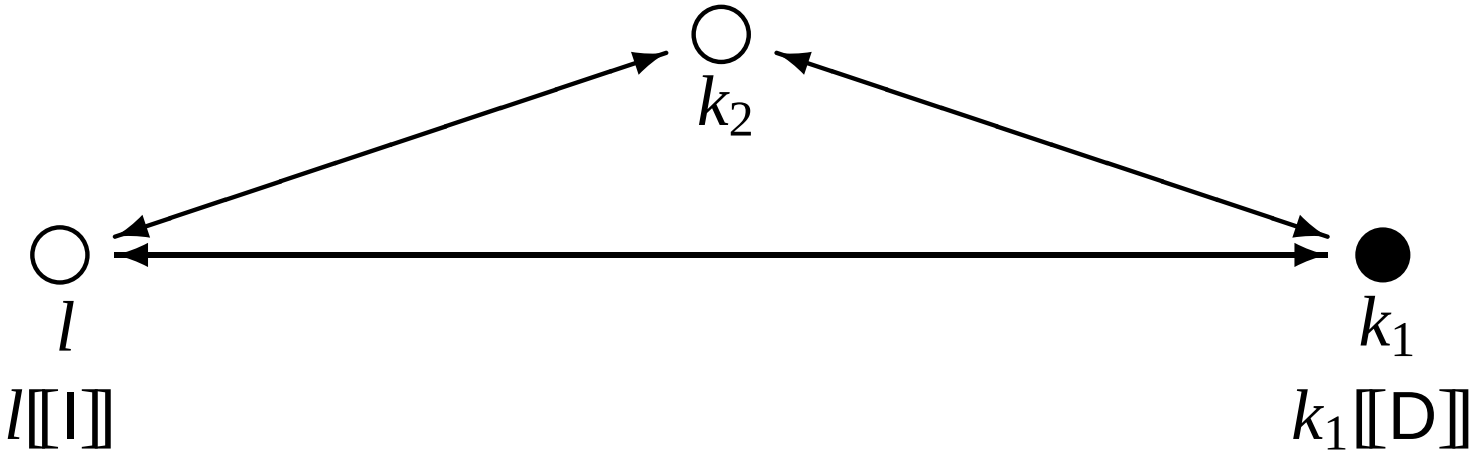

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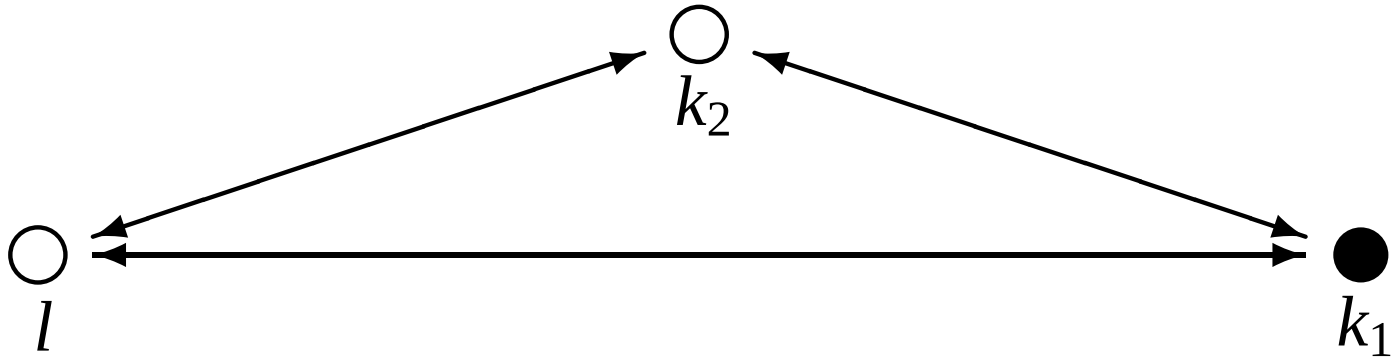

serverLnk

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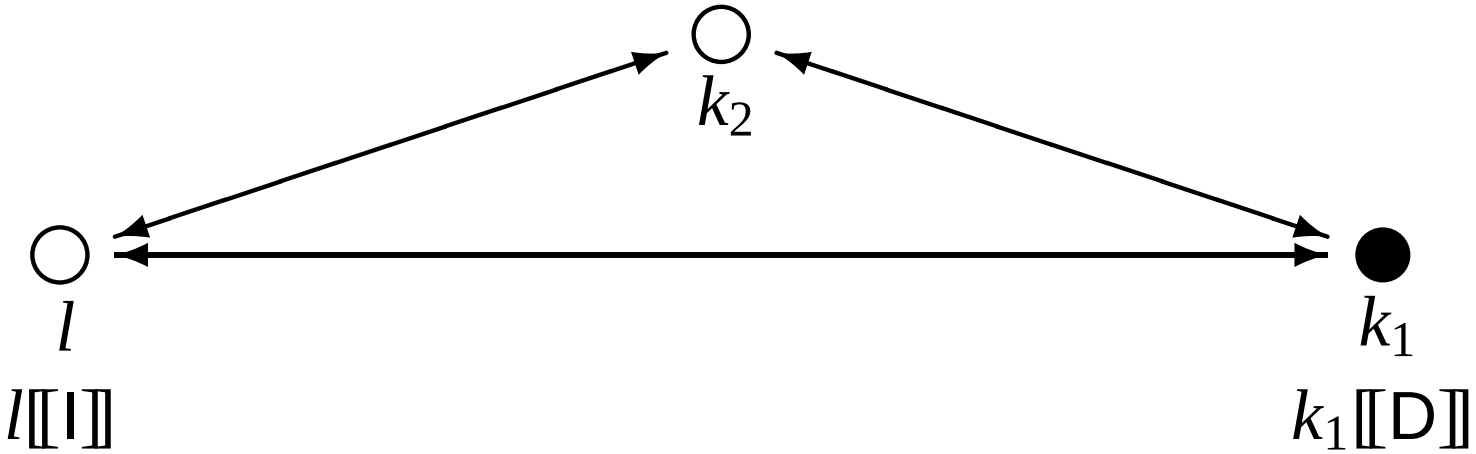

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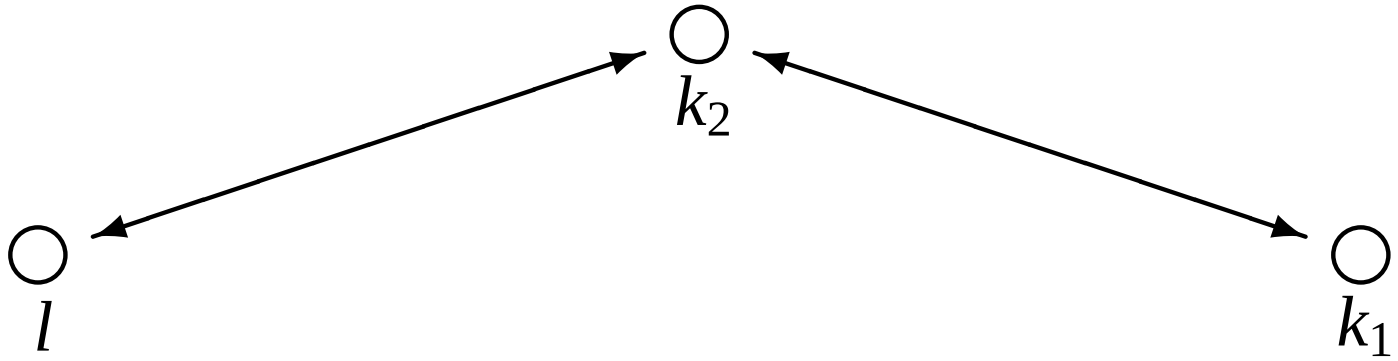

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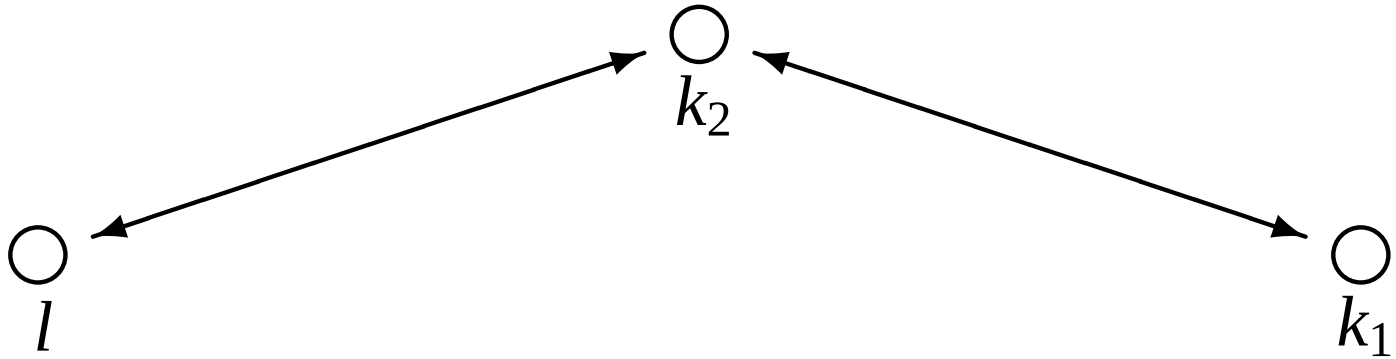

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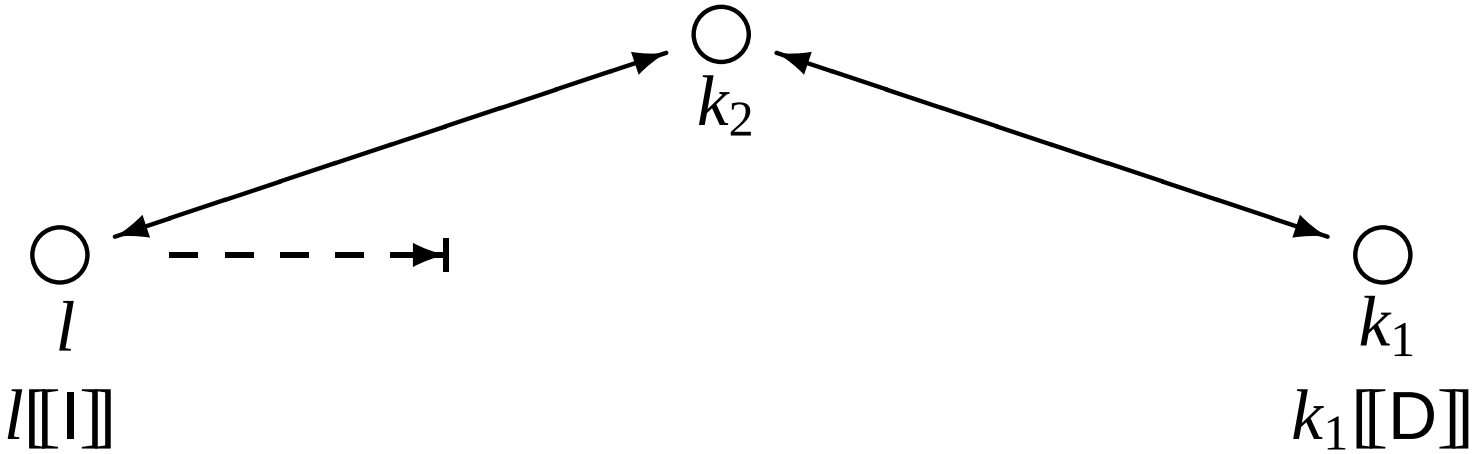

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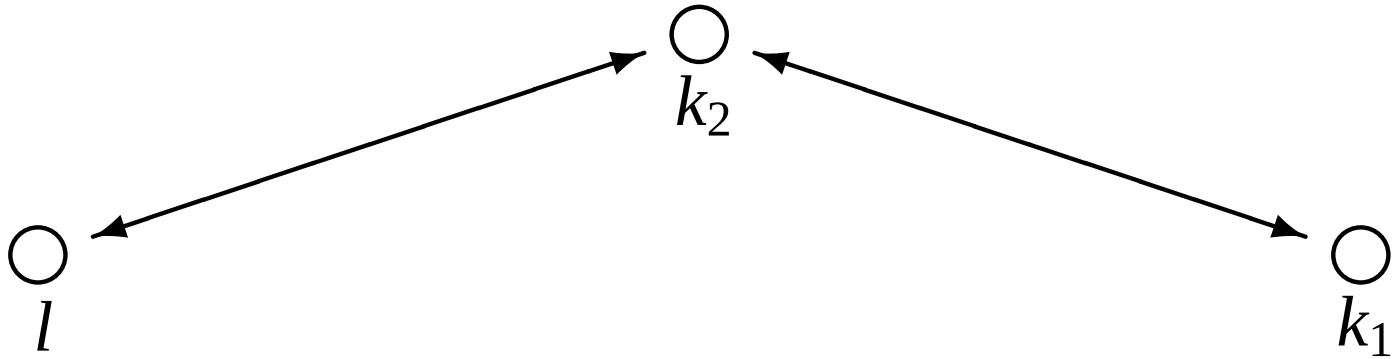

serverLnk

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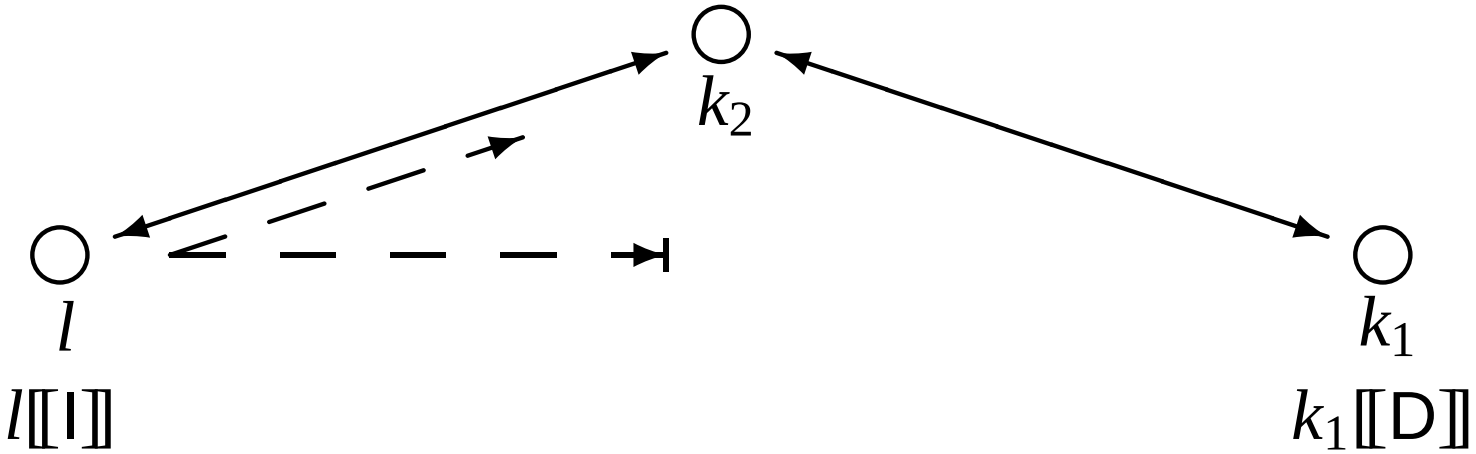

$D\pi F$: $D\pi$ with failure

$$l[[P]] \mid (\nu k)(k[[Q]] \mid l[[R]])$$

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$$\Delta \triangleright l[[P]] \mid (\nu k : \mathtt{T})(k[[Q]] \mid l[[R]])$$

DπF: Dπ with failure

Types

$$\mathtt{T},\mathtt{U} \;::=\; \mathtt{loc}[\mathtt{A}, \{l_1, .., l_n\}] \;\mid \mathtt{ch}$$

$$\mathtt{A} \;::=\; \mathtt{a} \mid \mathtt{d}$$

Processes

$$P, Q \;::=\; \ldots$$

$\mid$	$(\nu\, n : \mathtt{T})P$	(*typed scoping*)
$\mid$	kill	(*kill location*)
$\mid$	break l	(*break link*)
$\mid$	ping $l.P$ else Q	(*ping*)

DπF: Dπ with failure

Systems

$$N, M \quad ::= \quad \ldots \quad | (\nu\, n : \mathtt{T}) N$$

We work at the level of **Configurations**

$$\Delta \triangleright M$$

where Δ is a network representation

$D\pi F$: $D\pi$ with failure

(r-comm)

$$\frac{\Delta \vdash l : \textbf{alive}}{\Delta \triangleright l[\![a!\langle n\rangle.P]\!] \mid l[\![a?(x).Q]\!] \longrightarrow \Delta \triangleright l[\![P]\!] \mid l[\![Q\{^{n}/_{x}\}]\!]}$$

(r-go)

$$\frac{\Delta \vdash l : \textbf{alive} \qquad \Delta \vdash k : \textbf{alive} \qquad \Delta \vdash l \leftrightarrow k}{\Delta \triangleright l[\![\text{go } k.P]\!] \longrightarrow \Delta \triangleright k[\![P]\!]}$$

$D\pi F$: $D\pi$ with failure

(r-kill)

$$\frac{\Delta \vdash l : \mathbf{alive}}{\Delta \triangleright l[\![\mathsf{kill}]\!] \longrightarrow \Delta - l \triangleright l[\![\mathbf{stop}]\!]}$$

(r-brk)

$$\frac{\Delta \vdash l : \mathbf{alive} \qquad \Delta \vdash l \leftrightarrow k}{\Delta \triangleright l[\![\mathsf{break}\ k]\!] \longrightarrow \Delta - l \leftrightarrow k \triangleright l[\![\mathbf{stop}]\!]}$$

$D\pi F$: $D\pi$ with failure

(r-ping)

$$\frac{\Delta \vdash l : \mathbf{alive} \qquad \Delta \vdash k : \mathbf{alive} \qquad \Delta \vdash l \leftrightarrow k}{\Delta \triangleright l[\![\text{ping } k.P \text{ else } Q]\!] \longrightarrow \Delta \triangleright l[\![P]\!]}$$

(r-nping1)

$$\frac{\Delta \vdash l : \mathbf{alive} \qquad \Delta \vdash k : \mathbf{dead}}{\Delta \triangleright l[\![\text{ping } k.P \text{ else } Q]\!] \longrightarrow \Delta \triangleright l[\![Q]\!]}$$

(r-nping2)

$$\frac{\Delta \vdash l : \mathbf{alive} \qquad \Delta \vdash l \nleftrightarrow k}{\Delta \triangleright l[\![\text{ping } k.P \text{ else } Q]\!] \longrightarrow \Delta \triangleright l[\![Q]\!]}$$

Motivating Example (2)

$$\mathsf{M} \Leftarrow (\nu\, k)(l[\![a!\langle k\rangle]\!] \mid k[\![b!\langle\rangle]\!])$$

$$\mathsf{N} \Leftarrow (\nu\, k)(l[\![a!\langle k\rangle]\!] \mid k[\![c!\langle\rangle]\!])$$

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$$\mathsf{M} \not\cong \mathsf{N}$$

$$\mathsf{O} \Leftarrow l[\![a?(x).\mathsf{go}\ x.b?().\mathsf{go}\ l.\mathsf{ok}!\langle\rangle]\!]$$

$$\mathsf{M}|\mathsf{O} \Downarrow_{\mathsf{ok}@l}$$

$$\mathsf{N}|\mathsf{O} \not\Downarrow_{\mathsf{ok}@l}$$

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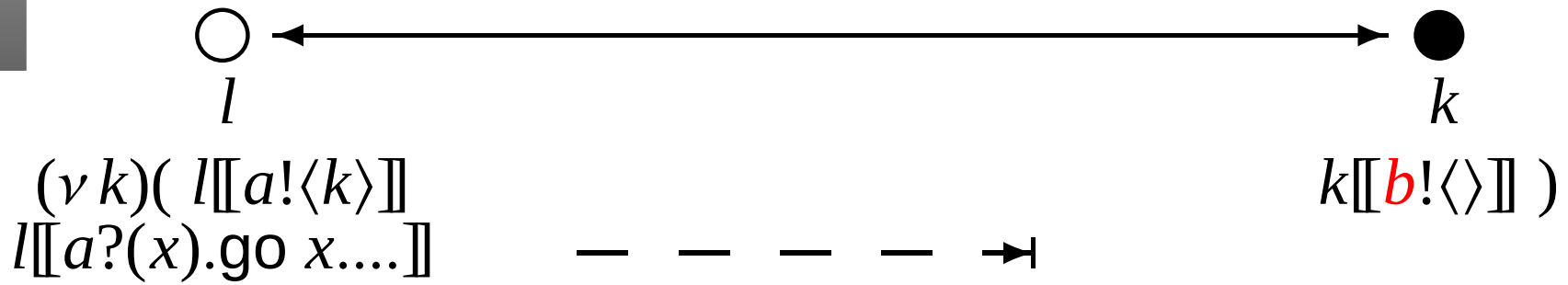

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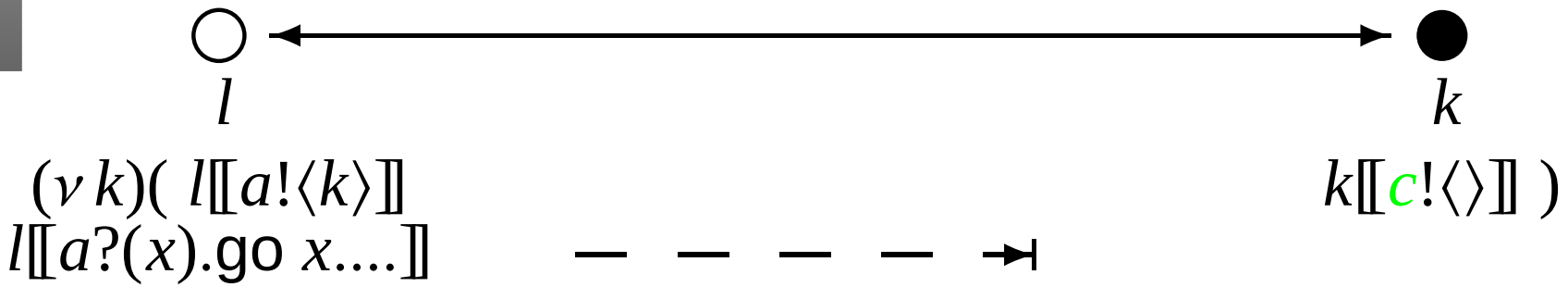

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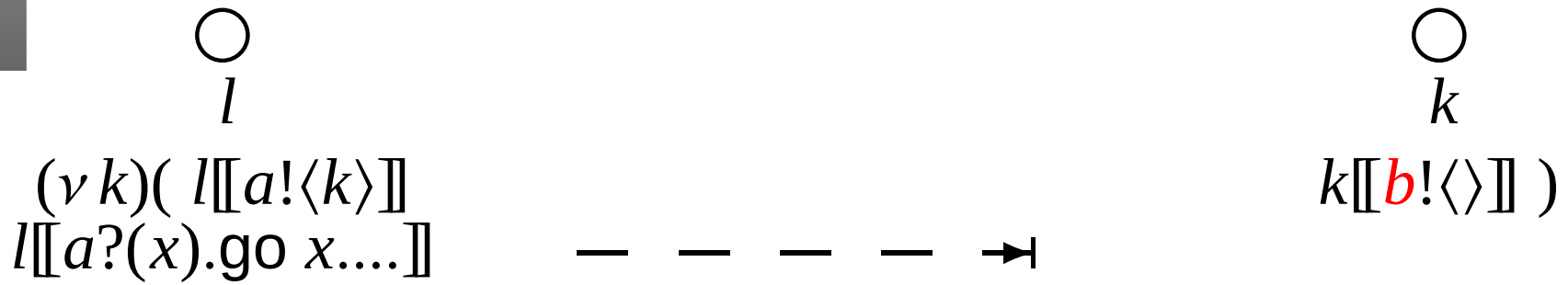

Motivating Example (2)

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For $\Delta \vdash l$: **alive**

$$\mathsf{M} \Leftarrow (\nu\, k : \mathsf{T})(l[\![a!\langle k\rangle]\!] \mid k[\![b!\langle\rangle]\!])$$

$$\mathsf{N} \Leftarrow (\nu\, k : \mathsf{T})(l[\![a!\langle k\rangle]\!] \mid k[\![c!\langle\rangle]\!])$$

$$\mathsf{O} \Leftarrow l[\![a?(x).\mathrm{go}\ x.b?().\mathrm{go}\ l.\mathrm{ok}!\langle\rangle]\!]$$

$$\mathsf{M}|\mathsf{O}\Downarrow\!\!\!\!\!\!/\ _{\mathrm{ok}@l}$$
$$\mathsf{N}|\mathsf{O}\Downarrow\!\!\!\!\!\!/\ _{\mathrm{ok}@l}$$

$\Delta \triangleright \mathsf{M} \cong \Delta \triangleright \mathsf{N}$ for certain types T

Technical Development

- We define a reduction barbed congruence, $\cong$ for systems running over the same network, Δ.

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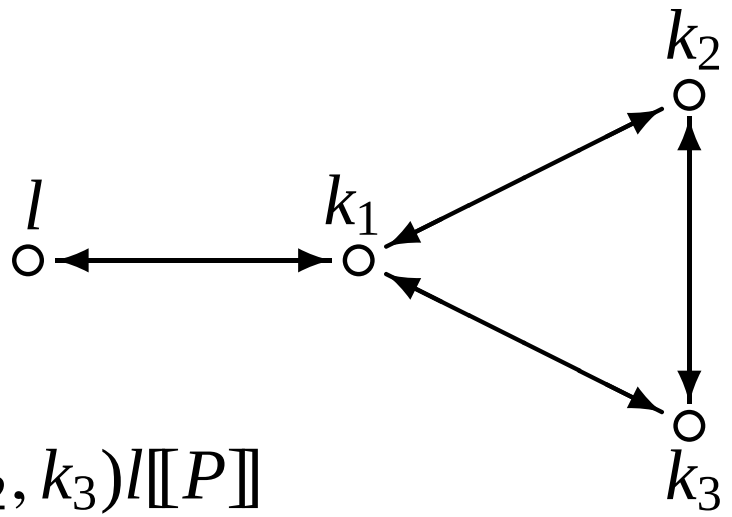
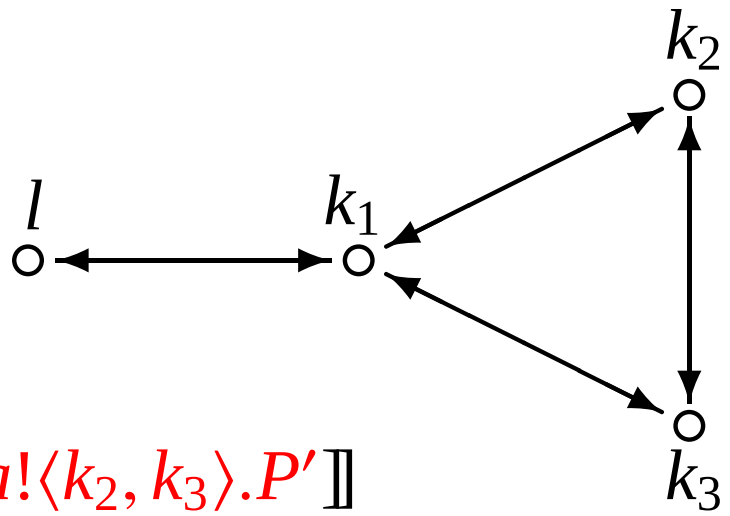
- We define an alternative network representation, Σ, that encodes, in addition to the state of the network, the observer partial view. (Δ is a simple case of Σ)
- We define a labelled transition system for configurations subject to Σ: labels record changes in observable part of Σ.
- We define a bisimulation $\approx$ and prove that it coincides with $\cong$.

Application: Network Discovery



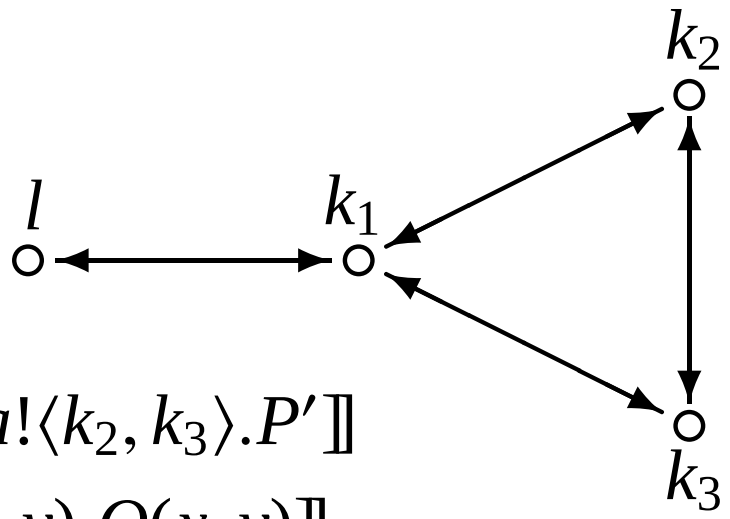
$$(\nu k_1, k_2, k_3) l[\![P]\!]$$

Application: Network Discovery



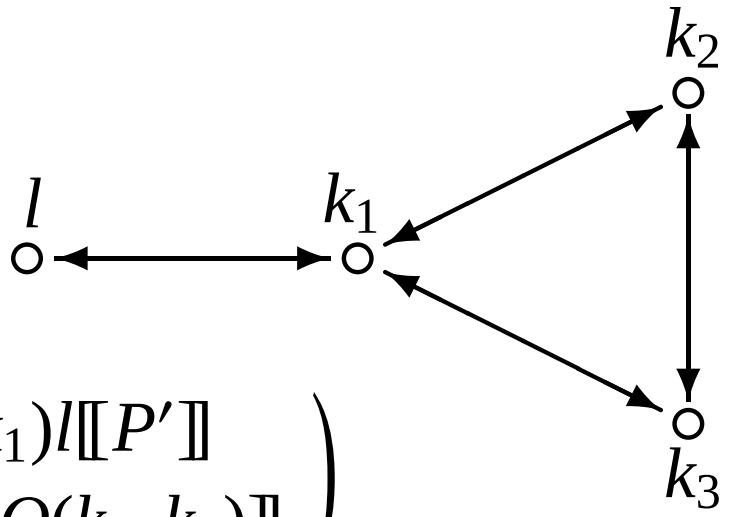
$$(\nu k_1, k_2, k_3) l[\![a!\langle k_2, k_3\rangle.P']\!]$$

Application: Network Discovery



$$(\nu k_1, k_2, k_3) l[\![a!\langle k_2, k_3\rangle.P']\!]$$
$$\mid l[\![a?(x,y).Q(x,y)]\!]$$

Application: Network Discovery



$$(\nu k_2, k_3)\left(\begin{array}{l}(\nu k_1) l[\![P']\!] \\ \mid l[\![Q(k_2, k_3)]\!]\end{array}\right)$$

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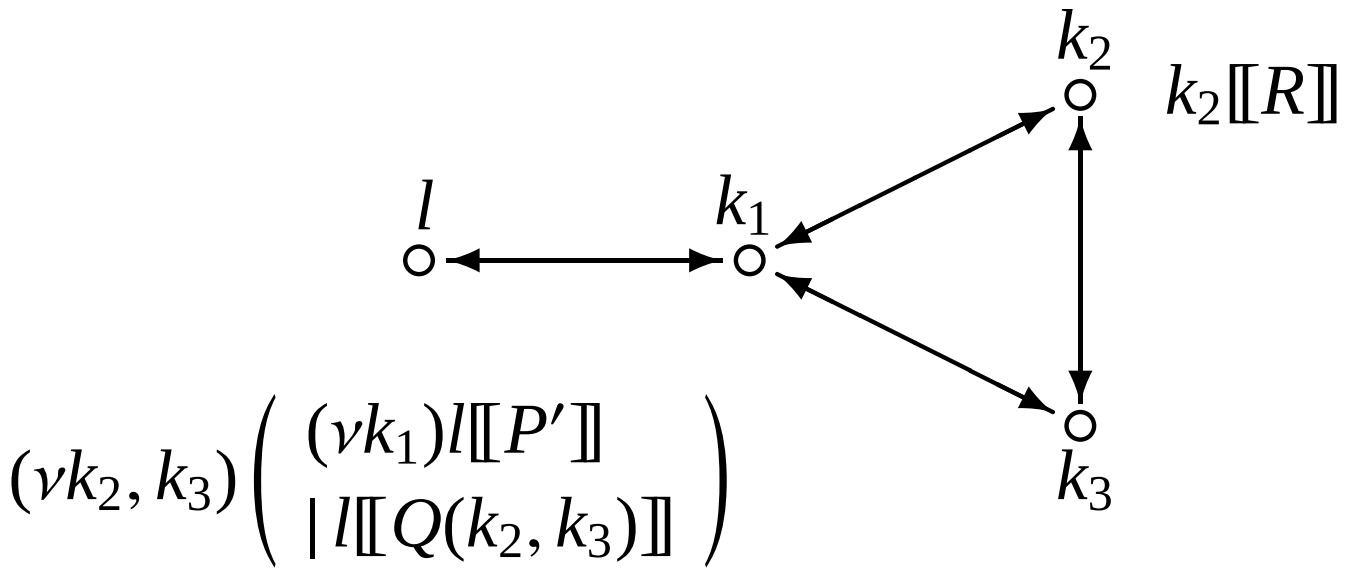

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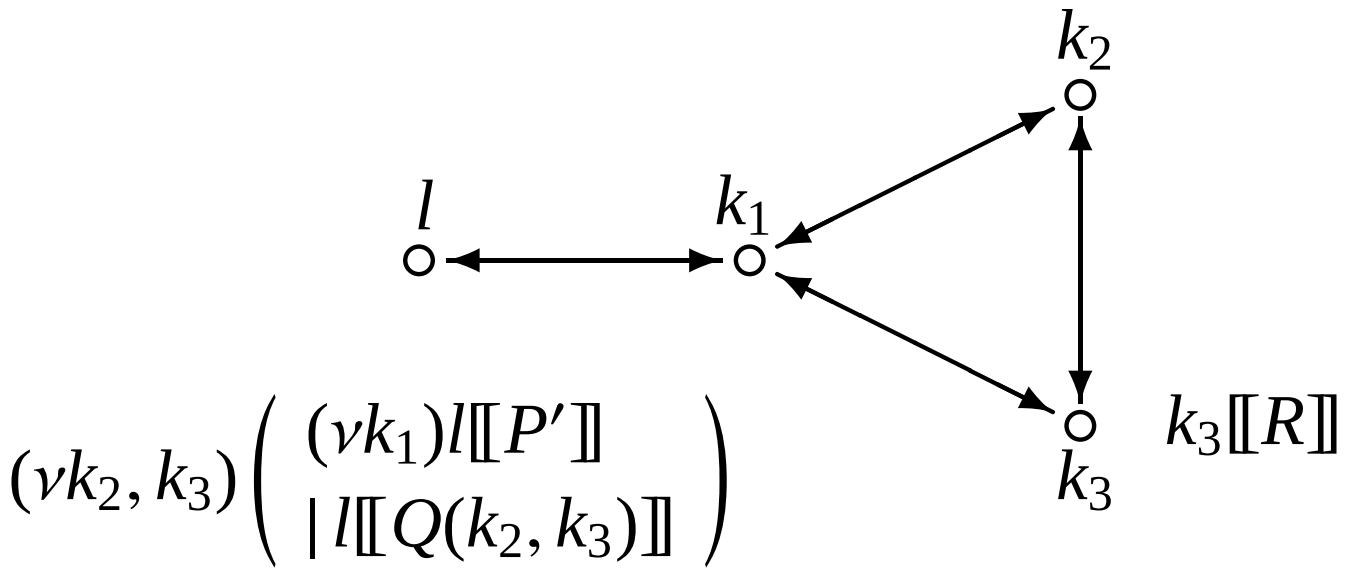

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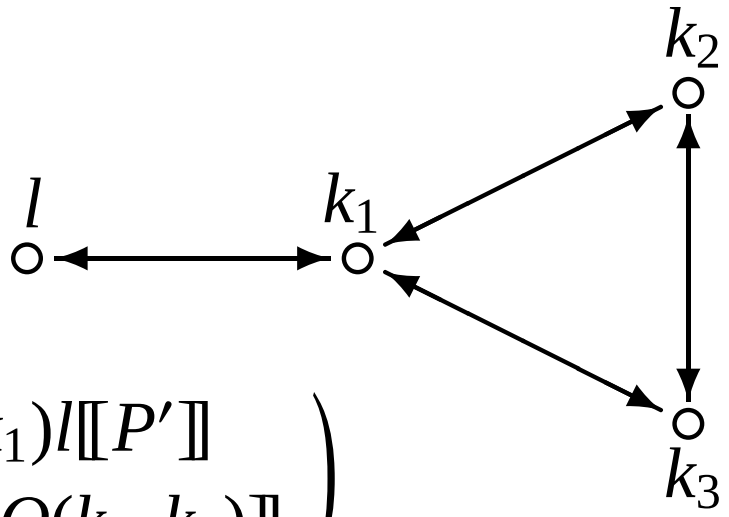

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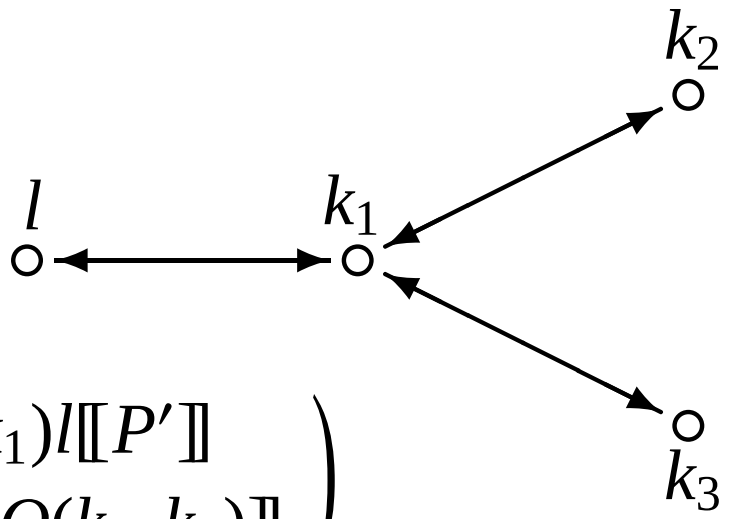

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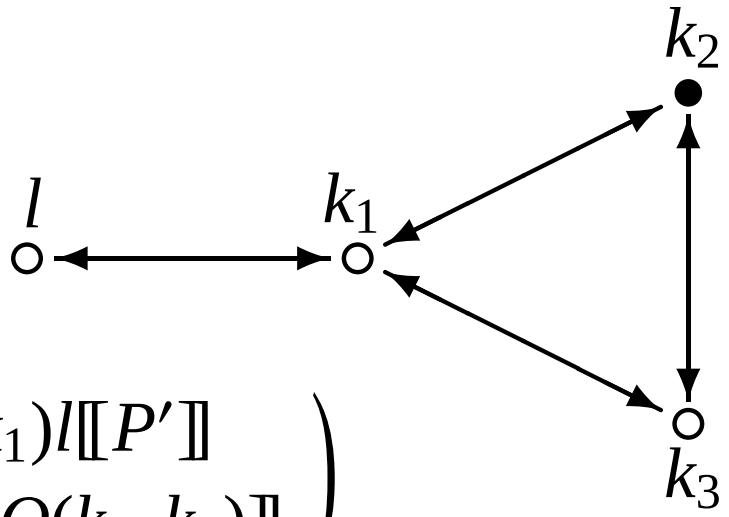

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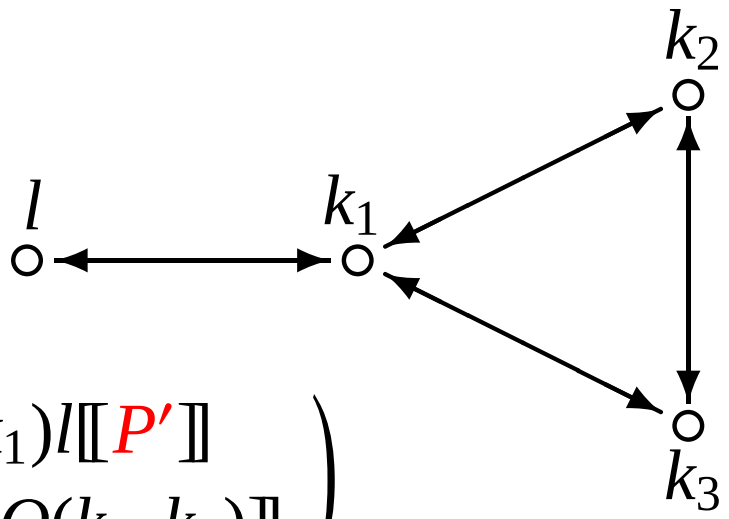

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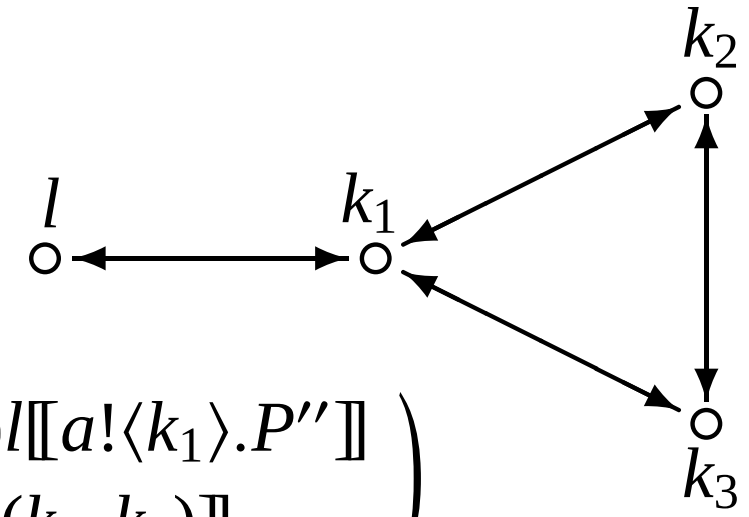

$$(\nu k_2, k_3)\left(\begin{array}{l}(\nu k_1) l[\![a!\langle k_1\rangle.P'']\!] \\ \mid l[\![Q(k_2, k_3)]\!]\end{array}\right)$$

References

- **Location and Link Failure in a Distributed π-calculus** ,
  Adrian Francalanza, Matthew Hennessy, University of Sussex Technical Report, 2005:01, January 2005.
- **Failure and Fault Tolerance in a Distributed π-calculus** ,
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