Typing migration-control in lsdπ

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Joint work with

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Lexically Scoped Distributed π

- Extends π, distributing processes over networks of named sites where they compute.
- Processes allowed to:
  - communicate via channels (as in π), but only locally
  - migrate from site to site.

Main concepts

In $lsd\pi$

- channels are
  - resources associated *uniquely* to sites
  - located at *creation* time
    - In $s\mathbf{[}(\boldsymbol{\nu}\, c)\ \ldots\mathbf{]}$, channel c is created *locally*, at s;
    - In $r\mathbf{[}(\boldsymbol{\nu}\, c@s)\ \ldots\mathbf{]}$, channel c is created *remotely*, to be located at s;

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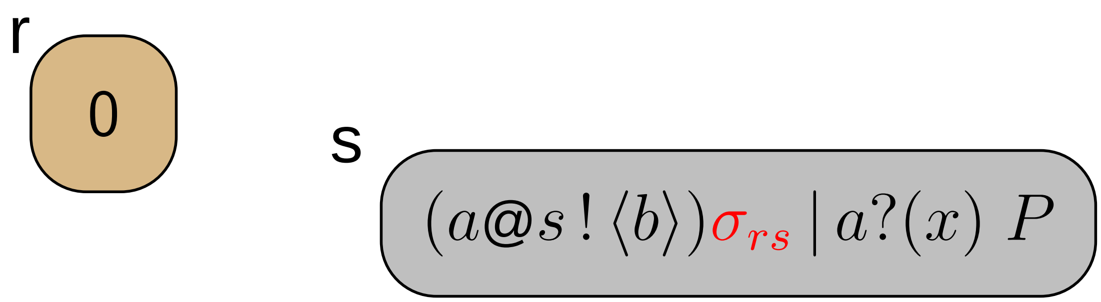
    - In $r\mathbf{[}(\boldsymbol{\nu}\, c@s)\ \ldots\mathbf{]}$, channel c is created *remotely*, to be located at s;
- sites are
  - *collections* of channels;
  - *shells* of local computations.

$$r[\![a@s\,!\,\langle b\rangle]\!] \parallel s[\![a?(x)\ P]\!]$$

$lsd\pi$ **by example**



$$r\mathbf{[}a@s\,!\,\langle b\rangle\mathbf{]} \parallel s\mathbf{[}a?(x)\ P\mathbf{]}$$

$$\downarrow$$

$$r\mathbf{[}0\mathbf{]} \parallel s\mathbf{[}(a@s\,!\,\langle b\rangle)\sigma_{rs} \mid a?(x)\ P\mathbf{]}$$

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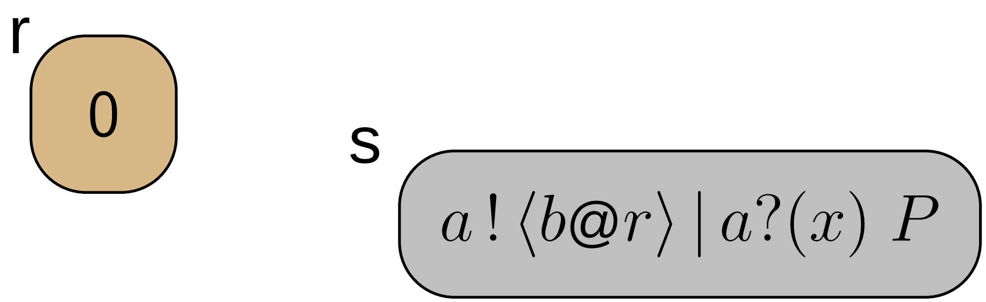

$$r\mathbf{[}a@s\,!\,\langle b \rangle\mathbf{]} \parallel s\mathbf{[}a?(x)\ P\mathbf{]}$$

$$\downarrow$$

$$r\mathbf{[0]} \parallel s\mathbf{[}(a@s\,!\,\langle b \rangle)\color{magenta}{\sigma_{rs}} \mid a?(x)\ P\mathbf{]}$$

$$=$$

$$r\mathbf{[0]} \parallel s\mathbf{[}a\,!\,\langle b@r \rangle \mid a?(x)\ P\mathbf{]}$$

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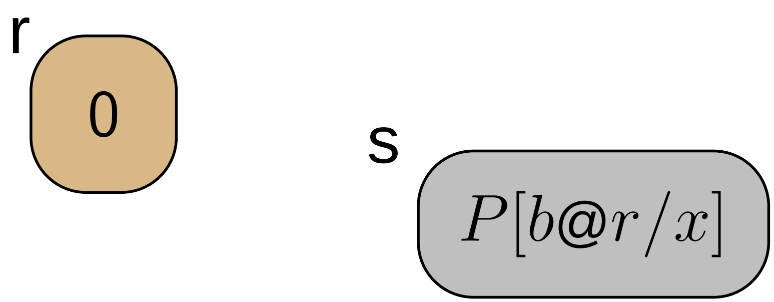

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$$\downarrow$$

$$r\mathbf{[0]} \parallel s\mathbf{[}P[b@r/x]\mathbf{]}$$

lsdπ motto

- Lexically Scoping Distribution:

what you see is what you get!

lsdπ motto

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what you see is what you get!

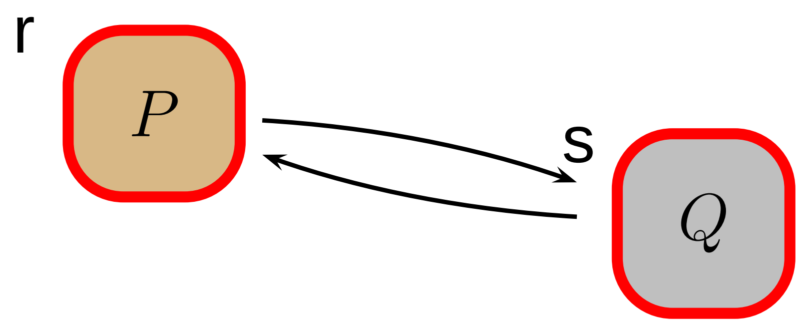
- a flavour ...

$$(\boldsymbol{\nu}\, a@s)\ r_{G_1}[a@s\,!\,\langle b\rangle] \parallel s_{G_2}[a?(x : S)\ P]$$

$\therefore$ simple names are local;

remote names are explicitly located;

Aim of this work



- Ensuring security policies: sites allowed to
  - send messages (remote communicating)
  - migrate processes
  - create remote names

Syntax (lsdπ)

- Processes

$$P, Q ::= \mathsf{0} \;\mid\; u\,!\,\langle v \rangle \;\mid\; u?(x:S)\;P \;\mid\; P \,|\, Q \;\mid\; (\boldsymbol{\nu}\, u)\;P$$

simple channels	a, b, c, x, y	channels	$u, v \quad ::= a \quad \mid \quad a@s$
sites	r, s, t	set of sites	R, S

Syntax (lsdπ)

- Processes

$$P, Q ::= \mathsf{0} \;\mid\; u\,!\,\langle v \rangle \;\mid\; u?(x : S)\; P \;\mid\; P \,|\, Q \;\mid\; (\boldsymbol{\nu}\, u)\; P$$

- Networks

$$N, M ::= \mathsf{0} \;\mid\; s_G[\![P]\!] \;\mid\; N \parallel M \;\mid\; (\boldsymbol{\nu}\, a@s)\; N$$

simple channels	a, b, c, x, y	channels	u, v	$::= a$ |	$a@s$
sites	r, s, t	set of sites	R, S		
$G?$	stay tunned ...				

Syntax (types)

$$
\begin{array}{llll}
\Gamma & ::= & \{s_1 : (\varphi_1, G_1), \ldots, s_n : (\varphi_n, G_n)\} & \text{typings} \\
\varphi & ::= & \{a_1 : \gamma_1, \ldots, a_n : \gamma_n\} & \text{site types} \\
G & ::= & \{\mathrm{rem} : S_1, \mathrm{mig} : S_2, \mathrm{new} : S_3\} & \text{site policies}
\end{array}
$$

Syntax (types)

Γ	$::=$	$\{s_1 : (\varphi_1, G_1), \ldots, s_n : (\varphi_n, G_n)\}$	typings
φ	$::=$	$\{a_1 : \gamma_1, \ldots, a_n : \gamma_n\}$	site types
G	$::=$	$\{\mathrm{rem} : S_1, \mathrm{mig} : S_2, \mathrm{new} : S_3\}$	site policies
γ	$::=$	$\mathrm{ch}(\gamma)@S^t \mid \mathrm{val}$	channel types
t	$::=$	$o \mid i \mid b$	site tags

Free names

r

$$(\boldsymbol{\nu}\, a)\left(\ldots a \ldots a@s \ldots\right)$$

Free names

r

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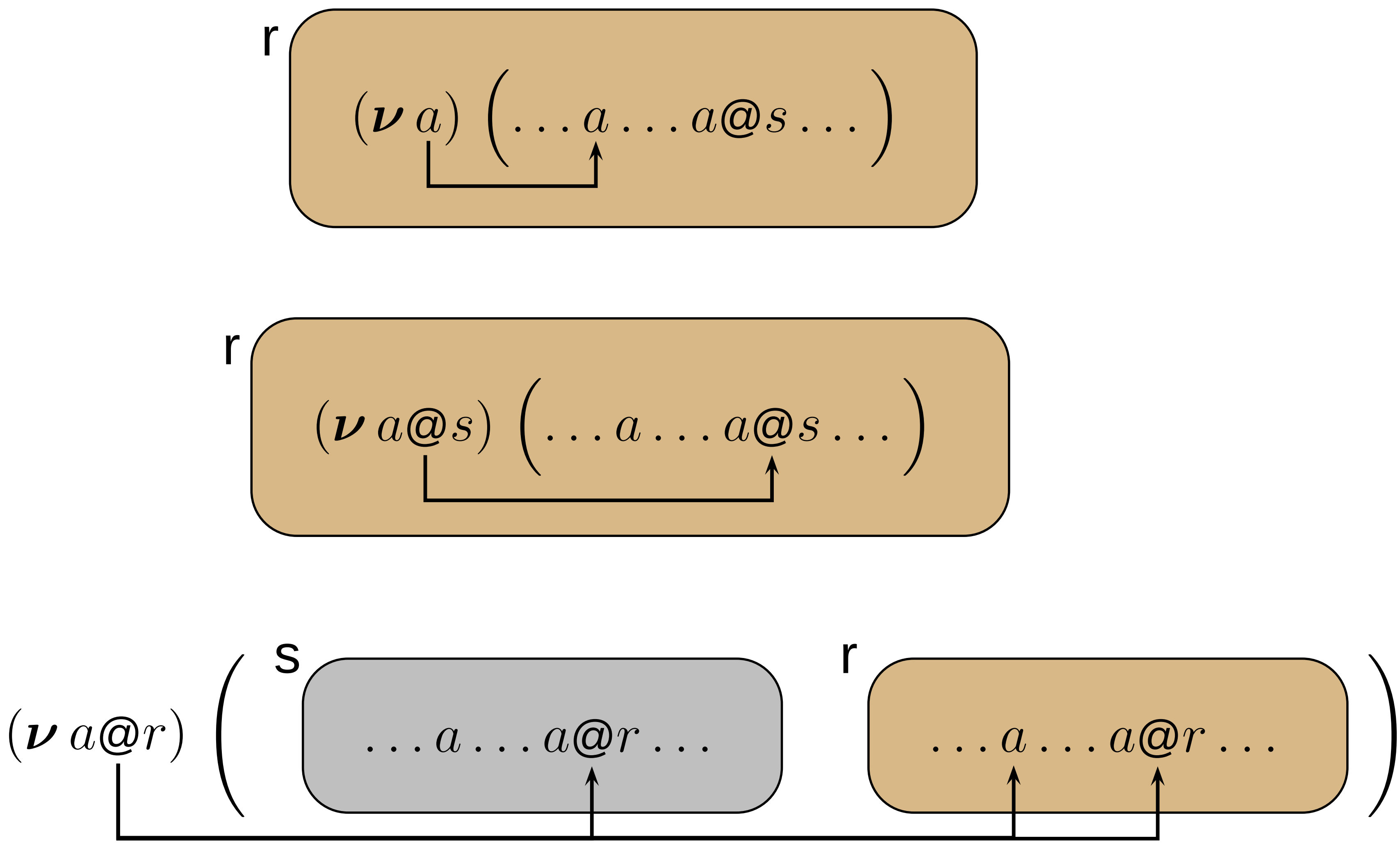
r

$$(\boldsymbol{\nu}\, a@s)\left(\ldots a \ldots a@s \ldots\right)$$

Free names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$(\boldsymbol{\nu}\, a@s)\left(\ldots a \ldots a@s \ldots\right)$
$(\boldsymbol{\nu}\, a@r)$
s
$\ldots a \ldots a@r \ldots$
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Structural congruence (some rules)

$$s_G[\![P \mid Q]\!] \equiv s_G[\![P]\!] \parallel s_G[\![Q]\!]$$

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$$(\boldsymbol{\nu}\, a@s)\ s_G[\![P]\!] \equiv s_G[\![(\boldsymbol{\nu}\, a@s)\ P]\!] \qquad a \notin \mathrm{fn}(P)$$

- Example:

$$(\boldsymbol{\nu}\, a@s)\ s_G[\![a\,!\,\langle b\rangle \mid a@s\,!\,\langle c\rangle]\!] \not\equiv s_G[\![(\boldsymbol{\nu}\, a@s)\ a\,!\,\langle b\rangle \mid a@s\,!\,\langle c\rangle]\!]$$

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Reduction rules (some rules)

$$s_G\mathbf{[}a\,!\,\langle v\rangle \mid a?(x : S)\ P\mathbf{]} \rightarrow P[v/x]$$

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$$\begin{aligned} &s_{G_1}[\![P]\!] \parallel r_{G_2}[\![a@s?(x:S)\ Q]\!] \\ &\qquad \to s_{G_1}[\![P \mid (a@s?(x:S)\ Q)\sigma_{rs}]\!] \parallel r_{G_2}[\![0]\!], \quad r \neq s \end{aligned}$$

σ_{rs} translates free names from r to s:

$$\begin{array}{ll} \sigma_{rs}(s) = s & \sigma_{rs}(a@s) = a \\ \sigma_{rs}(a) = a@r & \sigma_{rs}(a@t) = a@t, \quad t \notin \{r, s\} \end{array}$$

Security policies violation

Let $r \neq t$

- Remote communication

$$s_{\{\mathrm{rem}:\{t\}\}}\textbf{[}P\textbf{]} \parallel r_{G_1}\textbf{[}a@s\,!\,\langle x\rangle\textbf{]}$$

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$$s_{\{\mathrm{rem}:\{t\}\}}[\![b@r\,?\,(x : S)\ a@s\,!\,\langle x \rangle]\!] \parallel r_{\{\mathrm{mig}:\{s\}\}}[\![0]\!]$$

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$$s_{\{\mathrm{rem}:\{r\}\}}[\![a?(x:\{t\})\ 0]\!] \parallel r_{G_1}[\![a@s\,!\,\langle b@r\rangle]\!]$$

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- Migration

$$s_{\{\mathrm{mig}:\{t\}\}}[\![P]\!] \parallel r_{G_1}[\![a@s\,?\,(x:S)\;Q]\!]$$

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$$s_{\{\mathrm{rem}:\{r\}\}}[\![a?(x : \{r, t\})\ x\,!\,\langle c\rangle]\!] \parallel r_{\emptyset}[\![a@s\,!\,\langle b\rangle]\!]$$

Security policies violation

Let $r \neq t$

- Remote communication
- Migration
- Name creation

$$s_{\{\mathrm{new}:\{t\}\}}[\![P]\!] \parallel r_{G_1}[\![(\boldsymbol{\nu}\; a@s)\; Q]\!]$$

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- Migration
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$$(\boldsymbol{\nu}\, a@s)\ s_{\{\mathrm{new}:\{r\}\}}[\![P]\!] \parallel r_{G_1}[\![a@s\,!\,\langle b\rangle]\!] \parallel t_{G_2}[\![a@s\,!\,\langle c\rangle]\!]$$

Subtyping relation

$$b \leq i \qquad b \leq o$$

$$\frac{R \subseteq S}{S^o \leq R^o} \qquad \frac{S \subseteq R}{S^i \leq R^i} \qquad \frac{t \leq t'}{S^t \leq S^{t'}}$$

$$\gamma \leq \gamma \qquad \frac{\gamma_1 \leq \gamma_2 \qquad \gamma_2 \leq \gamma_3}{\gamma_1 \leq \gamma_3}$$

$$\frac{\gamma_1 \leq \gamma_2 \qquad S^t \leq R^{t'}}{\mathrm{ch}(\gamma_1)@S^t \leq \mathrm{ch}(\gamma_2)@R^{t'}}$$

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$\therefore$ Outputs may grow

Inputs may shrink

Judgments

- Typing names

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  - at runtime, P might be in any site of S

- Example

$$s_G\mathbf{[}a?(x : \{r, t\})\ x?(\ldots)\ P\mathbf{]}_{S=\{r,t\}}$$

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- Typing networks

$$\Gamma \vdash N$$

Typing located outputs

- Rule

$$\frac{\Gamma \vdash_s v : \gamma_2 \qquad \gamma_2 \leq \gamma_1 \qquad \Gamma(r)_1(a) = \mathrm{ch}(\gamma_1)@\{r\}^b \qquad S \subseteq \Gamma(r)_2(\mathrm{rem})}{\Gamma \vdash_{s,S} a@r\,!\,\langle v \rangle}$$

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Typing located inputs

- Rule

$$\frac{\begin{array}{c}\Gamma \vdash_{s,\{r\}} P \\ \Gamma(r)_1(a) = \mathrm{ch}(\gamma_1)@\{r\}^b \\ \Gamma(s)_1(x) = \mathrm{ch}(\gamma_2)@R^b \\ \mathrm{ch}(\gamma_2)@R^b \leq \gamma_1 \\ S \subseteq \Gamma(r)_2(\mathrm{mig})\end{array}}{\Gamma \setminus x@s \vdash_{s,S} a@r?(x:R)\ P}$$

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- Example

$$s_\emptyset[\![a@r?(x : \{t\})\ x\,!\,\langle c\rangle]\!] \parallel r_{\{\mathrm{mig}:\{s\}\}}[\![a\,!\,\langle b@t\rangle]\!] \parallel t_{\{\mathrm{rem}:\{r\}\}}[\![0]\!]$$

Typing located names (nets)

- Rule

$$\frac{\Gamma \vdash N \qquad S \setminus s \subseteq \Gamma(s)_2(\mathrm{new}) \qquad S \text{ is the set of sites where } a@s \text{ occurs free in } N}{\Gamma \setminus a@s \vdash (\boldsymbol{\nu}\, a@s)\ N}$$

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$$S = \{r\}$$
$$\Gamma(s) = \{(\emptyset, \{\mathrm{new} : \{r\}, \mathrm{rem} : \{r\}\})\}$$
$$\Gamma(r) = \{(b : \mathrm{ch}(\gamma)@\{r\}^b, \emptyset)\}$$

Runtime errors

$$\mathcal{E} = \{N | N \rightarrow^\star \nu\vec{X}(M' \parallel M)\}$$

and M of the form

- Remote communication

$$r_{G_1}\mathbf{[}P\mathbf{]} \parallel s_{G_2}\mathbf{[}a@r\,!\,\langle v\rangle\mathbf{]}, \qquad s \notin G_1(\mathrm{rem})$$

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- Name creation

$$r_{G_1}\llbracket P \rrbracket \parallel s_{G_2}\llbracket (\boldsymbol{\nu}\, a@r)\; P \rrbracket, \qquad s \notin G_1 (\text{new})$$

The usual properties

- Subject reduction

  if $\Gamma \vdash N$ and $N \rightarrow M,$ then $\Gamma \vdash M$

- Well-typed networks free of runtime errors

  if $\Gamma \vdash N$ and $N \rightarrow^{\star} M,$ then $M \notin \mathcal{E}$

Conclusions and further work

- we propose a type system to control:
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  - process migration
  - name creation
- But,
  - In $u?(x : S)\ P$, type S is fixed.
  - Sites are constants (used explicitly in types!)
- Further work
  - Solve the above limitations :))
  - Specify security policies at channel level
  - Adjust security policies dynamically