Mobile Ambients

Mobility

- name passing in the π-calculus models dynamically evolving network topology

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- Mobile Ambients: a model where term mobility is a primitive

From π-calculus to Mobile Ambients

$$\boxed{\pi} \quad P \;=\; \mathbf{0} \mid a(x).P \mid \overline{a}\langle x\rangle.P \mid (P_1|P_2) \mid\ !P \mid (\nu a)\,P \mid P + Q$$

From π-calculus to Mobile Ambients

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constructs for *space*

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$+$ *localities (ambients)*: $\boxed{n[P]}$

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constructs for *space*

+ *localities (ambients)*: $\boxed{n[P]}$

  spatial structure

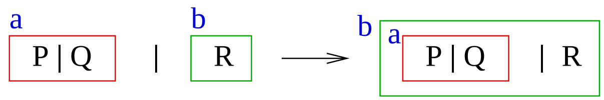
+ actions: *capabilities* $\boxed{M.P}$

  make the spatial structure evolve

Mobile Ambients – [Cardelli Gordon 1998]

$$
\begin{array}{rcl}
P & == & \mathbf{0} \mid a[P] \mid P_1|P_2 \mid !P \mid (\nu x)\,P \mid M.P \\
M & == & \mathsf{in}\,a \mid \mathsf{out}\,a \mid \mathsf{open}\,a
\end{array}
$$

Reduction, movement



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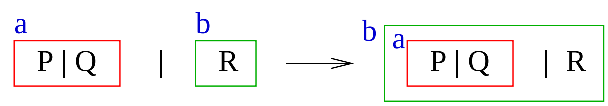

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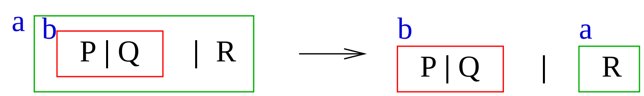

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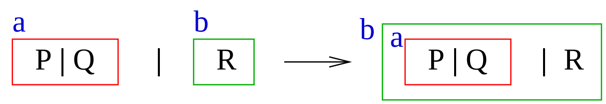

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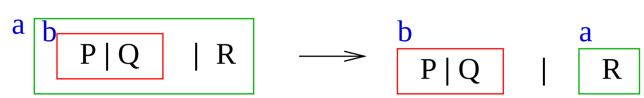

$$a[b[\mathsf{out}\, a.P \mid Q] \mid R] \quad\longrightarrow\quad b[P|Q] \mid a[R]$$

Remark: movements are *subjective*

Reduction, opening

$$a\,\boxed{P} \mid Q \longrightarrow P \mid Q$$

$$a[P] \mid \mathsf{open}\, a.Q \quad \rightarrow \quad P|Q$$

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- opening is “objective”

Reduction, opening

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- opening is "objective"
- an ambient disappears, its content is thrown in its enclosing ambient (capabilities act on a different locality)

Where does non-determinism come from in Mobile Ambients?

$$
\begin{array}{rcll}
a[\mathsf{in}\, b.P \mid Q] \mid b[R] & \longrightarrow & b[a[P|Q] \mid R] & \text{in} \\
a[b[\mathsf{out}\, a.P \mid Q] \mid R] & \longrightarrow & b[P|Q] \mid a[R] & \text{out} \\
a[P] \mid \mathsf{open}\, a.Q & \longrightarrow & P|Q & \text{open}
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$$

$$a[P] \mid b[\mathsf{in}\, a.Q \mid Q'] \mid a[R]$$

$$a[b[\mathsf{in}\, b'.P \mid \mathsf{out}\, a.P'] \mid b'[Q]]$$

Is name extrusion available in Mobile Ambients?

- structural congruence rules:

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- c is a secret that is carried along

Firewall

- $n[P]$ a firewall named n enclosing P

- capabilities $\mathsf{in}\,n$, $\mathsf{out}\,n$ are needed in order to cross the firewall

- the context $=$ the network

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- capabilities $\mathsf{in}\, n$, $\mathsf{out}\, n$ are needed in order to cross the firewall
- the context = the network

Example: an agent $Agent \;=\; k'[\mathsf{open}\, k.k''[B]]$,
the firewall $Firewall \;=\; w[k[\mathsf{out}\, w.\mathsf{in}\, k'.\mathsf{in}\, w.\mathbf{0}] | \mathsf{open}\, k'.\mathsf{open}\, k''.A]$

$$(\nu w)\,(Agent \mid Firewall) \;\approx\; (\nu w)\, w[B \mid A]$$

$$(\nu w)(w[k[\underline{\mathsf{out}\ w}.\mathsf{in}\ k'.\mathsf{in}\ w.\mathbf{0}] | \mathsf{open}\ k'.\mathsf{open}\ k''.A]) \quad | \quad k'[\mathsf{open}\ k.k''[B]]$$

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\downarrow \\
(\nu w)(w[\mathsf{open}\,k'.\mathsf{open}\,k''.A] \quad | \quad k'[\underline{\mathsf{in}\,w}.\mathbf{0}|k''[B]]) \\
\downarrow \\
(\nu w)w[\underline{\mathsf{open}\,k'}.\mathsf{open}\,k''.A \mid k'[\mathbf{0} \mid k''[B]]]
\end{array}
$$

$$(\nu w)(w[k[\underline{\mathsf{out}\ w}.\mathsf{in}\ k'.\mathsf{in}\ w.\mathbf{0}] | \mathsf{open}\ k'.\mathsf{open}\ k''.A]) \quad | \quad k'[\mathsf{open}\ k.k''[B]]$$

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\downarrow \\
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\downarrow \\
(\nu w)w[A \ | \ B]
\end{array}
$$

Locks and sums

$$acquire\ l.P \stackrel{\mathsf{def}}{=} \mathsf{open}\, l.P \qquad\qquad release\ l.P \stackrel{\mathsf{def}}{=} l[\,] \mid P$$

handshake: $acquire\ n.release\ m.P \mid release\ n.acquire\ m.Q$

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$$\begin{aligned}[\![n \Rightarrow P \ + \ m \Rightarrow Q]\!] \stackrel{\mathsf{def}}{=} \ & (\nu p, q, r)\,(\\ & \quad p[\mathsf{in}\, n.\mathsf{out}\, n.q[\mathsf{out}\, p.\mathsf{open}\, r.P]] \mid \\ & \quad p[\mathsf{in}\, m.\mathsf{out}\, m.q[\mathsf{out}\, p.\mathsf{open}\, r.Q]] \mid \\ & \quad \mathsf{open}\, q \mid r[\,])\end{aligned}$$

$$[\![n \Rightarrow P \ + \ m \Rightarrow Q]\!] \mid n[R] \ \rightarrow^{*}\approx P \mid n[R]$$

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- the model is "very distributed"
  - ▷ movement every where, at any level (except under capabilities)
  - ▷ autonomous movement: no synchronisation

Mobile Ambients are Turing complete

- ribbon cells: nested Ambients
  "leftmost and rightmost cells" : Ambients to extend the ribbon

- every cell contains an Ambient that represents its state

- head of the machine: **in** go right, **out** go left

Communications

what we have been discussing are *Pure Mobile Ambients*
let us now put some π-calculus into the language

Messages: $\langle M \rangle$ Abstractions: $(x).P$
Reduction: $\langle M \rangle \mid (x).P \;\to\; P_{\{x:=M\}}$

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- *local communications* (no medium)
- communication of *capabilities* in a broad sense
  (name, capability, path)

Well-formed terms

$$P \stackrel{\text{def}}{=} (\nu n)\,P \mid \mathbf{0} \mid P_1|P_2 \mid\ !P \mid M[P] \mid M.P \mid (x).P \mid \langle M \rangle$$
$$M \stackrel{\text{def}}{=} x \mid n \mid \mathsf{in}\,M \mid \mathsf{out}\,M \mid \mathsf{open}\,M \mid \epsilon \mid M_1.M_2$$

- variables (x) stand for names and capabilities
- badly formed terms: $n.P$, $(\mathsf{in}\,n)[P]$
- a simple type system can be defined to rule out badly formed terms

π in MA

$$
\begin{aligned}
[\![(\nu n)\, P]\!] &\stackrel{\mathsf{def}}{=} (\nu n)\,(n[!\mathsf{open}\, io] \mid [\![P]\!]) \\
[\![n(x).P]\!] &\stackrel{\mathsf{def}}{=} (\nu p)\,(io[\mathsf{in}\, n.(x).p[\mathsf{out}\, n.[\![P]\!]]] \mid \mathsf{open}\, p) \\
[\![\overline{n}m]\!] &\stackrel{\mathsf{def}}{=} io[\mathsf{in}\, n.\langle m \rangle] \\
[\![P \mid Q]\!] &\stackrel{\mathsf{def}}{=} [\![P]\!] \mid [\![Q]\!] \qquad [\![!P]\!] \stackrel{\mathsf{def}}{=} ![\![P]\!]
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\end{aligned}
$$

$\longrightarrow$ *remote inputs and outputs*

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- Zimmer 00 – π-calculus in Pure Mobile Ambients
  Mobile Ambients in Pure Mobile Ambients?
- similarly:
  are recursive definitions and replication equivalent in MA?

A young calculus

- since the 1998 paper *"Mobile Ambients"*, there have been numerous criticisms/counterproposals

the calculus, as it is, is:

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barbed equivalence: barbs are *ambients*
but then, what about a labelled transition system?