Information Flow in Boxed Ambient

I. Salvo

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Outline of the talk

- From Mobile Ambients to NBA
- Information Flow in Distributed Systems
- A Type System for Information Flow in Boxed Ambients
- Conclusions and Future Work

Ambient Calculus [Cardelli & Gordon 98]

- <u>Main Motivation</u>:
 - Define a calculus to model mobile computations (programming the Web)
- Formalize:
 - Named places (<u>ambients</u>) where computations happen
 - Hierarchical structure
 - Movement between places
 - Asyncronous communication among processes running in parallel inside the same ambient

Operational Semantics

A process may:

• comunicate locally in an asyncronous way: $\langle M \rangle \mid (x) . P \longrightarrow P\{x := M\}$

• cause the enclosing ambient to move inside or outside another ambient:

$$n[\text{in } m.P \mid Q] \mid m[R] \longrightarrow m[n[P \mid Q] \mid R]$$
$$m[n[\text{out } m.P \mid Q] \mid R]$$
$$\longrightarrow n[P \mid Q] \mid m[R]$$

• destroy the boundary of a sub-ambient: open $n.P \mid n[Q] \longrightarrow P \mid Q$

"Boxing" Ambients [Bugliesi, Castagna & Crafa, 01]

- open is essential for communication, but:
 - Dangerous for security:

 $m[\text{in } n.\text{bad}] \mid n[\text{open } m.P] \longrightarrow n[P \mid \text{bad}]$

- Complicates type systems
- Drop the open capability
- Introduce parent-child communication for expressivess

Boxed Ambient

 $(\text{Local}) \qquad (x)P \mid \langle M \rangle Q \longrightarrow P\{x := M\} \mid Q$ $(\text{Input } n) \qquad (x)^n P \mid n[\langle M \rangle \mid Q] \longrightarrow P\{x := M\} \mid n[Q]$ $(\text{Output } n) \qquad \langle M \rangle^n \mid n[(x)P \mid Q] \longrightarrow n[P\{x := M\} \mid Q]$ $(\text{Input } \uparrow) \qquad \langle M \rangle \mid n[(x)^{\uparrow}P \mid Q] \longrightarrow n[P\{x := M\} \mid Q]$ $(\text{Output } \uparrow) \qquad (x)P \mid n[\langle M \rangle^{\uparrow} \mid Q] \longrightarrow P\{x := M\} \mid n[Q]$

Boxed Ambient: Discussion

- Powerful Communication Mechanism Example: Broadcast $n[!\langle M \rangle \mid m[(x)^{\uparrow} \mid ...] \mid ... \mid p[(x)^{\uparrow} \mid ...]]$
- Source of grave interference $m[(x)^n . P \mid n[\langle M \rangle \mid (x) . Q \mid k[(x)^{\uparrow} . R]]]$

Boxed Ambient (II) [Bugliesi, Castagna & Crafa, 02]

 two non-interfering channels for local and upward communication:

(Local) $(x)P \mid \langle M \rangle Q \longrightarrow P\{x := M\} \mid Q$ (Input n) $(x)^{n}P \mid n[\langle M \rangle^{\uparrow} \mid Q] \longrightarrow P\{x := M\} \mid n[Q]$ (Output n) $\langle M \rangle^{n} \mid n[(x)^{\uparrow}P \mid Q] \longrightarrow n[P\{x := M\} \mid Q]$

NBA Calculus [Bugliesi, Crafa, Merro & Sassone 02]

- Expressiveness:
 - Ambients must statically know their children
 - do not learn about incoming ambients
- Introduce coaction as **binder**:

 $n[\operatorname{enter}\langle m, k \rangle . P \mid Q] \mid m[\operatorname{\overline{enter}}(x, k) . R \mid S] \\ \longrightarrow m[n[P \mid Q] \mid R\{x := n\} \mid S]$ $n[m[\operatorname{exit}\langle n, k \rangle . P \mid Q] \mid R] \mid \overline{\operatorname{exit}}(x, k) . S \\ \longrightarrow m[P \mid Q] \mid n[R] \mid S\{x := m\}$

NBA: Discussion

- Expressiveness: using guarded choice allow to encode the first version of BA
- Nice equational laws: LTS sematics
- Barbs:

$$P \downarrow_n \text{ iff } P \equiv (\nu \vec{m})(n[\overline{\text{enter}}(x,k).Q \mid R] \mid S)$$
$$P \Downarrow_n \text{ iff } \exists Q \text{ and } P \longrightarrow^* Q, Q \downarrow_n$$

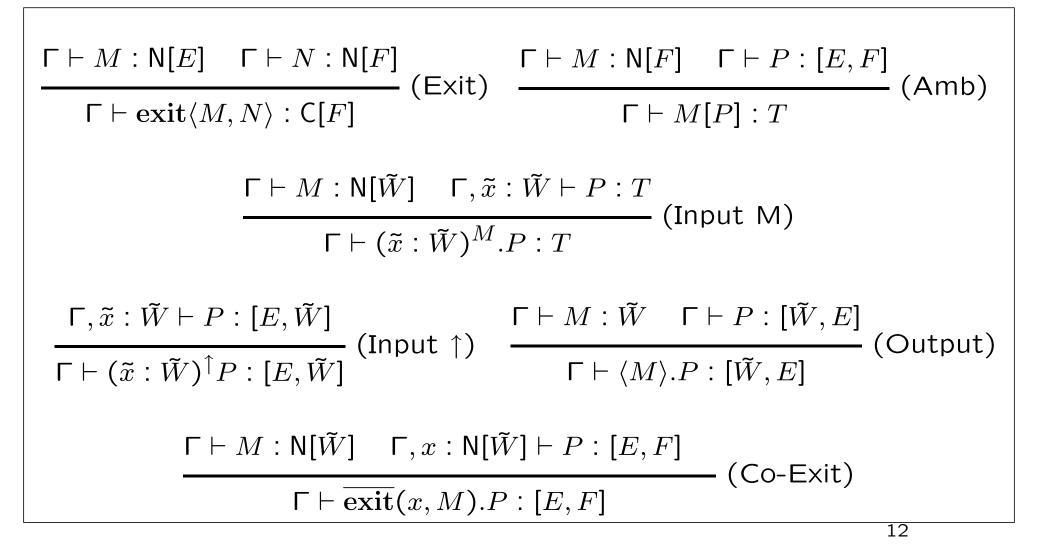
• It is equivalent to observe $\langle \cdot \rangle^{\uparrow}$

NBA Type System

• Types:

Message TypesW ::= N[E]
| C[E]ambient/password
capabilityExchange TypesE, F ::= Shh
 $| W_1 \dots W_k$ silent process
Tuples, $k \ge 0$ Process TypesT ::= [E, F]local/upward
exchange

NBA Typing Rules



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MAC Security Policy in NBA

- Each Ambient has a security clearance (types)
- Consider a set of subjects (Processes) and of objects (Ambients)
- Define a security policy (e.g no read-up, no writedown)
- Read Access: $m[(x)^n P \mid n[\langle M \rangle^{\uparrow} Q \mid R] \mid S]$
- Write Access: $m[\langle M \rangle^n P \mid n[(x)^{\uparrow}Q \mid R] \mid S]$

Implicit Information Flows

- The behavior of a low level entity depends indirectly from high level ones
- Example: testing the existence of a high level process maybe a relevant information
- Information flow is difficult to formalize: non interference (Goguen, Meseguer 82)

Example: e-commerce

- Consider an agent *P* that visits sites that offer a given service
- P stores the offer in its private aerea H
- We do not want a new offer depends on previously stored data and the vendors know the agent visited other sites

$$P \equiv l[!\overline{\text{enter}}(x,k).\langle \text{enter}\langle h,k'\rangle \rangle \mid Q \\ \mid h[!\overline{\text{enter}}(x,k').R \mid S]]$$

What the Example Shows

- The secret component contains low-level subcomponents
- Testing the presence of the secret component is a relevant information
- To enter the secret component a capability is communicated (low level information)
- Information inside *H* will be inside other secrets components

What has been done so far... [HR98, BCC02, ...]

- Usual approaches: Consider $\Gamma \vdash H$ a high level process
- Only well-typed contexts wrt a type system which discards "dangerous" flows of information
- Interference Free Processes *P* is interference free if, for all high level sources *H*,

$$P \mid H \cong_L P$$
$$P \cong_L Q \text{ iff } \forall C(), C(P) \Downarrow_l \Longleftrightarrow C(Q) \Downarrow_l$$

Our (forthcoming) approach

- Consider processes typed in a lightweight type system without information flow constraints
- Define the set of interference free process
- Define a type system that accepts only interference free processes

Non Interference (revisited)

• High Level Sources H is a high level source if $(\nu \vec{h})H \cong 0,$

where \vec{h} is the set of high free names of H

• Interference Free Processes *P* is interference free if, for all high level sources *H*,

 $(\nu \vec{h})(P \mid H) \cong (\nu \vec{h})P,$

where \vec{h} is the set of high free names of H and P

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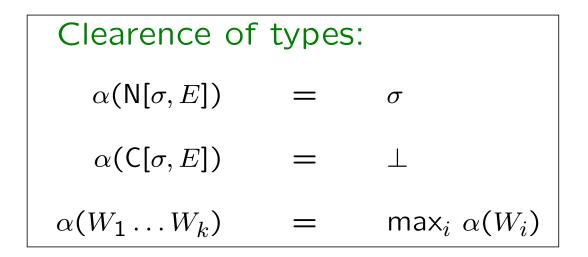
Security Types for NBA

• Types:

Exchange Types E, F ::= Shh silent process $| W_1 \dots W_k$ Tuples, $k \ge 0$

Process Types $T ::= [\sigma, E, F]$ local/upward exchange

Security Types for NBA



Type formation rules:
$$\Gamma \vdash E \quad \Gamma \vdash \alpha(E) \leq \sigma$$

 $\Gamma \vdash N[\sigma, E]$ (Type Amb) $\Gamma \vdash E_i \quad \Gamma \vdash \alpha(E_i) \leq \sigma$
 $\Gamma \vdash [\sigma, E_1, E_2]$ (Type Proc)

"Information Flow" Types for NBA

- Message types becomes: $N[\sigma, \tau, E]$
- Judgement has the shape:

 $\Gamma \vdash_{\phi} P : [\sigma, E, F]$

"Information Flow" Types Rules

$$\frac{\Gamma \vdash M : \mathsf{N}[\tau, \rho, E] \quad \Gamma, x : \mathsf{N}[\tau, -, \tilde{W}] \vdash_{\tau} P : [\sigma, E, F]}{\Gamma \vdash_{\phi} \overline{\operatorname{exit}}(x, M) . P : [\sigma, E, F]} \text{ (CoExit)}$$

$$\frac{\Gamma \vdash M : \mathsf{N}[\tau, -, \tilde{W}] \quad \Gamma, \tilde{x} : \tilde{W} \vdash_{\tau} P : [\sigma, E, F] \quad \mathsf{Safe}(\sigma, \phi, \tau)}{\Gamma \vdash (\tilde{x} : \tilde{W})^{M} . P : [\sigma, E, F]} \quad \mathsf{Safe}(\sigma, \phi, \tau) \text{ (Input M)}$$

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Conclusion and Future Work

- Main achievement: "type indepedent" definition of interference free process
- Study less restrictive type system
- Apply this approach to π -calculus and compare with previous work

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