Mobile Access Control

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Joint work with
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Boxed Ambients

Network

Classroom

Instructor

Mail

Destination

Mailer
Boxed Ambients

Network

Classroom

Instructor

Mail

Destination

Mailer
Boxed Ambients

Network
- Classroom
- Instructor
- Mail

Destination
Mailer
Boxed Ambients

Network

Classroom

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route
Boxed Ambients

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Classroom

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Boxed Ambients

Network

Classroom

Instructor

Destination

Mail

Mailer

msg
Boxed Ambients

Network

Classroom

Student

Mail

Destination

Mailer
Boxed Ambients

Network

Classroom

Student

Class Resp

Destination

Mailer

Student Network Class Resp
Security is Necessary for Correct Functionality

- Embedded devices often need to receive data (and increasingly new code) from remote sources
- If data (or new code) is corrupt, the functionality of device is at risk
- Need methods to verify security of communications
CPAP Machines - Current Method

- Doctor send you a Smart Card
- You insert the smart card into your machine
- When the machine is done interacting with the smart card, you take it out
- You mail the card back to the doctor
- The doctor places the smart card in his reader
- Security derives from the “belief” that the card is secure
- Networking is the way of the future
Boxed Ambients

Network

Patient1

Doctor

GetInfo

CPAP

Patient2

CPAP
Boxed Ambients

Network

Patient1

CPAP

Doctor

Patient2

GetInfo

CPAP
Boxed Ambients
Boxed Ambients

Network

Patient1

Doctor

CPAP

Patient2

GetInfo

CPAP
Boxed Ambients

Network

Patient1
  CPAP

Doctor

Patient2
  GetInfo
  CPAP
Boxed Ambients

Network

Patient1

CPAP

Doctor

Patient2

GetInfo

CPAP
Boxed Ambients

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Patient1

CPAP

Patient2

CPAP

Doctor

GetInfo
Boxed Ambients

Network

Patient1

CPAP

Doctor

GetInfo

Patient2

CPAP
Privacy

- How do we guarantee that only authorized agents access your CPAP?
Boxed Ambients with Security

Network

Patient1
- GetInfo
- CPAP

Doctor

Patient2
- CPAP
Boxed Ambients with Security

Network

Patient1
- GetInfo
- CPAP

Doctor

Patient2

CPAP
Boxed Ambients with Security

Network

Patient1

CPAP

GetInfo

Patient2

Doctor

CPAP
Role-Based Access Control

- Separate control into roles for users and access privileges for roles.
- Give one relation of users (and possibly active roles) to roles (that can be activated).
- Give separate relation of roles to privileges.

Access privileges: \( P : \text{Role set} \rightarrow \text{Acc set} \)
User roles: \( UserPolicy : \text{User} \times \text{Role set} \rightarrow \text{Role set} \)
Local Role-Based Access Control

- Have a notion of a location (boxed ambient)
- Each ambient assigns privileges to the resources it controls:
  - Entry into itself
  - Read access to its channel
  - Write access to its channel

- $Priv : Amb \rightarrow \text{Role set} \times \text{Role set} \times \text{Role set}$
  
  enter \quad read \quad write
Ambient

- Assume set of (public) ambient names $Amb$
- Ambients given by:
  \[ A ::= m_u[P]@\rho \]
  - Where $m \in Amb$
  - $\rho \in Roles$ (active roles for that process)
  - $u \in Users$
  - $P$ is a Process
Processes (simplified)

- Similar to $\pi$-calculus
- $\eta :: = * | \uparrow c | \downarrow c$ (local | with parent | with child)
- $P :: = \text{nil} | (P_1 | P_2) | !P$
  - $\nu(n:\tau).P$ (creates a new ambient $n$)
  - $<M>\eta.P$ (send message $M$ on $\eta$)
  - $(x)\eta.P$ (receive message into $x$ on $\eta$)
  - activate($r$).$P$ (activate role $r$ for $P$)
  - deactivate($r$).$P$ (deactivate role $r$ for $P$)
  - $C(c).P$ (execute capability $C$, creating local channel $c$)
- Message is a capability or variable (containing a capability)
Capabilities

- Two main kinds of capabilities: communicating and non-communicating (quiet)
- Quiet Capabilities:
  \[ Q ::= \text{inQ } m \mid \text{outQ } m \mid \text{inQ} \mid \text{outQ} \]
- Capabilities:
  \[ C ::= \text{in } m \mid \text{out } m \mid \text{in} \mid \text{out} \mid Q \mid Q.C \]
- Capabilities are the content of messages (M) and actions of processes
Dynamic Semantics

- to **activate** or **deactivate** a role.
- to describe when one ambient may **enter** or **exit** another.
- to describe **local** communication, and communication **across** ambient boundaries.
Dynamic Semantics: activate

\[ m_u [activate ( r ) . P]@\rho \rightarrow m_u [P]@(\rho \cup \{ r \}) \]

\[ m_u [deactivate ( r ) . P]@\rho \rightarrow m_u [P]@(\rho - \{ r \}) \]
Dynamic Semantics

\[ <M>^*.P \mid (x)^*.R \rightarrow P \mid R \{x:=M\} \]

(local communication)

\[ m_u [<M>\downarrow^c.P \mid n_v[ (x)^\uparrow^c.R]@\rho_n]@\rho_m \rightarrow m_u [P \mid n_v[R \{x:=M\}]@\rho_n]@\rho_m \]

(to child)

Similarly to parent
Dynamic Semantics: in

\[ n_u \ [\text{in } m \ (c_1) \cdot P_1 @ \rho_1 \mid R_1] @ \rho_n \]
\[ \mid m_v \ [\text{in } (c_2) \cdot P_2 @ \rho_2 \mid R_2] @ \rho_m \]

\[ \rightarrow \]

\[ m_u [n_v [P_1 \{c_1 := c\} @ \rho_1 \mid R_1] @ \rho_n \]
\[ \mid P_2 \{c_2 := c\} @ \rho_2 \mid R_2] @ \rho_m \]

- The capabilities in \( m \ (c_1) \) and in \( (c_2) \) are consumed.
- \( m \) and \( n \) now share a new communication channel \( c \).
Dynamic Semantics: out

\[ p_u[n_v[m_w[out p (c_1)]. P_1 | R_1] \rho_m | R_2] \rho_n \]
\[ | out (c_2). P_2 | R_3] \rho_p \]

\[ \rightarrow \]

\[ p_u[n_v[R_2] \rho_n | m_w[P_1\{c_1 := c\} | R_1] \rho_m \]
\[ | P_2 \{c_2 := c\} | R_3] \rho_p \]

- The capabilities \( out p (c_1) \) and \( out (c_2) \) are consumed.
- \( m \) and \( p \) now share a new communication channel \( c \).
Type System

- Our Type System prevents two forms of security violations:
  - Attempting to enter an ambient without proper authorization, and
  - Attempting to read from or write to channels without the corresponding permissions.
What can we do statically?

- Give static types to channels and ambients
- Ambient types: \( \tau ::= \text{amb} (\rho_{\text{in}}, \sigma) \)
- Channel types: \( \sigma ::= (\rho_r, \rho_w, \tau) \mid \text{ssh} \)
- Being in \( \rho_{\text{in}} \) guarantees you can enter the ambient
- Being in \( \rho_r \) guarantees you can read from the channel
- Being in \( \rho_w \) guarantees you can write to the channel
- \texttt{shh} means you cannot read or write to the channel
Typing Judgements

\[ \Gamma, \rho_{\text{here}}, \rho_{\text{deact}}, m, u |- P : \rho_{\text{act}} \]

Where

- \( P \) is a process
- \( m \) is the enclosing ambient
- \( u \) is the user that owns \( m \)
- \( \rho_{\text{here}} \) is the set of roles authorizing \( P \) to be in \( m \)
- \( \rho_{\text{deact}} \) is the set of roles that \( P \) can deactivate
- \( \rho_{\text{act}} \) is the set of currently active roles.
- \( \Gamma \) typing environment for message identifiers and channel names
Typing Judgements

- Other typing judgements have similar forms.

- The typing judgement for actions reflect how the different role sets are modified.

\[ \Gamma, \rho_{\text{here}}, \rho_{\text{deact}}, \rho_{\text{act}}, m, u \vdash a : (\Gamma, \rho_{\text{here}}, \rho_{\text{act}}) \]
Typing Rules: Role Activation

\[ r \in U(u, \rho_{\text{act}}) \]
\[ \Gamma, \rho_{\text{here}}, \rho_{\text{deact}}, \rho_{\text{act}}, m, u \vdash \text{activate}(r): (\Gamma, \rho_{\text{here}}, \rho_{\text{act}} \cup \{r\}) \]

\[ r \notin \rho_{\text{deact}} (\rho_{\text{act}} - \{r\} - \rho_{\text{deact}}) \cap \rho_{\text{here}} \neq \emptyset \]
\[ \Gamma, \rho_{\text{here}}, \rho_{\text{deact}}, \rho_{\text{act}}, m, u \vdash \text{deactivate}(r): (\Gamma, \rho_{\text{here}}, \rho_{\text{act}} - \{r\}) \]
Typing Rules: Data Exchange

Input
\[ \Gamma, m \vdash \eta : (\rho_r, \rho_w, \tau) \]
\[ (\rho_{act} - \rho_{deact}) \cap \rho_r \neq \emptyset \]

\[ \Gamma, \rho_{here}, \rho_{deact}, \rho_{act}, m, u \vdash (x)^{\eta} : (\Gamma + x:\tau, \rho_{here}, \rho_{act}) \]

Output
\[ \Gamma, m \vdash \eta : (\rho_r, \rho_w, \tau) \]
\[ (\rho_{act} - \rho_{deact}) \cap \rho_w \neq \emptyset \]
\[ \Gamma \vdash \text{M} : \tau \]

\[ \Gamma, \rho_{here}, \rho_{deact}, \rho_{act}, m, u \vdash <\text{M}>^{\eta} : (\Gamma, \rho_{here}, \rho_{act}) \]
Type Rules: Entrance

In

\[ \Gamma(n) = \text{amb}(\rho_{in}, \sigma) \]

\[ (\rho_{act} - \rho_{deact}) \cap \rho_{in} \neq \emptyset \]

\[ \Gamma, \rho_{\text{here}}, \rho_{deact}, \rho_{act}, m, u \vdash \text{in} n (c) : (\Gamma + c : \sigma, \rho_{in}, \rho_{act}) \]

Co-in

\[ \Gamma(m) = \text{amb}(\rho_{in}, \sigma) \]

\[ \Gamma, \rho_{\text{here}}, \rho_{deact}, \rho_{act}, m, u \vdash \overline{\text{in}}(c) : (\Gamma + c : \sigma, \rho_{\text{here}}, \rho_{act}) \]
Example

- Previous example can now work:
  - Give members of doctor’s office the doctor role
  - Patient allows GetInfo procedures with doctor role to enter, but not GetInfo procedures from other patients
  - Patients can’t (in general) activate the doctor role
CPAP Example

- No matter how we specify types for the ambients, the Patient1 GetInfo process will not type check if it requests to enter Patient2.

- We can find types that allow the Doctor GetInfo program to type check.
Results

- We defined an un-typed and a typed (not shown) transitional semantics.
- We show that on well-typed processes both transitional semantics coincide.
- The typed transitional semantics is of independent interest, and it is relevant to situations where the access control policy is only known at runtime.
Future Work

- Trusted and untrusted locations
- Role hierarchies
- Subtyping: Can a more (or less) restrictive type be used than the one given?
- Multiple channels between communicating ambients
- Implement on top of the Tunnel Calculus (Carl Gunter and Alwyn Goodloe)
Related Work

- Bonelli, Compagnoni, Dezani, and Garralda (MFCS04)
  - The calculus splits communication and mobility by using ambient names and port names.

- Braghin, Gorla, and Sassone (CSFW04)
  - They develop a type system for statically (and dynamically) checking code in the $\pi$-calculus with roles.

- Hennessy (TGC05)
  - Type system for the $D_\pi$-calculus
  - Uses dependent types to allow privileges to vary by the message received
  - No nesting of different user code or locations
  - No movement of locations, only code
Contributions

- We defined a boxed ambient calculus with Distributed Role-Based Access Control, where the privileges associated to processes change during computation.
- Privileges depend on location, owner, activated roles, and security policy.
- First calculus with distributed RBAC mechanism where the location of a process conditions its mobility and ability to communicate.
Thank You!