Formal Analysis of Policies in Wireless Sensor Network Applications

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Outline

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- Key elements of CaPI middleware:
  - Components
  - Wires
  - Policies

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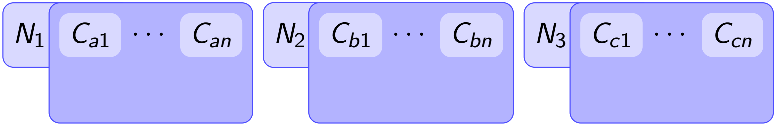
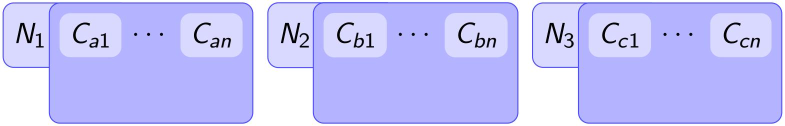


Graphical Representation of Wires



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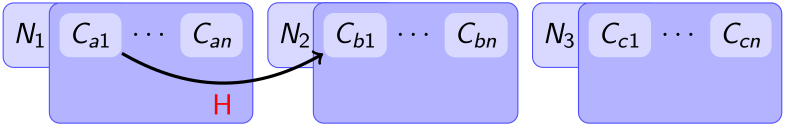

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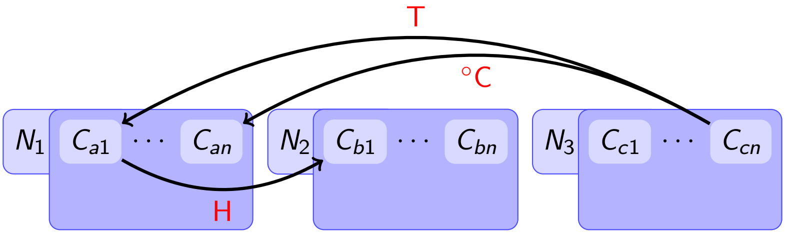

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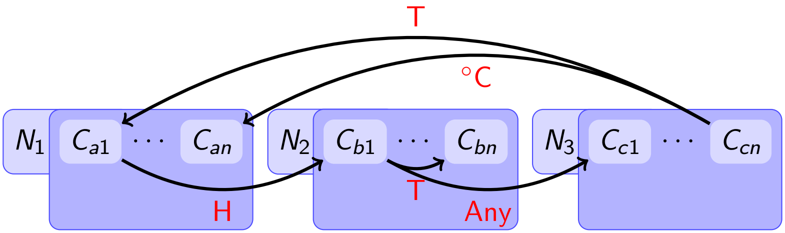

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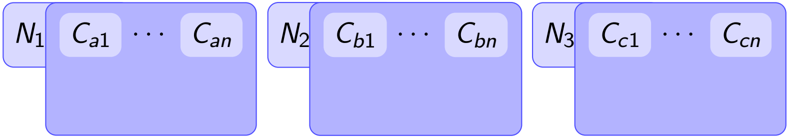

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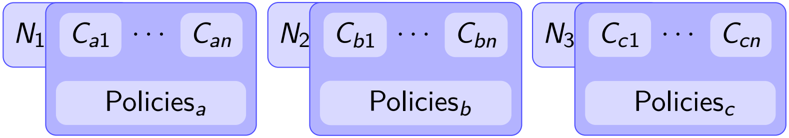

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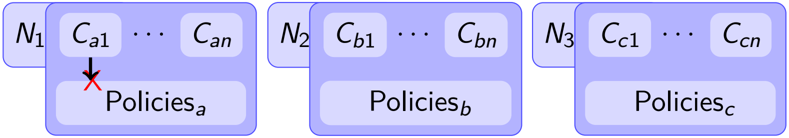

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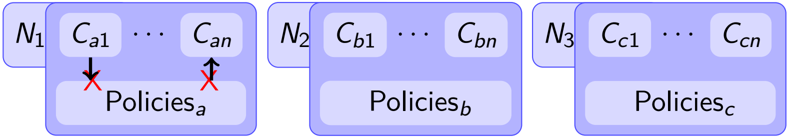

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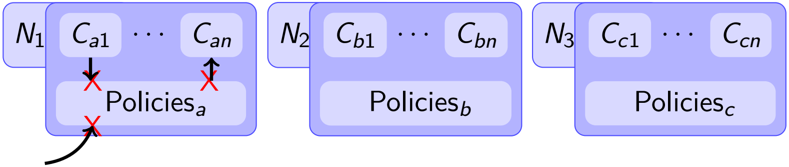

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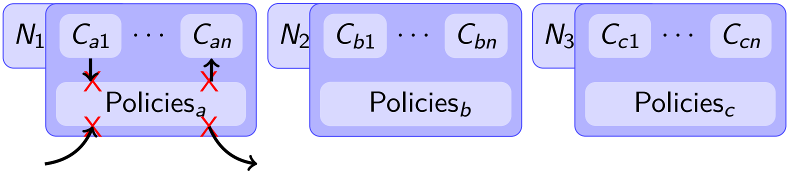

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- their semantics can conflict.

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Policies Example

P_1@N_1

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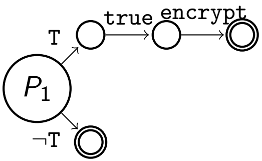

Policies Composition Example

P_1@N_1	P_2@N_1

`on event (T) as e`
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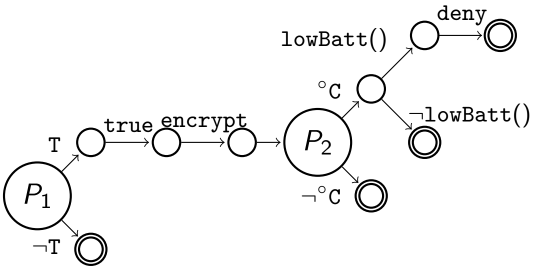

Policies Network Composition Example

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	`on event (Any) as e`
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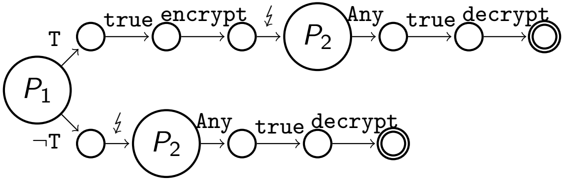
Wires on Any messages.



Policy Programs

$$
\begin{array}{rcl@{\qquad}r}
\textit{Policy Program } P & ::= & \texttt{on}(t)\{P\} & \textit{Type } t \in \mathcal{T} \\
 & | & \texttt{if}(g)\{P\} & \textit{If-Guard } g \in \mathcal{L} \\
 & | & a & \textit{Action } a \in \mathcal{A} \\
 & | & P; P' &
\end{array}
$$

$\mathcal{A} ::= \{$`allow`, `deny`, `encrypt`, `decrypt`, `sign`, `verify`, `persist`, `delete`$\}$.

Semantics Function

The idea is to capture what was drawn before: all paths of a tree of execution.

$$\begin{aligned}
[\![\mathtt{on}(t)\{P\}]\!]_C =& \{\tau \mid \tau \in [\![P]\!]_{C\cap\{t\}}, C \frown t\} \cup \{(\epsilon; C \cap \{\neg t\}) \mid C \frown \neg t\} \\
[\![\mathtt{if}(g)\{P\}]\!]_C =& \{\tau \mid \tau \in [\![P]\!]_{C\cup\{g\}}, C \frown g\} \cup \{(\epsilon; C \cup \{\neg g\}) \mid C \frown \neg g\} \\
[\![a]\!]_C =& \{(a; C)\} \\
[\![P; P']\!]_C =& \{(\overline{a}\,\overline{a}'; C') \mid (\overline{a}; C'') \in [\![P]\!]_C, (\overline{a}'; C') \in [\![P']\!]_{C''}\}
\end{aligned}$$

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Analysis

Specification of undesired/desired properties via modal logic:

```
[true*.encrypt.true*.↯.(!decrypt)*]<true*.decrypt> true;
                                                (dec-after-enc)
[true*.encrypt.true*.encrypt] false;            (enc-most-once)
[true*.encrypt]<true*.↯> true;                  (snd-after-enc)
```

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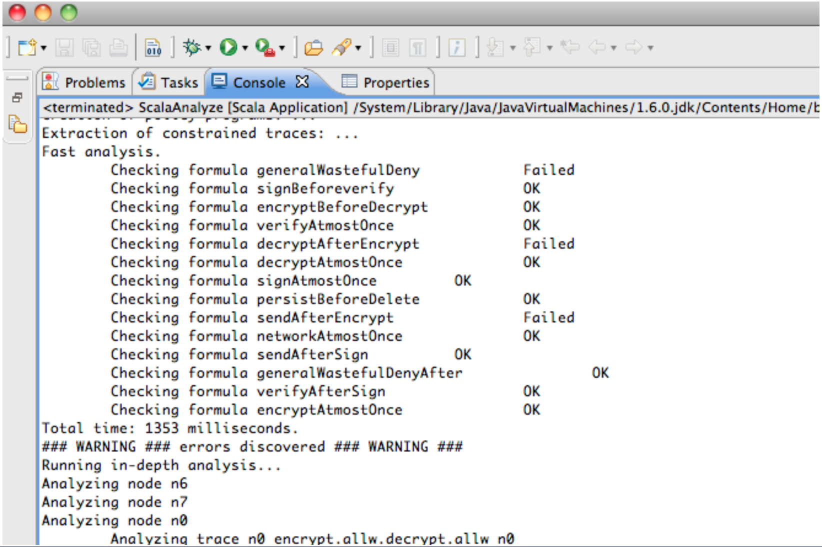
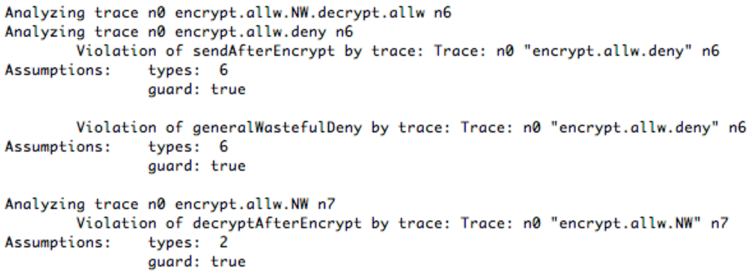
- extracts the formalization of policies;
- calculates the semantics of policy programs;
- analyzes the constrained trace semantics against some user-defined properties via `mCRL2`;
- scales linearly in terms of connections between nodes and number of policies (with similar logical conditions).

Tool- feedback



```
<terminated> ScalaAnalyze [Scala Application] /System/Library/Java/JavaVirtualMachines/1.6.0.jdk/Contents/Home/b
Extraction of constrained traces: ...
Fast analysis.
        Checking formula generalWastefulDeny            Failed
        Checking formula signBeforeverify               OK
        Checking formula encryptBeforeDecrypt           OK
        Checking formula verifyAtmostOnce               OK
        Checking formula decryptAfterEncrypt            Failed
        Checking formula decryptAtmostOnce              OK
        Checking formula signAtmostOnce         OK
        Checking formula persistBeforeDelete            OK
        Checking formula sendAfterEncrypt               Failed
        Checking formula networkAtmostOnce              OK
        Checking formula sendAfterSign          OK
        Checking formula generalWastefulDenyAfter               OK
        Checking formula verifyAfterSign                OK
        Checking formula encryptAtmostOnce              OK
Total time: 1353 milliseconds.
### WARNING ### errors discovered ### WARNING ###
Running in-depth analysis...
Analyzing node n6
Analyzing node n7
Analyzing node n0
        Analyzing trace n0 encrypt.allw.decrypt.allw n0
```

Tool- feedback



```
Analyzing trace n0 encrypt.allw.NW.decrypt.allw n6
Analyzing trace n0 encrypt.allw.deny n6
        Violation of sendAfterEncrypt by trace: Trace: n0 "encrypt.allw.deny" n6
Assumptions:    types:  6
                guard: true

        Violation of generalWastefulDeny by trace: Trace: n0 "encrypt.allw.deny" n6
Assumptions:    types:  6
                guard: true

Analyzing trace n0 encrypt.allw.NW n7
        Violation of decryptAfterEncrypt by trace: Trace: n0 "encrypt.allw.NW" n7
Assumptions:    types:  2
                guard: true
```

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- Provide a concurrency model for the modeled application.