Runtime Code Polymorphism as a Protection against Physical Attacks
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Core Idea: Runtime Code Polymorphism

Definition
Regularly changing the behaviour of a (secured) component, at runtime, while maintaining unchanged its functional properties.

What for?
- Protection against reverse engineering of SW
- the secured code is not available before runtime
- the secured code regularly changes its form (code generation interval $\omega \geq 1$)
- Protection against physical attacks
- polymorphism changes the spatial and temporal properties of the secured code: side channel & fault attacks
- combine with usual SW protections against focused attacks

How?
deGoal: runtime code generation for embedded systems
- fast code generation
- tiny memory footprint: proof of concept on TI's MSP430 (512 bytes of RAM)

Compilettes & deGoal in a Nutshell

A compilette is:
- an ad hoc code generator that targets one kernel
- aimed to be invocated at runtime

Polymorphic Code Generation

degol runtime capabilities
Performed in this order:
- register selection
- instruction selection
- instruction scheduling

Adaptation to achieve runtime code polymorphism:
- Portability to very small processors and secure elements
- Limited memory consumption
- Fast runtime code generation
- Ability to combine with hardware countermeasures
- Introduce alea during runtime code generation [1,2,3]
- Polymorphism:
  - random mapping to physical registers [1]
  - use of semantic equivalences [2]
  - instruction scheduling [3]
  - insertion of dummy operations [3]

Example: polymorphic AES

Polymorphic implementation of the SubBytes function:

```c
void gen_subBytes( cdg_insn_t* code, uint8_t* state_addr)
{
    // Begin code Prelude
    i
    #
    ...
}
```

Unprotected

Protected with code polymorphism

~100 EM traces of AES SubBytes

Execution times (in cycles), over 1000 runs:

<table>
<thead>
<tr>
<th></th>
<th>min</th>
<th>max</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>reference</td>
<td>6385</td>
<td>6385</td>
<td>6385</td>
</tr>
<tr>
<td>code generator</td>
<td>5671</td>
<td>12910</td>
<td>9345</td>
</tr>
<tr>
<td>polymorphic instance</td>
<td>7185</td>
<td>9745</td>
<td>8303</td>
</tr>
</tbody>
</table>

Impact of the code generation interval $\omega$:

<table>
<thead>
<tr>
<th>$\omega$</th>
<th>k</th>
<th>%</th>
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<tbody>
<tr>
<td>1</td>
<td>2.76</td>
<td>53.0%</td>
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<tr>
<td>5</td>
<td>1.59</td>
<td>18.4%</td>
</tr>
<tr>
<td>20</td>
<td>1.37</td>
<td>2.1%</td>
</tr>
<tr>
<td>100</td>
<td>1.31</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

$k$: overhead vs. reference implementation

%: percentage contribution of runtime code generation to the performance overhead

References