Runtime Code Polymorphism as a Protection against Physical Attacks
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Runtime Code Generation to Secure Devices

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
- Protection against physical attacks
- Portability to very small processors and secure elements
- Ability to combine with hardware countermeasures
- Ability to thwart channel & fault attacks
- Protection against physical 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)

Polymorphic Code Generation

deGoal runtime capabilities
Performed in this order:
1. register selection
2. instruction selection
3. 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)
{
    #define SBOX 

    Begin code Prelude
    Alloc uint32 state, sbox, i, x, y
    for (i = 0; i < 256; i++) { ...
    End
    ...
}
```

```
~100 EM traces of AES SubBytes
```

Unprotected
Protected with code polymorphism

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>
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<td>6385</td>
<td>6385</td>
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<tr>
<td>code generator</td>
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<td>12910</td>
<td>9345</td>
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<tr>
<td>polymorphic inst.</td>
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<td>9745</td>
<td>8303</td>
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Impact of the code generation interval $\omega$:

<table>
<thead>
<tr>
<th>$\omega$</th>
<th>$k$</th>
<th>%</th>
</tr>
</thead>
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<tr>
<td>5</td>
<td>1.59</td>
<td>18.4%</td>
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<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

