Compiler-based Countermeasure Against Fault Attacks
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Compiler-based Countermeasure Against Fault Attacks

The goal is to implement the instruction duplication technique as a countermeasure against Fault Attacks on an ARM 32-bit Microcontroller[1,2]. Operating inside a compiler allowed us to reduce the security overhead thanks to the flexibility and code transformations opportunities offered by compilers.

The user identifies the portions of the program to protect

```
@_to_secure_("fault")
int foo(int a, int b){
  ...
  return a + b + a;
}
```

The user has a full control over parts of the code to protect.

Instructions cannot be duplicated at the middle-end due to the SSA form

<table>
<thead>
<tr>
<th>SSA Form</th>
<th>LLVM Bytecode</th>
</tr>
</thead>
<tbody>
<tr>
<td>mul</td>
<td>%mul = mul %a, %b</td>
</tr>
<tr>
<td>add</td>
<td>%add = add %mul, %a</td>
</tr>
<tr>
<td>ret</td>
<td>%add = add %mul, %a</td>
</tr>
</tbody>
</table>

Unused and will be removed by the Dead Code Elimination pass.

We only select instructions that are suitable for duplication

![Diagram of instruction selection process](image)

We introduce a constraint: 

```
#dst ≠ #src
```

Registers are allocated in favor of duplication

The register allocator tends to reduce register pressure: Reusing the allocated registers as soon as possible.

When the liveness intervals (L) of registers are disjoint: 

```
{|L(vreg3)\cap L(vreg1)\cap L(vreg2)| = 0
```

Comparison with assembly approach

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Transformation</th>
<th>Duplication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>add r0, r0, r2</td>
<td>mov rx, r0</td>
<td>mov rx, r0</td>
</tr>
<tr>
<td>Our approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>add r0, r1, r2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AES 8-bit NIST on ARM Cortex-M3

<table>
<thead>
<tr>
<th>Unprotected</th>
<th>Protected</th>
<th>Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>6541 cycles</td>
<td>17311 cycles</td>
<td>× 2.03</td>
</tr>
</tbody>
</table>

**REFERENCE**

[1] Barenghi et al. Countermeasures against fault attacks on software implemented AES


**LEGEND**

- ✔️: Duplicable
- ❌: Not duplicable