HardBlare: a Hardware-Assisted Approach for Dynamic Information Flow Tracking

Mounir Nasr Allah, Guillaume Hiet, Muhammad Abdul Wahab, Pascal Cotret, Guy Gogniat, Vianney Lapotre

To cite this version:

HAL Id: hal-01311032
https://hal-centralesupelec.archives-ouvertes.fr/hal-01311032
Submitted on 23 Jun 2016

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**Introduction**

HardBlare proposes a software/hardware codesign methodology to ensure that security properties are preserved all along the execution of the system but also during files storage. The general context is to address Dynamic Information Flow Tracking (DIFT) that generally consists in attaching marks (also known as tags) to denote the type of information that are saved or generated within the system.

Let’s suppose that “print” function is public and the tag of a variable \( x \) is underlined in its name. The following example code demonstrates the usage of tags for type annotations:

\[
\begin{align*}
   \text{p} & = 3; \\
   \text{s} & = 42; \\
   \text{print}(\text{x});
\end{align*}
\]

Tag initialize Tag propagation Tag check

\[
\begin{array}{ccc}
\text{p} & \leftarrow \text{public} & \text{p} = 3; \\
\text{s} & \leftarrow \text{secret} & \text{s} = 42; \\
\text{x} & \leftarrow \text{p} + \text{s} = 5 & \text{x} = \text{p} + \text{s}; \\
\text{if (x != public)} & & \text{if (x != public)} \\
& & \text{raise interruption}
\end{array}
\]

**Static Analysis**

- During the compilation phase, a static analysis is done on the LLVM intermediate representation produced from the source code, and propagated to the ARM backend for the machine code generation.
- The result of static analysis gives a list of dependencies between information containers (e.g., registers, memory spaces...) for every basic blocks which are stored on a dedicated section in a ELF File.
- During run-time, the Program Trace Macrocell (PTM) generates a trace containing the address for each committed instruction modifying the PC value.
- Annotations related to the basic block identified by its address, given by the trace, are processed by the coprocessor to propagate tags.

**Example code**

```
{x = p + s;}
```

**State of the art**

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software</td>
<td>Flexible security policies</td>
<td>Overhead</td>
</tr>
<tr>
<td></td>
<td>Multiple attacks detected</td>
<td>(from 300% to 3700%)</td>
</tr>
<tr>
<td>Hardware</td>
<td>Low overhead (&lt;10%)</td>
<td>Invasive modifications</td>
</tr>
<tr>
<td></td>
<td>Few security policies</td>
<td>Fixed security policies</td>
</tr>
<tr>
<td>In-core DIFT</td>
<td>Low overhead (&lt;10%)</td>
<td>Invasive modifications</td>
</tr>
<tr>
<td></td>
<td>Few modifications to CPU</td>
<td>Energy consumption (x 2)</td>
</tr>
<tr>
<td>Dedicated CPU for DIFT</td>
<td>Low overhead (&lt;10%)</td>
<td>Wasting resources</td>
</tr>
<tr>
<td></td>
<td>Flexible security policies</td>
<td>Communication between CPU and DIFT</td>
</tr>
<tr>
<td>Dedicated DIFT Coprocessor</td>
<td>Low overhead (&lt;10%)</td>
<td>CPU not modified</td>
</tr>
</tbody>
</table>

**ARM Cortex-A9 Trace mode: CoreSight components**

- **Processing System (PS)**: ARM CoreSight Components export trace (for both CPUs) towards PL in PFT (Program Flow Trace) protocol.
- **FPGA Programmable Logic (PL)**: PFT Decoder decodes trace in usable format.
- **DFT Coprocessor**: Using decoded trace, DFT Coprocessor reads tags dependencies block.
- **DFT Coprocessor looks for the tags either in memory or tag register file.**
- **DFT Coprocessor computes tags depending on propagation rules.**
- **DFT Coprocessor updates corresponding tags.**
- **DFT Coprocessor checks for security policy violation and raise an interruption.**

**Main Contributions at a Glance**

- Hardware-assisted DIFT system with limited time overheads.
- Approach based on a non-modified CPU with a standard Linux and generic binaries. Could be implemented by industrial partners in medium-term.
- Hardened with hardware security mechanisms: trusted coprocessor storage and bus protection in terms of confidentiality/integrity.
- Contributions on software-related issues as well (static/dynamic IFC analysis, i.e. hybrid analysis).
- Perspectives on runtime reconfiguration and multicore/manycore systems.