PTCC Forward – 31/03/2026

Introduction to SAMVA

Antoine Gicquel - Sébastien Michelland

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Outline

1. Context
2. Introduction to SAMVA
3. Use case: CHAPATI

4. How it works - Algorithms
5. New features

Fault injection attacks evolution

Multi-fault : multiple fault injections during the same attack.

- Allows the disturbance to **persist over time**
  - Laser : multiple spots ; 300 instructions in a single fault [DRP+19]
  - Clock glitch : sequence of 20 instructions [CPH+21]
- Improved **spatial** and **temporal** precision

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Software countermeasures can be **compromised.** 

- Code and data redundancy
- Control flow integrity
- Specific data encoding

→ **Attacks require more code to be faulted** 

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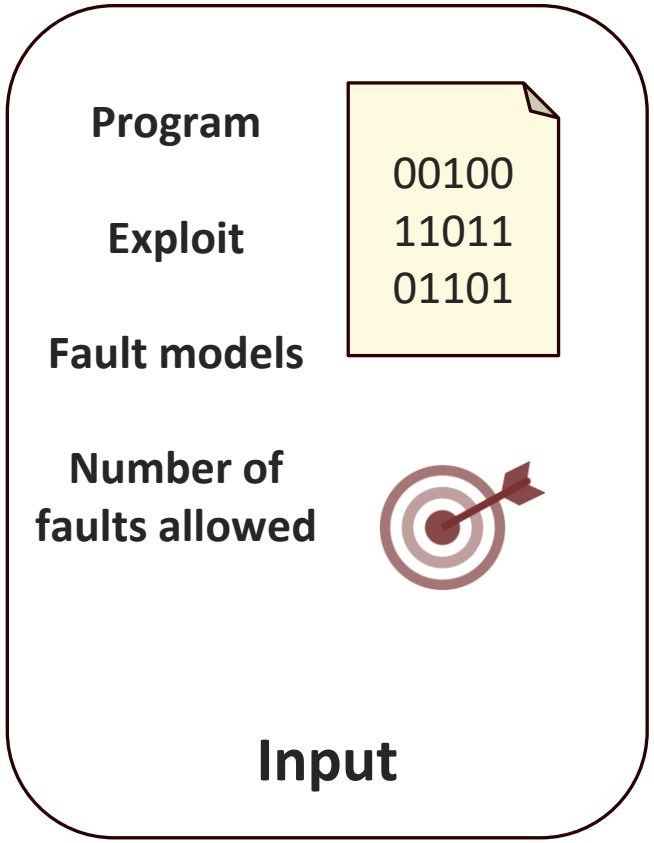
Program analysis



Assess security without conducting **fault injection campaign**.

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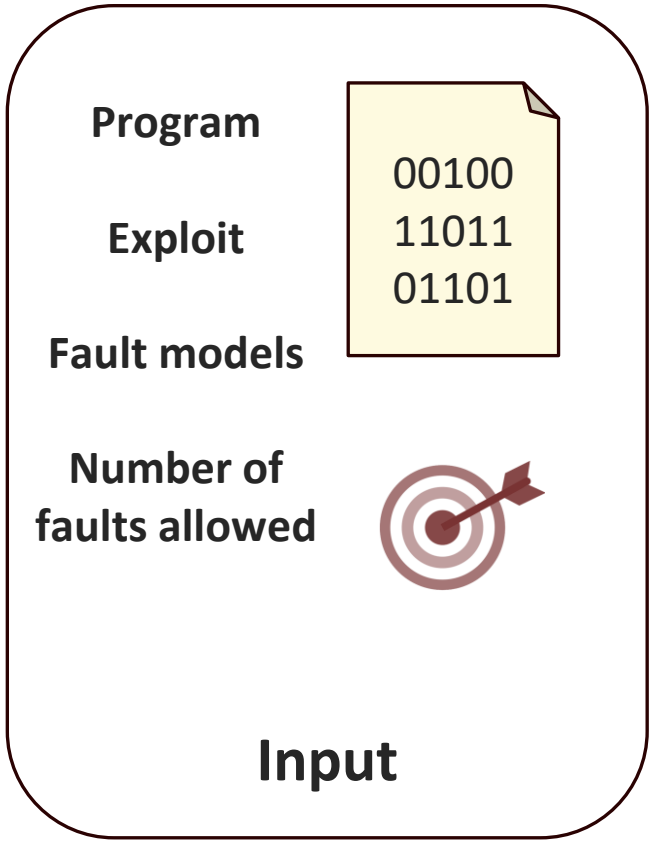

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- Fault models retrieved from characterization → **abstraction**
- Exploit depends on the program targeted
- Number of faults depends on the injection techniques

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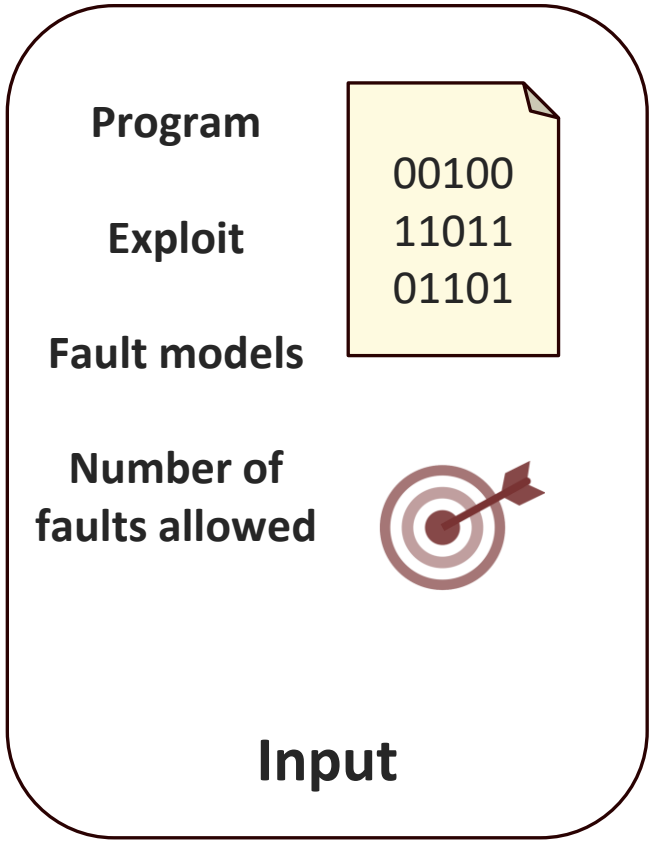

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Also helpful for **countermeasures** designers.

Program analysis

Program

Exploit

Fault models

00100
11011
01101

Number of faults allowed

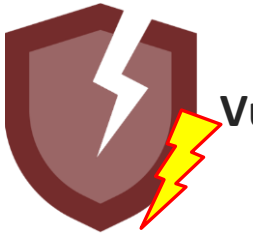
Input

Analysis

Simulation
Concrete values + Observation

Symbolic execution
Symbolic values + solver

Model checking
Formal model + Verification



Vulnerabilities

Formal proofs

Output

Difficulties related to multi-fault

Simulation: Impossible to be exhaustive

Symbolic execution: Forking / Solver

Model verification: Solver

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- Width of faults

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Here it comes... SAMVA

- **Antoine Gicquel PhD** ; **Sébastien Michelland Post-doc**
- Determines attack paths using **static analysis**
- Focus on **scalability** – numerous faults
- Supports **Arm** and **RISC-V**
- Written in Python, now open source!

Attacker threat considered

Accessibility exploit: reach several code locations while avoiding others,
e.g. granting authentication without getting detected.

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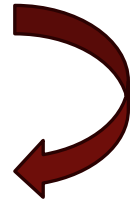
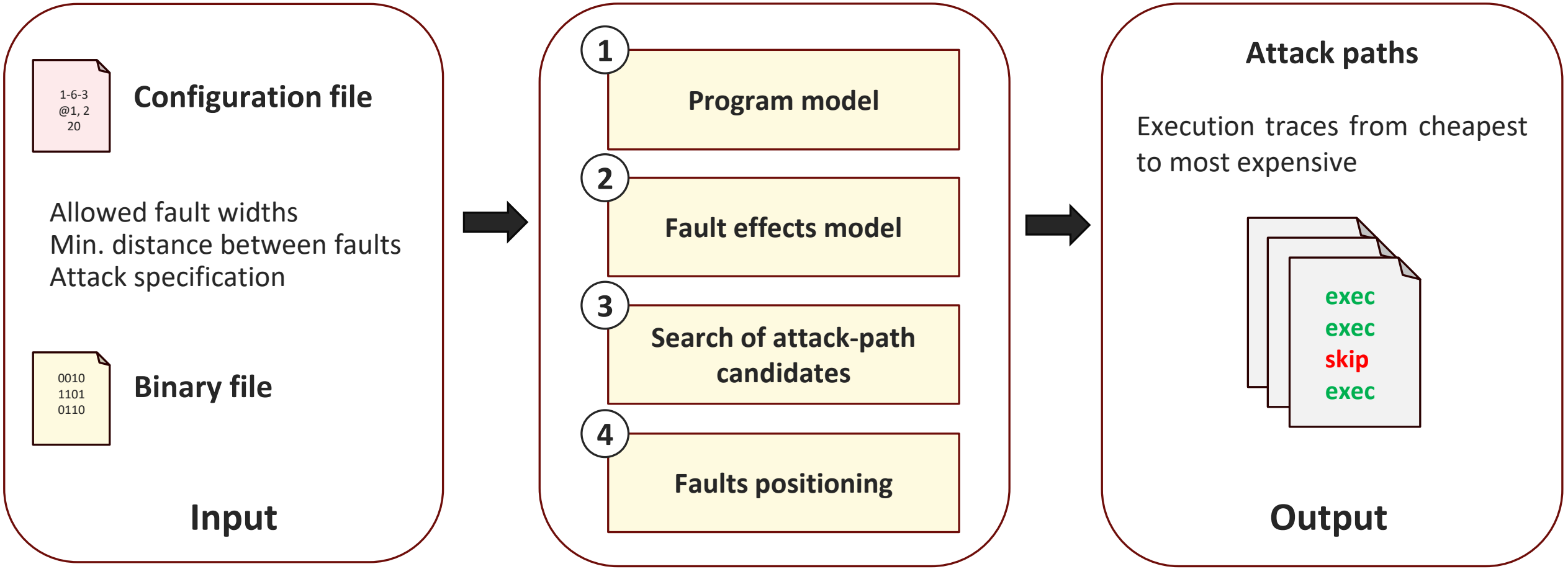


Word Replay

SAMVA Overview



1 Program model

Raw binary cannot be directly used by analysis → Require a **front-end**

- Disassemble the binary into instructions
- Analysis or reverse engineer some program properties
- Build intermediate representation (IR), in order to be architecture independent

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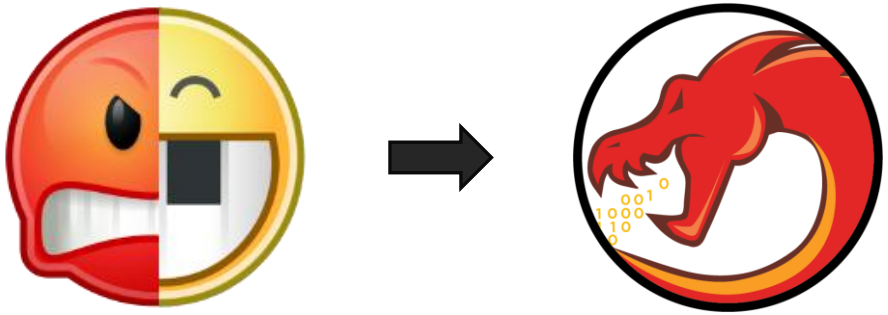
In the context of FORWARD, SAMVA switched from **angr** to **Ghidra**.



Supports **more architecture**, including RISC-V
Better **stability** and **support**

2 Fault effects model

- Build **Python objects** from PyGhidra and retrieve **instruction IR.**

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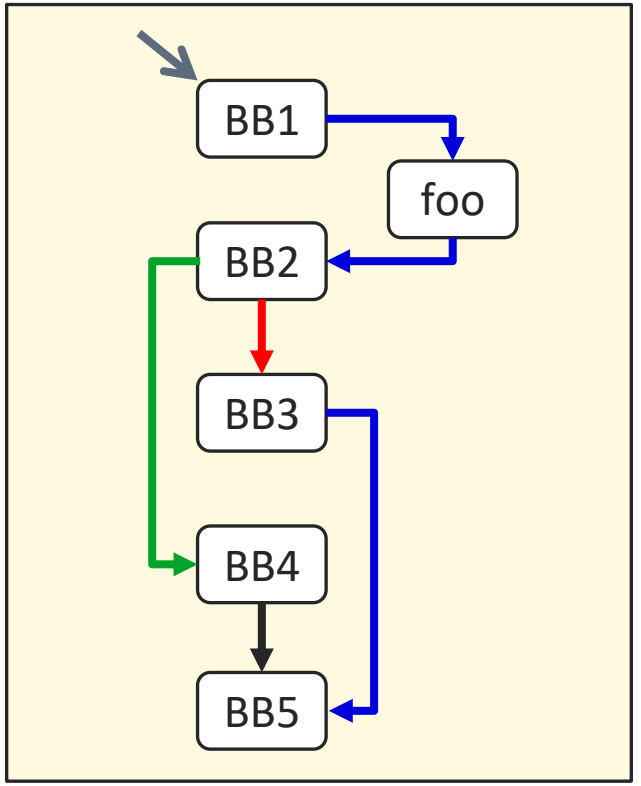
- Generate an **initial control flow graph (CFG).**
  - Node = basic block, i.e., straight-line sequence of code with only one entry point and only one exit
  - Edge = control flow between basic blocks, i.e., un·conditional branches



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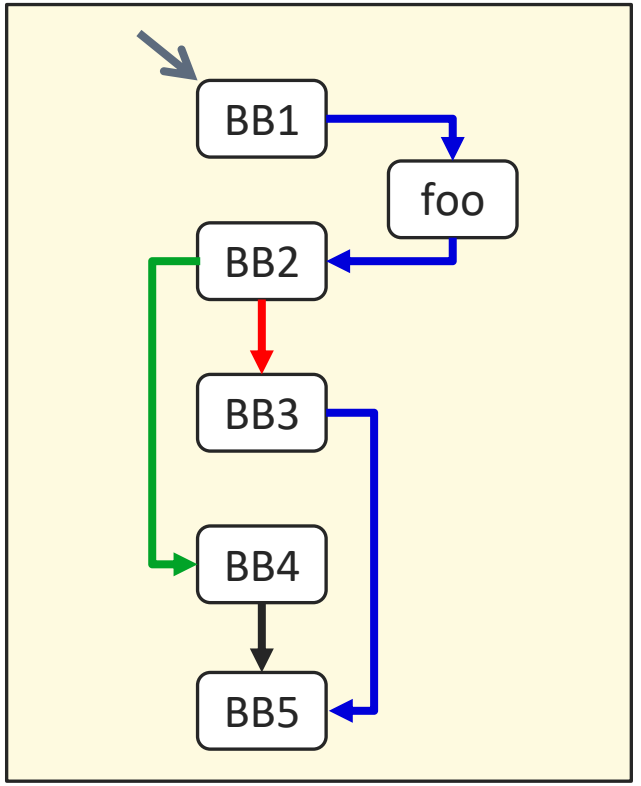
Afterward, **SAMVA runs passes** (in similar way as a compiler) by

- Adding or removing **edges** of the CFG
- Adding **attributes** on the edges of the CFG
- Adding **information** on instructions, words, basic blocks... All Python objects



Example of initial CFG

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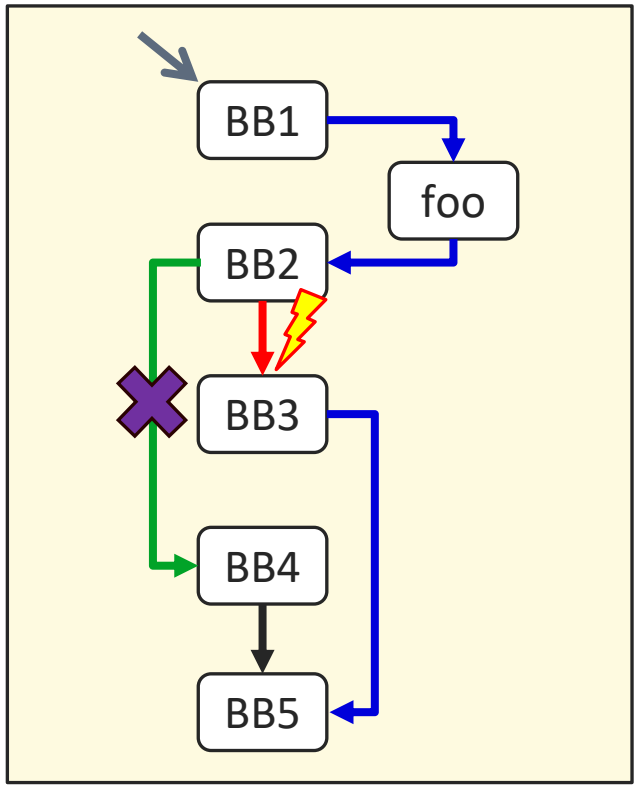
Remove the conditional branches edges



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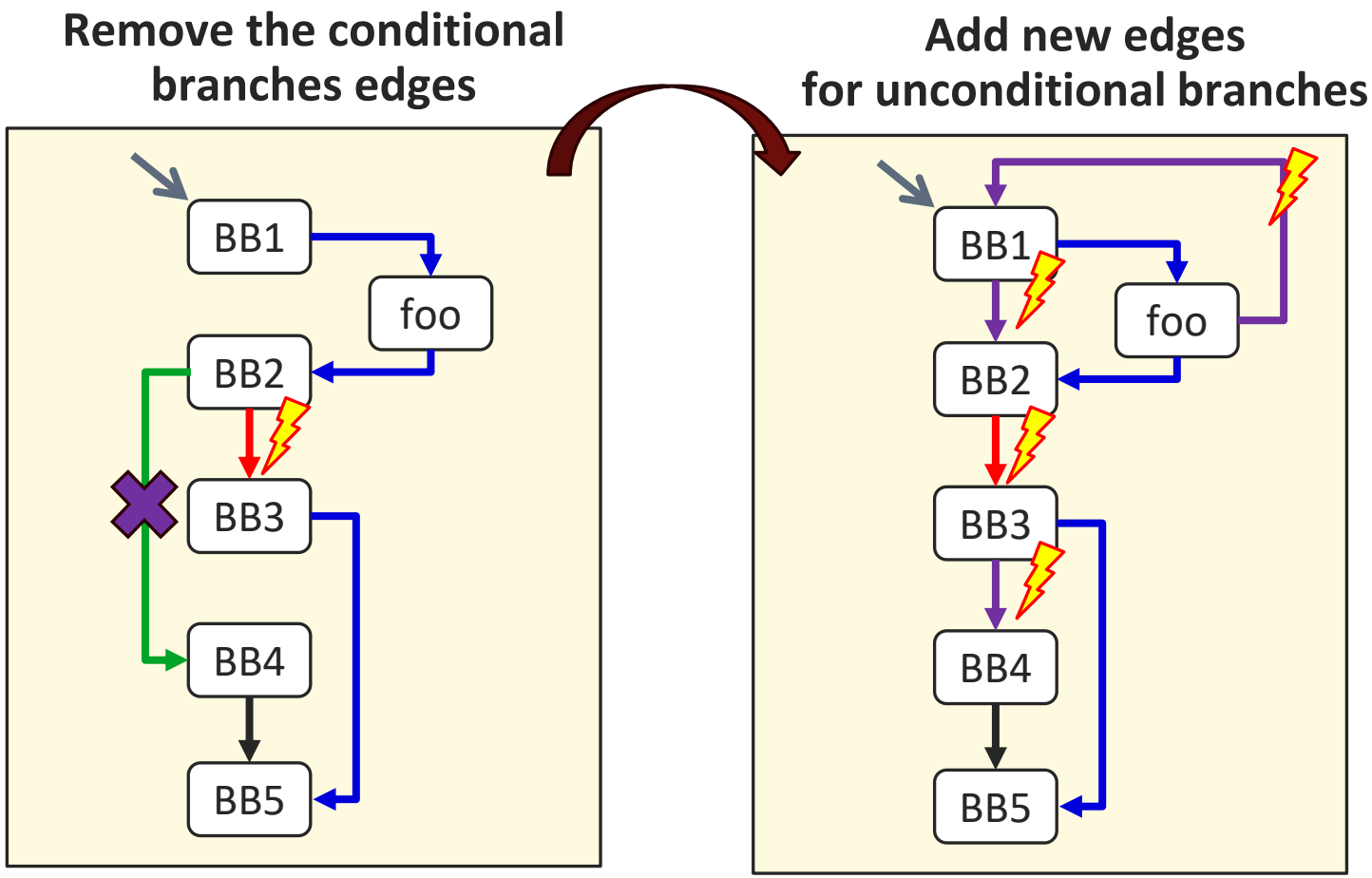

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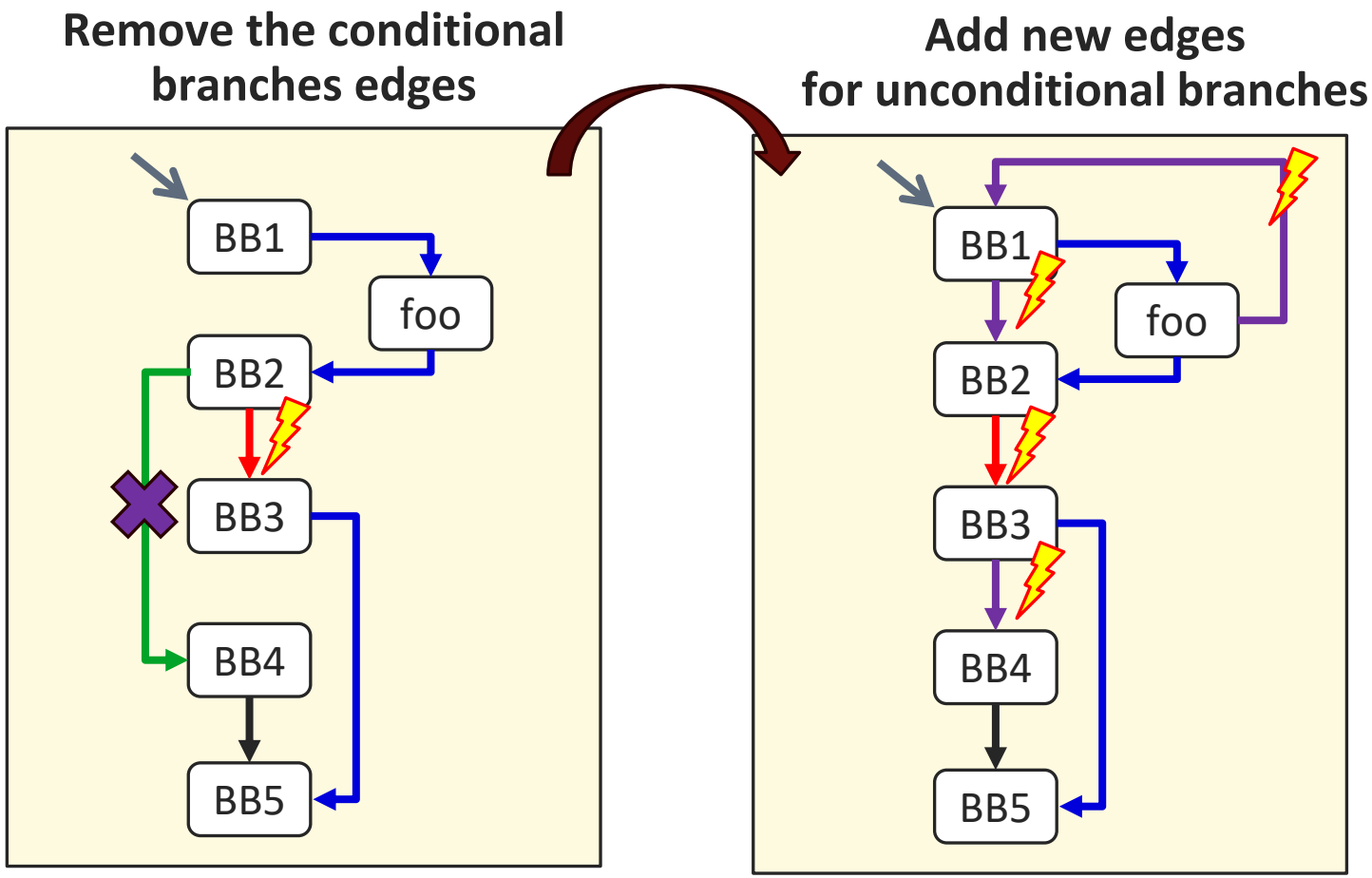
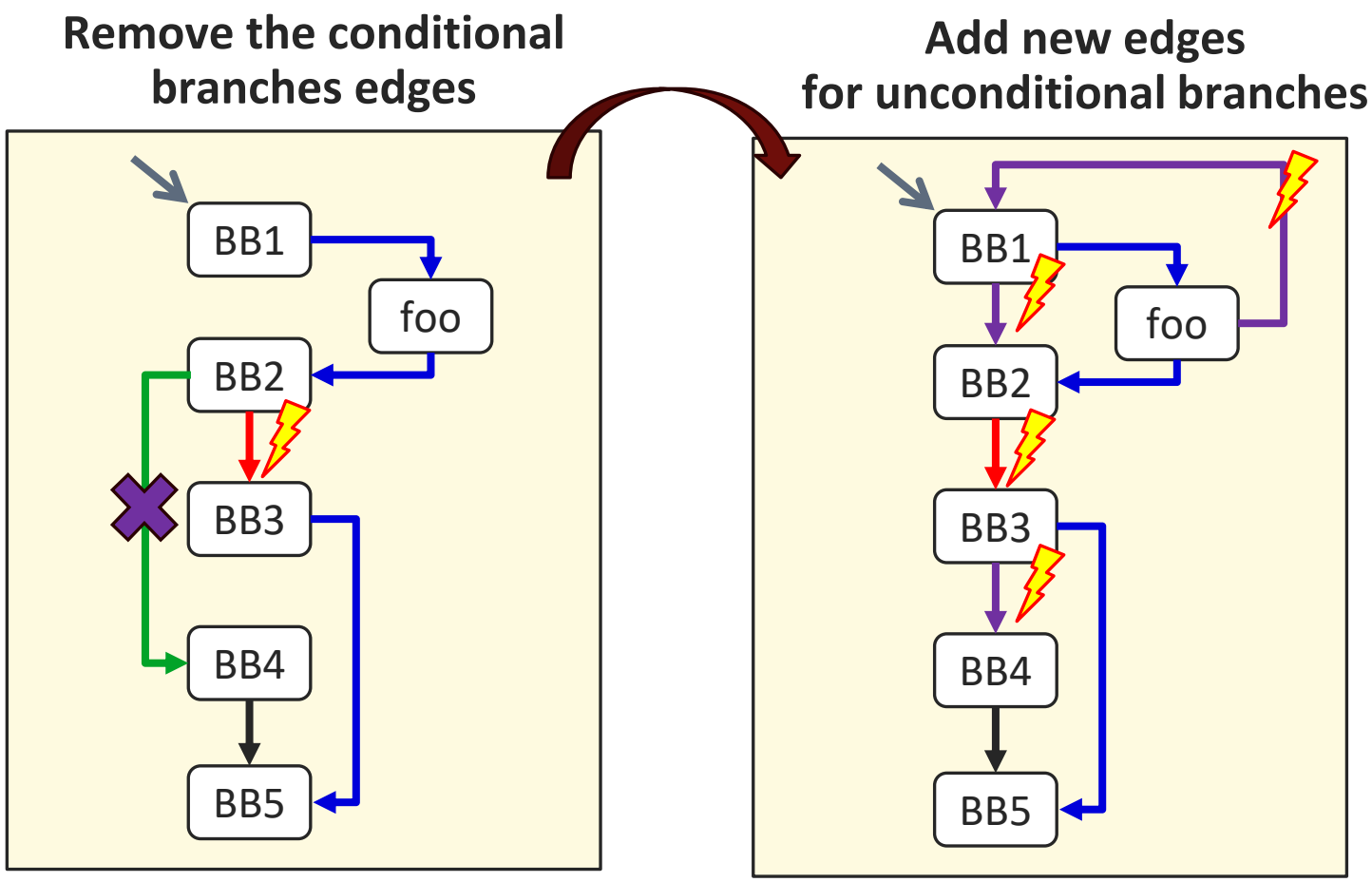


Add attributes on CFG edges.

Type per instruction

- **execute**
- **skip**
- **neutral**

Example of the instruction skip fault model



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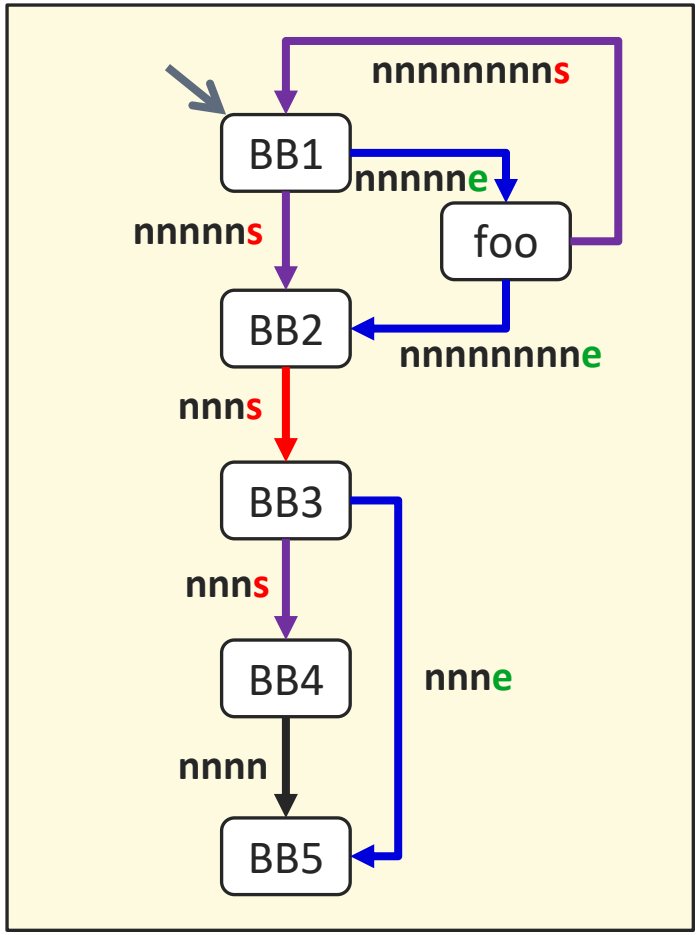
neutral is useful later to position the faults.

Additional typing rules can be executed (conditional passes).

3 Search of attack-path candidates (updated!)

Graph exploration algorithm

- Cheapest paths first
- Cost evaluation: fault positioning algorithm (Sébastien)



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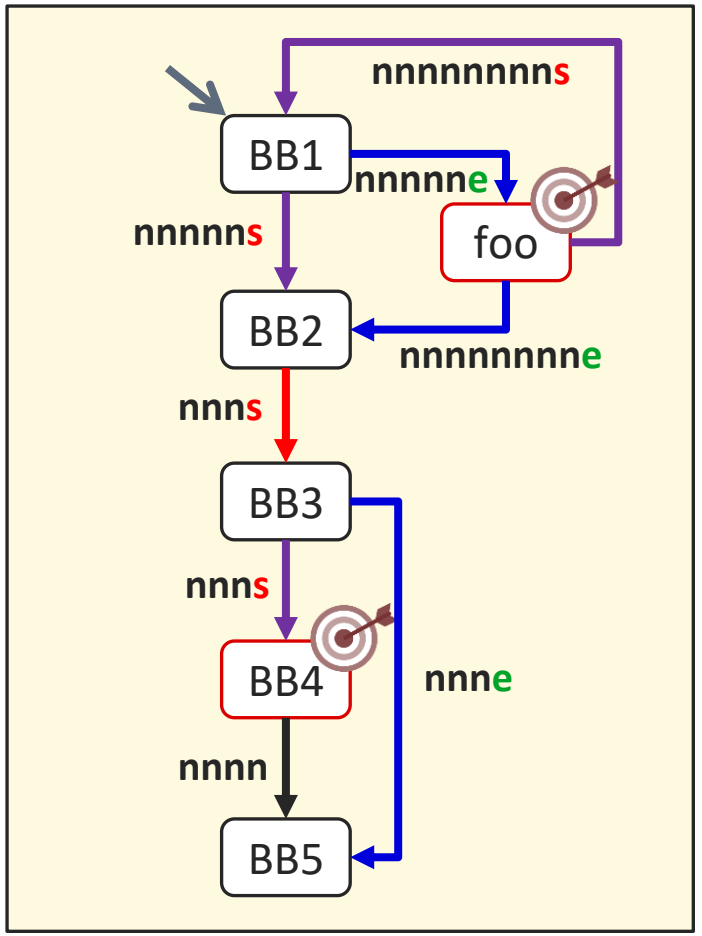
Depends on the exploit, e.g. targets = [foo; B4]



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Trace generation <address, instruction type>

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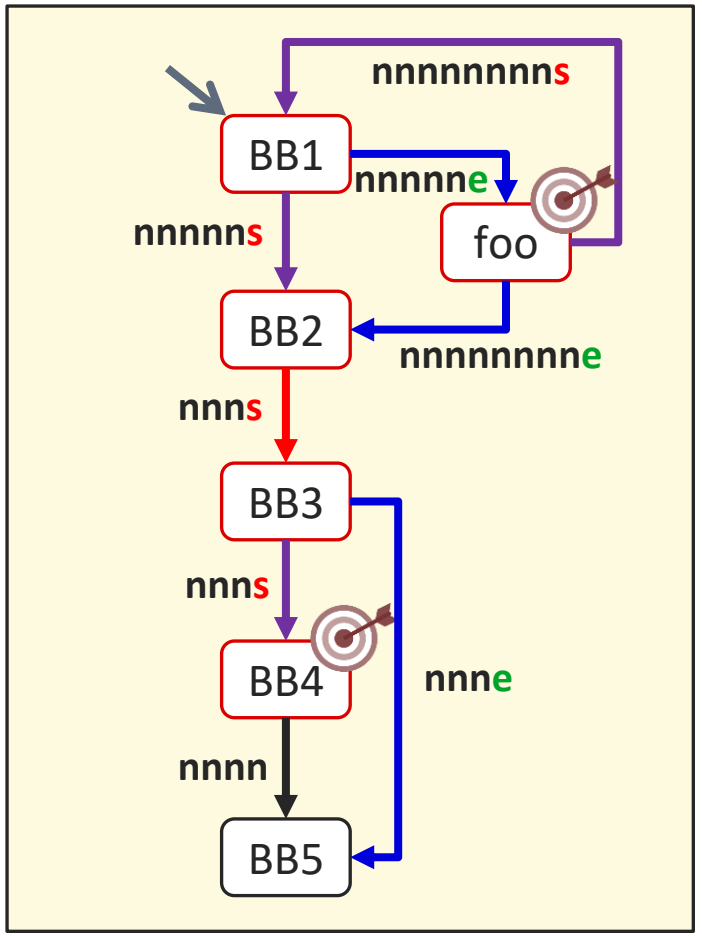
- **nnnnne + nnnnnnnne + nnnns + nnns**



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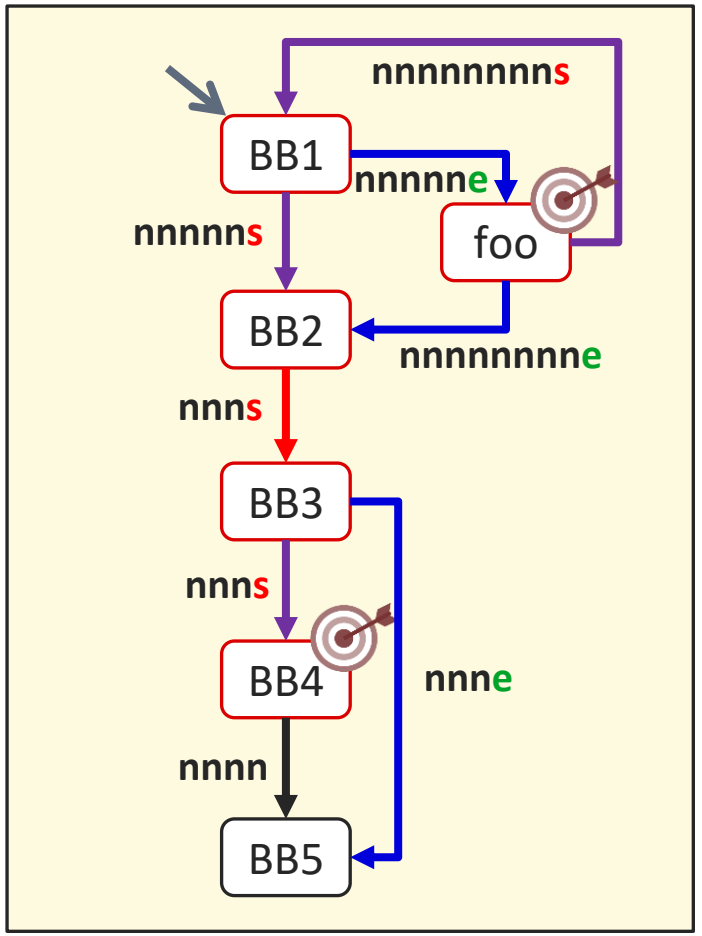
→ Possible according to attacker capacities?



4 Fault positioning (updated!)

```
0x104F8: execute
0x104FC: neutral
0x10500: neutral
0x10504: skip
0x10508: skip
0x1050C: neutral
0x10510: execute
0x10514: neutral
0x10518: neutral
0x1051C: skip
0x10520: skip
0x10524: neutral
0x10528: neutral
0x1052C: skip
0x10530: neutral
0x10534: neutral
0x10538: neutral
```

Conditions for fault positioning

- All instructions typed "**skip**" are covered by a fault
- No instructions typed "**execute**" are covered by a fault
- Fault width and distance between faults

Algorithm returns a list of fault sequences for a single candidate.
e.g. of a valid sequence: [(pos = 3, width = 3), (pos = 10, w = 5)]

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Can be validated using **simulation** with **Unicorn engine**.
Faults are simulated by PC manipulation.

Use case: CHAPATI

Difficulties to conduct physical fault injection attacks

- Lots of parameters to test: delay, duration, intensity, position of the fault
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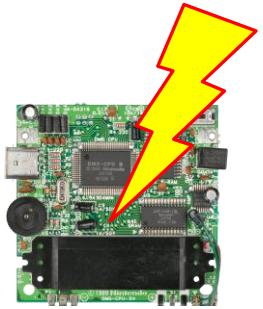
Program analysis → Enable an evaluator to find the instructions to fault, but...

How to conduct an attack from an attack path?

```
skip instruction x
skip instruction y
```


```
delay = 58 cycles
duration = 4 cycles
intensity = 0.7V
…
```



It is necessary to convert attack paths into physical parameters

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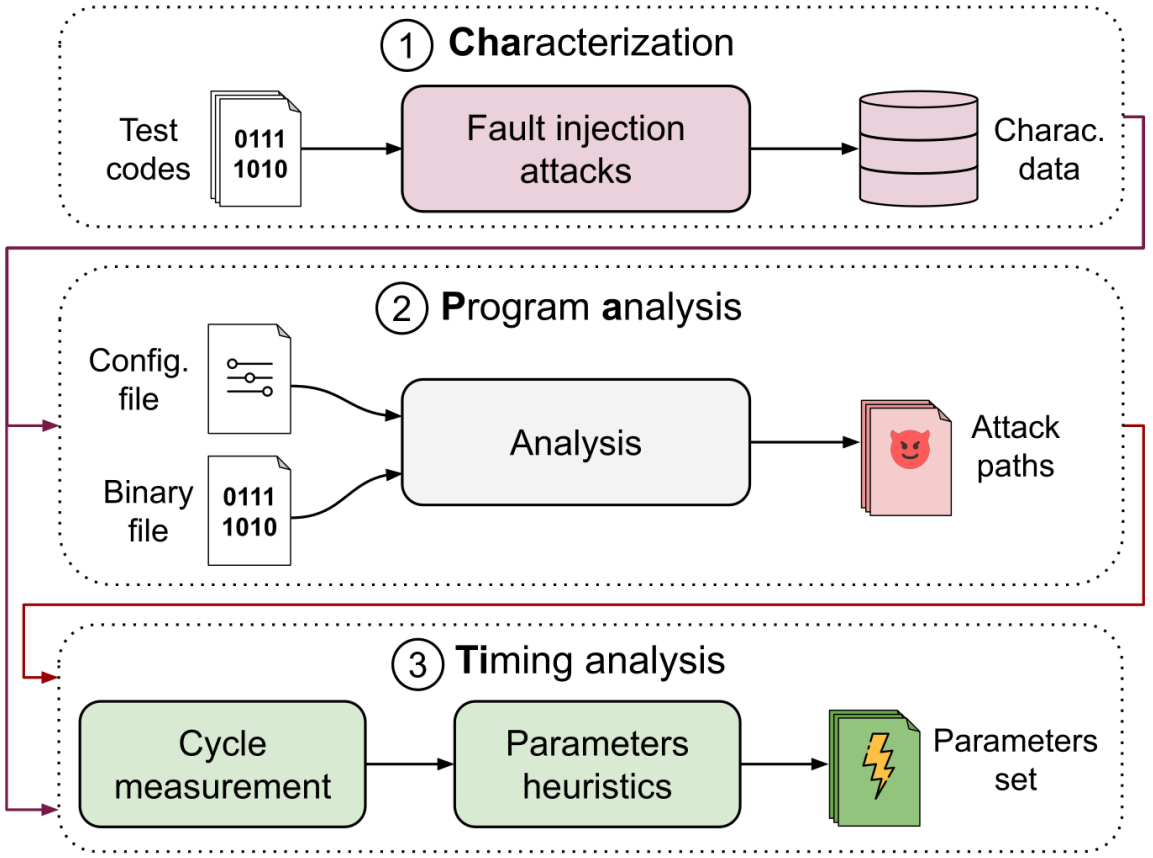

Methodology for facilitating multi-fault injection campaigns

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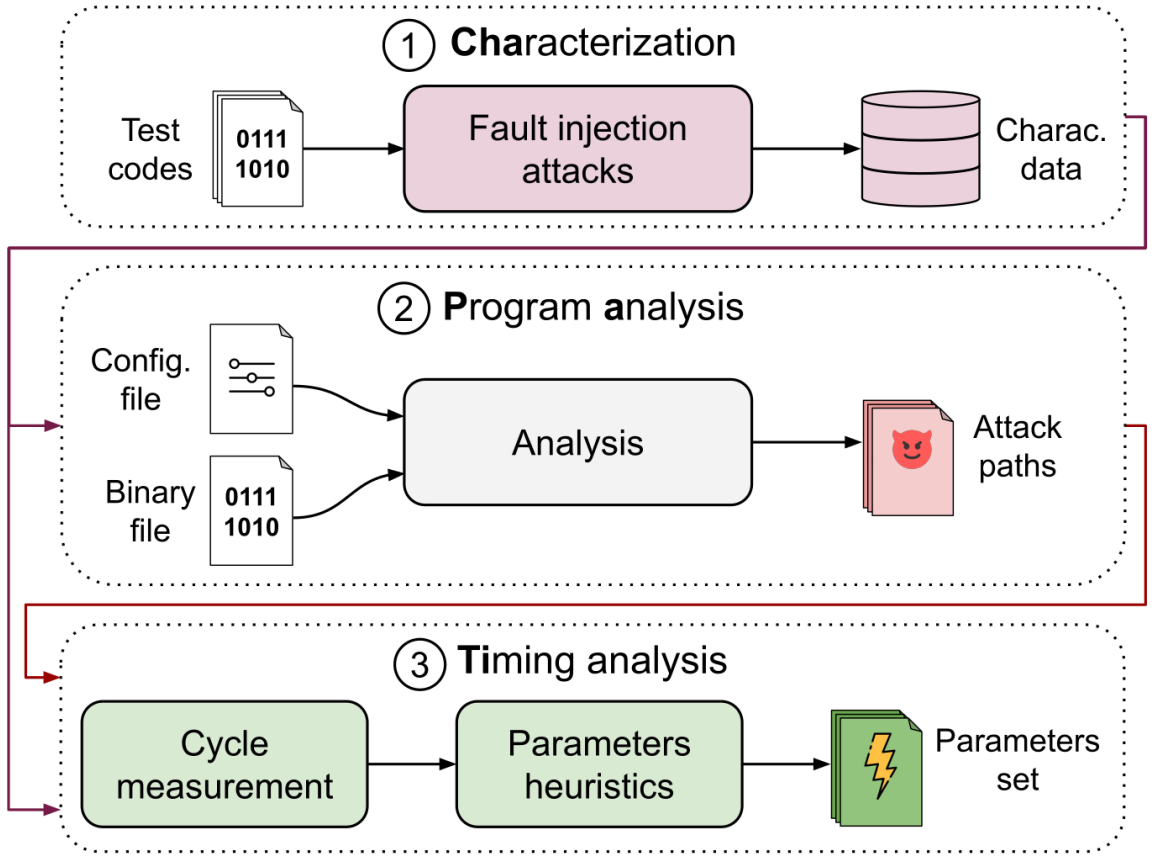

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Clock glitch experiments: Managed up to **8 faults** affecting more than **80 instructions**

Will be published at **HOST 2026** this year, let's meet there!

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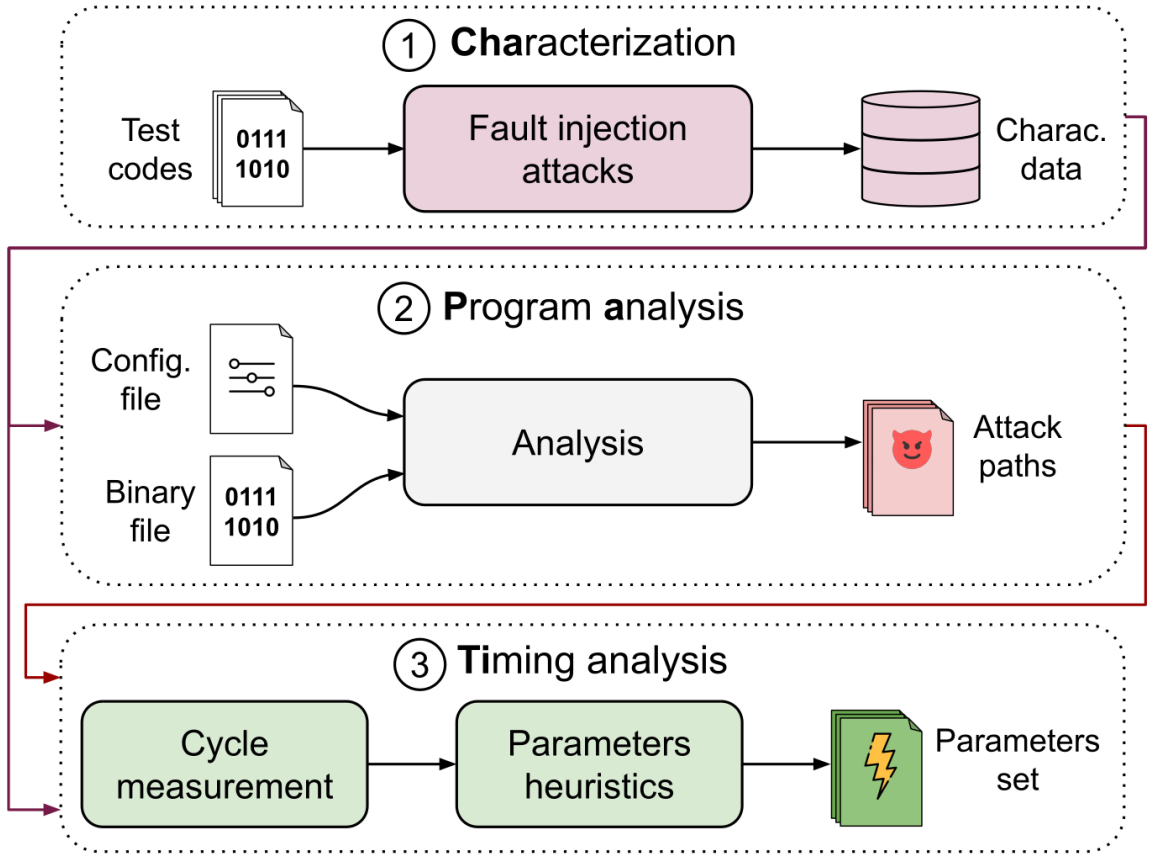

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