TRACK 2

HITB SECCONF
AMSTERDAM - 2021

LigthBranch : Binary fuzzing with snapshot-assisted-driven comparison branches analysis

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About me

- Kijong Son
- Security researcher @ KISA
- Penetration testing Instructor
  - Teaching courses
- Past Experiences
  - Penetration tester for 10+ years
  - Bug bounty program management
- Focusing on vulnerability and exploitation research

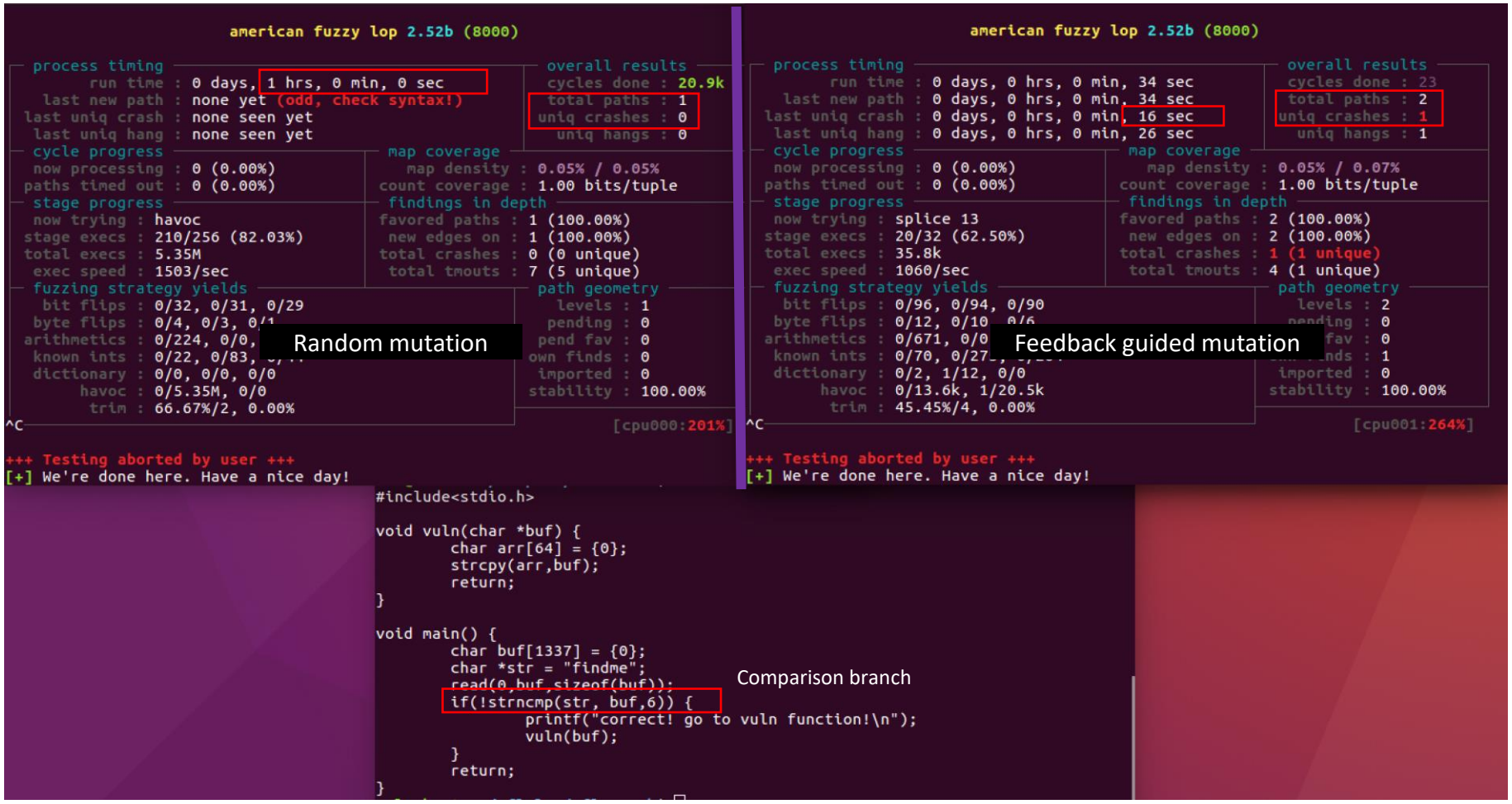
Agenda

- Motivation
- Introducing LightBranch
- Snapshot mechanism for input generation
- How we analyze comparison branches
- DEMO

Motivation

- Fuzzer tend to get stuck in the input validation code.
- Need to generate feedback information to guide fuzzer
- Time consuming to manually make a input dictionary.
  - Some mutation-based fuzzer supports user-supplied dictionaries
  - But In order to make a dictionary, It requires manual effort
- Automatic valid input generation for fuzzing

Random | Feedback



Interesting inputs

- Pre-defined Inputs that are required by program
  - Option, Command
  - File format
  - Protocol spec
- They tends to be compared at the front end of a program
- Play a big role in detecting new path during fuzzing

Input generation

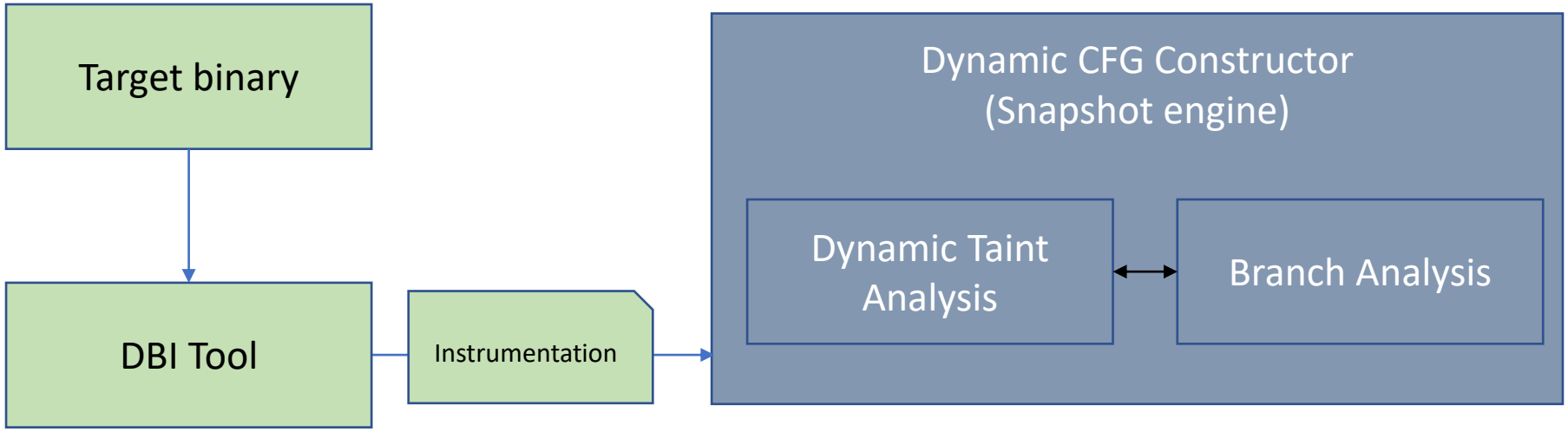
- Make a dictionary file
- Symbolic / Concolic execution
- Collect seed templates from web crawling
- Static/Dynamic binary or source code analysis

Our approach

Input learning with snapshot based comparison branches analysis

LightBranch Design

- LightBranch consists of three major components
  - (1) Dynamic CFG Constructor, (2) Taint analysis, (3) Branch analysis



Why snapshot?

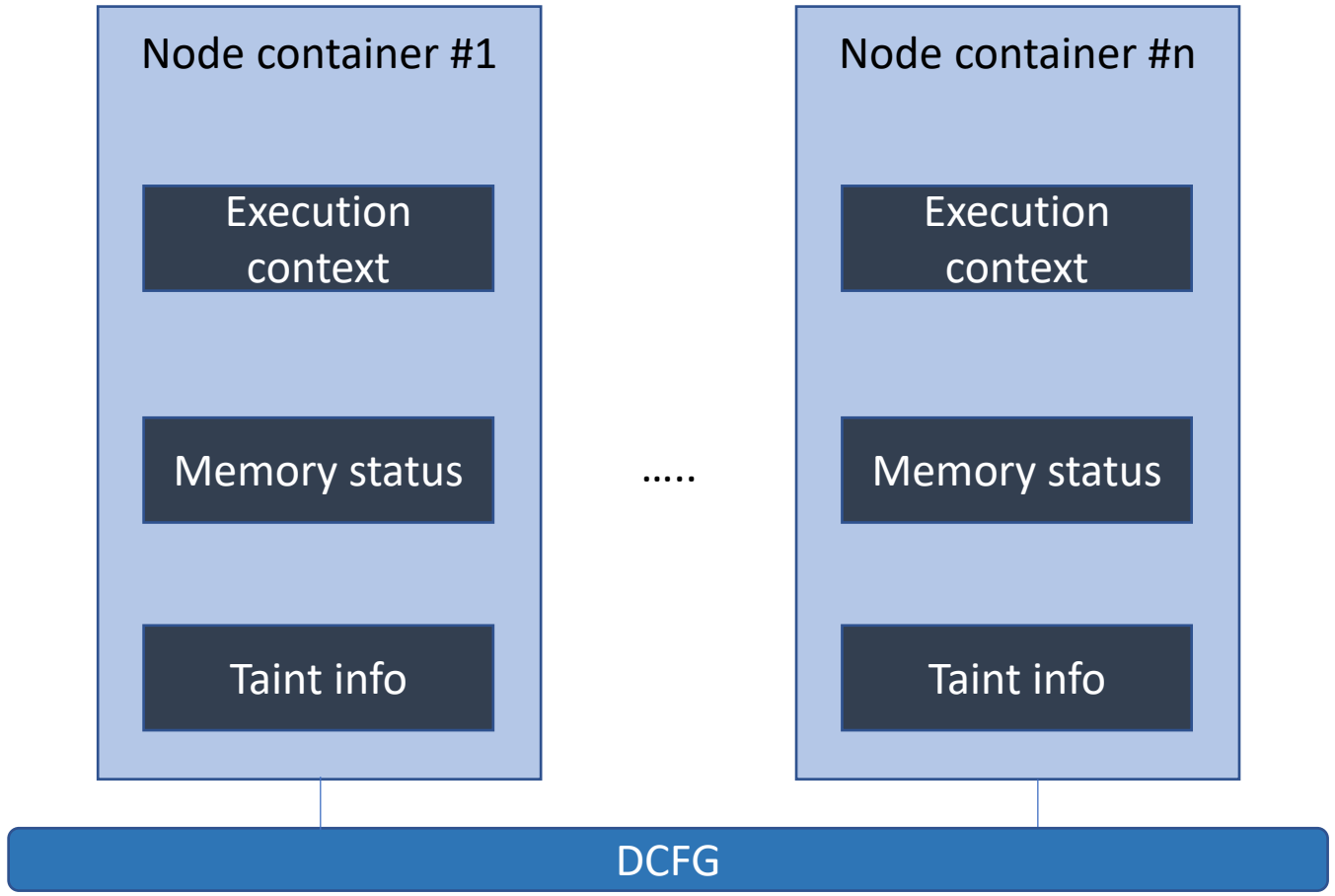
- Skip over unnecessary process startup code
- Execute both directions of conditional branch
- Extend taint propagation coverage
- More access to comparison branch with in-memory processing

Snapshotting with Dynamic CFG

- Generate dynamic control flow graph nodes
- Only conditional branch’s basic block is treated as node
- Each node represents a snapshot. It has a snapshot information
- Restoring a snapshot by referencing graph nodes
- Managing snapshot and restore scheduling

Node container internals

- Snapshot repository
  - Execution Context
  - Memory Status
  - Taint Information



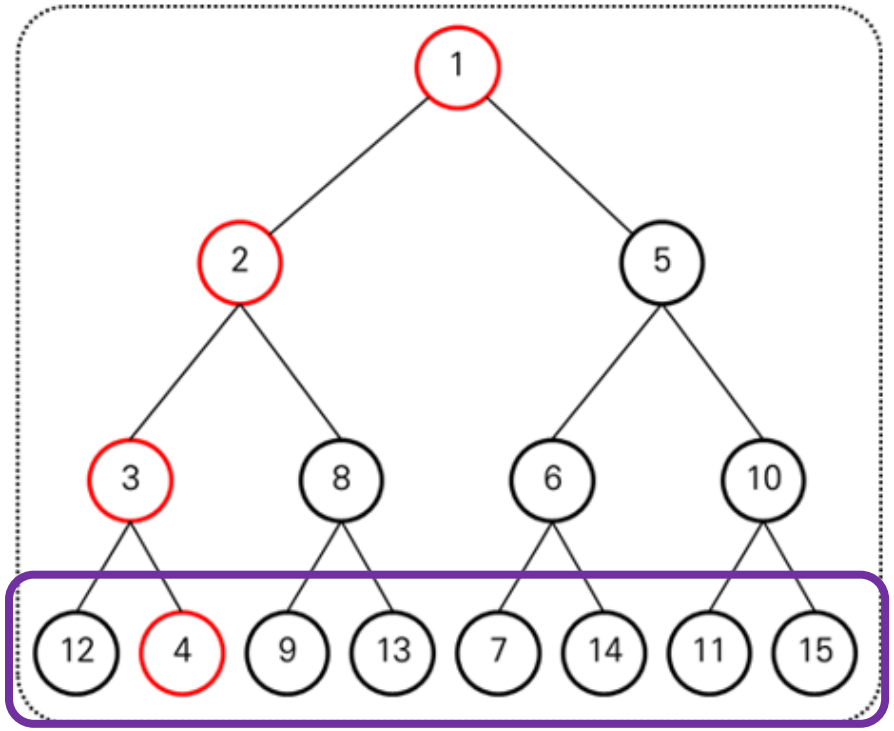
Snapshot creation flow

- Instrument head instruction of conditional branch's basic block
- Take a snapshot of runtime state of conditional branch
- Create node container to save snapshot information
- Manage all snapshots with CFG tree
- Restore snapshot under predefined conditions

Restore snapshot

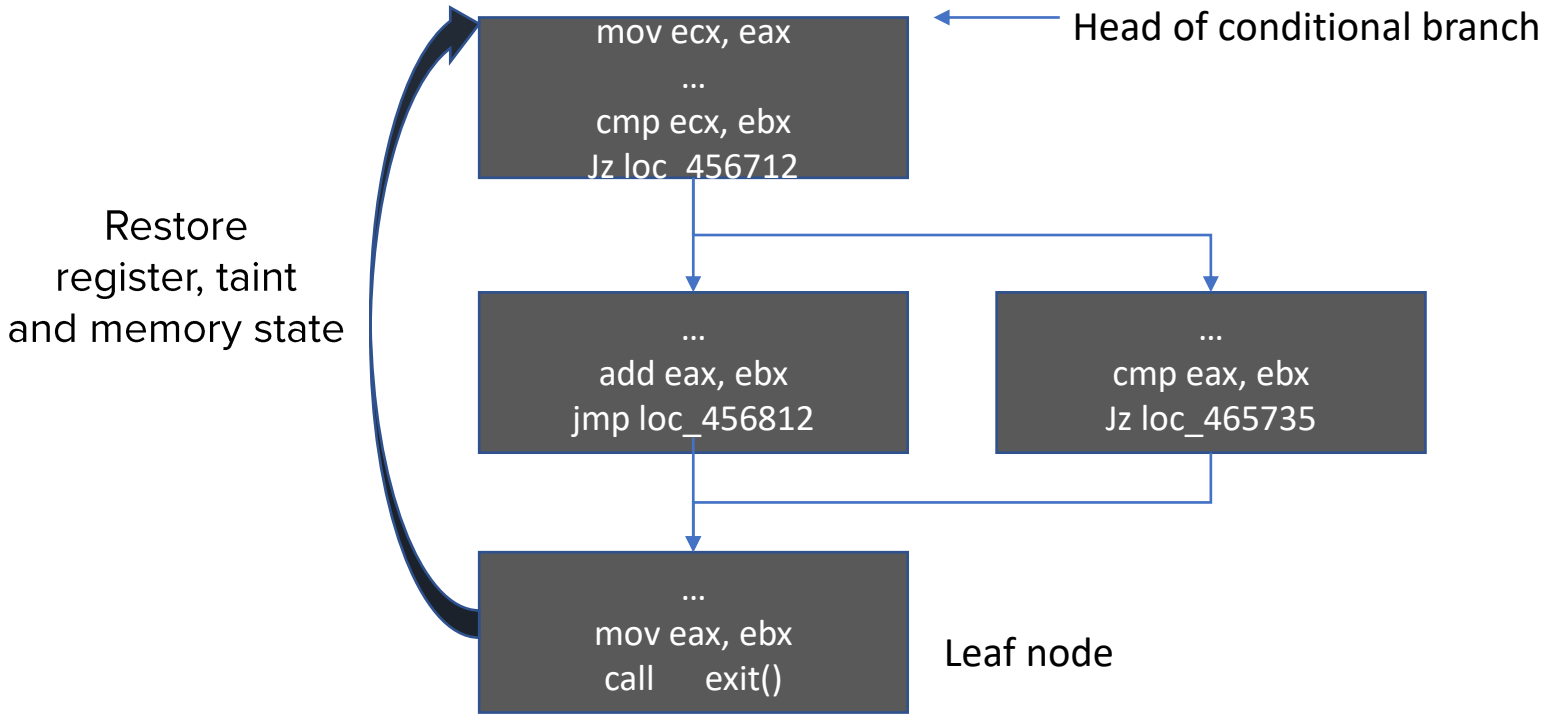
- The key idea for restoring snapshot is to detect leaf node.

- Leaf node that doesn't have child node
  - The end address of main function
  - Program exit functions are called
  - Exception signals are generated
  - Invalid instructions



Restore location

- Where is destination address for restoring?
  - The head of conditional branch's basic block



Snapshot rules

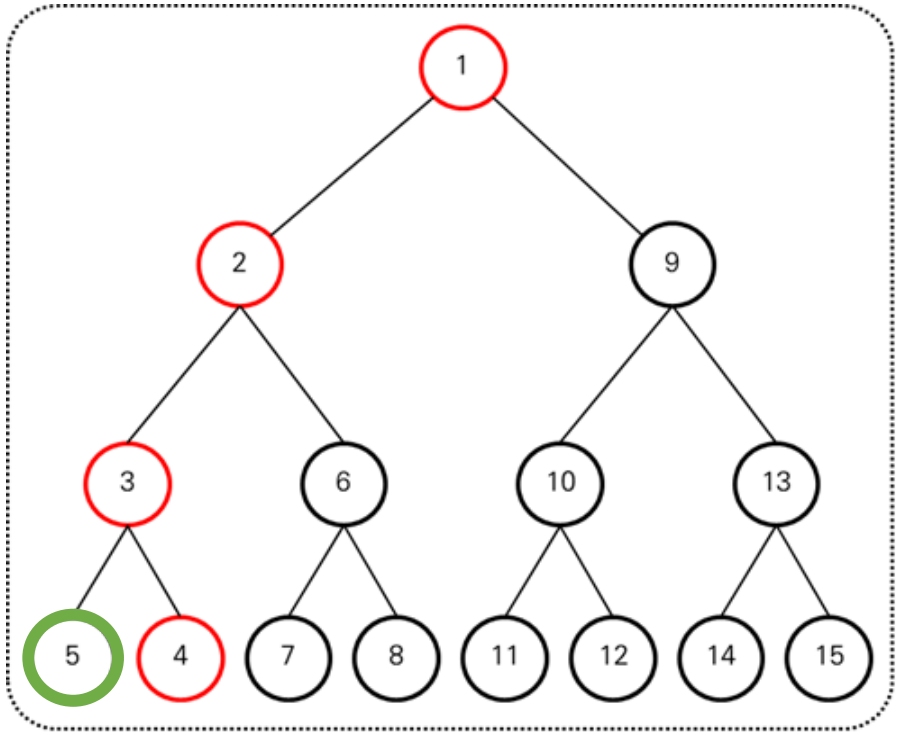
- Doesn’t take a snapshot for first basic block right after restoring
- The restored node is deleted from the node list
- (optional) Set depth of the deepest node level
- (optional) Allow the redundant snapshot mode

Memory snapshot

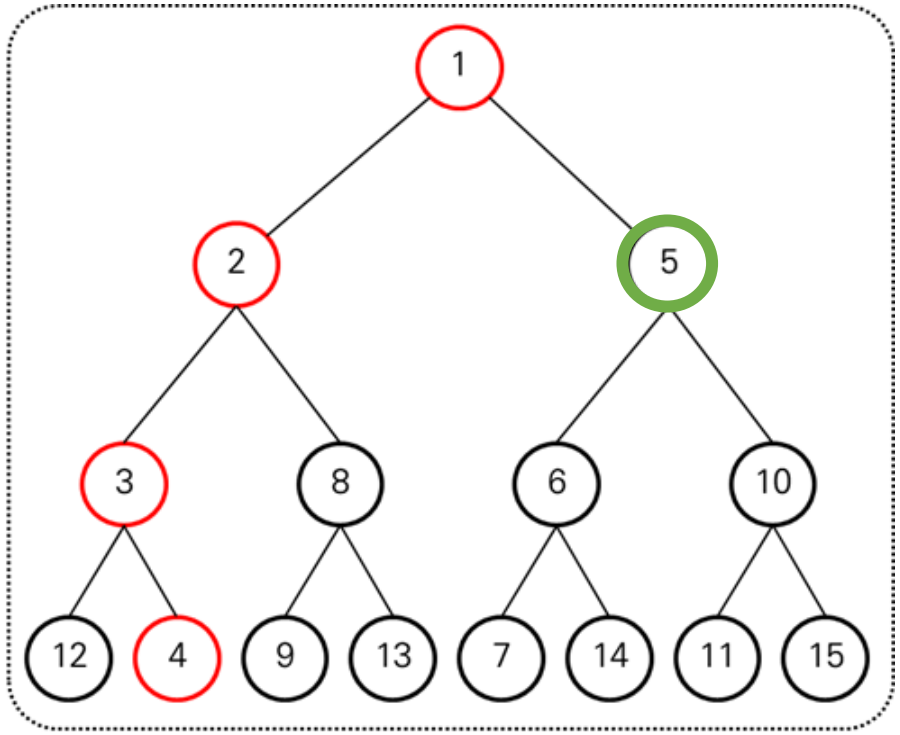
- Instrument the memory-writing instructions on trace level
- Preserve the original value of memory before writing
  - From the beginning of each conditional branch to right before being restored
- Save memory snapshot on each node container
- Memory snapshot rule
  - If a value is written to the same address multiple times, record only first original value in same node

Tree traversal for restore

- There are 2 cases of snapshot tree traversal



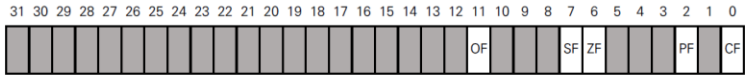
Bottom Up Restore



Top Down Restore

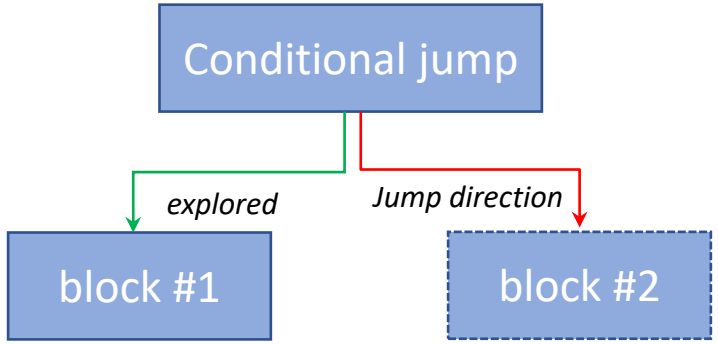
Control flow hijacking

- Check current flag register and then determine the jump direction



Instructions	Flags
JO	OF = 1
JNO	OF = 0
JS	SF = 1
JNS	SF = 0
JE JZ	ZF = 1
JNE JNZ	ZF = 0
JB JNAE JC	CF = 1
JNB JAE JNC	CF = 0
JBE JNA	CF = 1 or ZF = 1

Instructions	Flags
JA JNBE	CF = 0 and ZF = 0
JL JNGE	SF ⟨⟩ OF
JGE JNL	SF = OF
JLE JNG	ZF = 1 or SF ⟨⟩ OF
JG JNLE	ZF = 0 and SF = OF
JP JPE	PF = 1
JNP JPO	PF = 0
JCXZ JECXZ	%CX = 0 %ECX = 0



Validation check

- Read or Write Memory access
  - Collect address ranges from /proc/[PID]/maps file
  - Update address ranges because of dynamic memory allocation
  - Check invalid memory access
- Indirect call address
  - Get a register value and check if address is in code sections
- Null point access
- Double free and invalid free pointer

Snapshot for loop body

- Loop detection
  - Backward jump to address
  - Also check if jump address is greater than function's start address

- (optional) Set loop Iteration threshold to escape loop
  - To avoid unnecessary loop iteration
  - Count the number of execution times of backward jump
  - Restore snapshot if the threshold is reached

Comparison branch

- Compare with two operands and then jump somewhere

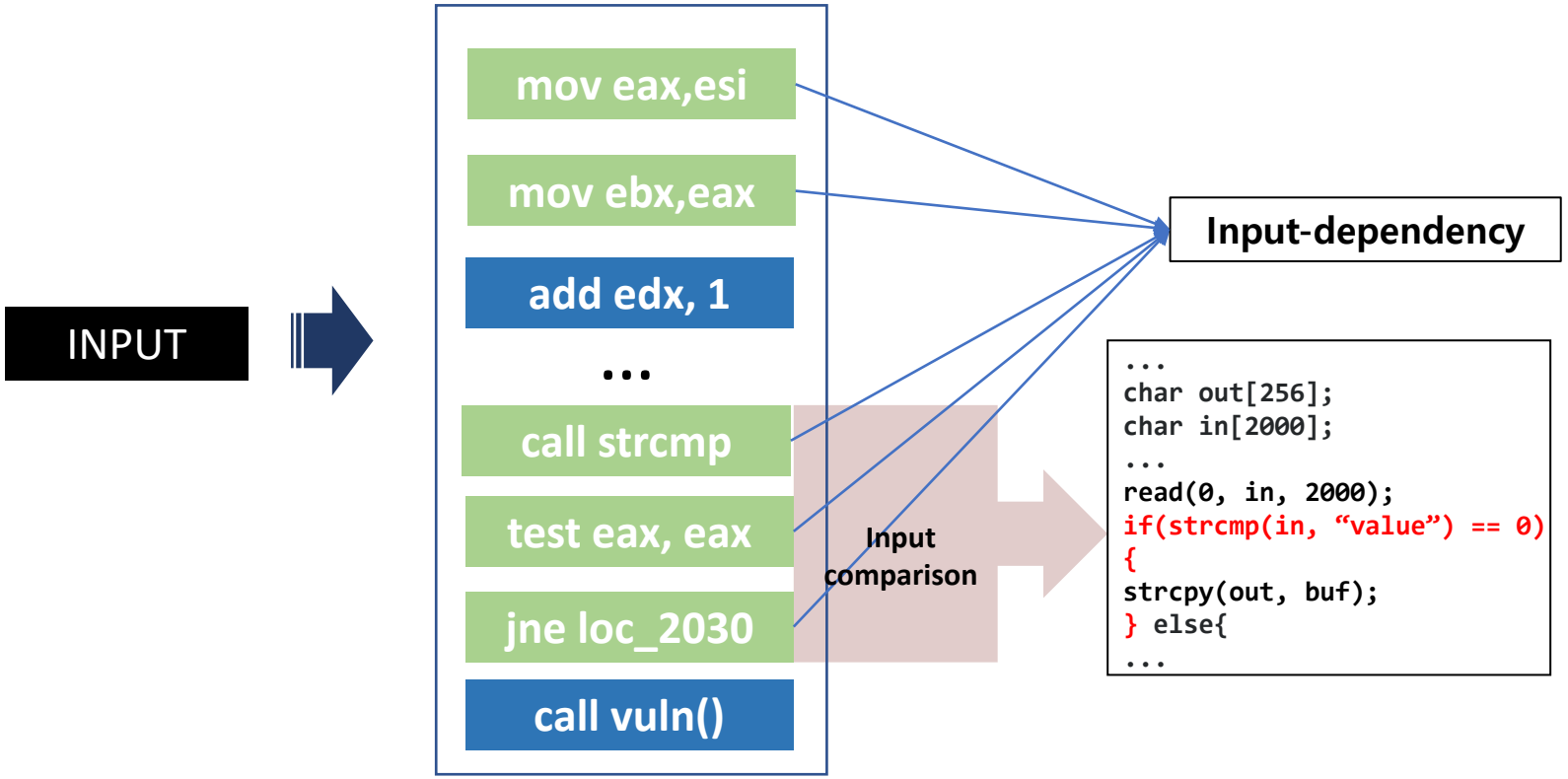
```
if(comparison_is_true) {
        do_something;
}
else {
        do_something;
}
```

```
switch(expression) {
  case x:
        do_something
  case y:
        do_something
  default:
        do_something;
}
```

- Use Cases : Single branch, Nested branches, Branch in the loop

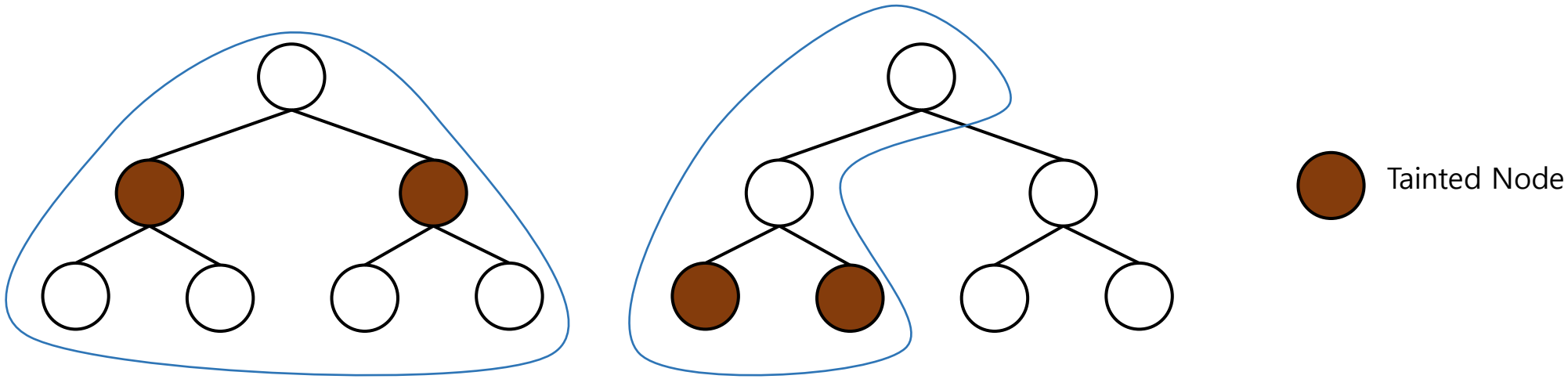
Input-dependency branch

- Dynamic taint propagation



Marking tainted node

- Tainted node in snapshot tree

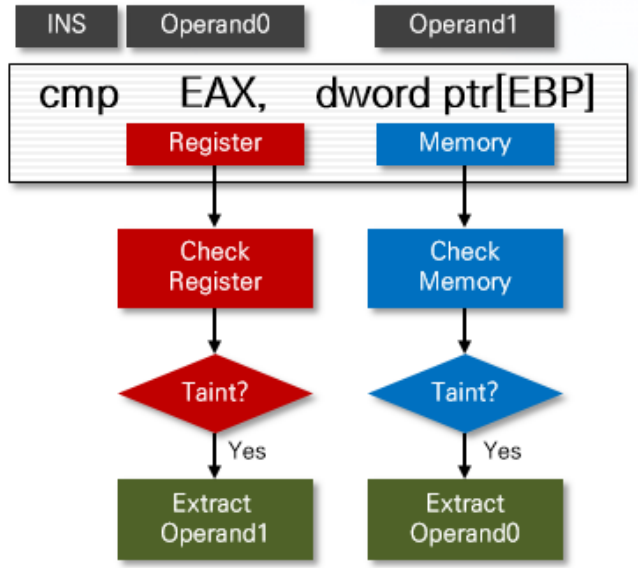


Extract comparison value

- Instrument compare instructions and functions
  - CMP and TEST assembly instruction
    - cmp, cmps, cmpsb, cmpsw, cmpsd, cmpsq, test
  - Repeat prefix instruction set(repe, repz, repne, repnz)
    - CMPSB, CMPSW, CMPSD, SCASB, SCASW, SCASD can be preceded by the rep prefix
    - Repeat execution of string instruction the number of times specified in counter register
  - *cmp library functions
    - memcmp
    - strcmp family

Extract comparison value

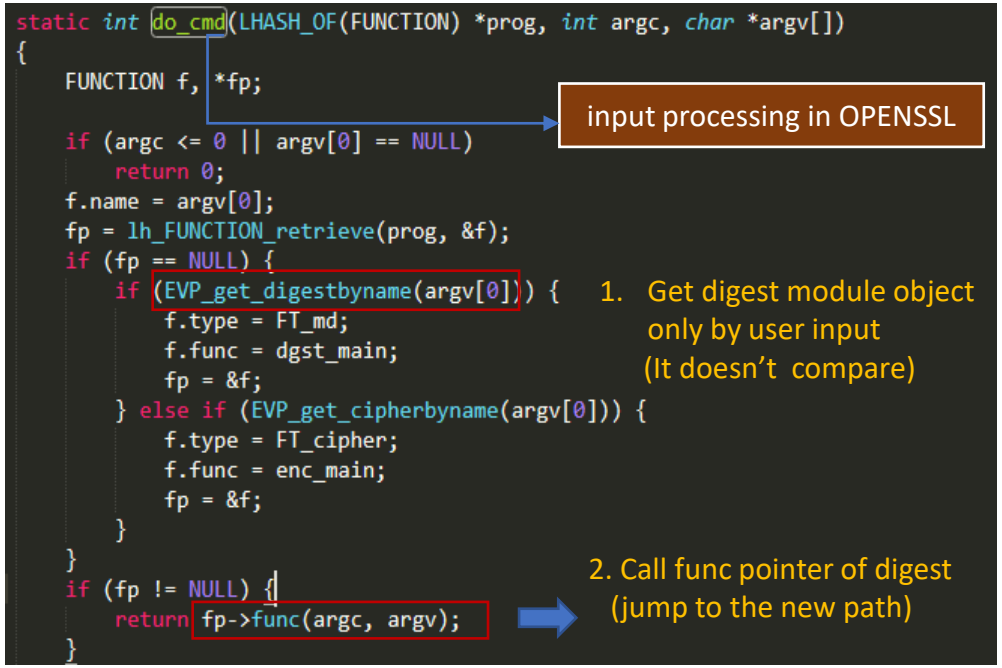
- Identify location which actually has comparison value.
- Which operands are tainted at comparison time
  - We need to identify non-tainted operand
- Check operand type of ‘non-tainted’ operand
  - Register, memory and immediate value
- Extract value of non-tainted operand according to type
  - CMP ➜ Get register, memory or immediate value
  - Rep prefix ➜ Get memory(RAX, RDI, RSI) with ECX
  - *cmp function ➜ Get argument



Support

- In Scope
  - Raw value of target operand

- Out of Scope
  - Compare it with transformed input
    - Dynamically encoded or encrypted
    - And there is no original of comparison value
  - No comparison target value
    - Get function pointer only by user input



Comparison of values from offset

- Extract the offset of ‘tainted’ operand
  - For that, check whether tainted operand uses index addressing before comparison

- Type of offset
  - Indirect offset ➜ Index register
  - Direct offset ➜ Constant, Immediate value

- Offset type is determined at compile time

```
if(!strncmp(input[10], "conf", 4)) { something; }

/*
push   0x4
push   0x80485d0 ; ‘conf'
lea    eax,[ebp-0x48]
add    eax, 0xa                ; add addressing
push   eax
call   0x8048380 <strncmp@plt>
add    esp,0x10
test   eax , eax
jne    0x804853e <main+115>
*/
```

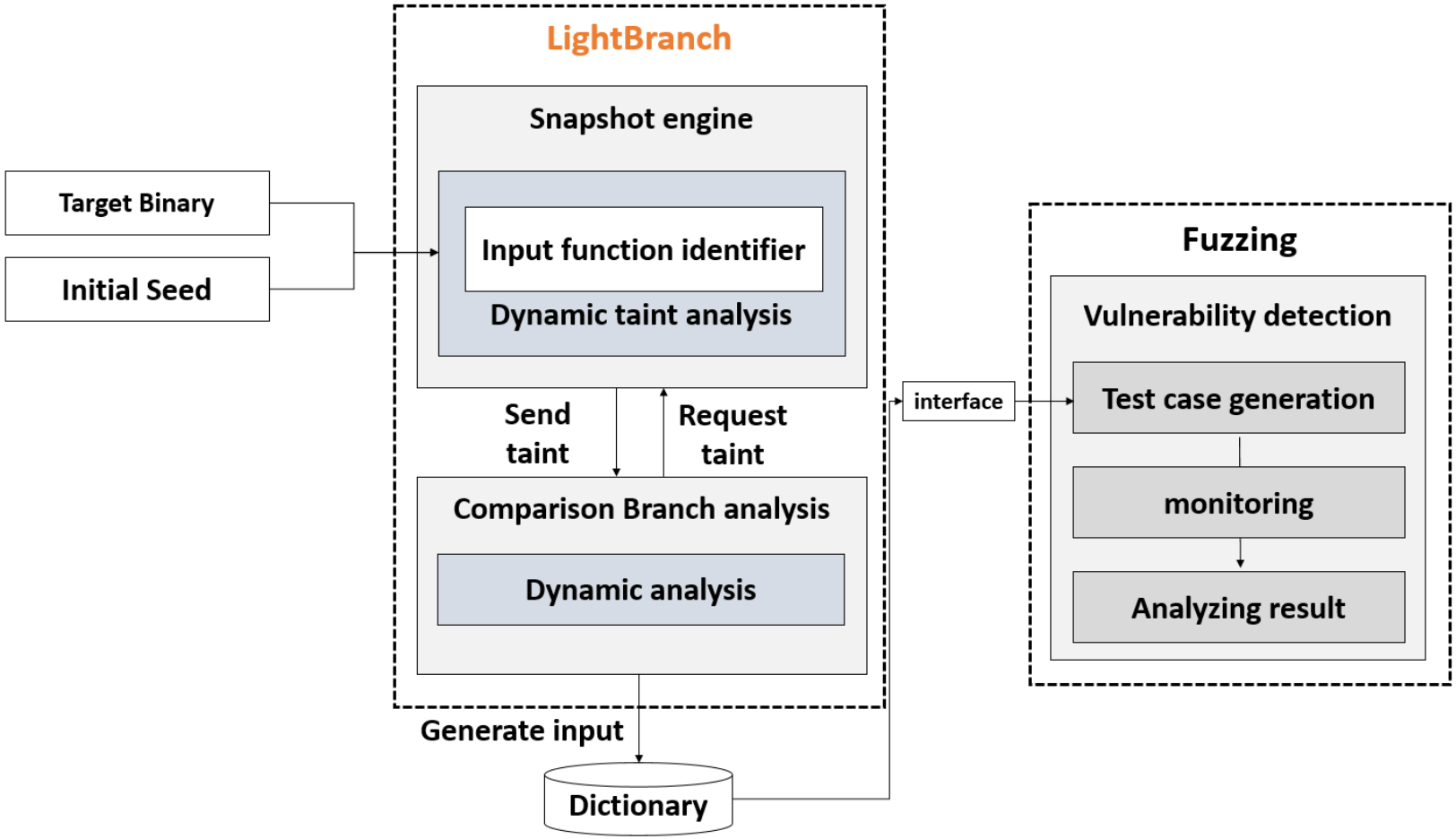
How we extract offset

- Use Backward taint analysis from tainted branch
- Which operands are tainted?
- Check the index addressing modes at a nearby basic blocks
  - Stack addressing, indirect/direct addressing, displacement addressing
- Extract offset value of “tainted” operand

Byte sequencing

- Identifying one byte character in the output
- Sort in ascending order of instruction addresses that was extracted
- Check offset value to concatenate byte strings
- Represent a sequence of bytes
- Save string to dictionary file

Fuzzing with LightBranch



Thank You

For your attention