Detecting and exploiting integer overflows

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Introduction to integer overflows
  Context
  Binary representation
  Integers misinterpretation

Automated detection
  Static binary analysis
  Data flow analysis
  Implementation

Conclusion
Work subject

Subject

Binary code static analysis for vulnerabilities detection
  ▶ Focus on arithmetic problems

Application security is critical for information systems
  ▶ Programming bad practices

Goals

  ▶ Work with a professional environment: IDA Pro
  ▶ Develop some analysis to make easier vulnerabilities detection
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Buffer overflow

![Diagram of buffer overflow with ESP and EBP registers showing local variables and parameters with 0x00000000 (low addresses) and 0xFFFFFFFF (high addresses).]
Buffer overflow vulnerabilities

**Exploitability**

Integer overflow can lead to buffer overflow
Buffer overflow can lead to arbitrary code execution

Integer overflows and buffer overflows top ranked by CWE
Exploitability (CWE):
- Buffer overflow: High to Very High (3rd)
- Integers overflow: Medium (16th)

**Conclusion**

We have to care about arithmetic overflow and avoid them
Buffer overflow vulnerabilities

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Basic C types on x86 32 bits:

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<tbody>
<tr>
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Signed values representation

For negative values, $MSB = 1$ (2’s complement representation)

\[\text{e.g. } -1 = 0xFFFFFFFF\]
x86 integers binary representation

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Dangerousness of misinterpreting

First issue

Small negative integers can be interpreted as huge integers

Dangerous cases:
- Sanity checks
- Copy operations
- Array indexations

Dangerous functions

Some famous functions: `strncpy`, `strncat`, `snprintf`, `memcpy`...
These functions take a length `unsigned` parameter
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**memcpy example**

```c
void *memcpy(void *dest, const void *src, size_t n);
```

⇒ What happens if this value is user-controlled?

Let’s take an example

**Bad**

```c
#define LEN 512
...
void vuln(char *src, int s) {
    char dst[LEN];
    int size = s;
    if(s < LEN) {
        memcpy(dst, src, size);
    }
}
...
vuln("Test", -1);
```
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Analysis

We have $size = -1 (0xFFFFFFFF)$
CPU compares $size$ and 512 as signed values

$\Rightarrow size < 512 == True$

Vulnerability

But `memcpy` takes a `unsigned` argument, so $size = 2^{32} - 1$

By consequences, a buffer overflow occurs

A potential attacker can take control of flow execution
 Dangerousness of misinterpreting

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We have \( size = -1 \) (0xFFFFFFFF)
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Pattern matching

Patterns

We look for interesting (= dangerous) patterns

Some patterns:

- Calls to dangerous functions (*memcpy, strncpy...*)
  - Search signed comparisons on unsigned parameters
- Dangerous instructions
  - `rep movsd`
- Array indexation
  - `movl $0x2a,−0×2c(%ebp,%eax,4)`
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Looking for interesting data dependencies

- Sensitive parameters (e.g. size from `memcpy`)
- Counter registers (e.g. `%ecx` for `rep` prefixed instructions)

Analysis steps

- Scan code to find interesting data
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Backward analysis

Dependencies

For a block $B$ we have: $\text{OUT}(B) = \bigcup_{S \in \text{Successors}(B)} \text{IN}(S)$
Backward analysis

Transfer function

Computes new tainted variables set for a basic block B:

$$IN(B) = F_B(StmSeq, OUT(B))$$

We must define a subset of x86 (grammar)

⇒ Focus on instructions that imply dependencies

Examples:

- $mov[\epsilon|s|sx|zx]$
- Binary operations ($add$, $addc$, $sub$, $sbb$, $and$, $xor$, $or...$)
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Environment

Several tools used:

- **Binary analysis environment**
  - IDA Pro
    - Very used in security industry
    - Powerful, many features available
      - CFG display
      - Several plugins

- **API**
  - First, IDAPython
    - API for Python script in IDA Pro
  - Then, Paimei Framework
    - Layer above IDAPython (easier to use)
Example on CVE-201-3970

[~] Search for predecessors: 0x5cb1fb46
[~] Previous bb: 0x5cb1fb21
push edi DEP: False
push eax DEP: False
call ds:__imp__CreateCompatibleDC@4 DEP: False
mov edi, eax DEP: True
cmp edi, ebx DEP: False
mov [ebp+var_4], edi DEP: True
jz loc_5CB1FCB8 DEP: False
[!] Pattern: 0x5cb1fbac : sbb eax, eax
[!] Pattern: 0x5cb1fbeb : cmp ecx, 100h : _CreateSizedDIBSECTION@28
Results

Pros:

- Automation
- Customization

Cons:

- False positive

Improvements:

- Improve data-flow analysis
  - Symbolic computation engine
- Add more dangerous code patterns
- Allow users to write their own patterns
  - Simple generic description language
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General conclusion

Great subject, interesting people

First approach in research

▶ Documentation stage
  ▶ Backward analysis
  ▶ Vulnerabilities examples

▶ Implementation experimentation

Use new tools, techniques and frameworks
Q & A