NC STATE UNIVERSITY

# CSC 574
# Computer and Network Security

# Sandboxing Applications

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## Native code

- Performance
- Legacy code
- Various languages

**Run a random binary on my system?**
**No way!**

## Sandboxing Native Code

## Trust the developer

- ActiveX, browser plug-ins, Java, etc.
- Code is signed
- Ask user if developer should be trusted
  - Good for known developers
  - Tricky for web applications

## Hardware/OS sandboxing

- Virtual machines
- Capsicum, seccomp
- OS kernel vulnerability
- OS incompatibility
  - System calls, threads, etc
  - Virtual memory layout
  - OS might not have a sandboxing mechanism
  - Might need to run it as root
- Hardware vulnerabilities

## Software Fault Isolation

- Before running a binary, verify it’s safe
- Safe instruction
  - Math, mov, etc
- Unsafe instruction
  - Memory access
  - Privileged instruction
- How to deal with unsafe instructions
  - Instrument
  - Prohibit

## Trusted Service Runtime

- Code that can be trusted and will perform the sensitive operations
  - Allocate memory
  - Threads
  - Message passing
- After verifying, safely run it in same process as other trusted code
- Allow the sandbox to call into trusted service runtime code

## Safety

- No disallowed instructions
  - Syscall, int
- All code and data within bound of module
  - Module cannot corrupt service runtime data structures
  - Module does not jump into existing code
    - ret2libc
    - ROP
  - Everything else should be protected from the module

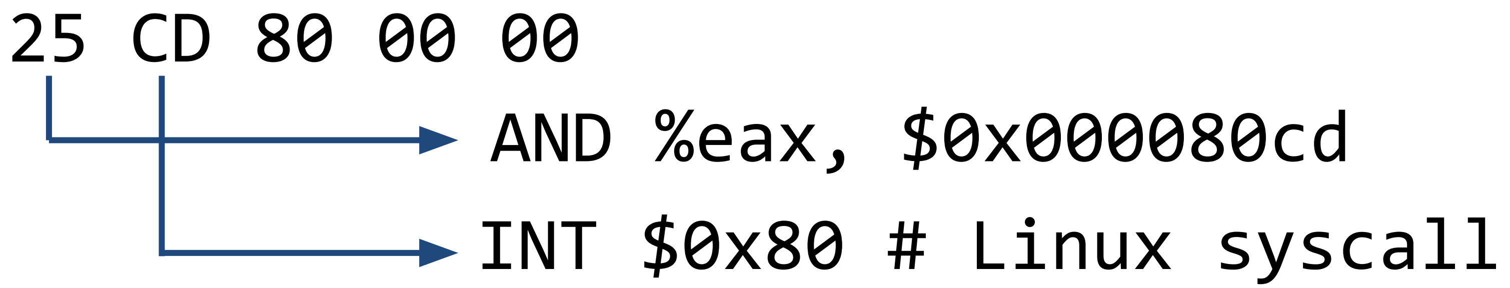
## Checks

- Scan the binary and look for “int” and “syscall” opcodes
  - If check passes, can start running code
  - All code is marked as read-only
  - All writable memory is non-executable

**Is this enough?**

## Check complications

- x86 has variable-length instructions
  - "int" and "syscall" instructions are 2 bytes long
  - Other instructions could be anywhere from **1 to 15 bytes**



```
25 CD 80 00 00
AND %eax, $0x000080cd
INT $0x80 # Linux syscall
```

**Should we scan the binary from every offset?**

## Reliable Execution

- Ensure code executes only instructions that verifier knows about
- Scan forward through all instructions, starting at the beginning
- If we see a jump instruction, make sure it's jumping to address we saw
  - Easy to ensure for static jumps (constant addr)
  - Cannot ensure statically for computed jumps (jump to addr from register)

## Computed jumps

- Add dynamic checks before jumps
- Checks for jumping to a register

```
AND $0xffffffe0, %eax # Clear last 4 bits
JMP *%eax
```

- Ensures that jumps go to multiples of 32-bit
  - Longer than the maximum instruction length
  - Power of 2
  - Fits trampoline code
  - We don’t want to waste space

## Computed jumps

- No instructions span a 32-byte boundary
- Compiler's job is to ensure these rules
  - Replace every computed jump with the two-instruction sequence
  - Add NOP instructions if some other instruction might span 32-byte boundary
  - Add NOPs to pad to 32-byte multiple if next instr is a computed jump target
  - Always possible because NOP instruction is just one byte

## Guarantees

- Verifier checked all instructions starting at 32-byte-multiple addresses
- Computed jumps can only go to 32-byte-multiple addresses
- What prevents the module from jumping past the AND, directly to the JMP?
  - The NaCl jump instruction will never be compiled so that the AND part and the JMP part are split by a 32-byte boundary. Thus, you could never jump straight to the JMP part

## What about RET instructions?

- Effectively a computed jump, but with address stored on stack
- Race condition
  - If we check the address on the stack, TOCTOU with another thread
- Prohibited
- pop + computed `jmp` code

## Segmentation

- We need to prevent jumps outside of the code
- x86 hardware provides "segments"
- Relative address within some segment
  - Segment specifies base+size
- Address translation:

(segment selector, addr) -> (segbase + addr % segsize)

## Invoking trusted code from sandbox

- Trampoline undoes the sandbox, enters trusted code
  - Starts at a 32-byte multiple boundary
  - Loads unlimited segment
  - Jumps to trusted code that lives above 256MB
- Trampoline must fit in 32 bytes
- Trusted code first switches to a different stack
- Trusted code reloads other segment selectors

## Service Runtime

- Memory allocation: sbrk/mmap
- Thread operations: create, etc
- IPC: initially with Javascript code on page that started this NaCl program
- Browser interface via NPAPI: DOM access, open URLs, user input, etc.
- No networking: can use Javascript to access network according to SOP

## Limiting code/data

- New segment with offset=0, size=256MB
- Set all segment selectors to that segment
- Modify verifier to reject any instructions that change segment selectors
- Ensures all code and data accesses will be within [0..256MB)

## How secure is Native Client

- Inner sandbox: validator has to be correct
- Outer sandbox: OS-dependent plan
- Why the outer sandbox?
  - Possible bugs in the inner sandbox.
- What could an adversary do if they compromise the inner sandbox?
  - Exploit CPU bugs.
  - Exploit OS kernel bugs.
  - Exploit bugs in other processes communicating with the sandbox process
- Service runtime: initial loader, runtime trampoline interfaces.
- Inter-module communication (IMC) interface + NPAPI: complex code, can (and did) have bugs

## What about buffer overflows?

- Any computed call (function pointer, return address) has to use 2-instr jump
- Only jump to validated code in the module's region
- Buffer overflows might allow attacker to take over module
- However, can't escape NaCl's sandbox

## Overhead

- CPU overhead dominated by code alignment requirements
  - Larger instruction cache footprint
- Minimal overhead for added checks on computed jumps
- Call-into-service-runtime performance seems comparable to Linux syscalls
- Average overhead is less than 5%

## Limitations

- Static code
  - No JIT
  - No shared libraries
- Dynamic code is possible to sandbox though!
  - Language-Independent Sandboxing of Just-In-Time Compilation and Self-Modifying Code

## You can use NaCl

```
<embed name="nacl_module" id="hello_world"
  width=0 height=0 src="hello_world.nmf"
  type="application/x-nacl" />
```

Source: https://developer.chrome.com/native-client/devguide/tutorial/tutorial-part1