Compilers and Security

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COMP 3002

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Outline

- Purposes
- Code obfuscation
  - control-flow graph obfuscation
  - variable hiding
- Digital signatures
- Code randomization
- Virtual machines
- Automated Theorem Proving

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Security and Compilers

- Tamper resistance
  - Code should run as shipped
  - Binary executables should not be modified
- Resistance against attacks
  - Buffer overflows
  - DoS attacks
- User security
  - Running untrusted binaries
- Attack scenarios
  - Attacker has access to
    - binaries, source code, a debugger, a service

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Code Obfuscation

- Code obfuscation makes the (compiled binary) code difficult or impossible to understand
- Different kinds of obfuscation
  - Flow-graph obfuscation
  - Variable hiding

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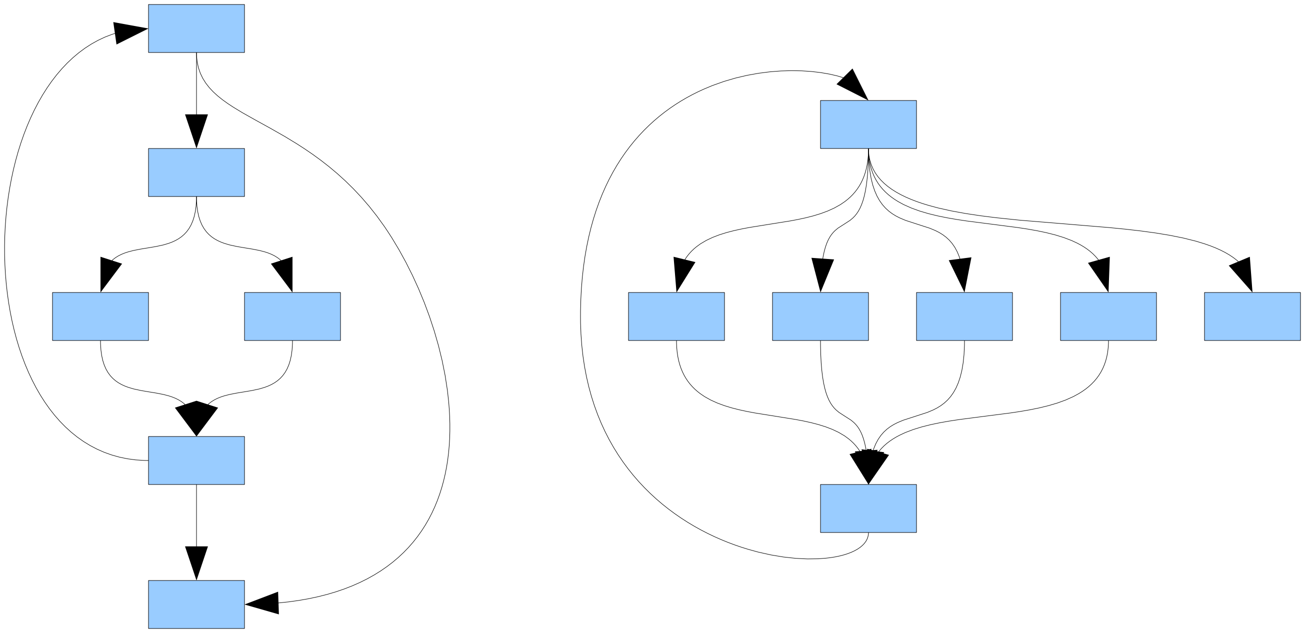
Flow-Graph Obfuscation

- What are these control-flow graphs doing?



The Big Switch

- Any control flow-graph can be turned into a giant switch statement contained in an infinite loop
  - Each block becomes a separate case
  - A variable controls which block to go to next
  - The cases can be arbitrarily numbered

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Variable Hiding

- We would like to obfuscate the values of variables in our program
  - Transform variables using algebraic (or bitwise boolean) transformations
- Example:
  - Replace x with u and use the u=x+27262
  - 'if (x > 10)' becomes 'if (u > 27262)'
- Example:
  - Replace y with v and use v=y*4635
  - 'if (y > 10)' becomes 'if (v > 46350)'
  - y+7 becomes v + 32445
  - x > y becomes 4635*(u - 27262) > v

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Variable Hiding

- Variable Hiding can be arbitrarily complicated
  - Can use cryptographic hash functions
    - if (x == 10) becomes:
      if (hash(x) == 38934782782928)
- Hiding the variable that controls flow is especially confounding
  - Transform x using addition, multiplication, and/or bitwise operations
  - switch (hash(x)) {case 83434727: ... case 2382722: ... }

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Obfuscating Compilers

- Several companies make obfuscating compilers
  - Angel Security
    - Randomized obfuscating compiler
    - Receives millions in funding from US DoD
  - Cloakware
    - Builds DRM around obfuscating compilers
    - iTunes, Blu-Ray, PVRs

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Digital Signatures

- Public/private digital signature schemes exist
  - Private key allows owner to sign any binary object
  - Public key allows anyone to verify a signature
- Use digital signature schemes to check that binaries were not tampered with
  - Software developer signs their binary
  - Code in the software checks the signature on the binary
  - Modifying the binary invalidates the signature and this can't be fixed without the public key

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Digital Signatures

- Problem:
  - Code in the binary checks the digital signature:
    - if (!verify_signature(this_file)) { exit(-1); }
  - Attacker can just delete this code
  - Signature is invalid, but no one checks it
- Solutions:
  - Have the OS check the signature
  - Spread the signature checking throughout the binary
    - More work for attacker
  - Obfuscate the signature checking
  - Obfuscate variables using a value that depends on a hash of the binary

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Randomizing Compilers

- Compilers have a lot of choice they can make
  - Order of functions in a binary
  - Order of variables on the stack
  - Order of global variables on the heap
  - Order of instructions within a basic block
  - Locations of basic blocks (especially with obfuscating)
- Randomizing compilers make some or/all of these choices randomly

Randomizing compilers

- Security advantage
  - More difficult to perform a buffer overflow attack if you don't know the layout of the binary
- IP rights enforcement advantage
  - Vendors can ship a different binary to every customer
  - Can identify customers who violate copyright

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Virtual Machines

- Some languages compile for use on virtual machines
  - JVM is an example
- A secure VM can enforce security policies
  - No file access
  - No network access
  - No access to personal information
  - No sharing of personal information (through data-flow analysis)

Automated Theorem Proving

- Some VMs prove things about the binaries before executing them
  - the value of x does not affect the value of y
  - the value of x does not affect any value transmitted over the network
  - ...
- The VM may refuse to run some code if it can not prove the theorem it needs
  - Problem: Reasoning about code leads to undecideable problems

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Proof-Carrying Code

- To help with automated theorem proving, some code is *proof carrying*
  - Finding proofs of theorem takes a long time
  - Checking proofs is easy
- The code comes with proofs of statements like
  - the value of x does not affect the value of y
  - the value of x does not affect any value transmitted over the network
  - ...
- The VM can load the program much faster this way

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Summary

- Code obfuscation
  - Makes code difficult to
    - understand, reverse-engineer, or modify (while still preserving correctness)
- Digital signatures
  - Make it difficult to modify code
- Code randomization
  - Can make every executable unique
    - Acts as a watermark
    - Makes some attacks more difficult
- Virtual Machines and Theorem Proving
  - Allows fine-grained control over what a is allowed to do