Malware

EECS 388

March 16, 2015

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Outline

- The Malware Bestiary
- Infecting Hosts
- Spreading
- Detection and Defense

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Malware definition and goals

- What is malware?
  - Set of instructions that run on your computer and do something an attacker wants it to do.
- Goals:
  - Steal private data
  - Display ads, send spam, extortion
  - Damage local machine
  - Congest network
  - Attack other systems (DoS, relays)
  - Commit online fraud (click fraud, spam)
  - Grant unauthorized access (back door)

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The Problem of Malware

- How does it manage to run?
  - Buffer overflow in network-accessible vulnerable service
  - Vulnerable client (e.g. browser) connects to remote system that sends over an attack (a *driveby*)
  - *Social engineering:* trick user into running/installing
  - "Autorun" functionality (esp. from plugging in USB device)
  - Slipped into a system component (at manufacture; compromise of software provider; substituted via MITM)
  - Attacker with local access downloads/runs it directly
    - Might include using a "local root" exploit for privileged access

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Malware is on the rise -- increasing complexity and sophistication

- Why is malware such a major problem?
  - Client machines are badly insecure
- Species of malware:
  - Trojan horses
  - Viruses
  - Worms
  - Bots

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Trojan horse

- Software that appears to perform a desirable function but is actually designed to perform undisclosed malicious functions
- e.x. Spyware: installed by legitimate looking programs, then provides remote access to the computer, such as logging keys or sending back documents
- e.x. Adware: shows popup ads
  e.x. Ransomware: encrypts data and requires payment to decrypt

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Virus

- Self-replicating software that infects other programs by modifying them to include a version of itself
  - usually requires user intervention -- running a program or opening a file
- ex. Infecting executable files (spread when run)
- ex. Infecting document files, e.g. MS Word -- macro virus (spread when opened)
- Viruses can mutate to avoid detection, changing parts of their code while keeping the algorithm intact ("polymorphic" or "metamorphic" viruses)

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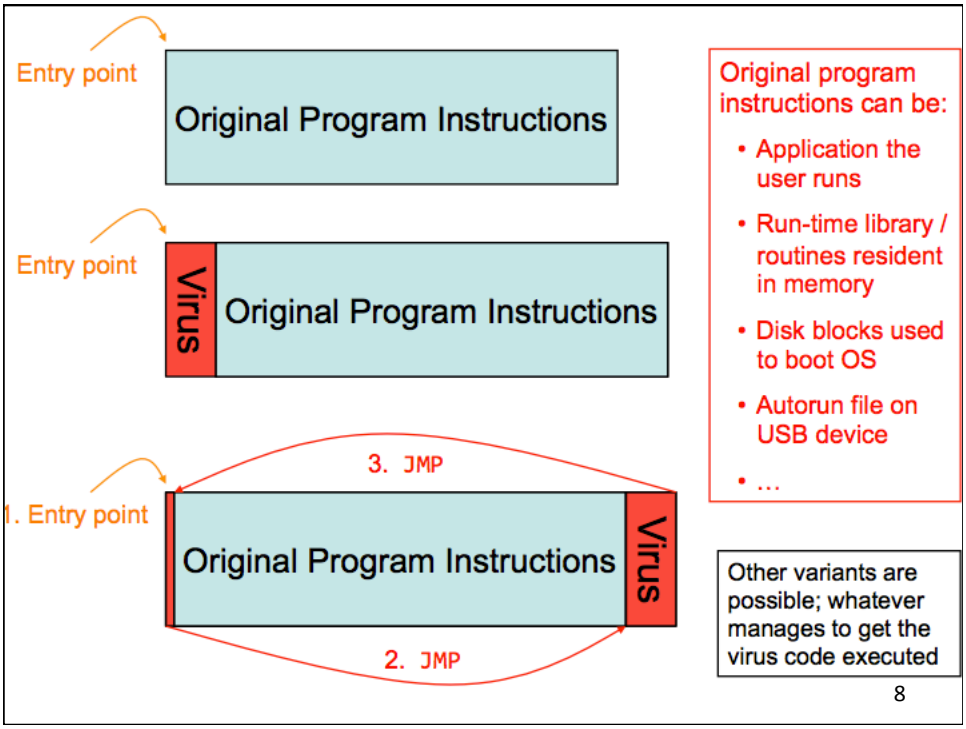

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Worm

- Self-replicating software that infects other systems by automatically spreading over the network
- Fast spreading worms an enormous threat -- fueled by software homogeneity compare to spread of infection disease.
- First worm: 1988 Morris worm -- creator now an MIT prof.
  - Infected ~10% of computers on the Internet (6000 machines): $10M in damages
- Direct descendent: 2001 Code Red worm - remote Windows exploit, memory resident, Infected > 500,000 servers ($2.6B in damages)

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Worm

- ex. Remote code-injection worm (e.g. Slammer 2003 -- single UDP packet!
  - exploited buffer overflow
  - infected whole vulnerable population in 10 minutes!
  - took down ATMs, 911 systems, airline ticketing)
- ex. Email attachment worm (e.g. Mydoom 2004)
- ex. XSS worm (e.g. Samy 2005)
- Increasing sophistication, commercialization (e.g., Conficker 2008)

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Avoiding Detection and Removal: Rootkits

- A component that uses stealth to maintain persistent and undetected presence on the machine
- Can be applied to any malware
- Operation:
  - Intercept system calls for listing files, processes, etc.
  - Filter out malware's files and processes
  - Example: Magic prefix -- sysfilename
  - Diagram:

    Applications --> System Call ---> (Rootkit) --> Kernel <-- Results --- If call is from rootkit application (e.g. sysrootkit.exe), don't filter!

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VM Rootkit

- Install a VM below the operating system -- Blue Pill (matrix)

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Bots and Botnets

- Wide scale, centrally controlled malware
- Bots infect many hosts (via any of the above methods) -- aka Zombies
- Botmaster controls bots remotely, via command and control infrastructure
- Botnet [diagram]: Botmaster -> Command and Control -> Many bots (swarm)
- Huge scale: Large botnets have 10,000s or 100,000s of bots
- Varying payloads: Instruct bots to carry out functions: Send spam, DDoS, Infect other hosts (often: Trojan email attachment)
- Financial motives: Sometimes sell time on bots to others (Dark cloud)

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Bots and Botnets

- Command and control
  - Centralized: Single server directs bots
    - Simple, but easy to detect/disable
  - Distributed: Bots exchange control messages via P2P network
    - Complex, but hard to detect/disable
- Example: Storm
  - Probably ~1M Bots, first installed by Storm email worm in 2007
  - P2P communication, advanced cryptography (control messages signed)
  - Uses: Spam, Stock Fraud, Phishing

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Botnet Wars

- Bots are valuable, so owners want to keep them installed
- Rival bots might replace them, other malware might cause the PC owner to clean up
- Advanced bots now try to defend the PC! Patch vulnerabilities, even install pirated AV!
- User's incentives? If botnet is only attacking others?

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Defenses

- Anti-viruses (defense against trojans, viruses, bots, slow worms)
- Perfect virus detector is impossible!
  - Assume P is a perfect detector, V is a virus
  - V can call P: if P(V) = true -> halt; if P(V) = false -> spread
- Signature detection
  - Find a string that can identify the virus (like a fingerprint)
  - Difficult against mutating viruses
- Heuristic detection
  - Analyze program behavior to identify unusual patterns
  - E.g. network access, file open or delete, modify boot sector

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Defenses

- Tripwire
  - Store hash of known-good binaries and config files
  - Later, compare to detect changes
  - Need to boot from external device to avoid rootkits
- Defending against fast-spreading worms?
  - Too quick to use a signature - detect in the network instead
  - Infer worm signature (< 1 second), suppress traffic spreading the worm

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Summary

- Malware = malicious code that runs on a victim's system
  - Infection can occur in a variety of ways
- Some malware propagates automatically
  - Viruses
  - Worms
- Botnet = set of compromised machines
  - Botnets are a modern, persistent, and very real threat
  - Extremely hard problem

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Closing Thought!

- As long as criminals can continue to monetize malware, the malware threat is likely to remain

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Polymorphic Code

- Create a representation of data apparently completely unrelated to the original: encryption!
- Idea: every time your virus propagates, it inserts a newly encrypted copy of itself
  - Clearly, encryption needs to vary
    - Either by using a different key each time
    - Or by including some random initial padding (like an IV)
  - Note: weak (but simple/fast) crypto algorithm works fine
    - No need for truly strong encryption, just obfuscation
- When injected code runs, it decrypts itself to obtain the original functionality

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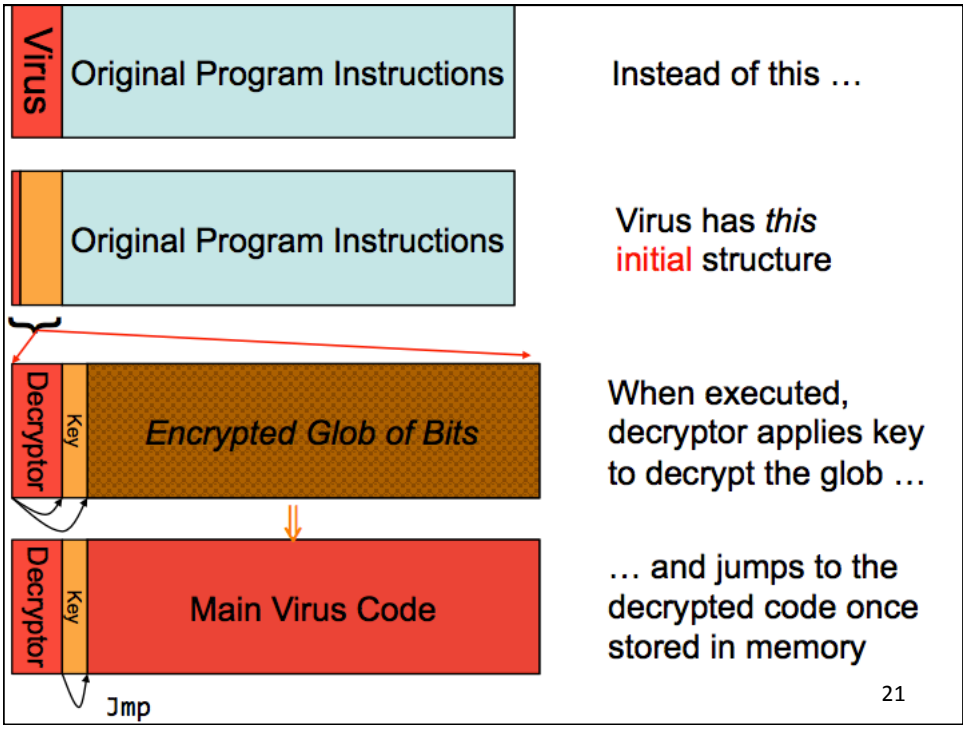
Virus
Original Program Instructions
Instead of this …
Original Program Instructions
Virus has *this* initial structure
Decryptor
Key
Encrypted Glob of Bits
When executed, decryptor applies key to decrypt the glob …
Decryptor
Key
Main Virus Code
… and jumps to the decrypted code once stored in memory
Jmp
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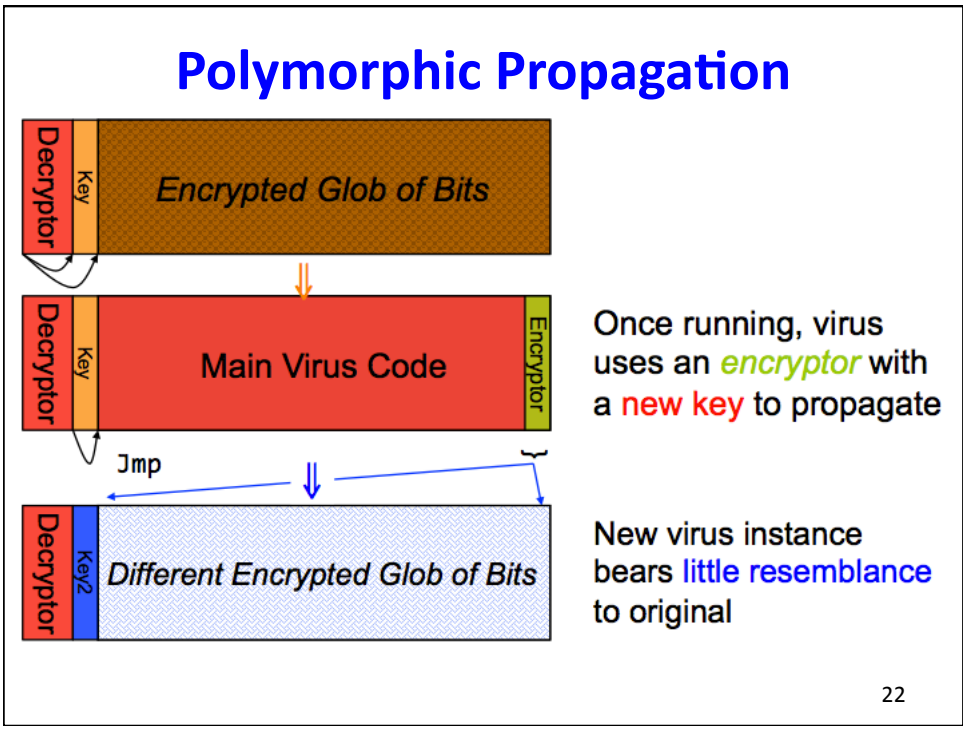
Polymorphic Propagation
Decryptor
Key
Encrypted Glob of Bits
Decryptor
Key
Main Virus Code
Encryptor
Once running, virus uses an *encryptor* with a new key to propagate
Jmp
Decryptor
Key2
Different Encrypted Glob of Bits
New virus instance bears little resemblance to original
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Arms Race: Polymorphic Code

- Given polymorphism, how might we then detect viruses?
- Idea #1: use narrow sig. that targets decryptor
  - Issues?
    - Less code to match against " more false positives
    - Virus writer spreads decryptor across existing code
- Idea #2: execute (or statically analyze) suspect code to see if it decrypts!
  - Issues?
    - Legitimate "*packers*" perform similar operations (decompression)
    - How long do you let the new code execute?
      - If decryptor only acts after lengthy legit execution, difficult to spot

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Metamorphic Code

- Idea: every time the virus propagates, generate *semantically* different version of it!
  - Different semantics only at immediate level of execution; higher-level semantics remain same
- How could you do this?
- Include with the virus a code rewriter:
  - Inspects its own code, generates random variant, e.g.
  - Renumber registers
  - Change order of conditional code
  - Reorder operations not dependent on one another
  - Replace one low-level algorithm with another
  - Remove some do-nothing padding and replace with different do- nothing padding ("chaff")

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Detecting Metamorphic Viruses?

- Need to analyze execution behavior
  - Shift from syntax (*appearance* of instructions) to semantics (*effect* of instructions)
- Two stages: (1) AV company analyzes new virus to find behavioral signature; (2) AV software on end systems analyze suspect code to test for match to signature
- What countermeasures will the virus writer take?
  - Delay analysis by taking a long time to manifest behavior
    - Long time = await particular condition, or even simply clock time
  - Detect that execution occurs in an analyzed environment and if so behave differently
    - E.g., test whether running inside a debugger, or in a Virtual Machine
- Counter-countermeasure?
  - AV analysis looks for these tactics and skips over them
- Note: attacker has edge as *AV products supply an **oracle!***

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Infection Cleanup

- Once malware detected on a system, how do we get rid of it?
- May require restoring/repairing many files
  - This is part of what AV companies sell: per-specimen disinfection procedures
- What about if malware executed with adminstrator privileges?
  - rebuild system from **original media** + **data backups**
- Malware may include a **rootkit**: *kernel patches* to hide its presence (its existence on disk, processes)

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Infection Cleanup, con't

- If we have complete source code for system, we could rebuild from that instead, couldn't we?
- Suppose forensic analysis shows that virus introduced a backdoor in `/bin/login` executable
- Cleanup procedure: rebuild `/bin/login` from source !

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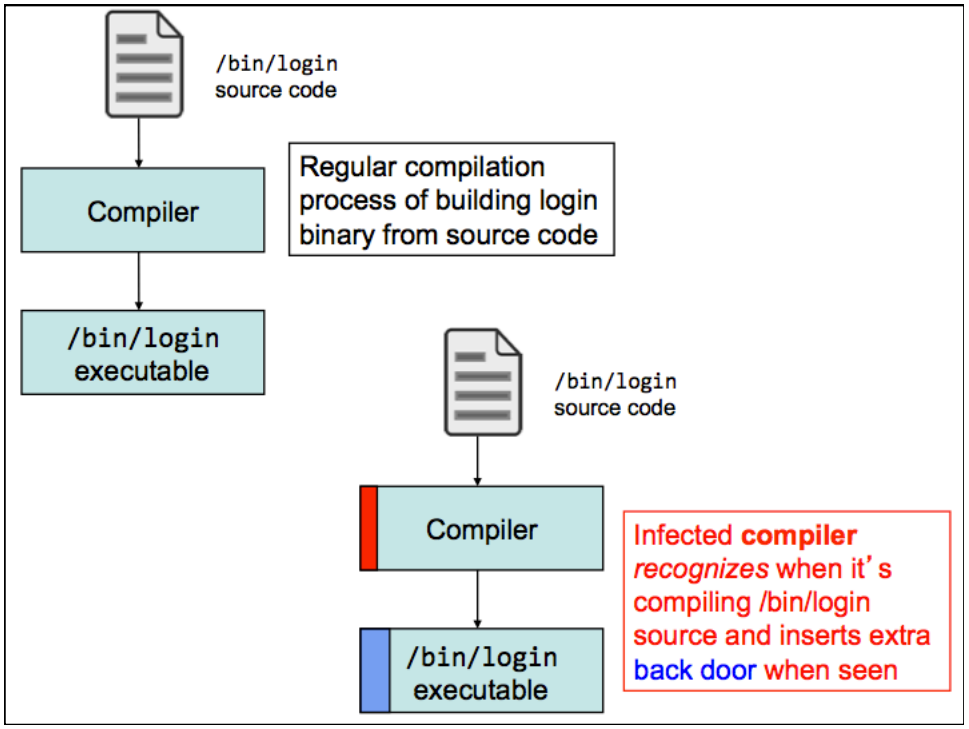

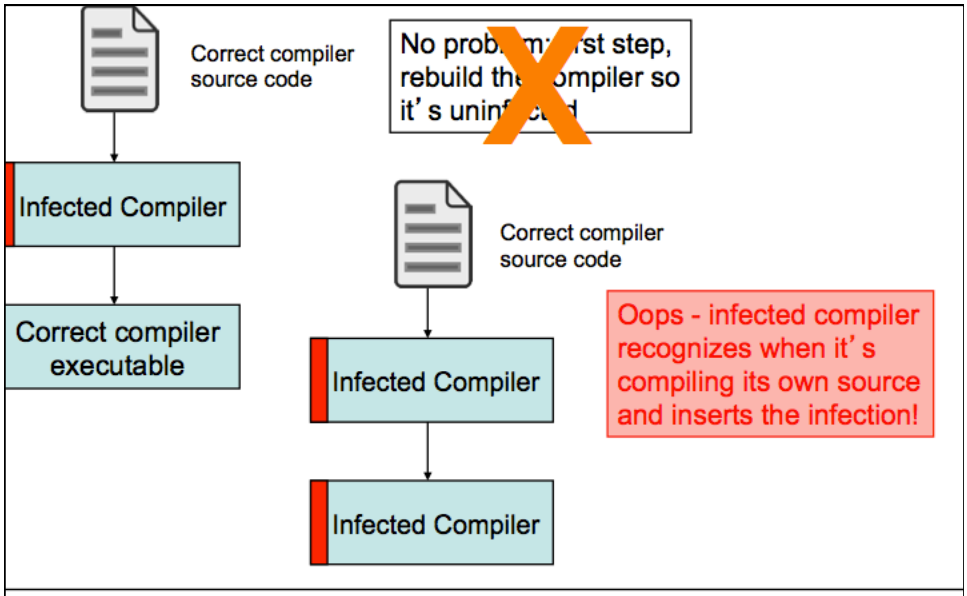

No amount of careful source-code scrutiny can prevent this problem.
And if the *hardware* has a back door …

Reflections on Trusting Trust
Turing-Award Lecture, Ken Thompson, 1983

Fighting Bots / Botnets

- How can we defend against bots / botnets?
- Defense #1: prevent the initial bot infection
  - Equivalent to preventing malware infections in general !. HARD
- Defense #2: Take down the C&C master server
  - Find its IP address, get associated ISP to pull plug

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Fighting Bots / Botnets

- Botmaster countermeasures?
  - Counter #1: keep moving around the master server
    - Bots resolve a domain name to find it
    - Rapidly alter address associated w/ name ("fast flux")
  - Counter #2: buy off the ISP !

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Fighting Bots / Botnets

- Defense #3: Legal action
  - Use law enforcement to seize the domain names and IP addresses used for C&C
  - This is what's currently often used, often to good effect !

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Botmaster counter-measure?

- Each day (say), bots generate large list of possible domain names using a Domain Generation Algorithm
  - Large = 50K, in some cases
- Bots then try a random subset looking for a C&C server
  - Server **cryptographically signs** its replies, so bot can't be duped
  - Attacker just needs to hang on to a small portion of names to retain control over botnet
- Counter-counter measure?
  - Behavioral signature: look for hosts that make a lot of failed DNS lookups (research)

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Addressing The Botnet Problem

- What are our prospects for securing the Internet from the threat of botnets? What angles can we pursue?
  - Angle#1:detection/cleanup
    - Detecting infection of individual bots hard as it's the *defend-against-general-malware* problem
    - Detecting bot doing C&C likely a losing battle as attackers improve their sneakiness & crypto
  - Cleanup today lacks oomph:
    - **Who's responsible?** ! and do they **care**?
  - Angle#2: go after the C&C systems/botmasters
    - Difficult due to ease of Internet anonymity & complexities of international law.

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Addressing The Botnet Problem

- Angle #3: prevention
  - Bots require installing new executables or modifying existing ones
  - Perhaps via infection !
    - or perhaps just via user being fooled / imprudent
- In general, preventing malware infection is *hard.* Really hard!
- This is an asymmetric problem
  - Defenders must defend everything
  - Attackers need only a handful of targets

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Addressing The Problem, con't

- Bette rmodels?
- We could lock down systems so OS prohibits user from changing configuration
  - Sacrifices flexibility
  - How does this work for home users?
  - => Mobile (Android/iOS). Did this solve the problem?
- Or: structure OS/browser using Privilege Separation
  - Does this solve the problem?
  - Depends on how granular the privileges are … and how secure the privileged components are

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