Computer Security: Principles and Practice

Chapter 6: Malicious Software

Malware

“A program that is inserted into a system, usually covertly, with the intent of compromising the confidentiality, integrity, or availability of the victim’s data, applications, or operating system or otherwise annoying or disrupting the victim.”

Malicious software

- Programs exploiting system vulnerabilities
- Known as malicious software or malware
  - program fragments that need a host program
    - e.g. viruses, logic bombs, and backdoors
  - independent self-contained programs
    - e.g. worms, bots
  - replicating or not
- Sophisticated threat to computer systems

Malware Terminology

- Payload: *actions of the malware*
- Virus: *attaches itself to a program*
- Worm: *propagates copies of itself to other computers*
- Logic bomb: *"explodes" when a condition occurs*
- Trojan horse: *fakes/contains additional functionality*
- Backdoor (trapdoor): *allows unauthorized access to functionality*
- Mobile code: *moves unchanged to heterogeneous platforms*
- Auto-rooter Kit (virus generator): *malicious code (virus) generators*
- Spammer and flooder programs: *large volume of unwanted "pkts"*
- Keyloggers: *capture keystrokes*
- Rootkit: *sophisticated hacker tools to gain root-level access*
- Zombie: *software on infected computers that launch attack on others (aka bot)*
- Crimeware: *kits for building malware; include propagation and payload mechanisms* (Zeus, Sakura, Blackhole, Phoenix)

Viruses

- Piece of software that infects programs
  - modifying them to include a copy of the virus
  - so it executes secretly when host program is run
- Specific to operating system and hardware
  - taking advantage of their details and weaknesses
- A typical virus goes through phases of:
  - dormant: *idle*
  - propagation: *copies itself to other program*
  - triggering: *activated to perform functions*
  - execution: *the function is performed*

Virus structure

- Components:
  - infection mechanism: enables replication
  - trigger: event that makes payload activate
  - payload: what it does, malicious or benign
- Prepended/postpended/embedded
- When infected program invoked, executes virus code then original program code
- Can block initial infection (difficult) or propagation (with access controls)

Virus structure

```
    program V :=

{goto main;
    1234567;

    subroutine infect-executable :=
        {loop:
        file := get-random-executable-file;
        if (first-line-of-file = 1234567)
          then goto loop
          else prepend V to file; }

    subroutine do-damage :=
        {whatever damage is to be done}

    subroutine trigger-pulled :=
        {return true if some condition holds}

main:   main-program :=
        {infect-executable;
        if trigger-pulled then do-damage;
        goto next;}

next:

}
```

- A virus such as the one just described is easily detected because an infected version of a program is longer than the corresponding uninfected one.
- A way to thwart such a simple means of detecting a virus is to compress the executable file so that both the infected and uninfected versions are of identical length.

Compression virus

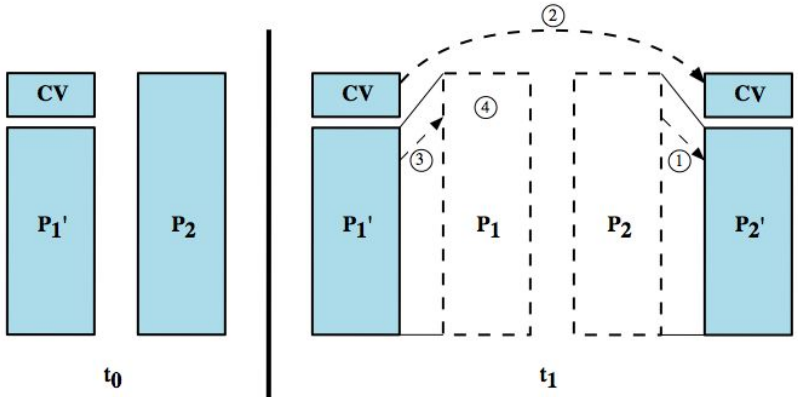
```
    program CV :=

{goto main;
    01234567;

    subroutine infect-executable :=
          {loop:
               file := get-random-executable-file;
          if (first-line-of-file = 01234567) then goto loop;
        (1)     compress file;
        (2)     prepend CV to file;
        }

main:   main-program :=
          {if ask-permission then infect-executable;
        (3)     uncompress rest-of-file;
        (4)     run uncompressed file;}
        }
```

P1 is infected



Virus classification

- By target
  - boot sector: *infect a master boot record*
  - file infector: *infects executable OS files*
  - macro virus: *infects files to be used by an app*
  - multipartite: infects multiple ways
- By concealment
  - encrypted virus: *encrypted; key stored in virus*
  - stealth virus: *hides itself (e.g., compression)*
  - polymorphic virus: *recreates with diff "signature"*
  - metamorphic virus: *recreates with diff signature and behavior*

Macro and scripting viruses

- Became very common in mid-1990s since
  - platform independent
  - infect documents
  - easily spread
- Exploit macro capability of Office apps
  - executable program embedded in office doc
  - often a form of Basic
- More recent releases include protection
- Recognized by many anti-virus programs

E-Mail Viruses

- More recent development
- Melissa
  - exploits MS Word macro in attached doc
  - if attachment opened, macro activates
  - sends email to all on users address list and does local damage

Virus countermeasures

- Prevention: ideal solution but difficult
- Realistically need:
  - detection: determine what occurred
  - identification: identify the specific virus
  - removal: remove all traces
- If detected but can't identify or remove, must discard and replace infected program

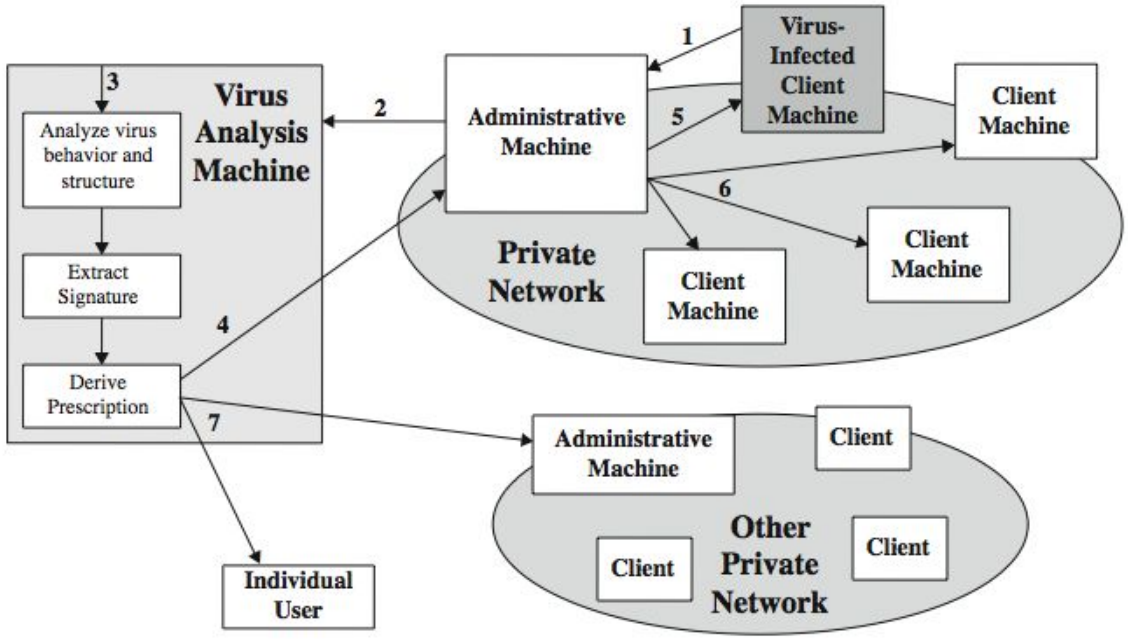
Anti-virus evolution

- Virus & antivirus tech have both evolved
- Early viruses simple code, easily removed
- As viruses become more complex, so did the countermeasures
- Generations
  - first - signature scanners (bit patterns all the same)
  - second – heuristics (integrity checks; checksums)
  - third - identify actions (find by actions they do)
  - fourth - combination packages

Generic decryption (GD)

- Runs executable files through GD scanner:
  - CPU emulator to interpret instructions
  - virus scanner to check known virus signatures
  - emulation control module to manage process
- Lets virus decrypt itself in interpreter
- Periodically scan for virus signatures
- *Let virus do the work for an antivirus program by exposing it in a controlled environment*

Digital immune system

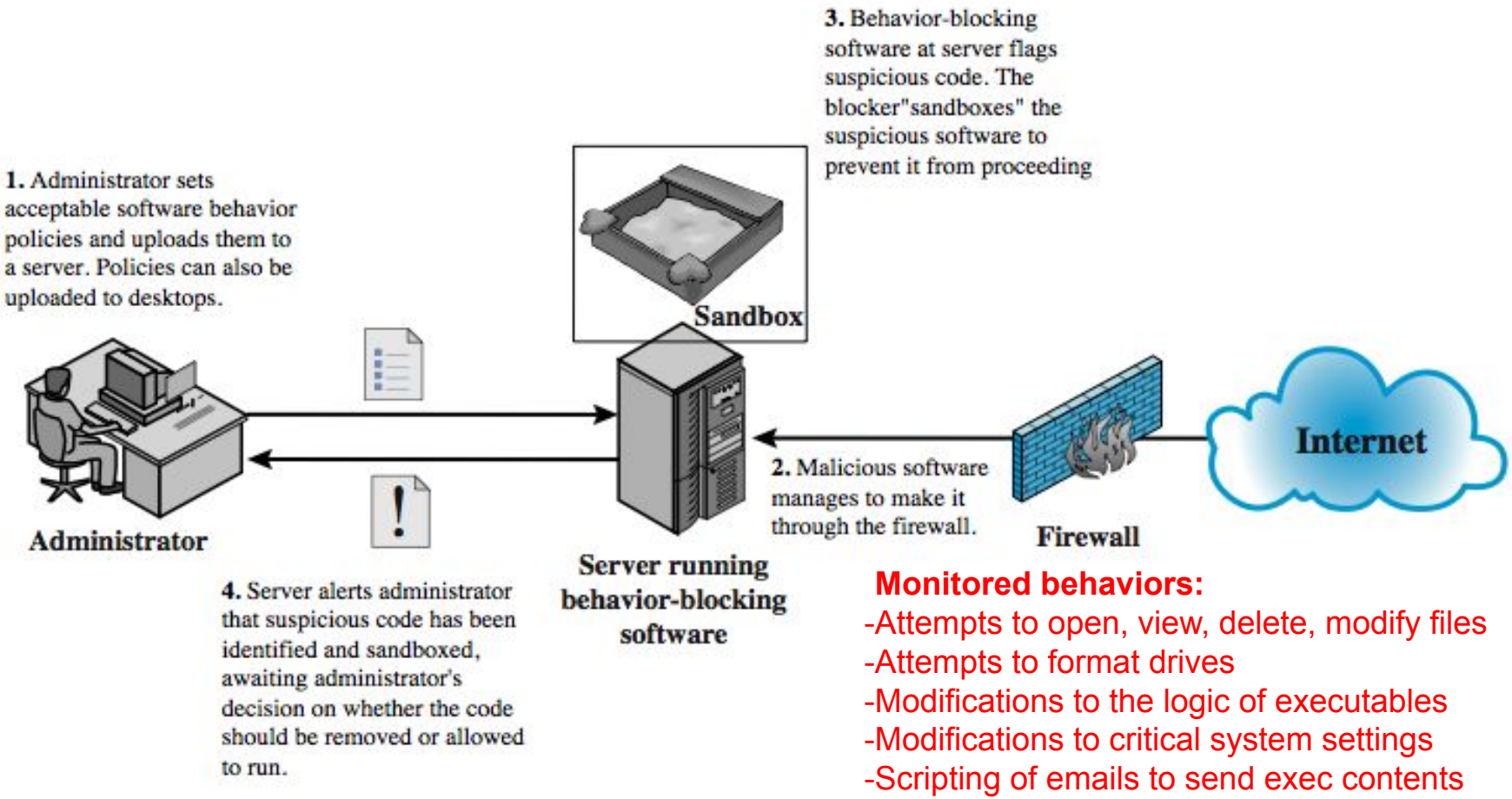


1. A monitoring pgm infers a virus, sends a copy to an adm machine
2. Adm encrypts, sends to a central analysis machine
3. Central analysis: Safe exec of virus, analyze, give a prescription
4. Prescription sent back to the adm machines
5. Adm machine forwards to all clients
6. Prescription forwarded to other organizations
7. Subscribers worldwide receive regular updates

IBM/Symantec Project

Behavior-blocking software

Integrates with the OS; looks for bad behavior



Monitored behaviors:

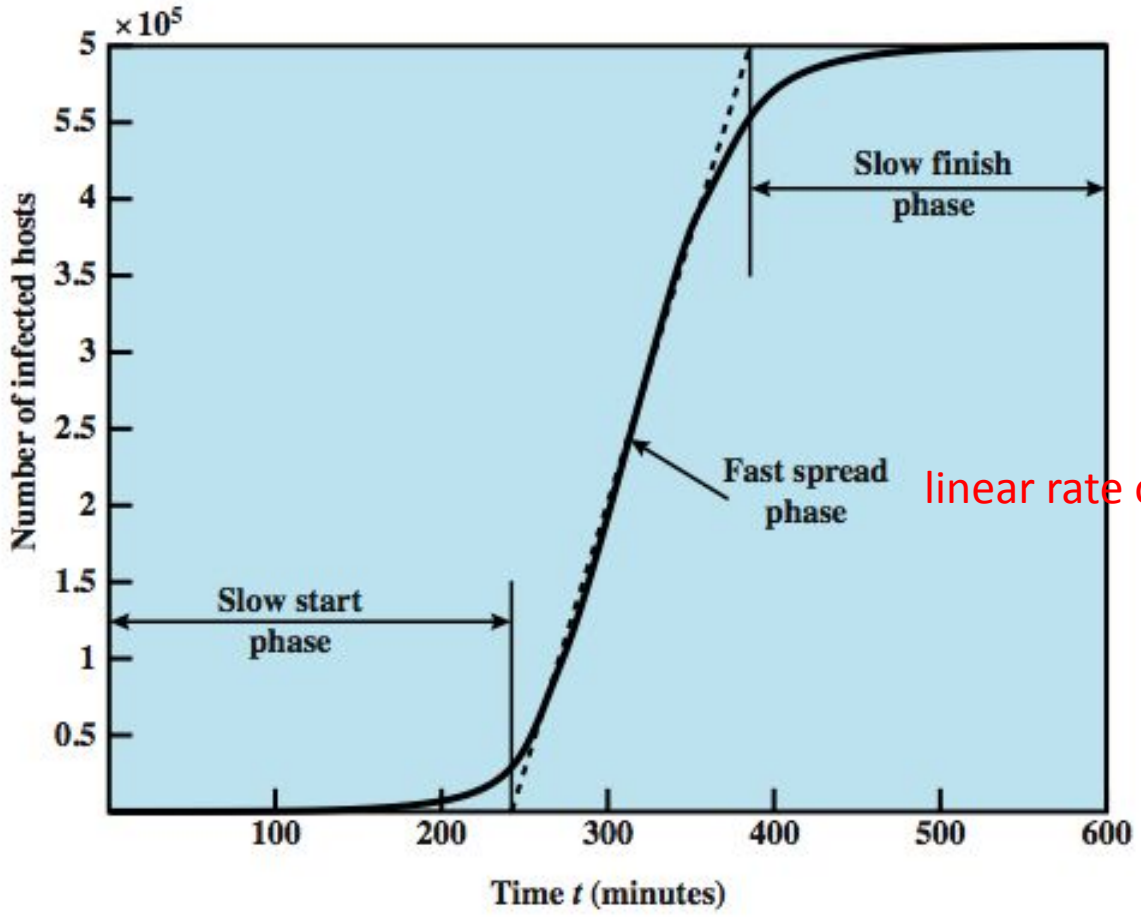
-Attempts to open, view, delete, modify files
-Attempts to format drives
-Modifications to the logic of executables
-Modifications to critical system settings
-Scripting of emails to send exec contents

Worms

- Replicating program that propagates over net
  - using email, remote exec, remote login
- Has phases like a virus:
  - dormant, propagation, triggering, execution
  - propagation phase: searches for other systems, connects to it, copies self to it and runs
- May disguise itself as a system process
- Concept seen in Brunner's novel "Shockwave Rider"
- Implemented by Xerox Palo Alto labs in 1980's, but to search idle systems to run a computationally intensive task.

Worm Propagation Model

(based on recent attacks)



linear rate of infection

exponential rate of infection

Morris worm

- One of best known worms
- Released by Robert Morris in 1988
  - Affected 6,000 computers; cost $10-$100 M
- Various attacks on UNIX systems
  - cracking password file to use login/password to logon to other systems
  - exploiting a bug in the finger protocol
  - exploiting a bug in sendmail
- If succeed to have remote shell access
  - sent bootstrap program to copy worm over

More recent worm attacks

- Melissa
  - 1998: exploiting Microsoft Word macro embedded in an attachment.
  - 1999: could be activated merely by opening an e-mail that contains the virus, rather than by opening an attachment.
  - 100.000 computers in 3 days
- Code Red
  - July 2001 exploiting MS Internet Information Server (IIS) bug
  - probes random IP address, does DDoS attack
  - consumes significant net capacity when active
  - 360,000 servers in 14 hours
- Code Red II variant includes backdoor: hacker controls the worm
- SQL Slammer *(exploited buffer-overflow vulnerability)*
  - early 2003, attacks MS SQL Server
  - compact and very rapid spread
- Mydoom *(100 M infected email messages in 36 hours)*
  - mass-mailing e-mail worm that appeared in 2004
  - installed remote access backdoor in infected systems

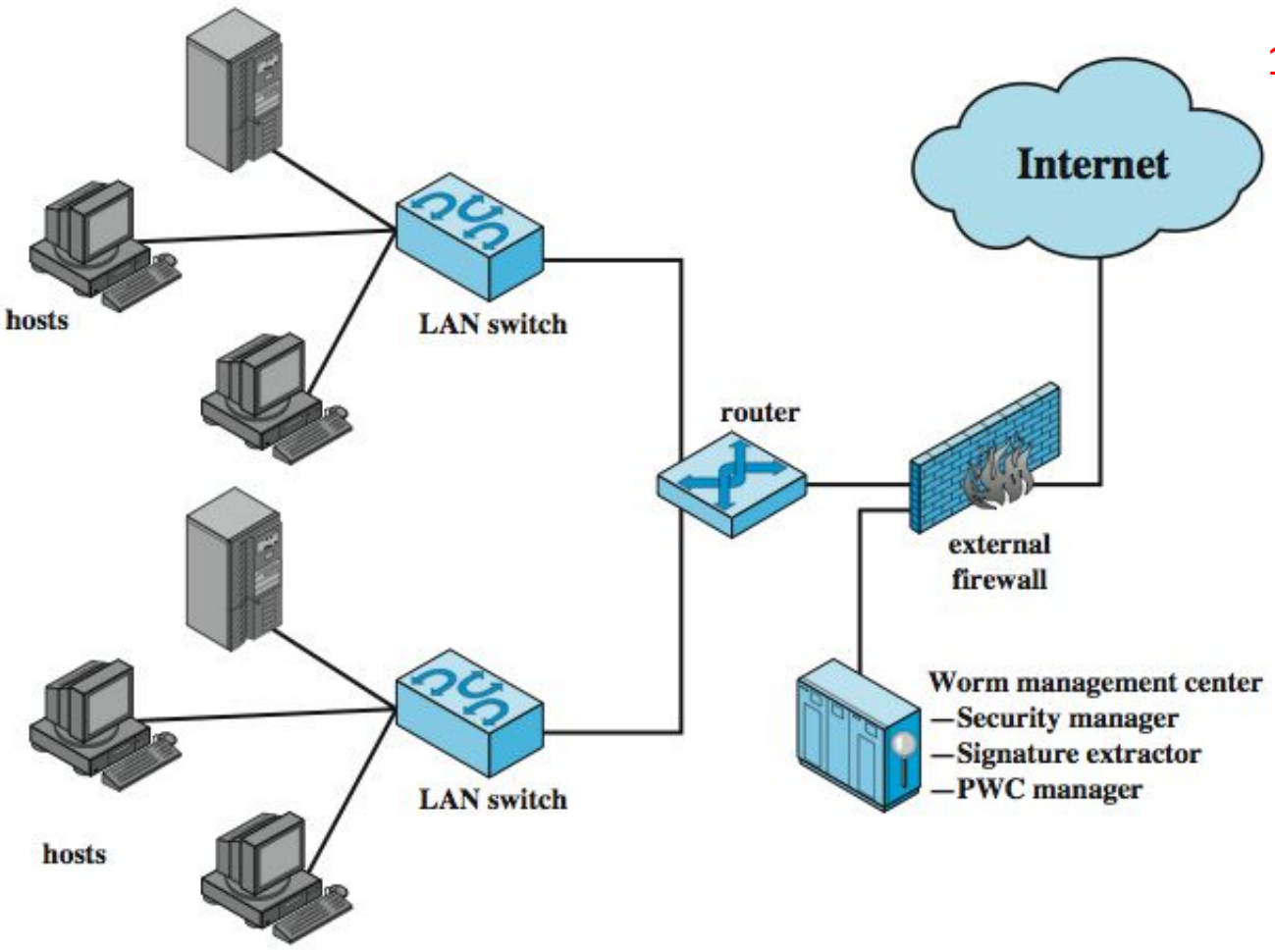
State of worm technology

- Multiplatform: not limited to Windows
- Multi-exploit: Web servers, emails, file sharing …
- Ultrafast spreading: do a scan to find vulnerable hosts
- Polymorphic: each copy has a new code
- Metamorphic: change appearance/behavior
- Transport vehicles (e.g., for DDoS)
- Zero-day exploit of unknown vulnerability (to achieve max surprise/distribution)

Worm countermeasures

- Overlaps with anti-virus techniques
- Once worm on system A/V can detect
- Worms also cause significant net activity
- Worm defense approaches include:
  - signature-based worm scan filtering: define signatures
  - filter-based worm containment (focus on contents)
  - payload-classification-based worm containment (examine packets for anomalies)
  - threshold random walk scan detection (limit the rate of scan-like traffic)
  - rate limiting and rate halting (limit outgoing traffic when a threshold is met)

Proactive worm containment (PWC)



1. PWC agent monitors outgoing traffic for increased activity

2. When an agent notices high traffic, it informs the PWC manager; mgr propagates to other hosts

3. Hosts receive alert and decide if to ignore (based on time of last incoming pkt)

4. Relaxation period (based on threshold)

Mobile code

- Scripts, macros or other portable instructions
- Popular ones: JavaScript, ActiveX, VBScript
- Heterogeneous platforms
- From a remote system to a local system
- Can act as an agent for viruses, worms, and Trojan horses
- Mobile phone worms: communicate through the Bluetooth connections (e.g., CommWarrior on Symbian but attempts also on Android and iPhone)

Client-side vulnerabilities

- Drive-by-downloads: common in recent attacks
- Exploits browser vulnerabilities (when a user visits a website controlled by the attacker or a compromised website)
- Clickjacking

Social engineering, spam, email, Trojans

"Tricking" users to assist in the compromise of their own systems or personal information.

- Spam e-mail may account for 90% or more of all e-mail sent. Spam is:
  - Advertising
  - Attached documents with malware
  - Attached Trojan horse program
  - Phishing attack
- Trojan horse: looks like a useful tool but contains hidden code

Payload

What actions a malware will take on the system?

- Data destruction, theft
- Data encryption (ransomware)
- Real-world damage
  - Stuxnet: caused physical damage also (targeted to Siemens industrial control software)
- Logic bomb

Payload attack agents: bots (zombie/drone)

- Program taking over other computers and launch attacks
  - hard to trace attacks
- If coordinated form a ***botnet***
- Characteristics:
  - **remote control facility** (distinguishing factor from worm)
    - via IRC/HTTP etc
  - spreading mechanism
    - attack software, vulnerability, scanning strategy
- Various counter-measures applicable (IDS, honeypots, …)

Uses of bots

- DDoS
- Spamming
- Sniffing traffic
- Keylogging
- Spreading malware
- Installing advertisement
- Manipulating games and polls

Payload: information theft

- Credential theft, key loggers, spyware
- Phishing identify theft
- Spear phishing (act as a trusted source for a specific target: e-mail is carefully crafted to suit its recipient specifically)

Payload: backdoor and rootkits

- A **backdoor** is a secret entry point into a program to gain access without going through the usual security access procedures.
- Usually implemented as a network service listening on some non-standard port.
- Security measures must focus on the program development and software update activities, and on programs that wish to offer a network service.

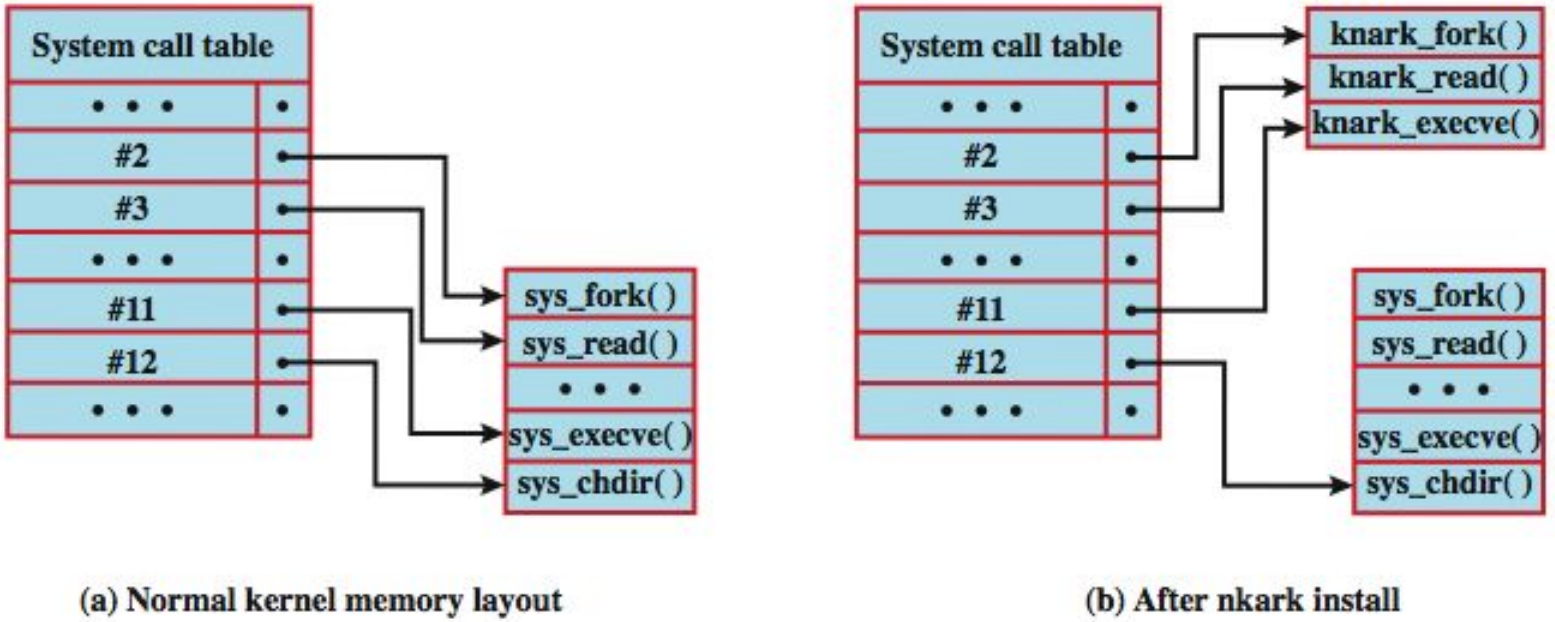
Payload: backdoor and rootkits

- A rootkit is a set of programs installed for admin access
- It determines a malicious and stealthy changes to host O/S
- May hide its existence
  - subverting report mechanisms on processes, files, registry entries etc
- May be persistent (survives reboot) or memory-based
- Do not rely on vulnerabilities
  - installed via Trojan
  - installed via hackers

Rootkit System Table Mods

A Unix Example

User API calls refer to a number; the system
maintains a system call table with one entry per number;
each number is used to index to a corresponding system routine



(a) Normal kernel memory layout

(b) After nkark install

rootkit modifies the table and the calls go to the hackers replacements

Countermeasures for Malware

- Prevention:
  - Ensure all systems are as current as possible, with all patches applied
  - Set appropriate access controls on the applications and data stored on the system, to reduce the number of files that any user can access
  - Use appropriate user awareness and training

Countermeasures for Malware

- If prevention fails, use technical mechanisms to support the following threat mitigation options:
  - Detection, identification, removal
- Requirements
  - Generality
  - Timeliness
  - Resiliency
  - Minimal DoS costs
  - Transparency
  - Global/local coverage (inside and outside attackers)

Summary

- introduced types of malicous software
  - incl backdoor, logic bomb, trojan horse, mobile
- virus types and countermeasures
- worm types and countermeasures
- bots
- rootkits