Lecture 22
November 14, 2025

ECS 235A, Computer and Information Security

Administratrivia

- All submitted homework 2s have been graded
- Any homework 2 not turned in by Monday will lose 50% of the grade

  Any homework 2 not turned in by noon Tuesday will not be accepted

Computer Worm

- A program that copies itself from one computer to another
- Originated as a tool for distributed computations
  - Schoch and Hupp: animations, broadcast messages
  - Segment: part of program copied onto workstation
  - Segment processes data, communicates with worm's controller
  - Any activity on workstation caused segment to shut down

Example: Internet Worm of 1988

- Targeted Berkeley, Sun UNIX systems
  - Used virus-like attack to inject instructions into running program and run them
  - To recover, had to disconnect system from Internet and reboot
  - To prevent re-infection, several critical programs had to be patched, recompiled, and reinstalled
- Analysts had to disassemble it to uncover function
- Disabled several thousand systems in 6 or so hours

Example: Christmas Worm

- Distributed in 1987, designed for IBM networks
- Electronic letter instructing recipient to save it and run it as a program
  - Drew Christmas tree, printed “Merry Christmas!”
  - Also checked address book, list of previously received email and sent copies to each address
- Shut down several IBM networks
- Really, a macro worm
  - Written in a command language that was interpreted

Computer Worm Structure

- *Target Selection*: worm determines which systems to spread to
- *Propagation*: worm attempts to infect chosen targets
- *Execution*: worm carries out action after it becomes resident on a target
  - This phase may be empty

Example: Internet Worm

- Target selection: chose targets from lists of trusted hosts, and hosts trusted by users whose passwords had been guessed
- Propagation: tried to exploit 4 vulnerabilities
  - *sendmail* (SMTP server) in debug mode
  - *fingerd* (information server) buffer overflow attack
  - used guessed passwords
  - tried to exploit trust relationships
- Execution: took actions to:
  - Concealed its presence
  - Prevent reinfection
  - Tried to guess passwords on local system (to be used in target selection)

Stuxnet

- Found in 2010, targeted Siemens centrifuges used in process to enrich uranium
  - Compromised Windows software first, then the PLC in centrifuges
    - Very sophisticated evasion, exploits, and use of first PLC rootkit
  - Spun them at nonstandard speeds so they tore apart
- Entered system via infected USB stick with a Trojan horse
  - Looked on local network for Windows-based systems to infect; if found, infected no more than 3
- On system, checked to see if it was part of a specific industrial control system
  - No: did nothing
  - Ye: acted

Stuxnet (*con't*)

- Tried to download most current version of itself
- Exploited vulnerabilities in infected system's PLC to take control of attached centrifuges
  - Also corrupted information sent to the controllers so they would not detect anything was wrong until centrifuges went out of control
- Believed developed by one or more nation-states due to its complexity, sophistication
- Other equally sophisticated worms found since then
  - Flame: spread in ways similar to Stuxnet, but only gathers information from microphones, keystrokes, network traffic, and so forth for the attackers to retrieve

Importance of Stuxnet

- Earlier research showed physical systems vulnerable to attacks from connected computers
- Stuxnet showed these attacks can be launched over the Internet

Bots

- *bot*: malware that carries out some action in co-ordination with other bots
- *botmaster*: attacker controlling the bots on one or more systems
- *command and control (C&C) server*, *mothership*: system(s) the attacker uses to control the bots
- *C&C channels*: communication paths used to communicate with bots
  - Distinguishing characteristic of bot is the use of this channel
  - Can be triggered, updated over this
- *botnet*: a collection of bots

Life Cycle of a Bot in a Botnet

1. Bot infects system
2. Bot checks for a network connection, looks for either C&C server or another bot it can communicate with
3. Bot gets commands sent by C&C server or other bot
   - These may include adding components to add to what the bot can do
4. Bot executes these commands
   - May send results to somewhere else

Organization of a Botnet

- *Centralized*; each bot communicates directly with C&C server
  - Potential problem: C&C server can become a bottleneck
- *Hierarchical*: C&C server communicates with set of bots, which in turn act as C&C servers for other bots, in a hierarchy
  - Good for controlling large botnets such as Torpig (over 180,000 bots) and Mirai (estimated to have 493,000 bots)
- *Peer-to-peer*: no single C&C server; bots act as peers, and botnet is a peer-to-peer network
  - High latency; to join the botnet, a bot scans addresses until it finds another bot, then forwards message to it

Example: GTBot (Centralized)

- One of the earliest bots; used IRC channel as C&C channel
- Get it onto a Windows system running mIRC client
  - Installed scripts to monitor the channel looking for specific keywords
  - Also program to hide the bot, and possibly other programs to propagate the bot to other systems and install servers on them
- Once instance (Backdoor.IRC.Aladinz) installs and hides itself, then notifies attacker (via IRC channel) it is resident
  - This has lots of tools to launch attacks

Example: Torpig (Hierarchical)

- Based on Mebroot rootkit
- Bot installed itself so it is executed at boot, *before* the operating system loaded
- Then contacted Mebroot C&C server to get modules to add to bot
  - Compromises sensitive data like passwords
  - Data sent to Torpig C&C server
- Server acknowledges upload
  - Can also send file with addresses of backup Torpig C&C servers, and how often the bot should contact the server

Example: Trojan.Peacomm (Peer-to-Peer)

- Bot gets on Windows system
- Uses peer-to-peer protocol to connect to peers
  - Addresses of at least 100 peers stored in bot
- Looks for a value encoding a UTL pointing to another component
  - Downloads and executes this component
  - Many possible components, including one for spamming, one for reaping email addresses for spam, one to launch a distributed denial of service attack

Content Delivery Networks and IP Flux

- Content delivery networks (Netflix, Amazon, etc.) have many servers
  - These are invisible to the client
  - When DNS gets target system, it returns IP address to client
- As these networks grew, needed way to prevent any single server from being overloaded
- Mechanism is to change IP address associated with a particular host name over a very short period of time (called *IP flux*)
  - So, while traffic appears to go to one particular system, it is actually sent to whichever server has the address currently

Applying This to Botnets

- Goal: make it harder to locate bots
  - Especially C&C servers
- Approach: associate list of IP addresses with host name
- *IP flux botnet*: change binding between host name (in bot) and IP address, going down the list (*flux*)
  - *Single flux botnet*: list of IP addresses is large; host name is registered to one of these addresses, and after a short time deregistered and reregistered using a different IP address
  - *Double flux botnet*: do the same with IP addresses of the DNS servers used to look up the IP addresses
- Also called *fast flux botnets*

Example: Flame (Fast Flux Botnet)

- Bot gathers information from infected system, network
  - This is then retrieved over C&C channel to Flame server
  - Server can also send new modules for bot
- When Flame installed:
  - Check for network by trying to connect to well-known servers; assume successful
  - Flame had 5 domains initially for the Flame server; Flame server could add more to this list
    - Communication over SSL; Flame's certificate was self-signed
  - Preliminary analysis: more than 50 host names and more than 15 IP addresses related to C&C messages; later raised number of C&C hosts to around 100

Variation: Domain Flux

- Instead of holding host name fixed and changing the associated IP address, change host name and keep associated IP address fixed
  - Called *domain flux*
- Advantage: host name associated with C&C server for a short period of time
  - With IP flux, finding host name identifies C&C server
- Example: Torpig
  - Compute a host name that is fixed for current week number and year; append ".com", ".net", ".biz" suffixes and probe for each
  - If no luck, generate name based on current day, append suffixes, probe for each
  - If no luck, go to fixed list of host names

Rabbit, Bacterium

- A program that absorbs all of some class of resources
- Example: for UNIX system, shell commands:

```
while true
do
   mkdir x
   chdir x
done
```

- Exhausts either disk space or file allocation table (inode) space

Logic Bombs

- A program that performs an action that violates the site security policy when some external event occurs
- Example: program that deletes company's payroll records when one particular record is deleted
  - The "particular record" is usually that of the person writing the logic bomb
  - Idea is if (when) he or she is fired, and the payroll record deleted, the company loses *all* those records

Adware

- Trojan horse that gathers information for marketing purposes and displays advertisements
  - Often selects ads to display based on gathered information
- Believed to have originated with a company announcing it would make its software available for free, because it would pop up window advertising company
  - Benign as user had to opt in
  - Spread through distribution of program only

Types of Behavior

- *Low severity behavior*: just display ads, don't transmit information
- *Medium severity behavior*: transmits information deemed low risk, such as location information, and may display ads based on this
- *High severity behavior*: transmits personal information, and displays ads tailored to devices, people with those characteristic
  - Typically very aggressive (annoying)
  - Sometimes called *madware*

Getting Adware On a System

- Put on a web site user visits
  - Put it in a banner enticing the user to click on it; this installs the adware
  - Page may require user to install software to view parts of web site; software contains adware
  - If page refreshes automatically, it may direct browser to run an executable
    - Usually browser notifies user via a dialog box that may require a click; on click, program runs and installs adware
  - Some browser plug-ins download, execute files automatically; there may be no indication of this
    - Called *drive-by downloading*

Getting Adware on a System

- Put into software that user downloads
  - Very common with mobile apps
- Problem: app asks for permission to carry out its tasks
  - Some may be unnecessary; often hard for users to minimize permissions set
  - Thus app may have access to camera, microphone, and may be able to make calls without going through dialing interface — and user does not realize this
- Example: survey of 900 Android apps
  - 323 had unnecessary permissions