CS459/698 Privacy, Cryptography, Network and Data Security

Malicious Software

Winter 2025, Monday/Wednesday 4:00pm-5:20pm

Malware?

What is malware?

- Various forms of software written with malicious intent
- Common characteristic of all types of malware: needs to be executed in order to cause harm
- How might malware get executed?

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- Common characteristic of all types of malware: needs to be executed in order to cause harm
- How might malware get executed?
  - User action
  - Downloading and running malicious software
  - Viewing a web page containing malicious code
  - Opening an executable email attachment
  - Inserting a CD/DVD or USB flash drive
  - Exploiting an existing flaw in a system
  - Buffer overflows in network daemons
  - Buffer overflows in email clients or web browsers

Some types of malware

- Viruses
  - Malicious code that adds itself to benign programs/files
  - Code for spreading + code for actual attack
  - Usually activated by users
- Worms
  - Malicious code spreading with no or little user involvement
- Trojans
  - Malicious code hidden in seemingly innocent program that you download

Viruses

What is a virus?

- A virus is a particular kind of malware that infects other files
- Traditionally, a virus could infect only executable programs
- Nowadays, many data document formats can contain executable code (such as macros)
- Many different types of files can be infected with viruses
- Typically, when the file is executed (or sometimes just opened), the virus activates, and tries to infect other files with copies of itself
- In this way, the virus can spread between files, or between computers

Infection

- What does it mean to “infect” a file?
- The virus modifies a (non-malicious) program or document (the host) in such a way that executing or opening it will transfer control to the virus
  - The virus can do its “dirty work” and then transfer control back to the host
- For executable programs:
  - The virus will modify other programs and copy itself to the beginning of the targets’ program code
- For documents with macros:
  - The virus will edit other documents to add itself as a macro which starts automatically when the file is opened

Infection

- In addition to infecting other files, a virus will try to infect the computer itself
  - This way, every time the computer is booted, the virus is automatically activated
- It might put itself in the boot sector of the hard disk
- It might add itself to the list of programs the OS runs at boot time
- It might infect one or more of the programs the OS runs at boot time
- It might try many of these strategies
  - But it’s still trying to evade detection!

Spreading

- How do viruses spread between computers?
- Usually, when the user sends infected files (hopefully not knowing they're infected!) or compromised website links to his friends
- A virus usually requires some user action to spread to another machine
  - If it can spread on its own (via email, for example), it's more likely to be a worm than a virus

Payload

- In addition to trying to spread, what else might a virus try to do?
- Some viruses try to evade detection by disabling any active virus scanning software
- Most viruses have some sort of payload
- At some point, the payload of an infected machine will activate, and do something (usually bad)
  - Erase your hard drive, or make your data inaccessible
  - Subtly corrupt some of your spreadsheets
  - Install a keystroke logger to capture your online banking password
  - Start attacking a particular target website

Spotting viruses

- When should we look for viruses?
  - As files are added to our computer
    - Via portable media
    - Via a network
  - From time to time, scan the entire state of the computer
    - To catch anything we might have missed on its way in
    - But of course, any damage the virus might have done may not be reversible

- How do we look for viruses?
  - Signature-based protection
  - Behaviour-based protection

Signature-based protection

- Keep a list of all known viruses
- For each virus in the list, store some characteristic features (the signature)
- Most signature-based systems use features of the virus code itself
  - The infection code
  - The payload code
- Can also try to identify other patterns characteristic of a particular virus
  - Where on the system it tries to hide itself
  - How it propagates from one place to another

Polymorphism

- To evade signature-based virus scanners, some viruses are polymorphic
  - This means that instead of making perfect copies of itself every time it infects a new file or host, it makes a modified copy instead
  - This is often done by having most of the virus code encrypted
    - The virus starts with a decryption routine which decrypts the rest of the virus, which is then executed
    - When the virus spreads, it encrypts the new copy with a newly chosen random key

- **Q:** How would you scan for polymorphic viruses?

Behaviour-based protection

- Signature-based protection systems have a major limitation
  - You can only scan for viruses that are in the list!
  - But there are brand-new viruses identified every day
  - What can we do?
- Behaviour-based systems look for suspicious patterns of behaviour, rather than for specific code fragments
  - Some systems run suspicious code in a sandbox first

Worms

What is a worm?

- A worm is a self-contained piece of code that can replicate with little or no user involvement
- Worms often use security flaws in widely deployed software as a path to infection
- Typically:
  - A worm exploits a security flaw in some software on your computer, infecting it
  - The worm immediately starts searching for other computers (on your local network, or on the Internet generally) to infect
  - There may or may not be a payload that activates at a certain time, or by another trigger

The Morris worm

- The first Internet worm, launched by a graduate student at Cornell in 1988
- Once infected, a machine would try to infect other machines in three ways:
  - Exploit a buffer overflow in the “finger” daemon
  - Use a back door left in the “sendmail” mail daemon
  - Try a “dictionary attack” against local users’ passwords. If successful, log in as them, and spread to other machines they can access without requiring a password
- All three of these attacks were well known!
- First example of buffer overflow exploit in the wild
- Thousands of systems were offline for several days

The Code Red worm

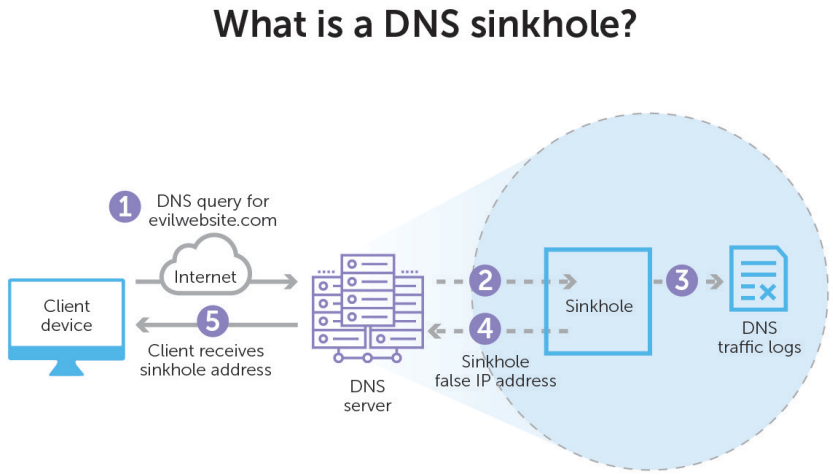
- Launched in 2001
- Exploited a buffer overflow in Microsoft's IIS web server (for which a patch had been available for a month)
- An infected machine would:
  - Deface its home page
  - Launch attacks on other web servers (IIS or not)
  - Launch a denial-of-service attack on a handful of web sites, including www.whitehouse.gov
  - Installed a back door to deter disinfection
- Infected 250,000 systems in nine hours

The Slammer worm

- Launched in 2003, performed denial-of-service attack
- First example of a “Warhol worm”
  - A worm which can infect nearly all vulnerable machines in just 15 minutes
- Exploited a buffer overflow in Microsoft’s SQL Server (also had a patch available)
- A vulnerable machine could be infected with a single UDP packet!
  - This enabled the worm to spread extremely quickly
  - Exponential growth, doubling every 8.5 seconds
  - 90% of vulnerable hosts infected in 10 minutes

Conficker Worm

- First detected in November 2008
- Propagated a command-and-control style botnet
- Security experts had to generate and sinkhole C&C domains
- Number of infected hosts in 2009: 9–15 million, 2011: 1.7 million, 2015: 400,000



Stuxnet

- Discovered in 2010
- Allegedly created by the US and Israeli intelligence agencies
- Allegedly (pretty sure now) targeted Iranian uranium enrichment program
- Targets Siemens SCADA systems installed on Windows. One application is the operation of centrifuges
- It tries to be very specific and uses many criteria to select which systems to attack after infection

Stuxnet

- **Very promiscuous:** Used 4(!) different zero-day attacks to spread. Has to be installed manually (USB drive) for air-gapped systems.
- **Very stealthy:** Intercepts commands to SCADA system and hides its presence
- **Very targeted:** Detects if variable-frequency drives are installed, operating between 807–1210 Hz, and then subtly changes the frequencies so that distortion and vibrations occur resulting in broken centrifuges.

Stuxnet

- "Iranian President Mahmoud Ahmadinejad observes computer monitors at the Natanz uranium enrichment plant in central Iran, where Stuxnet was believed to have infected PCs and damaged centrifuges."

https://www.wired.com/2014/11/countdown-to-zero-day-stuxnet/

Worms and the “salami attack”

- A salami attack is made up of smaller, seemingly inconsequential, attacks
- Classic example: send the fractions of cents of round-off error from many accounts to a single account owned by the attacker
- More commonly:
  - Credit card thieves make very small charges to very many cards
  - Clerks slightly overcharge customers for merchandise
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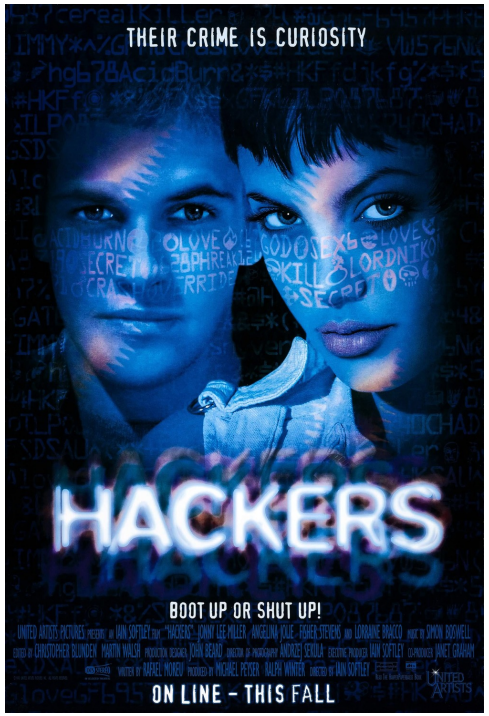

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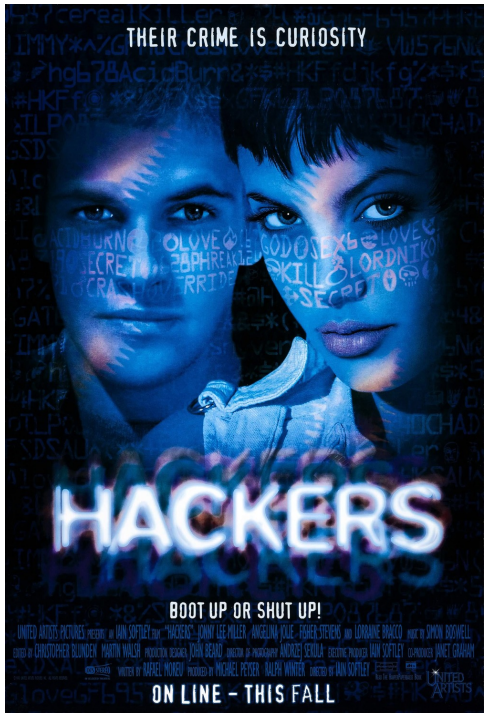

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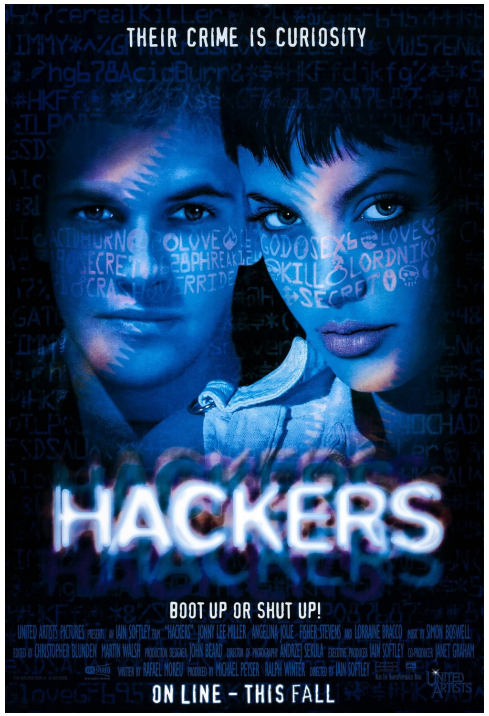

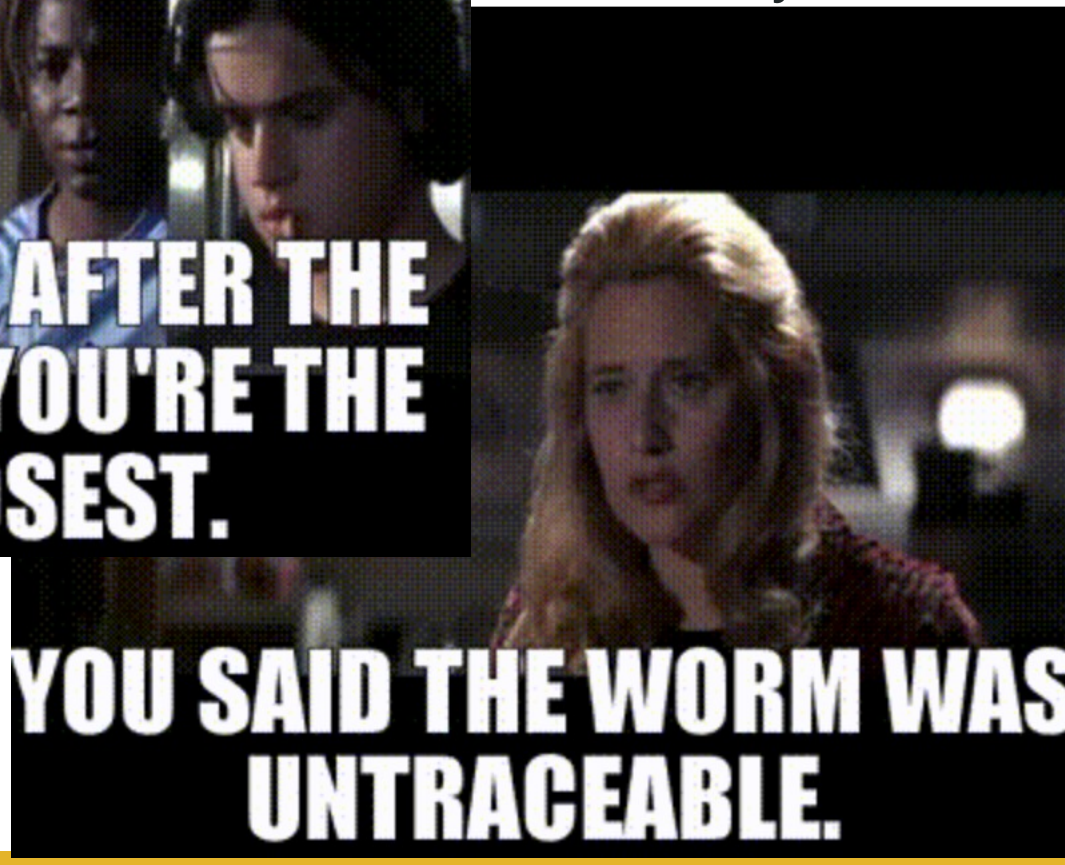

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Trojans

Have you ever seen this?

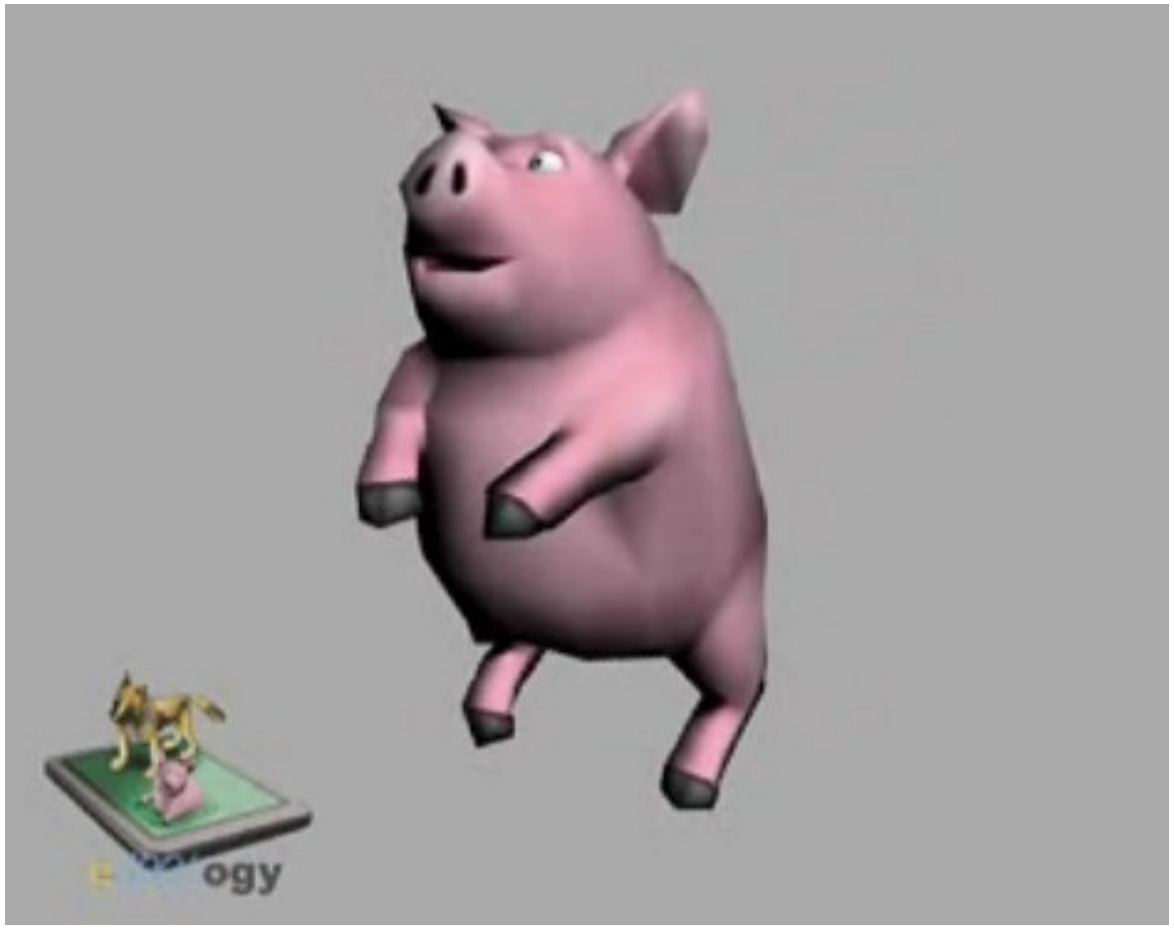
http://www.sampsonuk.net/B3TA/TrojanHorse.jpg

What are Trojan Horses?

- Trojan horses are programs which claim to do something innocuous (and usually do), but which also hide malicious behaviour

"You're surfing the Web and you see a button on the Web site saying, "Click here to see the dancing pigs." And you click on the Web site and then this window comes up saying, "Warning: this is an untrusted Java applet. It might damage your system. Do you want to continue? Yes/No." Well, the average computer user is going to pick dancing pigs over security any day. And we can't expect them not to." — Bruce Schneier

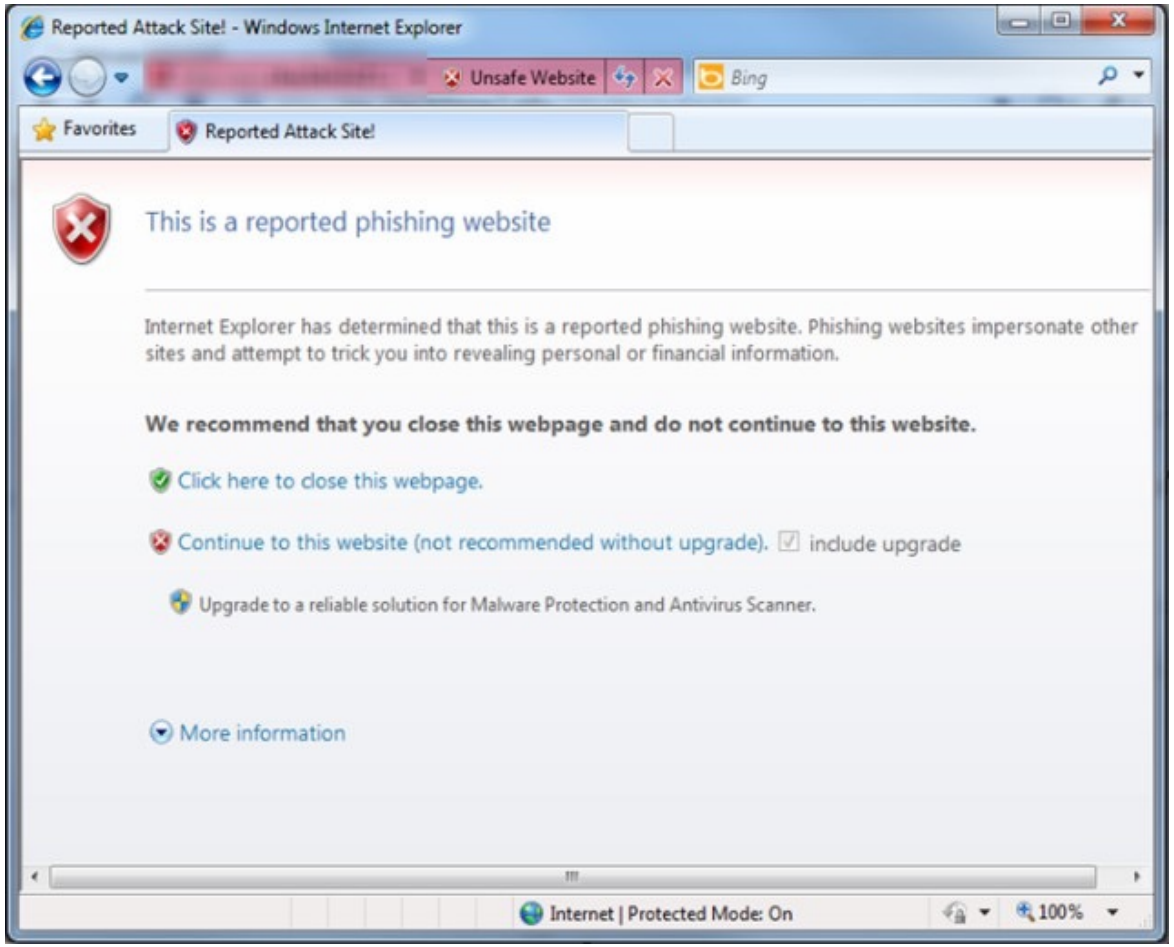
Dancing Pig



How do Trojan Horses work?

- Gain control by getting the user to run code of the attacker's choice, usually by also providing some code the user wants to run
- "PUP" (potentially unwanted programs) are an example
- For scareware, the user might even pay the attacker to run the code
- The payload can be anything; sometimes the payload of a Trojan horse is itself a virus, for example
- Trojan horses usually do not themselves spread between computers; they rely on multiple users executing the "trojaned" software

Scareware



http://static.arstechnica.com/malware_warning_2010.png

Ransomware

https://en.wikipedia.org/wiki/WannaCry_ransomware_attack#/media/File:Wana_Decrypt0r_screenshot.png

How does ransomware work?

- Demands ransom to return some hostage resource to the victim
- CryptoLocker in 2013:
  - Spread with spoofed e-mail attachments from a botnet
  - **Encrypted** victim's hard drive
  - Demanded ransom for **private key**
  - Botnet taken down in 2014; estimated ransom collected between $3 million to $30 million
- Could also be scareware

WannaCry

- Launched in May 2017, ransomware
- Infected ~230,000 computers
- Exploits a Windows SMB vulnerability originally discovered by the NSA
- NSA kept it secret (and exploited it)
- The “Shadow Brokers” leaked it (and others) in April 2017
- Microsoft had released a patch after being alerted by NSA but many systems remained unpatched
- Emergency patch for Windows XP and 8 in May 2017

WannaCry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Why 'WannaCry' Malware Caused Chaos for National Health Service in U.K.
The cyberattack has quickly become another political football in the years-long battle over the funding, remit, and existential future of the NHS.

Botnets

New Generation Botnets

- Today’s botnets are very sophisticated
- Virus/worm/trojan for propagation, exploit multiple vulnerabilities
- Stealthiness to hide from owner of computer
- Code morphing to make detection difficult
- Bot usable for different attacks (spam, DDoS,...)

Botnet’s infrastructure

- Distributed, dynamic & redundant control infrastructure
  - “Fast Flux”
    - A single host name maps to hundreds of addresses of infected machines
    - Machines proxy to malicious websites or to “mothership”
    - Machines are constantly swapped in/out of DNS to make tracking difficult
- Domain Generation Algorithm
  - Infected machine generates a large set (50,000 in the case of Conficker) of domain names that changes every day, contacts a random subset of these names for updates
  - To control the botnet, authorities would have to take control of 50,000 different domain names each day

Motivations for building botnets

- Earlier worms (Nimda, Slammer) were written by hackers for fame with the goal to spread worm as fast as possible
  - Caused disruption and helped detection
- Today's botnets are controlled by crackers looking for profit, which rent them
  - Criminal organizations
- Can spread more slowly and in targeted ways
  - Intelligence and espionage?

Sample botnet: Storm

- In September 2007, Storm Worm botnet included hundreds of thousands or even millions of machines
- Bots were used to send out junk emails advertising web links that when clicked attempted to download and install worm, or to host these websites
- Botnet was also rented out for pharmacy and investment spam
- As a self-defence mechanism, it ran DDoS attacks against Internet addresses that scanned for it
- Problem: its P2P protocol created >10 times usual P2P traffic (=> detectable)

Sample botnet: Mirai

- In Fall 2016, the Mirai botnet attacked several high-profile targets, including a popular security blog and a large DNS provider
- Attack traffic of so far unseen 1 Tbps or more
- Botnet consisted of 600,000 IoT devices (routers, cameras) infected due to unchanged default passwords
- Distribution based on self-propagating worm
- Each bot flooded targets with UDP, TCP, and HTTP traffic, no amplification or reflection
- Botnet is believed to be part of a rivalry between Minecraft server operators

The new script kiddie on the block

- For all of the discussed attacks, exploit code and complete attack scripts are available on the Internet
- Script kiddies can download scripts and raise an attack with minimum effort

- There are even tools that allow easy building of individual attacks:

E.g., Metasploit Framework, based on existing exploits

E.g., LOIC, stress testing and denial-of-service