Computer Security (COM-301)

Malware

Introduction

Slides created by Carmela Troncoso
Some slides/ideas adapted from: Gianluca Stringhini / Emiliano de Cristofaro / George Danezis

Previous attacks: the adversary actively exploits model/ design/ implementation errors

Insecure interactions between components

Usually enabled by lack of checks when processing input

'OS Command Injection'

```
$username = $_POST['user'];
$command = 'ls -l /home/' . $username;
system($command);
```

Problem if $username='; rm – rf'

'Cross-site scripting'

```
$username = $_GET['userName'];
echo '<div class="header"> Welcome, ' . $username . '</div>';
```

Problem if $username='<script>....</script>'

'Cross-site Request Forgery'

```
<form action='http://epflHR.ch/paystudent.php' id='form' method='post'>
<input type='hidden' name='firstname' value='Ugo'>
<input type='hidden' name='lastname' value='Damiano'>
<input type='hidden' name='amount' value = '1000 CHF'>
```

Problem if on the server side a user is logged in (the server-side code will process the form with THAT user's privileges)

Risky Resource Management

Enabled by lack of checks or careless programming

'Uncontrolled Format String'

```
#include<stdio.h>
int main(int argc, char** argv) {
    char buffer[100];
    strncpy(buffer, argv[1], 100);
    printf(buffer);
    return 0;
}
```

Problem if argv[1]='%d %d %d %d' (the program will read from the stack)

Memory safety ('buffer overflow')

```
void vulnerable(char *buf) {
        free(buf);
        buf[12] = 42;
}
```

Accessing a freed memory region

Code Injection

Inject arbitrary code in the stack and execute it

Control Flow Hijack

Inject arbitrary return pointers to execute desired existing instructions

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Network attacks

Lack of security mechanisms in network protocols

'ARP/DNS/BGP Hijacking'

Change association of high-level and low-level addresses, names, routes

'Denial of Service'

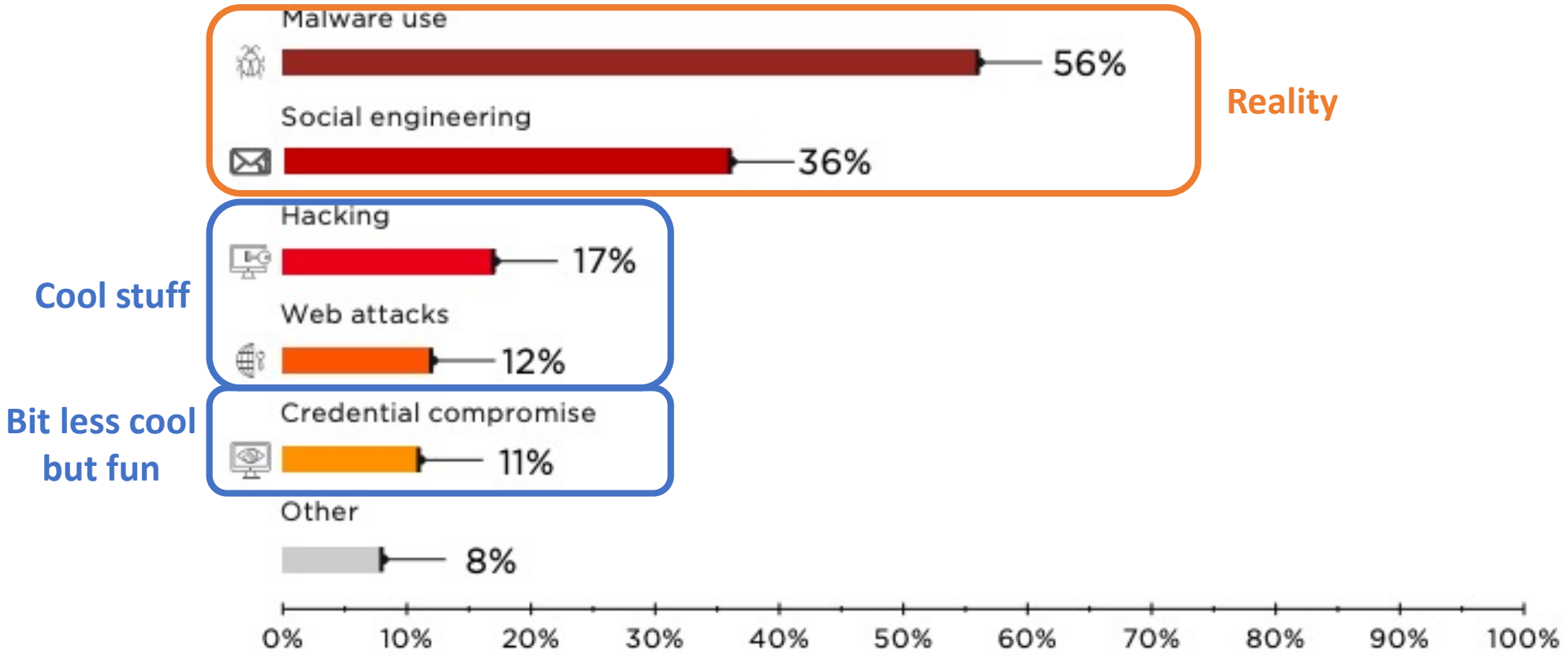
Capability of adversaries to exhaust the resources of a victim by using flaws at the network or application layers

Expert adversary

requires deep understanding of computer systems and networks

"Manual" adversary

requires manual coding and testing to find the vulnerabilities and exploit them



https://www.ptsecurity.com/ww-en/analytics/cybersecurity-threatscape-2019-q1/

Malware

Short for “Malicious Software”

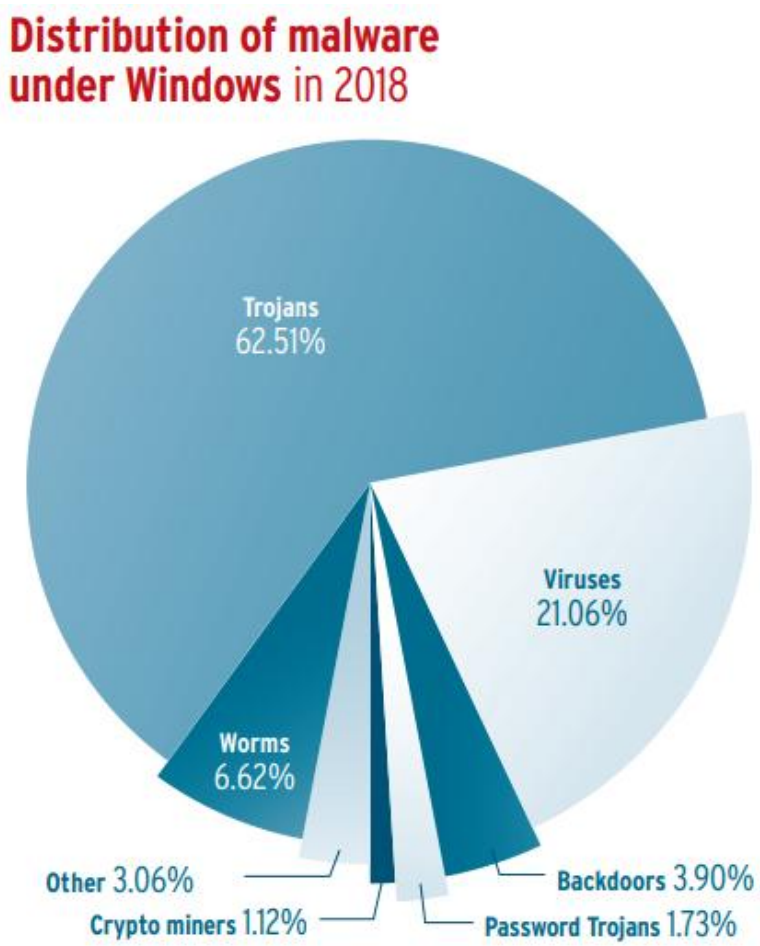
Software that **fulfills the author’s malicious intent**

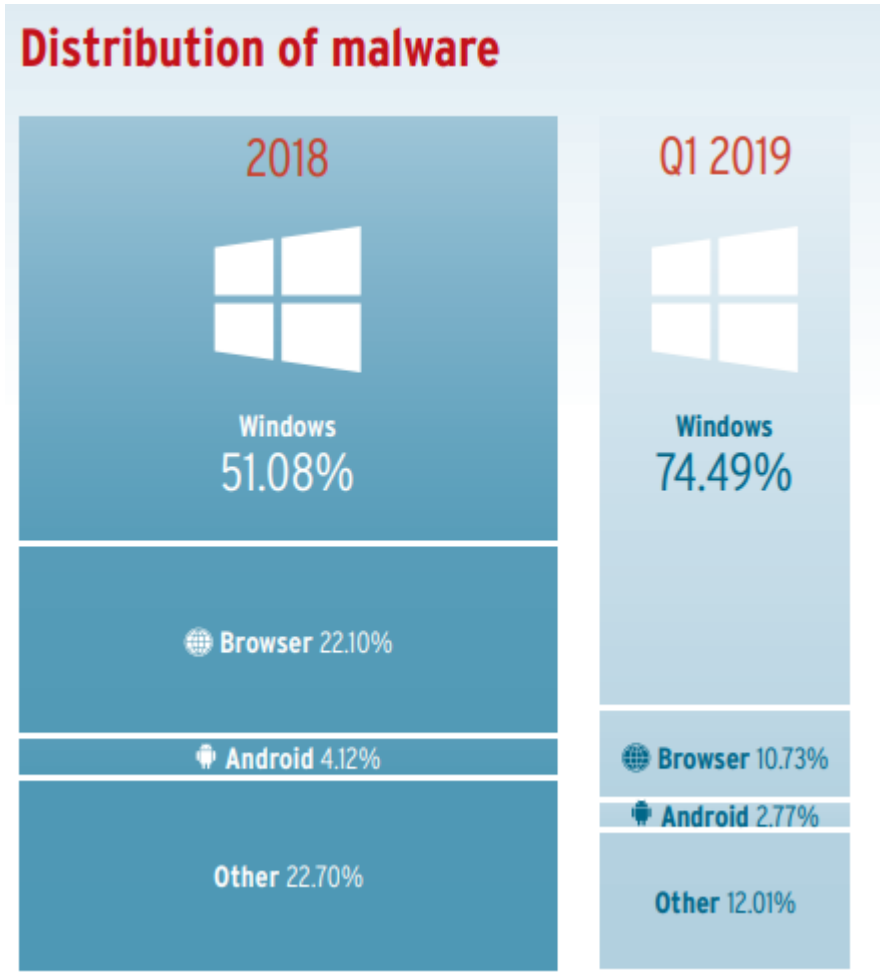
Intentionally written to cause adverse effects

Many flavors with a common characteristic: **perform some unwanted activity**

Malware != virus

Virus is a kind of Malware





https://www.av-test.org/fileadmin/pdf/security_report/AV-TEST_Security_Report_2018-2019.pdf

Malware – why the rise?

Homogeneous computing base

Windows/Android make very tempting targets

Clueless user base

Many targets available

Unprecedented connectivity

Deploying remote / distributed attacks is increasingly easier

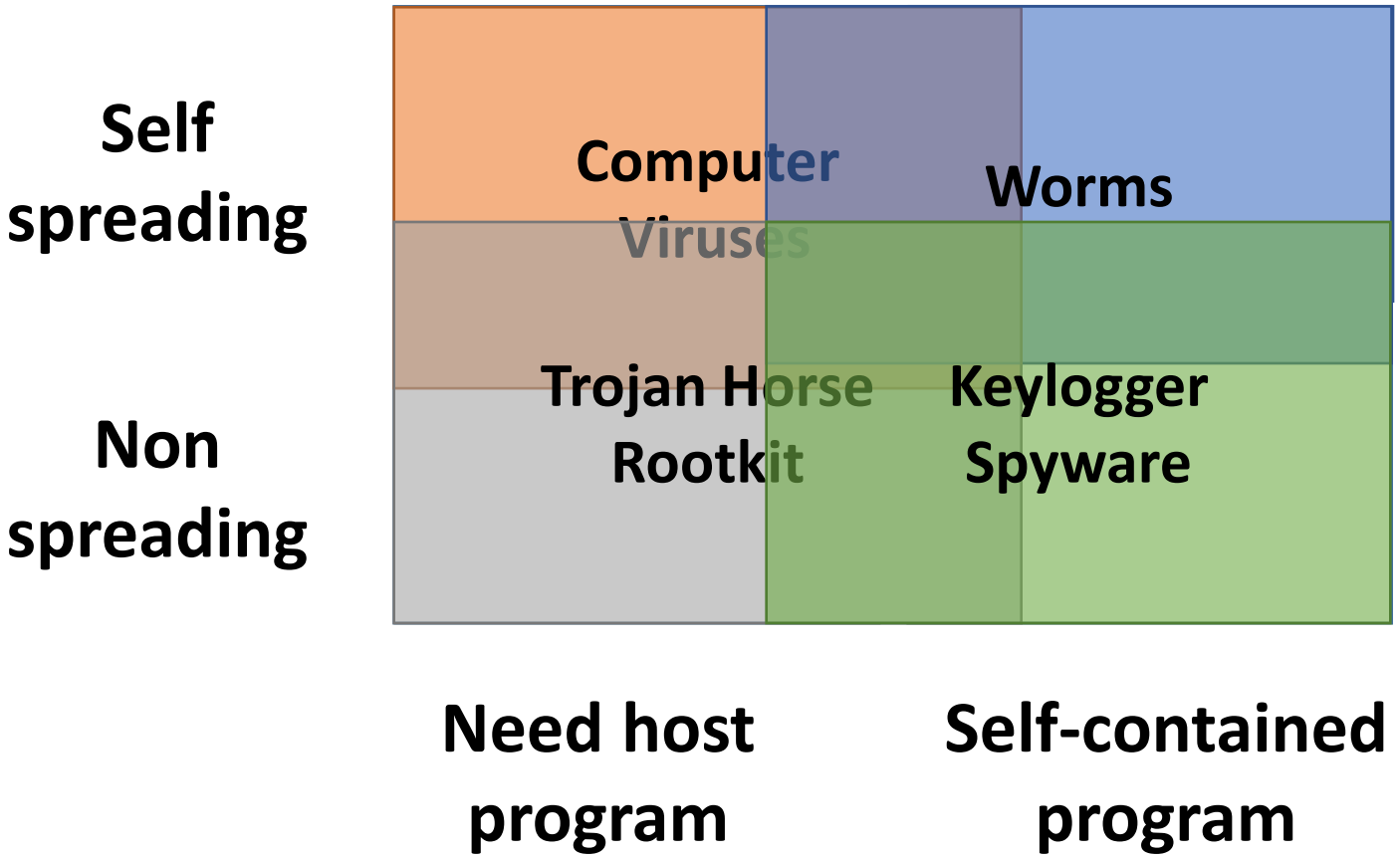
Malicious code has become profitable!

Compromised computers can be sold and/or used to make money (and Bitcoins)

ATTACKER ENGINEERING PROCESS

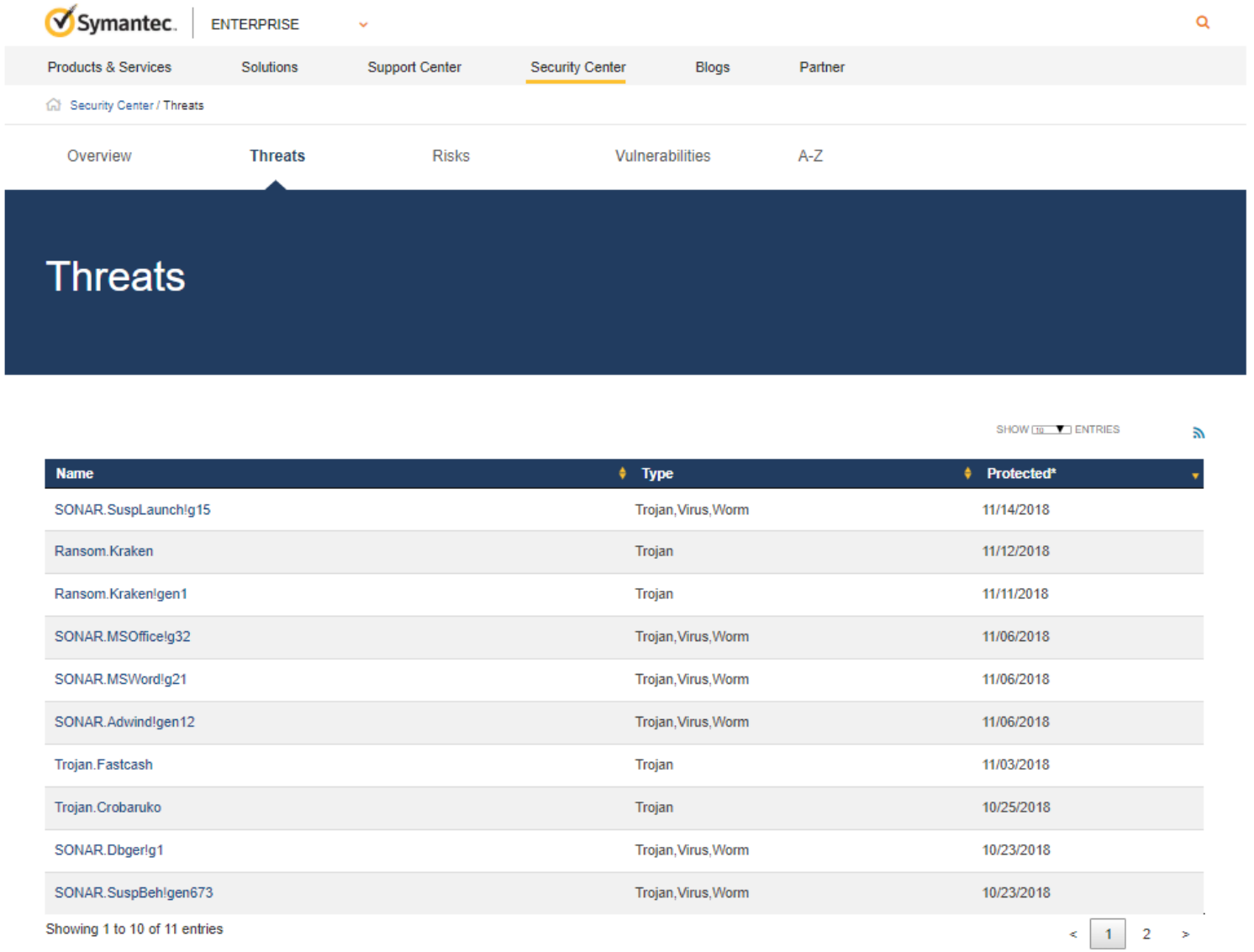
- Exploit new capabilities
- Exploit new entities (that are less prepared than expected in the design phase!)

Malware – taxonomy



Malware – taxonomy

Modern malware tends to combine “the best” of the categories to achieve its purpose



[DEPRECATED]

Lists of:

- **Threats**
- **Vulnerabilities**
- **Risks**

To go further:

BOOK

Computer viruses : from theory to applications

Filiol, Eric

Paris : Springer Paris

2005

Available at EPFL Library Basement area A (DVD/CD). Please ask the desk. (004.49 FIL) and other locations ›

Chapters of this book (14) ›

TURING AWARD LECTURE

Reflections on Trusting Trust

To what extent should one trust a statement that a program is free of Trojan horses? Perhaps it is more important to trust the people who wrote the software.

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Malware

Types of Malware

Slides created by Carmela Troncoso
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Virus (1)

RANSOMWARE: malware that threatens to destroy a system unless the owner pays money to receive the "antidote"

Piece of software that **infects** programs to monitor / steal / destroy

- Viruses modify programs to include a (possibly modified) copy of themselves
- Viruses **cannot** survive without the host

What are the permissions of a virus?

- The same permissions as the host!
  - virus can do anything that the host program is permitted to do
  - virus **executes** secretly when the host program is run

The host program would be acting as… ?

Yes! The confused deputy again!

Recurring problem in security!

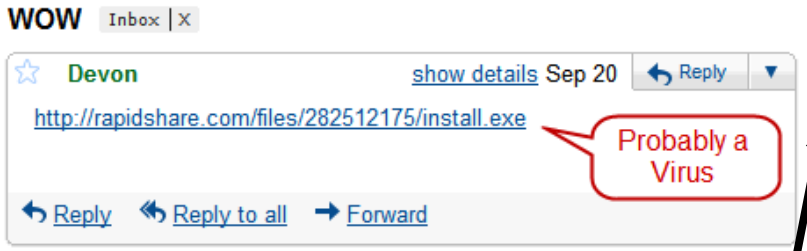
Mitigation: follow the least privilege principle!

Specific to operating system and hardware

- take advantage of their details and weaknesses

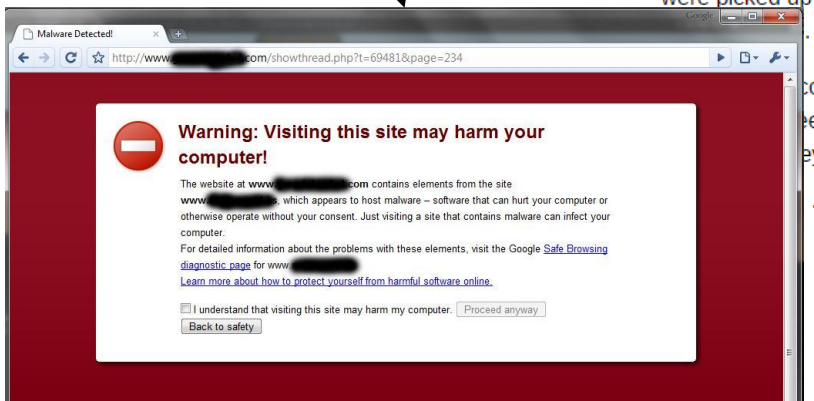
Virus (2)

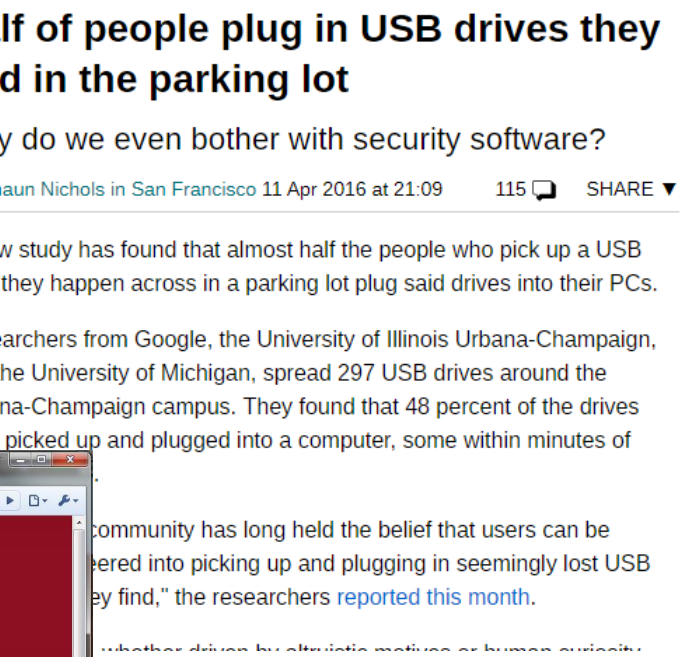
Replicates to infect other content or machine (host spreads through network or hardware)



email

web





Half of people plug in USB drives they find in the parking lot

Why do we even bother with security software?

By Shaun Nichols in San Francisco 11 Apr 2016 at 21:09 115 SHARE ▼

A new study has found that almost half the people who pick up a USB stick they happen across in a parking lot plug said drives into their PCs.

Researchers from Google, the University of Illinois Urbana-Champaign, and the University of Michigan, spread 297 USB drives around the Urbana-Champaign campus. They found that 48 percent of the drives were picked up and plugged into a computer, some within minutes of

community has long held the belief that users can be eered into picking up and plugging in seemingly lost USB ey find," the researchers reported this month.

https://heimdalsecurity.com/blog/practical-online-protection-where-malware-hides/

Virus – where can they act

File infection

Overwrite (substitute the original program), *Parasitic* (append and modify)

Macro infection

Overwrite macro executed on program load (MS Excel, Word)

Need to find an exploit to insert the macro

Boot infection

Most difficult! …and most dangerous

Infect booting partition

Melissa (1999) - Slide Quadrant: Self-spreading / Need host program.

The host:

It infects Microsoft Word documents (.doc) using a "Macro“ (a small script inside the document designed to automate tasks)

A user receives an email titled "Important Message from [Name]" and opens the attached Word file named list.doc.

First payload:

Once opened, the macro executes, modifies global settings in Word to reattach itself to any other word document opened.

Secretly accesses the user’s Microsoft Outlook address book to send infected doc file ...

Second payload:

When the current minute matches the day when it is being launched, it inserts the quote "Twenty-two points, plus triple-word-score, plus 50 points for using all my letters. Game's over. I'm outta here.“ (Bart Simpson)

Virus – defenses

Antivirus Software

Signature-based detection

sequence of bytes/instructions that are known to be part of the virus

Database of byte-level or instruction-level signatures that match virus

Wildcards and regular expression can be used

Hash of known malicious programs

Heuristics (check for signs of infection / anomalies) and

incorrect header sizes, suspicious code section name

Behavioral signatures – detect series of changes done by a virus

Sandboxing

Run untrusted applications in restricted environment (e.g., use a VM)

Worm

Self-replicating computer program that uses a network to send copies of itself to other nodes

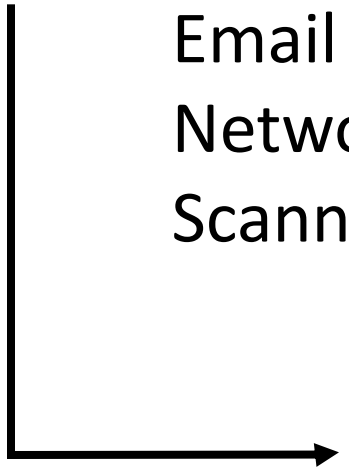
Does not need a host program to execute

Autonomous spread over the network

Email harvesting (address book, inbox, browser cache)

Network enumeration

Scanning (at random or targeted)



Email: requires human interaction (fake `from`, hidden attachments)

Network: automated!

Worm example - WannaCry (2017)

A case of **Ransomware**

→ **Require money to recover system**

Exploits a vulnerability revealed in a NSA hacking toolkit leak

- Mishandled packets for the Microsoft Server Message Block (protocol for shared access) enable arbitrary code execution
- The leak contained vulnerabilities in systems from e.g., Cisco Systems and Fortinet Inc

Encrypted data and asked for ransom in Bitcoins

- 300$ in 3 days or 600$ in 7 days or **DELETE**

>200,000 victims

$130,634 obtained in ransom

billions of dollars in damage, UK Hospitals affected

Worm example - WannaCry (2017)

A case of **Ransomware**

→ **Require money to recover system**

How did it end?

The worm “kill switch” was found

- Upon installation, the malware checked the existence of a web. If yes, it stopped.
- A researcher registered the website and the worm stopped

Why have a kill switch?

- Avoid worm study if hijacked, or if in sandbox

Worm – defenses

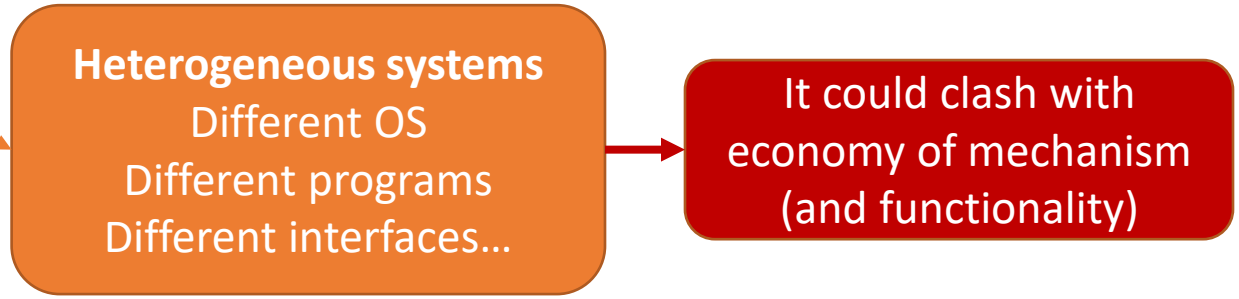
Host-level

Protecting software from remote exploitation → **Attacks & Software security lecture!**

Stack protection techniques → **Software security lecture!**

Achieve diversity to increase protection → require more sophisticated worms

Antivirus (email-based Worms)



Network-level

Limit the number of outgoing connections: limit worm spreading

Personal firewall

e.g., block outgoing SMTP connections from unknown applications

Intrusion detection systems

Intrusion detection systems – what they do

Host-based vs. Network-based

Host: process running on a host. Detects local malware

Network: network appliance monitoring all traffic

Signature based vs. Anomaly-based detection

Signature: identifies known patterns

+ low false alarms

- expensive (need up-to-date signatures), can't find new attacks

Anomaly: attempts to identify behavior different than legitimate

+ adapt to new attacks (legitimate does not change!)

- high number of false alarms

Trojan Horse

Malware that *appears to perform a desirable function* but it also performs **undisclosed malicious activities**

Requires users to **explicitly** run the program

Cannot replicate but can do any malicious activity

Spy on sensitive user data (spyware)

Allow remote access (backdoor)

Base for further attacks→ act as mail relay (for spammers)

Damage routines (corrupting files)

Defense: Sign programs? Train users?

and follow least privilege principle!

Trojan Horse examples:
Zeus (2007 …)
Tiny Banker Trojan (2012)

Goal: steal users sensitive data, such as account login information and banking codes.

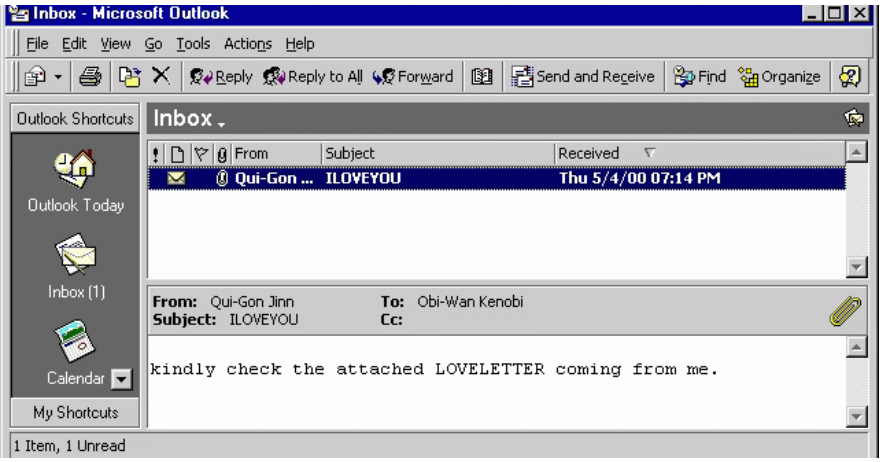
Mode of Operation 1

1. Sniff packets to learn when a user visits **a banking website**
2. Steal credentials before they are sent → send to malware server
   Reads keystrokes before encryption!!

Mode of Operation 2

1. Sniff packets to learn when a user visits **a banking website**
2. Steal appearance from website
3. Ask questions to user on a pop-up → send answer to malware server

Example Worm+Virus+Trojan – ILoveYou (2000)



Target: Windows 9X/2000

"LOVE-LETTER-FOR-YOU.txt.vbs" sent as email attachment

Known extension to Windows, hidden from users!
Users think they open a text file, not an executable

Operation:

Replaced files with extensions JPG, JPEG, VBS, JS, DOC, … by itself
The script adds Windows Registry data for automatic startup on system boot
Downloaded a Trojan part “Barok”: "WIN-BUGSFIX.EXE“ (steal passwords)
(also: virus-like because, it sent itself to each entry Outlook address book, sometimes changing subject)

Damage: $10 billion

Rootkit

Adversary controlled code that takes residence **deep within the TCB** of a system

- Hides his presence by modifying the OS

Installed by an attacker **after** a system has been compromised

- Difficult to detect
  - Replace system programs with trojaned versions
  - Modify kernel data structures to hide processes, files, and network activities
- Allows the adversary to return on a later time

Defense (difficult!): Integrity checkers user/kernel level

Rootkit+Worm example: Stuxnet (2010)

Goal: Attack SCADA (Control systems) of Iran's nuclear power plants

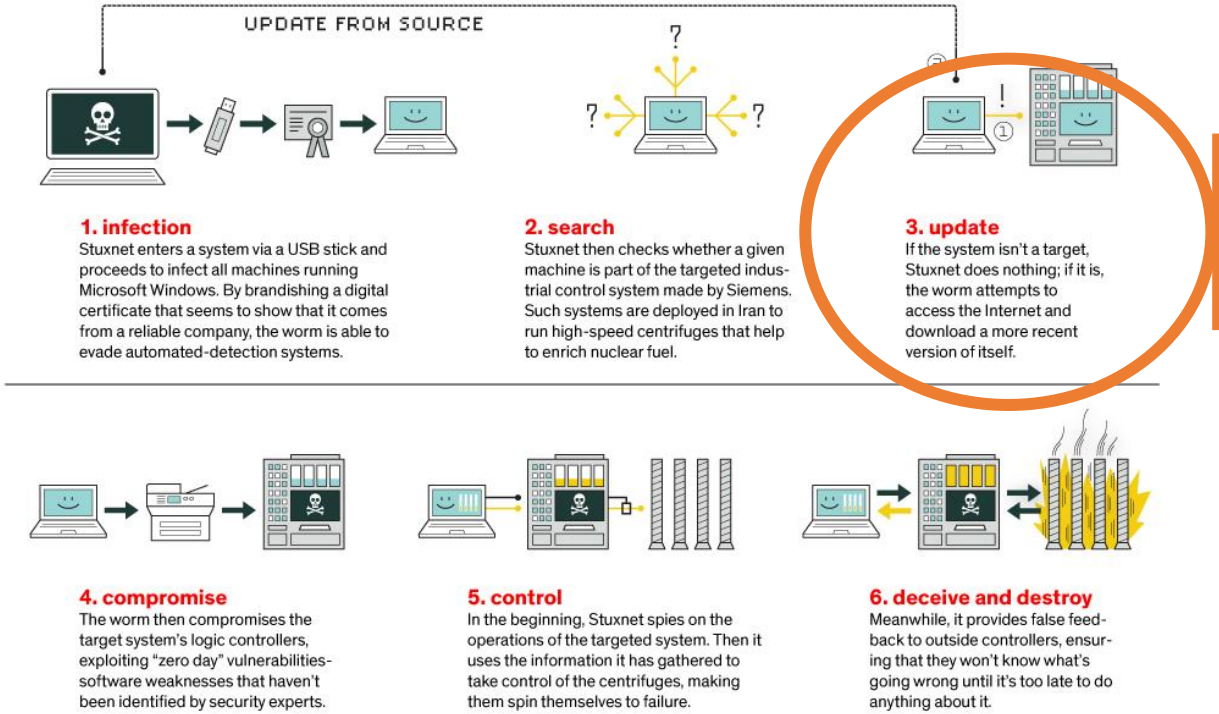
Three modules:

Worm: spread Stuxnet's payload

Link file: executed malicious code

Rootkit: hide the presence of malicious file to avoid detection

Stuxnet needs to be in the network, but the network is closed and disconnected
→ Entered via infected USB



Very targeted attack. If the system infected is not a target, the malware stays dormant.

Authorship?

Alleged Israel/US Cyberweapon

https://spectrum.ieee.org/telecom/security/the-real-story-of-stuxnet/

Backdoor

A **hidden** functionality that allows the adversary to bypass some security mechanism

Why not “audit” the program?

We can audit the program source

what if the **compiler** is malicious and introduces backdoors?

Chain of reasoning leads us to suspect all programs down to the very first compiler!

Key paper: *Thompson, Ken. "Reflections on trusting trust." Communications of the ACM (1984)*

More readable summary: https://www.schneier.com/blog/archives/2006/01/countering_trus.html

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Botnets

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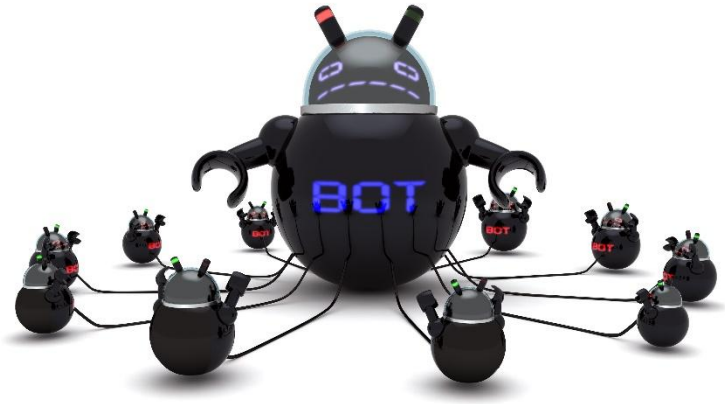
Botnets

Attacks at scale!!



Multiple (millions) compromised **hosts** under the control of a single entity

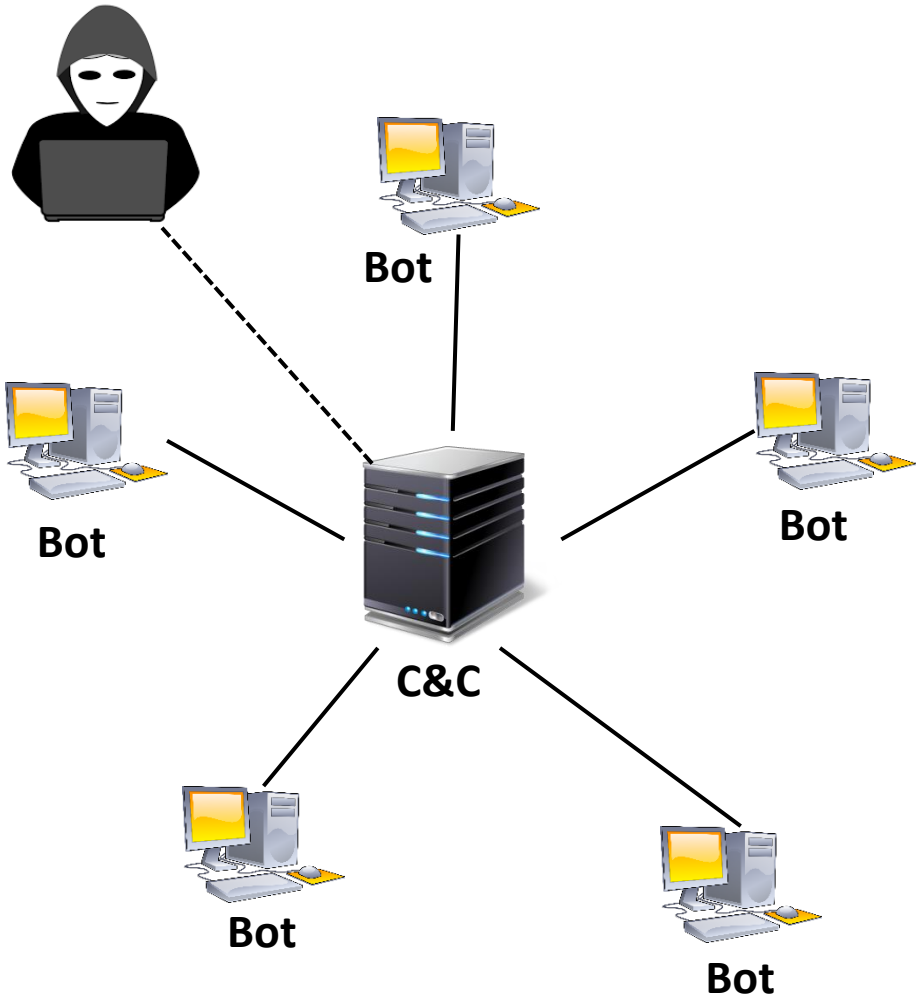
“zombies” or “bots”

uses

Bot-net command & control (C&C)

System to keep track of bots and send commands to them

Botnets - Star Topology

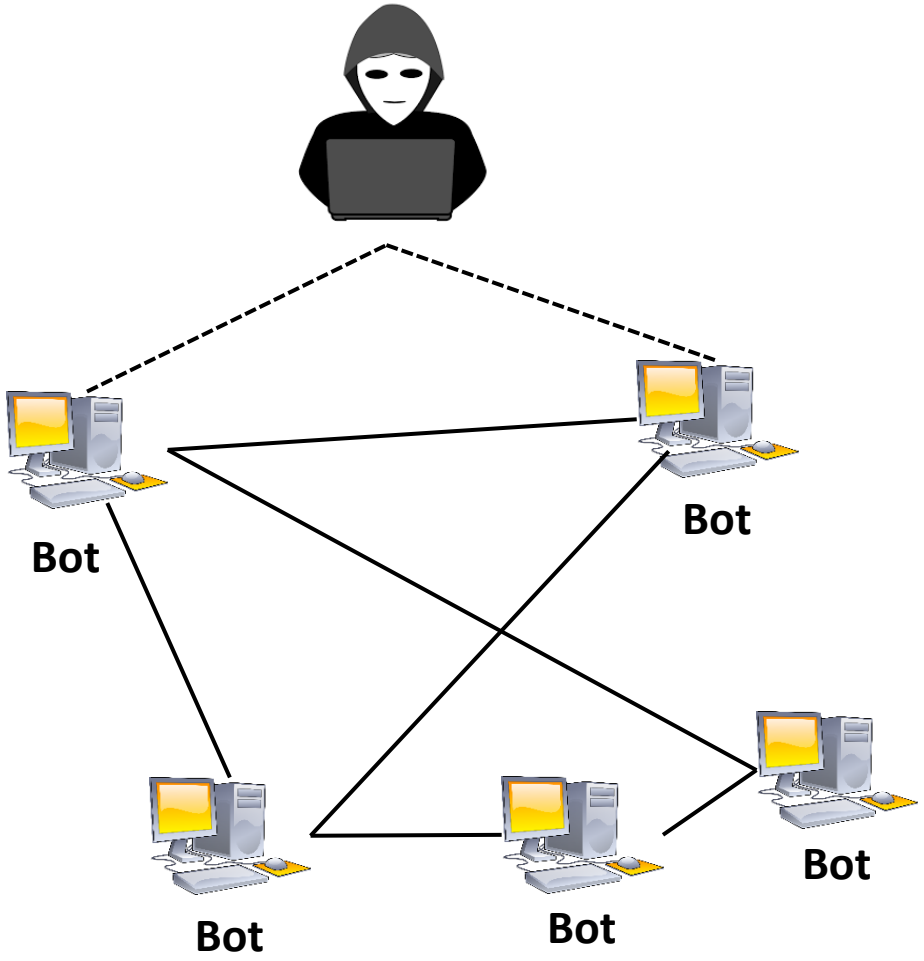


What is the problem here?

C&C single point of failure

the botnet violates the *least common mechanism* principle!

Botnets – P2P Topology

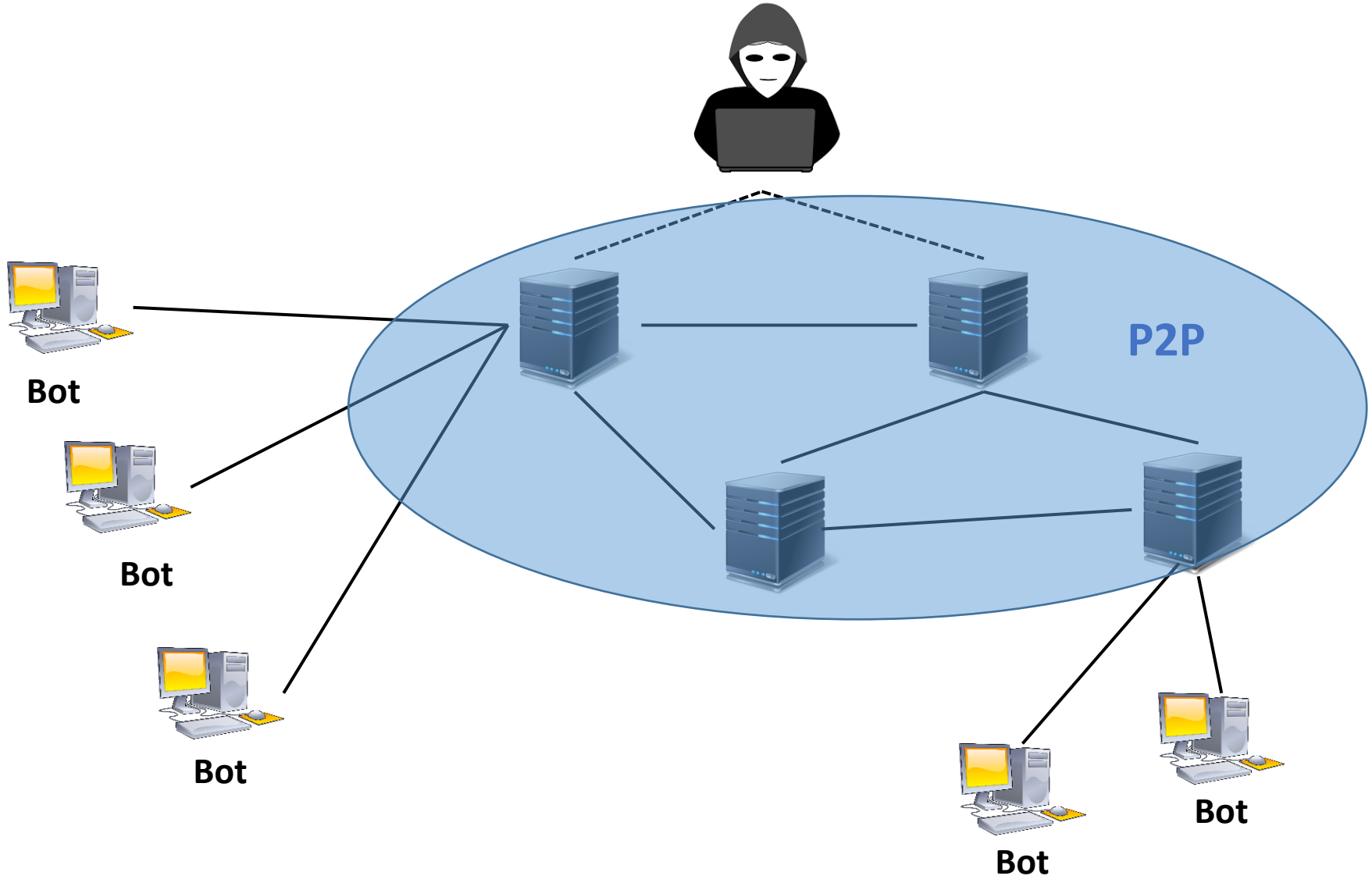


No Command and Control!!

Difficult management (join? leave?)

Vulnerable to attacks in which too many bots are taken over
(these are called Sybil attacks)

Botnets – Hybrid



Monetizing Botnets

Rental – “Pay me money, and I’ll let you use my botnet…”

DDoS extortion – “Pay me or I take down your legitimate business”

Bulk traffic selling – “Pay me to boost visit counts on your website”

Click fraud – “Simulate clicks on advertised links to generate revenue”

Distribute Ransomware – “I’ve encrypted your hard drive, pay!”

Advertise products – “Pay me, I will leave comments all around the web”

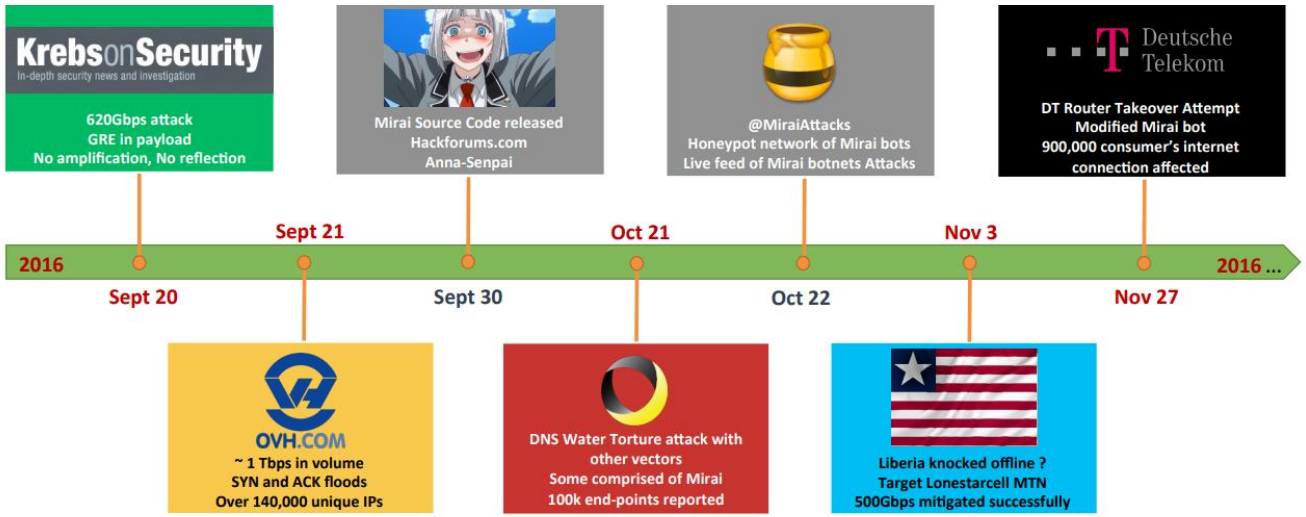
Bitcoin mining!!

…

Example Botnet – Mirai (2016)

Target: IoT devices

scanning of Telnet ports, attempted to log in using 61 username/password combos



Open source code – variants appear all the time

Wicked (2018): scans ports 8080, 8443, 80, and 81 and attempts to locate vulnerable, unpatched IoT devices running on those ports.

https://www.nanog.org/sites/default/files/1_Winward_Mirai_The_Rise_v1.pdf
https://www.usenix.org/system/files/conference/usenixsecurity17/sec17-antonakakis.pdf

Botnets: defense

Attack C&C infrastructure

Take communication channel off-line

Hijack/poison DNS to route traffic to black hole

Honeypots

Vulnerable computer that serves no purpose other than to attract attackers and study their behavior in controlled environments

Study botnet behavior to find defense (or study ecosystem)

Summary

Malware = software intentionally malicious

Can be exploited by non-experienced adversaries

Many types depending on
(auto) replication, need for a host

Botnets – attacks at scale!