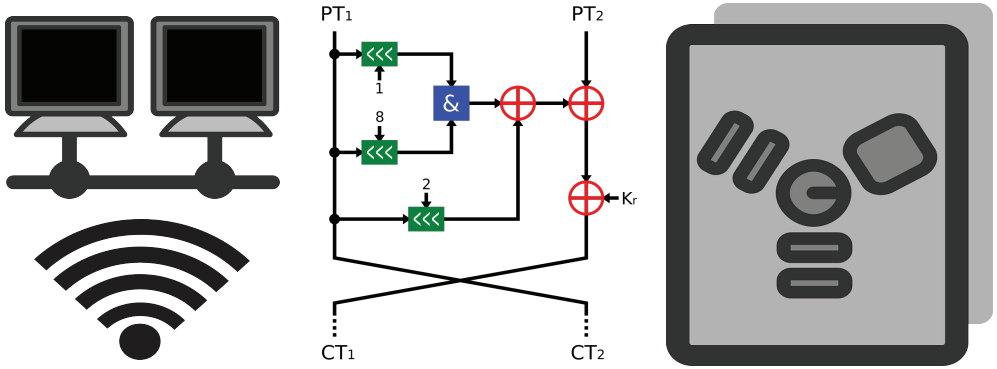
CSE 40567 / 60567: Computer Security



Security Basics 3

My office hours will be held in
182D Fitzpatrick going forward

Homework #1 has been released. It is due Tuesday, Jan. 28th at 11:59PM

See **Assignments Page** on the course website for details

Basic Terminology

System

1. Product or component
2. All of the above + an OS, communications and other infrastructure components
3. All of the above + one or more applications
4. All of the above + IT staff
5. All of the above + internal users and management
6. All of the above + customers and other external users

Protocol

A **protocol** is a series of steps, involving two or more parties, designed to accomplish a task

- Participants must know the protocol and all of the steps to follow
- Everyone involved in the protocol must agree to follow it
- The protocol must be unambiguous
- The protocol must be complete
- **It should not be possible to do more or learn more than what is specified in the protocol**

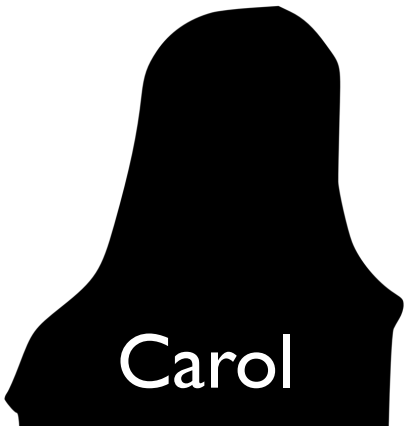
Principal Actors

To demonstrate protocols, we need the help of some friends:

First participant in all protocols (A)

Second participant in all protocols (B)

Some protocols are between more than two actors



Participant in three- and four-way protocols (C)

Participant in four-way protocols (D)

Not everyone is honest…

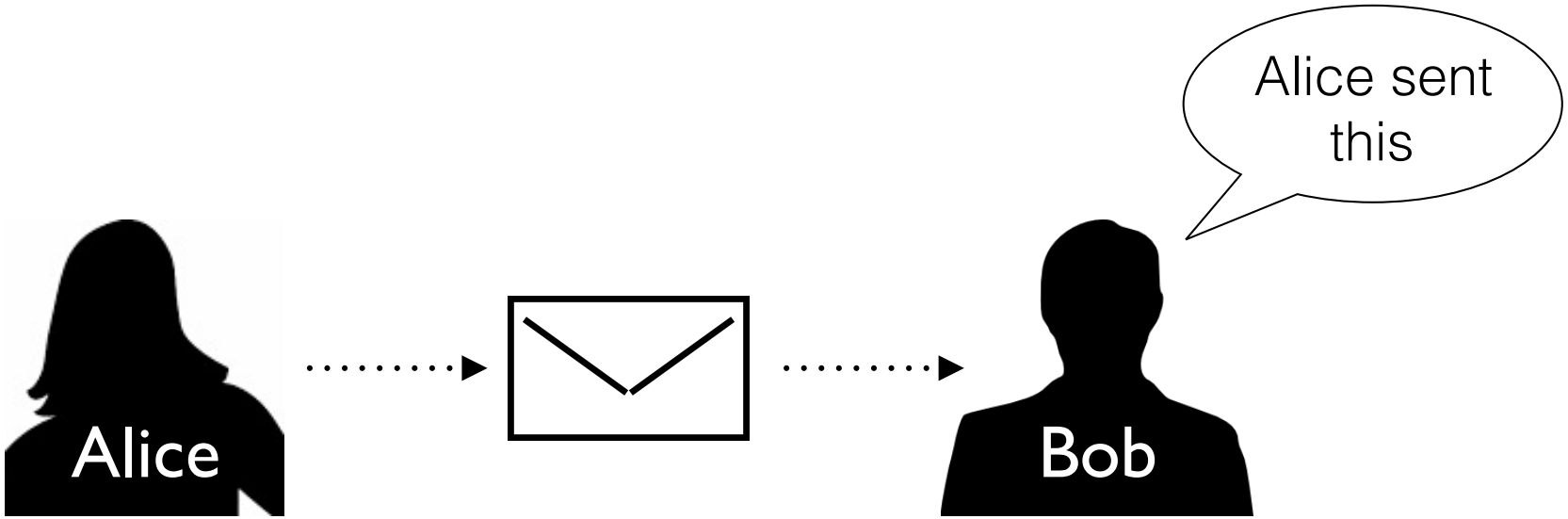
Eavesdropper (E)

Not everyone is honest…

Malicious active attacker (M)

Authentication

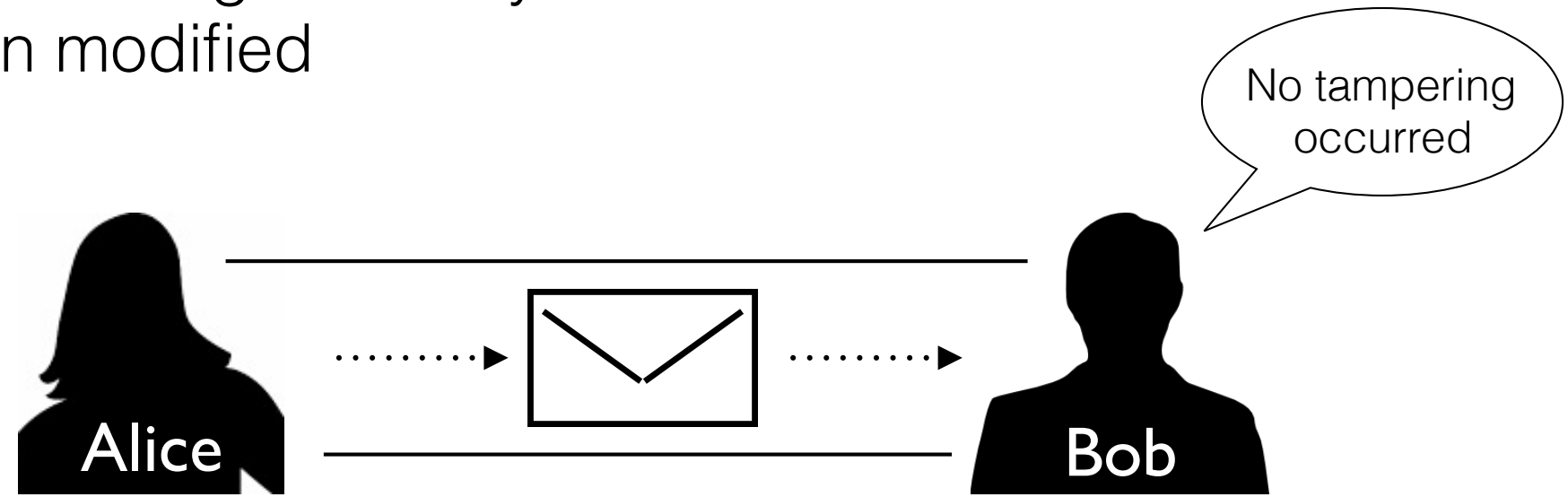
It should be possible for the receiver of a message to determine its origin



An intruder should not be able to impersonate someone else

Integrity

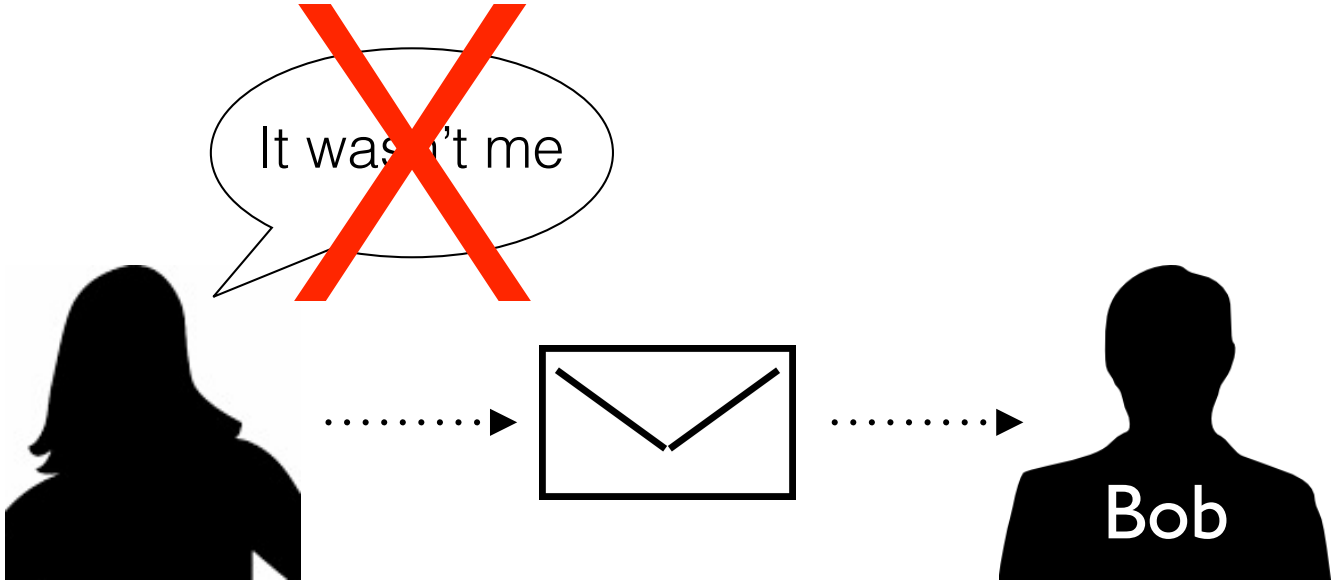
It should be possible for the receiver of a message to verify that it hasn't been modified



An intruder should not be able to substitute a false message for a legitimate one

Non-repudiation

A sender should not be able to falsely deny later that a message was sent



Identity

Correspondence between the names of principals, signifying that they refer to the same person or equipment

Alice acting as **Bob**'s manager

Bob acting as Carol's manager

Bob as branch manager signing a loan contract jointly with Dave

Security Policy

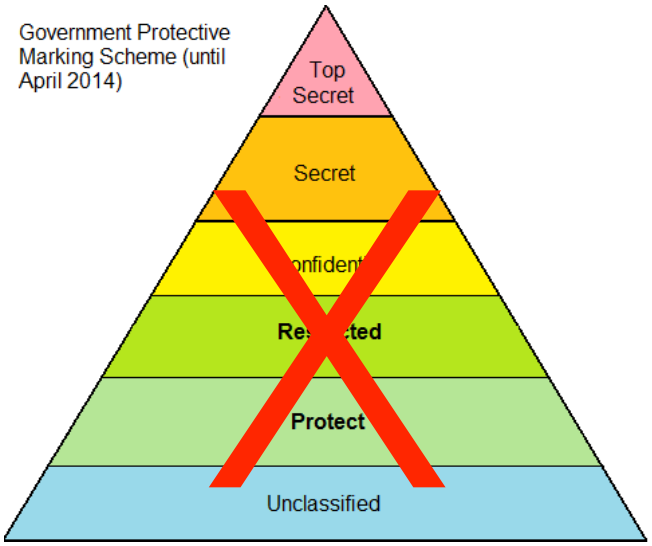
A succinct statement of a system's protection strategy

Example: Bank's Policy

- Each credit must be matched by an equal and opposite debit
- All transactions over $1,000 must be authorized by two managers

Trust

A **trusted** system or component is one whose failure can break the security policy



Government Security Classifications Policy
BY 3.0 Bobrayner

Edward Snowden
BY 3.0 Hic et nunc

Trustworthy

A **trustworthy** system or component is one that won't fail

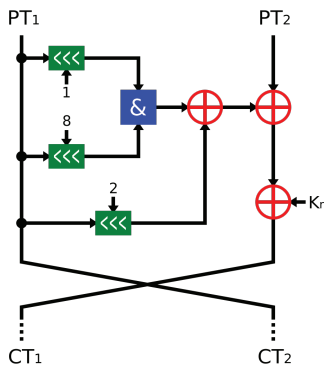
Example:

An uninterruptible power supply is a trustworthy component of a buildings's power system

Secrecy

The effect of the mechanisms used to limit the number of principals who can access information

Common mechanisms to provide secrecy:



Cryptography

Access Controls

Confidentiality

Involves an obligation to protect some other person's or organization's secrets if you know them

Example:

In the United States, medical records stored by a healthcare provider are confidential, and protected by HIPAA

Privacy

Privacy = choice & control over use and disclosure of our identity and our information

Unfortunate Privacy Truisms

1. Most people don’t value their privacy until it is threatened or lost

2. Once invalidated or lost, you will need to regain your privacy over and over again…

Security vs. Privacy

- Accountable to Commander, President or Board of Directors

Chairman of the board of Orkla (cc) BY-2.0 Guri Dahl

- Accountable to the subject of the data

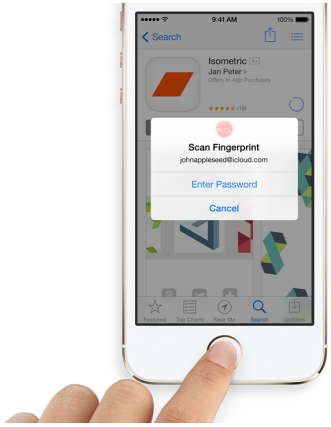


Image Credit: C. Zibreg, idownloadblog.com

- Access and use controls defined by the system owner

- Access and use controls defined by design, use limitation, subject consent and legislation

Security vs. Privacy

- Generally focused on protecting against outsiders

Great Wall of China near Jinshanling CC BY-SA Jakubhal

- Requires protecting against outsiders, insiders, and system owners

New Office BY 2.0 Jakubhal

- Short-term risk based assessment. (How likely is it?)

6 months

- Long-term capabilities based assessment (Is it possible?)

30 years

Nymity (Identifiability)

Measures the degree to which information is personally identifiable or recoverable.

Anonymity

The quality or state of being unknown.
without name

Non-Reversible Pseudonymity or polynymity

Reversible Polynymity

from Greek pseudonumon, neuter of pseudonumos, *falsely named*

And poly meaning many, with polynymity meaning *many named*

Reversible Pseudonymity

Verinymity

from Latin *verus*, true,
truly named

Vulnerability

Property of a system or its environment which, in conjunction with an internal or external *threat*, can lead to a *security failure*

A security failure is a breach of the system's security policy

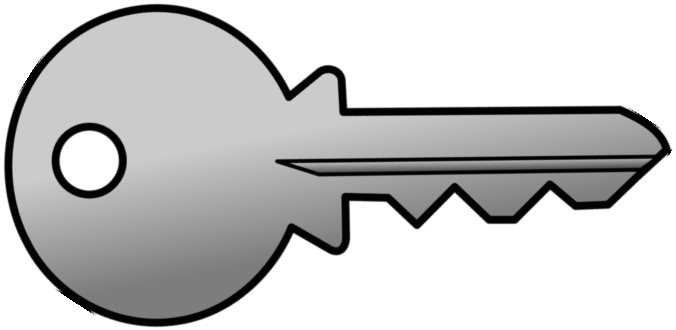
Example:

Heartbleed bug: improper input validation in the implementation of the TLS heartbeat extension of OpenSSL

Authentication Mechanisms

Key

- A piece of information that determines the functional output of a cryptographic algorithm (K)
- Could be any one of a large number of values
  - The range of possible values is called the **keyspace**



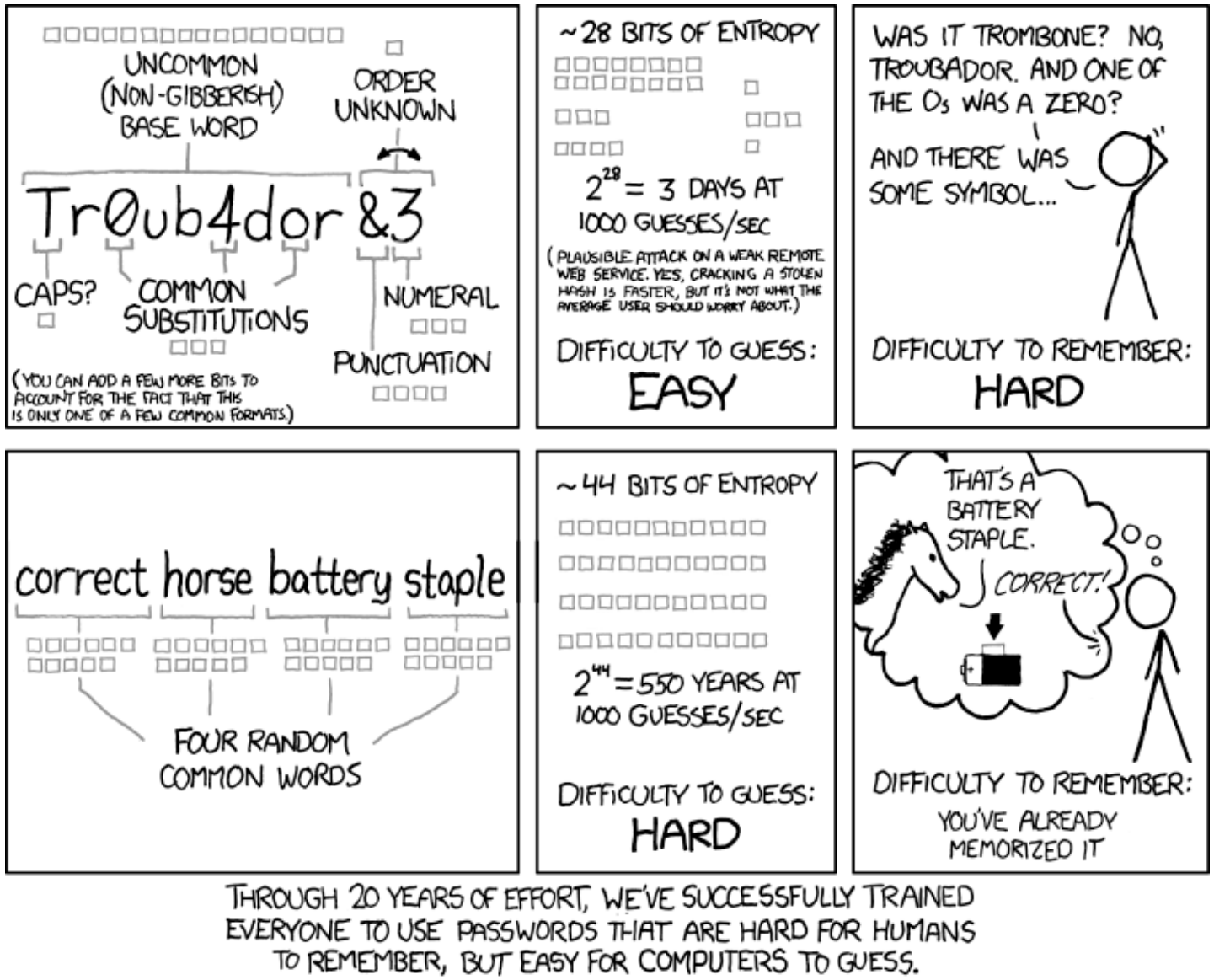
Passwords

- The most common user-facing embodiment of a key
- And one of the biggest practical problems facing security engineering today

Trouble with passwords

- People can't remember infrequently-used, frequently-changed, or many similar items
- The same passwords are reused for different applications

Advice from XKCD



“My advice is to take a sentence and turn it into a password. Something like ‘This little piggy went to market’ might become ‘tlpWENT2m’. That nine-character password won't be in anyone's dictionary. Of course, don't use this one, because I've written about it. Choose your own sentence…”

- Bruce Schneier

B. Schneier, “Choosing Secure Passwords,” *Schneier on Security, 2014*

Sensible password advice

- Never reuse a password you care about. An attacker can steal it from a low security site (your blog) and attack a higher stakes site (your bank).
- Don't bother updating your password regularly
- Be wary of the "secret question"; this is sometimes easier to break than your password itself.
- Use two-factor authentication.

B. Schneier, "Choosing Secure Passwords," *Schneier on Security, 2014*

Two-factor authentication

- Combines something you know with something you have
- Attacker needs to compromise both factors to gain access to the system

‘tIpWENT2m’ +

(User’s Password) (One-time Password)

One-time passwords

- Use a password once, then invalidate it
  - Defeats eavesdropping
- Commonly found in two-factor authentication schemes

RSA SecureID

A handheld authenticator token from RSA based on an internal clock, secret key and display

Challenge-Response

- One-time authentication mechanism using a non-repeating challenge from a server
- The response is a function of the challenge and a secret known to the client

```
challenge: 00193 Wed Sep 11 11:22:09 2015
response: ab0dh1kd0jkfj1kye./
```

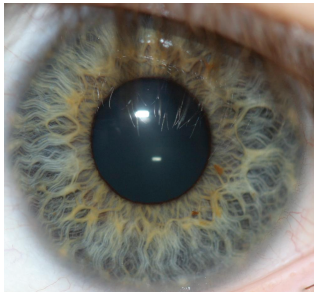
Smart Cards

- Portable device with a CPU, I/O and a few thousand bytes of memory
- “Something you have” rather than “something you know”
- Can compute portions of cryptographic protocols for security and convenience purposes

JaCarta smart card based on Java Card technology

Biometrics

Biometrics: “the use of physical or behavioral properties of human beings for automatic identity recognition”



General Categories of Attacks

B. Schneier, Applied Cryptography Second Edition, Wiley, 1996

W. R. Cheswick, S. M. Bellovin, A. D. Rubin, Firewalls and Internet Security, Second Edition, Addison Wesley, 2003

Reconnaissance

- Attacker needs to find vulnerabilities before exploiting them
- Reconnaissance can be conducted physically, on the host, or over the network

Port scanning and OS fingerprinting are common forms of network recon.

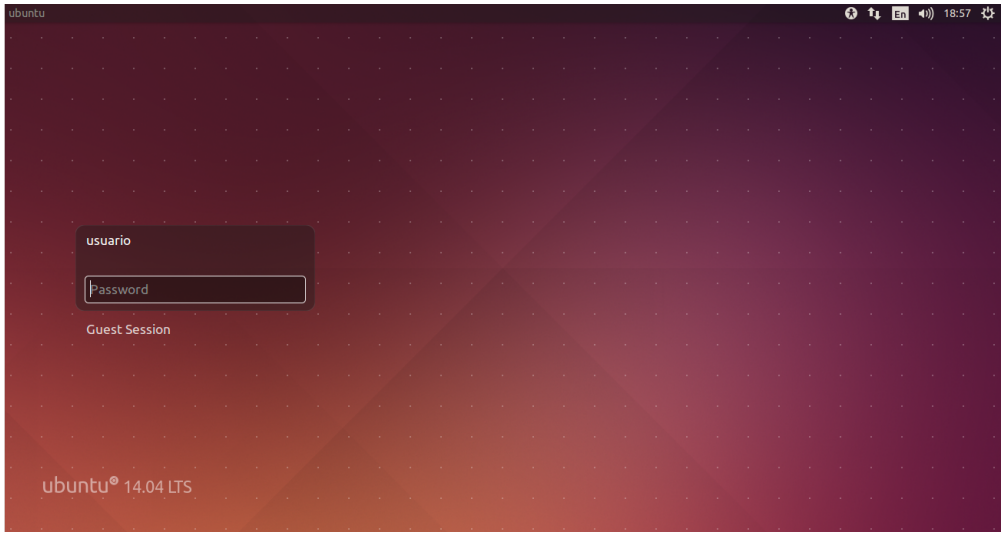
```
[root@darkstar ~]# nmap -sS -O scanme.Nmap.Org

Starting Nmap 5.21 ( http://nmap.org ) at 2010-04-05 10:46 IDT
Nmap scan report for scanme.Nmap.Org (64.13.134.52)
Host is up (0.18s latency).
rDNS record for 64.13.134.52: scanme.nmap.org
Not shown: 993 filtered ports
PORT      STATE  SERVICE
25/tcp    closed smtp
53/tcp    open   domain
70/tcp    closed gopher
80/tcp    open   http
113/tcp   closed auth
8009/tcp  open   ajp13
31337/tcp closed Elite
Device type: general purpose
Running: Linux 2.6.X
OS details: Linux 2.6.15 - 2.6.26

OS detection performed. Please report any incorrect results at
 http://nmap.org/submit/ .
Nmap done: 1 IP address (1 host up) scanned in 23.19 seconds
[root@darkstar ~]#
```

Stealing Passwords

1. Steal plaintext passwords (not as common these days)
2. Steal encrypted passwords and crack them (surprisingly easy)
3. Tap a legitimate terminal session and log the password
4. Shoulder surf the password



Login ubuntu

Brute Force Attack

- Could be a dictionary attack (often quick)

```
cultivating
cultivation
cultivator
cultlike
...
```

- Could be an attack against the bits of the key (typically not quick)

```
0000000000
0000000001
0000000010
0000000011
...
```

How long does a brute force attack against a keyspace take?

64-bit RC5 key cracked using 331,252 computers over 1,757 days (2002)

http://www.distributed.net/RC5/en

Dan Boneh's advice: algorithms with a brute force effort of less than 2^{90} are weak

https://www.coursera.org/course/crypto

768-bit RSA key factored in about half a year on 80 processors (2010)

http://eprint.iacr.org/2010/006.pdf

Reverse Engineering

- Plaintext secrets are often hardcoded in a binary program
- Low-level examination of the binary can yield those secrets:
  - Running it with a debugger
  - Profiling contents of memory
  - Disassembling and examining assembler code

Siemens PLC Hole:

Hardcoded Password in Firmware

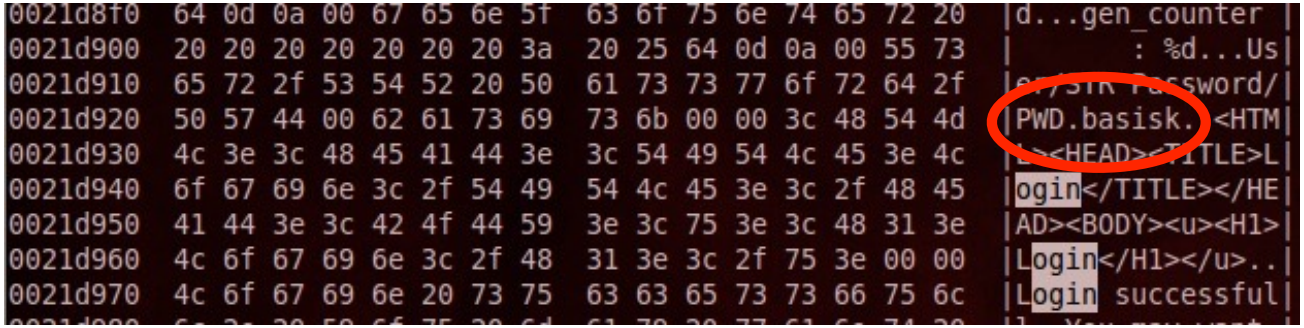
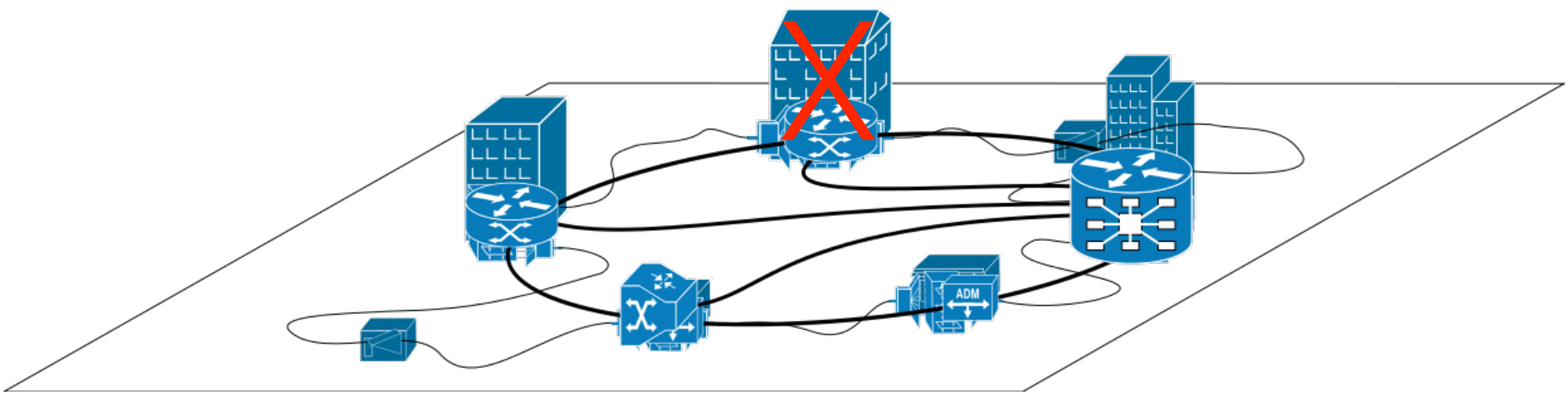


Image Credit: http://www.digitalbond.com/blog/2011/08/08/beresford-backdoor-explored/

K. Zetter, “Hard-coded password and other security holes found in Siemens control system,” Wired, Aug. 2011

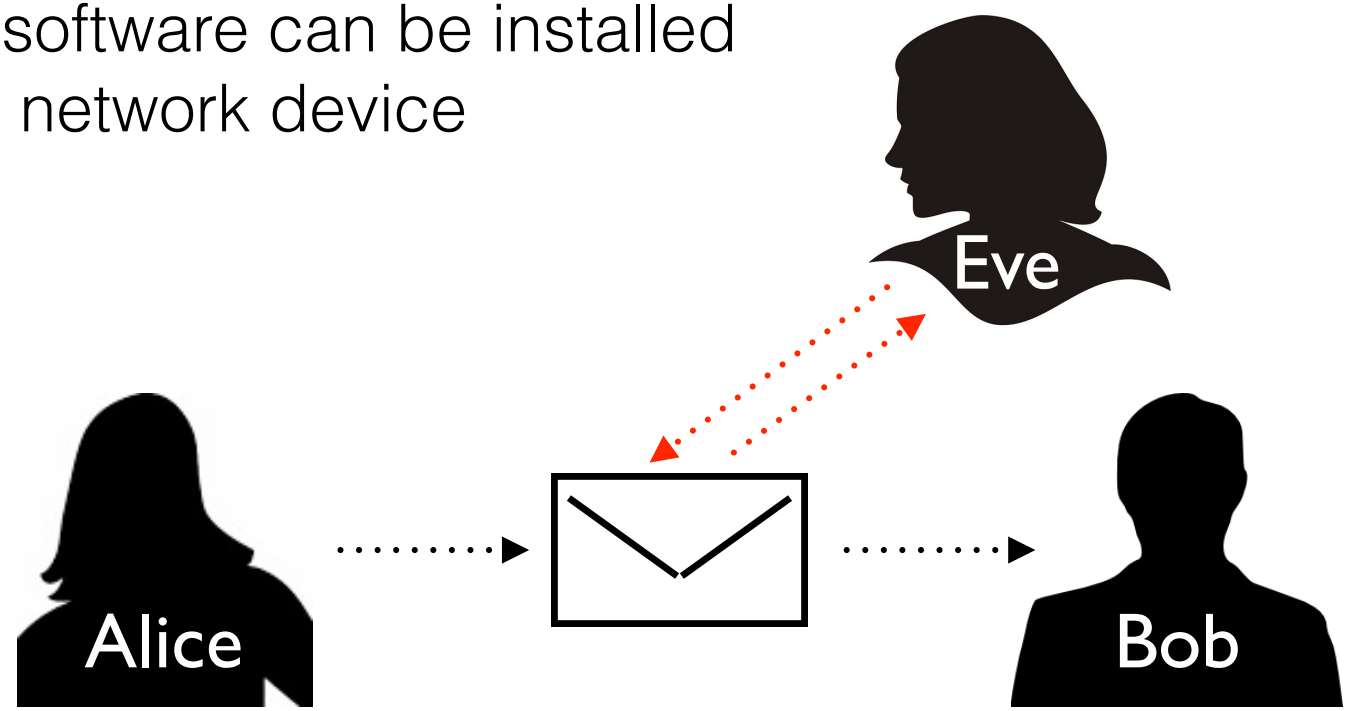
Denial of Service (DoS)

- The goal isn't to gain access, but to make a resource unavailable to users
- Can take place at the host or network level
- Often associated with extortion and activism



Eavesdropping

- Passively watching a channel can yield a lot of information
  - Even if payloads are encrypted, packet headers can still be useful
- Monitoring software can be installed on a host or network device



Man-in-the-Middle Attack

- General category of attacks
- Active attacks are a lot more powerful than passive ones
- A “man-in-the-middle” can modify, delete, and create new messages

Local Exploitation of Bugs

- Target vulnerabilities on a single host system
- Requires some level of access to that system
- Goal is usually privilege escalation
  - Could also target data and meta-data

Privilege Escalation

Some accounts have more privilege than others

Example: UID 0 in Unix is the super user

This attack exploits a bug, design flaw or configuration problem in an OS or application

Linux Kernel 2.6.34 - CAP_SYS_ADMIN x86 - Local Privilege Escalation Exploit

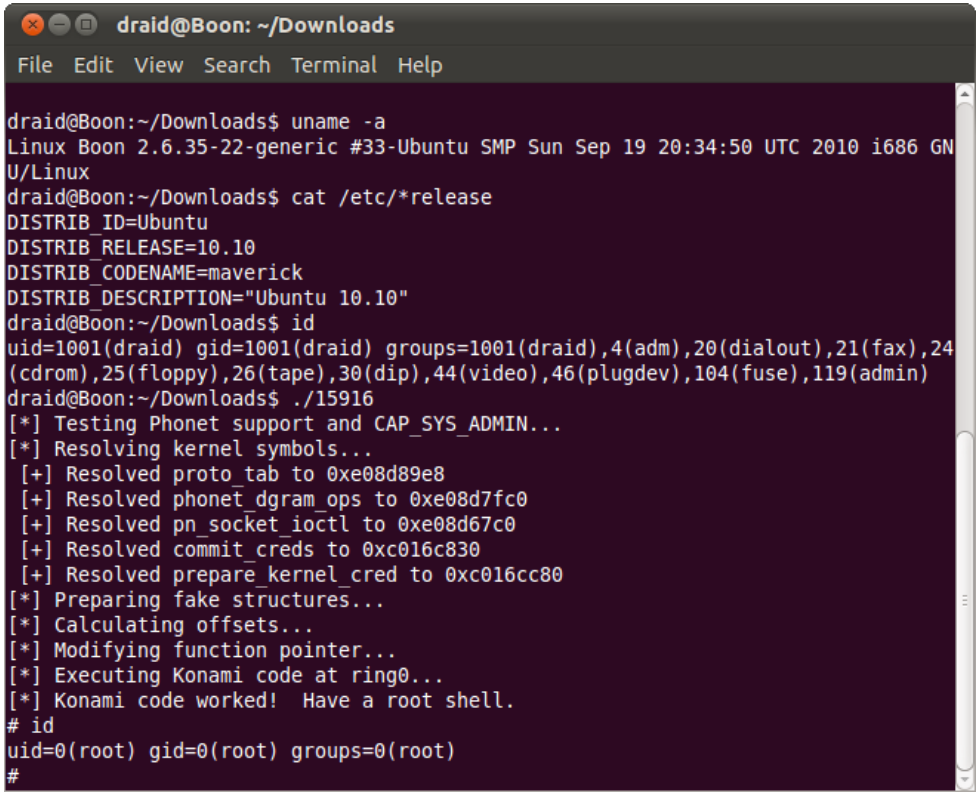


Image Credit: https://www.exploit-db.com/exploits/15916/

Remote Exploitation of Bugs

- Target vulnerabilities on a server
- Does not require some previous level of access
- Goal is unauthorized access
  - Could also target data and meta-data

Example: ProFTPD IAC - Remote Root Exploit

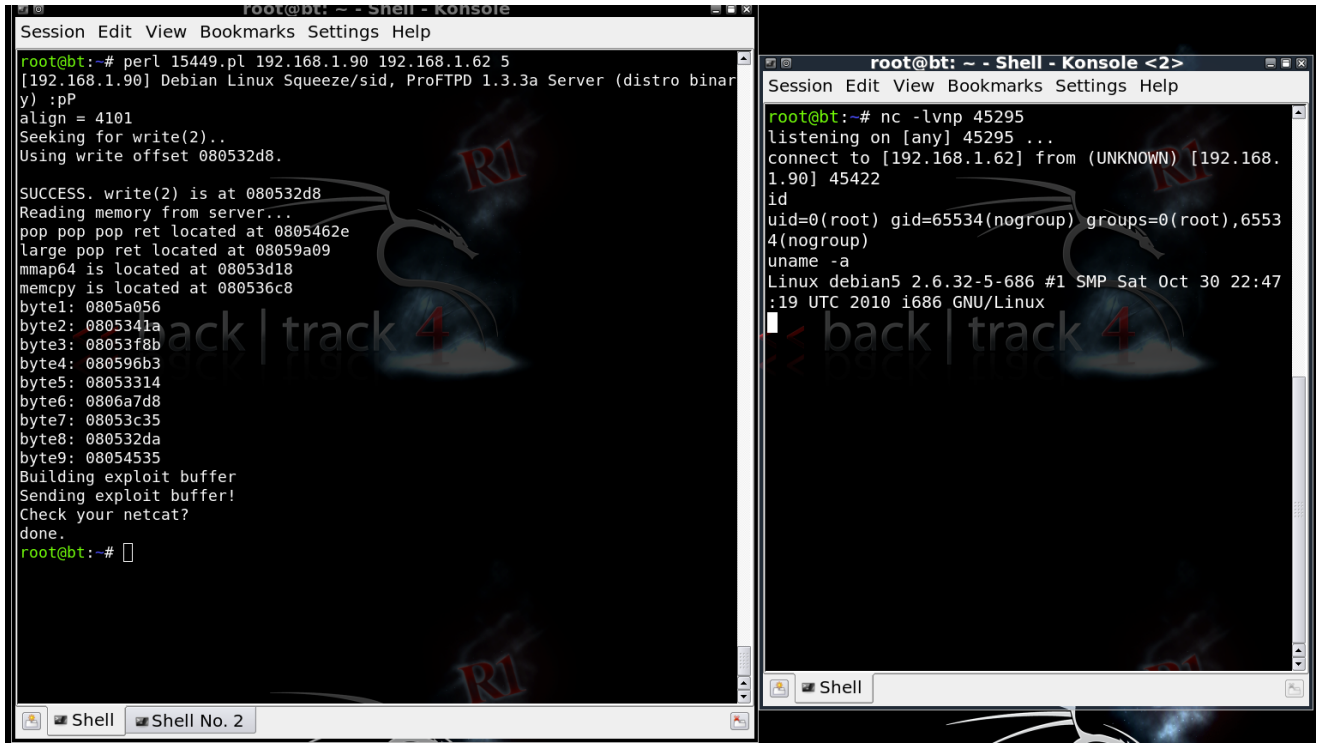
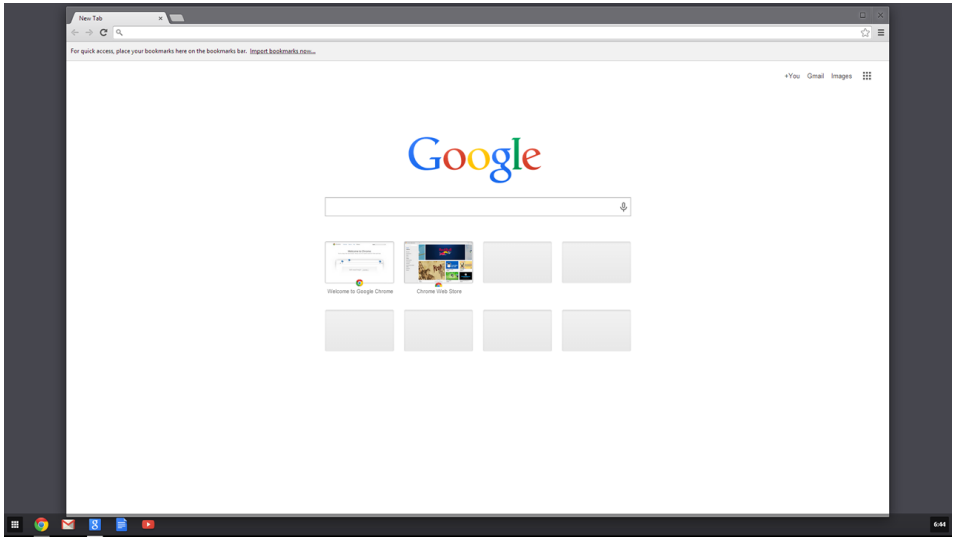


Image Credit: https://www.exploit-db.com/exploits/15449/

Client-Side Exploitation

- Remote server attacks a vulnerability in a local client
  - Web browsers
  - Mobile apps
  - Cloud-based apps



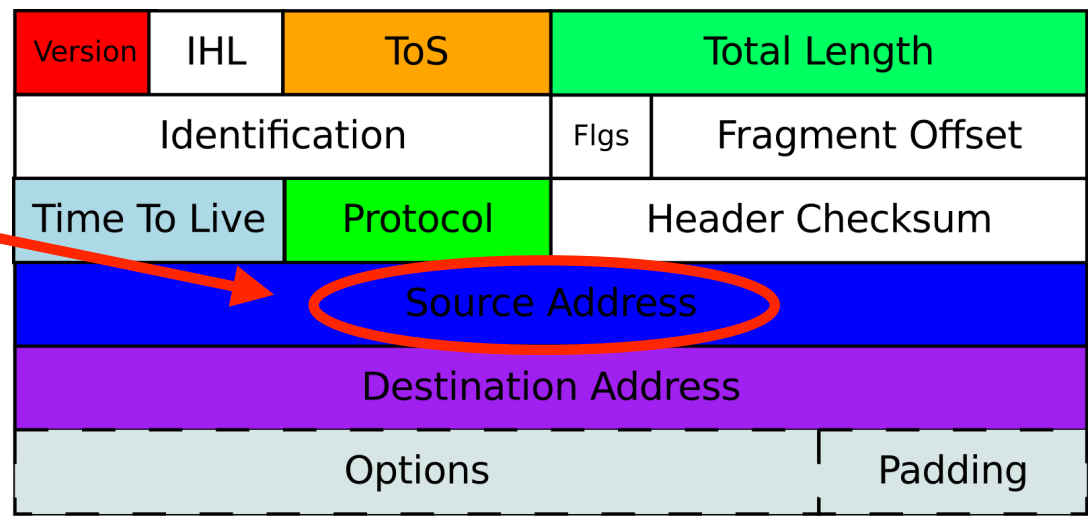
Authentication Failures and Race Conditions

- Packet spoofing: Source IP address is forged to exploit a trust relationship in the network
- Authentication race: attacker collects just enough information to make educated guesses about credentials before the user finishes authenticating

With raw socket interface + root privileges, this is easy

Library: libcrafter

https://github.com/pellegre/libcrafter



Protocol Failures

Sometimes the software and configuration is fine, but the underlying **protocol** is flawed

Two hypothetical flaws in ssh:

1. NFS-mounted home directory; attacker spoofs NFS replies to inject bogus `authorized_keys` file
2. User copies .ssh directory to new system; new system can be accessed by any key trusted to the old system

Viruses and Worms

Automated attack propagation is more effective if you don't have a specific target in mind

Early (yellow), middle (orange), and late (red) stages of the Code Red worm on July 19th, 2001

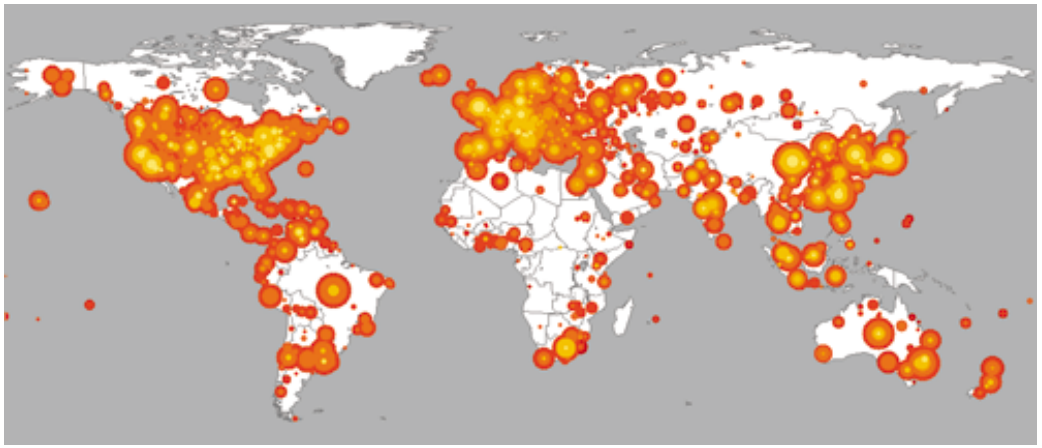


Image Source: https://www.caida.org/research/security/code-red/coderedv2_analysis.xml

Worms: travel by themselves

Viruses: travel attached to another program

Information Leakage

- Most protocols give away some information
  - After all, we need to do *something* useful with them
- Sometimes that information can be used to aid an attack

Example: DNS

No information leak:

```
wjs3@cortex:~$ host -l uccs.edu
; Transfer failed.
Host uccs.edu.vast.uccs.edu not found: 9(NOTAUTH)
; Transfer failed.
```

Information leak:

```
wjs3@cortex:~$ host -l vast.uccs.edu
vast.uccs.edu has address 128.198.147.37
vast.uccs.edu name server dns.securics.com.
vast.uccs.edu name server vast-ns1.uccs.edu.
access.vast.uccs.edu has address 128.198.147.20
alfred-old.vast.uccs.edu has address 128.198.147.16
alfred-old.vast.uccs.edu has address 128.198.147.17
babel.vast.uccs.edu has address 128.198.147.130
bbb-server.vast.uccs.edu has address 128.198.147.167
bilbo.vast.uccs.edu has address 128.198.61.27
blade1.vast.uccs.edu has address 128.198.61.19
blade2.vast.uccs.edu has address 128.198.61.20
boromir.vast.uccs.edu has address 128.198.61.25
cadbury.vast.uccs.edu has address 128.198.147.38
cobain.vast.uccs.edu has address 128.198.147.200
cvpr11.vast.uccs.edu has address 10.201.0.1
...
```

Backdoors

- Something left behind on a system or network to grant an attacker future access
  - Credentials, user-land software, or kernel-land software
  - Firewall holes and routing rules

What does this kernel module code do?

Backdoor access via the creation of a specific file

```
int bd_utime(const char *filename, struct utimbuf *buf)
{
  int tmp;
  char *k_pathname;
  char name[] = FILE_NAME;

  /* copy to kernel space */
  k_pathname = (char*) kmalloc(256, GFP_KERNEL);

  copy_from_user(k_pathname, filename, 255);

  /* Is the pathname our secret one? If so make the current uid special. */
  if (strstr(k_pathname, (char*)&name) != NULL)
     u = current->uid;

   tmp = (*orig_utime)(filename, buf);
   return tmp;
}
```

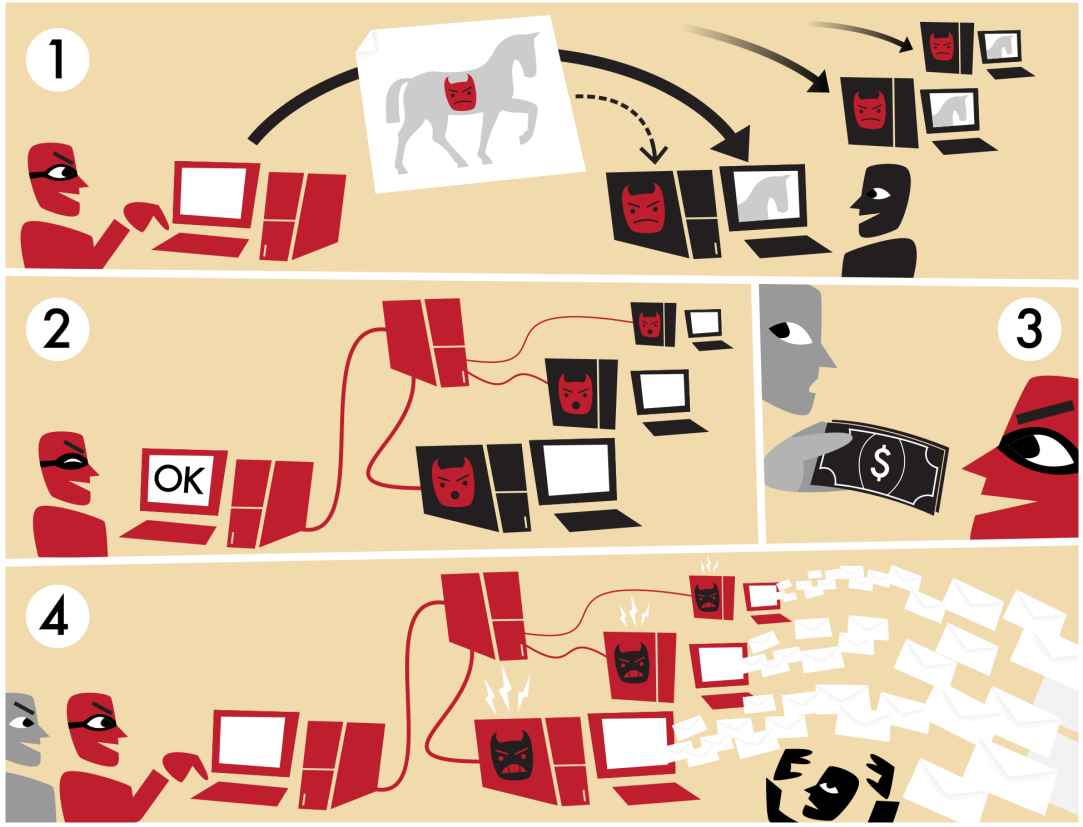
Bots

- A bot is a piece of software that runs an automated task over the Internet
  - Not necessarily malicious (e.g., web crawlers, slack bots, wikipedia bots etc.)
- Can spread via a Virus, Worm, or Trojan Horse (similar to a virus, but doesn't replicate itself)
- Malicious bots are typically designed for spam, denial service attacks, site traffic generation, and game resource harvesting.

Botnets

Common Scenario:

1. Malicious code infects systems
2. Infected systems connect to Command & Control server
3. Spammer buys access to botnet
4. Spammer sends instructions via C&C server



How a botnet works

General Categories of Countermeasures

Cryptography

Definition: The art and science of keeping messages secure is **cryptography**

Code Obfuscation

The operation of code can reveal problems to an attacker

Example: frustrate Java decompilers

```
import java.applet.Applet;

public class Acroweb extends Applet
{
  public static boolean wtwwtLx = true;

  public void init()
  {
    126;
    (41 << 2);
    0;
    (67 >> 1);
    3;
    (72 << -1);
    4;
    try
    {
      String str1 = "wjxjtxwjLPjjPjtxxxwPjPjjPwwLwtLLLwjPPjPLPtwwjLjPwxtxjPwtw
      86;
      39;
      (-2);
      (88 >> 0);
      -1;
      (-1);
      String str2 = Titles.xwwwxjPwxLjt(0);
      (-4);
      52;
      38;
      (37 + 3);
```

Image source: http://malwageddon.blogspot.com/2014/01/deobfuscation-tips-reversing-java.html

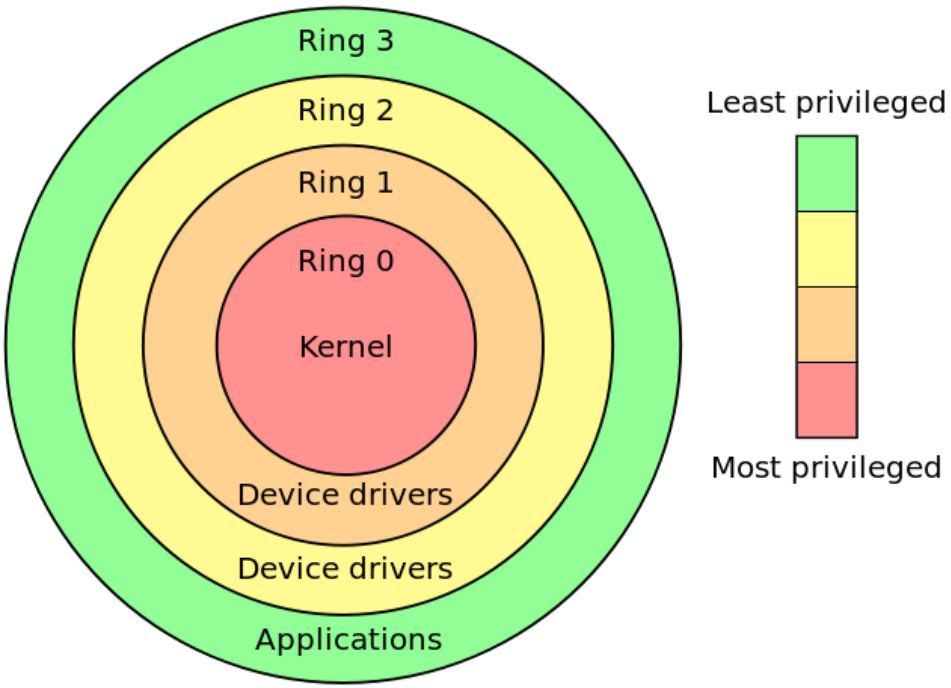
Don't rely on this: assume an attacker can gain access to the code

Access Control

- Mediate access to files, communication ports and other system resources
  - Example: `r` for read permission, `w` for write permission, `x` for execute permission, and – for no access at all

	OS	**Account App**	**Account Data**	**Audit Trail**
Alice	`rwx`	`rwx`	`rw`	`r`
Bob	`x`	`x`	`rw`	–
Carol	`rx`	`r`	`r`	`r`

Privilege Separation

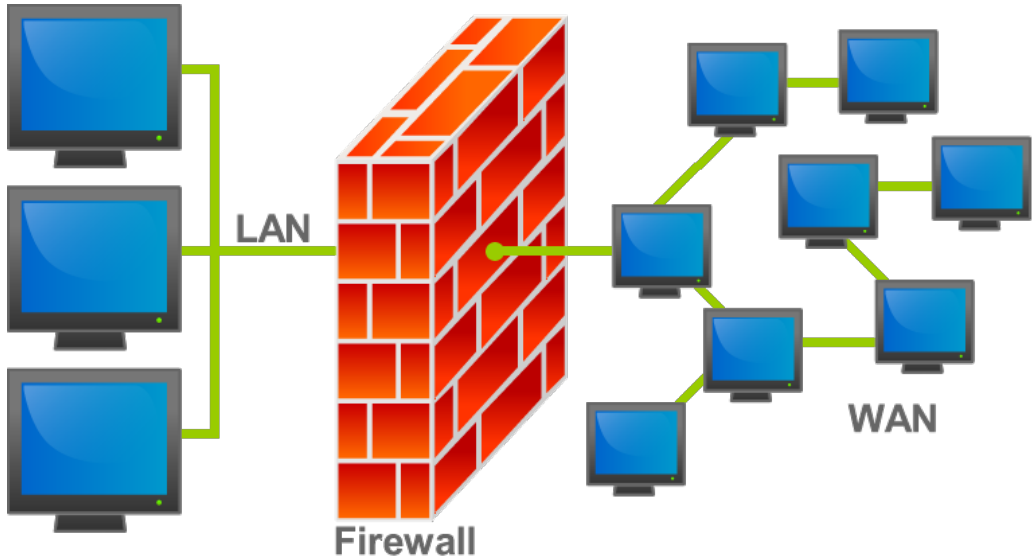


Privilege rings for the x86 available in protected mode
OgreBot

General strategy: restrict what the userland can do, and what hardware it can access

Firewalls

A broad definition: any device, software, or arrangement of equipment that limits network access

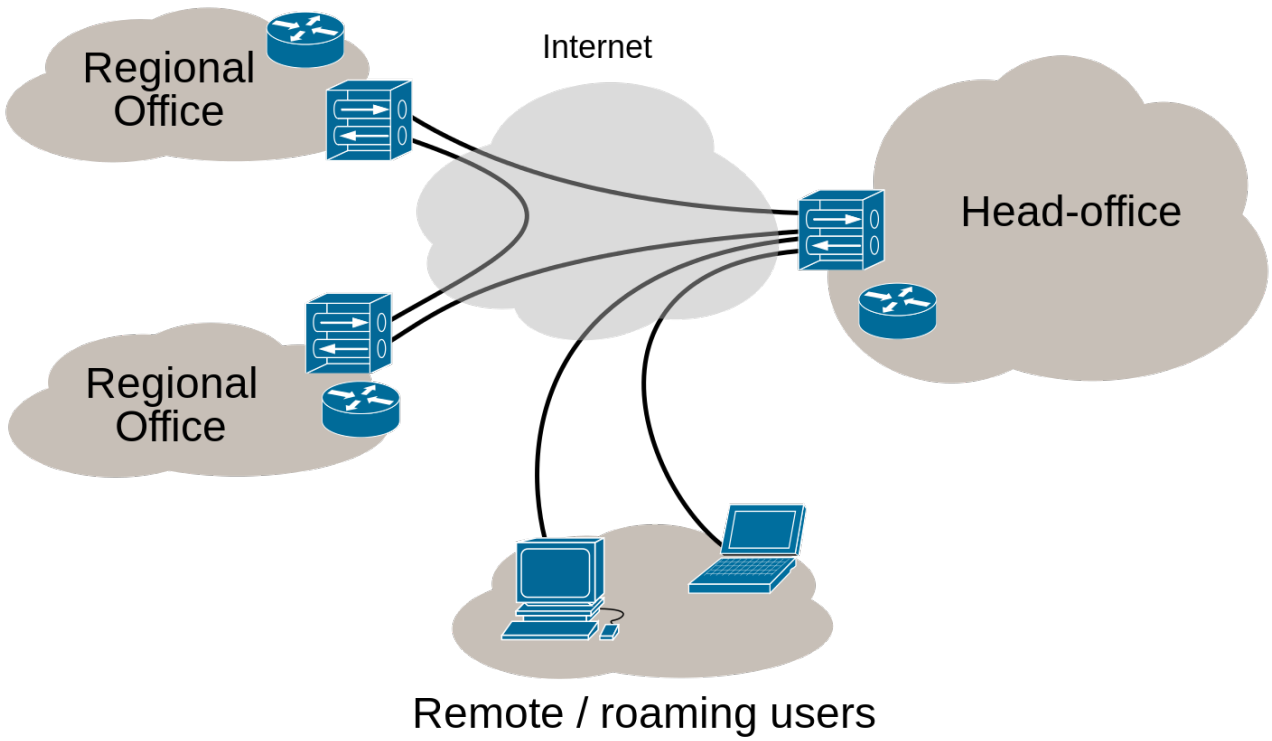


An illustration of where a firewall would be located in a network.

Virtual Private Network

Corporate traffic passed over the Internet is encrypted from firewall to firewall

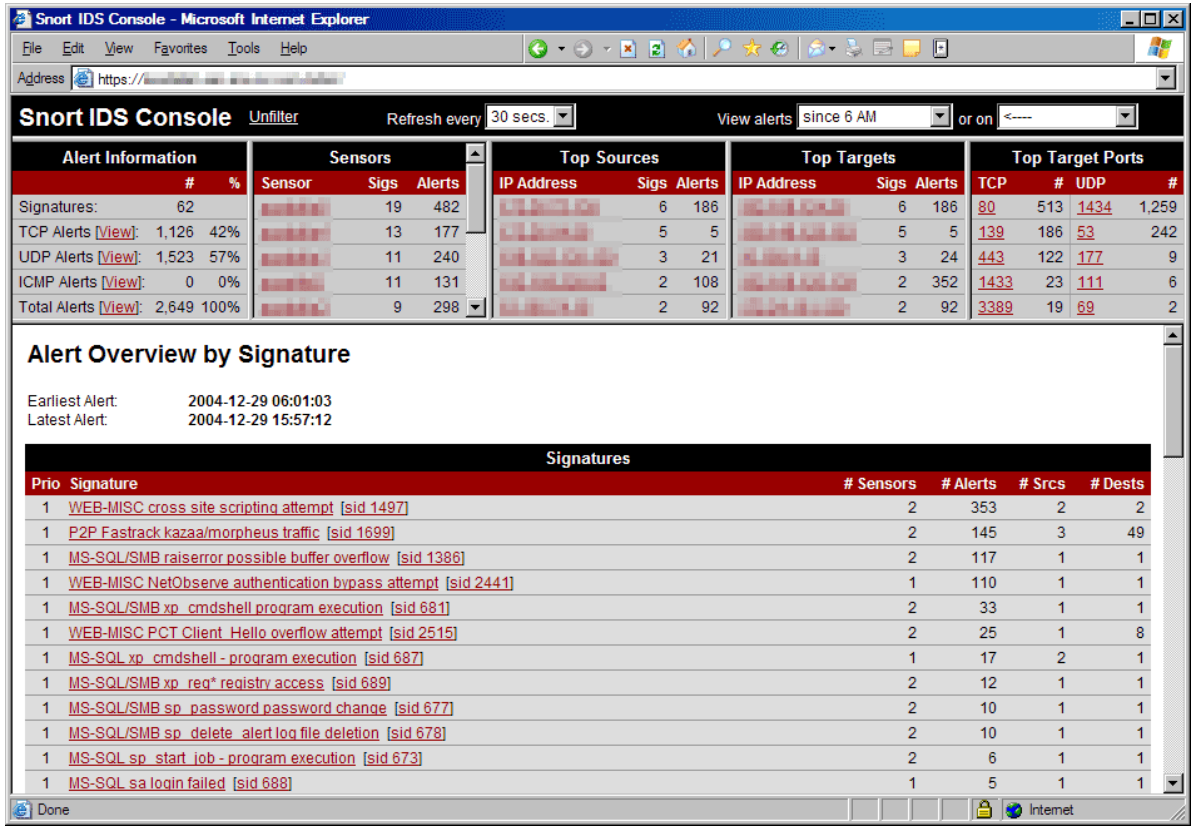
Internet VPN



Intrusion Detection Systems

Two types:

1. Signature-based IDS
2. Statistical anomaly-based IDS



Snort ids console