WILLIAM & MARY

CHARTERED 1693

CSCI 667: Concepts of Computer Security

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Derived from slides by William Enck, Micah Sherr and Patrick McDaniel

Announcement

- Project Status Presentations (Nov 21, 2017)
  - Optional: 1-5 bonus credits
  - Reserve your spot by **email**
  - Will send details on **Piazza** on Friday
- Guest Lecture next class (Virtual)
- Research Plan due on 11/14


Worms

Worms

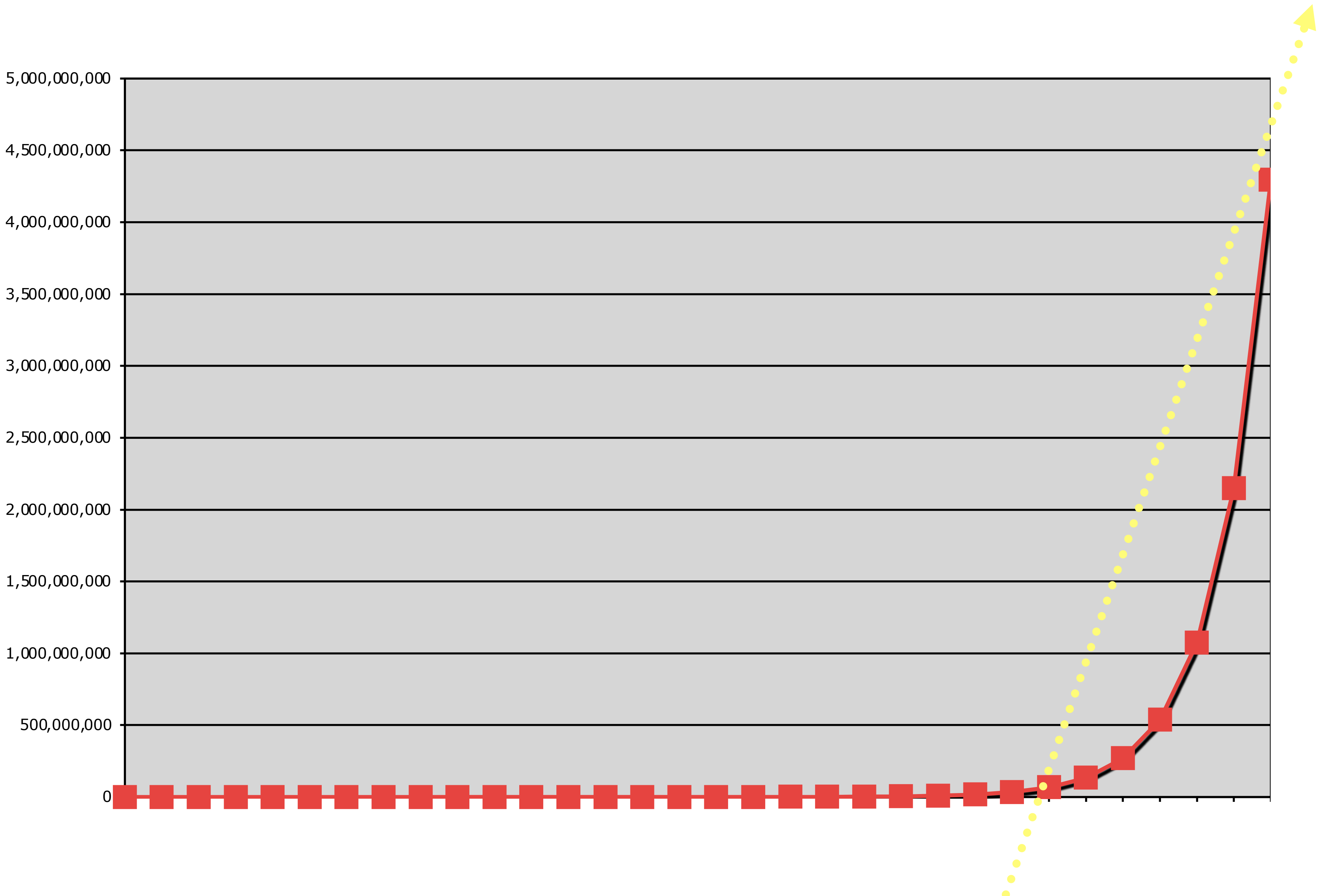
- A worm is a self-propagating program that:
  1. Exploits some vulnerability on a target host
  2. (often) imbeds itself into a host …
  3. Searches for other vulnerable hosts …
  4. Goto step 1

The Danger

- What makes worms so dangerous is that *infection grows at an exponential rate*
  - A simple model:
    - *s* (search) is the time it takes to find vulnerable host
    - *i* (infect) is the time is take to infect a host
  - Assume that t=0 is the *worm outbreak*, the number of hosts at t=j is

$$2^{(j/(s+i))}$$

The result



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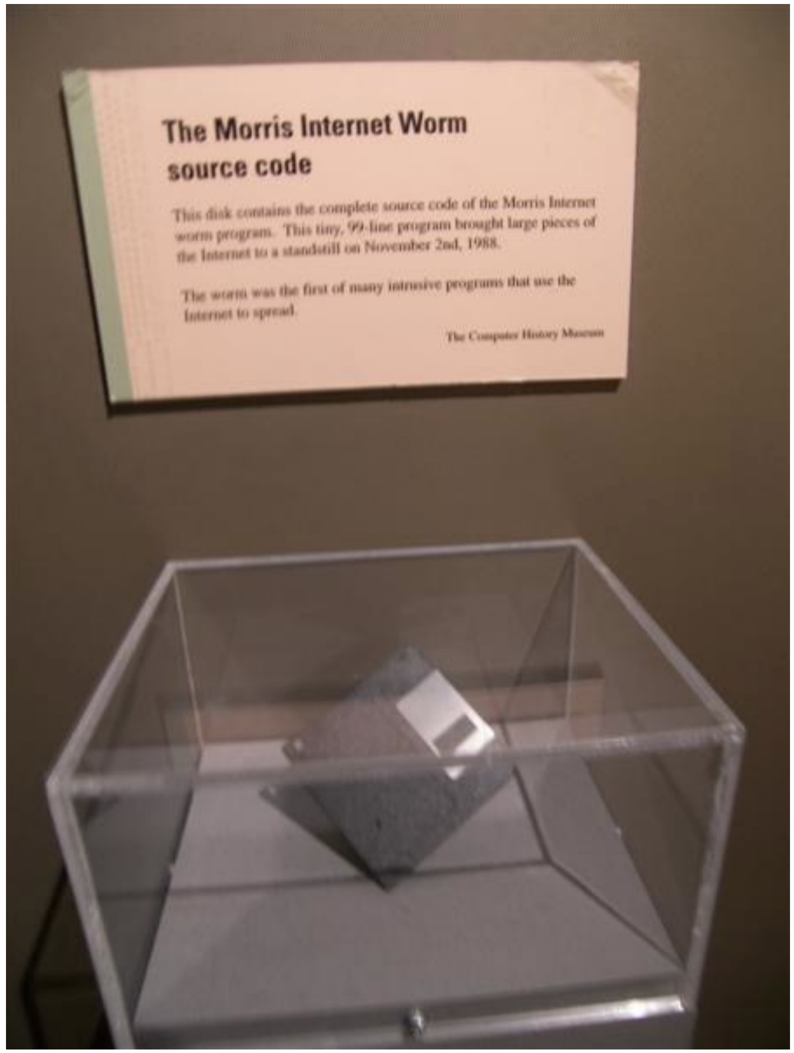
The Morris Worm



Robert Morris

- 1988: Graduate student at Cornell University
- Son of Robert Morris, chief scientist at National Computer Security Center (division of NSA)
- Now a professor at MIT

November 2nd, 1988

- 6pm: someone ran a program at a computer at MIT
- The program collected host, network, and user info...
- ... and then spread to other machines running Sun 3, VAX, and some BSD variants
- ... rinse and repeat

November 2nd, 1988

- Computers became multiply infected
- Systems became overloaded with processes
- Swap space became exhausted, and machines failed
- Wednesday night: UC Berkeley captures copy of program

- 5AM Thursday: UC Berkeley builds *sendmail* patch to stop spread of worm
- Difficult to spread knowledge of fix
  - Not coincidentally, the Internet was running slow
- Around 6,000 machines (~10% of Internet) infected at cost of $10M-$100M

Morris Worm: Attack Vectors

- rsh: terminal client with network (IP)-based authentication
- fingerd: used *gets* call without bounds checking
- sendmail: DEBUG mode allows remote user to run commands
  - lots of sendmail daemons running in DEBUG mode

Morris Worm: Propagation

- Worm would ask host if it was infected
  - If answer was no, worm would infect
  - If answer was yes, worm would infect with some small probability (to thwart trivial countermeasure)
- But... bug allowed worm to spread much faster than anticipated, infecting the same machines multiple times
- Lesson: Always thoroughly debug your worms.

Code Red - 2001

- Exploited a Microsoft IIS web-server buffer overflow
  - Scans for vulnerabilities over random IP addresses
  - Sometimes would deface the compromised website
- Initial outbreak on July 16th, 2001
  - version 1: contained bad randomness (fixed IPs searched)
  - version 2: fixed the randomness,
    - added DDoS of www.whitehouse.gov
    - Turned itself off and on (on 1st and 19th of month, attack 20-27th, dormant 28-31st)
- August 4 - Code Red II
  - Different code base, same exploit
  - Added local scanning (biased randomness to local IPs)
  - Killed itself in October of 2001

Stuxnet

- First reported June 2010
- Exploited **unknown vulnerabilities**
  - Not one zero-day
  - Not two zero-days
  - Not three zero-days
  - But four zero-days!
    - print spooler bug
    - handful of escalation-of-privilege vulnerabilities

Stuxnet

- Spread through infected USB drives
  - bypasses "***air gaps***"
- Worm actively targeted SCADA systems (i.e., industrial control systems)
  - looked for WINCC or PCS 7 SCADA management system
    - attempted 0-day exploit
    - also tried using default passwords
  - apparently, specifically targeted Iran's nuclear architecture

Stuxnet

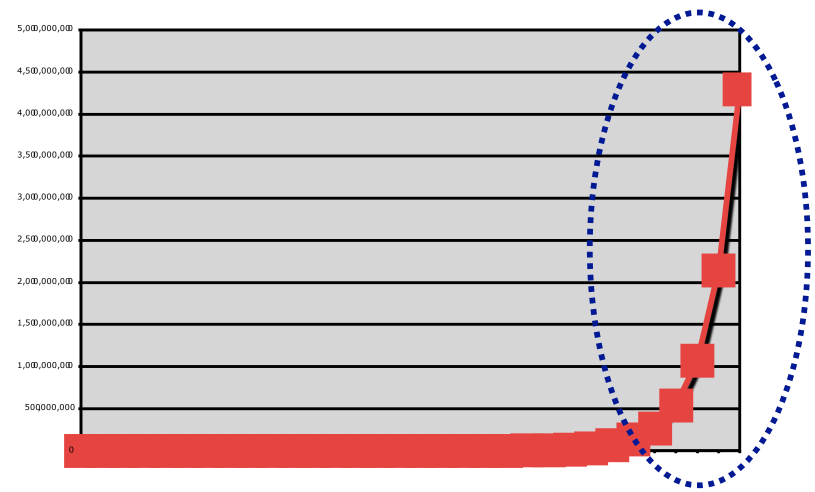
- Once SCADA system compromised, worm attempts to reprogram Programmable Logic Controllers (PLCs)
- Forensics aggravated by lack of logging in SCADA systems

Worms and infection

- **The effectiveness of a worm is determined by how good it is at identifying vulnerable machines**
- Multi-vector worms use lots of ways to infect: e.g., network, email, drive by downloads, etc.
- Example scanning strategies:
  - **Random IP:** select random IPs; wastes a lot of time scanning "dark" or unreachable addresses (e.g., Code Red)
  - **Signpost scanning:** use info on local host to find new targets (e.g., Morris)
  - **Local scanning:** biased randomness
  - **Permutation scanning:** "hitlist" based on shared pseudorandom sequence; when victim is already infected, infected node chooses new random position within sequence

Other scanning strategies

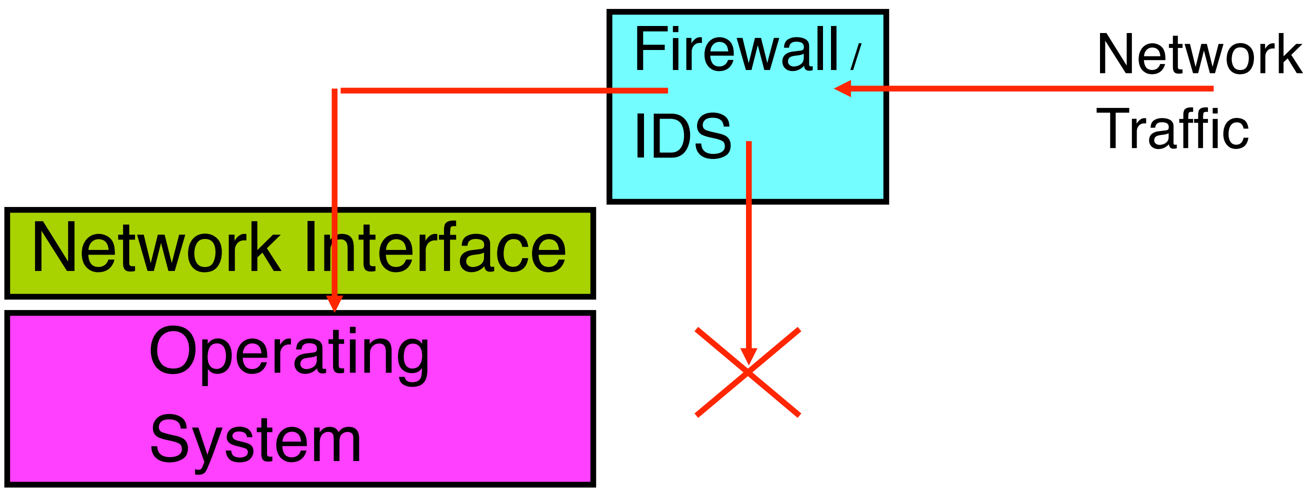
- The doomsday worm: a flash worm
  - Create a hit list of all vulnerable hosts
    - Staniford et al. argue this is feasible
    - Would contain a 48MB list
  - Do the infect and split approach
  - Use a zero-day exploit



- Result: saturate the Internet is less than *30 seconds*!

Worms: Defense Strategies

- (Auto) **patch** your systems: most large worm outbreaks have exploited known vulnerabilities (Stuxnet is an exception)
- **Heterogeneity**: use more than one vendor for your networks
- **IDS**: provides filtering for known vulnerabilities, such that they are protected immediately (analog to virus scanning)



- **Filtering**: look for unnecessary or unusual communication patterns, then drop them on the floor

Denial-of-Service (DoS)

Denial-of-Service (DoS)

- Intentional prevention of access to valued resource
  - CPU, memory, disk (system resources)
  - DNS, print queues, NIS (services)
  - Web server, database, media server (applications)
- **This is an attack on availability**
- Launching DoS attacks is easy
- Preventing DoS attacks is very hard

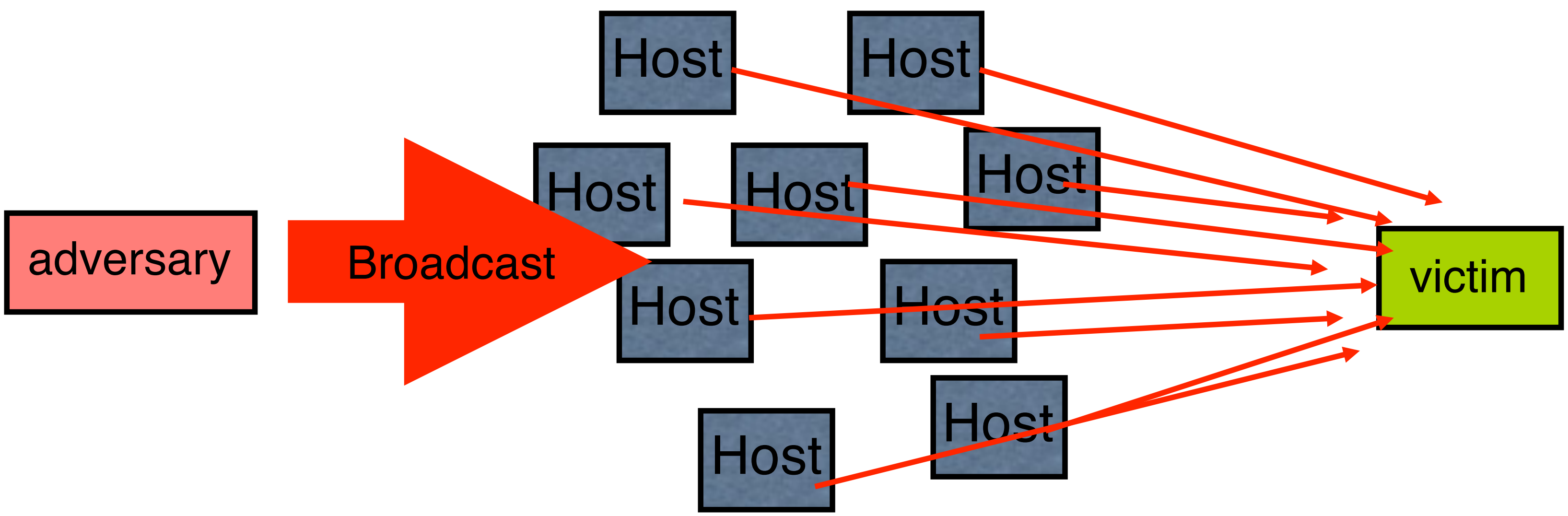
Canonical DoS - Request Flood

- Overwhelm some resource with requests
- e.g., web-server, phone system
- Most effective when processing request is expensive

Smurf Attacks

Example: SMURF Attacks

- Simple DoS attack:
  - Send a large number PING packets to a network's broadcast IP addresses (e.g., 192.168.27.255)
  - Set the source packet IP address to be your victim
  - All hosts will reflexively respond to the ping at your victim
  - … and it will be crushed under the load.
  - This is an **amplification attack** and a **reflection attack**



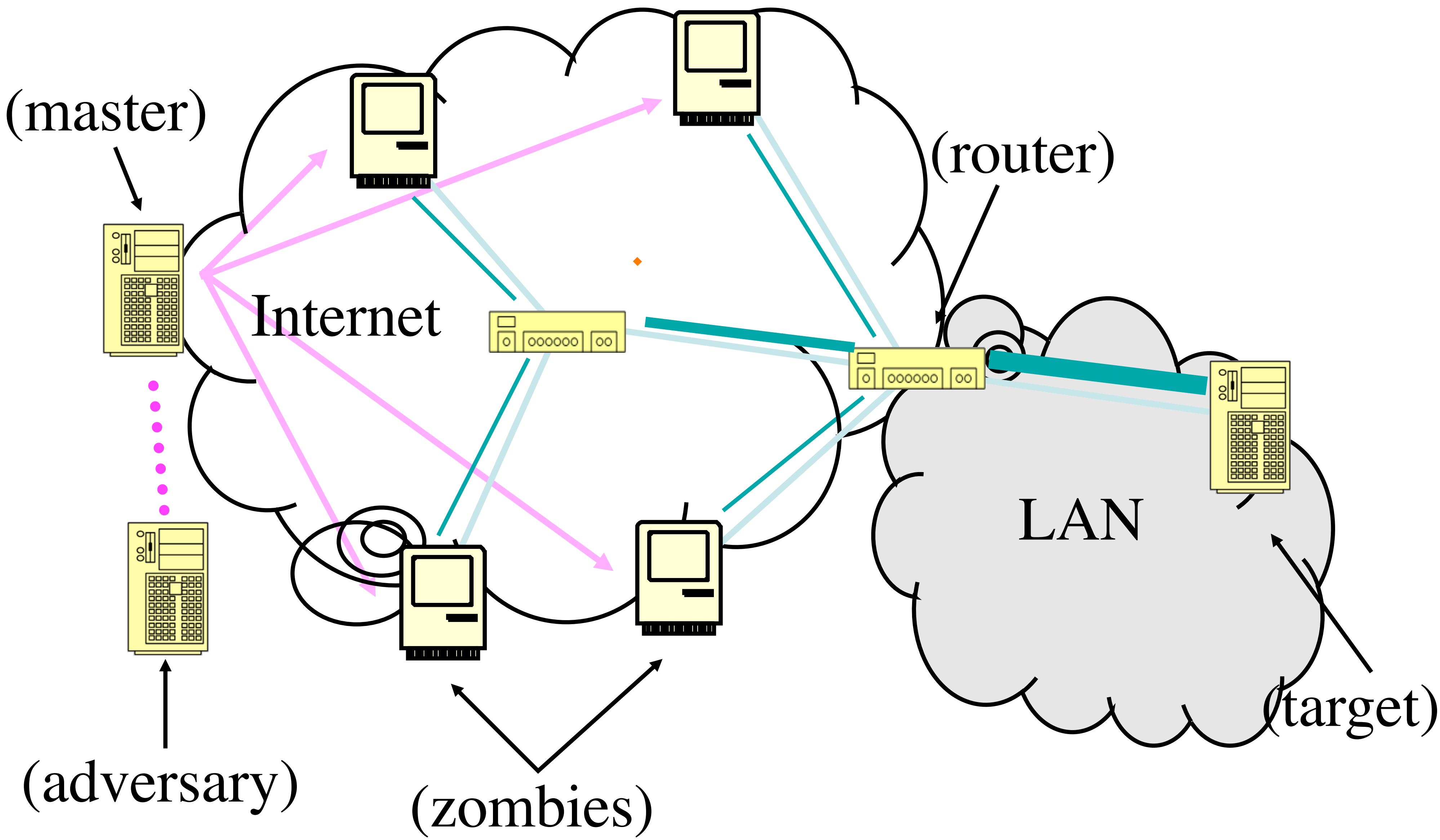
Distributed Denial-of-service (DDoS)

- DDoS: Network oriented attacks aimed at preventing access to network, host or service
  - Saturate the target's network with traffic
  - Consume all network resources (e.g., SYN flooding)
  - Overload a service with requests
    - Use "expensive" requests (e.g., "sign this data")
  - Can be extremely costly
- Result: service/host/network is unavailable
- Criminals sometimes use DDoS for racketeering
- Note: IP addresses of perpetrators are often hidden (spoofed)

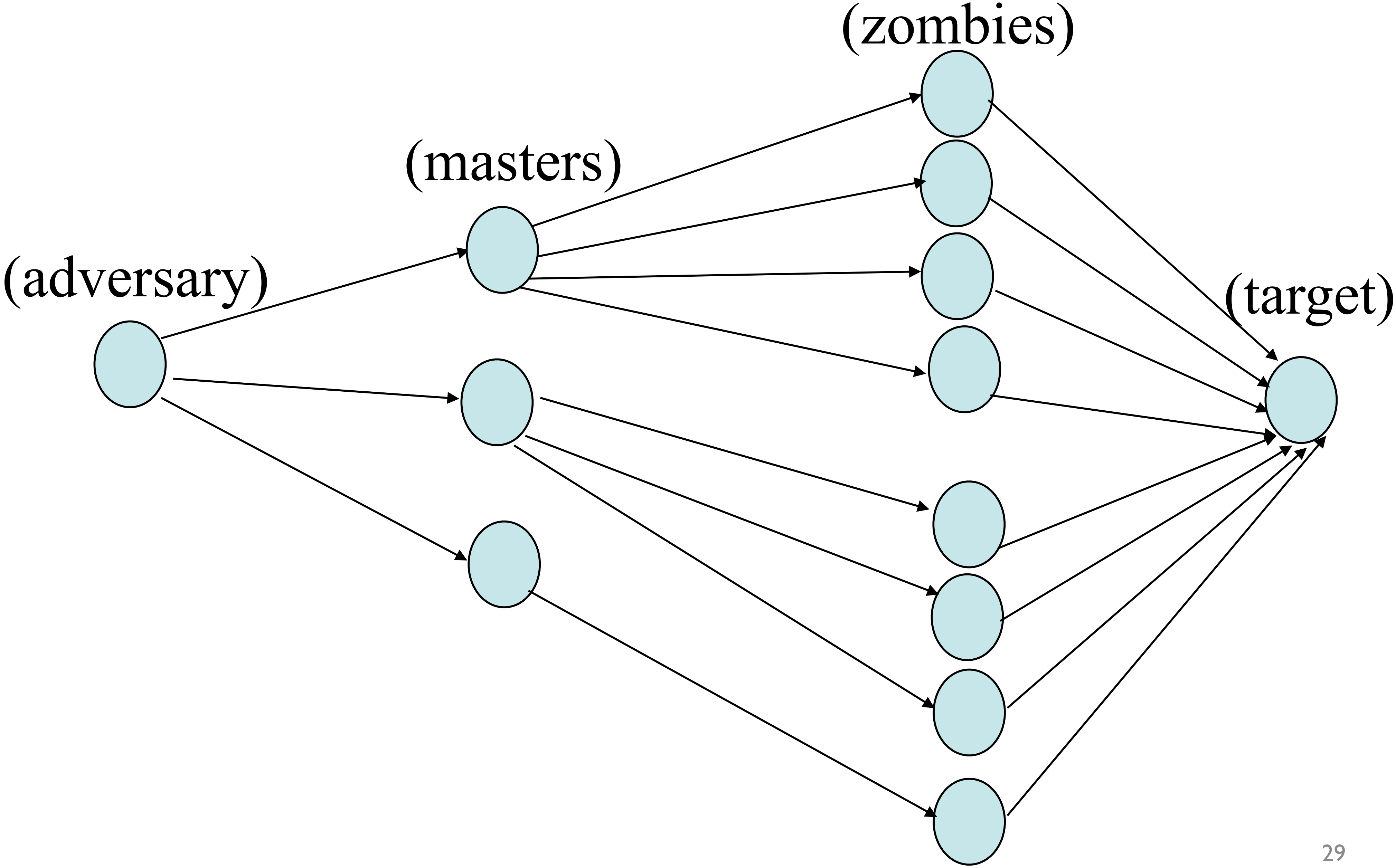
(D)DoS Techniques 101
(Don’t do these.)

- Send a stream of legitimate requests
- Send a few malformed packets
  - causing failures or expensive error handling
  - low-rate packet dropping (TCP congestion control)
  - “ping of death”
- Abuse legitimate access
  - Compromise service/host
  - Use its legitimate access rights to consume the rights for domain (e.g., local network)

The canonical DDoS attack



Adversary Network



Why DDoS?

- Motivations:
  - An axe to grind
  - Curiosity (script kiddies)
  - Blackmail / racketeering
  - Information warfare
  - Distraction

Q: An easy fix?

- How do you solve distributed denial of service?

Simple DDoS Mitigation

- **Ingress/Egress Filtering**: Helps spoofed sources, not much else
- Better Security
  - Limit availability of zombies (not feasible)
  - Prevent compromise and viruses (maybe in wonderful magic land where it rains chocolate and doughnuts)
- Quality of Service Guarantees (QoS)
  - Pre- or dynamically allocated bandwidth (e.g., diffserv)
  - Helps where such things are available
- Content replication
  - E.g,. CDS
  - Useful for static content

Pushback

- Initially, detect the DDoS and flag the sources/types/links of DDoS traffic
- **Pushback** on upstream routers
  - Contact upstream routers using PB protocol
  - Indicate some filtering rules (based on observed flows)
- Repeat as necessary towards sources
- Works well in wonderful magic land where it rains chocolate and doughnuts

Traceback

- With small probability (e.g., 1/20,000), routers include identity of previous hop with packet data
- For large flows, targets can reconstruct path to source
- Statistics say that the path will be exposed

DDoS Reality

- None of the "protocol oriented" solutions have really seen any adoption
  - too many untrusting, ill-informed, mutually suspicious parties must play together
- Real Solution
  - Large ISPs police their ingress/egress points very carefully
  - Watch for DDoS attacks and filter appropriately
  - Develop products that coordinate view from many vantage points in the network to identify upswings in traffic


KILL!

Botnets

- A **botnet** is a network of software robots (bots) run on **zombie machines** which are controlled by **command and control** networks
  - **IRCbots** - command and control over IRC
  - **Bot master** - owner/controller of network

What are botnets being used for?

Activities we have seen

piracy

Stealing CD Keys:

```
ying!ying@ying.2.tha.yang PRIVMSG #atta :BGR|0981901486 $getcdkeys
BGR|0981901486!nmavmkmyam@212.91.170.57 PRIVMSG #atta :Microsoft Windows
Product ID CD Key: (55274-648-5295662-23992).
BGR|0981901486!nmavmkmyam@212.91.170.57 PRIVMSG #atta :[CDKEYS]: Search
completed.
```

Mining (crypto currency or private data)

Reading a user's clipboard:

```
B][!Guardian@globalop.xxx.xxx PRIVMSG ##chem## :~getclip
Ch3m|784318!~zbhibvn@xxx-7CCCB7AA.click-network.com PRIVMSG ##chem## :-
[Clipboard Data]- Ch3m|784318!~zbhibvn@xxx-7CCCB7AA.click-network.com PRIVMSG
##chem## :If You think the refs screwed the seahawks over put your name down!!!
```

attacks

DDoS someone:

```
devil!evil@admin.of.hell.network.us PRIVMSG #t3rr0r0Fc1a :!pflood 82.147.217.39
443 1500 s7n|2K503827!s7s@221.216.120.120 PRIVMSG #t3rr0r0Fc1a :\002Packets\002
\002D\002one \002;\002>\n s7n|2K503827!s7s@221.216.120.120 PRIVMSG #t3rr0r0Fc1a
flooding....\n
```

hosting

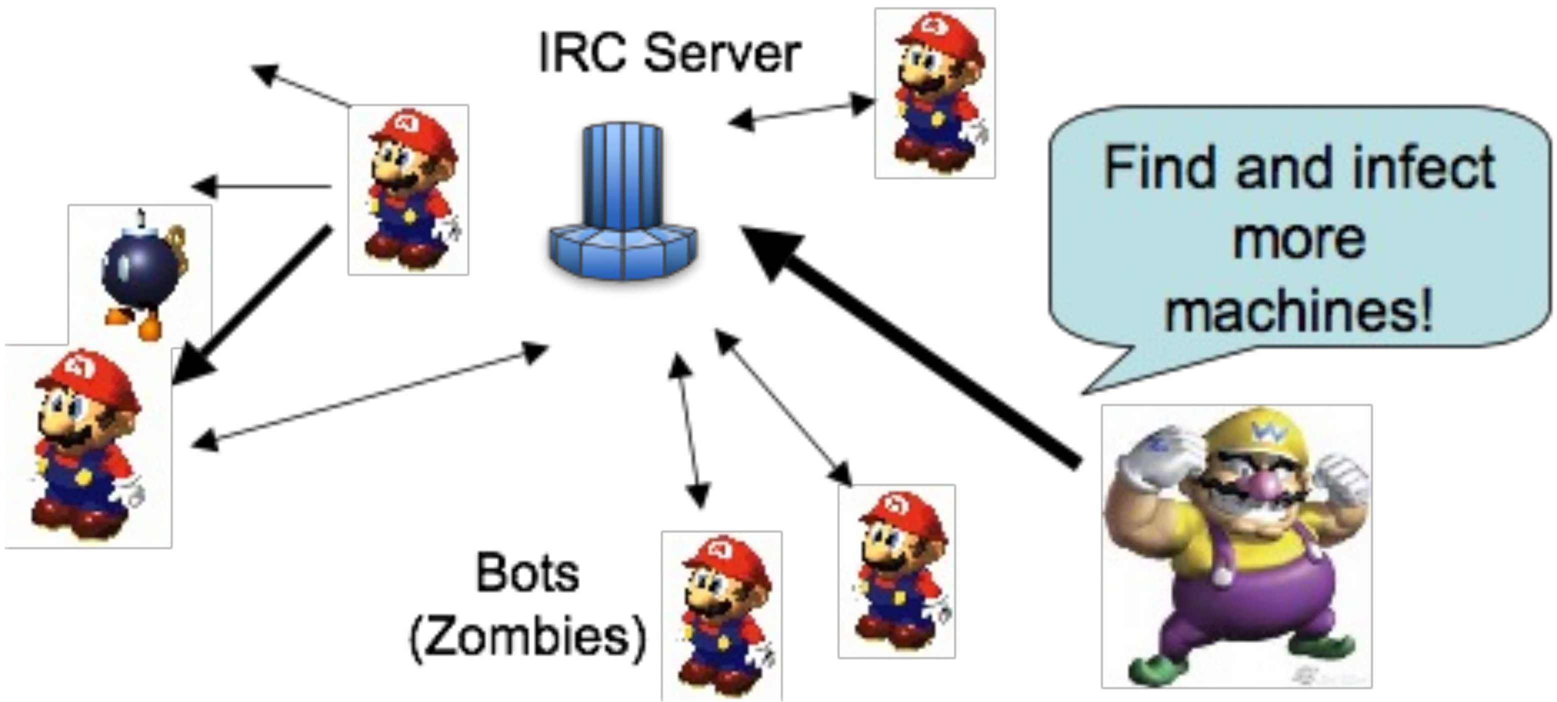
Set up a web-server (presumably for phishing):

```
[DeXTeR]!alexo@185-130-136-193.broadband.actcom.net.il PRIVMSG [Del]29466
:.http 7564 c:\\ [Del]38628!zaazbob@born113.athome233.wau.nl PRIVMSG _[DeXTeR]
:[HTTPD]: Server listening on IP: 10.0.2.100:7564, Directory: c:\\.
```

IRC

- Internet Relay Chat
  - before AOL chat rooms
  - equally creepy
- Supports one-to-many or many-to-many chat
- Supports many **channels** (sometimes password protected)
- Client/server architecture

IRC botnets



Other Channels

- Common IRC ports are frequently blocked
- How else can bots receive direction?
  - Other IM protocols?
  - Twitter
  - Common Web pages (e.g., reddit)
- Advantages / Disadvantages?