CIS 551 / TCOM 401

Computer and Network Security

Spring 2007

Lecture 13

Announcements

- Project 2 is on the web.
  - Due: March 15th
  - Send groups to Jeff Vaughan (vaughan2@seas) today.

- Plan for today:
  - Automatic Signature Extraction
  - Other kinds of Intrusion Detection Tools

Naïve Content Sifting

- ProcessTraffic(packet, srcIP, dstIP) {
```
  count[packet]++;
  Insert(srcIP, dispersion[packet].sources);
  Insert(dstIP, dispersion[packet].dests);
  if (count[packet] > countThresh
     && size(dispersion[packet].sources) > srcThresh
     && size(dispersion[packet].dests) > dstThresh) {
        Alarm(packet)
  }
}
```

- Tables count and dispersion are indexed by entire packet content.

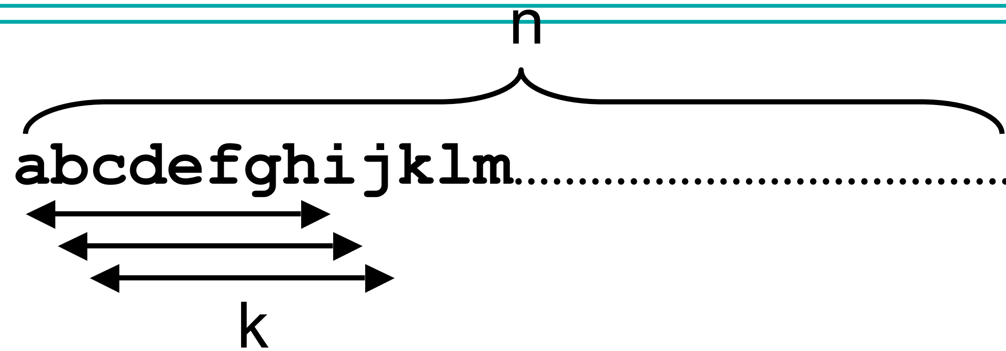
Practical Content Sifting

- Reduce size of count table by:
  - Hashing the packet content to a fixed size (*not* cryptographic hashes)
  - Hash collisions may lead to false positives
  - So, do multiple different hashes (say 3) -- worm content is flagged only if counts along all hashes exceed a threshold

- Include the destination port in the hash of the packet content
  - Current worms target specific vulnerabilities, so they usually aim for a particular port.

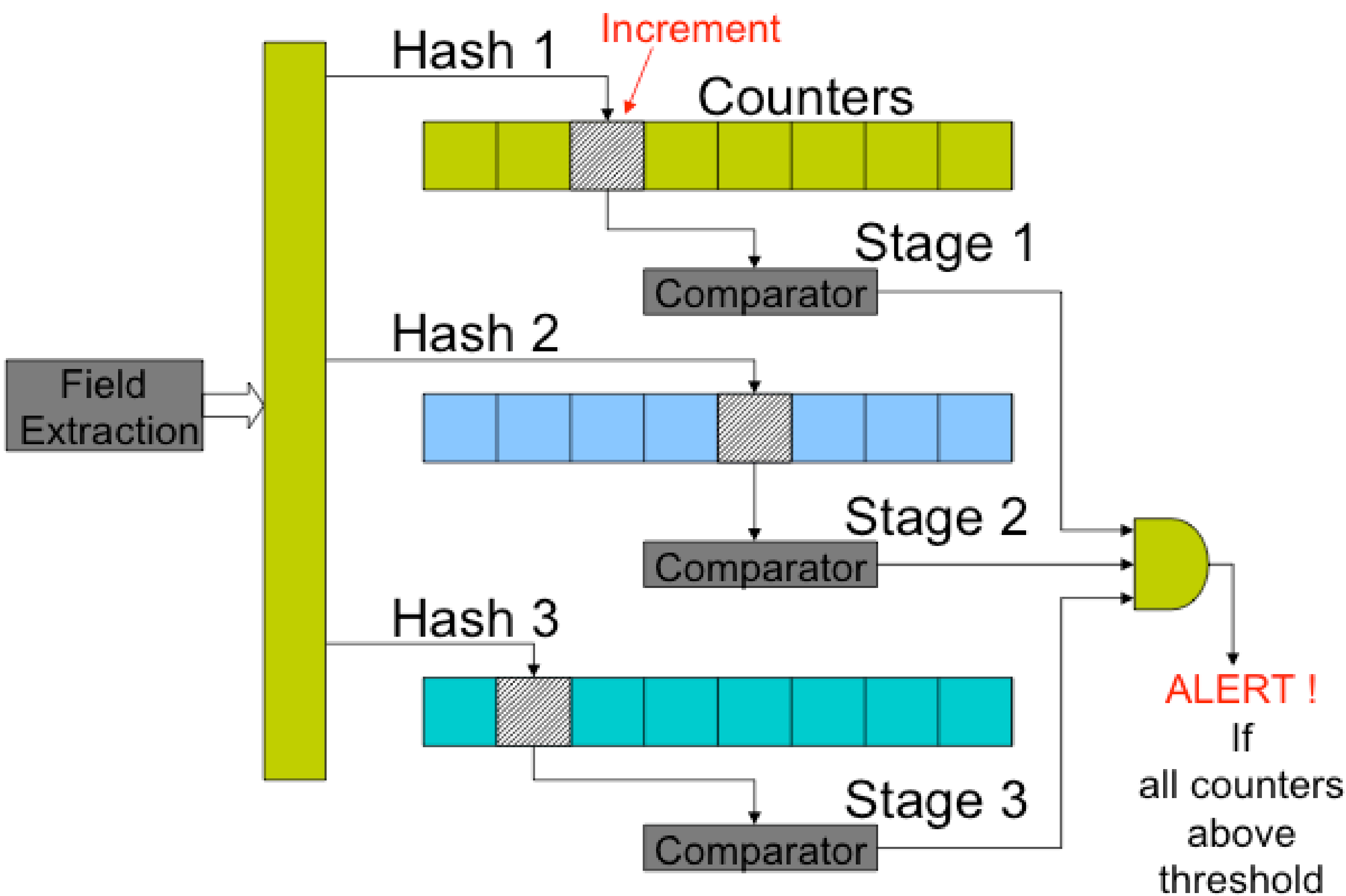
- To check for substring matches they propose to use a Rabin fingerprint
  - Probabilistic, incrementally computable hash of substrings of a fixed length.

Rabin Fingerprints



- Given string of length n
  - Write as sequence of bytes: $t_0\ t_1\ t_2\ \dots\ t_n$
- Check all possible substrings of length k
- Choose constants p (a prime) and M (modulus)
- Fingerprint for substrings are:
  - $F_1 = (t_0{*}p^{(k-1)} + t_1{*}p^{(k-2)} + \dots + t_k) \bmod M$
  - $F_2 = (t_1{*}p^{(k-1)} + t_2{*}p^{(k-2)} + \dots + t_{k+1}) \bmod M$
    $= (F_1 * p + t_{k+1} - t_0{*}p^k) \bmod M$
  - $F_3 = (F_2 * p + t_{k+2} - t_1{*}p^k) \bmod M$
  - $F_i = (F_{i-1} * p + t_{k+i-1} - t_{i-1}{*}p^k) \bmod M$
- For efficiency, precompute table of $x{*}p^k$

Multistage Filters, Pictorially



Tracking Address Dispersion

- In this case, we care about the number of distinct source (or destination) addresses in packets that contain suspected worm data.

- Could easily keep an exact count by using a hash table, but that becomes too time and memory intensive.
  - In the limit, need one bit per address to mark whether it has been seen or not.

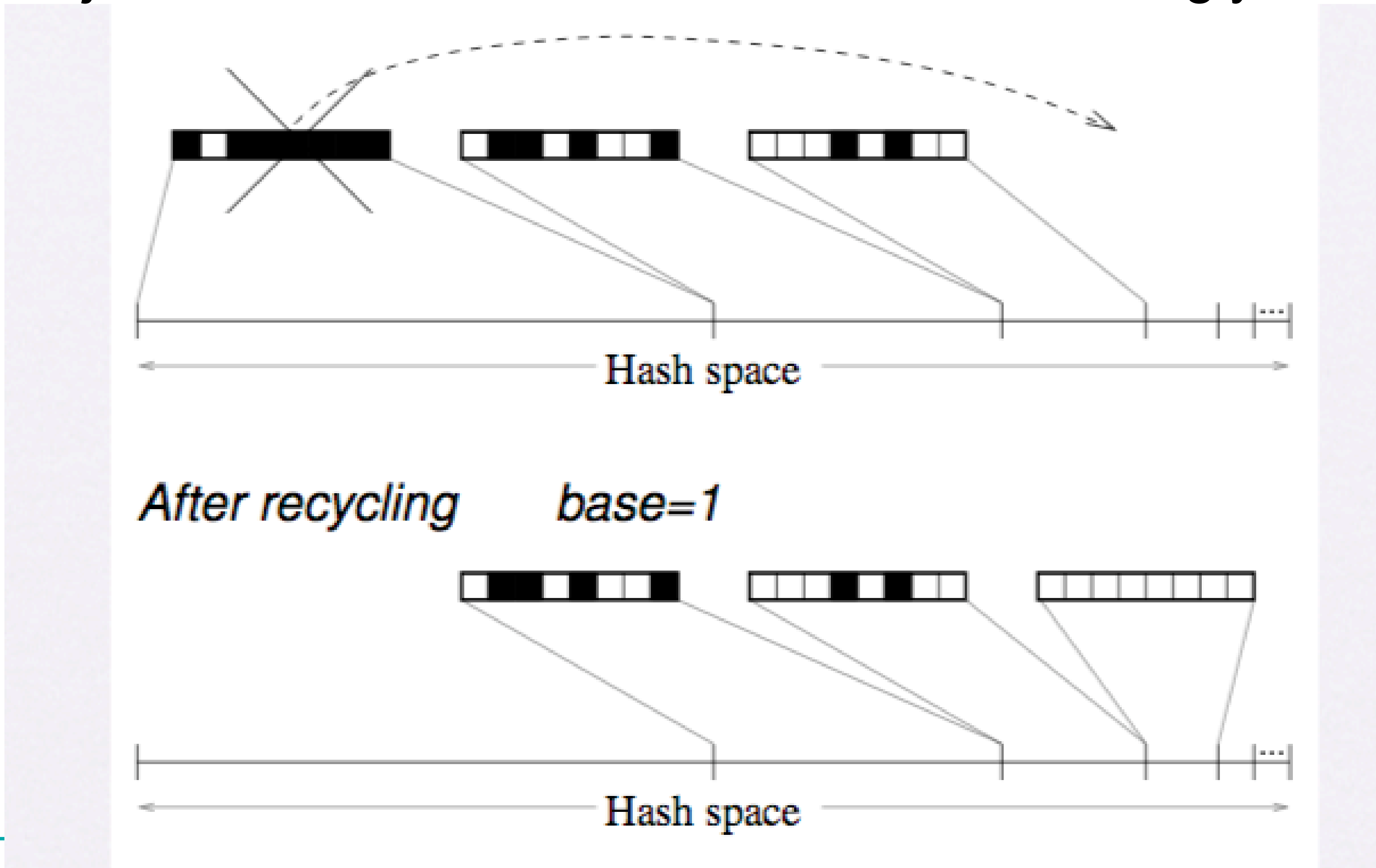
- Instead: Keep an *approximate* count
- Scalable bitmap counters
  - Reduce memory requirements by 5x

Scalable Bitmap Counters

- Suppose there are 64 possible addresses and you want to use only 32 bits to keep track of them.
- High-level idea:
  – Hash the address into a value between 0 and 63
  – Use only the lower 5 bits (yielding 32)
  – To estimate actual number of addresses, multiply the number of bits set in the bitmap by 2.

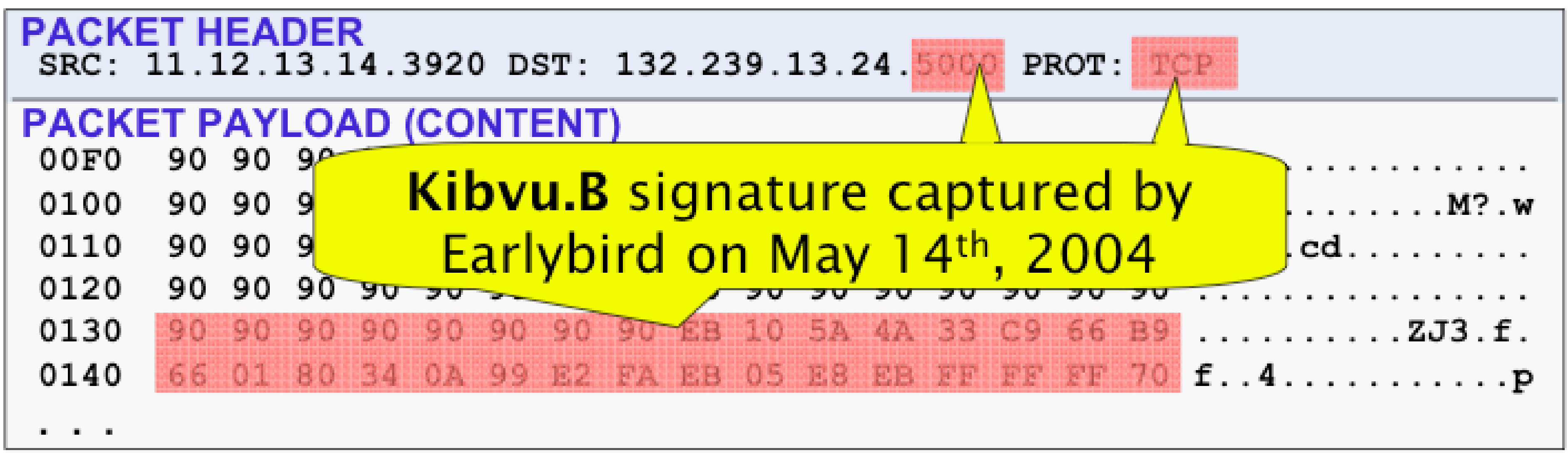
Multiple Bitmaps, Pictorially

- Recycle bitmaps after they fill up
- Adjust the scale factors on the counts accordingly



Results

- Earlybird successfully detects and extracts virus signatures from every known recent worm (CodeRed, MyDoom, Sasser, Kibvu.B,…)
- Tool generates content filter rules suitable for use with Snort



Analysis

- False Positives:
  - SPAM
    - No solution yet
  - BitTorrent (35% of Internet traffic?!)
    - Replicates packets, so it actually looks like worm traffic
  - Common protocol headers
    - HTTP and SMTP
    - Some P2P system headers
    - Solution: whitelist by hand
- False Negatives:
  - Hard (impossible?) to prove absence of worms
  - Over 8 months Earlybird detected all worm outbreaks reported on security mailing lists

Attacks

- What about violating the assumptions?
  - Invariant content
  - Worm propagates randomly
  - Worm propagates quickly

Polymorphic Viruses/Worms

- Virus/worm writers know that signatures are the most effective way to detect such malicious code.

- Polymorphic viruses mutate themselves during replication to prevent detection
  - Virus should be capable of generating many different descendents
  - Simply embedding random numbers into virus code is not enough

Strategies for Polymorphic Viruses

- Change data:
  - Use different subject lines in e-mail
- Encrypt most of the virus with a random key
  - Virus first decrypts main body using random key
  - Jumps to the code it decrypted
  - When replicating, generate a new key and encrypt the main part of the replica
- Still possible to detect decryption portion of the virus using virus signatures
  - This part of the code remains unchanged
  - Worm writer could use a standard self-decompressing executable format (like ZIP executables) to cause confusion (many false positives)

Advanced Evasion Techniques

- Randomly modify the *code* of the virus/worm by:
  - Inserting no-op instructions: subtract 0, move value to itself
  - Reordering independent instructions
  - Using different variable/register names
  - Using equivalent instruction sequences:

    y = x + x   vs.   y = 2 * x
  - These viruses are sometimes called "metamorphic" viruses in the literature.

- There exist C++ libraries that, when linked against an appropriate executable, automatically turn it into a metamorphic program.

- Sometimes vulnerable software itself offers opportunities for hiding bad code.
  - Example: ssh or SSL vulnerabilities may permit worm to propagate over encrypted channels, making content filtering impossible.
  - If IPSEC becomes popular, similar problems may arise with it.

Other Evasion Techniques

- Observation: worms don't need to scan randomly
  - They won't be caught by internet telescopes
- *Meta-server* worm: ask server for hosts to infect (e.g., Google for "**powered by php**")
- *Topological* worm: fuel the spread with local information from infected hosts (web server logs, email address books, config files, SSH "known hosts")
  - No scanning signature; with rich inter-connection topology, potentially very fast.
- Propagate slowly: "trickle" attacks
  - Also a very subtle form of denial of service attacks

Witty Worm

- Released March 19, 2004.
- Single UDP packet exploits flaw in the *passive analysis* of Internet Security Systems products.
- “Bandwidth-limited” UDP worm like Slammer.
- Vulnerable pop. (12K) attained in 75 minutes.
- Payload: *slowly corrupt random disk blocks*.

Witty, con’t

- Flaw had been announced the *previous day*.
- Telescope analysis reveals:
  - Initial spread seeded via a *hit-list*.
  - In fact, targeted a U.S. military base.
  - Analysis also reveals “Patient Zero”, a European retail ISP.
- Written by a Pro.

Broader View of Defenses

- Prevention -- *make the monoculture hardier*
  - Get the code right in the first place …
    - … or figure out what's wrong with it and fix it
  - Lots of active research (static & dynamic methods)
  - Security reviews now taken seriously by industry
    - E.g., ~$200M just to *review* Windows Server 2003
  - But very expensive
  - And very large Installed Base problem

- Prevention -- *diversify the monoculture*
  - Via exploiting existing heterogeneity
  - Via creating artificial heterogeneity

Broader View of Defenses, con't

- Prevention -- *keep vulnerabilities inaccessible*
  - Cisco's *Network Admission Control*
    - Examine hosts that try to connect, block if vulnerable
  - Microsoft's *Shield*
    - Shim-layer blocks network traffic that fits known *vulnerability* (rather than known *exploit*)

Detecting Attacks

- Attacks (against computer systems) usually consist of several stages:
  - Finding software vulnerabilities
  - Exploiting them
  - Hiding/cleaning up the exploit

- Attackers care about finding vulnerabilities:
  - What machines are available?
  - What OS / version / patch level are the machines running?
  - What additional software is running?
  - What is the network topology?

- Attackers care about not getting caught:
  - How detectible will the attack be?
  - How can the attacker cover her tracks?

- Programs can automate the process of finding/exploiting vulnerabilities.
  - Same tools that sys. admins. use to audit their systems…
  - A worm is just an automatic vulnerability finder/exploiter…

Attacker Reconnaissance

- Network Scanning
  - Existence of machines at IP addresses
  - Attempt to determine network topology
  - ping, tracert
- Port scanners
  - Try to detect what processes are running on which ports, which ports are open to connections.
  - Typical machine on the internet gets 10-20 port scans per day!
  - Can be used to find hit lists for flash worms
- Web services
  - Use a browser to search for CGI scripts, Javascript, etc.

Determining OS information

- Gives a lot of information that can help an attacker carry out exploits
  - Exact version of OS code can be correlated with vulnerability databases
- Sadly, often simple to obtain this information:
  - Just try telnet

```
playground~> telnet hpux.u-aizu.ac.jp
Trying 163.143.103.12 ...
Connected to hpux.u-aizu.ac.jp.
Escape character is '^]'.
HP-UX hpux B.10.01 A 9000/715 (ttyp2)

login:
```

Determining OS

- Or ftp:

```
$ ftp ftp.netscape.com 21
Connected to ftp.gftp.netscape.com.
220-36
220 ftpnscp.newaol.com FTP server (SunOS 5.8) ready.
Name (ftp.netscape.com:stevez):
331 Password required for stevez.
Password:
530 Login incorrect.
ftp: Login failed.
Remote system type is UNIX.
Using binary mode to transfer files.
ftp> system
215 UNIX Type: L8 Version: SUNOS
ftp>
```

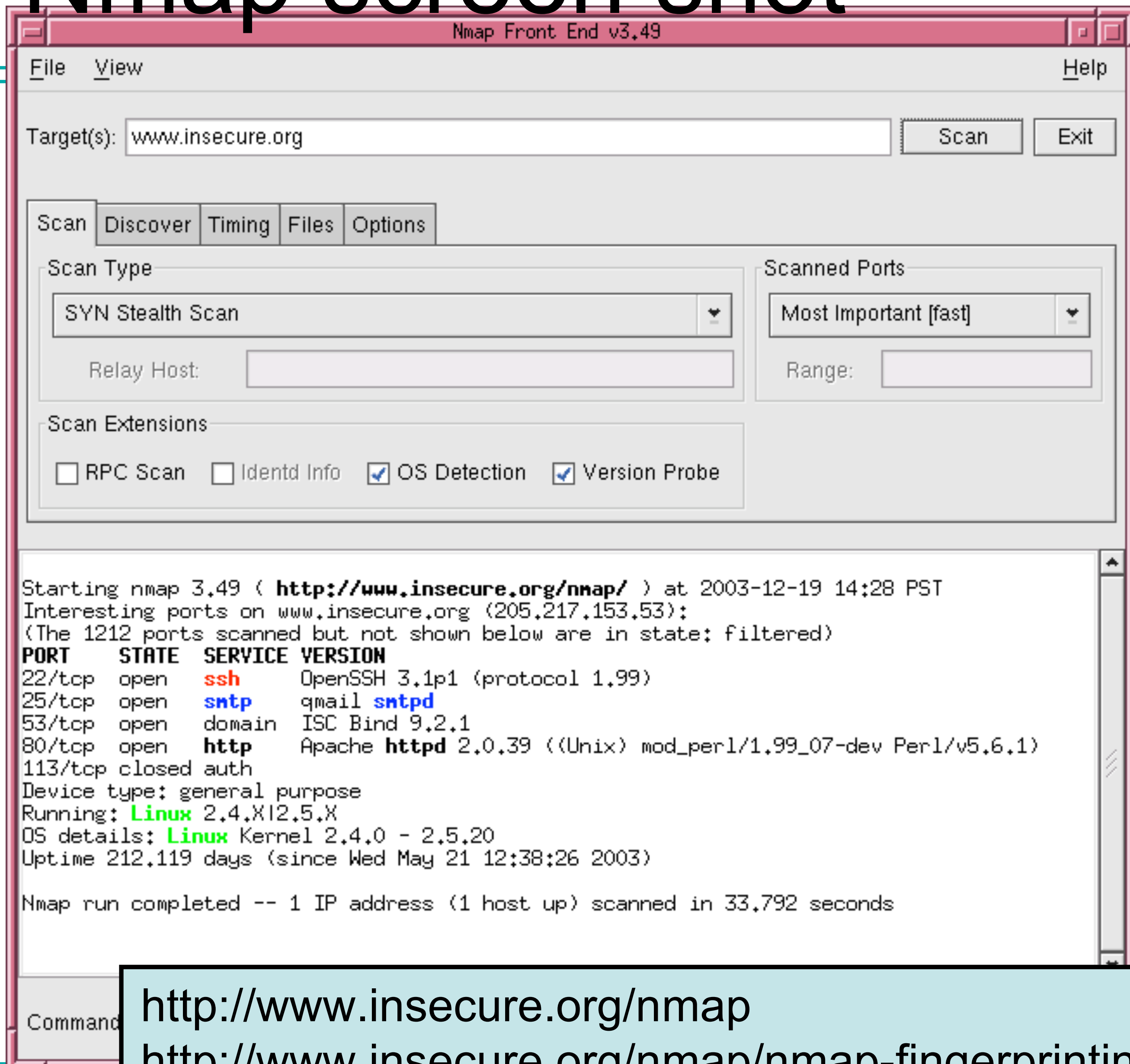
Determining OS

- Exploit different implementations of protocols
  - Different OS's have different behavior in some cases
- Consider TCP protocol, there are many flags and options, and some unspecified behavior
  - Reply to bogus FIN request for TCP port (should not reply, but some OS's do)
  - Handling of invalid flags in TCP packets (some OS's keep the invalid flags set in reply)
  - Initial values for RWS, pattern in random sequence numbers, etc.
  - Can narrow down the possible OS based on the combination of implementation features
- Tools can automate this process

Auditing: Remote auditing tools

- Several utilities available to "attack" or gather information about services/daemons on a system.
  - SATAN (early 1990's):
    Security Administrator Tool for Analyzing Networks
  - SAINT - Based on SATAN utility
  - SARA - Also based on SATAN
  - Nessus - Open source vulnerability scanner
    - http://www.nessus.org
  - Nmap
- Commercial:
  - ISS scanner
  - Cybercop

Nmap screen shot



http://www.insecure.org/nmap
http://www.insecure.org/nmap/nmap-fingerprinting-article.html

Kinds of Auditing done

- Nessus web pages:
  - Backdoors
  - CGI abuses
  - Denial of Service
  - Finger abuses
  - Firewalls
  - FTP
  - Gain a shell remotely
  - Gain root remotely
  - Netware
  - NIS
  - Port scanners
  - Remote file access
  - RPC
  - Settings
  - SMTP problems
  - SNMP
  - Useless services
  - Windows
  - Windows : User management

- Doing this kind of auditing by hand is complex and error prone
- These tools aren't fool proof or complete.