Application Firewalls

Moving Up the Stack

- Why move up the stack?
- Apart from the limitations of packet filters discussed last time, *firewalls are inherently incapable of protecting against attacks on a higher layer*
- IP packet filters (plus port numbers...) can't protect against bogus TCP data
- A TCP-layer firewall can't protect against bugs in SMTP
- SMTP proxies can't protect against problems in the email itself, etc.

Advantages

- Protection can be tuned to the individual application
- More context can be available
- You only pay the performance price for that application, not others

Disadvantages

- Application-layer firewalls don't protect against attacks at *lower* layers!
- They require a separate program per application
- These programs can be quite complex
- They may be very intrusive for user applications, user behavior, etc.

Example: Protecting Email

- Do we protect inbound or outbound email? Some of the code is common; some is quite different
- Do we work at the SMTP level (RFC 2821) or the mail content level (RFC 2822)?
- What about MIME?
- (What about S/MIME- or PGP-protected mail?)
- What are the threats?

Email Threats

- The usual: defend against protocol implementation bugs
- Virus-scanning
- Anti-spam?
- Javascript? Web bugs in HTML email?
- Violations of organizational email policy?
- Signature-checking?

Inbound Email

- Email is easy to intercept: MX records in the DNS route inbound email to an arbitrary machine
- Possible to use "*" to handle entire domain
- Example: DNS records exist for `att.com` and `*.att.com`
- Net result: all email for that domain is sent to a front end machine

Different Sublayers

- Note that are are multiple layers of protection possible here
- The receiving machine can run a hardened SMTP, providing protection at that layer
- Once the email is received, it can be scanned at the content layer for any threats
- The firewall function can consist of either or both

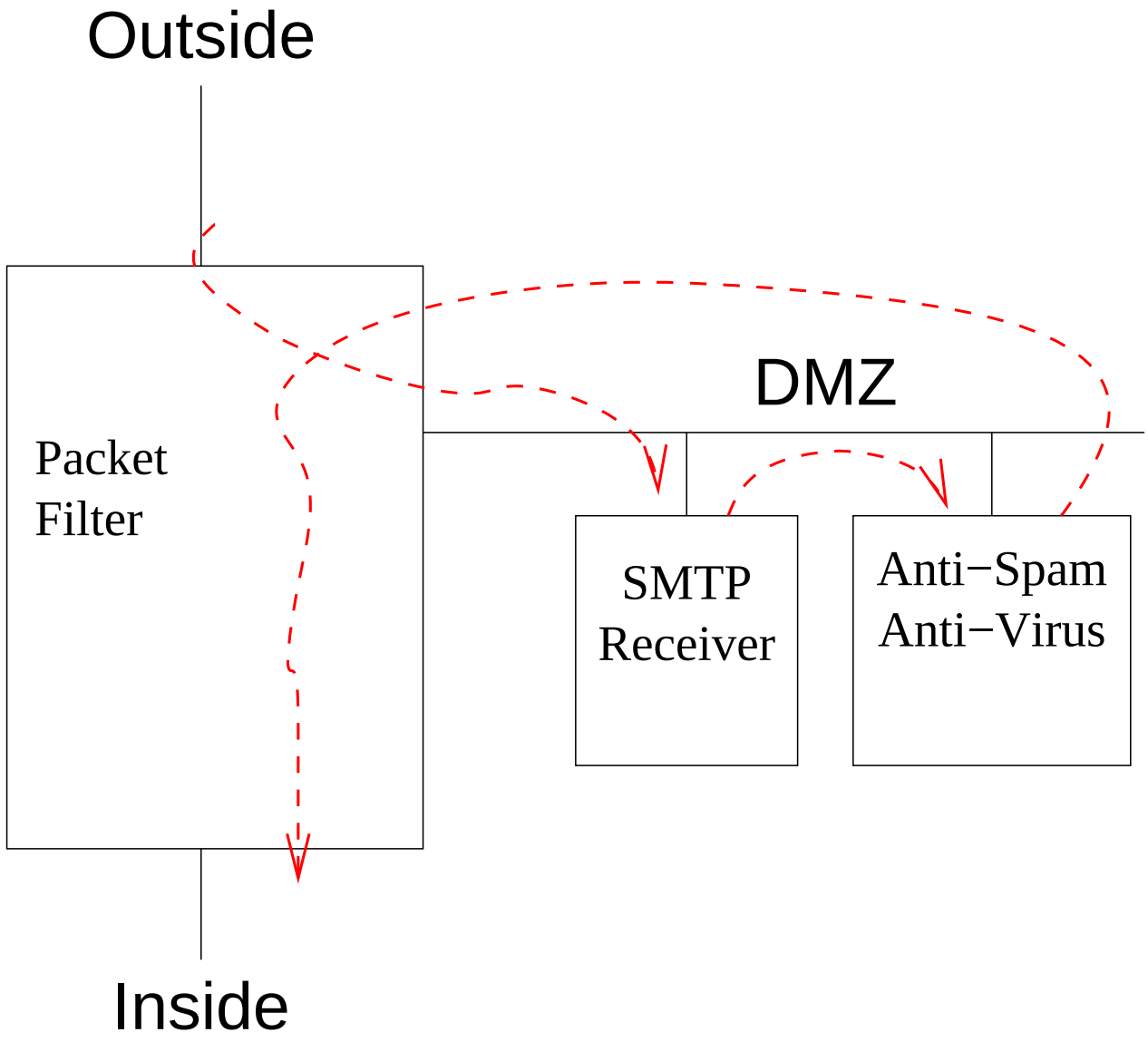
Outbound Email

- No help from the protocol definition here
- But — most mailers have the ability to forward some or all email to a relay host
- Declare by administrative fiat that this must be done
- Enforce this with a packet filter. . .

Combining Firewall Types

- Use an application firewall to handle inbound and outbound email
- Use a packet filter to enforce the rules

Firewalling Email



Enforcement

- Email can't flow any other way
- The only SMTP server the outside can talk to is the SMTP receiver
- It forwards the email to the anti-virus/anti-spam filter, via some arbitrary protocol
- That machine speaks SMTP to some inside mail gateway
- Note the other benefit: if the SMTP receiver is compromised, it can't speak directly to the inside

Outbound Email

- Again, we use a packet filter to block direct outbound connections to port 25
- The only machine that can speak to external SMTP receivers is the dedicated outbound email gateway
- That gateway can either live on the inside or on the DMZ

The DNS

DNS Issues

- UDP (discussed previously)
- Internal versus external view
- DNS cache corruption
- Optimizing DNSSEC checks

UDP Issues

- Remember the DNS server location discsussed last time
- In fact, what we did there was use an application-level relay to work around packet filter restrictions
- We're lucky — since the DNS protocol includes provision for recursion, it requires no application changes for this to work

Internal Versus External View

- Should outsiders be able to see the names of all internal machines?
- What about `secretproject.foobar.com`?
- Solution: use two DNS servers, one for internal requests and one for external request
- Put one on each side of the firewall
- Issue: which machine does the NS record for `foobar.com` point to, the inside or the outside server?
- Can be trickier than it seems — must make sure that internal machines don't see NS records that will make them try to go outside directly

Cache Contamination Attacks

- DNS servers cache results from queries
- Responses can contain "additional information" — data that may be helpful but isn't part of the answer
- Send bogus DNS records as additional information; confuse a later querier

DNS Filtering

- All internal DNS queries go to a *DNS switch*
- If it's an internal query, forward the query to the internal server or pass back internal NS record
- If it's an external query, forward the query to outside, but:
  - Scrub the result to remove any references to inside machines
  - Scrub the result to remove any references to any NS records; this prevents attempts to go outside directly
- Use a packet filter to block direct DNS communication

Application Proxies

Small Application Gateways

- Some protocols don't need full-fledged handling at the application level
- That said, a packet filter isn't adequate
- Solution: examine some of the traffic via an application-specific proxy; react accordingly

FTP Proxy

- Remember the problem with the PORT command?
- Scan the FTP control channel
- If a PORT command is spotted, tell the firewall to open that port temporarily for an incoming connection
- (Can do similar things with RPC — define filters based on RPC applications, rather than port numbers)

CS @CU

Attacks Via FTP Proxy

- Downloaded Java applets can call back to the originating host
- A malicious applet can open an FTP channel, and send a PORT command listing a vulnerable port on a nominally-protected host
- The firewall will let that connection through
- Solution: make the firewall smarter about what host and port numbers can appear in PORT commands...

Web Proxies

- Again, built-in protocol support
- Provide performance advantage: caching
- Can enforce site-specific filtering rules

Circuit Gateways

Circuit Gateways

- Circuit gateways operate at (more or less) the TCP layer
- No application-specific semantics
- Avoid complexities of packet filters
- Allow controlled inband connections, i.e., for FTP
- Handle UDP
- Most common one: SOCKS. Supported by many common applications, such as Firefox and GAIM.

Application Modifications

- Application must be changed to speak the circuit gateway protocol instead of TCP or UDP
- Easy for open source
- Socket-compatible circuit gateway libraries have been written for SOCKS — use those instead of standard C library to convert application

Adding Authentication

- Because of the circuit (rather than packet) orientation, it's feasible to add authentication
- Purpose: extrusion control

Personal and Distributed Firewalls

Rationale

- Conventional firewalls rely on topological assumptions — these are questionable today
- Instead, install protection on the end system
- Let it protect itself

Personal Firewalls

- Add-on to the main protocol stack
- The "inside" is the host itself; everything else is the "outside"
- Most act like packet filters
- Rule set can be set by individual or by administrator

Saying "No", Saying "Yes"

- It's easy to reject protocols you don't like with a personal firewall
- The hard part is saying "yes" safely
- There's no topology — all that you have is the sender's IP address
- Spoofing IP addresses isn't that hard, especially for UDP

Application-Linked Firewalls

- Most personal firewalls act on port numbers
- At least one such firewall is tied to applications — individual programs are or are not allowed to talk, locally or globally
- Pros: don't worry about cryptic port numbers; handle auxiliary ports just fine
- Cons: application names can be just as cryptic; service applications operate on behalf of some other application

Distributed Firewalls

- In some sense similar to personal firewalls, though with central policy control
- Use IPsec to distinguish "inside" from "outside"
- Insiders have inside-issued certificates; outsiders don't
- Only trust other machines with the proper certificate
- No reliance on topology; insider laptops are protected when traveling; outsider laptops aren't a threat when they visit

The Problems with Firewalls

Problems

- Corrupt insiders
- Connectivity
- Laptops
- Evasion

Corrupt Insiders

- Firewalls assume that everyone on the inside is good
- Obviously, that's not true
- Beyond that, active content and subverted machines mean there are bad actors on the inside

Connectivity

- Firewalls rely on topology
- If there are too many conections, some will bypass the firewall
- Sometimes, that's even necessary; it isn't possible to effectively firewall all external partners
- A large company may have hundreds or even thousands of external links, most of which are unknown to the official networking people

CS@CU

Laptops

- Laptops, more or less by definition, travel
- When they're outside the firewall, what protects them?
- At one conference, I spotted at least a dozen other attendee machines that were infected with the Code Red virus
- (Code Red only infected web servers. Why were laptops running web servers?)

Evasion

- Firewalls and firewall administrators got too good
- Some applications weren't able to run
- Vendors started building things that ran over HTTP
- HTTP usually gets through firewalls and even web proxies...

Midterm

Conditions

- Open book, open notes
- No computers or calculators
- 75 minutes

Format

- Approximately 8 questions
- I'm not asking you to write programs
- Three types of questions
  - Explanations of certain concepts, above the pure memorization level
  - Carrying out tasks based on things discussed in class
  - Design questions (i.e., ones intended to make you think)

Material

- Everything through today's lecture
- If it's in my slides or I said it in class, you're responsible for it
- There will be some material based more on the readings
- You're responsible for the assigned readings at about the level of class coverage.