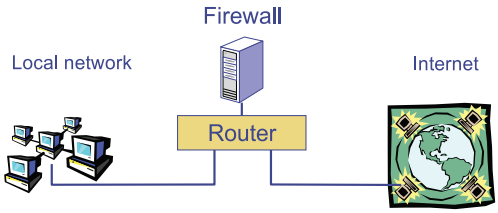
Insecure network services

- **NFS (port 2049)**
  - Read/write entire FS as any non-root user given a dir. handle
  - Many OSes make handles easy to guess
- **Portmap (port 111)**
  - Relays RPC requests, making them seem to come from localhost
  - E.g., old versions would relay NFS mount requests
- **FTP (port 21) – server connects back to client**
  - Client can specify third machine for "bounce attack"
- **YP/NIS – serves password file, other info**
- **A host of services have histories of vulnerabilities**
  - DNS (53), rlogin (513), rsh (514), NTP (123), lpd (515), . . .
  - Many on by default—compromised before OS fully installed

Firewalls

- **Separate local area net from Internet**
  - Prevent bad guys from interacting w. insecure services
  - Perimeter-based security



All packets between LAN and internet routed through firewall

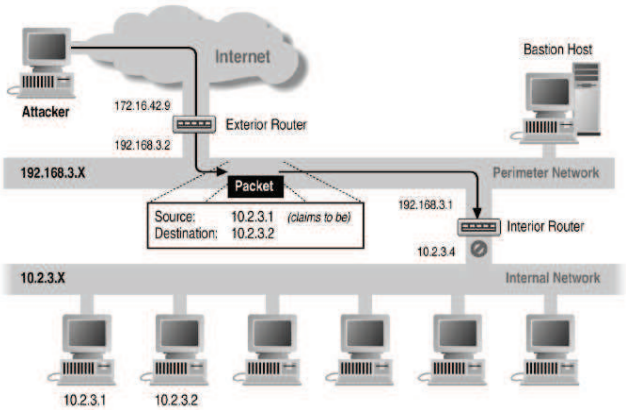
Two separable topics

- **Arrangement of firewall and routers**
  - Separate internal LAN from external Internet
  - Wall off subnetwork within an organization
  - Intermediate zone between firewall and rest of network (called demilitarized zone or "DMZ")
  - Personal firewall on end-user machine
- **How the firewall processes data**
  - Packet filtering router
  - Application-level gateway
    Proxy for protocols such as ftp, smtp, http, etc.
  - Personal firewall
    E.g., disallow telnet connection from email client

Packet filtering

- **Filter packets using transport layer information**
  - Examine IP, and ICMP/TCP/UDP header of each packet
  - IP Source, Destination address
  - Protocol
  - TCP/UDP source & destination ports
  - TCP flags
  - ICMP message type
- **Example: coping with vulnerability in lpd**
  - Block any TCP packets with destination port 515
  - Outsiders shouldn't be printing from outside net anyway

Example: blocking forgeries



- **Should block incoming packets "from" your net**
- **Egress filtering: block forged outgoing packets**

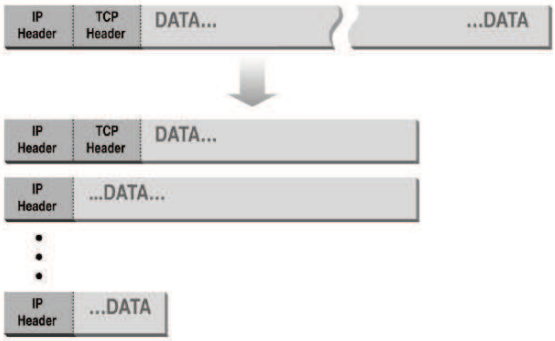
Example: blocking outgoing mail

- **At Stanford, all mail goes out through main servers**
  - Result of Sircam worm
    . . . infected & mailed users' files around as attachments
  - Could have disclosed sensitive information
  - Mail servers now scan attachments for worms
  - Also reduces threat of Stanford being used to spam
- **How to enforce?**
- **Block outgoing TCP packets**
  - If destination port is 25 (SMTP – mail protocol)
  - And if source IP address is not a Stanford mail server

Blocking by default

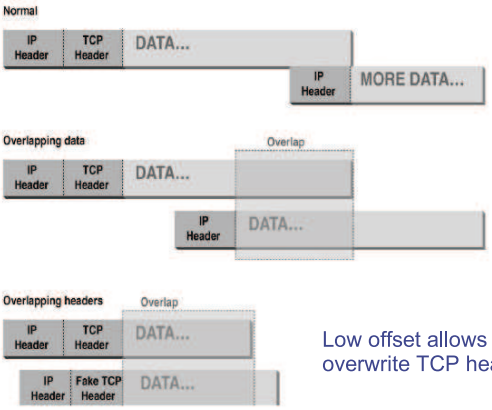
- **Often don't know what people run on their machines**
- **In many environments better to be safe:**
  - Block all incoming TCP connections
  - Explicitly allow incoming connections to particular hosts
    E.g., port 80 on web server, port 25 on mail server, . . .
  - But still must allow *outgoing* TCP connections
    (users will revolt if they can't surf the web)
- **How to enforce?**
  - Recall all but first packet in TCP flow has ACK flag set
  - Block incoming TCP packets w. SYN flag but not ACK flag

Fragmentation



- **Recall IP fragmentation—Why might this complicate firewalls?**

Abnormal fragmentation



Low offset allows second packet to overwrite TCP header at receiving host

Fragmentation attack

- **Say firewall requires ACK in incoming TCP segments**
- **First packet**
  - Fragmentation Offset = 0.
  - DF (Don't fragment) = 0, MF (More Fragments) = 1
  - Set ACK bit
- **Second packet**
  - Frag. Offset = 1: (overwrites all but 8 bytes of first pkt)
  - DF (Don't fragment) = 0, MF (More Fragments) = 0
  - Set SYN and clear ACK in flags
- **Host reassembles packets into valid SYN segment**

Blocking UDP traffic

- **Some sites block most UDP traffic**
  - UDP sometimes viewed as "more dangerous"
  - Easier to spoof source address
  - Used by insecure LAN protocols such as NFS
- **Often more convenient to block only *incoming* UDP**
  - E.g., allow internal machines to query external NTP servers
  - Don't let external actors to exploit bugs in local NTP software
    (unless client specifically contacts bad/spoofed server)
- **Must keep state in firewall – like a NAT**
  - Remember ⟨local IP, local port, remote IP, remote port⟩ for each outgoing UDP packet
  - Allow incoming packets that match saved flow
  - Time out flows that have not been recently used

Network intrusion detection

- **Many holes exploited over the network**
  - Buffer overruns in servers
  - Servers with bad implementations
    ("login -froot", telnet w. LD_LIBRARY_PATH)
- **Want to detect people exploiting such bugs**
- **Want to detect activities performed by people who've penetrated server**
  - Setting up IRC bot
  - Running particular commands, etc.
- **Do so with network-based intrusion-detection system (IDS)**

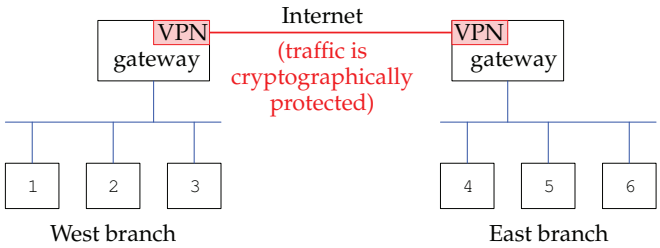
Detect in network monitor

- **Attach IDS machine to DMZ**
- **Sniff all packets in and out of the network**
- **Process packets to identify possible intruders**
  - Secret, per-network rules identify possible attacks
  - Is it a good idea to keep rules secret?
- **React to any threats**
  - Alert administrators of problems in real time
  - Switch on logging to enable later analysis of potential attack
  - Take action against attackers – E.g., filter all packets from host that seems to be attacking

Deep packet inspection

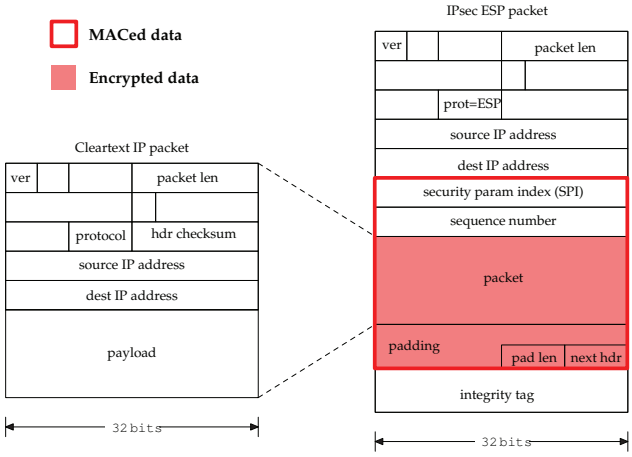
- **May want to block attacks as they are happening**
  - E.g., Stanford can detect your broken software, but can't force you to patch it
  - But if your PC joins a botnet, it's Stanford's problem
  - Best to block attacks as they happen
- **Many attacks require particular fingerprints**
  - E.g., attack packet may include copy of a worm
- **Can amass database of "bad" fingerprints to block**
  - Manually or semi-manually widely done, but slow to adapt to new attacks
  - Heuristics can catch attacks as they happen…
- **But if such countermeasures were uniformly and widely deployed, attackers would defeat them**

Virtual Private Networks (VPNs)



- **What if firewall must protect more than one office**
- **Extend perimeter w. Virtual Private Networks (VPNs)**
- **Two popular VPN protocols:**
  - IPsec encrypts at IP layer (bad for NATs)
  - OpenVPN tunnels IP inside SSL (inside TCP)

IPsec ESP protocol



ESP high-level view

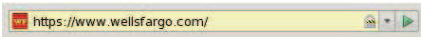
- **Encapsulates one IP packet inside another**
- **Each endpoint has *Security Association DB* (SAD)**
  - Is a table of *Security Associations* (SAs)
  - Each SA has 32-bit *Security Parameters Index* (SPI)
  - Also, source/destination IP addresses, crypto algorithm, keys
- **Packets processed based on SPI, src/dest IP address**
  - Usually have one SA for each direction betw. two points
- **SAD managed "semi-manually"**
  - Manually set key
  - Or negotiate it using IKE protocol

ESP details

- **Must avoid replays**
  - Keep counter for 64-bit sequence number
  - Receiver must accept some packets out of order (e.g., up to 32)
  - Only low 32 bits of sequence number in actual packet (would be bad if you lost 4 billion packets)
- **Support for traffic flow confidentiality (TFC)**
  - Can pad packets to fixed length
  - Can send dummy packets
- **Support for encryption without MAC… Bummer!**
  - Rationale: App might be SSL, which has MAC-only mode
  - But then attacker can mess with destination address!

SSL/TLS [RFC 5246] Overview

- **SSL offers security for HTTP protocol**
  - That's what the padlock means in your web browser

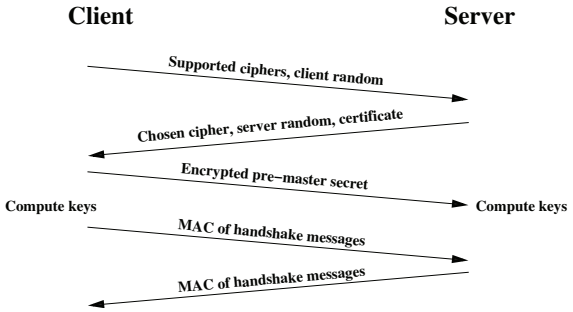


- **Authentication of server to client**
- **Optional authentication of client to server**
  - Incompatibly implemented in different browsers
  - CA infrastructure not in widespread use
- **Confidentiality of communications**
- **Integrity protection of communications**

Ciphersuites: Negotiating ciphers

- **Server authentication algorithm (RSA, DSS)**
- **Key exchange algorithm (RSA, DHE)**
- **Symmetric cipher for confidentiality (RC4, DES, AES)**
- **MAC (HMAC-MD5, HMAC-SHA)**

Overview of SSL Handshake



From "SSL and TLS" by Eric Rescorla

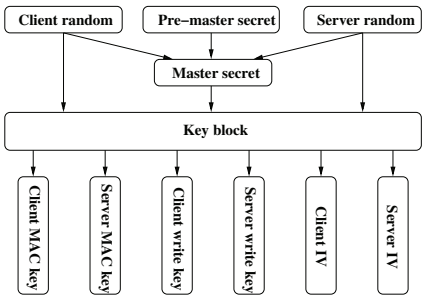
SSL Handshake

- **Client and server negotiate on cipher selection**
- **Cooperatively establish session keys**
- **Use session keys for secure communication**
- **Details**
  - Multiple messages per stage
  - Get an idea of protocol in action:
    `openssl s_client -connect www.paypal.com:443`

Establishing a Session Key

- **Server and client both contribute randomness.**
- **Client sends server a "pre-master secret" encrypted with server's public key**
- **Use randomness and pre-master secret to create session keys:**
  - Client MAC
  - Server MAC
  - Client Write
  - Server Write
  - Client IV
  - Server IV

Establishing a Session Key



From "SSL and TLS" by Eric Rescorla

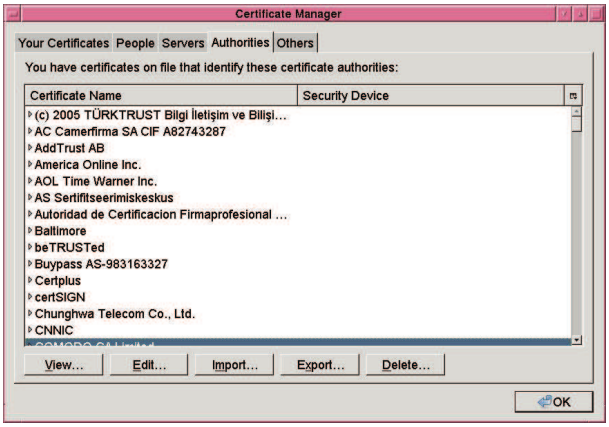
Session Resumption

- **Problem: Public key crypto expensive**
- **New TCP connection, reuse master secret.**
  - Avoids unnecessary public key cryptography.
- **Combines cached master secret with new randomness to generate new session keys.**
- **Works even when the client IP changes (servers cache on session ID, clients cache on server hostname).**

What does CA mean by certificate?

- **That a public key belongs to someone authorized to represent a hostname?**
- **That a public key belongs to someone who is associated in some way with a hostname?**
- **That a public key belongs to someone who has lots of paper trails associated to a company related to a hostname?**
- **That the CA has no liability, or $100,000, or $250,00?**
- **>100-page Certification Practice Statement (CPS)**

So many CAs...



CA Convenience vs. Security

- **How convenient is a Verisign certificate?**
  - Need fee + cooperation from Stanford IT to get one here
  - Good for credit cards, but shuts out many other people
- **How trustworthy is a Verisign certificate?**
  - In mid-March 2001, VeriSign, Inc., advised Microsoft that on January 29 and 30, 2001, it issued two... [fraudulent] certificates.... The common name assigned to both certificates is "Microsoft Corporation."

    VeriSign has revoked the certificates.... However... it is not possible for any browser's CRL-checking mechanism to locate and use the VeriSign CRL.

    – Microsoft Security Bulletin MS01-017

2-minute stretch