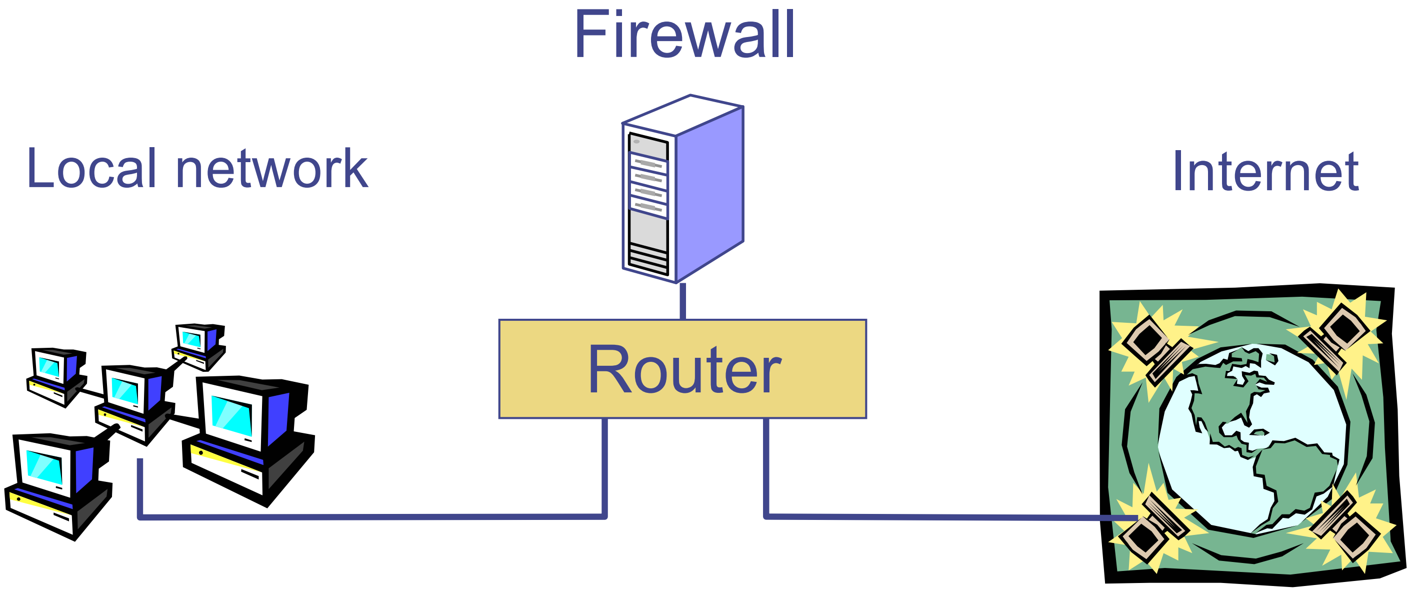
Insecure network services

- **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

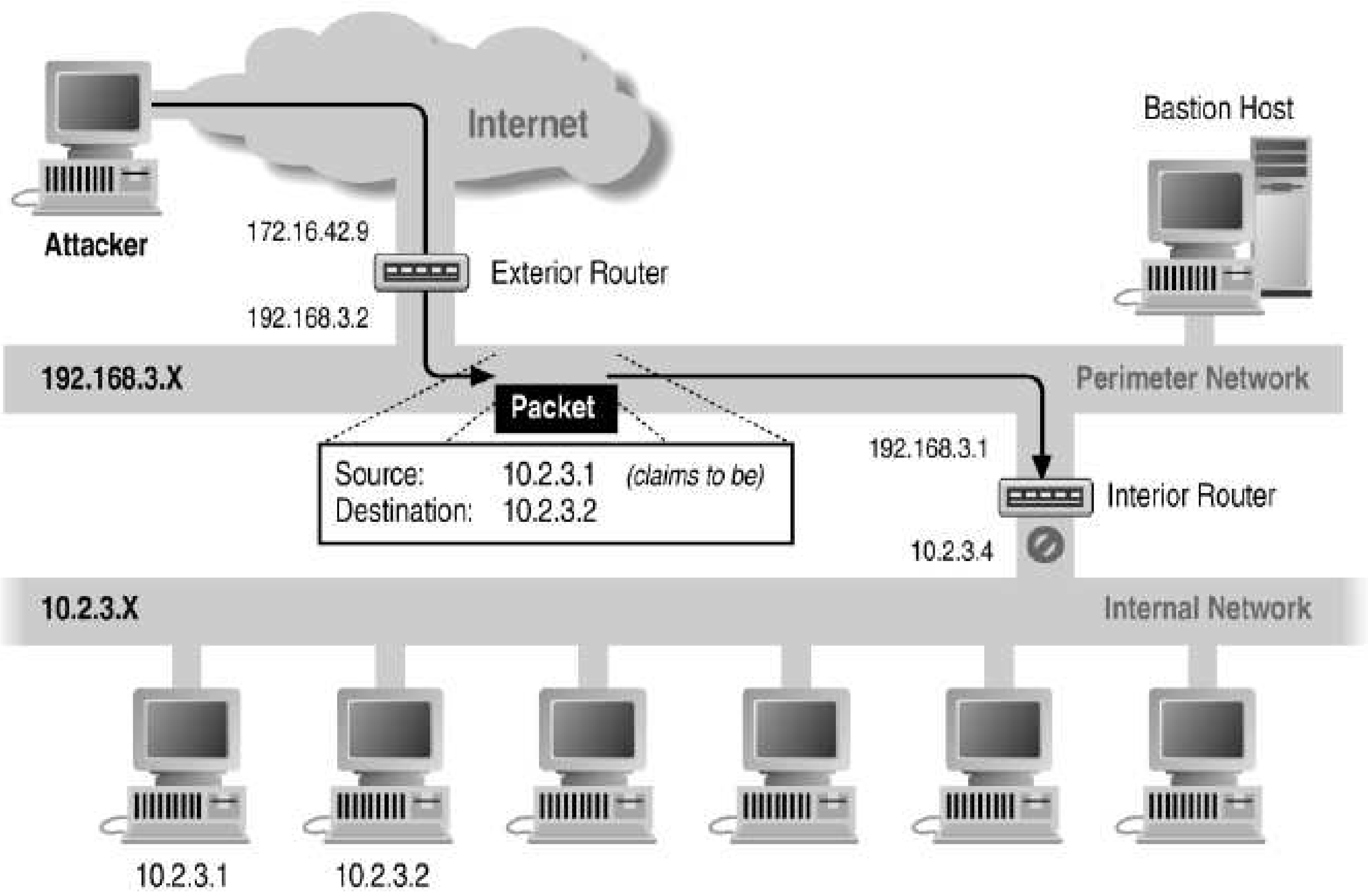
    Proxy for protocols such as ftp, smtp, http, etc.
  - Personal firewall

    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

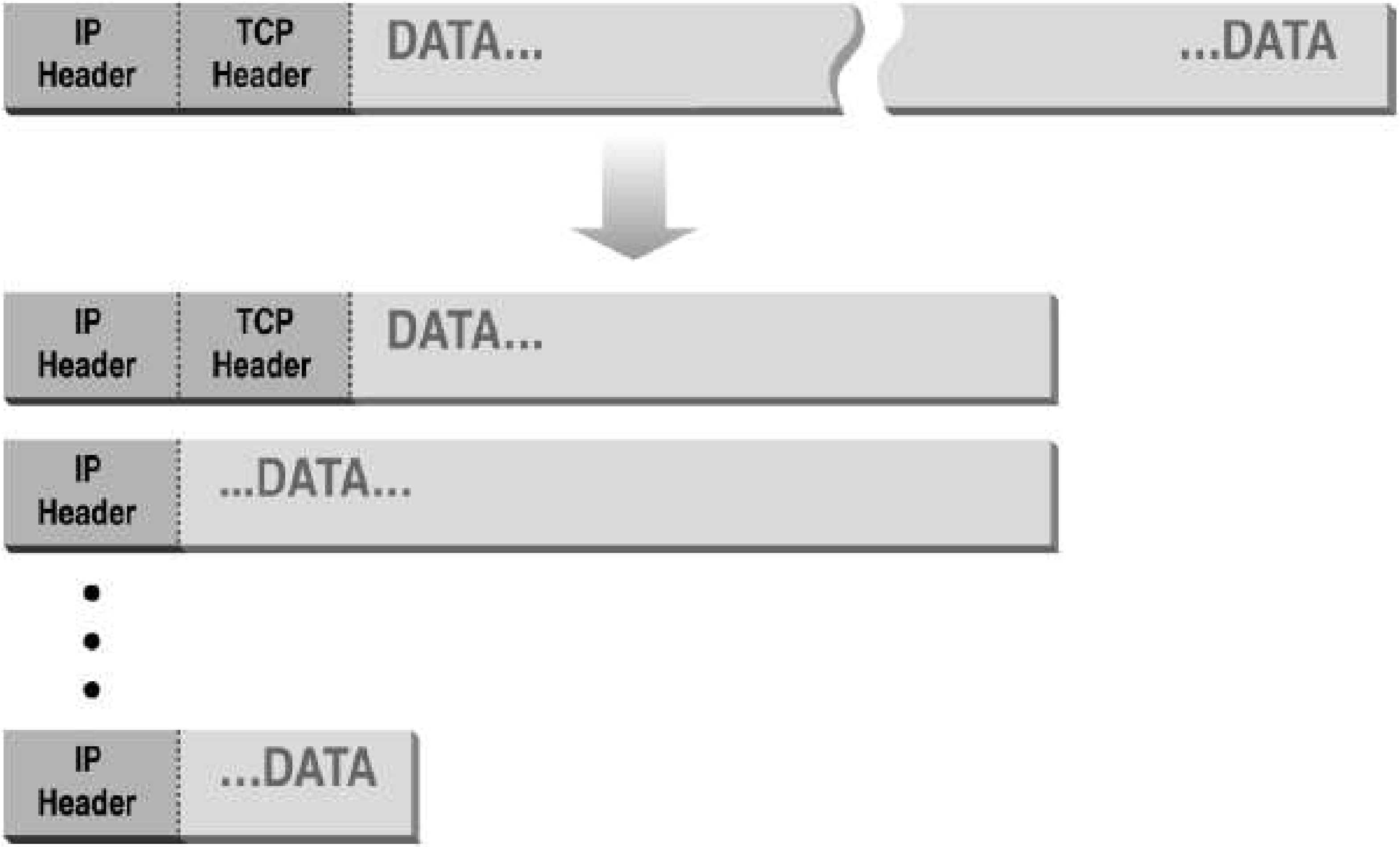
Example: blocking outgoing mail

- **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

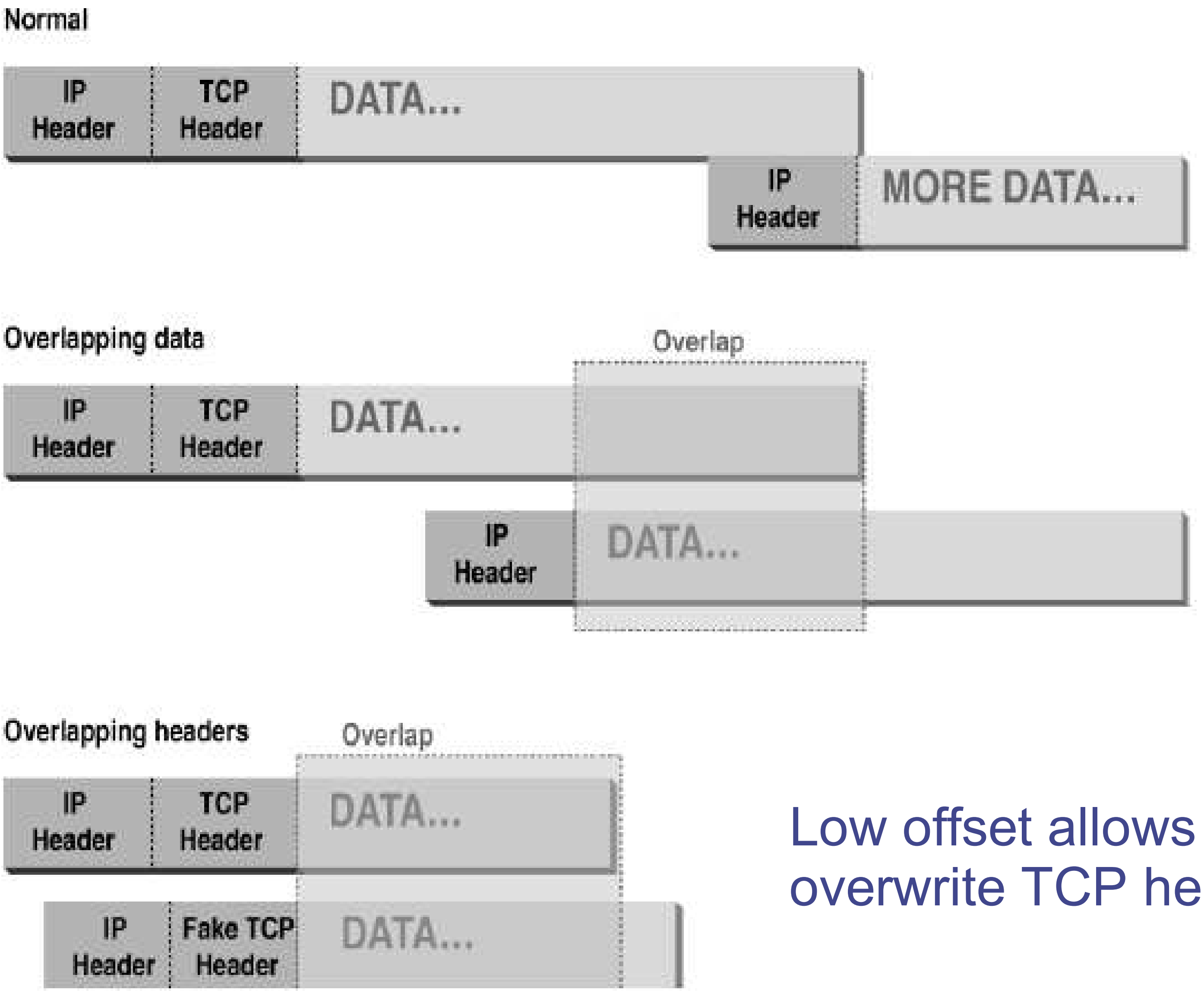
- **Often don't know what people run on their machines**
- **In many environments better to be safe:**
  - Block all incoming TCP connections
  - Explicitly allow incoming connections to particular hosts
    E.g., port 80 on web server, port 25 on mail server, . . .
  - But still must allow *outgoing* 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)**

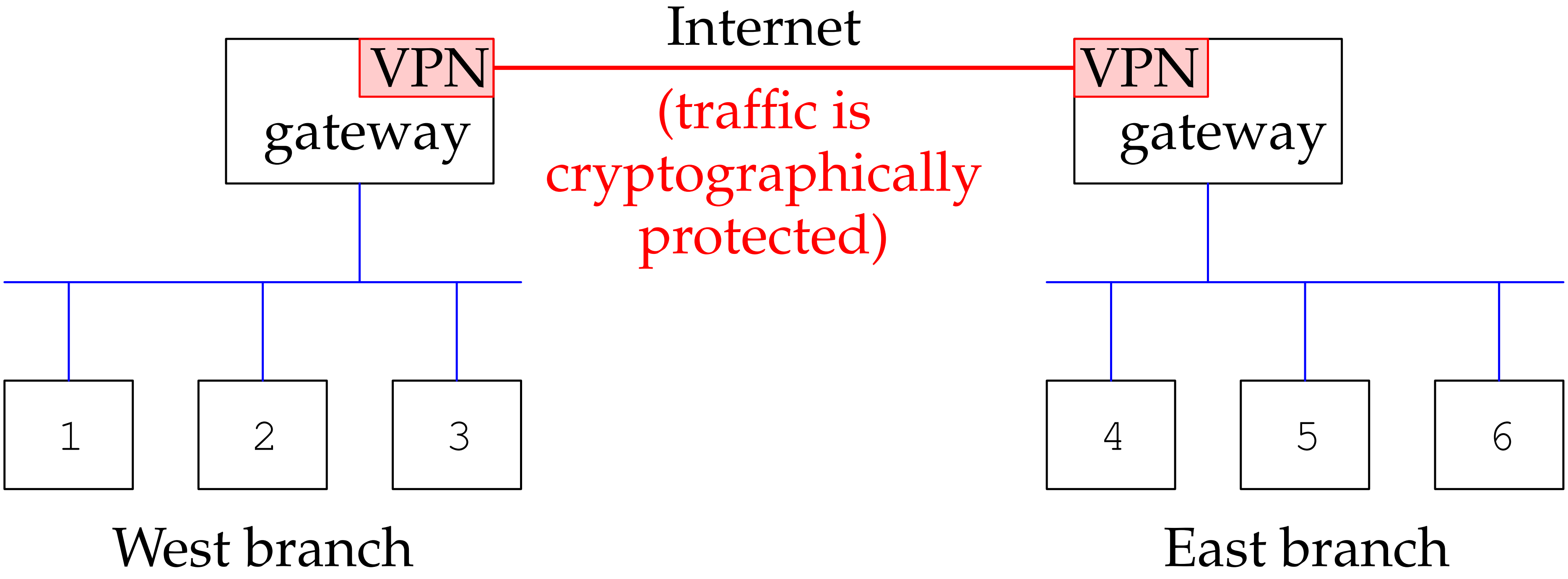
Detect in network monitor

- **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

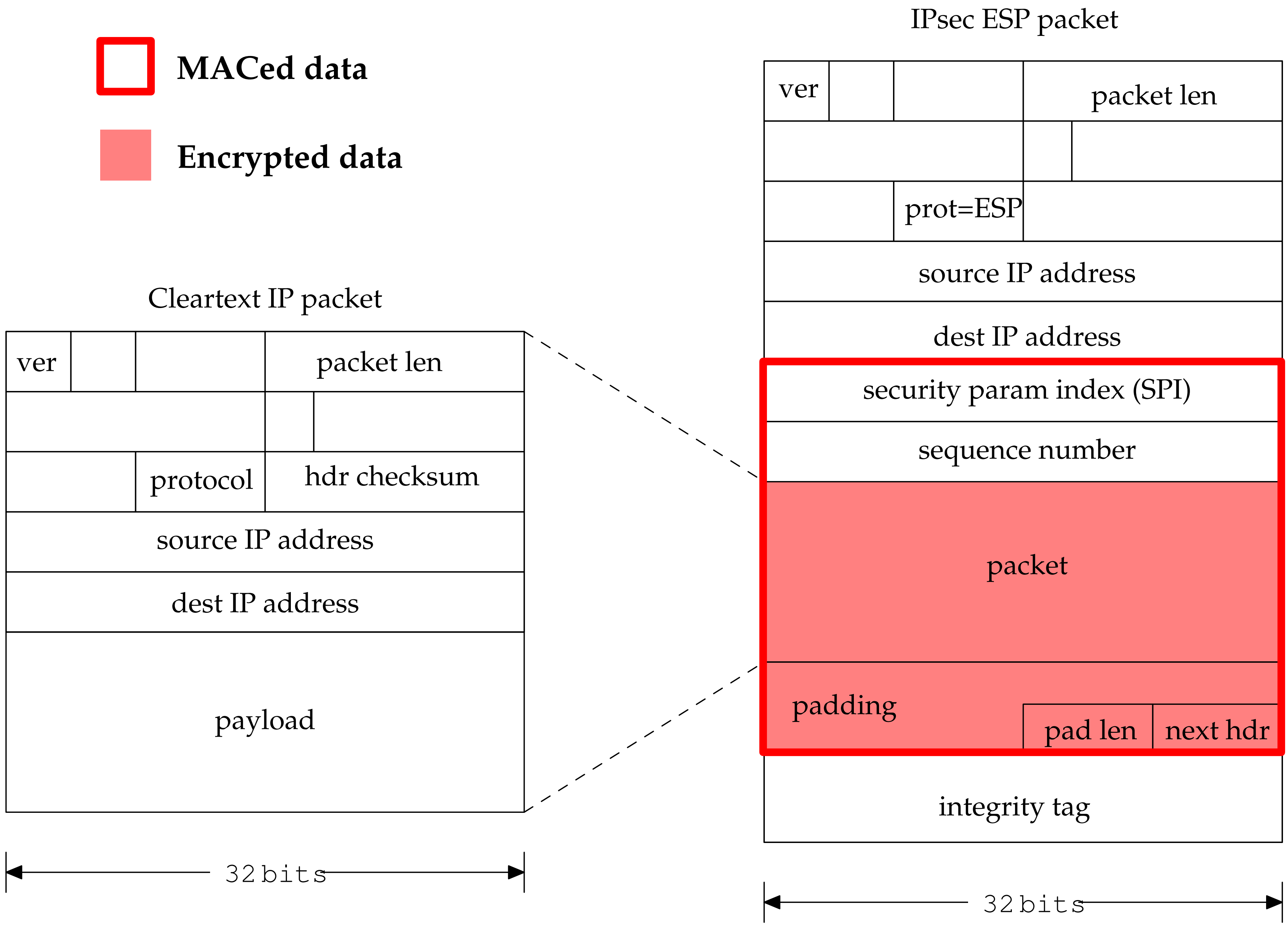
- **May want to block attacks as they are happening**
  - E.g., Stanford can detect your broken software, but can't force you to patch it
  - But if your PC joins a botnet, it's Stanford's problem
  - Best to block attacks as they happen
- **Many attacks require particular fingerprints**
  - E.g., attack 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



□ MACed data

🟥 Encrypted data

Cleartext IP packet

ver | | | packet len

| |

| protocol | hdr checksum

source IP address

dest IP address

payload

32 bits

IPsec ESP packet

ver | | | packet len

| |

| prot=ESP |

source IP address

dest IP address

security param index (SPI)

sequence number

packet

padding | pad len | next hdr

integrity tag

32 bits

ESP high-level view

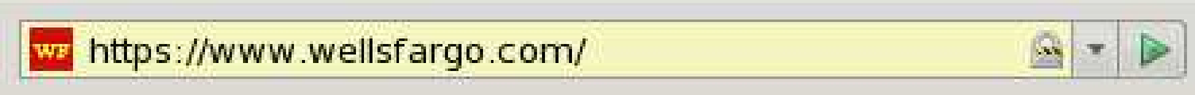
- **Encapsulates one IP packet inside another**
- **Each endpoint has *Security Association DB* (SAD)**
  - Is a table of *Security Associations* (SAs)
  - Each SA has 32-bit *Security Parameters Index* (SPI)
  - Also, source/destination IP addresses, crypto algorithm, keys
- **Packets processed based 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



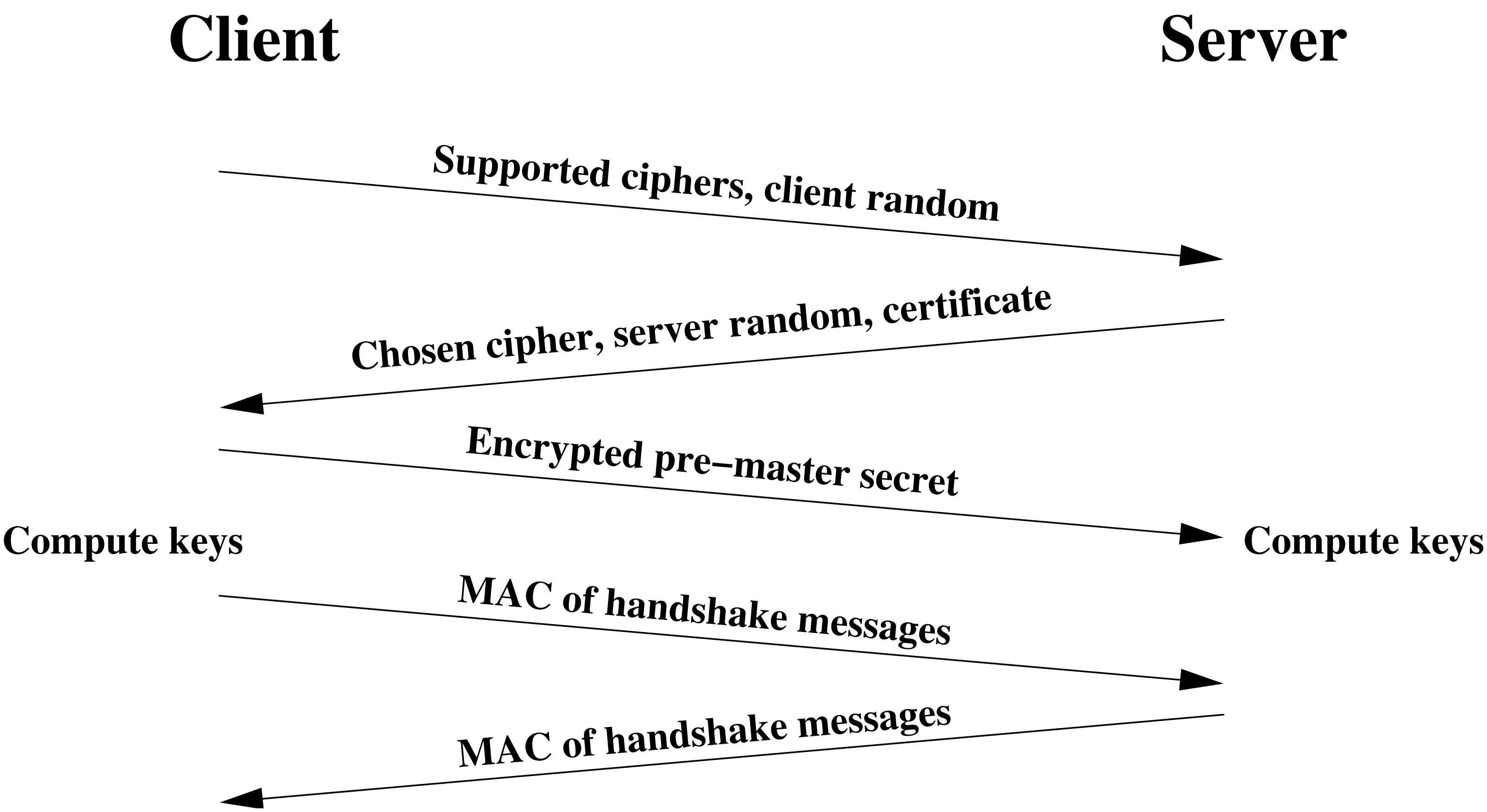
https://www.wellsfargo.com/

- **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



Client

Server

Supported ciphers, client random

Chosen cipher, server random, certificate

Encrypted pre–master secret

Compute keys

Compute keys

MAC of handshake messages

MAC of handshake messages

From “SSL and TLS” by Eric Rescorla

SSL Handshake

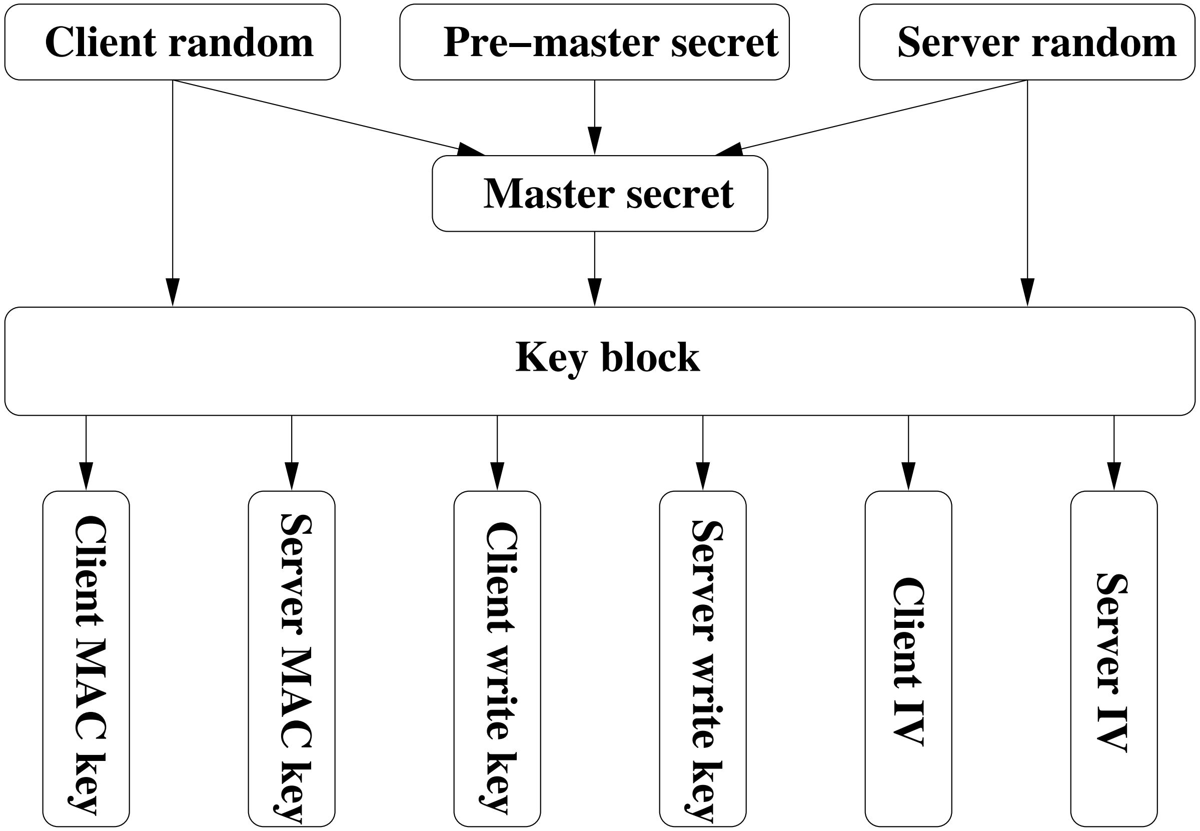
- **Client and server negotiate on cipher selection**
- **Cooperatively establish session keys**
- **Use session keys for secure communication**
- **Details**
  - Multiple messages per stage
  - Get an idea of protocol in action:

    ```
    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

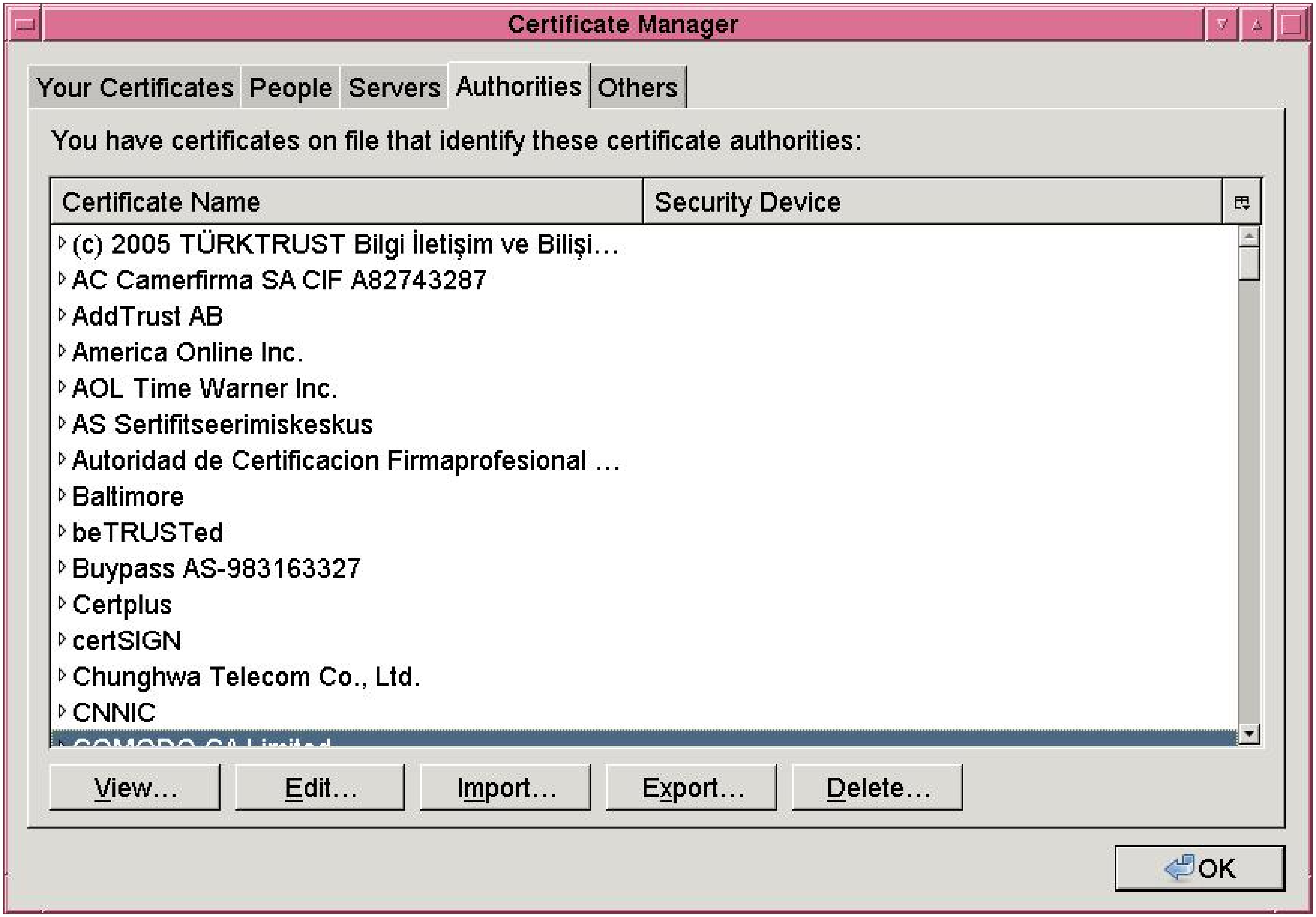
Session Resumption

- **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…



You have certificates on file that identify these certificate authorities:

Certificate Name	Security Device
(c) 2005 TÜRKTRUST Bilgi İletişim ve Bilişi…	
AC Camerfirma SA CIF A82743287	
AddTrust AB	
America Online Inc.	
AOL Time Warner Inc.	
AS Sertifitseerimiskeskus	
Autoridad de Certificacion Firmaprofesional …	
Baltimore	
beTRUSTed	
Buypass AS-983163327	
Certplus	
certSIGN	
Chunghwa Telecom Co., Ltd.	
CNNIC	
COMODO CA Limited	

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