CSE 484 and CSE M 584 (Winter 2009)

Symmetric Encryption & Authentication + Networks

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Thanks to Dan Boneh, Dieter Gollmann, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

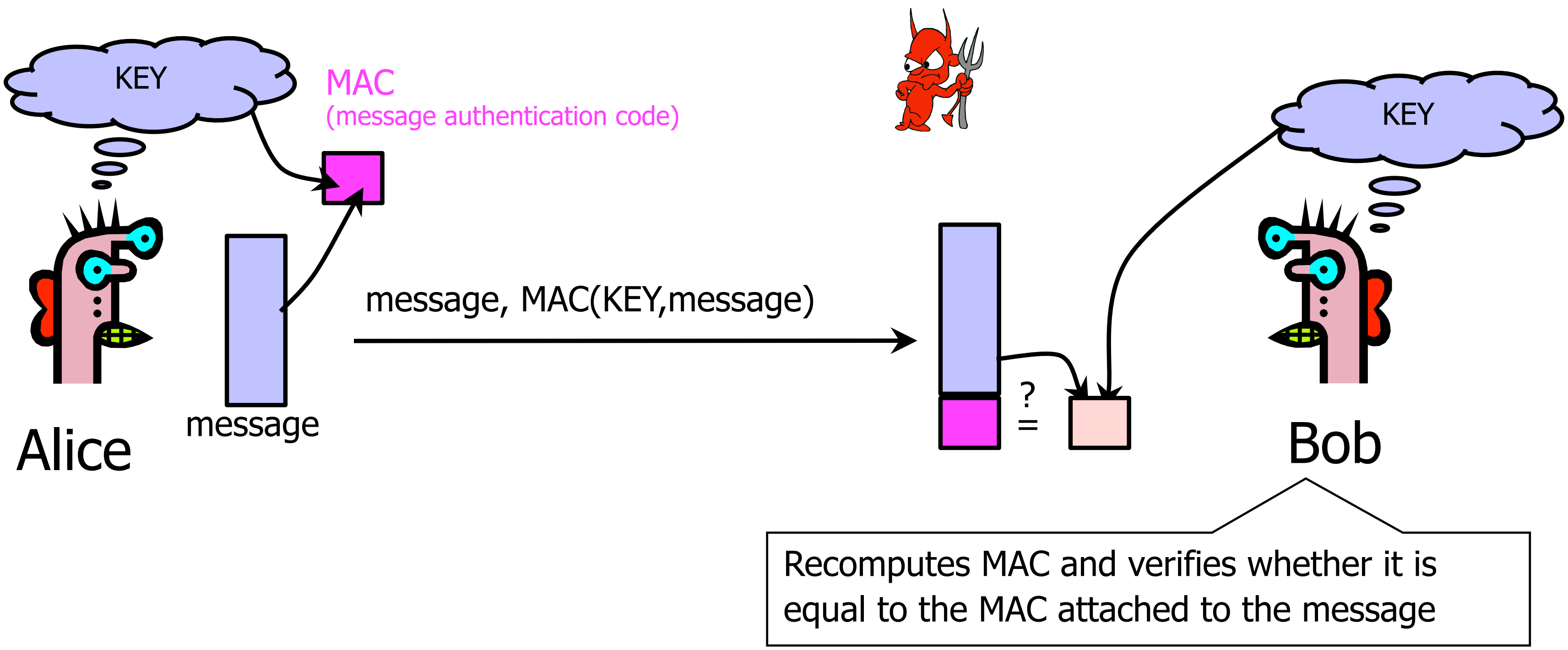
Goals for Today

- Lab 2
- Homework 2 out shortly (will also be short)
- Grading

Goals for Today

- Finish symmetric crypto
- Network Security Attacks
  - Routing
  - IP
  - TCP
  - DNS
- Key points:
  - Failures at interaction between layers
  - Asymmetry between attacker and defender
  - Some attacks designers never considered
  - All motivations for existing security decisions (SSL/TLS, filter certain types of packets, check inputs, etc).

Authentication Without Encryption



Integrity and authentication: only someone who knows KEY can compute MAC for a given message

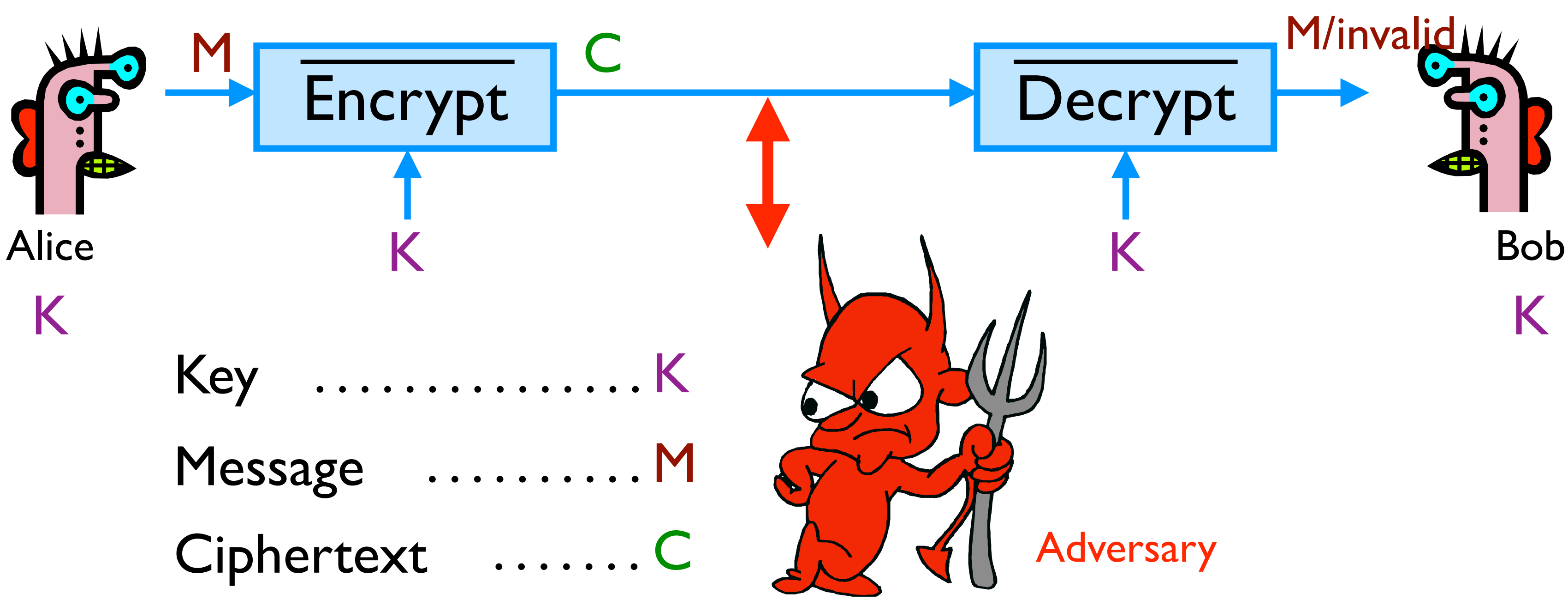
CBC-MAC (whiteboard)

- Design
- Attack:
  - Arbitrary Length Messages
  - Possibly: Encode length at end

Achieving Both Privacy and Integrity

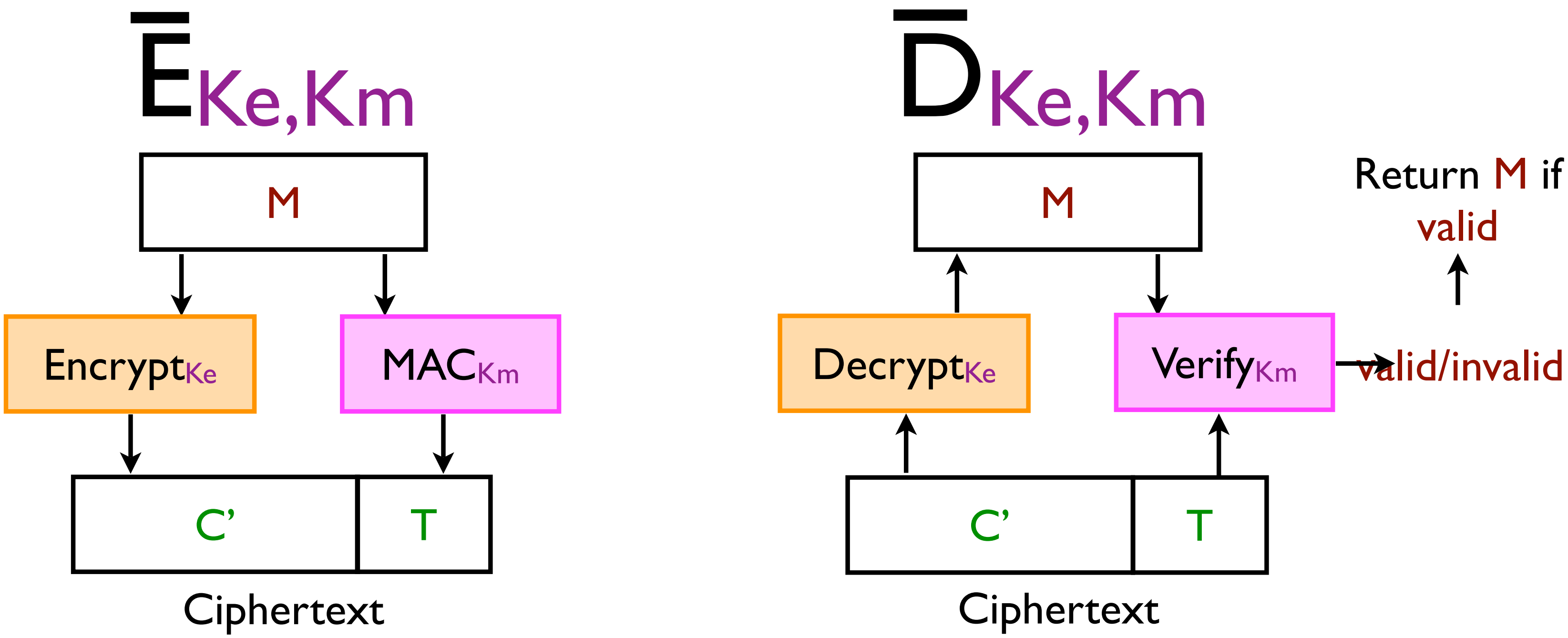
Authenticated encryption scheme

Recall: Often desire both privacy and integrity. (For SSH, SSL, IPsec, etc.)



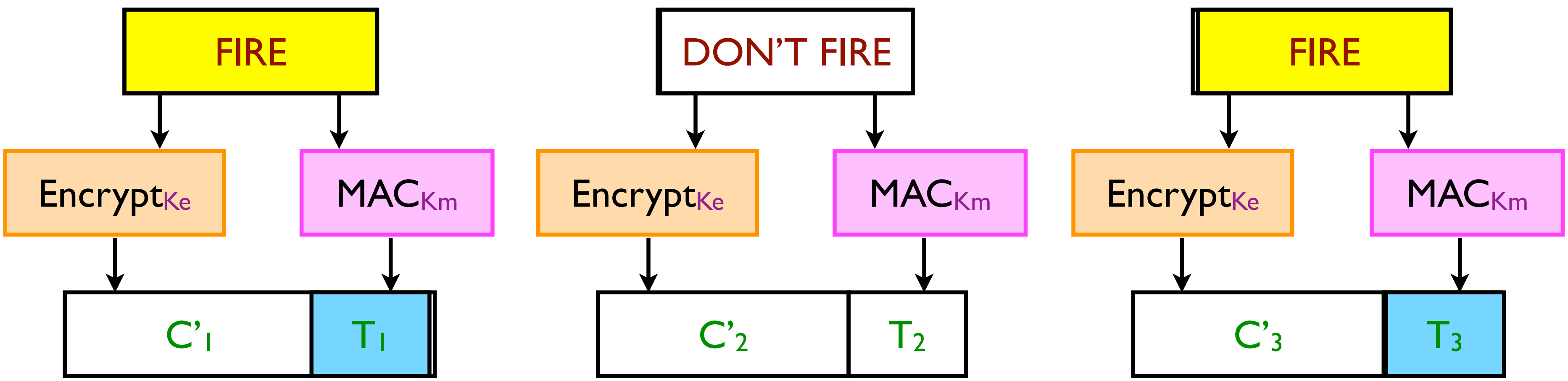
Some subtleties! Encrypt-and-MAC

Natural approach for authenticated encryption: Combine an encryption scheme and a MAC.



But insecure! [BN, Kra]

Assume Alice sends messages:



If $T_i = T_j$ then $M_i = M_j$

Adversary learns whether two plaintexts are equal.

Especially problematic when $M_1, M_2, \ldots$ take on only a small number of possible values.

The Secure Shell (SSH) protocol is designed to provide:

- Secure remote logins.
- Secure file transfers.

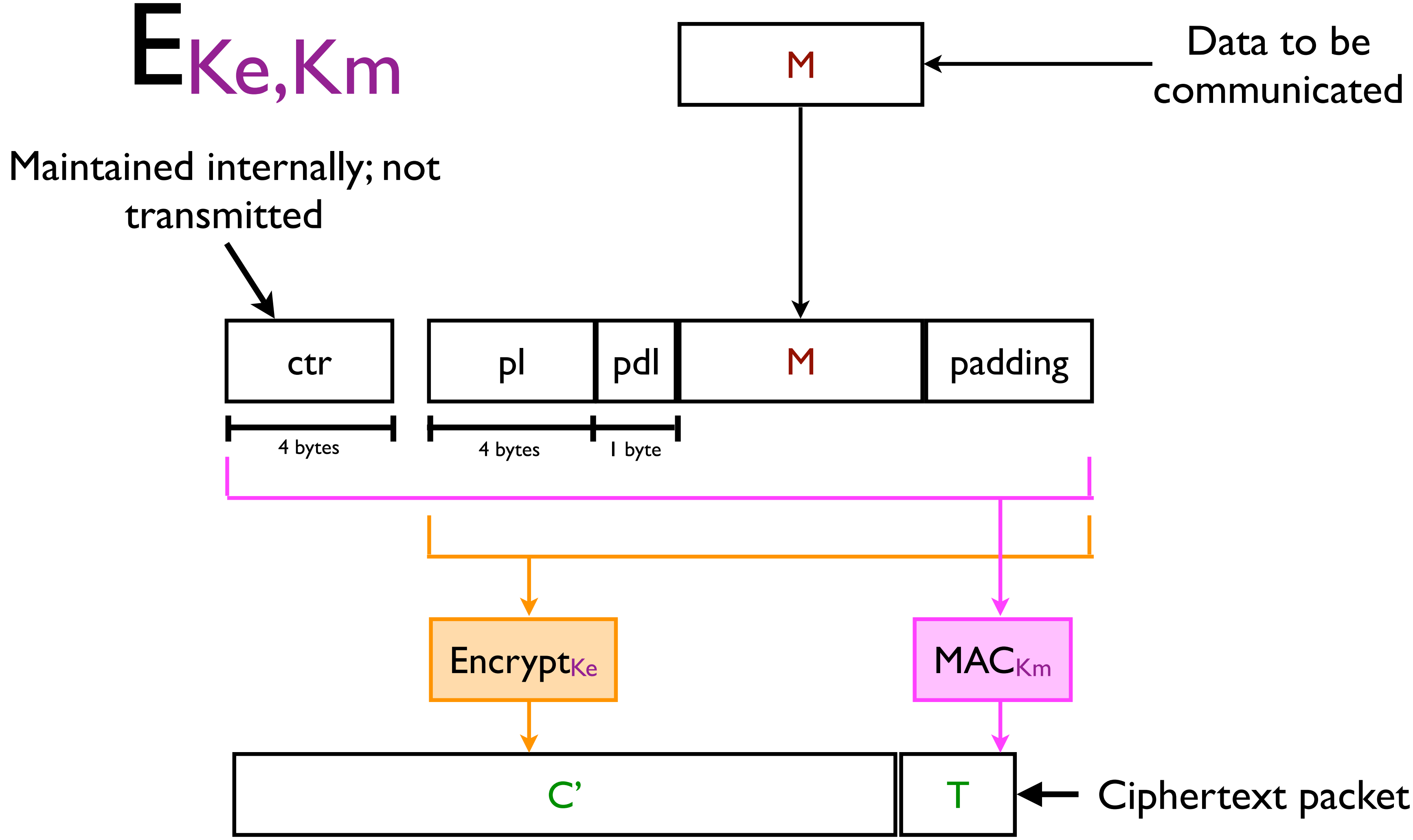
Where security includes:

- Protecting the privacy of users' data.
- Protecting the integrity of users' data.

OpenSSH is included in the default installations of OS X and many Linux distributions.

Authenticated encryption in SSH

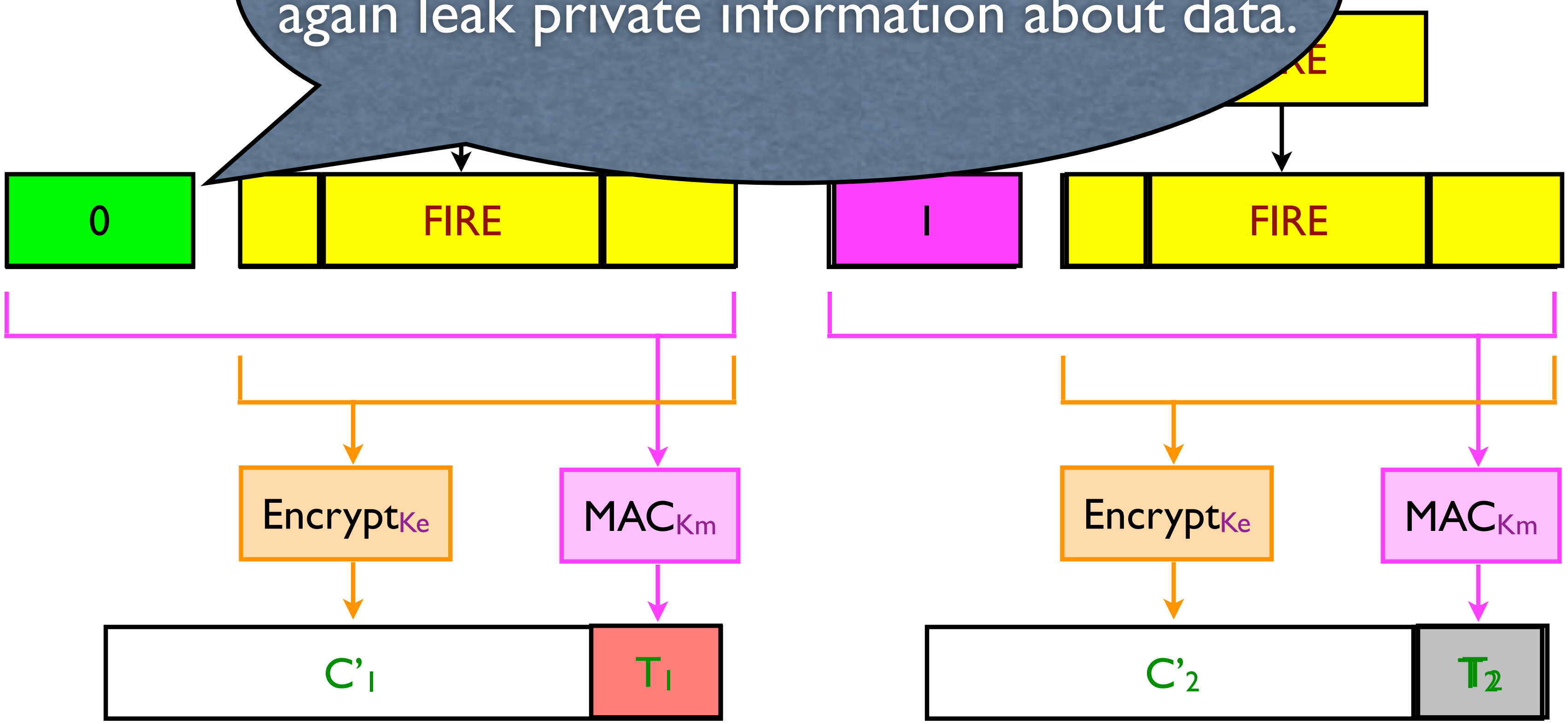
$\bar{E}_{Ke,Km}$



What's different about SSH?

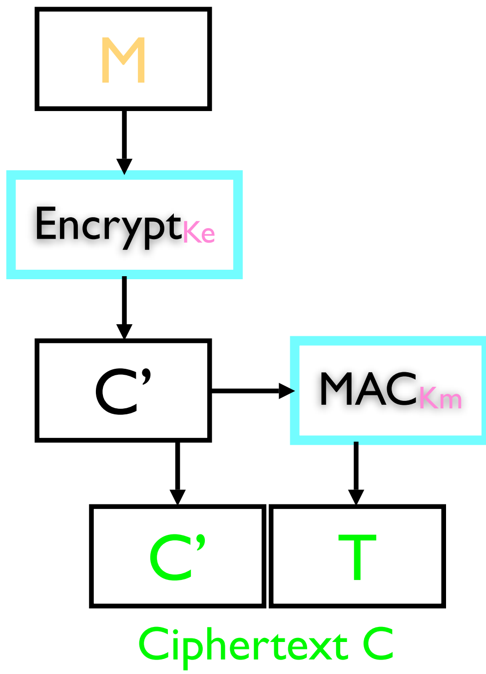
Assume Al … me.

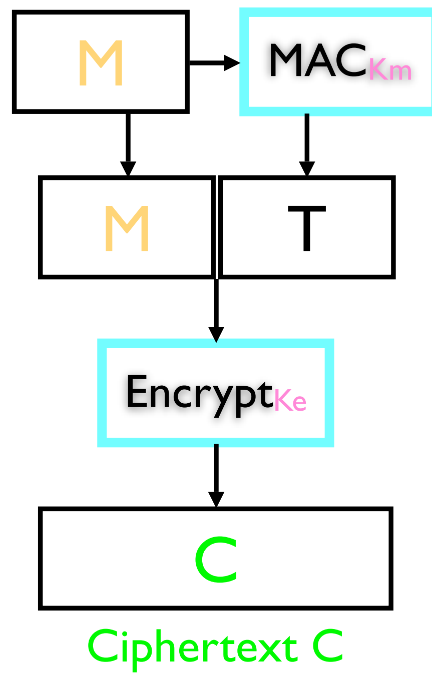
But if counters repeat, tags may once again leak private information about data.

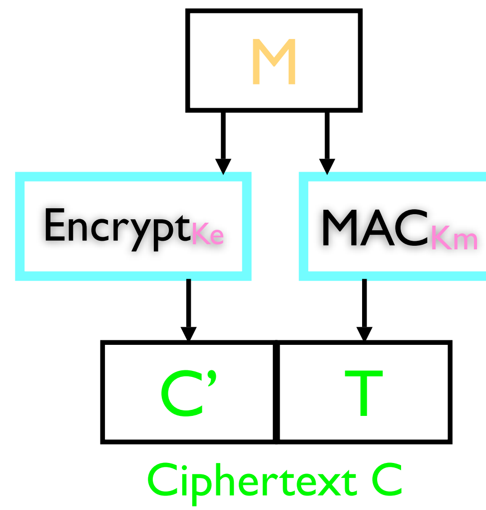


Then the tags T_1 and T_2 will be different with high probability.

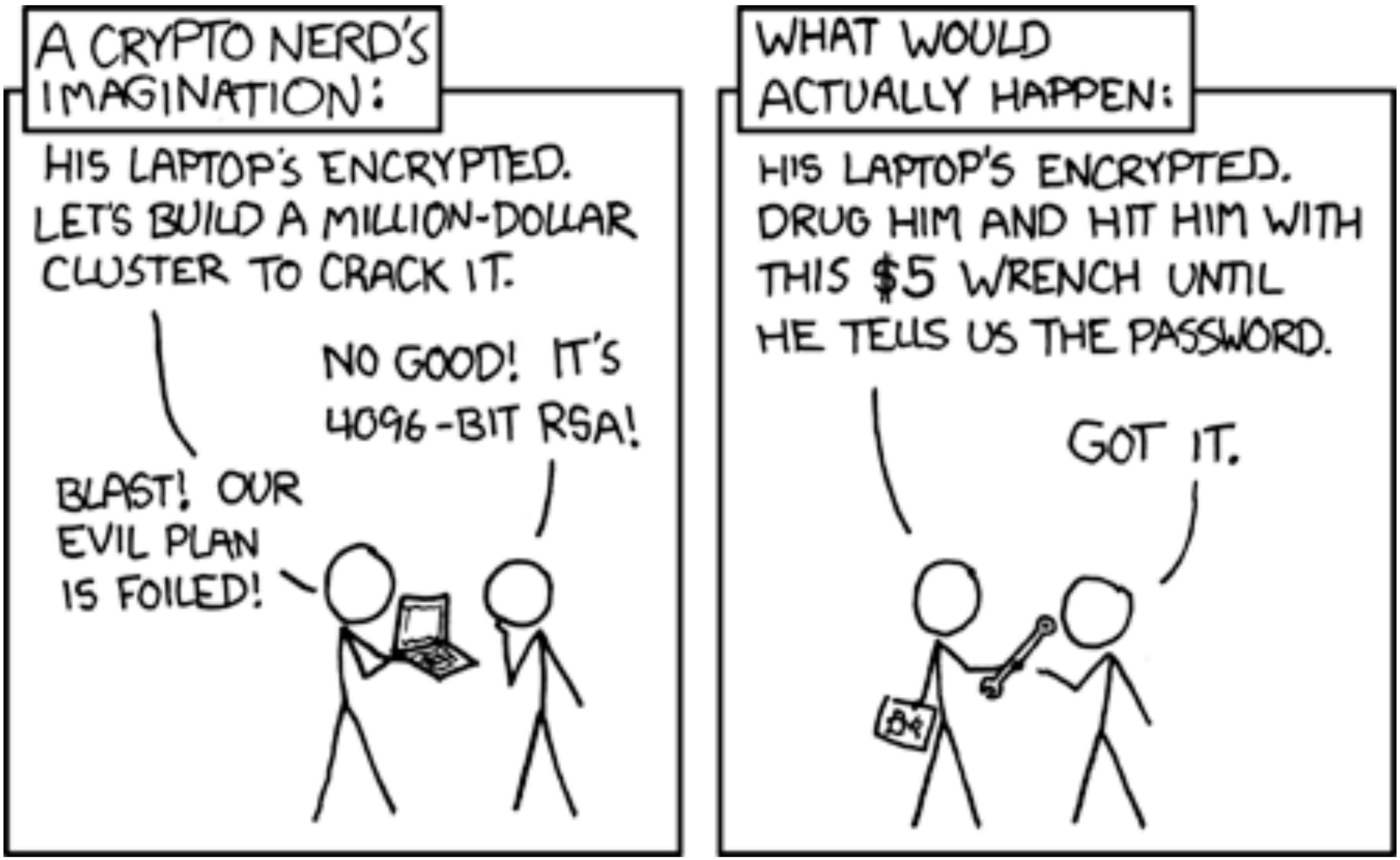
Results of [BN00,Kra01]



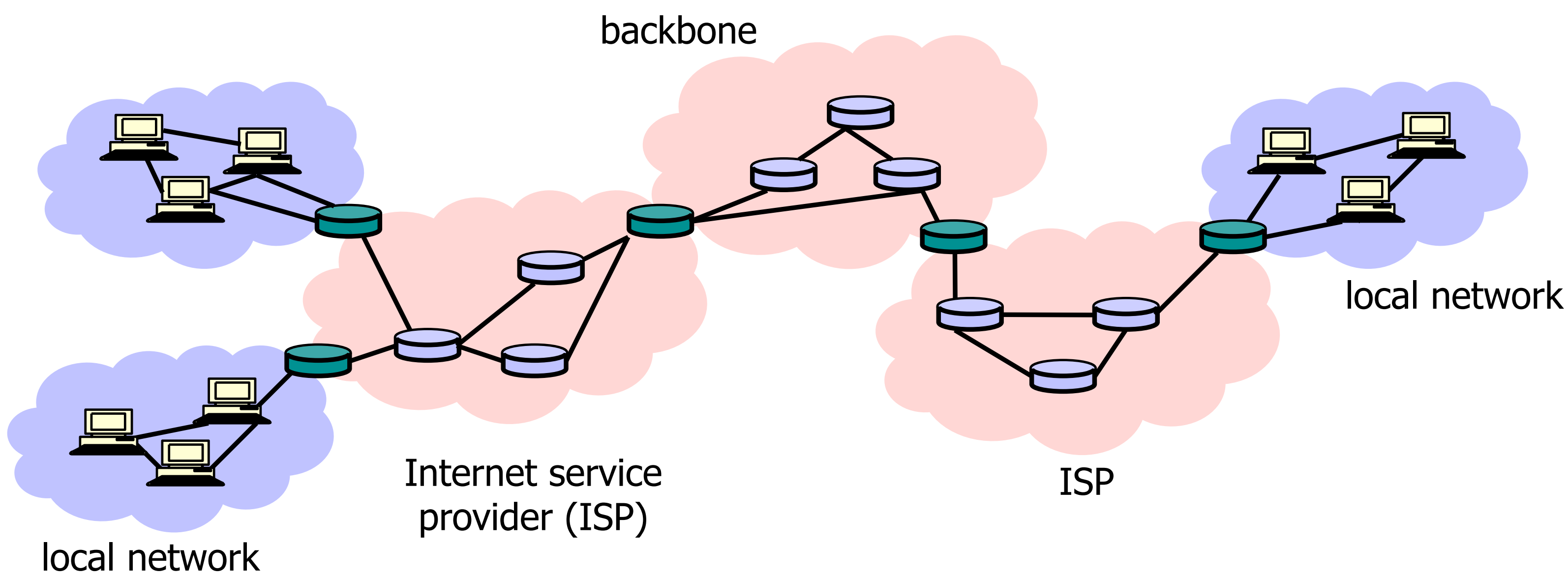




	Encrypt-then-MAC	MAC-then-Encrypt	Encrypt-and-MAC
Privacy	Strong (CCA)	Weak (CPA)	Insecure
Integrity	Strong (CTXT)	Weak (PTXT)	Weak (PTXT)

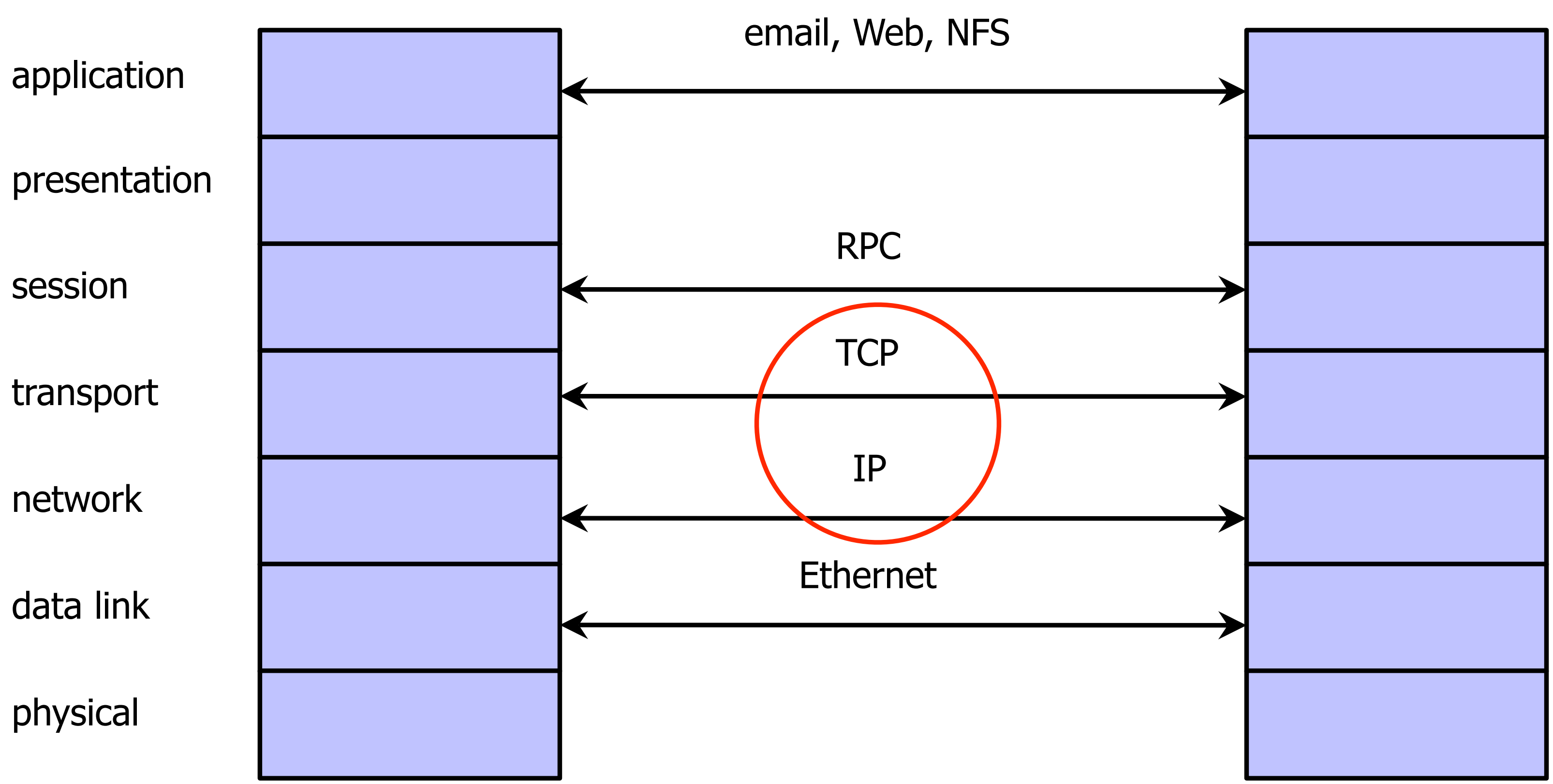

A CRYPTO NERD'S IMAGINATION:
HIS LAPTOP'S ENCRYPTED. LET'S BUILD A MILLION-DOLLAR CLUSTER TO CRACK IT.
NO GOOD! IT'S 4096-BIT RSA!
BLAST! OUR EVIL PLAN IS FOILED!
WHAT WOULD ACTUALLY HAPPEN:
HIS LAPTOP'S ENCRYPTED. DRUG HIM AND HIT HIM WITH THIS $5 WRENCH UNTIL HE TELLS US THE PASSWORD.
GOT IT.

Internet Infrastructure

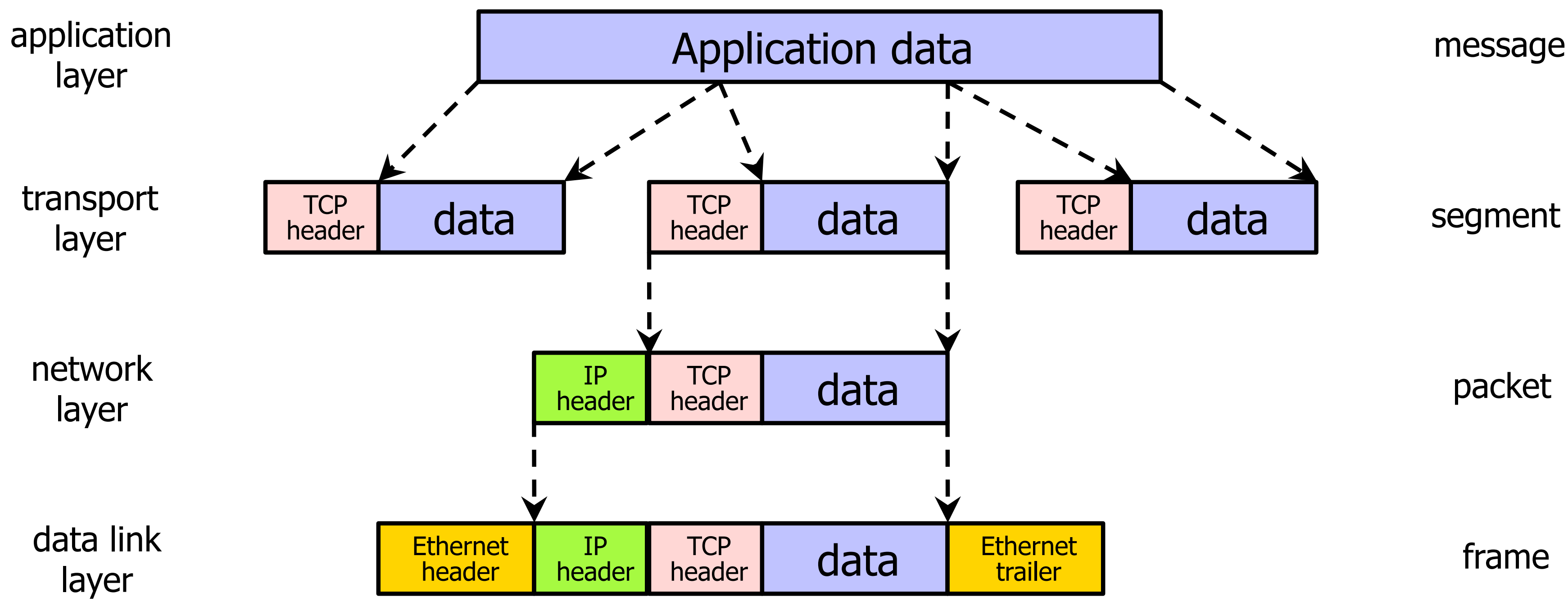


- TCP/IP for packet routing and connections
- Border Gateway Protocol (BGP) for route discovery
- Domain Name System (DNS) for IP address discovery

OSI Protocol Stack

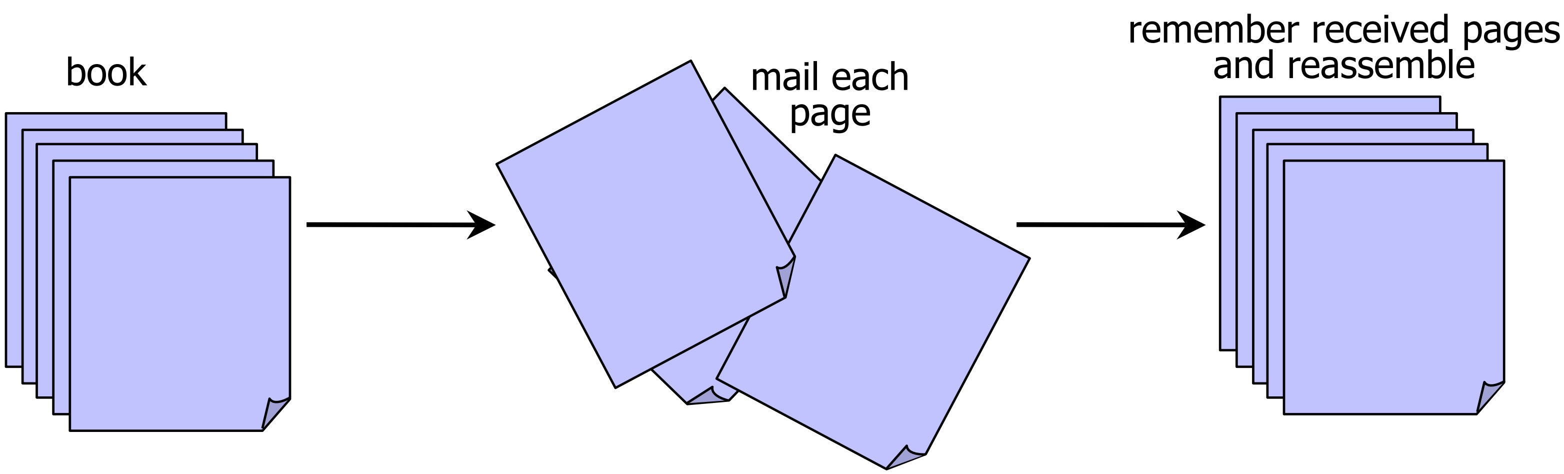


Data Formats



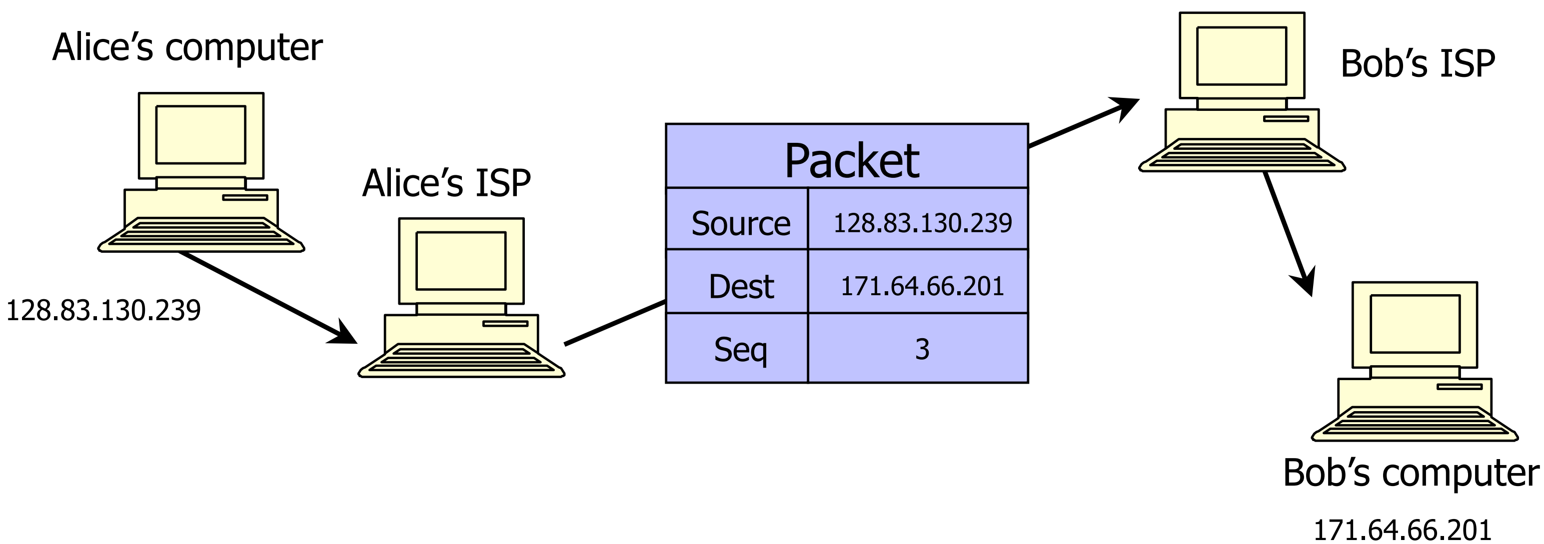
TCP (Transmission Control Protocol)

- Sender: break data into packets
  - Sequence number is attached to every packet
- Receiver: reassemble packets in correct order
  - Acknowledge receipt; lost packets are re-sent
- Connection state maintained on both sides



IP (Internet Protocol)

- Connectionless
  - Unreliable, “best-effort” protocol
- Uses numeric addresses for routing
  - Typically several hops in the route



IP Routing

- Routing of IP packets is based on IP addresses
- Routers use a forwarding table
  - Entry = destination, next hop, network interface, metric
  - For each packet, a table look-up is performed to determine how to route it
- Routing information exchange allows update of old routes and creation of new ones
  - RIP (Routing Information Protocol)
  - OSPF (Open Shortest Path First Protocol)
  - BGP (Border Gateway Protocol)

BGP Misconfiguration

- Domain advertises good routes to addresses it does not known how to reach
  - Result: packets go into a network “black hole”
- April 25, 1997: “The day the Internet died”
  - AS7007 (Florida Internet Exchange) de-aggregated the BGP route table and re-advertised all prefixes as if it originated paths to them
  - In effect, AS7007 was advertising that it has the best route to <u>every</u> host on the Internet
  - Huge network instability as incorrect routing data propagated and routers crashed under traffic

1873
diggs

digg it

YouTube hijacked by Pakistan, caused global outage!

blogs.zdnet.com — YouTube has been blocked by Pakistan's government because it contained “blasphemous content, videos and documents". Shortly after, Pakistan shutdown YouTube globally by (possibly accidentally) hijacking their IP space via BGP!

ICMP (Control Message Protocol)

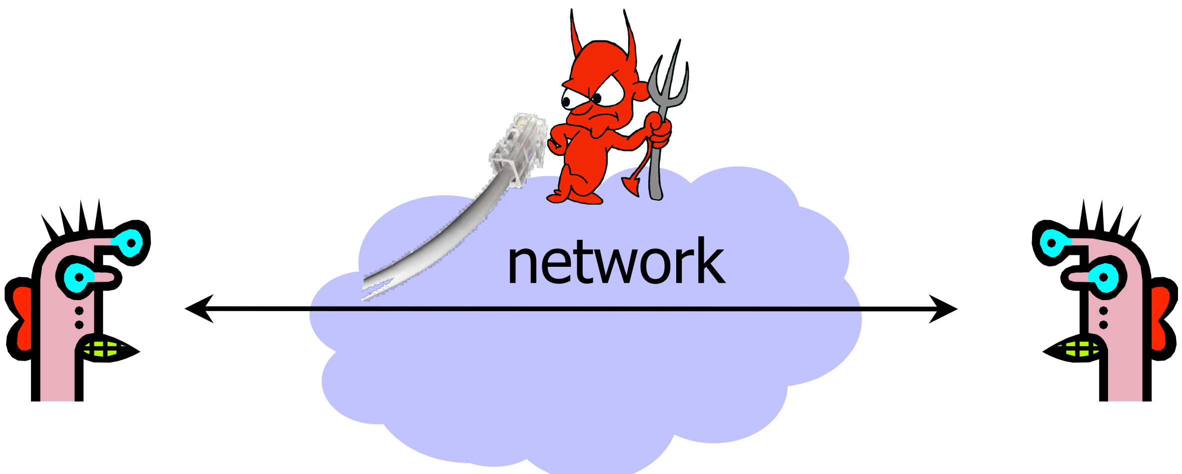
- Provides feedback about network operation
  - "Out-of-band" messages carried in IP packets
  - Error reporting, congestion control, reachability, etc.
- Example messages:
  - Destination unreachable
  - Time exceeded
  - Parameter problem
  - Redirect to better gateway
  - Reachability test (echo / echo reply)
  - Message transit delay (timestamp request / reply)

Security Issues in TCP/IP

- Network packets pass by untrusted hosts
  - Eavesdropping (packet sniffing)
- IP addresses are public
  - Smurf attacks
- TCP connection requires state
  - SYN flooding
- TCP state is easy to guess
  - TCP spoofing and connection hijacking

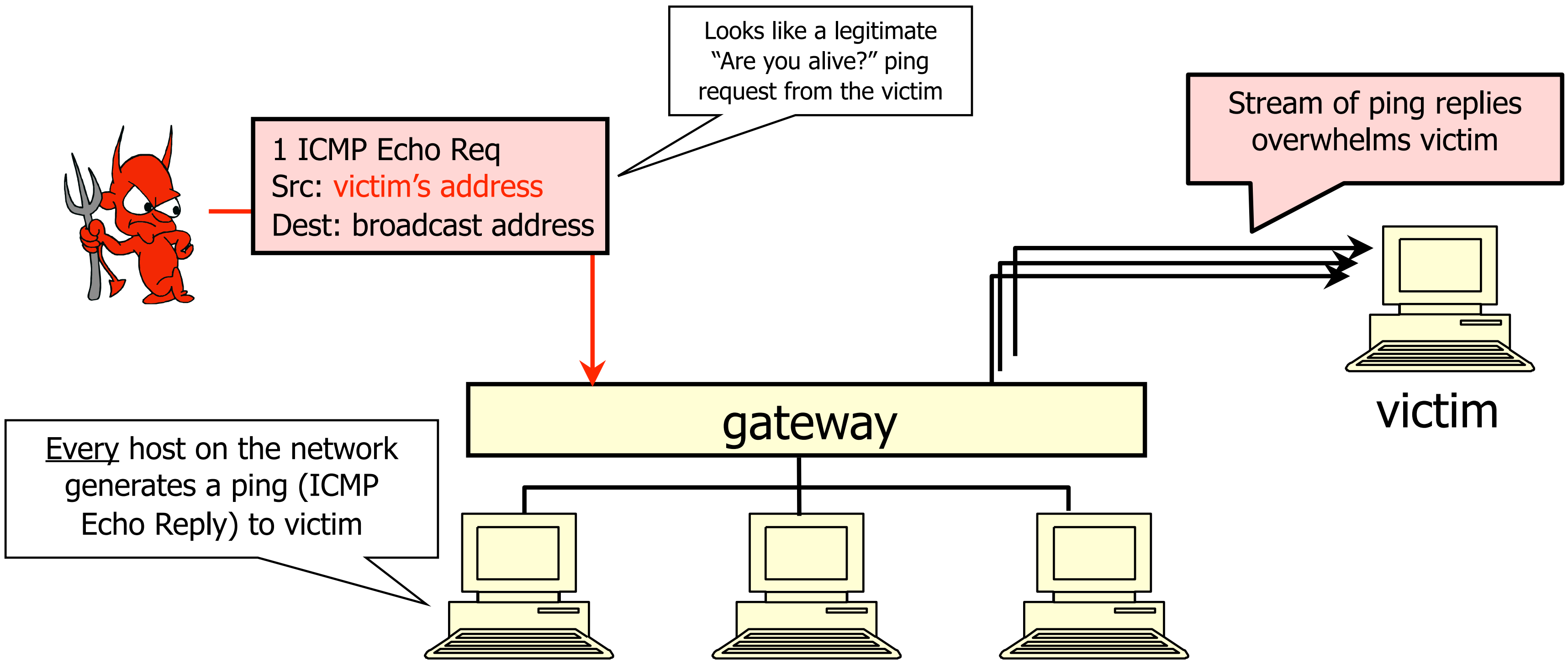
Packet Sniffing

- Many applications send data unencrypted
  - ftp, telnet send passwords in the clear
- Network interface card (NIC) in "promiscuous mode" reads all passing data



Solution: encryption (e.g., IPSec), improved routing

Smurf Attack



Solution: reject external packets to broadcast addresses

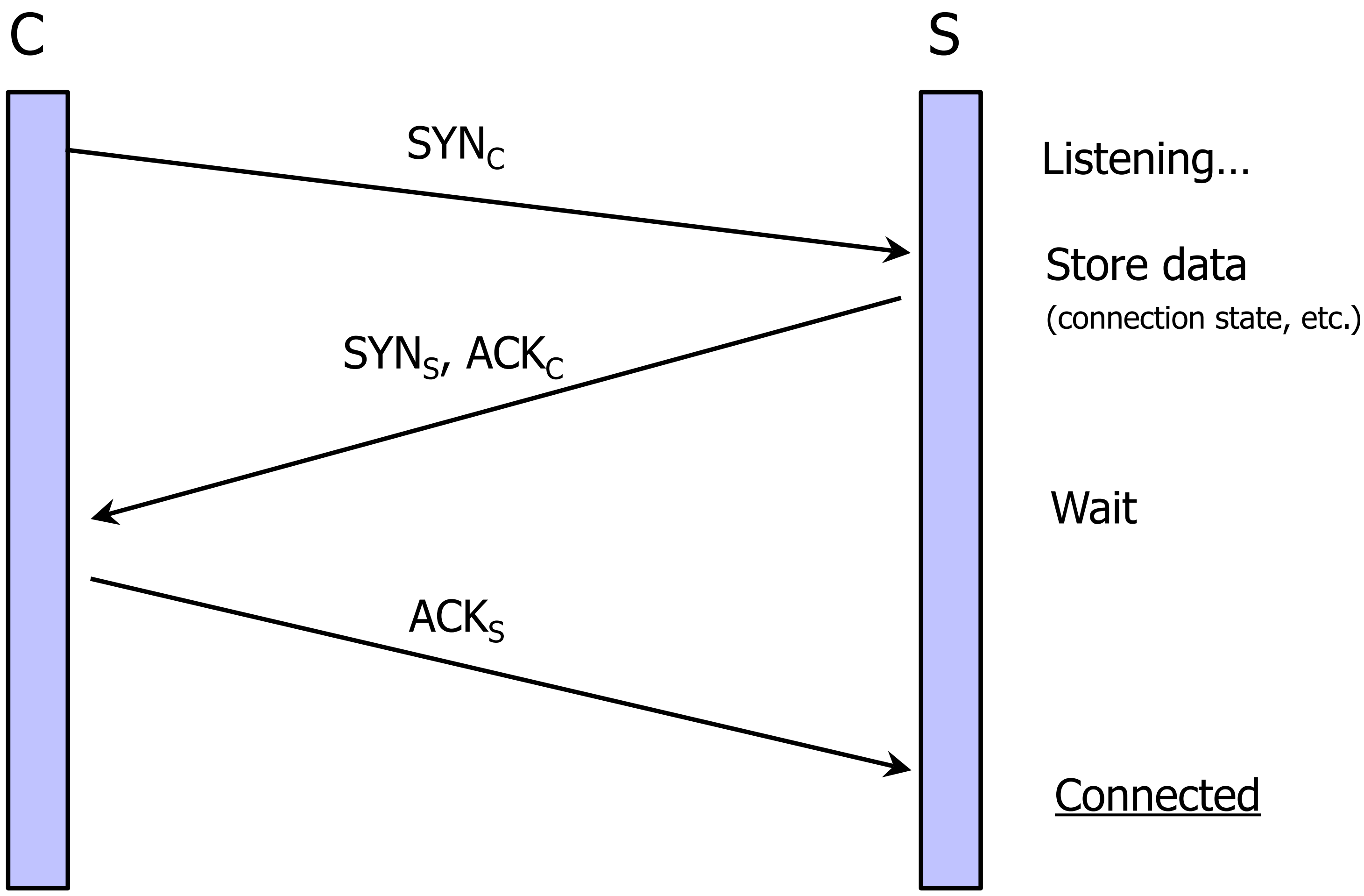
"Ping of Death"

- If an old Windows machine received an ICMP packet with a payload longer than 64K, machine would crash or reboot
  - Programming error in older versions of Windows
  - Packets of this length are illegal, so programmers of Windows code did not account for them

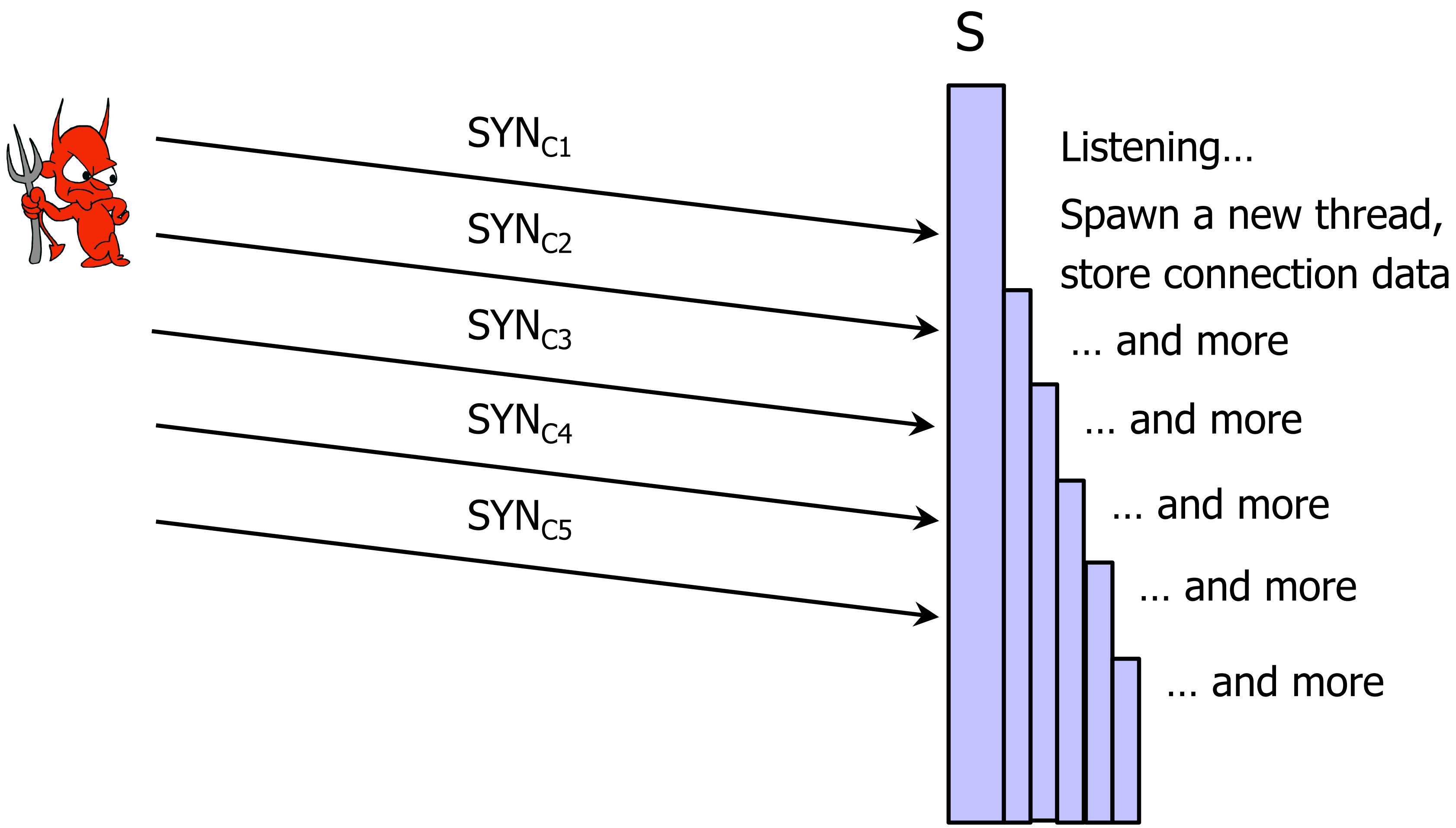
- Recall "security theme" of this course - every line of code might be the target of an adversary

Solution: patch OS, filter out ICMP packets

TCP Handshake



SYN Flooding Attack



SYN Flooding Explained

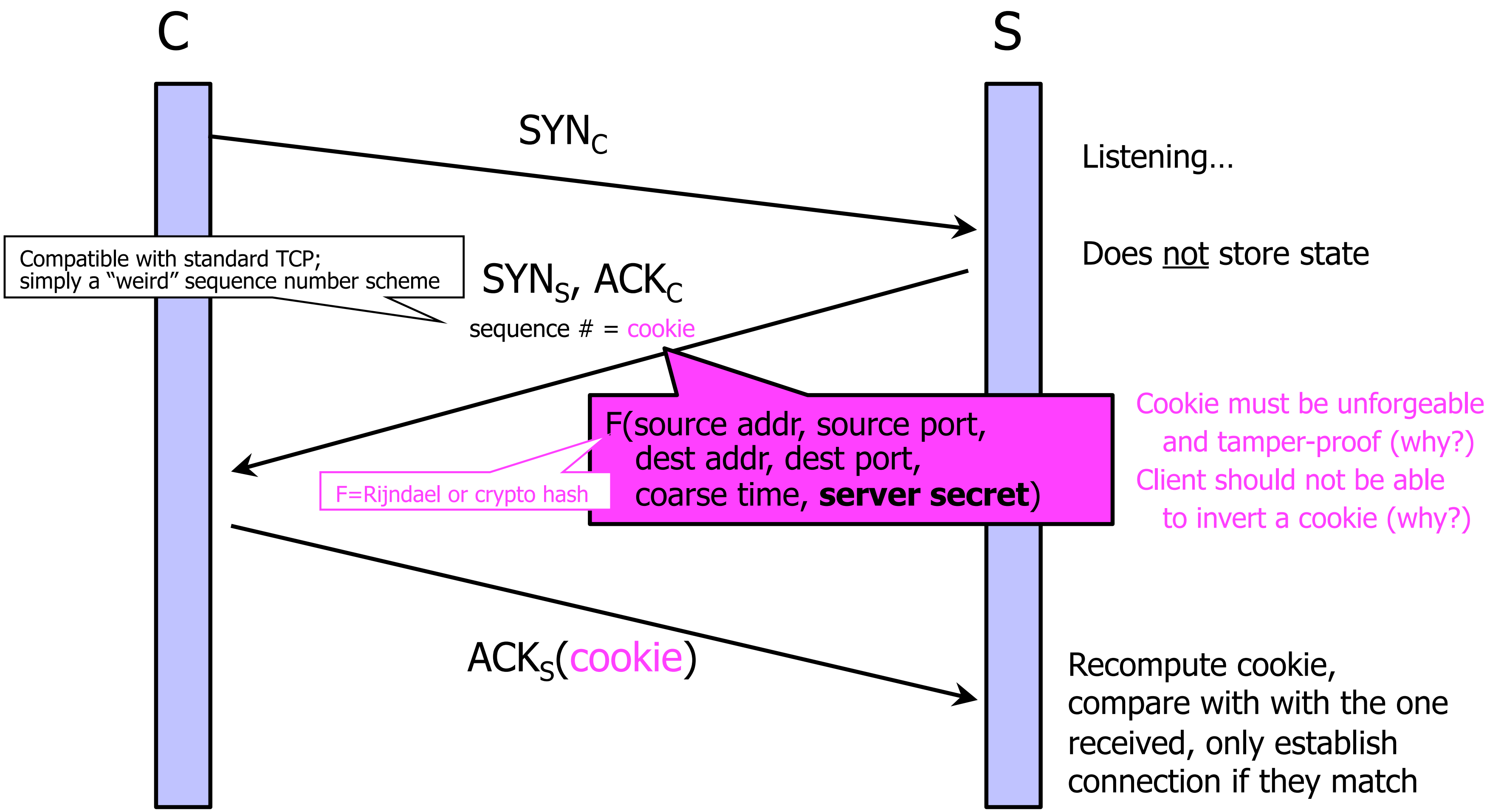
- Attacker sends many connection requests with spoofed source addresses
- Victim allocates resources for each request
  - Connection state maintained until timeout
  - Fixed bound on half-open connections
- Once resources exhausted, requests from legitimate clients are denied
- This is a classic denial of service (DoS) attack
  - Common pattern: it costs nothing to TCP initiator to send a connection request, but TCP responder must allocate state for each request (asymmetry!)

Preventing Denial of Service

- DoS is caused by asymmetric state allocation
  - If responder opens a state for each connection attempt, attacker can initiate thousands of connections from bogus or forged IP addresses
- Cookies ensure that the responder is stateless until initiator produced at least 2 messages
  - Responder's state (IP addresses and ports of the connection) is stored in a cookie and sent to initiator
  - After initiator responds, cookie is regenerated and compared with the cookie returned by the initiator

SYN Cookies

[Bernstein and Schenk]



More info: http://cr.yp.to/syncookies.html

Anti-Spoofing Cookies: Basic Pattern

- Client sends request (message #1) to server
- Typical protocol:
  - Server sets up connection, responds with message #2
  - Client may complete session or not (potential DoS)
- Cookie version:
  - Server responds with hashed connection data instead of message #2
  - Client confirms by returning hashed data
    - If source IP address is bogus, attacker can't confirm
  - Need an extra step to send postponed message #2, <u>except</u> in TCP (SYN-ACK already there)

Another Defense: Random Deletion

SYN_C

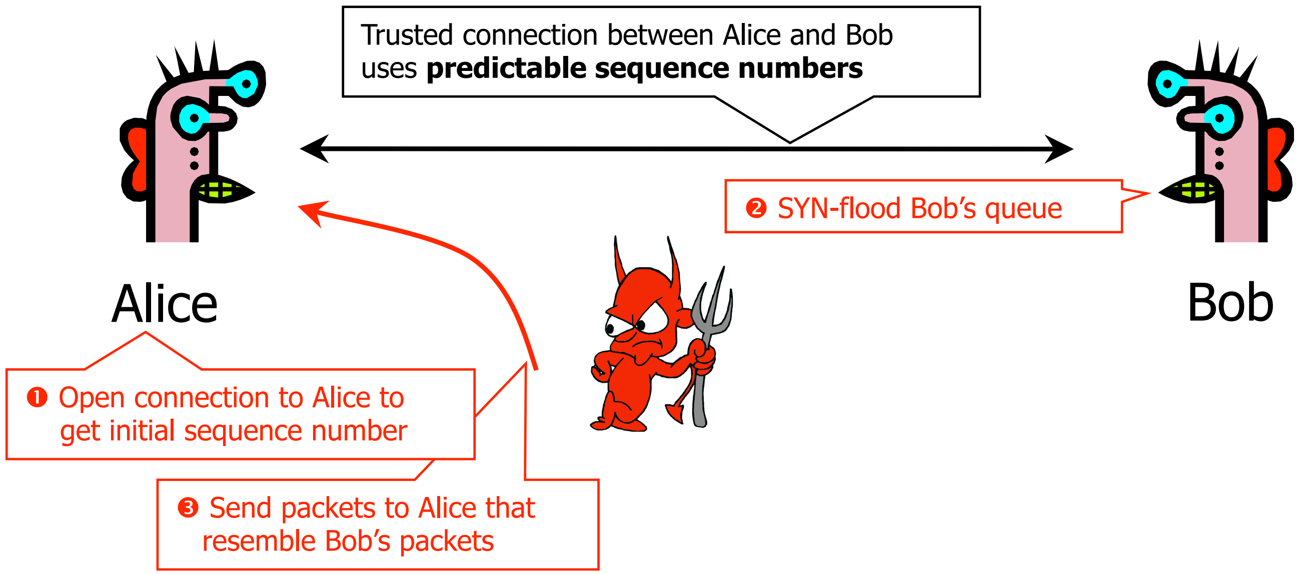
half-open connections
121.17.182.45
231.202.1.16
121.100.20.14
5.17.95.155

- If SYN queue is full, delete random entry
  - Legitimate connections have a chance to complete
  - Fake addresses will be eventually deleted
- Easy to implement

TCP Connection Spoofing

- Each TCP connection has an associated state
  - Sequence number, port number
- TCP state is easy to guess
  - Port numbers are standard, sequence numbers are often predictable
  - Can inject packets into existing connections
- If attacker knows initial sequence number and amount of traffic, can guess likely current number
  - Send a flood of packets with likely sequence numbers

“Blind” IP Spoofing Attack



- Can’t receive packets sent to Bob, but maybe can penetrate Alice’s computer if Alice uses IP address-based authentication
  - For example, rlogin and many other remote access programs uses address-based authentication

DoS by Connection Reset

- If attacker can guess current sequence number for an existing connection, can send Reset packet to close it
  - With 32-bit sequence numbers, probability of guessing correctly is $1/2^{32}$ (not practical)
  - Most systems accept large windows of sequence numbers $\Rightarrow$ much higher probability of success
    - Need large windows to handle massive packet losses