Network Security

(From Slides/Notes)

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Network Attacks Are Common

- Attack Types:
  - Denial of service attacks
  - Spam
  - Worms & Viruses
  - and others
- Attack targets
  - End systems including attacks on Web servers, TCP, etc.
  - Links
  - Routers
  - DNS
  - And others
- Who are the attackers?
  - Script kiddies
  - Professionals who do it for money

Mounting An Attack

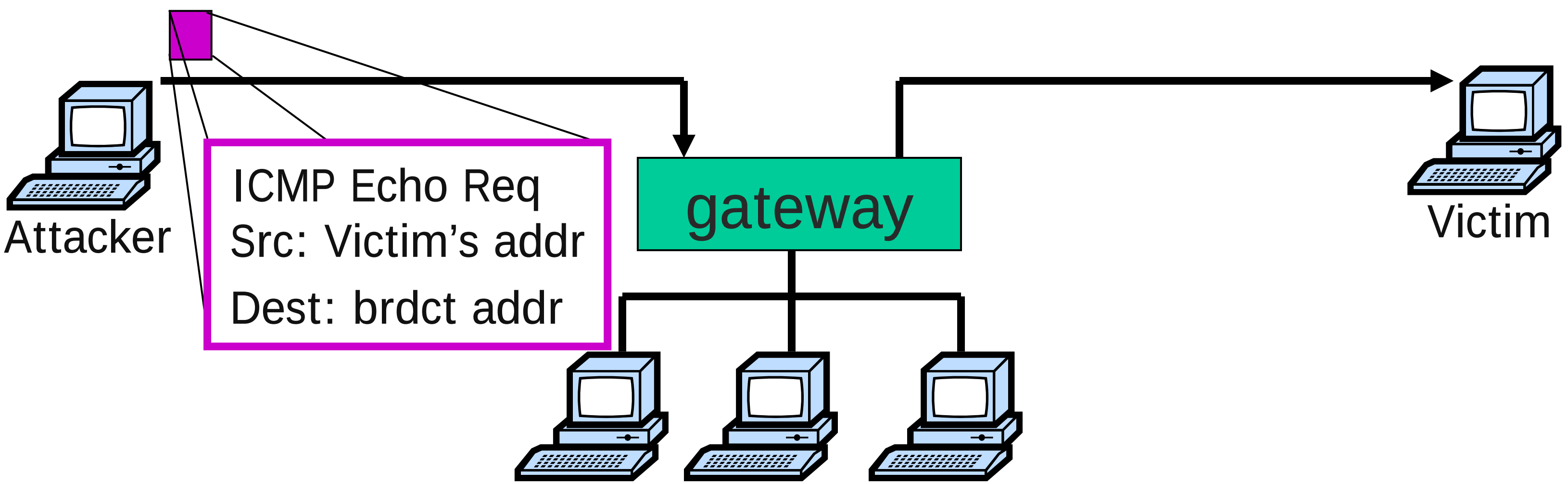
Attacker's Goals

- Hide
- Maximize damage

These goals are essential to understand what makes an attack effective and how to counter attacks

Attacker Wants to Hide

- Spoof the source (IP address, email account, ...)
- Indirection
  - Reflector attacks: E.g., Smurf Attack



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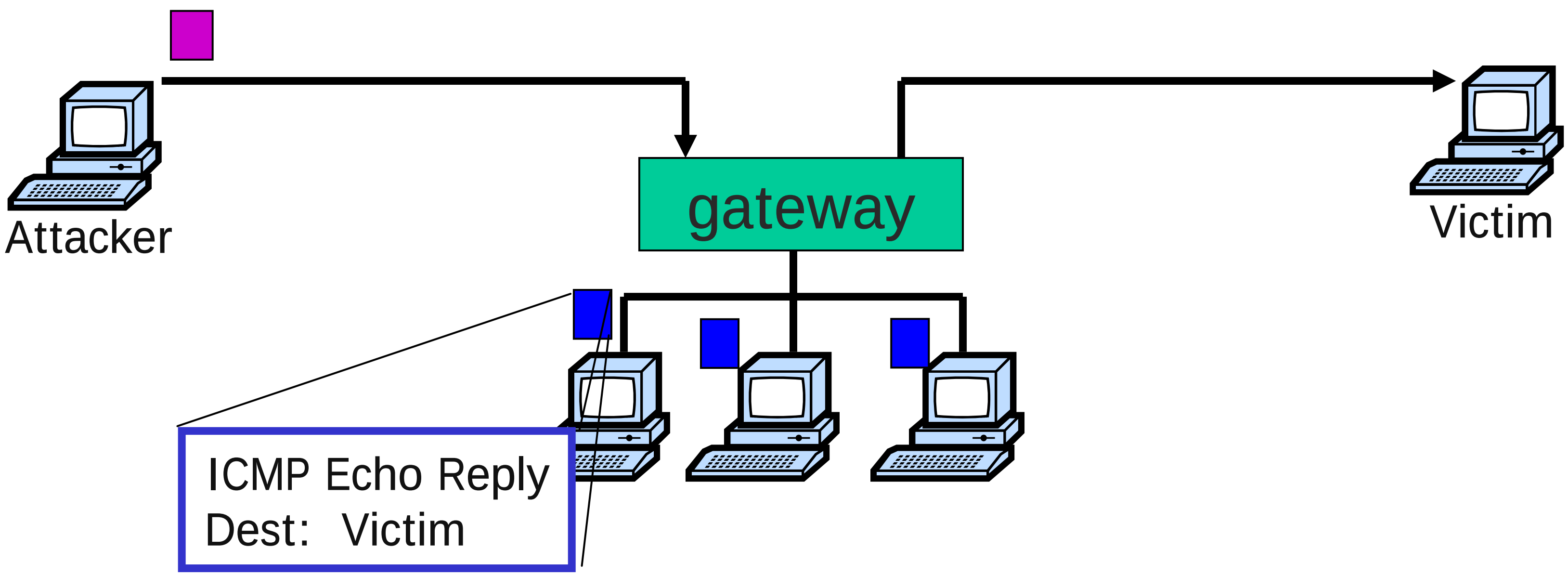
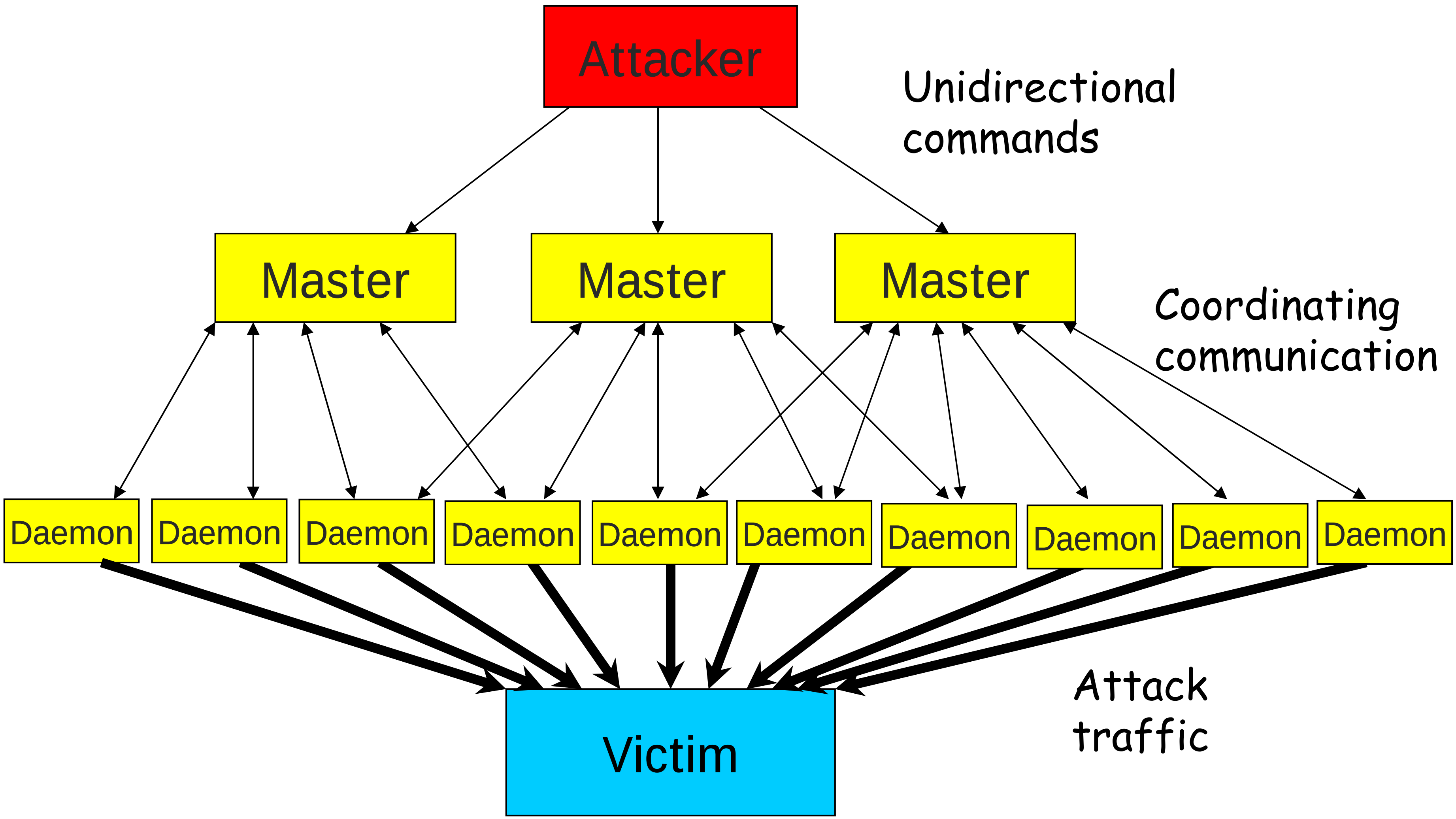


Increase Damage → Go Fully Distributed → Use a Botnet



Some Distributed Denial of Service (DDoS) Tools

- Many public tools for flooding a victim with unwanted traffic
- Trin00 (Trinoo)
  - Client ported to Windows
- TFN – Tribe Flood Network
  - TFN2K – Updated for 2000
- Stacheldraht
  - German for "Barbed Wire"

Trin00

- a.k.a. "The Distributed DoS Project"
- Strengths
  - Password protected options, encrypted daemon list
    - Startup, remote control, and kill
  - Attacker talks to client using tcp
  - Master and daemons use udp
- Weakness
  - All messages (commands) sent in clear. Easy to fingerprint if network is infected

Trinoo Transcript

```
Connection to port (default 27665/tcp)

attacker$ telnet 10.0.0.1 27665
Trying 10.0.0.1
Connected to 10.0.0.1
Escape character is '^]'.
Kwijibo
Connection closed by foreign host. . . .


attacker$ telnet 10.0.0.1 27665
Trying 10.0.0.1
Connected to 10.0.0.1
Escape character is '^]'.
Betaalmostdone
trinoo v1.07d2+f3+c..[rpm8d/cb4Sx/]

trinoo>
```

TrinOO Commands

- **dos <IP> - command to initiate a DoS against the targeted <IP> address**
- **mdos <IP1:IP2:IP3> - sends command to attack three IP addresses, sequentially**
- **die – shut down the master**
- **mdie <password> - if correct password specified, packet is sent out to all daemon nodes to shutdown**
- **mping – ping sent to all nodes in the deamon list**
- **killdead – delete deamon nodes from list that didn't reply to ping**
- **bcast – gives a list of all active daemons**
- **mstop – Attempts to stop an active DoS attack. Never implemented by the author(s), but the command is there**

Bots Stories

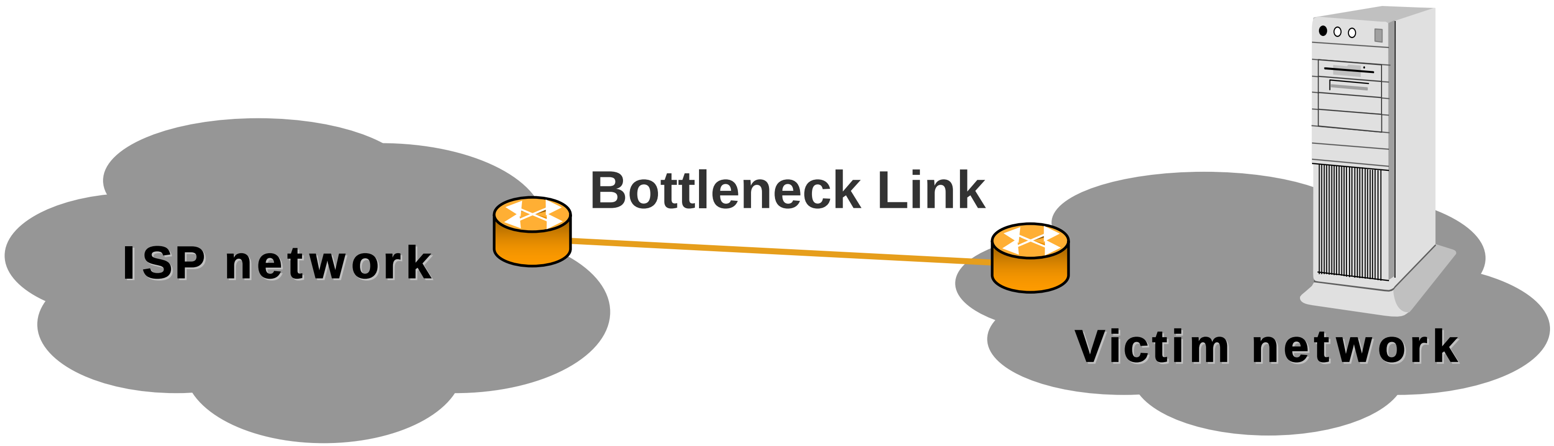
- Every day 30,000 new machines become zombies/bots
- Bots of 20,000+ machines are reported
- Bots are rented by the hour
- Bots are used for a variety of attacks, DDoS, Spam, as web servers which serve illegal content,…

Attacks

Attacks on Bandwidth

- Brute force attack
- Attacker sends traffic to consume link bandwidth
- What kind of packets?
  - ICMP Echo (e.g., TFN); UDP data (e.g., Trinoo, TFN); Junk TCP data or Ack packets (Stacheldraht v2.666, mstream); TCP SYN packets (TFN, Stacheldraht)

Defending against bandwidth attacks is hard

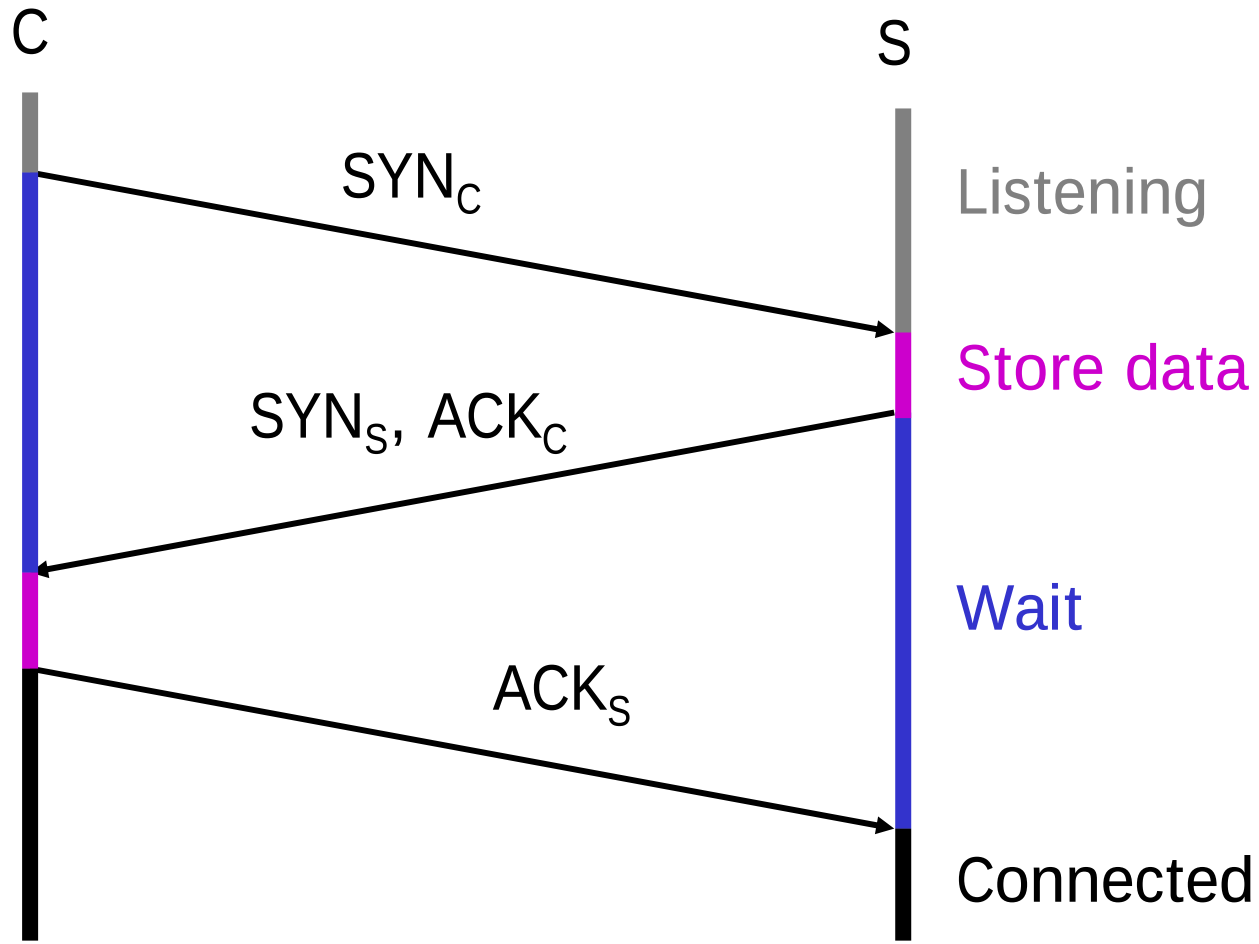


- Should drop packets before the bottleneck, i.e., at ISP
- But
  - ISPs are not willing to deploy complex filters for each client
  - ISPs have no strong incentive; they charge clients for the traffic
- Big companies defend themselves by using very high bandwidth access links

Attacks on TCP

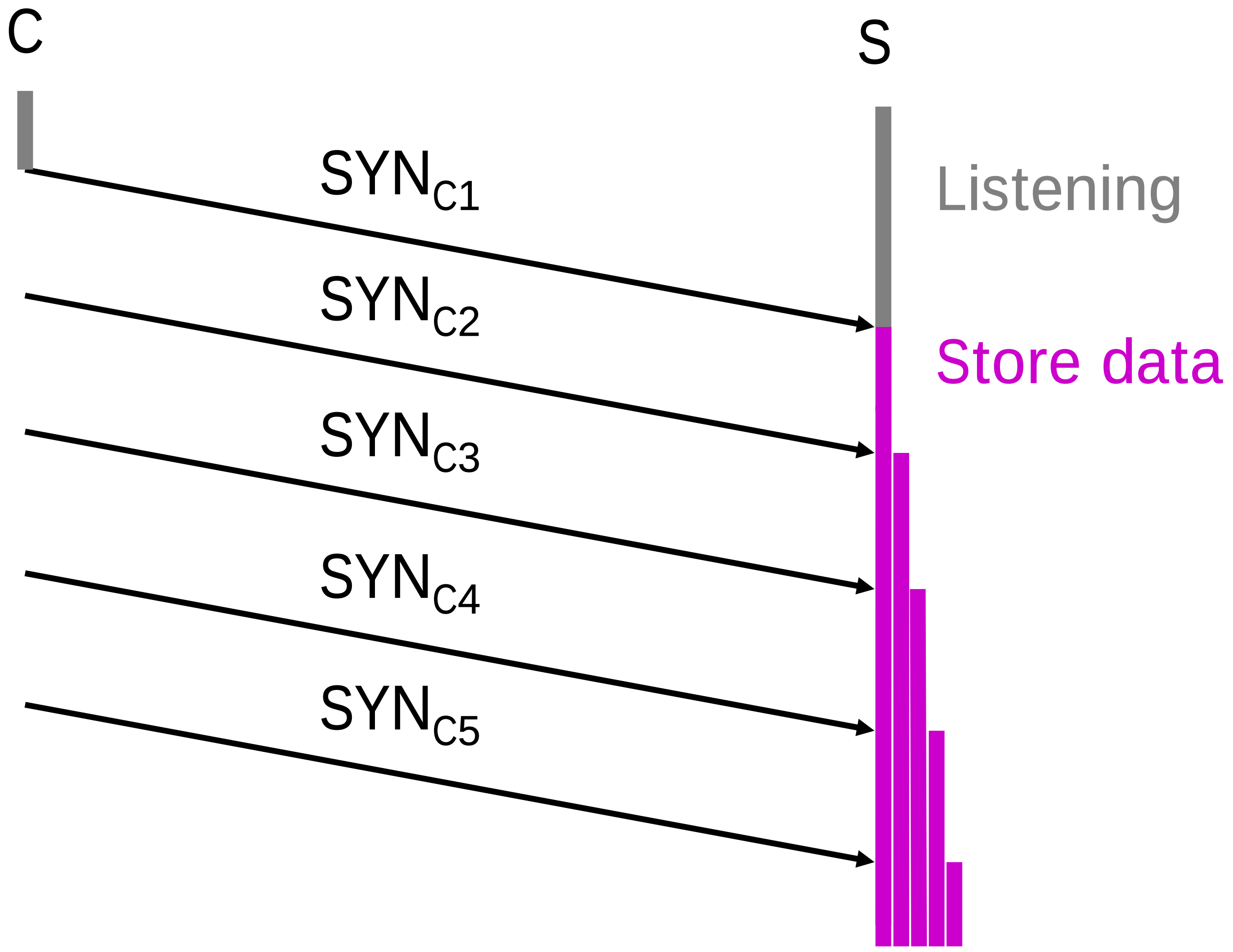
<u>TCP DoS Attacks:</u>

TCP SYN Flood



TCP DoS Attacks:

TCP SYN Flood



TCP DoS Attacks:

TCP SYN Flood

- Usually targets connection memory → Too many half-open connections

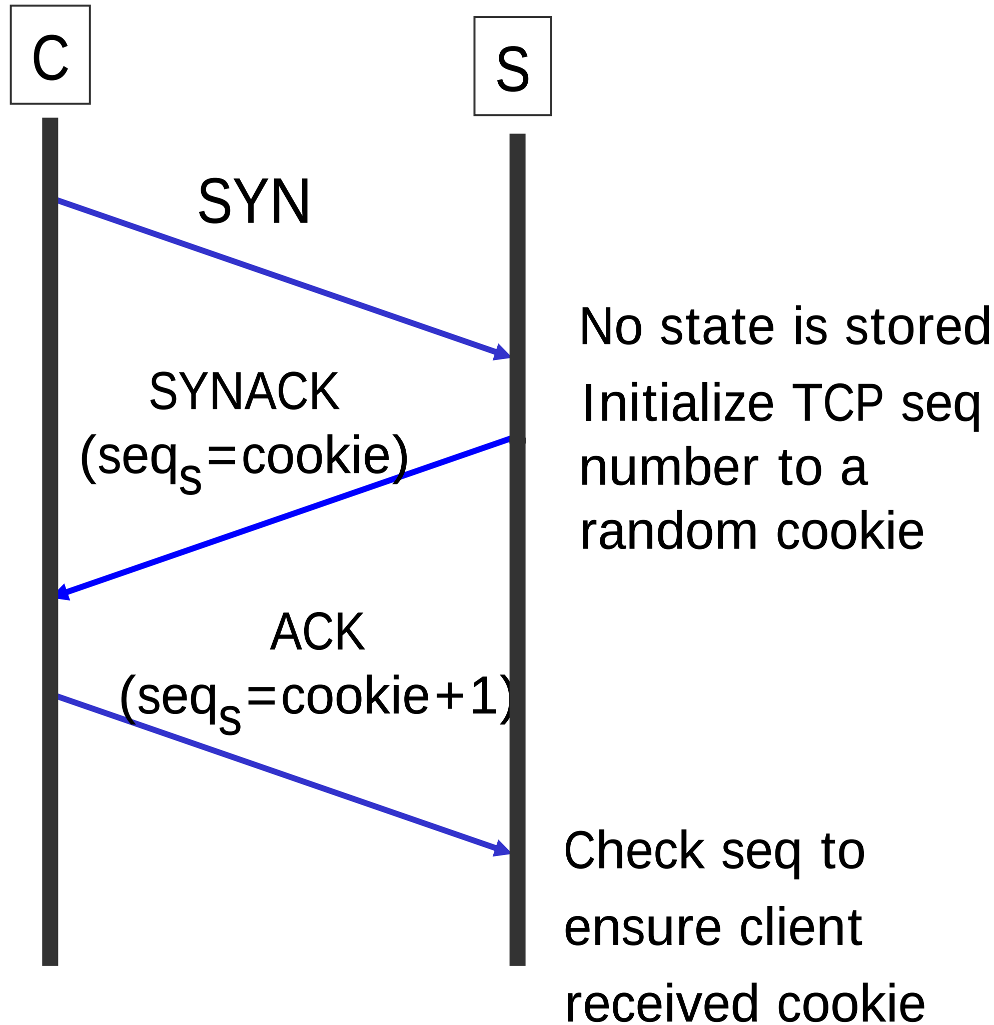
- Potential victim is any TCP-based server such as a Web server, FTP server, or mail server

- To check for SYN flood attacks
  - Run `netstat -s |grep "listenqueue overflows“` and check whether many connections are in "SYN_RECEIVED"

- How can the server deal with it?
  - Server times out half-open connection
  - SYN cookies and SYN caches prevent spoofed IP attacks

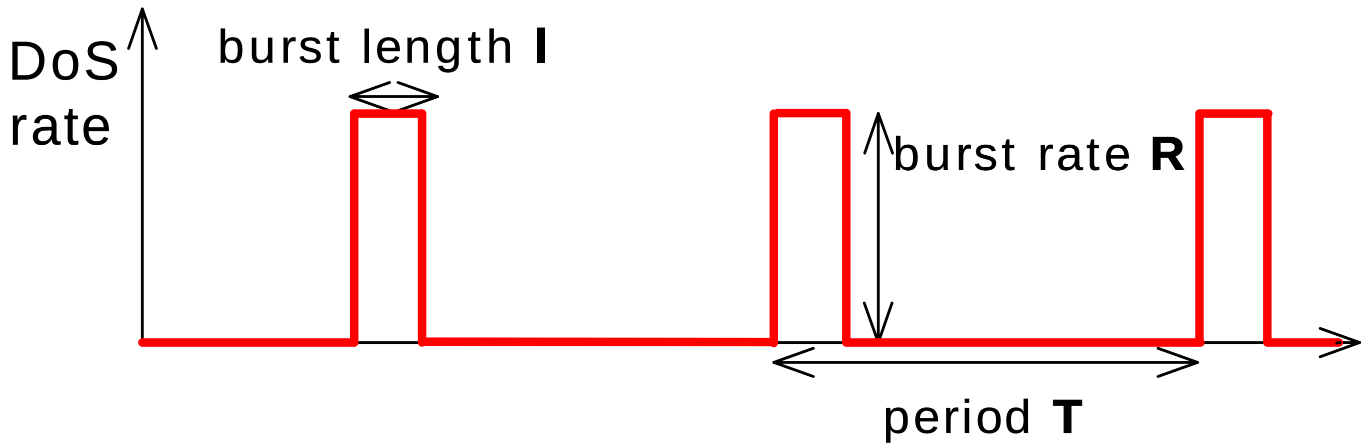
SYN Cookie

- Ensures IP address is not spoofed
- How? check that the client can receive a packet at the claimed source address



TCP DoS Attacks:

Low Rate TCP-Targeted Attacks

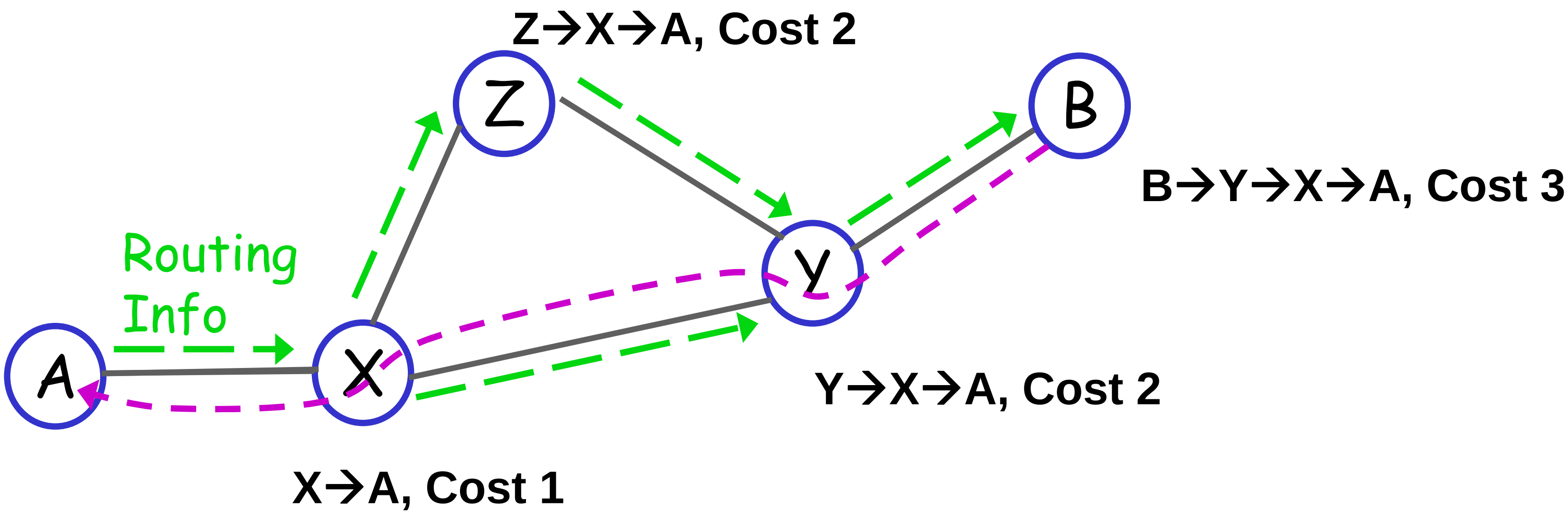


- Provoke a TCP to repeatedly enter retransmission timeout by sending a square-wave (l~RTT, T~minRTO)
- Hard to detect because of its low average bandwidth
- Randomizing TCP timeout helps but doesn't solve problem

Attacks on Routers

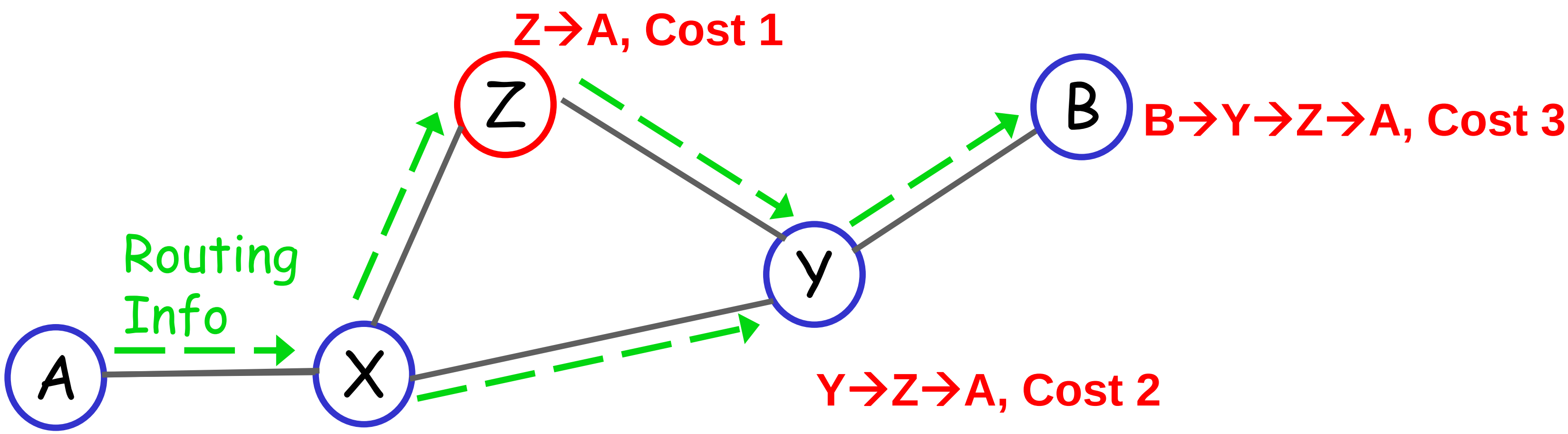
Attacks on Routers:

Routing Protocols



Attacks on Routers:

Attacks on Routing Table



- Attacker needs to get access to a router
- Attacks
  - Prefix hijacking by announcing a more desirable route
    - Z can lie about its route to A
  - Overload routers CPU by too many routing churns
  - Overload the routing table with too many routes
    - Causes router to run out of memory or CPU power for processing routes
    - E.g., AS7007

Countering Routing Table Attacks

- Authenticate routing adjacencies
- ISPs should filter routing advertisements from their customers
- Secure BGP [Kent et al]
  - Every ISP sign its advertisements creating a chain of accountability (e.g., X sends $\{ Z: \{Y\}_Z \}_X$
  - Too many signatures → too slow
    - With no authentication needs a few usec; MD5 ~100 usec; RSA ~1 sec

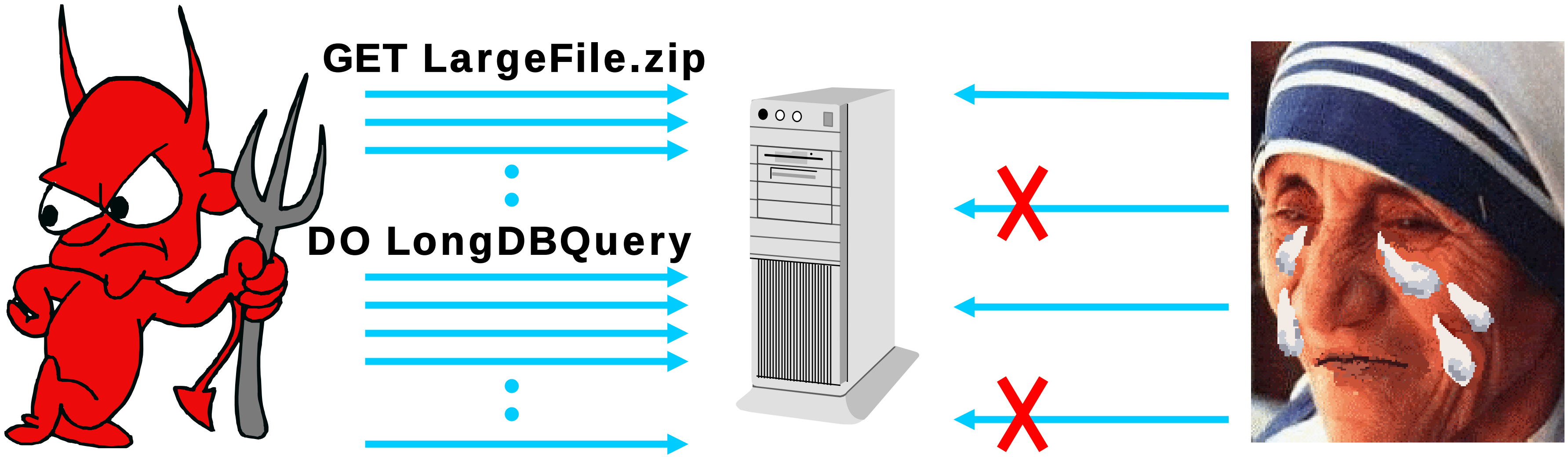
DoS Attacks on Web Servers

DoS Attacks on Web Servers

- Most known attacks
  - E.g., Yahoo, Amazon, …
  - Moore et al report over 12,000 attacks in 3-week, intentity as high as 600,000 pkts/s
- Recently taking the form of Cyber Mafia
  - Pay us $50,000 to protect you from attacks similar to the one on last Tuesday
- Becoming more distributed
  - Less spoofing of IP addresses
- Attack types
  - Attacks on TCP or Link bandwidth can be used against a Web server
  - Attacks on higher level protocols like HTTP

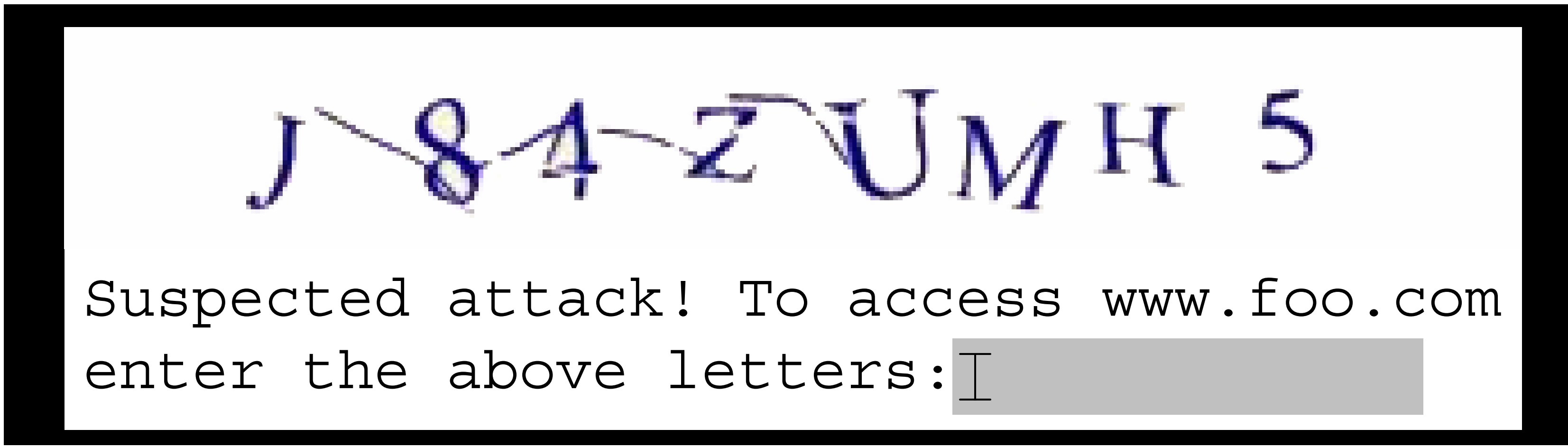
DoS Attacks on Servers:

Attacks that Mimic Legitimate Traffic



- Attacker compromises many machines causing them to flood victim with HTTP requests (e.g., MyDoom worm)
- Attacked resources
  - DB and Disk bandwidth
  - Socket buffers, processes, …
  - Dynamic content, password checking, etc.
- Hard to detect; attack traffic is indistinguishable from legitimate traffic

Proposals for Graphical Solutions



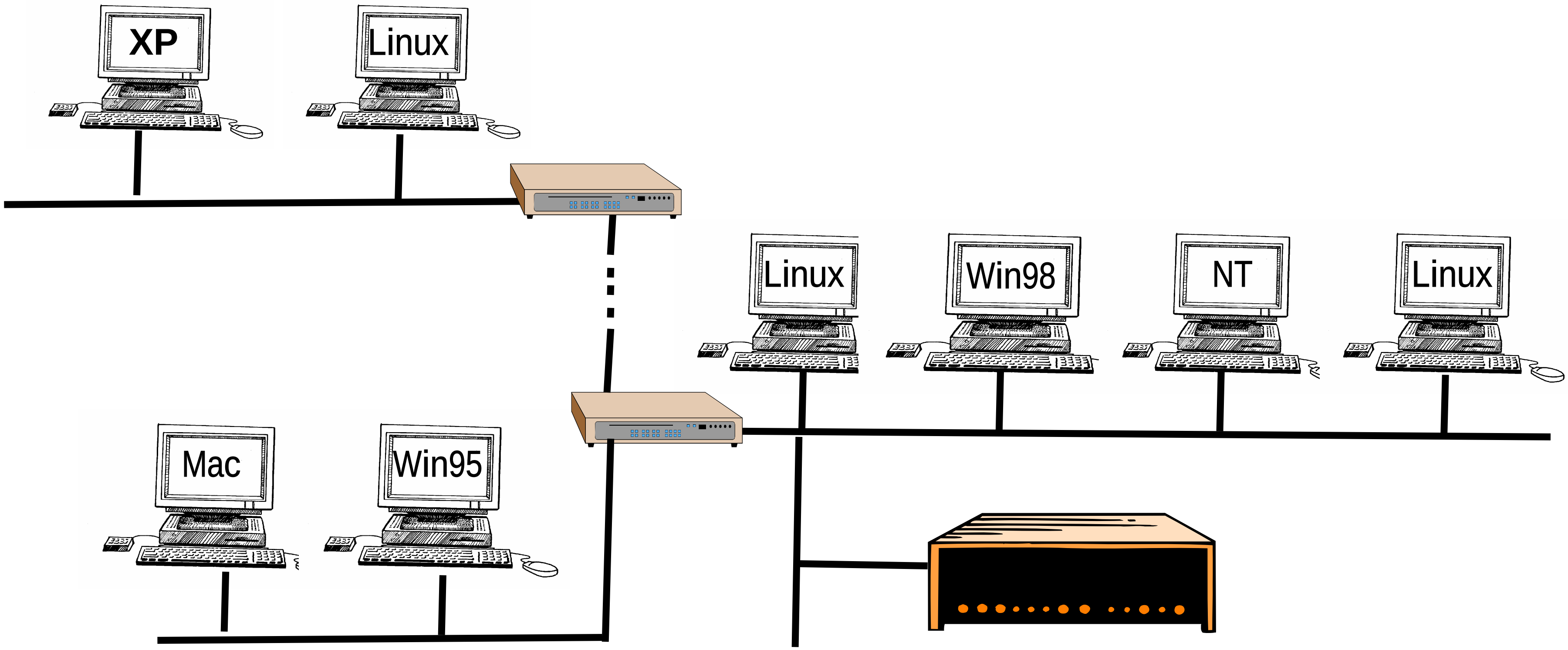
- Not that simple:
  - Should send test and check answer without allowing the unauthenticated clients access to server resources, including TCP sockets. Otherwise attack is accomplished.
  - Some people can't or don't want to answer graphical tests but are legitimate users

Detection

Detection Issues

- Detecting What?
  - Detecting the offending packets
  - Some attack characteristics (e.g., how many zombies)
  - The occurrence of an attack
- Offline vs. realtime
  - Realtime detection may help in throttling the attack while forensics might help in suing the attacker
- Detection cost
  - Can attacker mount an attack on the detection mechanism? How would that affect the protected system?

Network Intrusion Detection



- NIDS box monitors traffic entering and leaving your network
- In contrast to firewalls, NIDS are passive

Approaches to Intrusion Detection

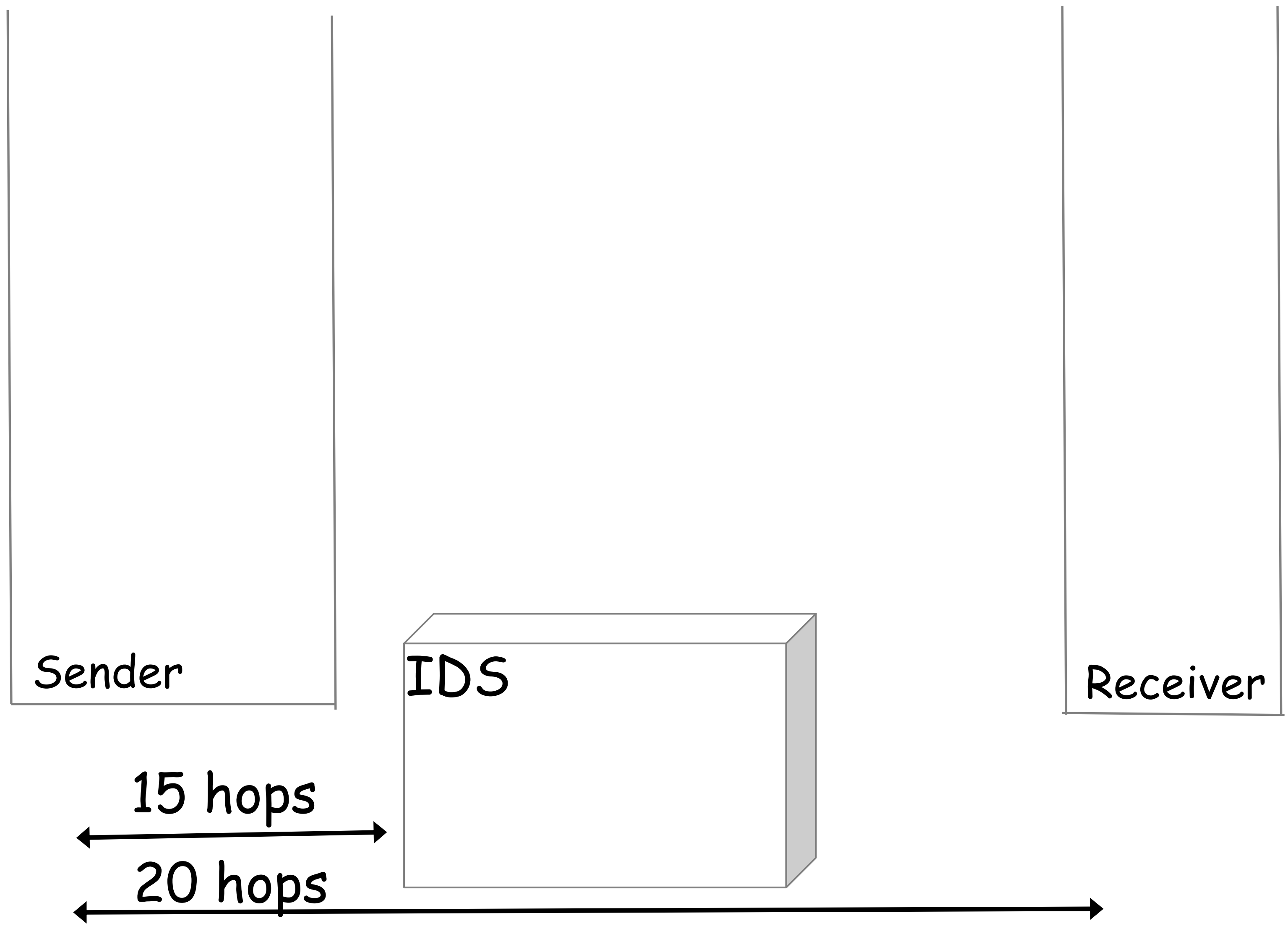
1. Signature Based: Keeps a DB of known attack signatures and matches traffic against DB (e.g., Bro, Snort)
   - Pros
     - Easy to understand the outcome
     - More accurate in detecting known attacks
   - Cons
     - Can't discover new attacks
2. Anomaly Based: Matches traffic against a model of normal traffic and flags abnormalities (e.g., EMERALD)
   - Pros
     - Can deal with new attacks
   - Cons
     - Modeling normal. it is hard to describe what is normal
     - Limits new applications
     - Less accurate detection of known attacks
3. Hybrid: Matches against DB of known attacks. If no match, it checks for anomaly

Evasion Problem in NIDS

- Consider scanning traffic for a particular string ("`USER root`")
- Easiest: scan for the text in each packet
  - No good: text might be split across multiple packets
- Okay, remember text from previous packet
  - No good: out-of-order delivery
- Okay, fully reassemble byte stream
  - Costs **state** ….
  - …. and still evadable

Source: Vern Paxson

Evading Detection Via Ambiguous TCP Retransmission



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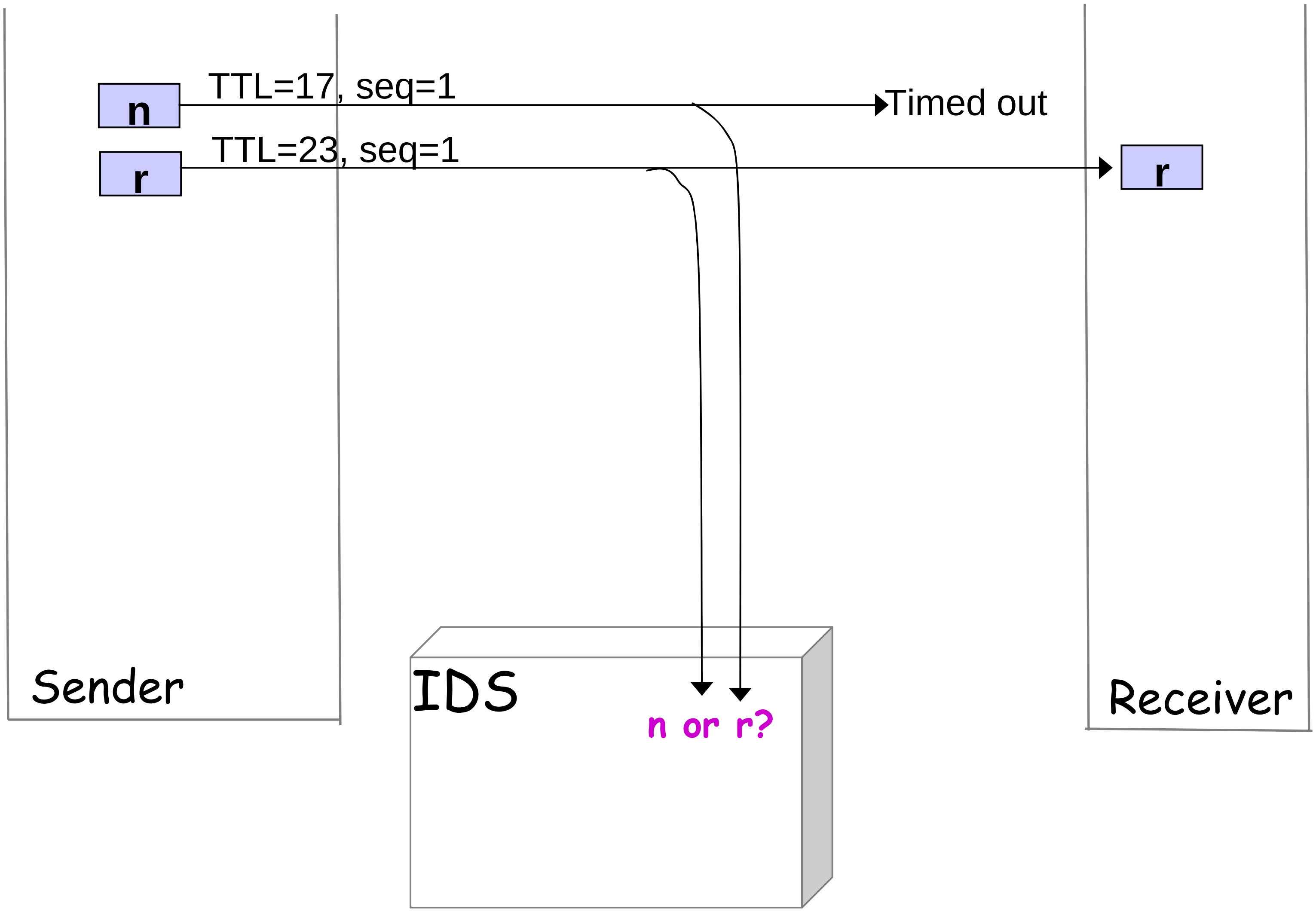

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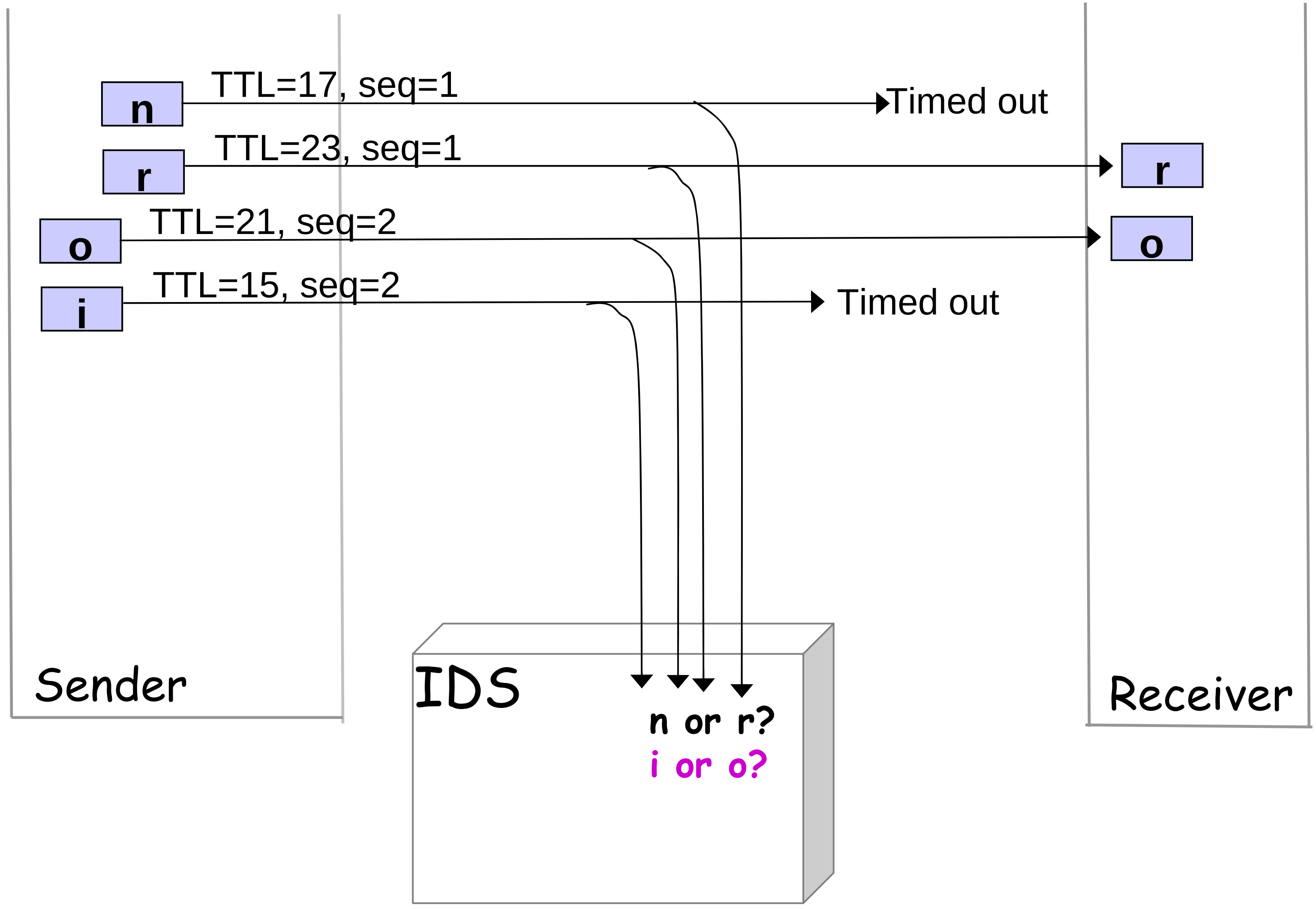

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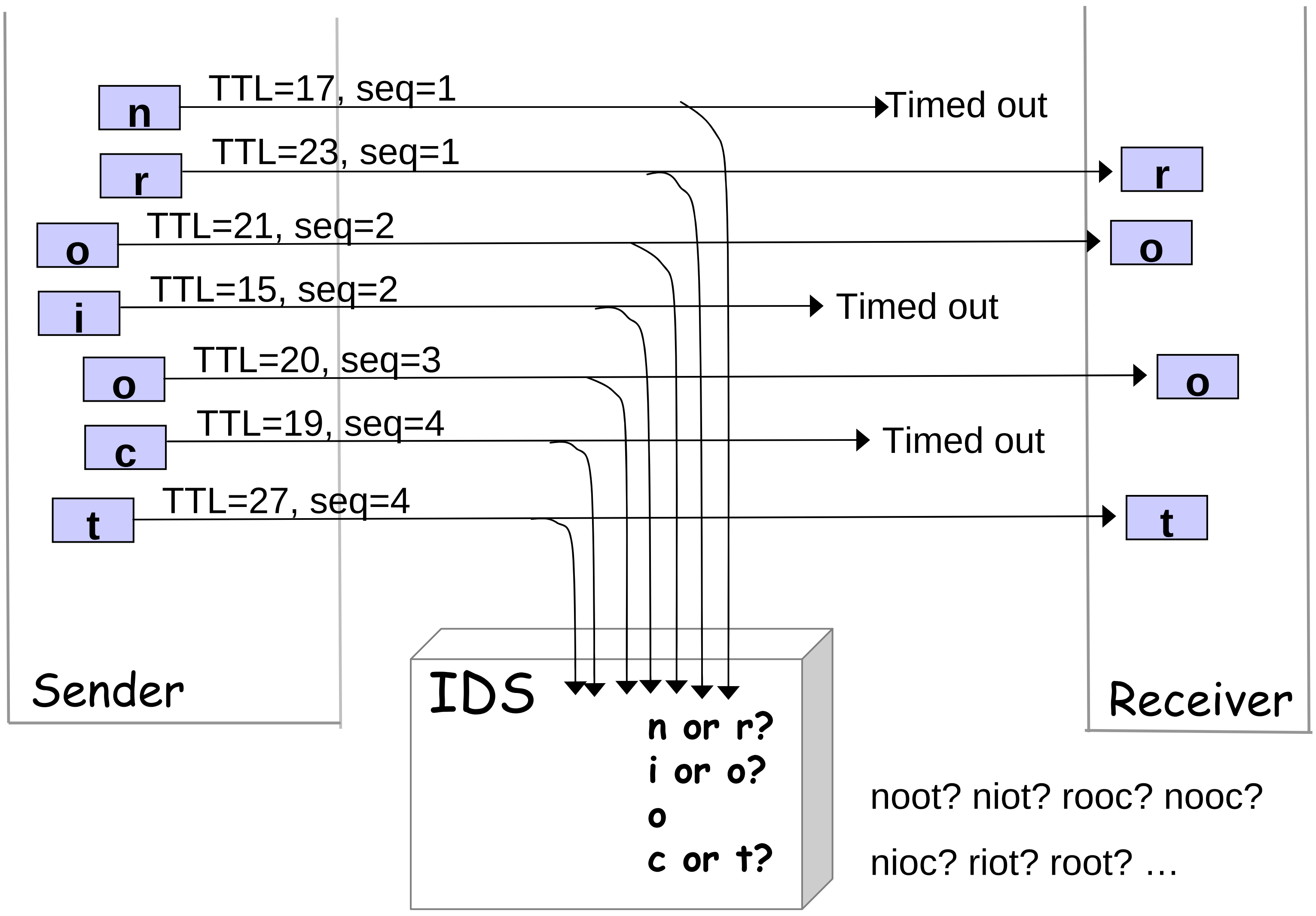


noot? niot? rooc? nooc?

nioc? riot? root? …

Bypassing NIDS

- Evasion
- Insertion
- DoS it
- Hack it
- Cause many false alarms until admin stops paying attention

Examples of Anomaly Detection

- Detecting Large Bandwidth Consumers
- MULTOPs
- Distinguishing DDoS from flash-crowd

Detecting Malicious TCP Flows

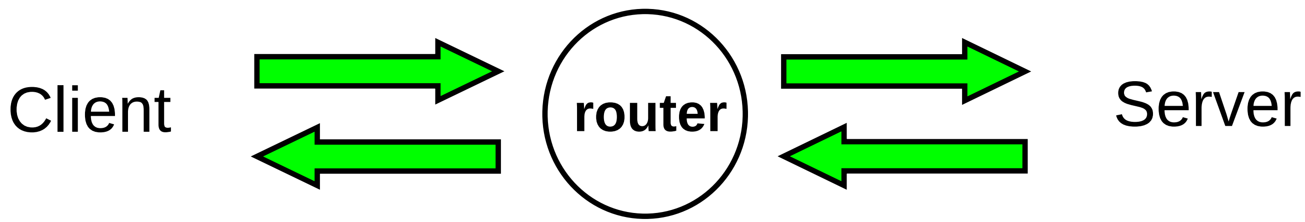
- TCP throughput is a function of its drop rate

$$Thru = \frac{1.2}{RTT * \sqrt{drop\_rate}}$$

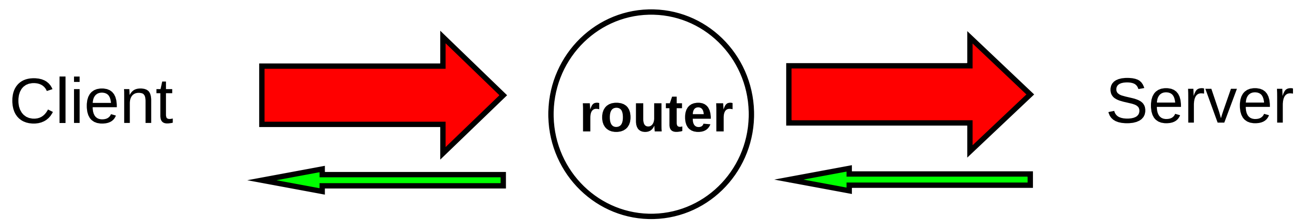
- Router monitors the rate of each TCP flow and compares it against the above equation
- Make it more scalable by using statistical monitoring at routers to find unfriendly flows

MULTOPS
protects web servers against BW attacks

HTTP Traffic is mostly from server to client



Normal: proportional packet rates



Attack: disproportional packet rates

Drop packets from sources sending disproportionate flows

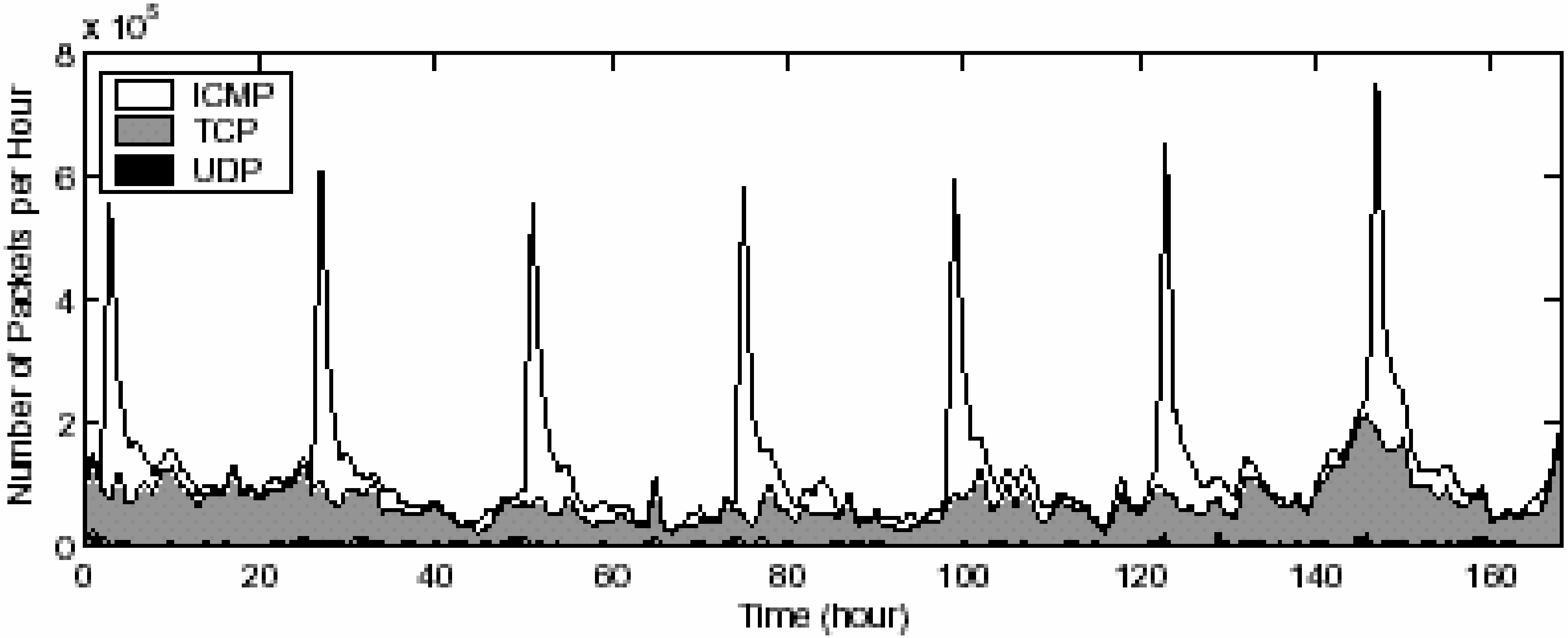
Distinguish DDoS Attacks from Flash Crowd

- Jung et al. identify whether overload is created by flash crowd or DDoS
- Idea: Prefixes of client addresses in DDoS attacks are randomly distributed, whereas in a flash crowd they are closer to the prefix distribution of the server's usual traffic

Network Telescopes

- Detect the occurrence of large scale abusive activities
- Idea: monitor an unused cross-section of Internet address space. Packets received at these unused addresses are signs of attacks
  - “Backscatter” from DoS (attacker spoof an address from monitored space causing the victim to reply to the monitor)
  - Attackers probing blindly
  - Random scanning from worms
- If you monitor 1/n the IP address space, by the time you observe the abusive activity it has affected about $2^{32}/n$ Internet hosts

Hourly Background Radiation Seen at a 2,560-Address Network Telescope



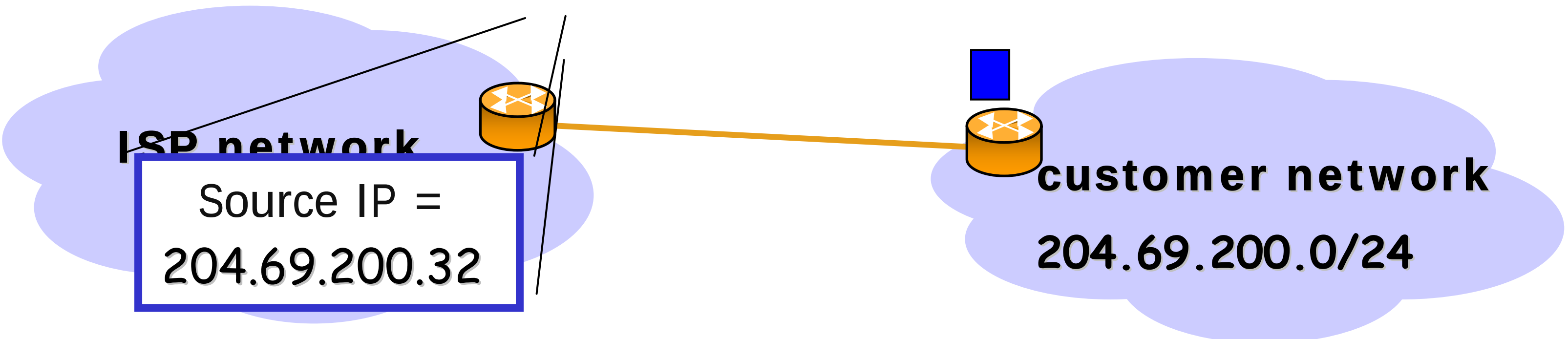
Source: Vern Paxson

Authentication & Establishing Identity

Establish Identity

- Find the source of the offending traffic
- Important for blacklisting, imposing legal/social charges, fix the zombies, …

Ingress Filtering

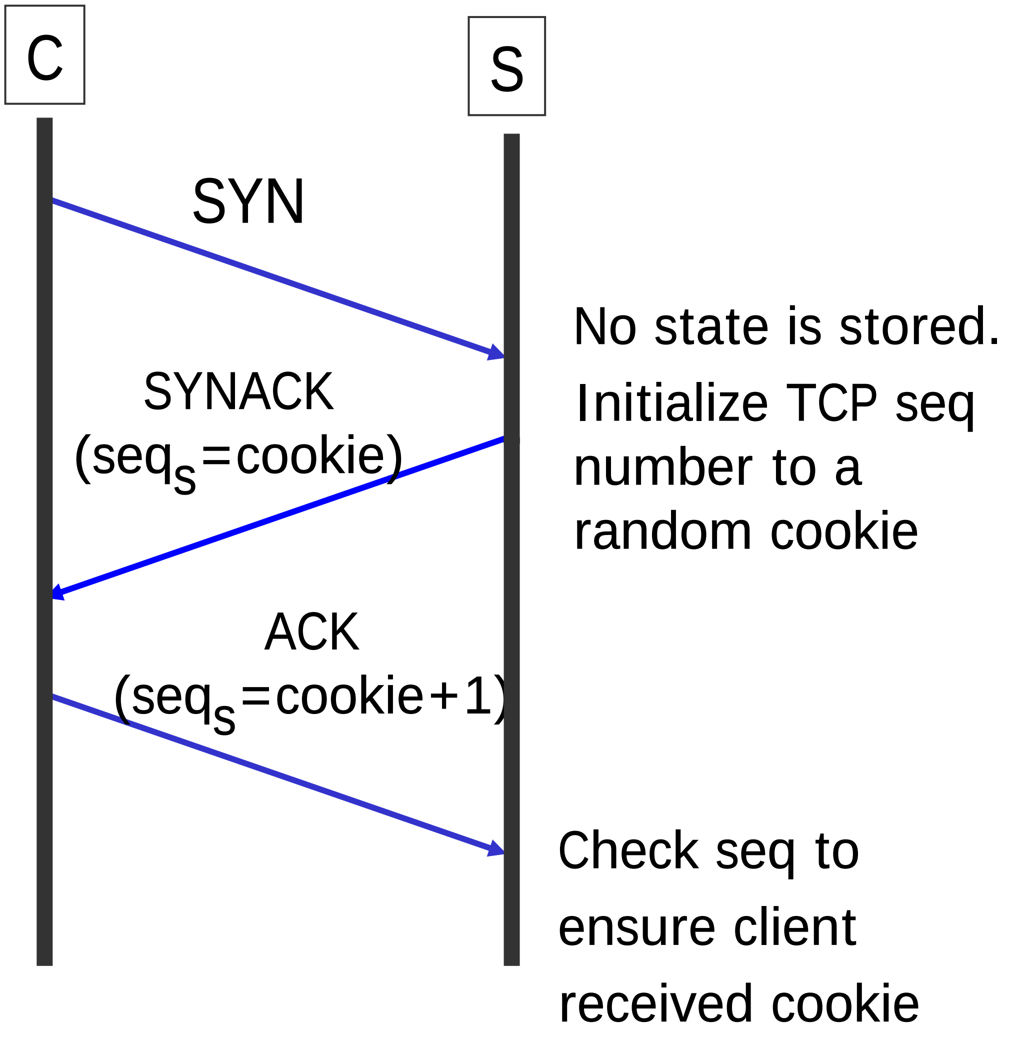


- An ISP checks that all packets from a customer network use a source address from the customer's allocated address space [RFC 2827]
- Also, the customer checks that all packets leaving its network have the correct source prefix

Methods for authenticating a source:

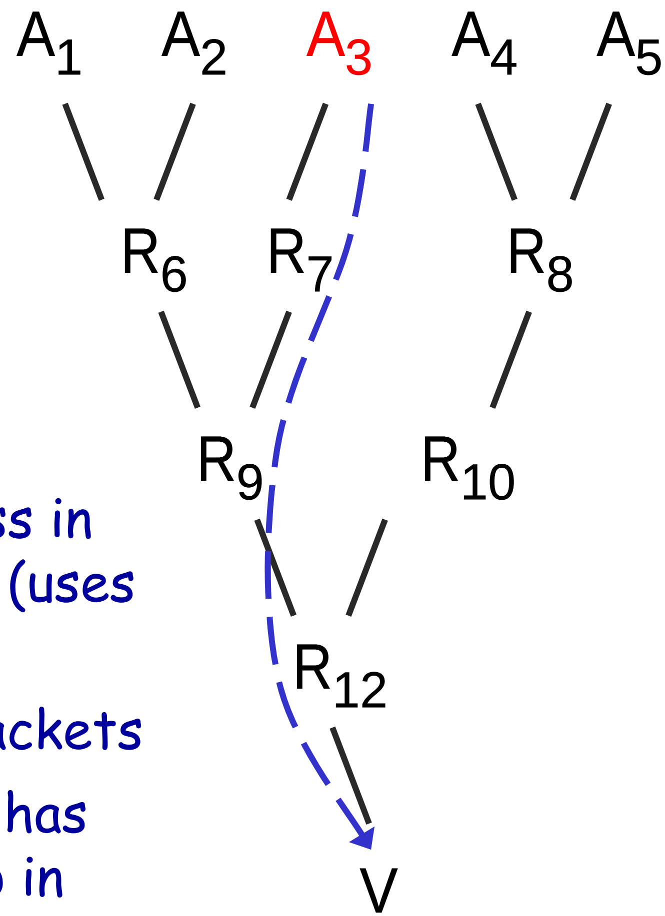
Different forms of pinning a route

- Circuit switching
- Virtual Circuit
- SYN Cookie



IP Traceback

- Relies on routers' help in detecting the attack path
  - Assume you trust routers
- Probabilistic traceback:
  - Every router writes its IP address in the packet with some probability (uses fragment field in IP header)
  - Victim reconstructs path from packets
  - Router at distance d from victim has probability $p(1-p)^{d-1}$ of showing up in marked packets



Authorization

- Who are the legitimate senders?
  - Private services → legitimate users have known IP addresses, known passwords, …
    - E.g., authentication of routing adjacencies
  - Public services → hard, don't know legitimate users
    - E.g., Google, Amazon, …
    - Should ask what makes a certain access pattern legitimate
      - Human User → graphical test, …
      - Reasonable number of http requests per IP address?
      - No weird connection behavior (keeping half-open connections for long time)
- Problems with checking authorization
  - Compromised machines may expose passwords and login info

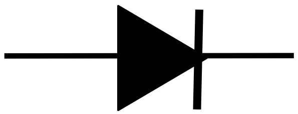
Cost of Checking Identity

- Cost << service/attack cost; Otherwise it is not worth it
  - Costly authentication schemes are prone to DoS attacks
    - E.g., attack on password authentication
  - Also costly authentication mechanisms slow down the service
    - secure BGP slows down routing making it hard to deploy

Filtering & Throttling

Firewalls

- A barrier between us and them
  - Limits communication to the outside world, so that only a few machines are exposed to attacks
- Semantics

inside  outside

- Why?
  - Most hosts have security holes
  - Firewalls run less code and hence have fewer bugs
  - Firewalls can be professionally administered

Possible Firewall Actions

- Access control (a list of good addresses and bad addresses)
- Ingress/egress filtering
  - Packets coming in must have outside source
  - Packets leaving must have an inside source
- Rate limiting
  - Limit rate of ICMP packets and/or SYN packets

- All of these steps may interfere with legitimate traffic
- They don't help when attacks come from inside

NAT (Network Address Translator) as a Firewall

- NAT deals with shortage of IPv4 addresses
  - why there is a shortage?
    - 2^{32} addresses; Hierarchical assignment
- Main idea behind NAT
  - Not all addresses are used at the same time globally
  - Many communications are local → don't need global addresses.

How does NAT work?

- Assign the global address to the NAT box
- Assign local addresses to machines behind the NAT (e.g., 10.0.0.0/8)
- Locally, advertise the NAT as the router connecting the network to the rest of the world → packets destined to outside destinations are going to leave through the NAT
- When a local host sends a packet to an outside destination
  - NAT capture the packet and replaces it source address and port
  - NAT adds binding to its table (Local_IP-Local_Port →global_IP-Global-Port)
  - NAT sends packet
  - When ack comes form the destination, NAT checks its table to replace the global source address and port with the local ones
  - Nat also checks the filter that should be applied to the incoming packet

NAT Functionality