Network Security
CS 136
Computer Security
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Outline

- Basics of network security
- Definitions
- Sample attacks
- Defense mechanisms

Some Important Network Characteristics for Security

- Degree of locality
- Media used
- Protocols used

Degree of Locality

- Some networks are very local
  - E.g., an Ethernet
  - Only handles a few machines
  - Benefits from:
    - Physical locality
    - Small number of users
    - Common goals and interests
- Other networks are very non-local
  - E.g., the Internet backbone
  - Vast numbers of users/sites share bandwidth

Network Media

- Some networks are wires, cables, or over telephone lines
  - Can be physically protected
- Other networks are satellite links or other radio links
  - Physical protection possibilities more limited

Protocol Types

- TCP/IP is the most used
  - But it only specifies some common intermediate levels
  - Other protocols exist above and below it
- In places, other protocols replace TCP/IP
- And there are lots of supporting protocols
  - Routing protocols, naming and directory protocols, network management protocols
  - And security protocols (IPSec, ssh, ssl)

Implications of Protocol Type

- The protocol defines a set of rules that will always be followed
  - But usually not quite complete
  - And they assume everyone is at least trying to play by the rules
  - What if they don't?
- Specific attacks exist against specific protocols

Threats to Network Security

- Pretty much the usual suspects:
  - Wiretapping
  - Impersonation
  - Message confidentiality
  - Message integrity
  - Denial of service

Why Are Networks Especially Threatened?

- Many "moving parts"
- Many different administrative domains
- Everyone can get some access
- In some cases, trivial for attacker to get a foothold on the network
- Networks encourage sharing
- Networks often allow anonymity

What Can Attackers Attack?

- The media connecting the nodes
- Nodes that are connected to them
- Routers that control the traffic
- The protocols that set the rules for communications

Wiretapping

- An obvious network vulnerability
  - But don’t forget, “wiretapping” is a general term
    - Not just networks are vulnerable
- **Passive wiretapping** is listening in illicitly on conversations
- **Active wiretapping** is injecting traffic illicitly

Wiretapping on Wires

- Signals can be trapped at many points
- Actually tapping into some physical wires is possible
- Other "wires" are broadcast media
  - **Packet sniffers** can listen to all traffic on a broadcast medium
- Subverted routers and gateways also offer access

Wiretapping on Wireless

- Often just a matter of putting an antenna up
  - Though position may matter a lot
  - Generally not even detectable that it's happening
  - Directional antennae and frequency hopping may add challenges
- Active threats are easier to detect
  - And, for satellites, technically challenging

Impersonation

- A packet comes in over the network
  - With some source indicated in its header
- Often, the action to be taken with the packet depends on the source
- But attackers may be able to create packets with false sources

Methods of Network Impersonations

- Even in standard protocols, often easy to change fields in a header
  - When created or later
  - E.g., IP allows forging source addresses
- Existing networks have little or no built-in authentication

Authentication to Foil Impersonation

- Higher level protocols often require authentication of transmissions
- Much care required to ensure proper authentication
- And not having authentication underneath can cause many problems
- Authentication schemes are rarely perfect

Violations of Message Confidentiality

- Other problems can cause messages to be inappropriately divulged
- Misdelivery can send a message to the wrong place
  - Clever attackers can make it happen
- Message can be read at an intermediate gateway or a router
- Sometimes an intruder can get useful information just by traffic analysis

Message Integrity

- Even if the attacker can't create the packets he wants, sometimes he can alter proper packets
- To change the effect of what they will do

Denial of Service

- Attacks that prevent legitimate users from doing their work
- By flooding the network
- Or corrupting routing tables
- Or flooding routers
- Or destroying key packets

How Do Denial of Service Attacks Occur?

- Basically, the attacker injects some form of traffic
- Most current networks aren't built to throttle uncooperative parties very well
- All-inclusive nature of the Internet makes basic access trivial
- Universality of IP makes reaching most of the network easy

Some Sample Attacks

- Smurf attacks
- SYN flood
- Ping of Death

Smurf Attacks

- Attack on vulnerability in IP broadcasting
- Send a ping packet to IP broadcast address
  - With forged "from" header of your target
- Resulting in a flood of replies from the sources to the target
- Easy to fix at the intermediary
  - Don't allow IP broadcasts to originate outside your network
- No good solutions for victim

SYN Flood

- Based on vulnerability in TCP
- Attacker uses initial request/response to start TCP session to fill a table at the server
- Preventing new real TCP sessions
- SYN cookies and firewalls with massive tables are possible defenses

Normal SYN Behavior

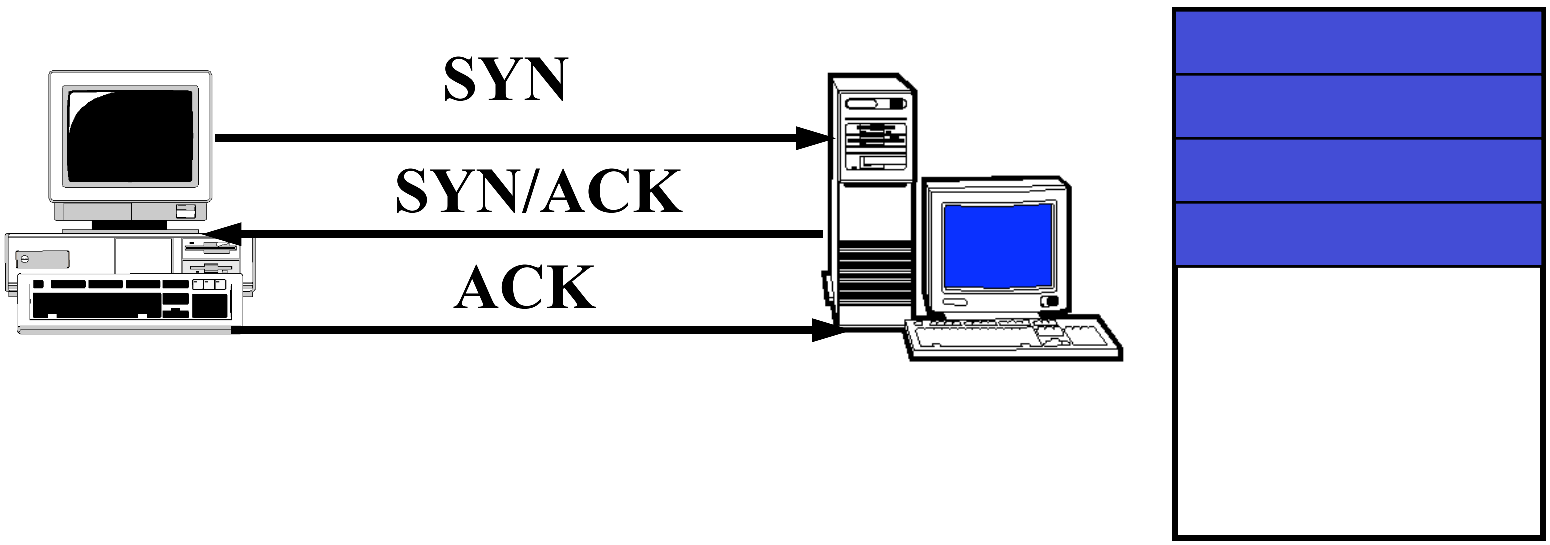
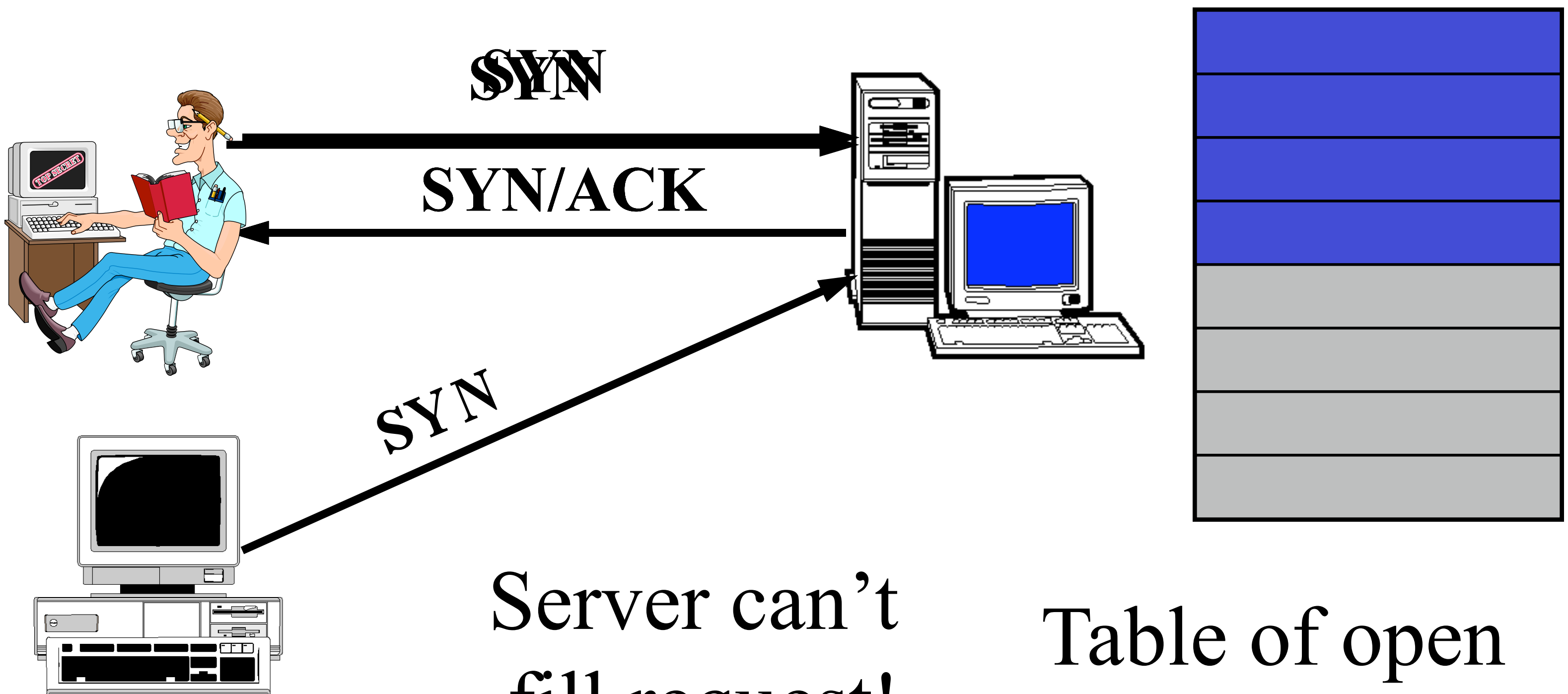


Table of open TCP connections

A SYN Flood



Server can't fill request!

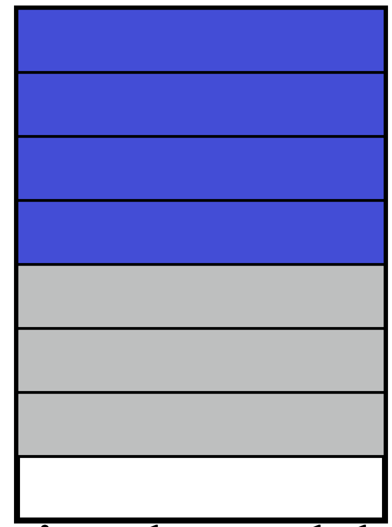
Table of open TCP connections

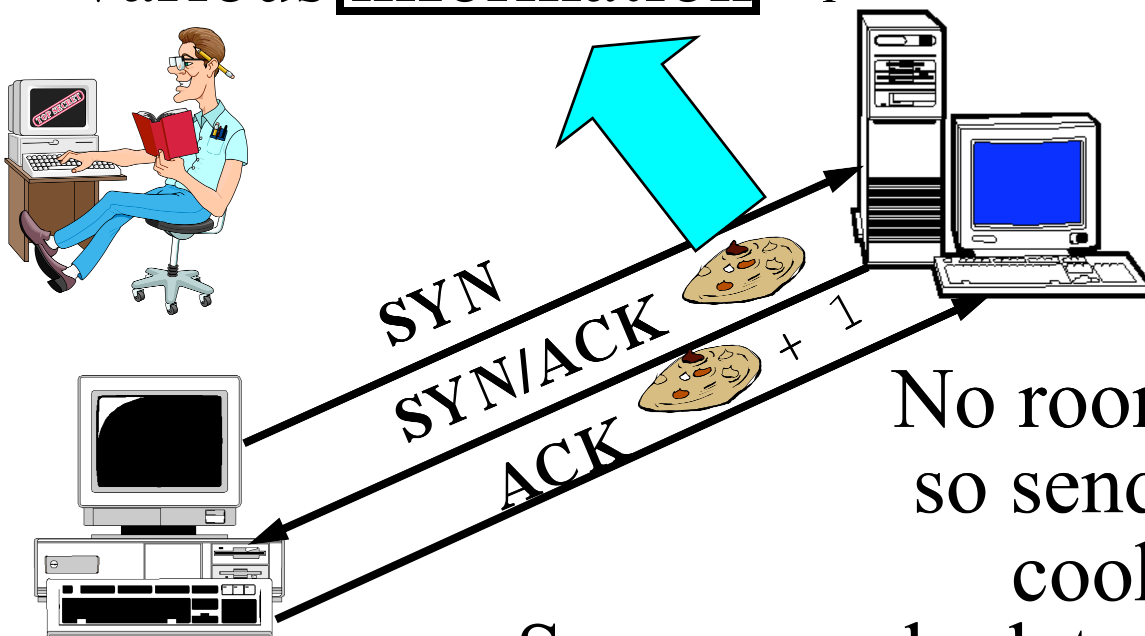
SYN Cookies

SYN/ACK number is secret function of various information

Client IP address & port, server's IP address and port, and a timer

KEY POINT: Server doesn't need to save cookie value!





No room in the table, so send back a SYN cookie, instead

Server recalculates cookie to determine if proper response

The Ping of Death

- IP packets are supposed to be no longer than 65,535 bytes long
- Can improperly send longer IP packets
- Some OS networking software wasn't prepared for that
  - Resulting in buffer overflows and crashes
- Can filter out pings, but other IP packets can also cause problem
- OS patches really solve the problem

Network Security Mechanisms

- Again, the usual suspects -
  - Encryption
  -
  -
  -
  - Traffic control

Encryption for Network Security

- Relies on the kinds of encryption algorithms and protocols discussed previously
- Can be applied at different places in the network stack
- With different effects and costs

IPSec

- Standard for applying cryptography at the network layer of IP stack
- Provides various options for encrypting and authenticating packets
  - On end-to-end basis
  - Without concern for transport layer (or higher)

What IPSec Covers

- Message integrity
- Message authentication
- Message confidentiality

What Isn't Covered

- Non-repudiation
- Digital signatures
- Key distribution
- Traffic analysis
- Handling of security associations
- Some of these covered in related standards

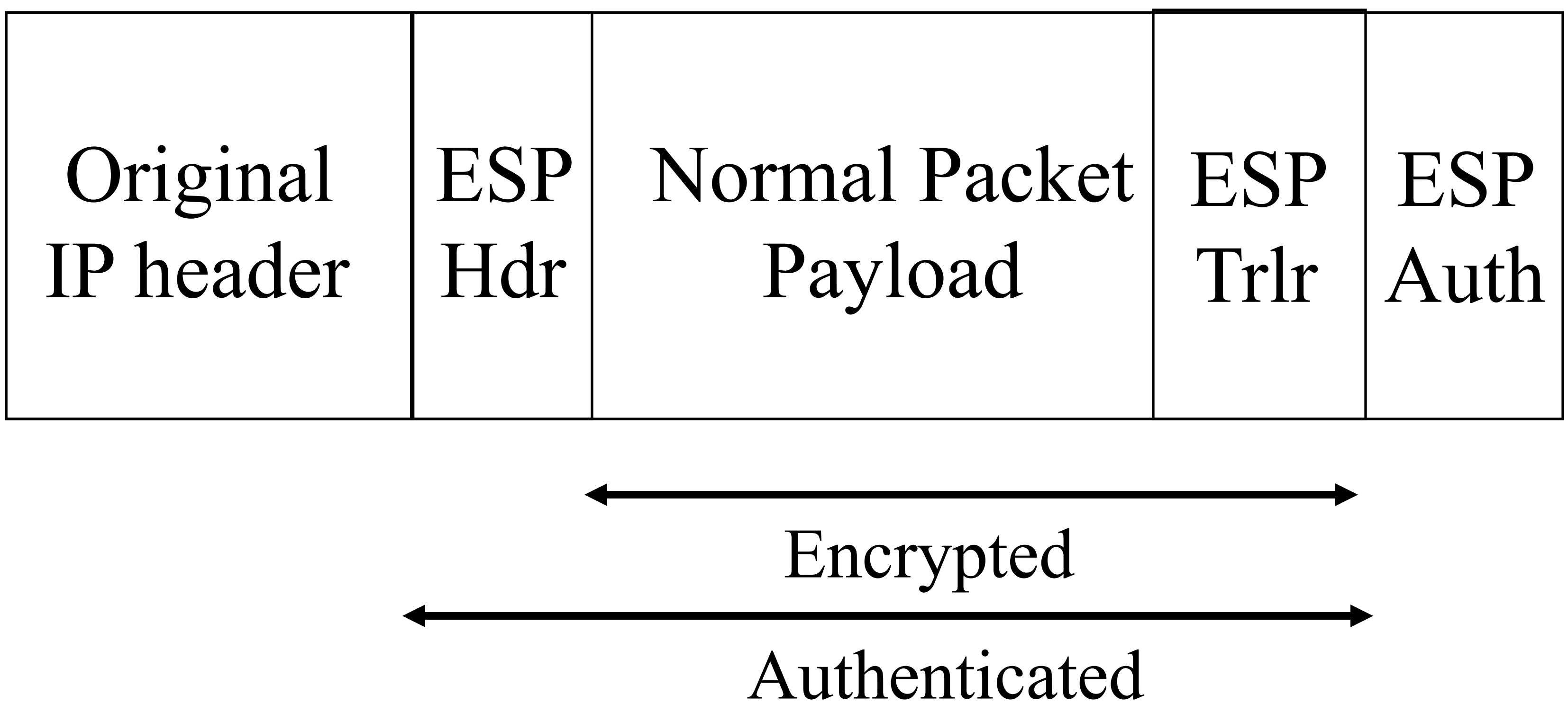
Some Important Terms for IPsec

- Security Association - “A Security Association (SA) is a simplex "connection" that affords security services to the traffic carried by it.
  – Basically, a secure one-way channel
- SPI (Security Parameters Index) – Combined with destination IP address and IPsec protocol type, uniquely identifies an SA

General Structure of IPsec

- Really designed for end-to-end encryption
  - Though could do link level
- Designed to operate with either IPv4 or IPv6
- Meant to operate with a variety of different encryption protocols
- And to be neutral to key distribution methods

ESP Transport Mode



What IPsec Requires

- Protocol standards
  - To allow messages to move securely between nodes
- Supporting mechanisms at hosts running IPsec
  - E.g., a Security Association Database
- Lots of plug-in stuff to do the cryptographic heavy lifting

The Protocol Components

- Pretty simple
- Necessary to interoperate with non-IPsec equipment
- So everything important is inside an individual IP packet's payload
- No inter-message components to protocol
  - Though some security modes enforce inter-message invariants

The Supporting Mechanisms

- Methods of defining security associations
- Databases for keeping track of what's going on with other IPsec nodes
  - To know what processing to apply to outgoing packets
  - To know what processing to apply to incoming packets

Plug-In Mechanisms

- Designed for high degree of generality
- So easy to plug in:
  - Different crypto algorithms
  - Different hashing/signature schemes
  - Different key management mechanisms

Status of IPsec

- Accepted Internet standard
- Widely implemented and used
  - Supported in Windows 2000, XP, and Vista
  - In Linux 2.6 kernel
- The architecture doesn't require everyone to use it
- RFC 3602 on using AES in IPsec still listed as "proposed"
- Expected that AES will become default for ESP in IPsec

Traffic Control Mechanisms

- Filtering
  - Source address filtering
  - Other forms of filtering
- Rate limits
- Protection against traffic analysis
  - Padding
  - Routing control

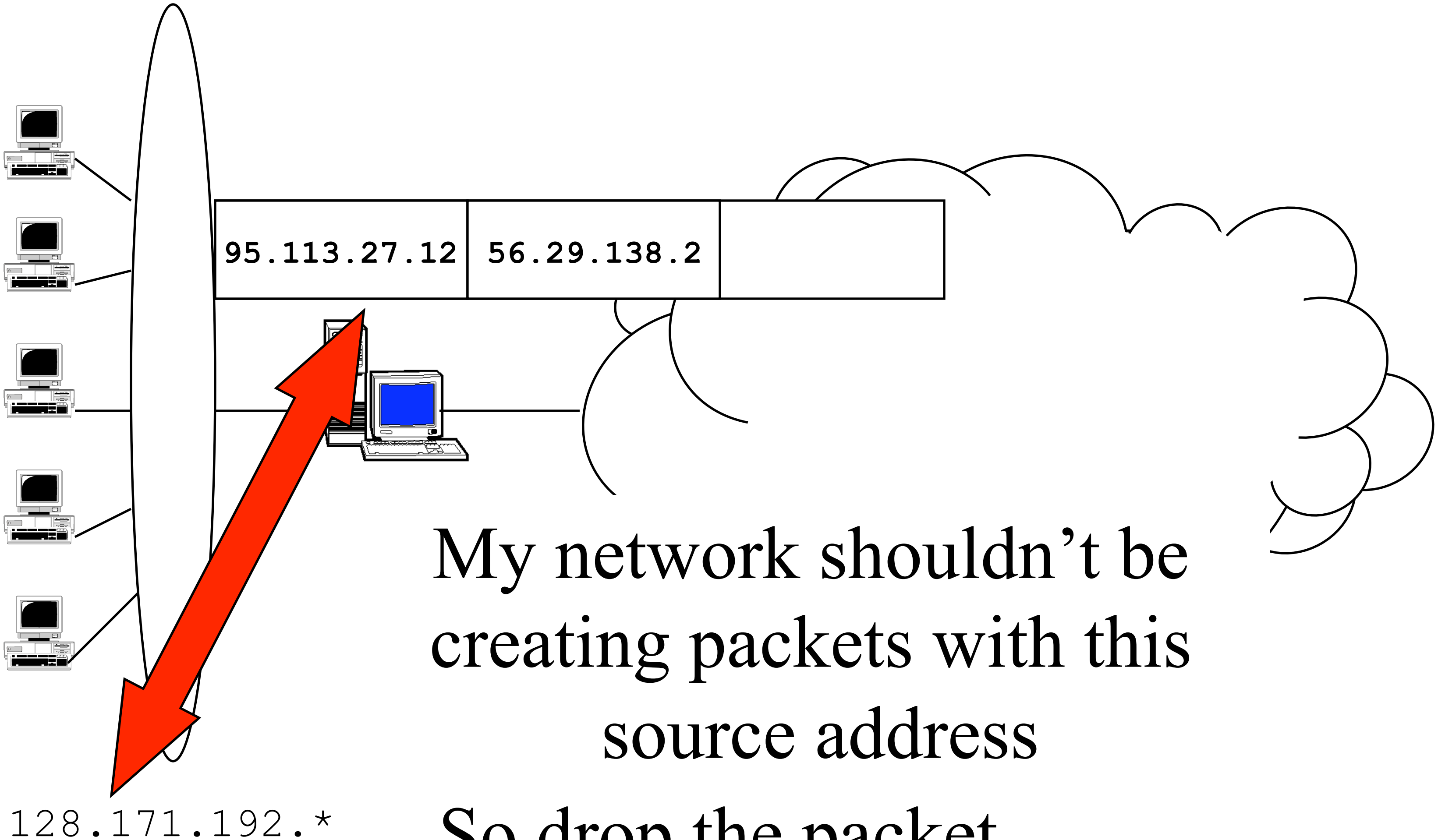
Source Address Filtering

- Filtering out some packets because of their source address value
  - Usually because you believe their source address is spoofed
- Often called ingress filtering
  - Or egress filtering . . .

Source Address Filtering for Address Assurance

- Router “knows” what network it sits in front of
  - In particular, knows IP addresses of machines there
- Filter outgoing packets with source addresses not in that range
- Prevents your users from spoofing other nodes’ addresses
  - But not from spoofing each other’s

Source Address Filtering Example



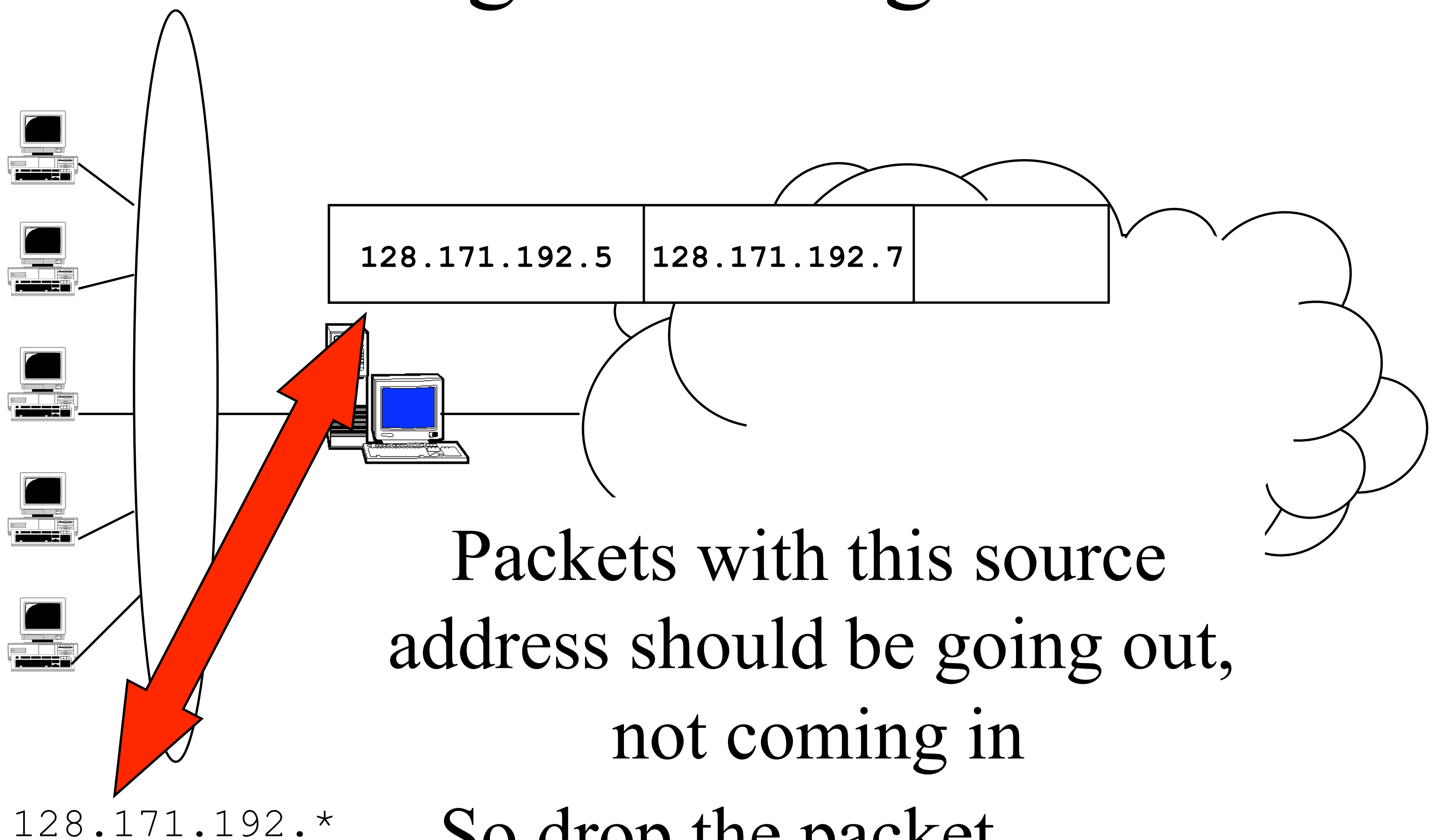
My network shouldn't be creating packets with this source address

So drop the packet

Source Address Filtering in the Other Direction

- Often called egress filtering
  - Or ingress filtering . . .
- Occurs as packets leave the Internet and enter a border router
  - On way to that router's network
- What addresses shouldn't be coming into your local network?

Filtering Incoming Packets



Packets with this source address should be going out, not coming in

So drop the packet

Other Forms of Filtering

- One can filter on things other than source address
  - Such as worm signatures, unknown protocol identifiers, etc.
- Also, there are unallocated IP addresses in IPv4 space
  - Can filter for packets going to or coming from those addresses
- Also, certain source addresses are for local use only
  - Internet routers can drop packets to/from them

Rate Limits

- Many routers can place limits on the traffic they send to a destination
- Ensuring that the destination isn't overloaded
  - Popular for denial of service defenses
- Limits can be defined somewhat flexibly
- But often not enough flexibility to let the good traffic through and stop the bad

Padding

- Sometimes you don't want intruders to know what your traffic characteristics are
- Padding adds extra traffic to hide the real stuff
- Fake traffic must look like real traffic
  – Usually means encrypt it all
- Must be done carefully, or clever attackers can tell the good stuff from the noise

Routing Control

- Use ability to control message routing to conceal the traffic in the network
- Used in *onion routing* to hide who is sending traffic to whom
  - For anonymization purposes
- Routing control also used in some network defense
  - To hide real location of a machine
  - E.g., SOS DDoS defense system