Network Security
CS 239
Computer Security
March 1, 2006

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 small number of machines, mostly related ones
- Other networks are very non-local
  - E.g., the Internet backbone
  - Vast numbers of users/sites share bandwidth

Implications of Locality

- Truly local networks may gain from physical security
- Relative trustworthiness of all participants may help
- Common interests of all on a local network may be helpful, too
- Wide area networks generally harder

Network Media

- Some networks are wires or cables
- Other networks run over the telephone lines
- Other networks are radio links to satellites
- Other networks are broadcast radio links

Implications of Media Type

- Wires can sometimes be physically protected
- Radio links generally can't
  - Though power and technology requirements for satellite links may provide some help
  - Directional antennae can also help

Protocol Types

- TCP/IP is probably the most widespread
  - 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

Methods of Attacks on Message Integrity

- Replacing part of a packet
- Changing headers to alter destination of a packet
  - Or its source
- Inserting improper packets into a proper packet stream

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

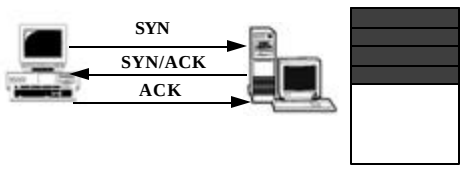
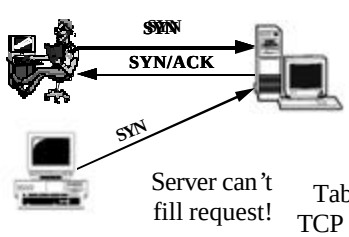


Table of open TCP connections

A SYN Flood

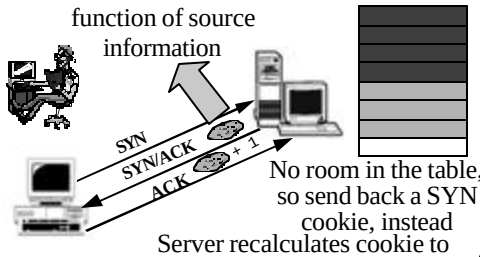


Server can't fill request!

Table of open TCP connections

SYN Cookies

SYN/ACK number is function of source information



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

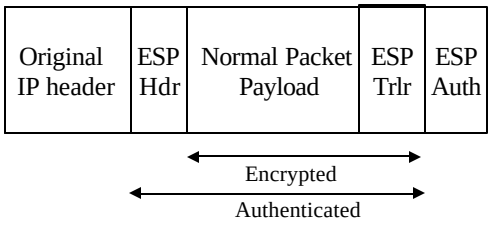
Some Important Terms for IPsec

- 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 and XP
  - 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

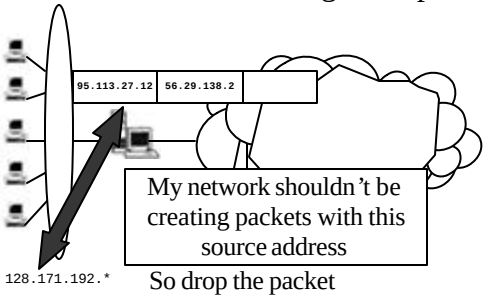
Source Address Filtering

- 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

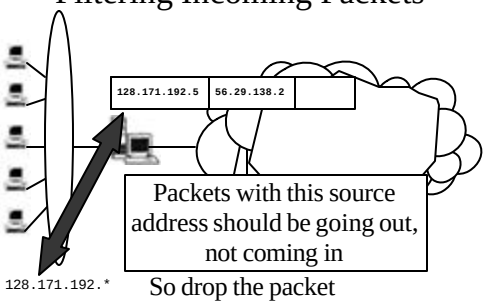
Source Address Filtering Example



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



Ingress/Egress Filtering

- Filtering source addresses for validity often called either ingress filtering or egress filtering
- Unfortunately, a lot of confusion on which is which
  - Conflicting RFCs, for example
- Basically, *ingress* is going in
- And *egress* is coming out
- Usually, it's a question of perspective

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
- Requires that fake traffic is not differentiable from real
- 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
- Especially important when trying to handle **covert channels**
  - Encapsulated users or programs trying to leak information out