INFS 766
Internet Security Protocols

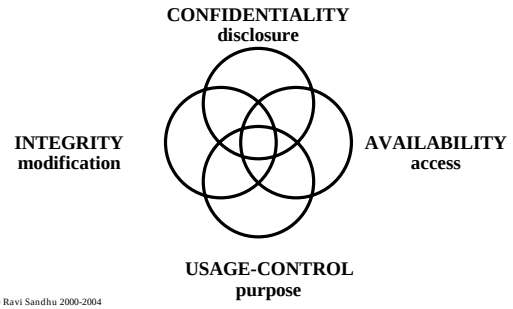
Lecture 1
Firewalls

Prof. Ravi Sandhu

INTERNET INSECURITY

- Internet insecurity spreads at Internet speed
  - Morris worm of 1987
  - Password sniffing attacks in 1994
  - IP spoofing attacks in 1995
  - Denial of service attacks in 1996
  - Email borne viruses 1999
  - Distributed denial of service attacks 2000
  - Fast spreading worms and viruses 2003
  - Spam 2004
  - … no end in sight
- Internet insecurity grows at super-Internet speed
  - security incidents are growing faster than the Internet (which has roughly doubled every year since 1988)

SECURITY OBJECTIVES



SECURITY TECHNIQUES

- Prevention
  - access control
- Detection
  - auditing/intrusion detection
  - incident handling
- Acceptance
  - practicality

THREATS, VULNERABILITIES ASSETS AND RISK

- THREATS are possible attacks
- VULNERABILITIES are weaknesses
- ASSETS are information and resources that need protection
- RISK requires assessment of threats, vulnerabilities and assets

RISK

- **Outsider Attack**
  - insider attack
- **Insider Attack**
  - outsider attack

PERSPECTIVE ON SECURITY

- No silver bullets
- A process NOT a turn-key product
- Requires a conservative stance
- Requires defense-in-depth
- A secondary objective
- Absolute security does not exist
- Security in most systems can be improved

PERSPECTIVE ON SECURITY

- absolute security is impossible does not mean absolute insecurity is acceptable

INTRUSION SCENARIOS

CLASSICAL INTRUSIONS SCENARIO 1

- Insider attack
  - The insider is already an authorized user
- Insider acquires privileged access
  - exploiting bugs in privileged system programs
  - exploiting poorly configured privileges
- Install backdoors/Trojan horses to facilitate subsequent acquisition of privileged access

CLASSICAL INTRUSIONS SCENARIO 2

- Outsider attack
- Acquire access to an authorized account
- Perpetrate an insider attack

NETWORK INTRUSIONS SCENARIO 3

- Outsider/Insider attack
- Spoof network protocols to effectively acquire access to an authorized account

DENIAL OF SERVICE ATTACKS

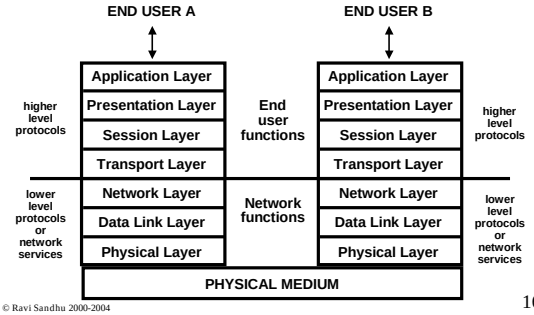
- **Flooding network ports with attack source masking**
- **TCP/SYN flooding of internet service providers in 1996**

INFRASTRUCTURE ATTACKS

- **router attacks**
  - **modify router configurations**
- **domain name server attacks**
- **internet service attacks**
  - **web sites**
  - **ftp archives**

INTERNET ARCHITECTURE AND PROTOCOLS

OSI REFERENCE MODEL



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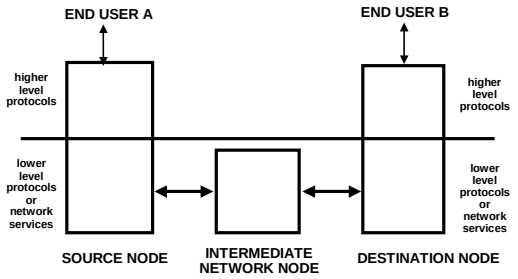


TCP/IP PROTOCOL STACK BASIC PROTOCOLS

layer				
5-7	TELNET	FTP	SMTP	HTTP etc
4	TCP	UDP		
3	IP			
2	Ethernet	Token-Ring	ATM	PPP etc

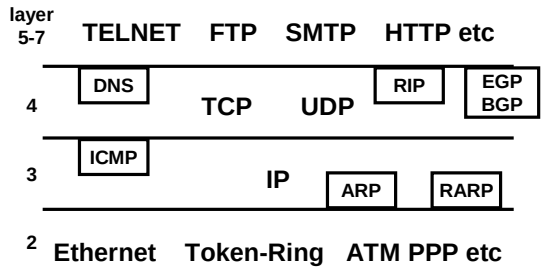
TCP/IP PROTOCOL STACK BASIC PROTOCOLS

- **IP (Internet Protocol)**
  - **connectionless routing of packets**
- **UDP (User Datagram Protocol)**
  - **unreliable datagram protocol**
- **TCP (Transmission Control Protocol)**
  - **connection-oriented, reliable, transport protocol**

TCP/IP PROTOCOL STACK BASIC PROTOCOLS

- **TELNET: remote terminal**
- **FTP (File Transfer Protocol)**
- **TFTP (Trivial File Transfer Protocol)**
- **SMTP (Simple Mail Transfer Protocol)**
- **RPC (Remote Procedure Call)**
- **HTTP (Hyper Text Transfer Protocol)**
- **and others**

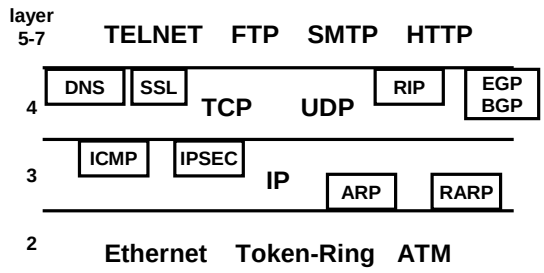
TCP/IP PROTOCOL STACK INFRASTRUCTURE PROTOCOLS



TCP/IP PROTOCOL STACK INFRASTRUCTURE PROTOCOLS

- **ICMP: Internet Control Message Protocol**
- **ARP: Address Resolution Protocol**
- **RARP: Reverse Address Resolution Protocol**
- **DNS: Domain Name Service**
- **RIP: Routing Information Protocol**
- **BGP: Border Gateway Protocol**
- **EGP: External Gateway Protocol**

TCP/IP PROTOCOL STACK SECURITY PROTOCOLS



INTERNET STANDARDS PROCESS

- **IETF: Internet Engineering Task Force**
  - **Application Area**
  - **General Area**
  - **Internet Area**
  - **Operational Requirements Area**
  - **Routing Area**
  - **Security Area**
  - **Transport Area**
  - **User Services Area**

IETF SECURITY AREA ACTIVE WORKING GROUPS

- An Open Specification for Pretty Good Privacy (openpgp)
- Authenticated Firewall Traversal (aft)
- Common Authentication Technology (cat)
- IP Security Policy (ipsp)
- IP Security Protocol (ipsec)
- IP Security Remote Access (ipsra)
- Intrusion Detection Exchange Format (idwg)
- Kerberized Internet Negotiation of Keys (kink)
- Kerberos WG (krb-wg)
- One Time Password Authentication (otp)
- Public-Key Infrastructure (X.509) (pkix)
- S/MIME Mail Security (smime)
- Secure Network Time Protocol (stime)
- Secure Shell (secsh)
- Securely Available Credentials (sacred)
- Security Issues in Network Event Logging (syslog)
- Simple Public Key Infrastructure (spki)
- Transport Layer Security (tls)
- Web Transaction Security (wts)
- XML Digital Signatures (xmldsig)

RFCs AND IETF DRAFTS

- **RFCs**
  - **Standards**
    - **Proposed Standard**
    - **Draft Standard**
    - **Internet Standard**
  - **Informational**
  - **Experimental**
  - **Historic**
- **IETF drafts**
  - **work in progress**
  - **expire after 6 months**

MUST, SHOULD, MAY

- **MUST**
  - **mandatory, required of compliant implementations**
- **SHOULD**
  - **strongly recommended but not required**
- **MAY**
  - **possibility**
  - **even if not stated a may is always allowed unless it violates MUST NOT**

TCP/IP VULNERABILITIES

BASIC TCP/IP VULNERABILITIES

- **many dangerous implementations of protocols**
  - **sendmail**
- **many dangerous protocols**
  - **NFS, X11, RPC**
  - **many of these are UDP based**

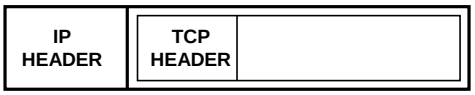
BASIC TCP/IP VULNERABILITIES

- **solution**
  - **allow a restricted set of protocols between selected external and internal machines**
  - **otherwise known as firewalls**

IP PACKET

- header
- data
  - carries a layer 4 protocol
    - TCP, UDP
  - or a layer 3 protocol
    - ICMP, IPSEC, IP
  - or a layer 2 protocol
    - IPX, Ethernet, PPP

TCP INSIDE IP



IP HEADER FORMAT

- version: 4bit, currently v4
- header length: 4 bit, length in 32 bit words
- TOS (type of service): unused
- total length: 16 bits, length in bytes
- identification, flags, fragment offset: total 16 bits used for packet fragmentation and reassembly
- TTL (time to live): 8 bits, used as hop count
- Protocol: 8 bit, protocol being carried in IP packet, usually TCP, UDP but also ICMP, IPSEC, IP, IPX, PPP, Ethernet
- header checksum: 16 bit checksum
- source address: 32 bit IP address
- destination address: 32 bit IP address

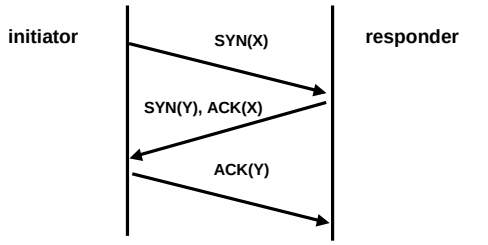
IP HEADER FORMAT

- options
  - source routing
    - enables route of a packet and its response to be explicitly controlled
  - route recording
  - timestamping
  - security labels

TCP HEADER FORMAT

- source port number
  - source IP address + source port number is a socket: uniquely identifies sender
- destination port number
  - destination IP address + destination port number is a socket : uniquely identifies receiver
- SYN and ACK flags
- sequence number
- acknowledgement number

TCP 3 WAY HANDSHAKE



TCP SYN FLOODING ATTACK

- **TCP 3 way handshake**
  - **send SYN packet with random IP source address**
  - **return SYN-ACK packet is lost**
  - **this half-open connection stays for a fairly long time out period**
- **Denial of service attack**
- **Basis for IP spoofing attack**

IP SPOOFING

- **Send SYN packet with spoofed source IP address**
- **SYN-flood real source so it drops SYN-ACK packet**
- **guess sequence number and send ACK packet to target**
  - **target will continue to accept packets and response packets will be dropped**

TCP SESSION HIJACKING

- **Send RST packet with spoofed source IP address and appropriate sequence number to one end**
- **SYN-flood that end**
- **send ACK packets to target at other end**

SMURF ATTACK

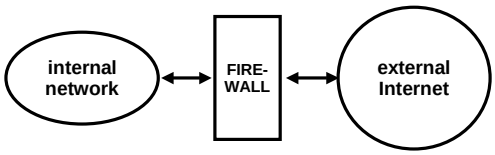
- **Send ICMP ping packet with spoofed IP source address to a LAN which will broadcast to all hosts on the LAN**
- **Each host will send a reply packet to the spoofed IP address leading to denial of service**

ULTIMATE VULNERABILITY

- **IP packet carries no authentication of source address**
- **IP spoofing is possible**
  - **IP spoofing is a real threat on the Internet**
  - **IP spoofing occurs on other packet-switched networks also, such as Novell's IPX**
- **Firewalls do not solve this problem**
- **Requires cryptographic solutions**

FIREWALLS

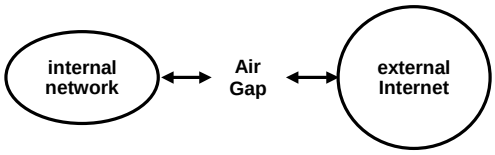
WHAT IS A FIREWALL?



WHAT IS A FIREWALL?

- **all traffic between external and internal networks must go through the firewall**
  - **easier said than done**
- **firewall has opportunity to ensure that only suitable traffic goes back and forth**
  - **easier said than done**

ULTIMATE FIREWALL



BENEFITS

- **secure and carefully administer firewall machines to allow controlled interaction with external Internet**
- **internal machines can be administered with varying degrees of care**
- **does work**

BASIC LIMITATIONS

- **connections which bypass firewall**
- **services through the firewall introduce vulnerabilities**
- **insiders can exercise internal vulnerabilities**
- **performance may suffer**
- **single point of failure**

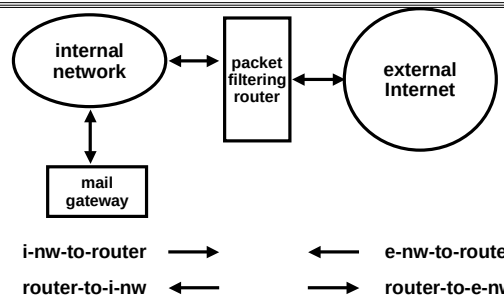
TYPES OF FIREWALLS

- **Packet filtering firewalls**
  - **IP layer**
- **Application gateway firewalls**
  - **Application layer**
- **Circuit relay firewalls**
  - **TCP layer**
- **Combinations of these**

PACKET FILTERING FIREWALLS

- **IP packets are filtered based on**
  - **source IP address + source port number**
  - **destination IP address + destination port number**
  - **protocol field: TCP or UDP**
  - **TCP protocol flag: SYN or ACK**

FILTERING ROUTERS



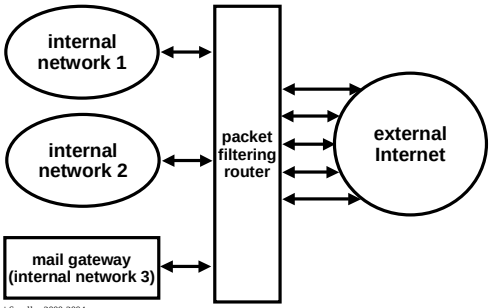
PACKET FILTERING FIREWALLS

- **drop packets based on filtering rules**
- **static (stateless) filtering**
  - **no context is kept**
- **dynamic (statefull) filtering**
  - **keeps context**

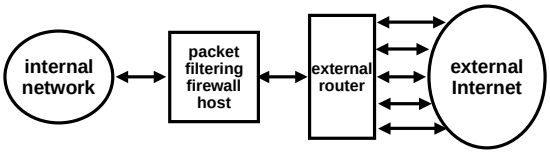
PACKET FILTERING FIREWALLS

- **Should never allow packet with source address of internal machine to enter from external internet**
- **Cannot trust source address to allow selective access from outside**

FILTERING ROUTERS



FILTERING HOST

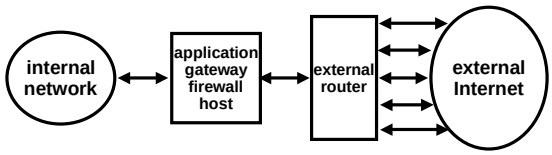


- **one can use a packet filtering firewall even if connection to Internet is via an external service provider**

PACKET FILTERING FIREWALLS

- packet filtering is effective for coarse-grained controls
- not so effective for fine-grained control
  - can do: allow incoming telnet from a particular host
  - cannot do: allow incoming telnet from a particular user

APPLICATION GATEWAY FIREWALLS



SIMPLEST CONFIGURATION

APPLICATION PROXIES

- have to be implemented for each service
- may not be safe (depending on service)

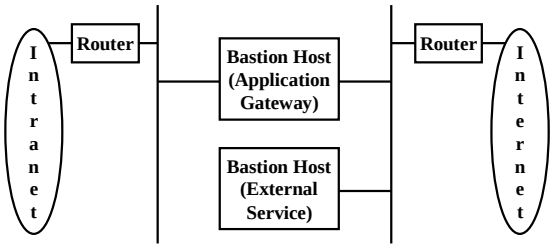
CLIENT-SIDE PROXIES Internal-Client External-Server

- allow outgoing http for web access to external machines from internal users
- requires some client configuration

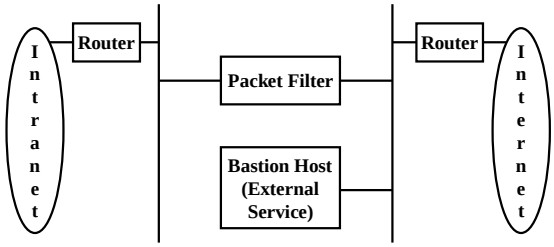
SERVER-SIDE PROXIES External-Client Internal-Server

- allow incoming telnet for access to selected internal machines from selected external users
- requires some cryptographic protection to thwart sniffing and IP spoofing
- becoming increasingly important for
  - electronic commerce
  - VPN
  - remote access security

FIREWALL ARCHITECTURES DUAL HOMED HOST



FIREWALL ARCHITECTURES SCREENED SUBNET



INTRUSION DETECTION

RELATED TECHNOLOGIES

- Intrusion detection
- Vulnerability assessment
- Incident response
- Honey pots
- Sniffer probes

INTRUSION DETETCION TECHNIQUES

- Policy detection (or knowledge-based)
  - default permit
    - attack-signature based detection
    - also called misuse detection
  - default deny
    - specification-based detection
- Anomaly detection (or behavior-based)
  - requires user profiling
  - requires some learning capability in the system
- Combinations of these

INTRUSION DETECTION DATA SOURCE

- network-based intrusion detection
  - multiple sensor points
- host-based intrusion detection
  - multi-host based
- application-based intrusion detection
- combinations of these

ATTACKER

- Outsider
  - easier
- insider
  - harder

INTRUSION DETECTION ISSUES

- **effectiveness**
- **efficiency**
- **security**
- **inter-operability**
- **ease of use**
- **transparency**

INTRUSION DETECTION CHALLENGES

- **False alarm rate**
- **Performance and scalability**

BASE RATE FALLACY

- **Test for a disease is 99% accurate**
  - **100 disease-free people tested, 99 test negative**
  - **100 diseased people tested, 99 test positive**
- **Prevalence of disease is 1 in 10,000**
- **Alice tests positive**
- **What is probability Alice has the disease?**

BASE RATE FALLACY

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  - **100 disease-free people tested, 99 test negative**
  - **100 diseased people tested, 99 test positive**
- **Prevalence of disease is 1 in 10,000**
- **Alice tests positive**
- **What is probability Alice has the disease?**
  1 in 100
- **False alarm rate: 99 in 100 !!!!!**

BASE RATE FALLACY BAYE'S THEOREM

- **population: 1,000,000**
- **diseased: 100**
- **disease free: 999,900**
- **false positive: 9,999**
- **true positive: 99**
- **Alice's chance of disease: 99/(9,999+99) = 1/100**

BASE RATE FALLACY 99.99% ACCURACY

- **population: 1,000,000**
- **diseased: 100**
- **disease free: 999,900**
- **false positive: 99.99**
- **true positive: 99.99**
- **Alice's chance of disease: 99.99/(99.99+99.99) = 1/2**

NETWORK-BASED INTRUSION DETECTION SIGNATURES

- **port signatures**
- **header signatures**
- **string signatures**

NETWORK-BASED INTRUSION DETECTION ADVANTAGES

- **Complements firewalls**
- **broad visibility into network activity**
- **no impact on network performance**
- **transparent installation**

NETWORK-BASED INTRUSION DETECTION DISADVANTAGES

- **False positives**
- **miss new unknown attacks**
- **scalability with high-speed networks**
- **passive stance**
- **emergence of switched Ethernet**

HOST-BASED INTRUSION DETECTION

- **host wrappers or personal firewalls**
  - **look at all network packets, connection attempts, or login attempts to the monitored machine**
    - **example, tcp-wrapper**
- **host-based agents**
  - **monitor accesses and changes to critical system files and changes in user privilege**
    - **example, tripwire**

INTRUSION DETECTION STANDARDS

- **None exist**
- **ongoing efforts**
  - **CIDF: common intrusion detection framework**
    for sharing information
  - **IETF Intrusion Detection Working Group**
    just started

INTRUSION DETECTION

- **Needs to integrate with other security technologies such as cryptography and access control**
- **one component of defense-in-depth layered security strategy**
- **incident-response and recovery are important considerations**