INFS 766
Internet Security Protocols

Lectures 1 and 2
Firewalls

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CONTACT INFORMATION

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OPENING REMARKS

SCHEDULE OF CLASSES

01/23/02	1	Firewalls
01/30/02	2	Firewalls
02/06/02	3	Cryptography
02/13/02	4	Cryptography
02/20/02	5	SSL
02/27/02	6	review
03/06/02	**exam 1**	**lectures 1-6**
03/13/02	–	Spring Break
03/20/02	7	Digital Certificates
03/27/02	8	IPSEC
04/03/02	9	IPSEC
04/10/02	10	Kerberos
04/17/02	11	PKCS
04/24/02	12	to be announced
05/01/02	13	review
05/08/02	**exam 2**	**lectures 7-13**

COURSE PREREQUISITE

- **Must have completed INFS 612 or equivalent**
  - **concurrent enrollment in INFS 612 does not satisfy prerequisite**
  - **make your own judgment about equivalence to INFS 612, please don't ask me**
- **INFS 762 is not required as a prerequisite**
- **Must be internet, web and pdf capable**
- **This is a protocols-oriented course**
  - **without these prerequisites you will have a hard time and will get no sympathy from me**

COURSE MATERIAL

- **No text book**
  - **No suitable book is available**
- **Lecture slides are posted on the class web site in pdf format**

GRADING

- **Two in-class closed book exams**
- **Equal weightage**
- **Each lecture is important**

REFERENCE BOOKS

- Network Security Essentials, William Stallings, Prentice-Hall, 2000
- Security Technologies for the World Wide Web, Rolf Oppliger, Artech House, 2000
- Internet and Intranet Security, Rolf Oppliger, Artech House, 1998
- Building Internet Firewalls, Brent Chapman and Elizabeth Zwicky, O'Reilly and Associates, 1995
- Network Security: Private Communication in a Public World, C. Kaufman, R. Perlman and M. Speciner, Prentice-Hall, 1995

WEB SOURCES

- **source for RFCs and IETF**
  - **http://www.ietf.org**
- **cryptographic sources**
  - **RSA's frequently asked questions: http://www.rsasecurity.com/rsalabs/faq/index.html**
  - **NIST encryption home page: http://csrc.nist.gov/encryption/**
- **firewall sources**
  - **Firewalls frequently asked questions: http://www.interhack.net/pubs/fwfaq/**

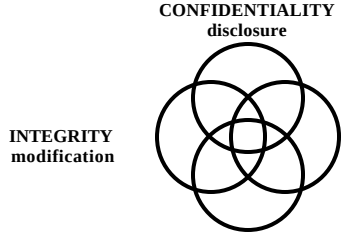
SECURITY COURSES CYCLE

- **Fall**
  - **INFS 762 Information Systems Security**
  - **INFS 767 Secure Electronic Commerce**
- **Spring**
  - **INFS 766 Internet Security Protocols**
  - **INFS 765 Database & Distributed Sys. Security**

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**
- **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**

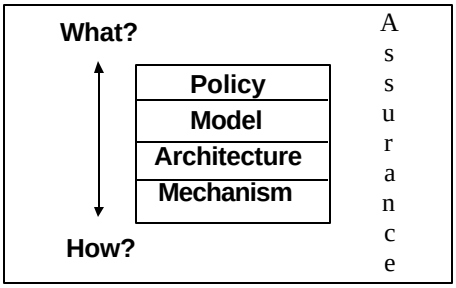
PERSPECTIVE ON SECURITY

- **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**

ENGINEERING AUTHORITY & TRUST 4 LAYERS



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

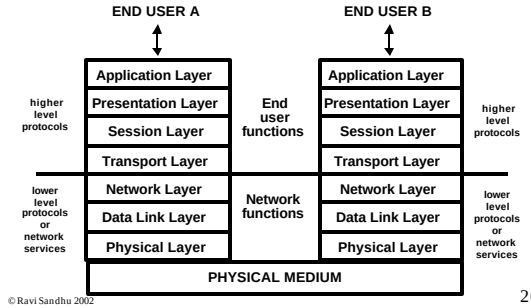
- **Flooding network ports with attack source masking**
- **TCP/SYN flooding of internet service providers in 1996**

INFRASTRUCTURE ATTACKS

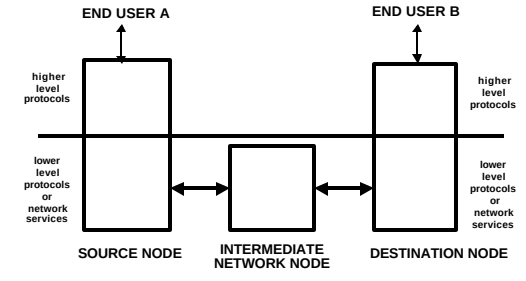
- **router attacks**
  - **modify router configurations**
- **domain name server attacks**
- **internet service attacks**
  - **web sites**
  - **ftp archives**

INTERNET ARCHITECTURE AND PROTOCOLS

OSI REFERENCE MODEL



OSI REFERENCE MODEL



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

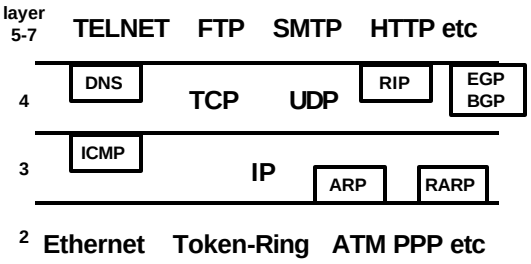
TCP/IP PROTOCOL STACK BASIC PROTOCOLS

- **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**

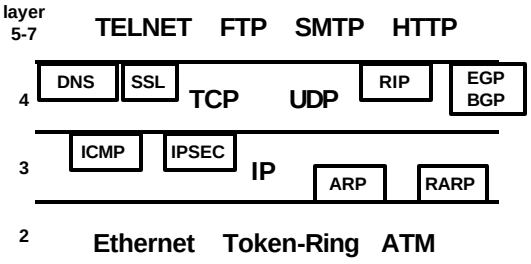
TCP/IP PROTOCOL STACK INFRASTRUCTURE PROTOCOLS



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**

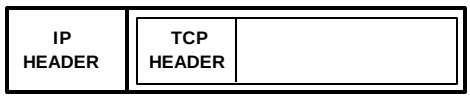
BASIC TCP/IP VULNERABILITIES

- **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

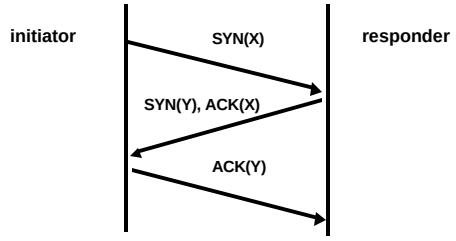
IP HEADER FORMAT

- **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

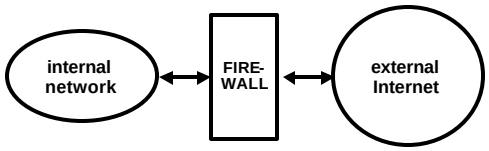
- Send RST packet with spoofed source IP address and appropriate sequence number to one end
- SYN-flood that end
- send ACK packets to target at other end

FIREWALLS

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

WHAT IS A FIREWALL?



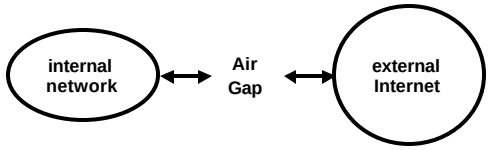
ULTIMATE VULNERABILITY

- 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

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

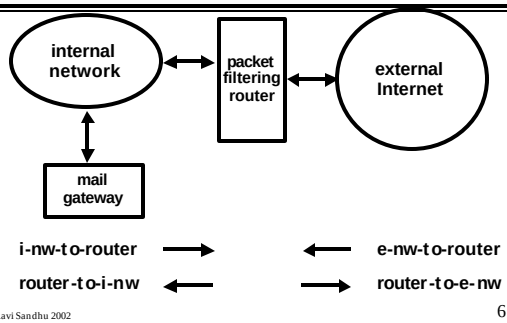
TYPES OF FIREWALLS

- 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



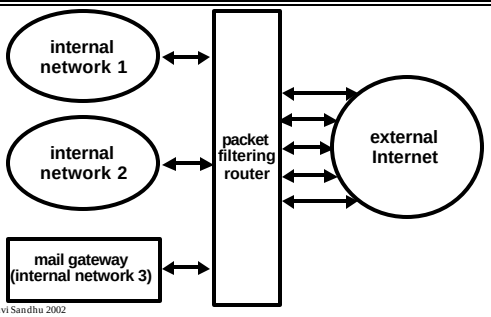
PACKET FILTERING FIREWALLS

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

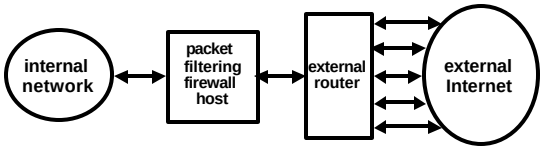
PACKET FILTERING FIREWALLS

- 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

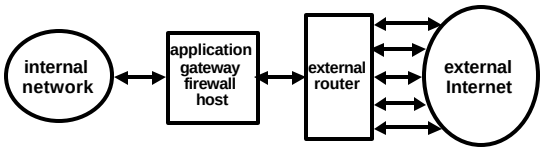


- one can use a packet filtering firewall even if connection to Internet is via an external service provider

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)

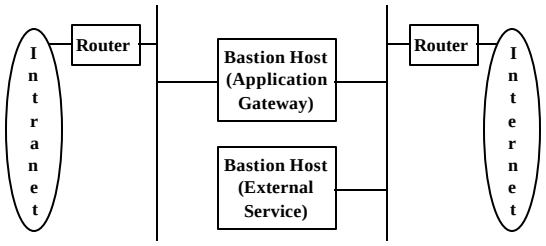
CLIENT-SIDE PROXIES
Internal-Client External-Server

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

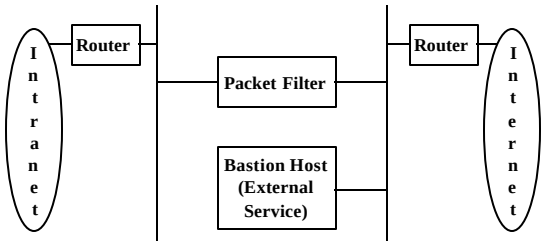
SERVER-SIDE PROXIES
External-Client Internal-Server

- 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

- **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?**
  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**