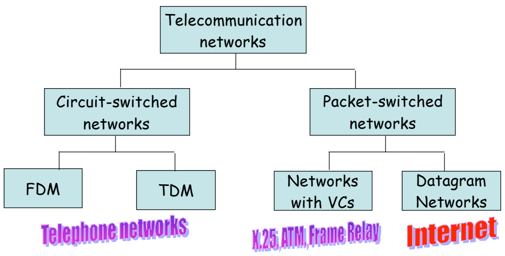
An Overview of Network Security

Coverage

- Lower Layers
- Upper Layers
- The Web

- From Security Point of View

Network taxonomy



Telecommunication networks

Circuit-switched networks

Packet-switched networks

FDM

TDM

Networks with VCs

Datagram Networks

Telephone networks

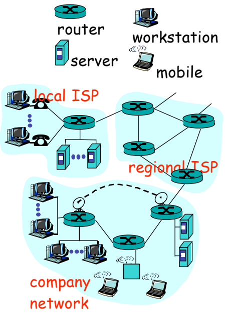
X.25, ATM, Frame Relay

Internet

What’s the Internet: “nuts and bolts” view

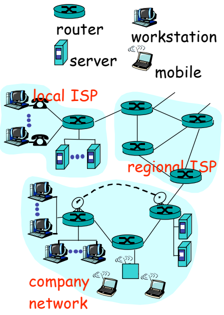
- millions of connected computing devices: *hosts, end-systems*
  - PCs workstations, servers
  - PDAs phones, toasters

  running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate = ***bandwidth***
- *routers:* forward packets (chunks of data)



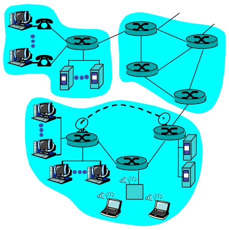
What’s the Internet: “nuts and bolts” view

- *protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, FTP, PPP
- *Internet:* “network of networks”
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



What’s the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - Web, email, games, e-commerce, database., voting, file (MP3) sharing
- communication services provided to apps:
  - connectionless
  - connection-oriented

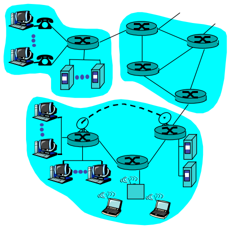


- cyberspace [Gibson]:

  “a consensual hallucination experienced daily by billions of operators, in every nation, ..."

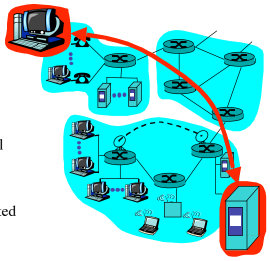
A closer look at network structure:

- network edge: applications and hosts
- network core:
  - routers
  - network of networks
- access networks, physical media: communication links



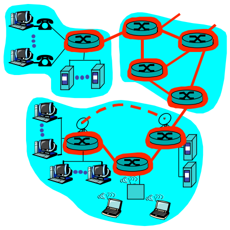
The network edge:

- end systems (hosts):
  - run application programs
  - e.g. Web, email
  - at “edge of network”
- client/server model
  - client host requests, receives service from always-on server
  - e.g. Web browser/server; email client/server
- peer-peer model:
  - minimal (or no) use of dedicated servers
  - e.g. Gnutella, KaZaA



The network core

- mesh of interconnected routers
- *the* fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete “chunks”



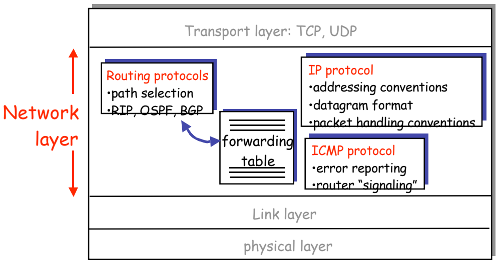
Lower Layers

- IP
- ARP
- ICMP
- TCP
- UDP
- SCTP

- Routing Protocols
  - RIP, OSPF, BGP
- DNS
- BOOTP & DHCP
- IPv6
- NAT
- Wireless Security

IP

A network layer protocol:



Transport layer: TCP, UDP

Network layer

Routing protocols
- path selection
- RIP, OSPF, BGP

IP protocol
- addressing conventions
- datagram format
- packet handling conventions

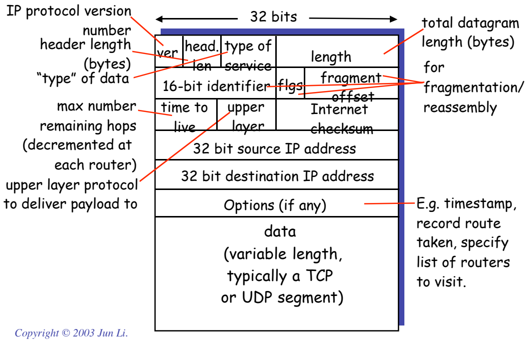
forwarding table

ICMP protocol
- error reporting
- router “signaling”

Link layer

physical layer

IP datagram format



32 bits

ver	head. len	type of service	length	
16-bit identifier			flgs	fragment offset
time to live		upper layer	Internet checksum	
32 bit source IP address				
32 bit destination IP address				
Options (if any)				
data (variable length, typically a TCP or UDP segment)				

IP protocol version number

header length (bytes)

“type” of data

max number remaining hops (decremented at each router)

upper layer protocol to deliver payload to

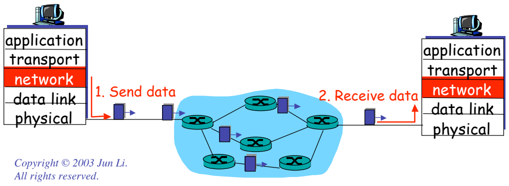
total datagram length (bytes)

for fragmentation/ reassembly

E.g. timestamp, record route taken, specify list of routers to visit.

IP Packet Forwarding

- no call setup at network layer
- routers: no state about end-to-end connections
  - no network-level concept of “connection”
- packets forwarded using destination host address
  - packets between same source-dest pair may take different paths

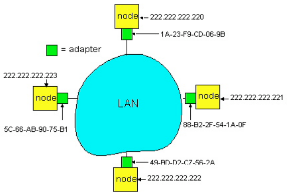


IP Security Issues

- IP Spoofing
  - Forged source address
    - Any host can transmit a packet with any source address
- Packet inception
  - Man-in-the-middle attack
- What else?

ARP: Address Resolution Protocol

Question: how to determine MAC address of B knowing B’s IP address?



- Each IP node (Host, Router) on LAN has ARP table
- ARP Table: IP/MAC address mappings for some LAN nodes

< IP address; MAC address; TTL>

- TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)

ARP Security Issues

- Problematic if an untrusted node has write access to the local net
- ARP spoofing
  - Use phony queries or replies
  - Such that all/some traffic misdirected
- What else?

ICMP: Internet Control Message Protocol

- used by hosts, routers, gateways to communication network-level information
  - error reporting: unreachable host, network, port, protocol
  - echo request/reply (used by ping)
- network-layer “above” IP:
  - ICMP msgs carried in IP datagrams
- ICMP message: type, code plus first 8 bytes of IP datagram causing error

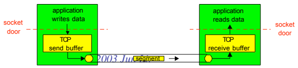
Type	Code	description
0	0	echo reply (ping)
3	0	dest. network unreachable
3	1	dest host unreachable
3	2	dest protocol unreachable
3	3	dest port unreachable
3	6	dest network unknown
3	7	dest host unknown
4	0	source quench (congestion control - not used)
8	0	echo request (ping)
9	0	route advertisement
10	0	router discovery
11	0	TTL expired
12	0	bad IP header

ICMP Security Issues

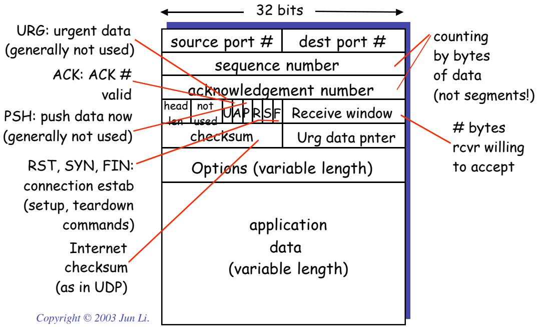
- ICMP can be abused to tear down connections
- Can also be abused to create new paths to a destination
  - Using the REDIRECT ICMP message
- Block ICMP messages at firewalls?

TCP

- point-to-point:
  - one sender, one receiver
- reliable, in-order *byte steam:*
  - no “message boundaries”
- pipelined:
  - TCP congestion and flow control set window size
- *send & receive buffers*
- full duplex data:
  - bi-directional data flow in same connection
  - MSS: maximum segment size
- connection-oriented:
  - handshaking (exchange of control msgs) init’s sender, receiver state before data exchange
- flow controlled:
  - sender will not overwhelm receiver



TCP Segment

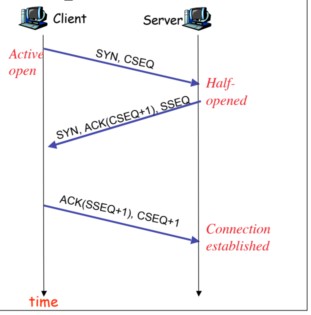


TCP Security Issues

- TCP open
- TCP privileged ports
- TCP stream vs. firewall

TCP Security Issues
- TCP Open

- SYN Attacks
  - Flood a TCP server with SYN packets
  - Make the server in half-opened status with many connections
  - Can cause DDoS
- Detect what services a server provides
- Sequence number attack
  - If an attacker can predict the sequence number expected by an victim



TCP Security Issues
- Privileged ports

- What are privileged ports
  - A unix convention that only can be created by the *root*
  - Less than 1024
  - Goal: remote systems can trust the authenticity of into written to such ports
- This goal really is just a hope
  - Not required by TCP specification
  - Meaningless on non-Unix systems
  - One may not necessarily trust the sanctity of a privileged port

TCP Security Issues
- TCP Stream vs. Firewall

- With TCP, data flows like a stream
  - There is no boundary
  - Thus hard for a firewall to filter individual packets

TCP Security Issues

- What else?

UDP

- Extends to applications the same level of service used by IP
  - Best-effort delivery
- Security Issues
  - UDP has no flow control, etc.
    - Large UDP transmissions may swamp the network
  - Certainly still has the IP spoofing problem
  - What else?

SCTP

- A new transport protocol (stream control transmission protocol)
- Read the brief description from course reserve materials

Routing Protocols

- Routing is the process of discovering, selecting, and employing paths from sources to destinations
- Often asymmetric
- RIP, OSPF, IS-IS, BGP, etc.

Security Issues

- Some routing options can be abused
  - Source routing
- A routing protocol itself can be subverted
  - Inject bogus routing updates, for example
    - A good router may be cheated to spread deceptive routing updates
  - A router could be compromised

BGP Security Issues

- BGP is a routing protocol for the core of the Internet at AS level
  - Routing announcements are exchanged via TCP
- Corrupt announcements can be used to perform a variety of attacks
  - An attacker can play BGP games
    - Can eavesdrop on, hijack or suppress BGP sessions
  - And other attacks

DNS

- A distributed database that maps hostnames to IP addresses, or vice versa
- Two logically distinct tree-structured namespaces
  - One for name to IP address (forward mapping), the other for IP address to name (backward mapping)
- Transport protocols for DNS
  - DNS query is UDP-based
  - But zone transfer is TCP-based
    - For backup servers to get a full copy of their portion in the name space

DNS Security Issues

- An attacker in control of the inverse mapping tree
  - A non-trusted IP address may thus map to a trusted name
  - Well, easy to deal if the forward mapping tree is authentic (cross-checking)
  - The attacker can further try to poison the victim’s DNS cache
- Omission of a trailing period
  - “foo.com” will be tried as “foo.com.cs.uoregon.edu” then “foo.com.uoregon.edu” then “foo.com.edu” then “foo.com”
  - What if an attacker builds a name server for “com.edu” domain?

BOOTP & DHCP

- DHCP is an extension of the simpler BOOTP
- Through a DHCP server, a client can obtain a lot of info
  - IP address
  - DNS server
  - Default route address
  - Default domain name, or even
  - NTS server
  - etc.

DHCP Security Issues

- DHCP runs on a LAN
  - Thus less security concerns
- But still subject to man-in-the-middle and DOS attacks
  - Essentially same security issues as ARP
- A rogue DHCP server?
- Applying for DHCP service endlessly?
  - To deplete available IP addresses for a local domain
- What else?

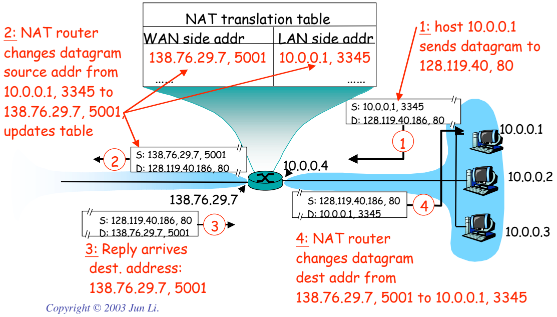
IPv6

- Same philosophy as IPv4 as an unreliable best-effort delivery protocol
- Allows interesting address types
  - *Anycast* adrdresses
    - Multiple machines map to the same address
  - *Site-local* addresses
    - Some addresses are purely local to a “site”
  - *Link-local* addresses
    - Limited to a single link
- New protocols
  - Neighbor Discovery protocol (similar to ARP)
  - DHCPv6

IPv6 Security Issues

- Renumbering
  - How to enfoce a secure incremental v4->v6 transition?
- Hosts can generate its own temporary IP address
  - Making the traceback harder
- *Anycast* addresses
  - How to decide exactly which machine is the attacker
- *Site-local* and *link-local* addresses
  - Uncertain whether this is a good access control mechanism
- IPv6-capable firewall?
- What else?

NAT: Network Address Translation



NAT translation table

WAN side addr	LAN side addr
138.76.29.7, 5001	10.0.0.1, 3345
……	……

1: host 10.0.0.1 sends datagram to 128.119.40, 80

2: NAT router changes datagram source addr from 10.0.0.1, 3345 to 138.76.29.7, 5001, updates table

3: Reply arrives dest. address: 138.76.29.7, 5001

4: NAT router changes datagram dest addr from 138.76.29.7, 5001 to 10.0.0.1, 3345

NAT Security Issues

- Does not get along well with encryption
  - The port number is often encrypted as part of IP payload
  - IPsec is not compatible with NAT
    - IPsec protects checksum, which includes the IP address

Wireless Security

- Limited energy
  - Battery attack
- Easier eavesdropping
  - Cannot just lock your office door
- Harder border control
  - Can a wireless firewall be set up?
- Fragile routing infrastructure
  - Normal wireless nodes used as forwarding nodes
- Harder to trace back an attacker
  - Nodes are often mobile
- Security service is often not available
  - Hardly any on authentication, key management, etc.