CSE 265: System and Network Administration

- TCP/IP Networking
  - We will cover just some of the practical issues
  - Highly recommend taking a networking course

- What is TCP/IP?
- Layers, addresses, NAT
- Protocols: ARP, DHCP

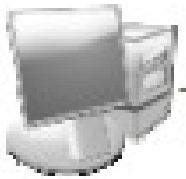
TCP/IP

- Most common networking protocol suite
- Foundation of the Internet
  - 2.8B+ users online worldwide (Dec 2013)
  - 1.01B+ hosts online (Jan 2014)
- Network applications typically use one of two transport protocols:
  - TCP – Transmission Control Protocol
  - UDP – User Datagram Protocol
- All traffic carried by IP – Internet Protocol

Protocols

- IP
  - Packet-oriented (routers don't care what is in packets or what came before)
- TCP
  - Connection-oriented, two-way, reliable, in-order transport of stream of bytes
  - Congestion control – slow down when congestion is noticed, speed up when resources available
  - Flow control – don't overwhelm receiver
- UDP
  - Unreliable but quick/easy transport of individual packets

TCP/IP network stack



Application Layer

When a user initiates a data transfer, this layer passes the request to the Transport layer

Transport Layer

The Transport layer attaches a header and passes the data to the Network Layer

Network Layer

At the Network layer, source and destination IP addresses are added for routing purposes

Datalink Layer

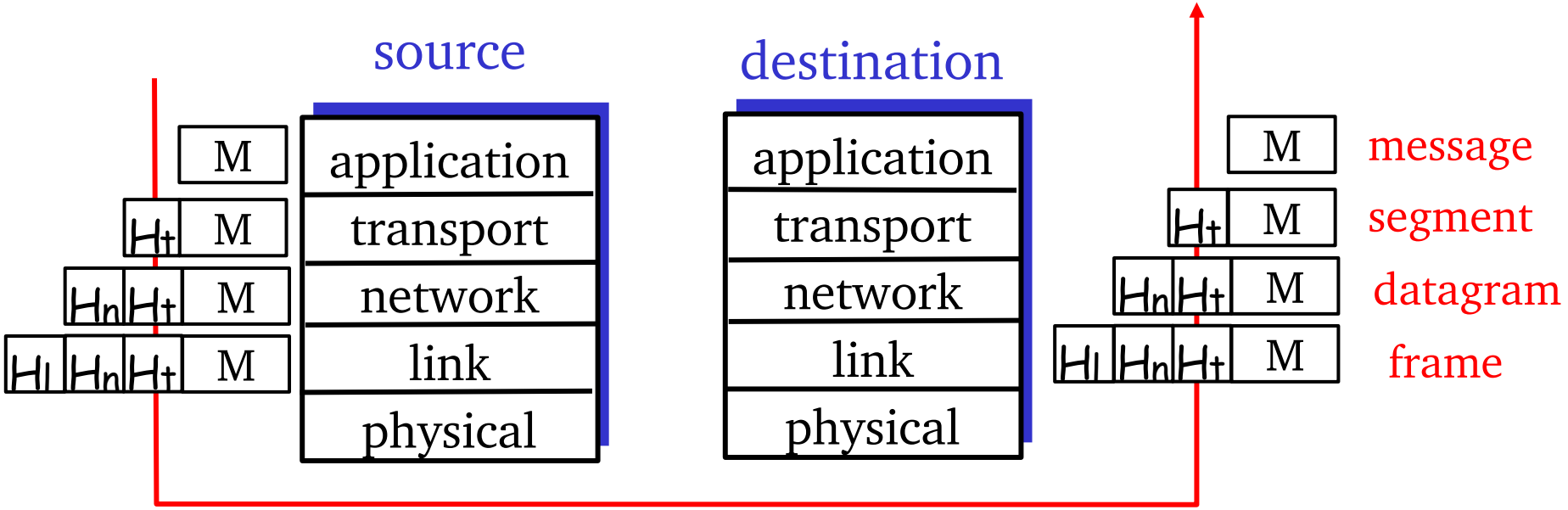
The Datalink layer executes error - checking over the flow of data between the above protocols and the physical layer

Physical Layer

The Physical layer moves the data out or in, along the transmission medium. (This medium might be Ethernet via coax, PPP via a modem, and so on.

Layers + Encapsulation

- As data is sent downward through the stack, it is encapsulated with layer-specific headers



- App sends 100 bytes
- UDP segment adds 8 bytes of header
- IP datagram adds 20 bytes
- Ethernet frame adds 18 bytes

Addressing

- Different layers use different addressing
  - App. layer (usu.) allows people to use hostnames
  - IP (network) layer requires IP addresses
  - Link layer requires MAC addresses
    - e.g., Ethernet (48 bits)
      - First 3 bytes are manufacturer ID
      - Last 3 bytes are serial number
- Ports identify process or service on a host
  - List of well-known ports in /etc/services
  - Ports <= 1024 are privileged ports (req. root)

Address types

- IP layer and link layer have multiple address types
  - Unicast – single host (network interface)
  - Broadcast – addresses that include all hosts on a particular network
    - All bits in host part of address are ones
  - Multicast – addresses that identify a group of hosts
    - IPv4 addresses with first byte in 224-239

IP Addresses

- IPv4 address has four bytes
  - Split into network and host portions
  - Internet originally used classes of IP addresses

Class	1st byte	Format	Comments
A	1-126	N.H.H.H.	Very early networks, DoD
B	128-191	N.N.H.H.	Large sites, usually subnetted
C	192-223	N.N.N.H.	Smaller sites
D	224-239		Multicast addresses
E	240-255		Experimental

  - www.lehigh.edu = 128.180.2.57
    - Class B (128.180); host portion is .2.57

Subnetting

- Individual networks are often **much** smaller than the class sizes
- Subnetting permits breaking up an allocation into multiple smaller networks
- Lehigh breaks up its Class B into many smaller networks, such as the old EECS nets
  - 128.180.5.*, 128.180.98.*, 128.180.14.*
  - Each can be broken down further

Subnetting Example

- 128.180 under class-full addressing is a Class-B with 65,534 addresses
- Subnetting extends the network address into host portion
- We specify a subnet 128.180.98
  - Using explicit subnet mask 255.255.255.0
  - Alternatively, with network bits specified explicitly
    - 128.180.98.0/24
  - Can also break on non-byte boundaries
    - 128.180.98.128/25
    - 128.180.120.0/22

CIDR

- Classless Inter-Domain Routing
  - Allows for shorter network address than class-specified – obsoletes network classes
  - Requires length field, e.g., 128.180.0.0/16
  - Aggregates smaller networks into single larger one
    - 192.200.254.0 + 192.200.255.0 = 192.200.254.0/23
  - Can now allocate portions of class A and B addresses
  - Aggregated networks reduces routing table growth

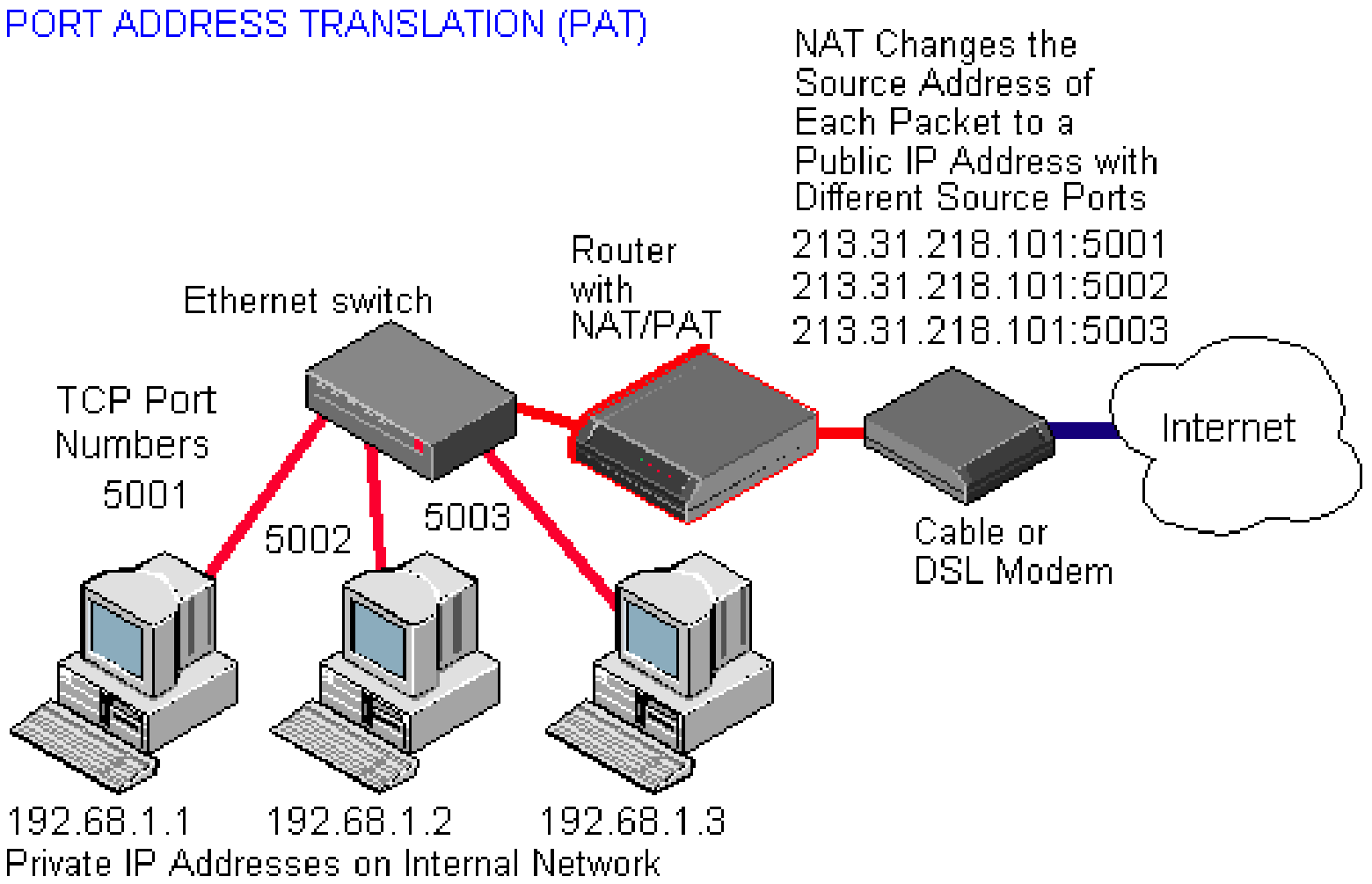
Address Shortage

- Before CIDR, concern for enough addresses
  - Class Bs would be gone by 1995
  - Router tables were exploding (growing beyond router capacities)
- CIDR + NAT + name-based virtual hosting greatly slowed down IP allocations
- IPv6 solves this (16 byte addresses!)

NAT

- Network Address Translation
  - Router intercepts packets, replaces internal network addresses and ports with externally visible addresses and ports
  - Maintains mapping so that external packets are directed to the right internal host
  - Typically uses a single public IP address, many ports, but can (in theory) map arbitrary hosts/ports
  - Capability built into many (cheap) routers, Linux

NAT: Network Address Translation



Private Addresses

- While a NAT can protect your internal addresses from being visible in IP headers, it isn't perfect
  - Some apps will encode addresses in data
  - What if you really want to connect to the external host with an IP address same as an internal host?
- Most use private address space (unroutable)

IP Class	From	To	CIDR Range
A	10.0.0.0	10.255.255.255	10.0.0.0/8
B	172.16.0.0	172.31.255.255	172.16.0.0/12
C	192.168.0.0	192.168.255.255	192.168.0.0/16

ARP: Address Resolution Protocol

- Once the routing of a packet has been determined, it must be transmitted to the next gateway or host on the local network
- LAN transmissions use LAN addresses
- ARP is used to discover the hardware address of the target IP address
- ARP sends a LAN broadcast asking who has the desired IP address; the owner responds with a unicast message with answer
  - Results cached in a table (also collected via snooping)

Sample ARP table

```
% /sbin/arp -a

davison.cse.lehigh.edu (128.180.121.225) at 00:11:43:A0:0F:D8 [ether] on eth0
wume2.cse.lehigh.edu (128.180.121.222) at 00:08:54:1E:44:D4 [ether] on eth0
pan.cse.lehigh.edu (128.180.120.90) at 00:14:4F:0F:9C:1A [ether] on eth0
wume1.cse.lehigh.edu (128.180.121.221) at 00:08:54:1E:44:D0 [ether] on eth0
chiron.cse.lehigh.edu (128.180.120.87) at 00:14:4F:21:44:D8 [ether] on eth0
xena.cse.lehigh.edu (128.180.120.86) at 00:14:4F:21:52:E0 [ether] on eth0
hydra.cse.lehigh.edu (128.180.120.89) at 00:14:4F:21:53:F2 [ether] on eth0
kato.eecs.lehigh.edu (128.180.120.6) at 08:00:20:C4:20:08 [ether] on eth0
noon.cse.lehigh.edu (128.180.121.219) at 00:0F:1F:F9:C1:68 [ether] on eth0
wume-lab2.cse.lehigh.edu (128.180.122.153) at 00:18:8B:24:5A:F4 [ether] on eth0
lu-gw.eecs.lehigh.edu (128.180.123.254) at 00:00:0C:07:AC:00 [ether] on eth0
nix.cse.lehigh.edu (128.180.120.88) at 00:14:4F:21:44:C4 [ether] on eth0
ceres.cse.lehigh.edu (128.180.120.91) at 00:14:4F:23:F9:80 [ether] on eth0
rosie.eecs.lehigh.edu (128.180.120.4) at 08:00:20:B1:FC:F3 [ether] on eth0
wume-lab1.cse.lehigh.edu (128.180.122.152) at 00:18:8B:24:5D:E2 [ether] on eth0
morning.cse.lehigh.edu (128.180.120.43) at 00:C0:9F:38:CD:51 [ether] on eth0
wume-lab6.cse.lehigh.edu (128.180.122.157) at 00:0A:E6:5D:48:03 [ether] on eth0
```


Network Configuration

- Adding a machine to a LAN
  - Assign unique IP address and hostname (per interface)
  - Set up host to configure network interfaces at boot time
  - Set up default route
  - Point to DNS name server (resolver)
- Files
  - /etc/sysconfig/network-scripts/ifcfg-eth0
  - Hostname, default route, IP address, netmask, broadcast
- DHCP could do all of this automatically

Mapping names to IP addresses

- Three choices: /etc/hosts, NIS, DNS
- Simplest: /etc/hosts

```
% more /etc/hosts
#
# Internet host table
#
127.0.0.1       localhost
128.180.120.15  proxima
128.180.120.9   mailhost
128.180.120.103 ariel
```

- Works when NIS or DNS is broken
  - e.g., at boot time

ifconfig

- Configure network interfaces with ifconfig
  - ifconfig eth0 128.138.240.1 netmask 255.255.255.0 up
  - shows configuration, e.g., for Solaris:

```
phobos:~% ifconfig -a
eth0      Link encap:Ethernet  HWaddr 88:51:FB:6F:F3:37
          inet addr:128.180.120.85  Bcast:128.180.123.255  Mask:255.255.252.0
          inet6 addr: fe80::8a51:fbff:fe6f:f337/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:82607119 errors:0 dropped:0 overruns:0 frame:0
          TX packets:52787875 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:23578082323 (21.9 GiB)  TX bytes:55411462770 (51.6 GiB)
          Interrupt:20 Memory:ec100000-ec120000
```

  - You've seen the output of ifconfig from your boot logs

CentOS/RHEL configuration files

- /etc/sysconfig/network
  - hostname, default route
- /etc/sysconfig/static-routes
  - static routes
- /etc/sysconfig/network-scripts/ifcfg-XXXX
  - IP address, netmask, broadcast address per interface
  - e.g., eth0, eth1, lo
- Use **ifup** and **ifdown** to change interface status, or use /etc/init.d/network

DHCP

- Dynamic Host Configuration Protocol
- Clients **lease** network config from server
  - IP addresses and netmasks
  - Gateways (default routes)
  - DNS name servers
  - Syslog hosts
  - X font servers, proxy servers, NTP servers
  - and more

How DHCP works
(at a high level)

- Client broadcasts a “Who am I?” message
- Local DHCP server responds with network configuration lease
- When lease is half over, client renews the lease
  - DHCP server must track lease info (persist through server reboots, etc.)
- DHCP used on almost all hosts at Lehigh

dhcpd configuration

```
#dhcpd.conf
#
option subnet-mask 255.255.255.0;
default-lease-time 600;
max-lease-time 7200;

subnet 192.168.1.0 netmask 255.255.255.0 {
   range 192.168.1.51 192.168.1.60;
   option broadcast-address 192.168.1.255;
   option routers gw.synack.net;
}
subnet 209.180.251.0 netmask 255.255.255.0 {
}
host gandalf {
   hardware ethernet 08:00:07:12:34:56;
   fixed-address gandalf.synack.net;
}
```

