

Connecting ethernets

- Hub/repeater (physical layer)
 - Retimes and reconstitutes Ethernet frames to all ports
 - Single collision domain
- Switch (link layer)
 - Learns locations of MAC addresses, selectively forwards frames
 - Receives, buffers, and retransmits packets
 - Separate collision domains
 - Required for GbE and 10GbE
- Router (IP/network layer)
 - Connects separate ethernet networks
 - Can connect different LAN/WAN technologies



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Routing

- Given a packet, on which of multiple network interfaces should it be sent?
- UNIX kernel keeps routing table (netstat -rn)
 - Sample from dual-homed host

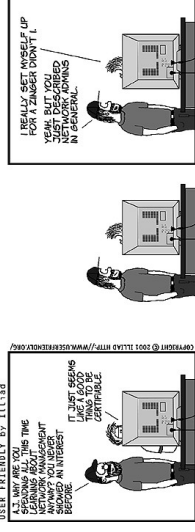
| Kernel IP routing table | | Genmask | Iface |
|-------------------------|----------------|-----------------|-------|
| Destination | Gateway | | |
| 128.180.98.128 | 0.0.0.0 | 255.255.255.128 | eth0 |
| 192.168.0.0 | 0.0.0.0 | 255.255.0.0 | eth1 |
| 127.0.0.0 | 0.0.0.0 | 255.0.0.0 | lo |
| 0.0.0.0 | 128.180.98.248 | 0.0.0.0 | eth0 |

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- Network Architecture
 - Hardware
 - Routing
 - Getting connected
 - Centralization/decentralization
 - Network topology
 - Network debugging tools

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Networking hardware

- Ethernet is the core of most networks
 - 10 Mbit 10Base2, 10BaseT
 - 100 Mbit 100BaseTX
 - 1 Gbit 1000BaseT
 - 10 Gbit 10GBase-T
- Many competing LAN technologies
 - ATM, Token Ring, FDDI
- Wireless
 - 802.11b/a/g/n/ac



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Network Topology

- Network architecture should
 - Be clean and simple
 - Provide for growth (new LAN segments, new remote offices)
 - Ensure reliability through redundancy
- Needs to consider both physical and logical topologies
- Typical logical forms: Star, Ring, Mesh
- Next are examples network topologies
 - Most are networks to which Lehigh is connected

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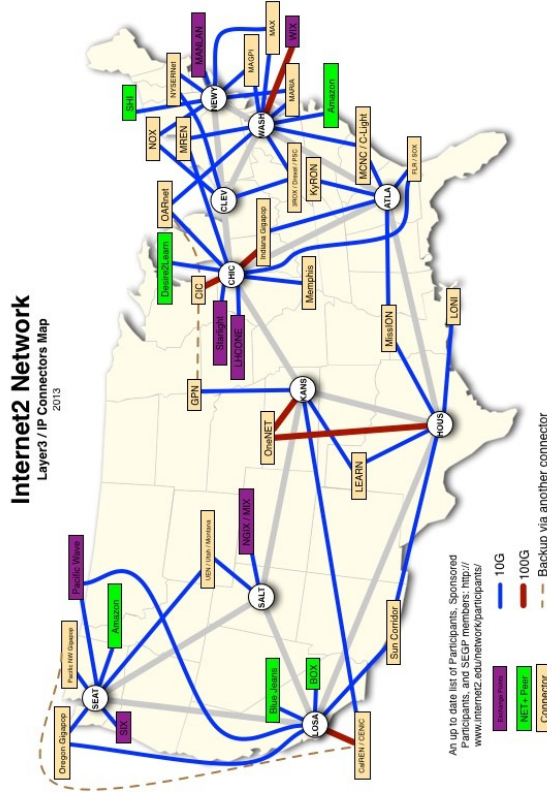
Routing continued

- Routing is static for most systems
 - Established when network card configured
- Additional static routes can be added using the route command
- Dynamic routing can be managed using quagga and xorp (ULSAH if interested)
 - routed and gated are obsolete

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Connecting to the Internet

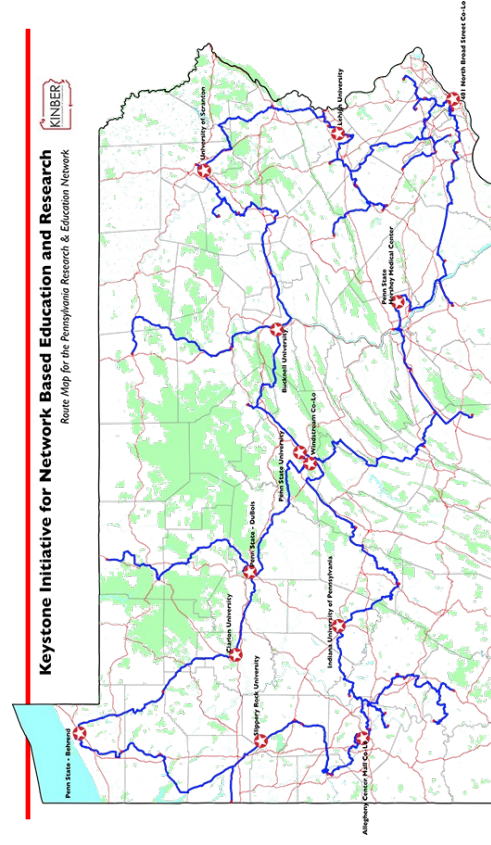
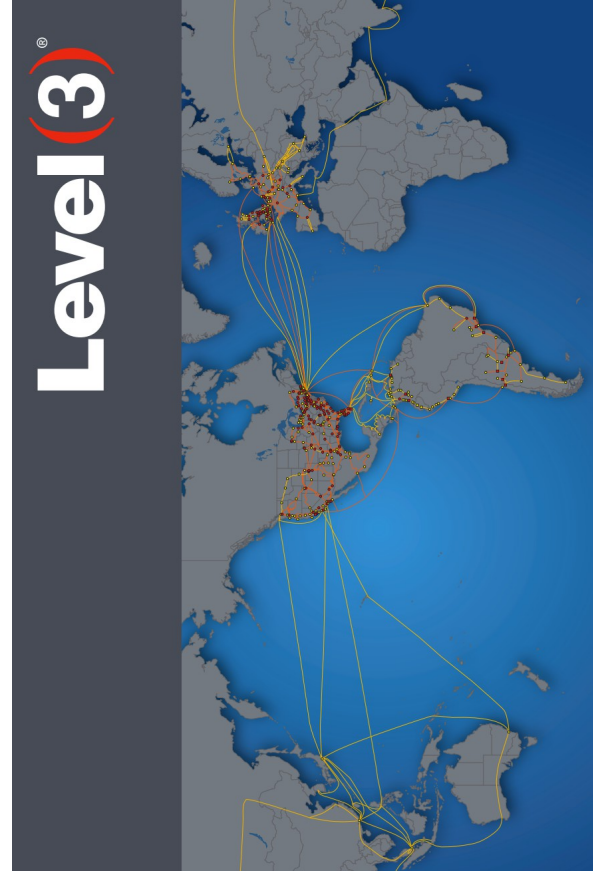
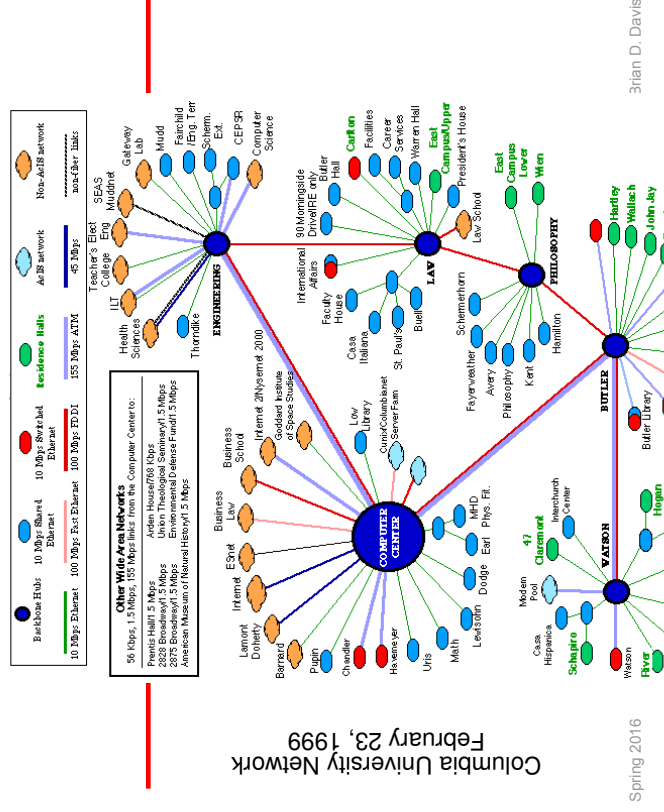
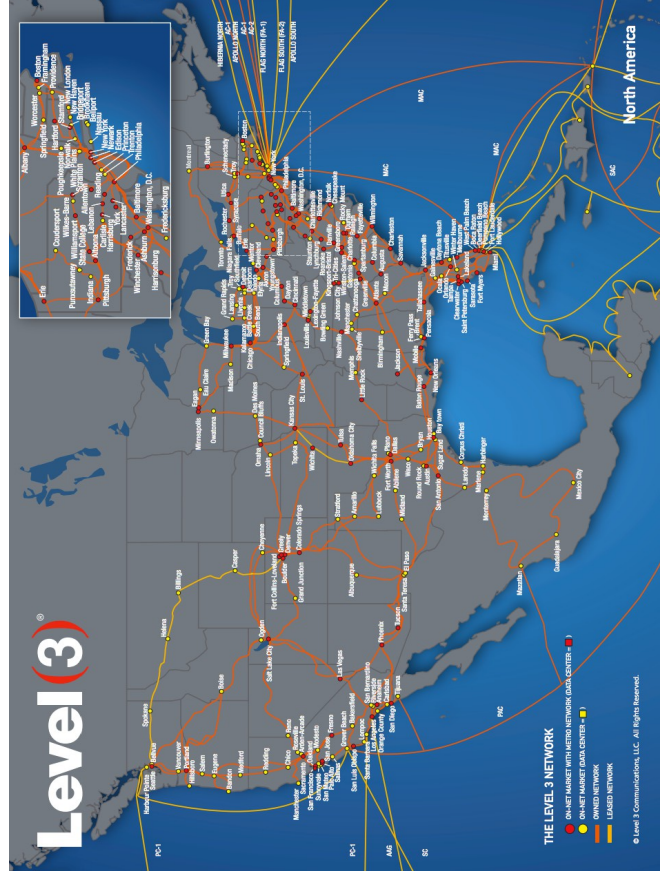
- How can you connect your network to the Internet?
 - Dialup
 - Wireless (cellular, satellite, point-to-point)
 - xDSL
 - Cable
 - ISDN
 - Frame relay
 - T1, T3, OC3, etc.



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ping

- If ping works, networking between hosts is likely to be working
- It does not test availability of services
- Some firewalls filter ICMP messages

```
# ping www.lehigh.edu
PING www.lehigh.edu (128.180.2.14) from 128.180.98.216: 56(84) bytes
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=1 time=0.859 ms
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=2 time=0.685 ms
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=3 time=0.648 ms
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=4 time=0.751 ms
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=5 time=0.667 ms
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=6 time=1.09 ms
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=7 time=0.725 ms
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=8 time=0.655 ms
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=9 time=0.663 ms
64 bytes from ws1.cc.lehigh.edu (128.180.2.14): icmp_seq=10 time=0.724 ms
```

```
--- www.lehigh.edu ping statistics ---
10 packets transmitted, 10 received, 0% loss, time 9091ms
rtt min/avg/max/mdev = 0.648/0.738/1.006/0.109 ms
```

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Network debugging

- Questions to ask
 - Do you have physical connectivity and a link light?
 - Is your interface configured properly?
 - Is DNS configured properly?
 - Do your ARP tables show other hosts?
 - Can you ping the localhost address (127.0.0.1)?
 - Can you ping other local hosts by IP address?
 - Can you ping other local hosts by hostname?
 - Can you ping hosts on another network?
 - Do high-level commands like telnet and ssh work?

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traceroute

- Finds the sequence of gateways traveled
- Works by increasing the TTL of the packet sent
- traceroute -n skips DNS

```
ariel% traceroute www.princeton.edu
traceroute to hulk.princeton.edu (128.112.128.15), 30 hops max, 40 byte
packets
 1 128.180.123.254 (128.180.123.254) 3.406ms 0.940ms 0.676ms
 2 ewfmb-gbe-a.cc.lehigh.edu (128.180.18.4) 0.407ms 0.465ms 0.640ms
 3 ewfmd-ewfmb.cc.lehigh.edu (128.180.128.82) 0.952ms 0.649ms 0.830ms
 4 ewfmc-ewfmd.cc.lehigh.edu (128.180.128.89) 1.005ms 1.687ms 1.464ms
 5 local.lehigh1.magpi.net (198.32.42.145) 5.148ms 4.810ms 4.721ms
 6 phl-02-08.backbone.magpi.net (198.32.42.197) 4.277ms 4.895ms 4.362ms
 7 remote.princeton.magpi.net (198.32.42.66) 33.474ms 20.958ms 20.399ms
 8 gigagate1.princeton.edu (128.112.12.21) 25.451ms 9.580ms 20.908ms
 9 hulk.princeton.edu (128.112.128.15) 11.067ms * 34.043ms
```

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Network tools

- ping
- traceroute
- netstat
- arp (saw earlier)
- tcpdump/wireshark (saw in lab)

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Remote access

- Connecting users to the organization
 - Check email, access data when traveling
 - Work from home
 - Remote facilities (e.g., stationed at customer site) but need access to organization network regularly
- Different needs, different support requirements
 - Establish an SLA
 - Worry about authentication, security, performance, costs
 - Consider centralization of authentication
 - Consider outsourcing changing technologies

netstat

- Tons o' network statistics

```
# netstat | more
Active Internet connections (w/o servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      0 0 someserver:www         td9091978.adsl.ter:1819 ESTABLISHED
tcp        0      0 0 someserver:www         td9091978.adsl.ter:1817 TIME_WAIT
tcp        0      0 0 someserver:www         unknown.servicen:53522 TIME_WAIT
tcp        0      0 0 someserver:www         l1157.inktomisea:49477 TIME_WAIT
tcp        0      0 1 someserver:1248        218.15.192.166:smtp    SYN_SENT
tcp        0      0 0 someserver:www         cable200-75-67-206:3307 FIN_WAIT2
tcp        0      0 0 someserver:1224        mx02.osn.de:smtp      ESTABLISHED
tcp        0      0 0 localhost:x11-ssh-offse localhost:57893        ESTABLISHED
tcp        0      0 0 localhost:6023         localhost:34263        FIN_WAIT1
```

- Can also show
 - interface configurations, routing tables, counter values

Packet sniffers

- Show you what is really on the network going past your network interface
 - Not as useful in a switched environment
- Examples: tcpdump, wireshark

```
# tcpdump
tcpdump: listening on eth0
19:05:08.220.168.28.55.http > wumel.cse.lehigh.edu.64207: P
1001579411:1001579684(273) ack 3591949882 win 65300 <nop,nop,timestamp
64538628 1686086162> (DF)
19:05:08 wumel.cse.lehigh.edu.36560 > G.ROOT-SERVERS.NET.domain: 7131
[1au] PTR? 55.28.168.220.in-addr.arpa. (55) (DF)
19:05:08 G.ROOT-SERVERS.NET.domain > wumel.cse.lehigh.edu.36560: 7131-
% 0/4/2 (164) (DF)
19:05:08 wumel.cse.lehigh.edu.36560 > l.gtld-servers.net.domain: 24184
A? NS1.APNIC.NET. (31) (DF)
19:05:08 wumel.cse.lehigh.edu.36560 > ns.ripe.net.domain: 12092 [1au]
PTR? 55.28.168.220.in-addr.arpa. (55) (DF)
```