Communications Network Design

lecture 18

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March 2, 2009

Tree-like networks implementations

We look into one example where tree-like network design is important: the design of Ethernet LANs. This leads onto consideration of the Internet as a larger "Network of networks".

Lecture goals/outline

- Talked about Internet in abstract terms
- Today we want to firm up some details
  - e.g. how do packets go across network
  - addresses, routing, forwarding
- Ethernet details
- references for today
  - [1]
  - http://www.ethermanage.com/ethernet/
  - http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/ethernet.htm
  - IEEE 802.3 standard
    see http://standards.ieee.org/getieee802/802.3.html

Routing vs Switching

Routing

- packets (headers) contain an "end" address
- "router" looks up address, and works out where to send the packet to get to its destination.
- forwarding is done hop by hop
  - each router does it independently

Switching

- virtual circuit (VC) created prior to data packet/cells
- packet (cells) contain "circuit ID"
- each switch looks at circuit ID, and sends to an outgoing link

Routing vs Switching

- there are many more addresses than circuits
  - routing tables are larger than circuit tables
    - lookups may be slower (not now)
  - address are larger (more bits)
    - more overhead per packet
  - forwarding implementations are often simpler
- circuits required to be set up earlier
  - can be a purely logical construct
    - maybe no resource allocation
    - circuit switching is not necessarily like dedicated circuits
  - complex circuit setup (UNI, RSVP)
    - more network **state**

Addresses

- IPv4 addresses, 32 bit, written as X.X.X.X
  - e.g. 10.1.2.255
  - subnet = group of IP addresses with a common **prefix**
    - e.g. private addresses 192.168.0.0/16
      - all address with same first **16** bits 192.168
      - 192.168.0.0 - 192.168.255.255
- Ethernet addresses: 48-bits written in hex as xx-xx-xx-yy-yy-yy, where
  - xx-xx-xx is manufactorer code
  - yy-yy-yy chosen to be unique
  - e.g. 00:0E:7F:2A:D3:4F
- IPv6 addresses, 128 bits — see [2]

Other types of communications

Not all communication is point-to-point

- **broadcast:** send a message to all receivers
  - e.g. cable TV
- **multicast:** send a message to a group of receivers
  - e.g. video-conference
- **anycast:** send a message to so it gets to at least one receiver
  - e.g. DNS

Different approaches may work best for different applications.

Ethernet

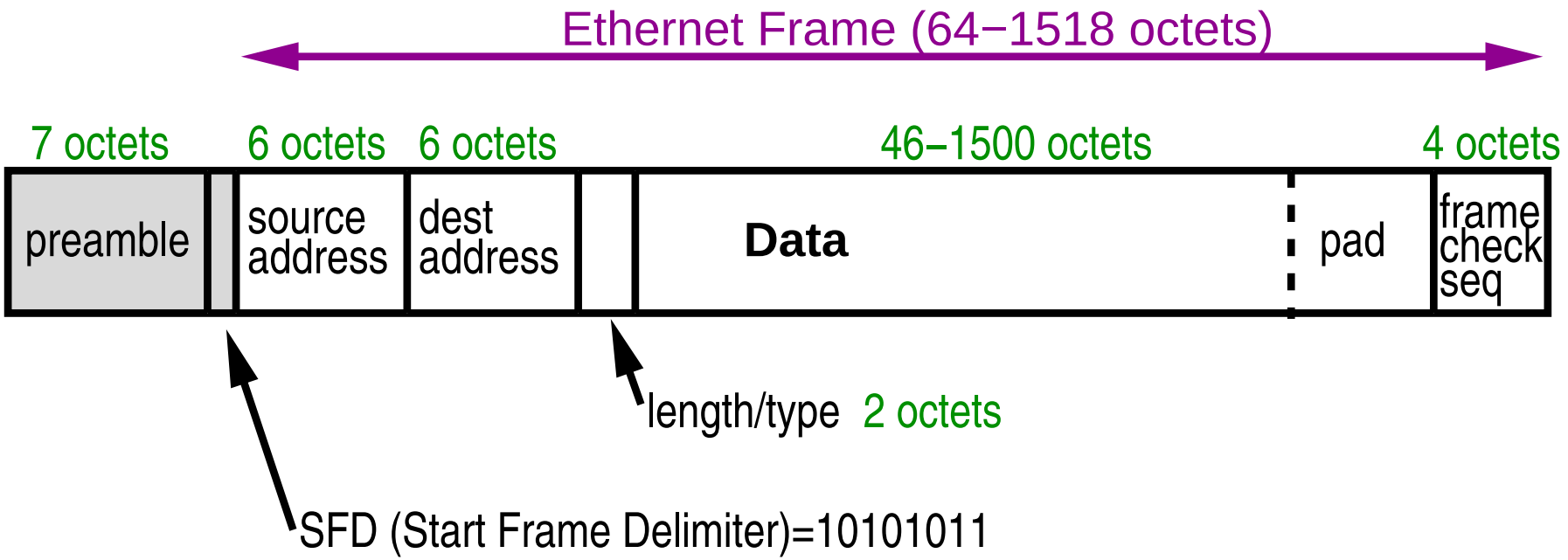
- Ethernet invented by Robert Metcalfe, c1973 [3]
- The physical medium (i.e., a cable) carries bits similarly to the way "luminiferous ether" was once thought to propagate electromagnetic waves.
- originally 3 Mbps
  - now there is a standard for 10 Gbps
- 1979: 3Com founded (by Metcalfe)
- 1980: standardized
- 1982: PC cards generaly available
- today: almost ubiquitous

Ethernet flavours

IEEE 802.3 standard = 1,562 pages

- 10-Mbps Ethernet (Thick Coaxial), 10BASE5.
- 10-Mbps Ethernet (Thin Coaxial), 10BASE2.
- 10-Mbps Ethernet (Twisted-Pair), 10BASE-T.
- 10-Mbps Ethernet (Fiber Optic), 10BASE-F.
- 100-Mbps Fast Ethernet (Fiber Optic), 100BASE-FX.
- 100-Mbps Fast Ethernet (Twisted-Pair), 100BASE-TX.
- 100-Mbps Fast Ethernet (Twisted-Pair), 100BASE-T4.
- 1-Gbps Gigabit Ethernet (Fiber Optic), 1000BASE-X
- 1-Gbps Gigabit Ethernet (Twisted-Pair), 1000BASE-T
- 10-Gbps 10-Gig-Ethernet, 10GBASE
- (another 12 variants at least)

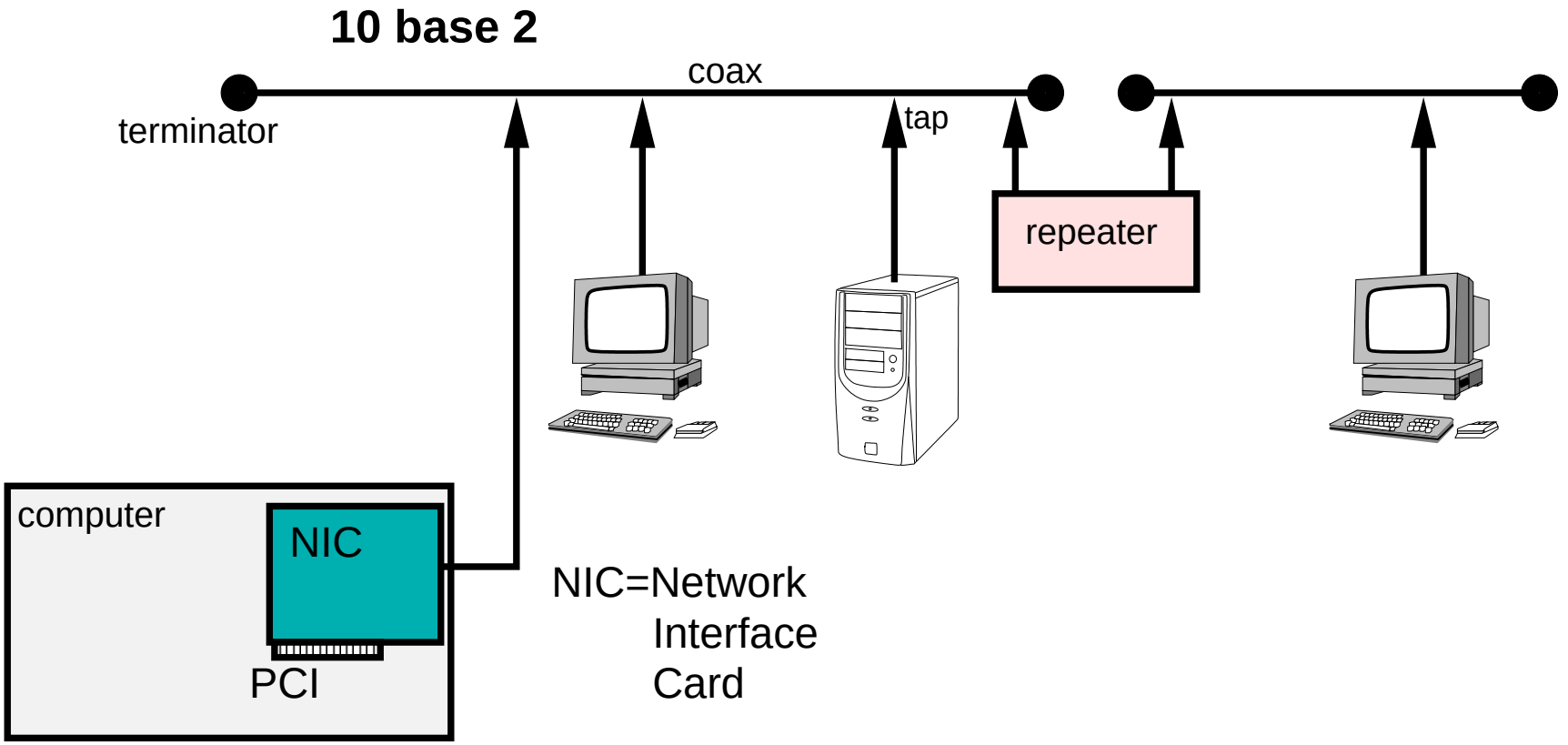
Ethernet frame



http://standards.ieee.org/getieee802/802.3.html

- this is a simplified view

Ethernet topologies: bus



- shared medium (coax cable)
- repeater simply extends max length of cable.
- failure anywhere disrupts network

CSMA/CD

Ethernet uses CSMA/CD for its MAC

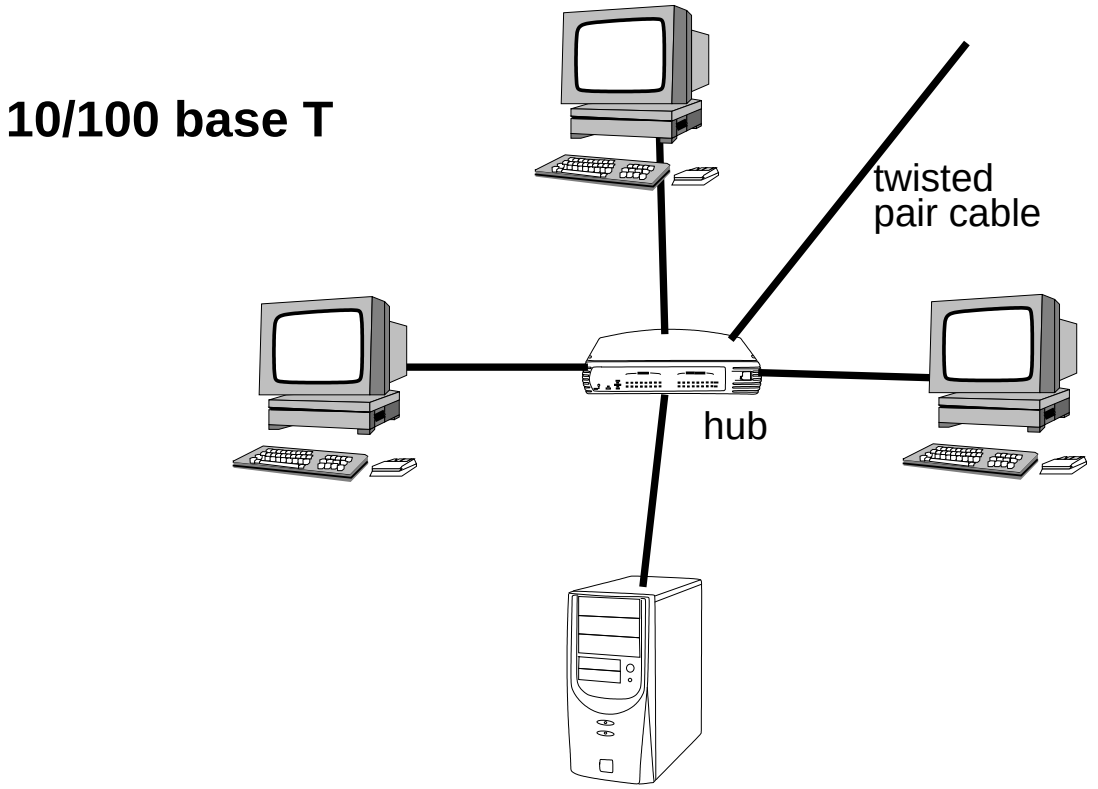
- Carrier Sense Multiple Access (CSMA)
  - before you transmit, sense medium to check if anyone else is transmitting
- with Collision Detection (CD)
  - sometimes, two hosts start transmitting at almost the same time
  - they won't sense each other in time
  - collision occurs
  - hence we need collision detection, and retransmission

MAC sub-layer (of Link layer)

Where-ever you have a shared tranmission medium (wire, fiber, RF band), you need a method to share.

- called the MAC sub-layer (Medium Access Control)
- several ways to share a common medium
  - **TDMA** (Time Division Multiple Access)
    - each transmitter gets its own time slot
  - **FDMA** (Frequency Division Multiple Access)
    - each transmitter gets its own frequency
  - **WDMA** (Wavelength Division Multiple Access)
    - each transmitter gets its own wavelength
  - **CDMA** (Code Division Multiple Access)
    - each transmitter gets its own code
  - **CSMA** (Carrier Sensing Multiple Access)
    - quite different – no reservation

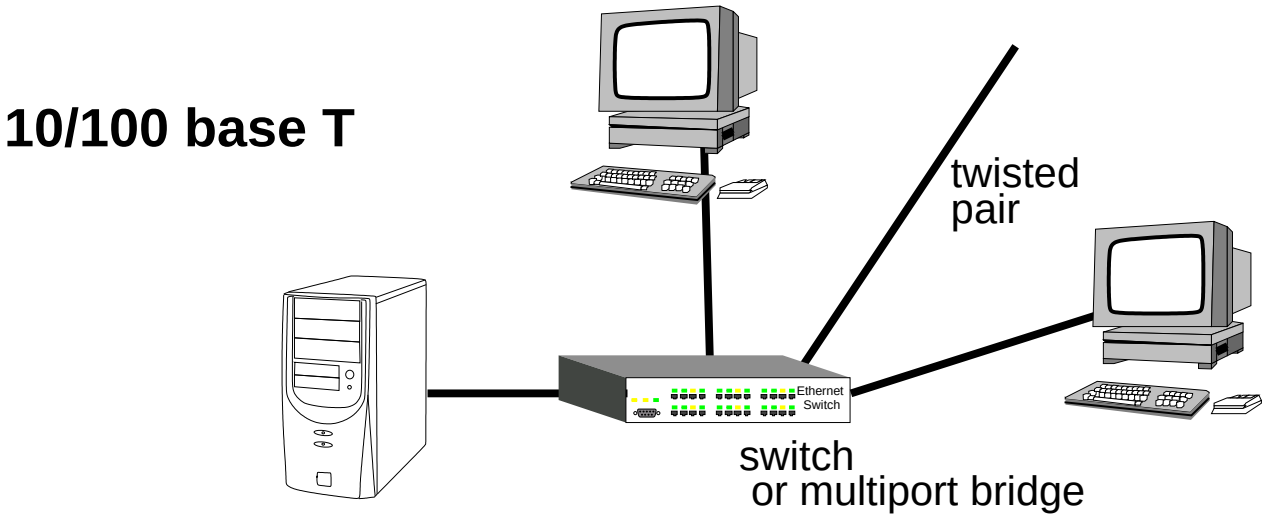
Ethernet topologies: hub/spoke



Star or
Hub and Spoke
topology

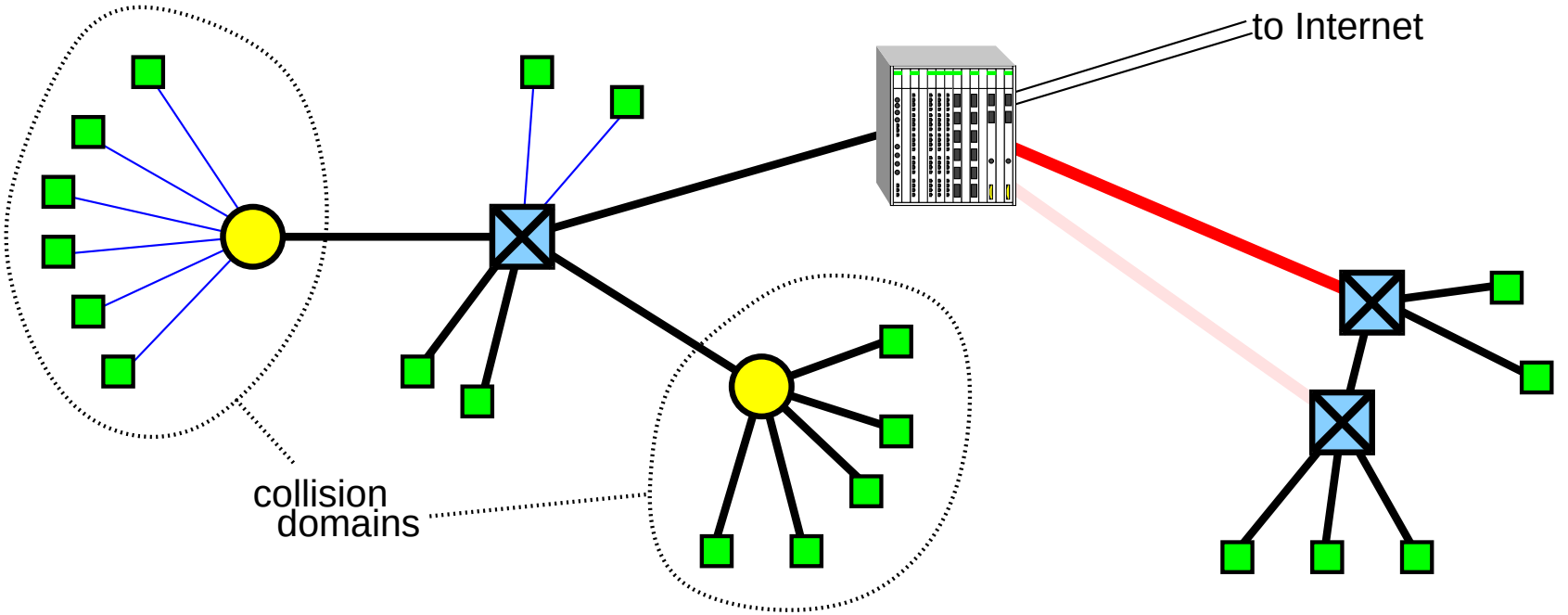
- shared medium (twisted pair cable)
- **passive** hub (multiport repeater) joins medium
- failure on link disrupts just that link
- failure on hub is still critical

Ethernet topologies: switched



- medium is no longer shared
- cables are now really point-to-point
- **active** switching of packets onto separate cables
- switch is just a multi-port bridge
- failures similar to hub
  - but we can build redundancy (STP)

Mixed Ethernet Topologies



DTE (Data Terminal Equipment, or Computer)

Hub

Switch

Router

Gig−E

Gig−E backup link

100 BASE−T

10 BASE−T

non−Ethernet (e.g. POS, ATM)

Switched Ethernet

Why call it switching (it isn't quite circuit switching)

- creates separate segments, each with shared medium only on the segment.
- think of Ethernet address, as address of circuit to that address
- bridged might be a better term than switched

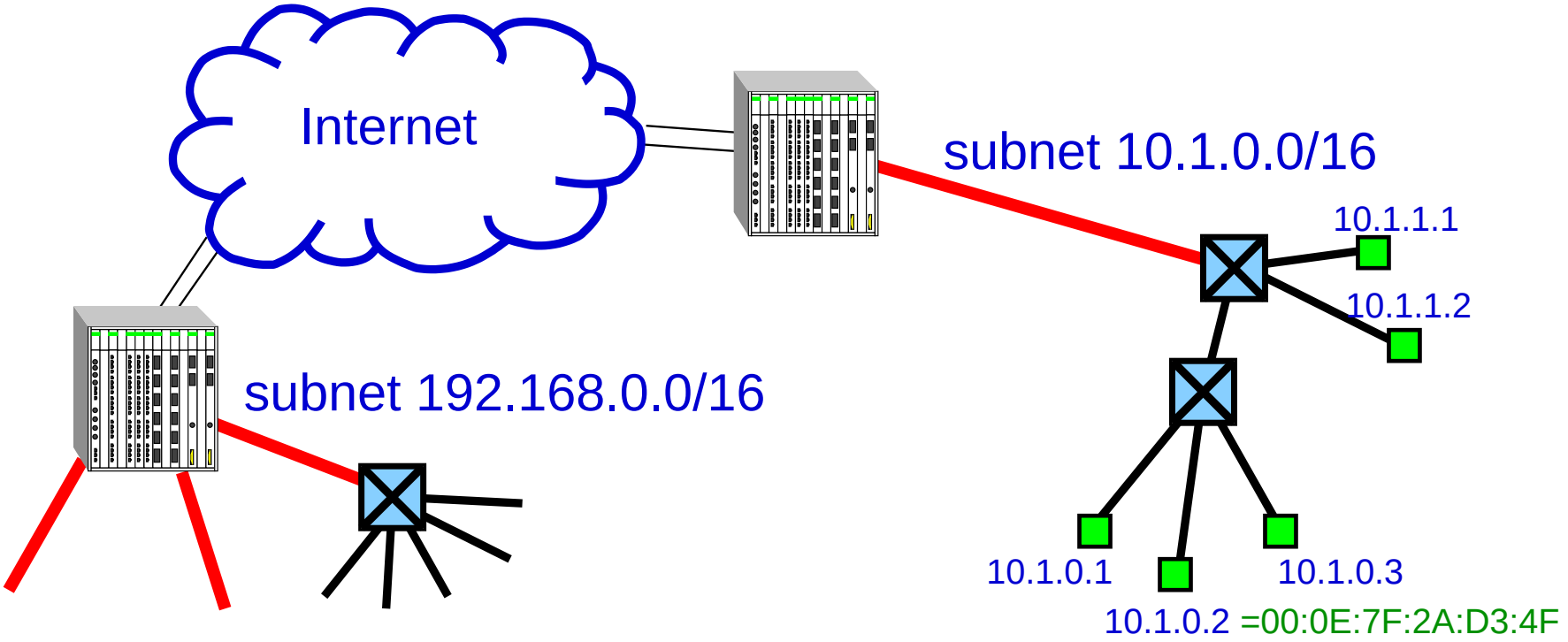
Combination of switches and hubs was common

- hubs are very cheap O($10)
- switches are more expensive O($100), but have better performance.
  - reduce size of collision domains
  - support higher speeds

Ethernet limits

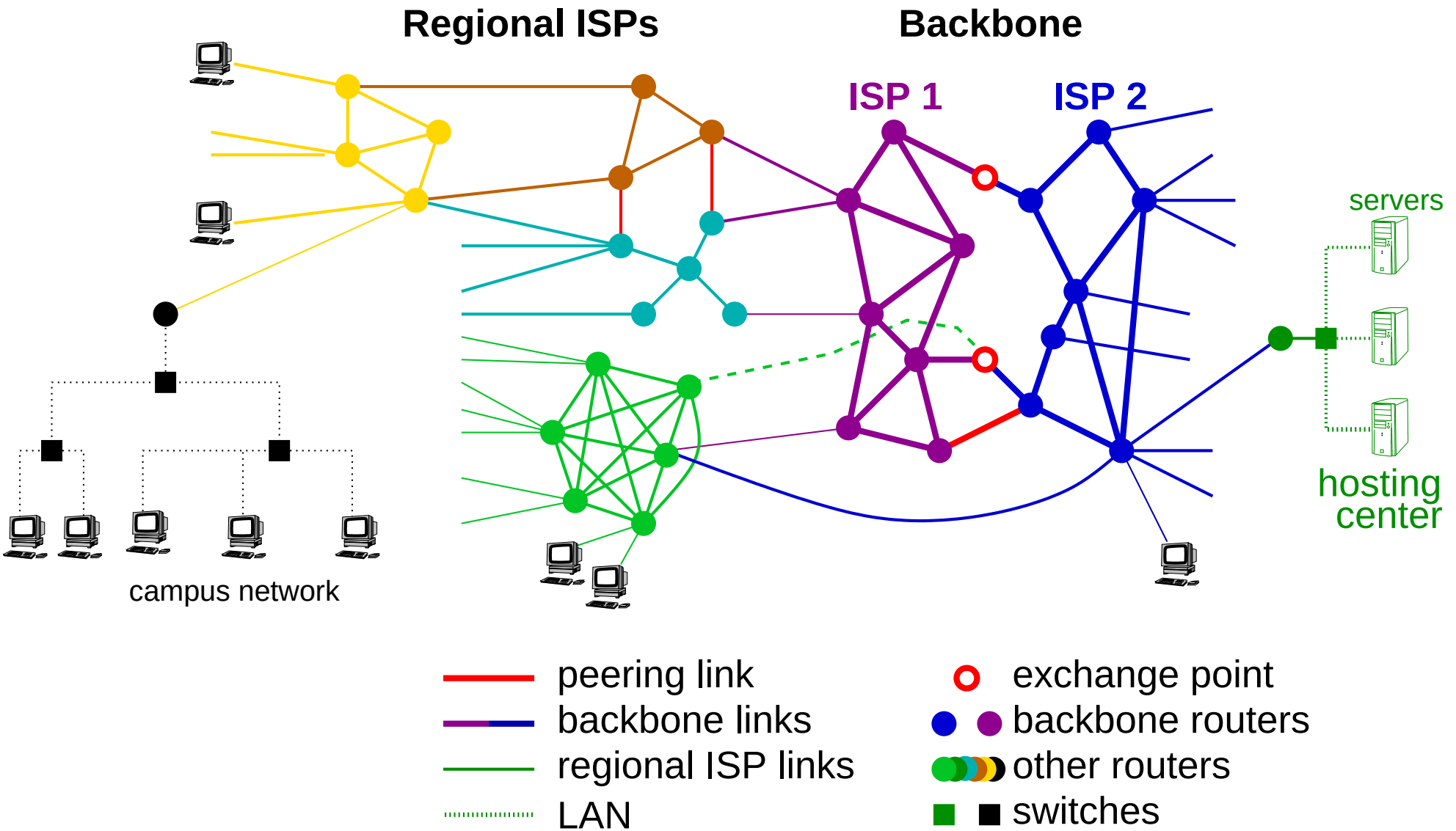
- limit to packet size (46-1500 byte payload)
  - Ethernet's prevalence has led to this being a common maximum IP packet size for the Internet.
- limit to cable lengths
  - need to maintain signal strength so max 100m per segment (repeaters can help, but can't have more than one)
  - collision detection imposes max limit 2500 meters for 10BASE-T, and 205 meters for 100BASE-T
  - these limits are less importance with intro of switching and fiber standards

Internet as a network of networks



- Internet connects up Ethernets
  - and other types of networks
- ARP (Address Resolution Protocol — RFC826 [4])
  - translates IP address to Ethernet address

Internet as a network of networks



References

[1] Z. Wenzel, J. Klensin, R. Bush, and S. Huter, "Guide to administrative procedures of the Internet infrastructure." IETF RFC 2901, 2000.

[2] S. Deering and R. Hinden, "Internet Protocol, Version 6 (IPv6)." IETF, Request for Comments: 2460, 1998.

[3] R. M. Metcalfe and D. R. Boggs, "Ethernet: Distributed packet switching for local computer networks," Communications of the ACM, vol. 19, no. 5, pp. 395 – 404, 1976.

[4] D. C. Plummer, "An Ethernet Address Resolution Protocol – or – Converting Network Protocol Addresses to 48.bit Ethernet Address for Transmission on Ethernet Hardware." IETF, Request for Comments: 826, 1982.