



# Networks

By:

Jonathan Reckner

Robert Holland

# Overview

- Introduction to Networks
- History
- In Depth Look at Networks
- Internet2
- Computational Science

# What is a Network?

- Networks are defined as the transmission of data over digital circuits.
- Why Important?
  - Email, interactions
  - Remote Logins
  - Data transfers
  - Internet
- WAN vs. LAN

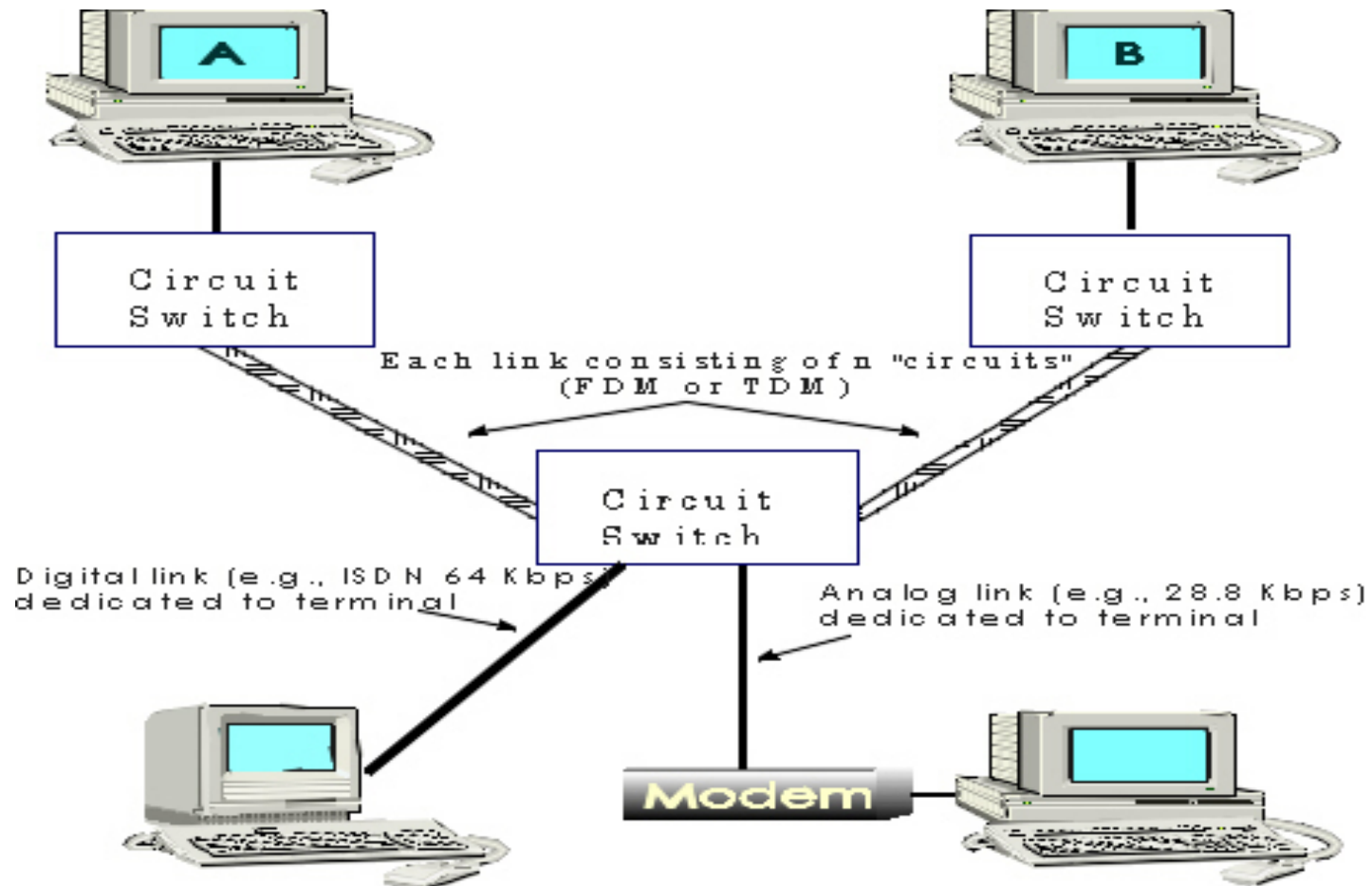
# History

- The concept of networking began in the early 1960's
- Timeshared computers made usage by geographically distributed users more practical
- How to best transmit information between locations?

# Circuit-switching

- Telephone network uses circuit-switching
- This means that a dedicated circuit is kept open between the sender and the receiver
  - The circuit may pass through a number of different communication links between its two ends
  - This is good for real-time communication at a constant rate

# Circuit-Switching Image



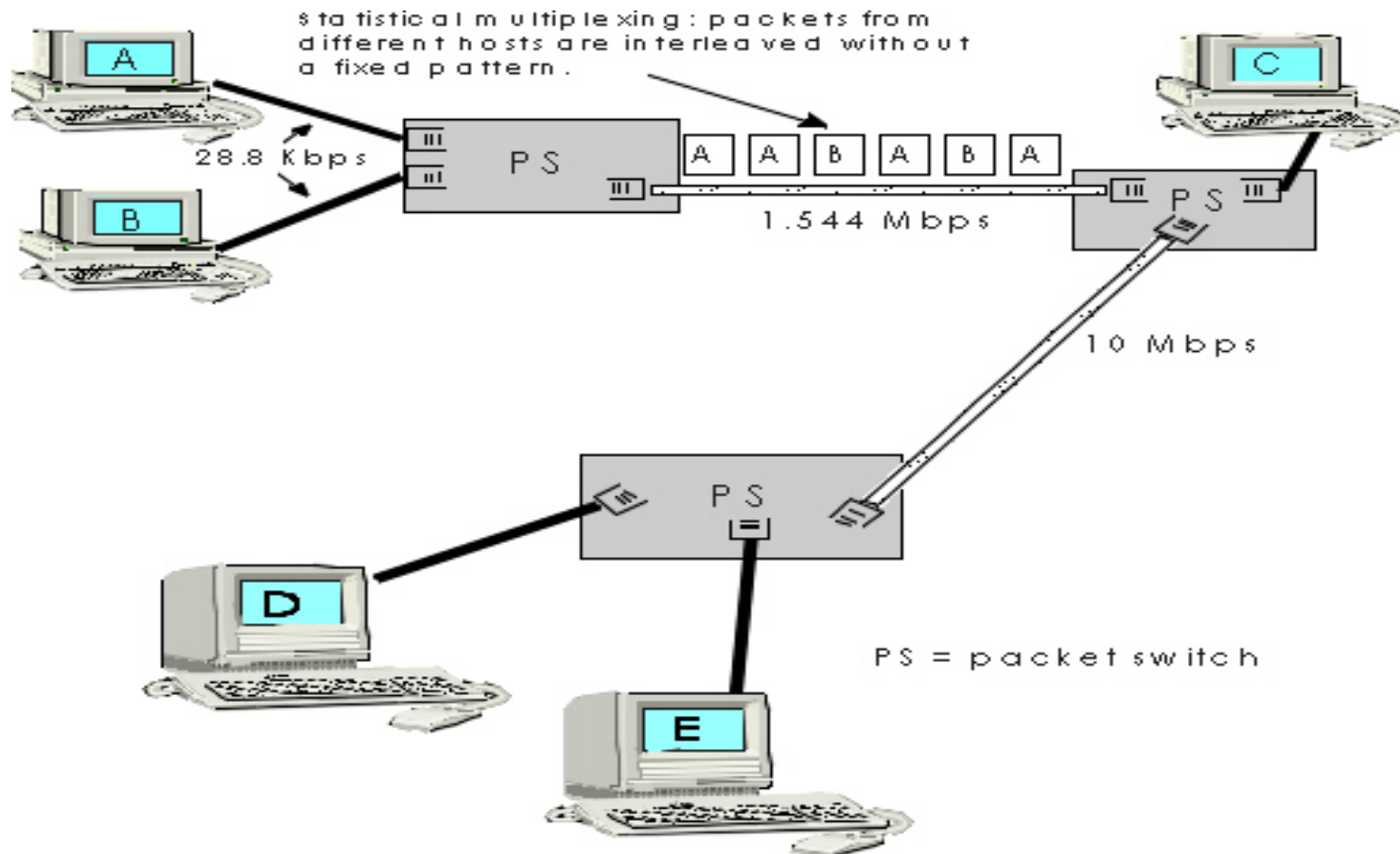
# Traffic

- Most computer traffic is "bursty"
  - i.e. has short periods of activity followed by long periods of inactivity
- This makes circuit-switching highly inefficient
  - lots of inactive time during which the circuit sits idle

# Solution

- Solution: packet-switching
  - Information is sent in discrete packets; packets from multiple sources can be interleaved with each other
  - Network resources are only used when information is actively being sent

# Packet Switching



# Packet-Switching Cont.

- Packet-switching was actually invented at about the same time by three different research groups.
  - Leonard Kleinrock at MIT
  - Paul Baran at the Rand Institute
  - Donald Davies and Ronald Scantlebury at the National Physical Laboratory in England

# First Packet-switched Computer

- The first packet-switched computer network was developed at the Advanced Research Projects Agency.
  - Led by J.C.R. Licklider and Lawrence Roberts, colleagues of Leonard Kleinrock at MIT
  - The overall plan for the "ARPAnet" was published by Roberts in 1967
  - Specified packet-switchers called Interface Message Processors (IMPs)
  - The first IMPs were installed at UCLA, the Stanford Research Institute, UC Santa Barbara, and the University of Utah in 1969
  - According to Kleinrock, the very first connection attempt, from UCLA to SRI, crashed the system

# IMP



# Internetworking

- The original ARPAnet was a single, closed network
- By the mid-1970's, other packet-switching networks had begun to show up, including ALOHAnet, Telenet, Tymnet, and Transpac
- In 1974, Vinton Cerf and Robert Kahn coined the term "internetworking" to describe the concept of interconnecting multiple networks into a single "network of networks"

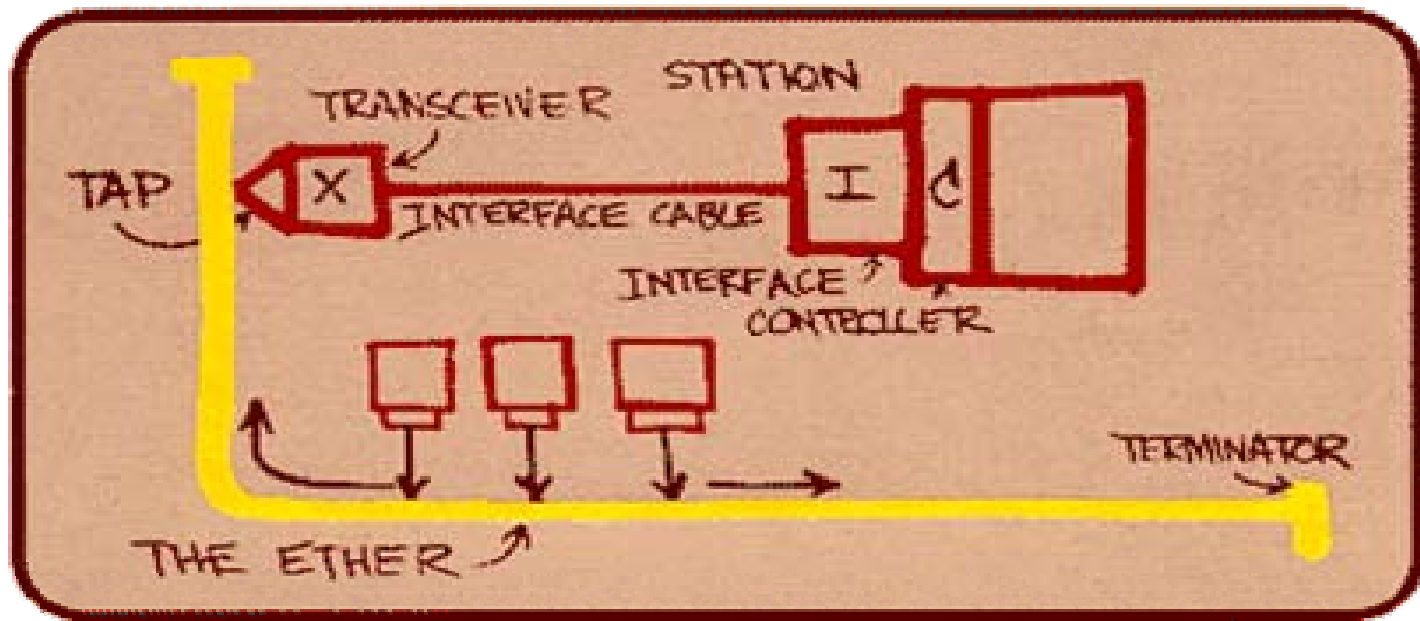
# Kahn's Basic Principles

- Kahn lays down the basic principles for an "open network architecture", forming the foundation of the modern Internet, including:
  - minimalism, autonomy: A network should be able to operate independently and require no internal changes to connect it to other networks
  - best effort service: Networks should be reliable, for example by checking to see if a packet failed to reach its destination and resending it if so
  - stateless routers: Routers in internetworked networks do not remember the messages that have passed through them
  - decentralized control: No global control over the internetworked networks exists

# Ethernet and Local Area Networks

- Robert Metcalfe, motivated by the need to connect multiple PCs, printers, and disks together, develops the basics of the Ethernet
- Ethernet would later become the basis for modern LANs

# Ethernet



# Network Structures

The image features a solid blue header bar at the top containing the text 'Network Structures' in white. Below the header is a large, empty teal rounded rectangle that frames the main content area of the slide.

# Speeds

- DS-1 (56K Modem Category)
- DSL & Cable ( Various Ranges)
- T1 (1.5 Million bits/second)
- T3 (45 Million bits/second)
- OC-3 (155 Million bits/second)
- OC-12 (4 x OC3)
- Distributed Teragrid Facility (DTF) (10Gb/s)
  
- Telecom and Network Speeds
  - [http://www.zytrax.com/tech/data\\_rates.htm](http://www.zytrax.com/tech/data_rates.htm)

# TeraGrid

- 40 gigabits per second—the fastest research network on the planet.
- 5 Points
  - National Center for Supercomputing Applications ([NCSA](#)) at the University of Illinois, Urbana-Champaign
  - San Diego Supercomputer Center ([SDSC](#)) at the University of California, San Diego
  - [Argonne National Laboratory](#) in Argonne
  - Center for Advanced Computing Research ([CACR](#)) at the California Institute of Technology in Pasadena
  - Pittsburgh Supercomputer Center ([PSC](#))
    - Added after the original four centers
    - Added in October 2002

# Network Topologies

- Different Types

- Ring

- Bus

- Star

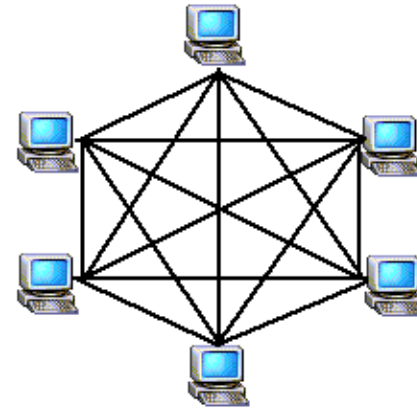
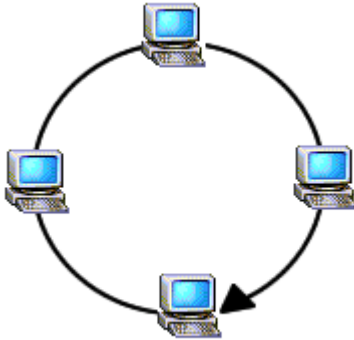
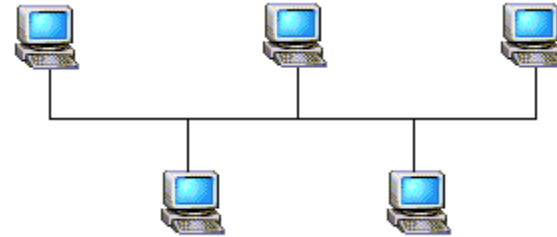
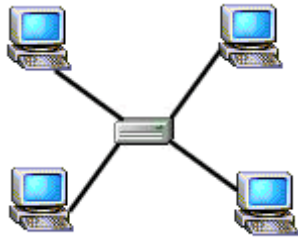
- Mesh - Full

- FNN

- UK – Klat2

- <http://www.mgnet.org/~douglas/Classes/cs521-s02/networks/networks.ppt> (Slides 38 - 52)

# Examples of Topologies



# Topology - Mesh

- Also known as Fully Connected
  - Each computer directly connected
  - Very expensive
  - Difficult to maintain
  - Able to route data quickly

# Topology - Star

- Connected to a central point
- Less expensive
- Easy to implement
- Each computer is only one hop from any other point in the network
- If central point goes down, whole network goes down

# Topology - Ring

- Each computer connected to the next and can reach any other computer by sending information around the ring
- Very cheap
- Broken link can isolate part of the network unless double ring

# Wiring

- How to connect these Networks
  - WAN
    - Most of the different speed types use different media
    - Existing phone lines are the largest form of media used
    - 56K, DSL, T1, T3 are all existing phone lines
    - Cable or coax used for awhile

# LAN Wiring

- Ethernet
  - Cat3, Cat5, Cat5e, Cat6
  - Different types of Ethernet
    - 10 Mbps—10Base-T Ethernet
    - 100 Mbps—Fast Ethernet
    - 1000 Mbps—Gigabit Ethernet
    - 2000 Mbps—2 Gigabit Ethernet
    - 10-Gigabit Ethernet (Up to 100m Reliably)
      - The work of the IEEE P802.3ae 10Gb/s Ethernet Task Force is now complete with the approval of IEEE Std 802.3ae-2002 at the June 2002 IEEE Standards Board meeting.

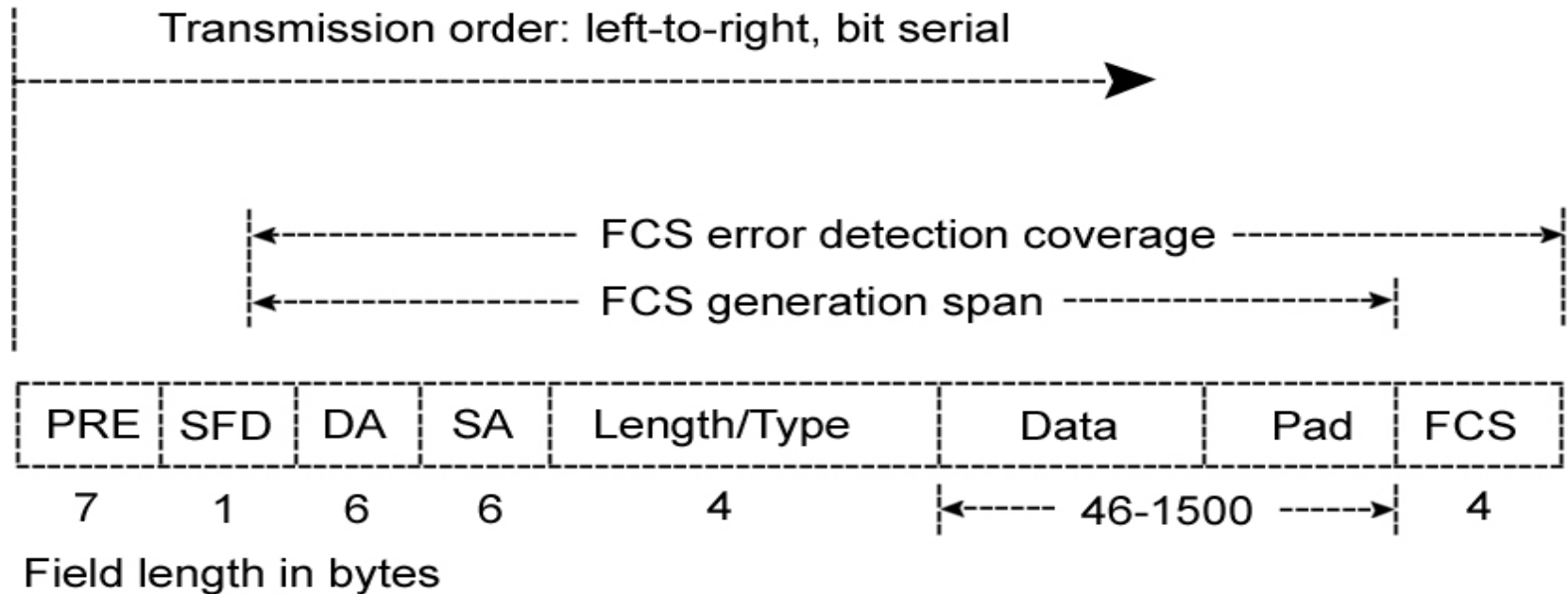
# The Basic Ethernet Frame Format

- **The Basic Ethernet Frame Format**
- The IEEE 802.3 standard defines a basic data frame format that is required for all MAC implementations, plus several additional optional formats that are used to extend the protocol's basic capability. The basic data frame format contains the seven fields shown in Figure 7-6.
- **Preamble (PRE)**—Consists of 7 bytes. The PRE is an alternating pattern of ones and zeros that tells receiving stations that a frame is coming, and that provides a means to synchronize the frame-reception portions of receiving physical layers with the incoming bit stream.
- **Start-of-frame delimiter (SOF)**—Consists of 1 byte. The SOF is an alternating pattern of ones and zeros, ending with two consecutive 1-bits indicating that the next bit is the left-most bit in the left-most byte of the destination address.
- **Destination address (DA)**—Consists of 6 bytes. The DA field identifies which station(s) should receive the frame. The left-most bit in the DA field indicates whether the address is an individual address (indicated by a 0) or a group address (indicated by a 1). The second bit from the left indicates whether the DA is globally administered (indicated by a 0) or locally administered (indicated by a 1). The remaining 46 bits are a uniquely assigned value that identifies a single station, a defined group of stations, or all stations on the network.

# The Basic Ethernet Frame Format - cont

- **Source addresses (SA)**—Consists of 6 bytes. The SA field identifies the sending station. The SA is always an individual address and the left-most bit in the SA field is always 0.
- **Length/Type**—Consists of 4 bytes. This field indicates either the number of MAC-client data bytes that are contained in the data field of the frame, or the frame type ID if the frame is assembled using an optional format. If the Length/Type field value is less than or equal to 1500, the number of LLC bytes in the Data field is equal to the Length/Type field value. If the Length/Type field value is greater than 1536, the frame is an optional type frame, and the Length/Type field value identifies the particular type of frame being sent or received.
- **Data**—Is a sequence of  $n$  bytes of any value, where  $n$  is less than or equal to 1500. If the length of the Data field is less than 46, the Data field must be extended by adding a filler (a pad) sufficient to bring the Data field length to 46 bytes.
- **Frame check sequence (FCS)**—Consists of 4 bytes. This sequence contains a 32-bit cyclic redundancy check (CRC) value, which is created by the sending MAC and is recalculated by the receiving MAC to check for damaged frames. The FCS is generated over the DA, SA, Length/Type, and Data fields.

# The Basic Ethernet Frame Format



PRE = Preamble

SFD = Start-of-frame delimiter

DA = Destination address

SA = Source address

FCS = Frame check sequence

# Network Components

- NIC
  - Network Interface Card
- Hub
- Switch
- Router

# Hubs

- Basic Element for connecting computers together for networks
- Splits a single incoming line into multiple destination lines.
- Hubs receive packets and then sends those packets to every node on the Hub this increases bottlenecking and traffic on the network

# Switches

- Ability to filter and send data to specific hardware ports
- Lowers network traffic and collisions by sending the packets only to their desired destination as opposed to the Hub which sends to all ports

# Router

- A router is a piece of equipment that connects at least two networks and forwards packets the most efficient way based on its knowledge of the connected networks.
- Typically maintain routing tables that contain available route, distance, and network congestion information
- Uses these tables along with complex algorithms to determine the most efficient way to send a packet across the network

# Addressing

- How is this data transferred?
- What are IP addresses?
- What is next?

# Addressing

- Each computer connected to a network is given an IP number.
- This number uniquely describes the computer while it is attached to its network.

# Closer Look at IP numbers

- 128.163.2.27 (<http://www.uky.edu>)
- 27 is the computer
  - This case: UKY Web server
- 2 is the subnet
  - Optional field when doing a lookup
- 128.163 is the network site
  - Registered by UK to host IP's to its subnets

# IP Classes

- **Class A**
  - supports 16 million hosts on each of 127 networks
- **Class B**
  - supports 65,000 hosts on each of 16,000 networks
- **Class C**
  - supports 254 hosts on each of 2 million networks
- **IP Index** - <http://blues.eurovia.es/mirrors/www.ipindex.net/>

# IP Index Example

- 128.160.0.0 Naval Research Laboratory (NET- SSCNET)
- 128.161.0.0 NASA Ames Research Center (NET-NSN-NET)
- 128.162.0.0 - 128.162.255.255 SGI (NET-SGI-1BLK)
- [128.163.0.0 University of Kentucky \(NET-UKY\)](#)
- 128.164.0.0 The George Washington University (NET-GWU-GATE)
- 128.165.0.0 Los Alamos National Laboratory (NET-LANL-INET)
- 128.166.0.0 Boeing Aerospace Corporation (NET-BAC-NET)
- 128.167.0.0 SURANET (NET-SURA-B)
- 128.168.0.0 Gold Hill Computers (NET-GOLDHILL)
- 128.169.0.0 University of Tennessee - Knoxville (NET-UTK)
- 128.170.0.0 PARAMAX Systems Corporation (NET-PARAMAX-WEST)
- 128.171.0.0 University of Hawaii (NET-HAWAII)
- 128.172.0.0 Virginia Commonwealth University (NET-VCU-LAN)
- 128.173.0.0 Communications Resources (NET-VA-TECH)
- 128.174.0.0 University of Illinois, CCSO (NET-UIUC-CAMPUS-B)
- 128.175.0.0 University of Delaware (NET-UDELNET)

# IPv6

- What is IPv6
- Whats new?
- Why do we need it?

# IPv4 vs. IPv6

## IPv4 address

- 127.0.0.1

## IPv6 address

- fe80:0:00:000:2a0:d2ff:fea5:e9f5
  - Equivalent to
    - fe80::2a0:d2ff:fea5:e9f5
    - a number of consecutive zeros can be abbreviated by a single "::"

# Looks more Complicated

- So What?

- IPv4

- $2^{32}$

- Approximately 4 billion hosts

- IPv6

- $2^{128}$

- 340282366920938463463374607431768211456

- Approximately 340 undecillion

- *n.* a million decillions ( $10^{66}$ );

- (*American & French*) a thousand decillions ( $10^{36}$ ).

# Internet2

- Whats next with Internet2?



# Introduction to Internet2

- Internet2 is a consortium being led by:
  - Universities
  - Industry
  - Corporations
  - Government
- To develop and deploy advanced network applications and technologies, accelerating the creation of tomorrow's Internet

# Primary Goals

- Create a leading edge network capability for the national research community
- Enable revolutionary Internet applications
- Ensure the rapid transfer of new network services and applications to the broader Internet community.

# Features of Internet2

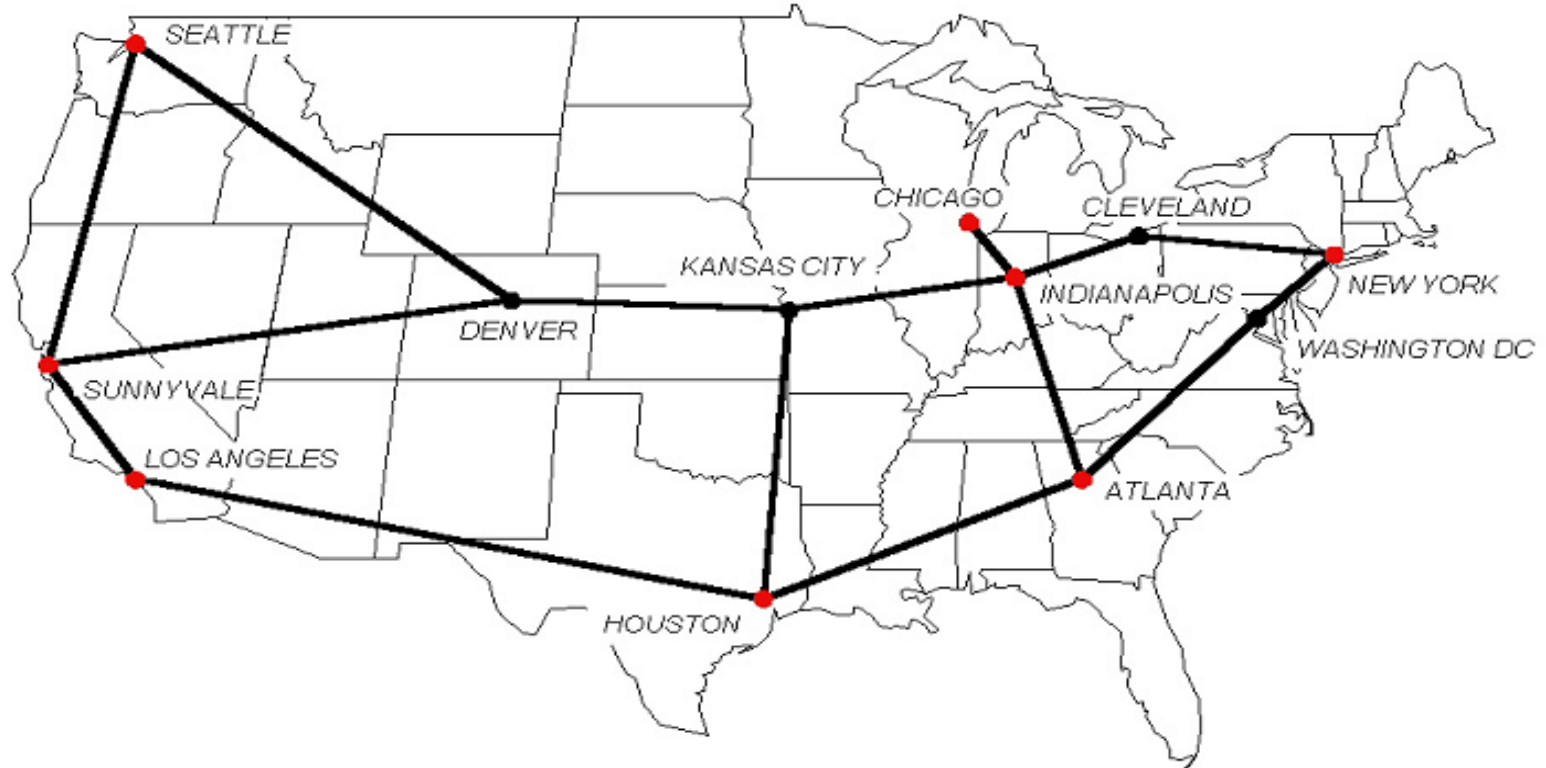
- Supports IPv6
- Packet Forwarding
- Packet obscuring
- Quality of Service

# Backbone

- Abilene
  - Connects regional network aggregation points, called gigaPoPs
    - A Gigabit Point of Presence
    - aggregation point for networking within a geographic region
  - In order to support Internet2 work
  - Work at OC-48
    - 2.4Gbps
    - GigaPOPs are the aggregation points

# Abilene Network

## Abilene Network Backbone - February 2002



# Middleware

- **Software**
  - Found between the network and its applications
  - Middleware includes:
    - Authentication
    - Identification
    - Authorization
    - Security

# Applications for Internet2

- Digital libraries, Virtual Laboratories, distance-independent learning and tele-immersion
- Packet Forwarding
- Domain name service (off site secondary)
- Network Time Servers
- Other possible services:
  - Multicast, Web caches, Netnews

# Current Applications

- **MedMid**
  - Middleware for Medical groups
  - Way to exchange medical information across the Internet2
    - Important new content-sharing tools
- **Voice over IP**
  - Working with
    - Digital Video Working Group
    - Quality of Service Working Group
    - Measurement Working Group
- **Various Video Applications**

# Resources

- <http://www.ccs.uky.edu/csep/csep.html>
- [http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito\\_doc/ethernet.htm#xtocid2](http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/ethernet.htm#xtocid2)
- <http://www.internet2.edu/>
- [http://www.webopedia.com/TERM/I/IP\\_address.html](http://www.webopedia.com/TERM/I/IP_address.html)
- <http://blues.eurovia.es/mirrors/www.ipindex.net/>
- [http://www.onlamp.com/pub/a/onlamp/2001/05/24/ipv6\\_tutorial.html](http://www.onlamp.com/pub/a/onlamp/2001/05/24/ipv6_tutorial.html)
- [http://www.sun.com/products-n-solutions/edu/events/archive/hpc/2002presentations/HPC\\_Consortium\\_816200213951.pdf](http://www.sun.com/products-n-solutions/edu/events/archive/hpc/2002presentations/HPC_Consortium_816200213951.pdf)
- <http://studynotes.net/net1.htm>
- <http://www.upenn.edu/computing/group/sug/presentation/jan00/tsld030.htm>
- <http://www.oit.umd.edu/cans/2001/Archives/dougvanhouweling/sld006.htm>