Extending LANs

- Why LANs are distance limited?
  - Signal loss at physical level
  - Coordination at logical level
- Engineers have developed a variety of ways to extend LAN connectivity.
- Most extension mechanisms use standard interface hardware and insert additional hardware components that can extend signals at longer distances.
- Fiber optic extensions, repeaters, bridges or switches and hubs can be used for extending LANs.

Fiber Modems
- The simplest LAN extension mechanism uses optical fibers and a pair of fiber modems extend the connection between a computer and a transceiver.
- Fibers have low delayed and high bandwidth.

Repeaters
- Repeaters connects a pair of cables and is an analog device.
- Its main job is to repeat every signal that it hears on one side to the other.

Extended Ethernet LAN with Repeaters
- Repeaters repeats everything, collision, noise, even thunderstorm!

Bridges
- Bridges also connects two networks,
  - but they understand frame format.
  - Has a separate HW address.
  - Can talk to each other.
- Listens to both the networks in promiscuous mode and can copy every frame it receives intact to the other network.
- Thus two LANs can work as one LAN.
- Computers would not know on which segment they are in.
Bridges
- Bridges can also perform frame filtering.
  - It looks into hardware address in the frames.
  - Relays the frames only if it is for a computer in another segment.

Bridging Between Buildings

How do they know which computer is in which side?

Bridging Across Long Distance

How Bridges know about the computer which did not talk?

Cycle of Bridges

- Parallelism
- How computers should be distributed at two segments?

Problem of Scale: WANs
- The techniques shown in last few slides show how the distance limitation of LANs be extended.
- But, they do not solve the problem of Scale. What if we have too many computers scattered across long distances, at different places?
  - Solution:
    - Packet Switches
      - Moves packet from one network to another.
      - Not only one or two but, many switches creates a network of networks.
      - Distributed routing.

WAN
how to win the limit on the number of computers?
Computers can communicate in parallel. But costly. Thus a combination of Switch & Hub is used.

One side connects to computers, other side connects to other packet switches.

Back Bone WANs with Packet Switches
- Computers now talk in parallel.
- Switches does store and forward

How do they know which computer is where and where to forward?

Physical Addressing in a WAN
- Each address is divided into two parts: switch address and computer address
- Each switch maintains a list of next-hop-address for each destination

Example of Next Hop Forwarding

Forwarding Table of Switch#2

Further Scalable WAN
- Scalable Network
  - Interior and
  - Exterior Packet Switches
- Scalable Address Table
  - Universality
    - Each should know the path to any computer.
  - Optimality
    - The path should be optimum too.
Routing in a WAN

Default Routing

Size of address Table?

Connectionless vs. Connection-oriented Switching

- A packet can explicitly carry the destination address. However, if lots of packets are going to the same destination, they can carry a small label.
  - Cost of Address field
  - Connection Setup Cost

- Example ATM:
  - VPI:VCI
  - Path identifier can change from switch to switch
  - Channel identified is used only by the destination switch.

Example WAN Technologies

- ARPANET
  - A defense initiative started in 1960s.
  - Legacy of Internet. Based on 56Kbps Leased serial lines.

- X.25
  - Developed by ITU, popular in Europe
  - Used for remote terminal placement of computers.
  - Not suitable for computer-computer communication.

- ISDN
  - Objective: data networking on voice system.
  - 64 Kbps data + 16 Kbps control channel.

Example WAN Technologies -2

- Frame Relay
  - Appropriate for long distance LAN bridging
  - Supports up to 8K frames on 1.5 Mbps or 56Kbps.

- SMDS (switched multi-megabit data service)
  - Designed to carry data.
  - Higher bandwidth than FR

- ATM
  - Most promising in WAN
  - Ensures quality of service.
  - Available in 155 Mbps/ 622 Mbps

Summary

- LAN technology can connect a community of computers.
- Solution to Distance Limitation
  - Repeaters & Bridges.
- Solution to Scale Limitation
  - Packet Switch for connection scaling.
- New Issue
  - Routing

10s of thousands of computers can be connected with the above Networking Infrastructure!
Summary (cont..)

- Technologies:
  - LANs: Ethernet, AppleTalk, IBM Token Ring
  - Fast LANs: FDDI, Fast Ethernet, HIPPI, ATM, Fiber Channel
  - WANs: ARPANET, X.25, ISDN, SMDS, Frame Relay, ATM

Computing Shortest Path (Dijkstra’s Algorithm)

\[ W_{ij} = \text{link cost between node } i \text{ and } j \]
\[ S_{i} = \text{all nodes except source; } R_{i} = \text{source for all connected nodes otherwise zero.} \]
\[ D_{i} = W_{\text{source}}[i] \text{ for nodes connected from src otherwise infinity.} \]

\[ \text{while (set } S \text{ is not empty) { } } \]
\[ \text{choose } u \text{ from set } S \text{ closest to source; } \]
\[ \text{if (} D_{u} \text{ is infinity) no path in } S \text{, exit; } \]
\[ \text{delete } u \text{ from } S; \]
\[ \text{for each } v \text{ such that } W_{u}[v] \text{ is an edge } { } \]
\[ \text{if (} v \text{ is still in } S \text{) { } } \]
\[ c = D_{u} + W_{u}[v]; \]
\[ \text{if } c < D_{v} \text{ { } } \]
\[ \text{R}_v = \text{R}_u; \]
\[ D_v = c; \]

Distributed Vector Distance Routing Table Computation

Given a local routing table with weight and an incoming message:

\[ \text{Repeat forever } { } \]
\[ \text{wait for next message from } N; \]
\[ \text{for each entry in the message } { } \]
\[ \text{if } V \text{ is destination and } D = \text{cost; } \]
\[ c = \text{distance to } N + D; \]
\[ \text{if } V \text{ is new destination } { } \]
\[ \text{add a new entry, for } V \text{ with next-hop } = N \text{ and } D = c; \]
\[ \text{if } V \text{ is there and next-hop is also } N \text{ } \]
\[ \text{replace local } D \text{ with } c; \]
\[ \text{if } V \text{ is there but next-hop is not } N \text{ but } D > c \text{ } \]
\[ \text{replace next-hop } = N \text{ and local } D = c; \]

Next Topic: Internetworking