Today’s Lecture

• Project 1
  – Q&A
• Packet Forwarding
  – Shared Access
  – Chapter 3.1

Read Chapter 3.2 for Thursday

Shared Access Networks

Outline
  Bus (Ethernet)
  Token ring (IBM, FDDI, RPR)
  Wireless (802.11, WiMAX)

Wi-Fi

• IEEE 802.11: 2.4 GHz band, 1 Mb/s
• IEEE 802.11b: 2.4 GHz band, 11Mb/s
• IEEE 802.11a: 5GHz band, 54Mb/s
• IEEE 802.11g: 2.4GHz band, 54Mb/s
• IEEE 802.11n: Dual band (2.4, 5), 270 Mb/s

MIMO Block Ack

Spread Spectrum

• Idea
  – Spread signal over wider frequency band than required
  – Originally designed to thwart jamming
• Frequency Hopping
  – Transmit over random sequence of frequencies
  – Sender and receiver share
    • Pseudorandom number generator
    • Seed
  – 802.11 uses 79 x 1MHz-wide frequency bands
Spread Spectrum (cont)

- Direct Sequence
  - For each bit, send XOR of that bit and \( n \) random bits
  - Random sequence known to both sender and receiver
  - Called \( n \)-bit chipping code
  - 802.11 defines an 11-bit chipping code

Collision Avoidance

- Similar to Ethernet
- Problem: hidden and exposed nodes

MACA

- Multiple Access with Collision Avoidance
- Sender transmits RequestToSend (RTS) frame
- Receiver replies with ClearToSend (CTS) frame
- Neighbors:
  - see CTS: keep quiet
  - see RTS but not CTS: ok to transmit
- Receiver sends ACK when has frame
  - neighbors silent until see ACK
- Collisions
  - no collision detection
  - known when CTS not received
  - exponential backoff

In general, bad, bad, bad

Supporting Mobility

- Case 1: ad hoc networking
- Case 2: access points (AP)
  - Tethered
    - Each mobile node associates with an AP
  - Active: when join or move
  - Passive: AP periodically sends Beacon frame

802.11

- Up to 2312 bytes of data
- 32-bit CRC
- 4 addresses, usage depends on mode:
  - Addr1 is target, Addr2 is source
  - Addr1 is ultimate target, Addr2: immediate sender,
    Addr3 is intermediate target, Addr4: original source
WiMAX
- Worldwide Interoperability for Microwave Access
- Standardized by WiMAX Forum, IEEE 802.16
- Typical distance: 1-6 miles, up to 30 miles
- “subscriber stations” (e.g., antenna on roof)
- Up to 70 Mbps
- Time Division Duplexing (TDD)
- Frequency Division Duplexing (FDD)

Cell Phone Technologies
- Uses base stations, area served called “cell”
- 1G: analog
- 2G, 2.5G (e.g., GSM): digital
- GPRS: General Packet Radio Service (typically 30-70 Kbps)
- 3G:
  - UMTS (Universal Mobile Telecommunications System)

Switching and Forwarding
Outline
- Store-and-Forward Switches
- Bridges and Extended LANs

Scalability
- Shared Access
  - More users -> worse performance
  - Why -> more competition
  - Fairness vs. quality of access?

Switch
- Switch allows us to logically separate the network
- Allows us to “connect on demand”

Scalability
- Demand = Destination Address
Scalable Networks

- **Switch**
  - Forwards packets from input port to output port
  - Port selected based on address in packet header

- **Advantages**
  - Cover large geographic area (tolerate latency)
  - Support large numbers of hosts (scalable bandwidth)

Source Routing

- Use, rotate
- Pop, fwd
- Point, fwd

Virtual Circuit Switching

- Set up and tear down
- Circuit on demand
- Connection-oriented model

- Analogy: phone call
- Each switch maintains a VC table

Example Tables

- **Circuit Table** (switch 1, port 2)

<table>
<thead>
<tr>
<th>VC In</th>
<th>VC Out</th>
<th>Port Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

- **Forwarding Table** (switch 1)

<table>
<thead>
<tr>
<th>Address</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
</tr>
</tbody>
</table>

Datagram Switching

- No connection setup phase
- Each packet forwarded independently
- Sometimes called connectionless model

- Analogy: postal system
- Each switch maintains a forwarding (routing) table
Virtual Circuit Model

- Typically wait full RTT for connection setup before sending first data packet.
- While the connection request contains the full address for destination, each data packet contains only a small identifier, making the per-packet header overhead small.
- If a switch or a link in a connection fails, the connection is broken and a new one needs to be established.
- Connection setup provides an opportunity to reserve resources.

Datagram Model

- There is no round trip delay waiting for connection setup; a host can send data as soon as it is ready.
- Source host has no way of knowing if the network is capable of delivering a packet or if the destination host is even up.
- Since packets are treated independently, it is possible to route around link and node failures.
- Since every packet must carry the full address of the destination, the overhead per packet is higher than for the connection-oriented model.

Bridges and Extended LANs

- LANs have physical limitations (e.g., 2500m)
- Connect two or more LANs with a bridge
  - accept and forward strategy
  - level 2 connection (does not add packet header)
- Ethernet Switch = Bridge on Steroids

Learning Bridges

- Do not forward when unnecessary
- Maintain forwarding table

- Learn table entries based on source address
- Table is an optimization; need not be complete
- Always forward broadcast frames

Spanning Tree Algorithm

- Problem: loops
- Bridges run a distributed spanning tree algorithm
  - Select which bridges actively forward
  - Developed by Radia Perlman
  - Now IEEE 802.1 specification

Algorithm Overview

- Each bridge has unique id (e.g., B1, B2, B3)
- Select bridge with smallest id as root
- Select bridge on each LAN closest to root as designated bridge (use id to break ties)
- Each bridge forwards frames over each LAN for which it is the designated bridge
Algorithm Details

- Bridges exchange configuration messages
  - id for bridge sending the message
  - id for what the sending bridge believes to be root bridge
  - distance (hops) from sending bridge to root bridge
- Each bridge records current best configuration message for each port
- Initially, each bridge believes it is the root

Algorithm Detail (cont)

- When learn not root, stop generating config messages
  - in steady state, only root generates configuration messages
- When learn not designated bridge, stop forwarding config messages
  - in steady state, only designated bridges forward config messages
- Root continues to periodically send config messages
- If any bridge does not receive config message after a period of time, it starts generating config messages claiming to be the root

Configuration

![Configuration Diagram](image)

Broadcast and Multicast

- Forward all broadcast/multicast frames
  - Current practice
- Learn when no group members downstream
- Accomplished by having each member of group $G$ send a frame to bridge multicast address with $G$ in source field

Limitations of Bridges

- Do not scale
  - Spanning tree algorithm does not scale
  - Broadcast does not scale
- Do not accommodate heterogeneity
- Caution: beware of transparency