Local Area Network Overview

LAN Applications (1)

- Personal computer LANs
  - Low cost
  - Limited data rate
- Back end networks
  - Interconnecting large systems (mainframes and large storage devices)
    - High data rate
    - High speed interface
    - Distributed access
    - Limited distance
    - Limited number of devices
LAN Applications (2)

• Storage Area Networks
  — Separate network handling storage needs
  — Detaches storage tasks from specific servers
  — Shared storage facility across high-speed network
  — Hard disks, tape libraries, CD arrays
  — Improved client-server storage access
  — Direct storage to storage communication for backup

• High speed office networks
  — Desktop image processing
  — High capacity local storage

• Backbone LANs
  — Interconnect low speed local LANs
  — Reliability
  — Capacity
  — Cost
LAN Architecture

- Topologies
- Transmission medium
- Layout
- Medium access control

Topologies

- Tree
- Bus
- Ring
- Star
**Bus and Tree**

- Multipoint medium
- Transmission propagates throughout medium
- Heard by all stations
  - Need to identify target station
    - Each station has unique address
- Full duplex connection between station and tap
  - Allows for transmission and reception
- Need to regulate transmission
  - To avoid collisions
  - To avoid hogging
    - Data in small blocks - frames
- Terminator absorbs frames at end of medium
**Ring Topology**

- Repeaters joined by point to point links in closed loop
  - Receive data on one link and retransmit on another
  - Links unidirectional
  - Stations attach to repeaters
- Data in frames
  - Circulate past all stations
  - Destination recognizes address and copies frame
  - Frame circulates back to source where it is removed
- Media access control determines when station can insert frame
Frame Transmission
Ring LAN

Star Topology

- Each station connected directly to central node
  - Usually via two point to point links
- Central node can broadcast
  - Physical star, logical bus
  - Only one station can transmit at a time
- Central node can act as frame switch
**Choice of Topology**

- Reliability
- Expandability
- Performance
- Needs considering in context of:
  - Medium
  - Wiring layout
  - Access control

**Bus LAN**

**Transmission Media (1)**

- Twisted pair
  - Early LANs used voice grade cable
  - Didn’t scale for fast LANs
  - Not used in bus LANs now
- Baseband coaxial cable
  - Uses digital signalling
  - Original Ethernet
**Bus LAN**

**Transmission Media (2)**

- Broadband coaxial cable
  - As in cable TV systems
  - Analog signals at radio frequencies
  - Expensive, hard to install and maintain
  - No longer used in LANs
- Optical fiber
  - Expensive taps
  - Better alternatives available
  - Not used in bus LANs
- All hard to work with compared with star topology twisted pair
- Coaxial baseband still (rarely) used but not often in new installations

**Ring and Star Usage**

- Ring
  - Very high speed links over long distances
  - Single link or repeater failure disables network
- Star
  - Uses natural layout of wiring in building
  - Best for short distances
  - High data rates for small number of devices
**Choice of Medium**

- Constrained by LAN topology
- Capacity
- Reliability
- Types of data supported
- Environmental scope

**Media Available (1)**

- Voice grade unshielded twisted pair (UTP)
  - Cat 3
  - Cheap
  - Well understood
  - Use existing telephone wiring in office building
  - Low data rates
- Shielded twisted pair and baseband coaxial
  - More expensive than UTP but higher data rates
- Broadband cable
  - Still more expensive and higher data rate
Media Available (2)

- High performance UTP
  - Cat 5 and above
  - High data rate for small number of devices
  - Switched star topology for large installations
- Optical fiber
  - Electromagnetic isolation
  - High capacity
  - Small size
  - High cost of components
  - High skill needed to install and maintain
    - Prices are coming down as demand and product range increases

Protocol Architecture

- Lower layers of OSI model
- IEEE 802 reference model
- Physical
- Logical link control (LLC)
- Media access control (MAC)
802 Layers - Physical

- Encoding/decoding
- Preamble generation/removal
- Bit transmission/reception
- Transmission medium and topology
802 Layers - Logical Link Control

- Interface to higher levels
- Flow and error control

Logical Link Control

- Transmission of link level PDUs between two stations
- Must support multi-access, shared medium
- Relieved of some link access details by MAC layer
- Addressing involves specifying source and destination LLC users
  - Referred to as service access points (SAP)
  - Typically higher level protocol
**LLC Services**

- Based on HDLC
- Unacknowledged connectionless service
- Connection mode service
- Acknowledged connectionless service

**LLC Protocol**

- Modeled after HDLC
- Asynchronous balanced mode to support connection mode LLC service (type 2 operation)
- Unnumbered information PDUs to support Acknowledged connectionless service (type 1)
- Multiplexing using LSAPs
**Media Access Control**

- Assembly of data into frame with address and error detection fields
- Disassembly of frame
  - Address recognition
  - Error detection
- Govern access to transmission medium
  - Not found in traditional layer 2 data link control
- For the same LLC, several MAC options may be available

**LAN Protocols in Context**
Media Access Control

- Where
  - Central
    - Greater control
    - Simple access logic at station
    - Avoids problems of co-ordination
    - Single point of failure
    - Potential bottleneck
  - Distributed

- How
  - Synchronous
    - Specific capacity dedicated to connection
  - Asynchronous
    - In response to demand

Asynchronous Systems

- Round robin
  - Good if many stations have data to transmit over extended period
- Reservation
  - Good for stream traffic
- Contention
  - Good for bursty traffic
  - All stations contend for time
  - Distributed
  - Simple to implement
  - Efficient under moderate load
  - Tend to collapse under heavy load
MAC Frame Format

- MAC layer receives data from LLC layer
- MAC control
- Destination MAC address
- Source MAC address
- LLS
- CRC
- MAC layer detects errors and discards frames
- LLC optionally retransmits unsuccessful frames

Generic MAC Frame Format

```
MAC Frame
| MAC Control | Destination MAC Address | Source MAC Address | LLC PDU | CRC |
```

```
LLC PDU
<table>
<thead>
<tr>
<th>1 octet</th>
<th>1</th>
<th>1 or 2</th>
<th>variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSAP</td>
<td>SSAP</td>
<td>LLC Control</td>
<td>Information</td>
</tr>
</tbody>
</table>

```

```
<table>
<thead>
<tr>
<th>I/G</th>
<th>DSAP value</th>
<th>C/R</th>
<th>SSAP value</th>
</tr>
</thead>
</table>
```

I/G = Individual/Group
C/R = Command/Response
Bridges

- Ability to expand beyond single LAN
- Provide interconnection to other LANs/WANs
- Use Bridge or router
- Bridge is simpler
  - Connects similar LANs
  - Identical protocols for physical and link layers
  - Minimal processing
- Router more general purpose
  - Interconnect various LANs and WANs
  - See later

Why Bridge?

- Reliability
- Performance
- Security
- Geography
Functions of a Bridge

- Read all frames transmitted on one LAN and accept those address to any station on the other LAN
- Using MAC protocol for second LAN, retransmit each frame
- Do the same the other way round

Bridge Operation
**Bridge Design Aspects**

- No modification to content or format of frame
- No encapsulation
- Exact bitwise copy of frame
- Minimal buffering to meet peak demand
- Contains routing and address intelligence
  - Must be able to tell which frames to pass
  - May be more than one bridge to cross
- May connect more than two LANs
- Bridging is transparent to stations
  - Appears to all stations on multiple LANs as if they are on one single LAN

**Bridge Protocol Architecture**

- IEEE 802.1D
- MAC level
  - Station address is at this level
- Bridge does not need LLC layer
  - It is relaying MAC frames
- Can pass frame over external communication system
  - e.g. WAN link
  - Capture frame
  - Encapsulate it
  - Forward it across link
  - Remove encapsulation and forward over LAN link
Fixed Routing

- Complex large LANs need alternative routes
  - Load balancing
  - Fault tolerance
- Bridge must decide whether to forward frame
- Bridge must decide which LAN to forward frame on
- Routing selected for each source-destination pair of LANs
  - Done in configuration
  - Usually least hop route
  - Only changed when topology changes
Bridges and LANs with Alternative Routes

Spanning Tree

- Bridge automatically develops routing table
- Automatically update in response to changes
- Frame forwarding
- Address learning
- Loop resolution
Frame forwarding

• Maintain forwarding database for each port
  —List station addresses reached through each port

• For a frame arriving on port X:
  —Search forwarding database to see if MAC address is listed for any port (except port X)
  —If address not found, forward to all ports (except X)
  —If address listed for port Y, check port Y for blocking or forwarding state
    • Blocking prevents port from receiving or transmitting
  —If not blocked, transmit frame through port Y

Address Learning

• Can preload forwarding database
• Can be learned
• When frame arrives at port X, it has come form the LAN attached to port X
• Use the source address to update forwarding database for port X to include that address
• Timer on each entry in database
• Each time frame arrives, source address checked against forwarding database
Spanning Tree Algorithm

- Address learning works for tree layout
  — i.e. no closed loops
- For any connected graph there is a spanning tree that maintains connectivity but contains no closed loops
- Each bridge assigned unique identifier
- Exchange between bridges to establish spanning tree
Layer 2 and Layer 3 Switches

- Now many types of devices for interconnecting LANs
- Beyond bridges and routers
- Layer 2 switches
- Layer 3 switches

Hubs

- Active central element of star layout
- Each station connected to hub by two lines
  - Transmit and receive
- Hub acts as a repeater
- When single station transmits, hub repeats signal on outgoing line to each station
- Line consists of two unshielded twisted pairs
- Limited to about 100 m
  - High data rate and poor transmission qualities of UTP
- Optical fiber may be used
  - Max about 500 m
- Physically star, logically bus
- Transmission from any station received by all other stations
- If two stations transmit at the same time, collision
**Hub Layouts**

- Multiple levels of hubs cascaded
- Each hub may have a mixture of stations and other hubs attached to from below
- Fits well with building wiring practices
  - Wiring closet on each floor
  - Hub can be placed in each one
  - Each hub services stations on its floor

**Two Level Star Topology**
Buses and Hubs

- Bus configuration
  - All stations share capacity of bus (e.g. 10Mbps)
  - Only one station transmitting at a time
- Hub uses star wiring to attach stations to hub
  - Transmission from any station received by hub and retransmitted on all outgoing lines
  - Only one station can transmit at a time
  - Total capacity of LAN is 10 Mbps
- Improve performance with layer 2 switch

Shared Medium Bus and Hub

(a) Shared medium bus

(b) Shared medium hub
**Layer 2 Switches**

- Central hub acts as switch
- Incoming frame from particular station switched to appropriate output line
- Unused lines can switch other traffic
- More than one station transmitting at a time
- Multiplying capacity of LAN
Layer 2 Switch Benefits

- No change to attached devices to convert bus LAN or hub LAN to switched LAN
- For Ethernet LAN, each device uses Ethernet MAC protocol
- Device has dedicated capacity equal to original LAN
  - Assuming switch has sufficient capacity to keep up with all devices
  - For example if switch can sustain throughput of 20 Mbps, each device appears to have dedicated capacity for either input or output of 10 Mbps
- Layer 2 switch scales easily
  - Additional devices attached to switch by increasing capacity of layer 2

Types of Layer 2 Switch

- Store-and-forward switch
  - Accepts frame on input line
  - Buffers it briefly,
  - Then routes it to appropriate output line
  - Delay between sender and receiver
  - Boosts integrity of network
- Cut-through switch
  - Takes advantage of destination address appearing at beginning of frame
  - Switch begins repeating frame onto output line as soon as it recognizes destination address
  - Highest possible throughput
  - Risk of propagating bad frames
    - Switch unable to check CRC prior to retransmission
**Layer 2 Switch v Bridge**

- Layer 2 switch can be viewed as full-duplex hub
- Can incorporate logic to function as multiport bridge
- Bridge frame handling done in software
- Switch performs address recognition and frame forwarding in hardware
- Bridge only analyzes and forwards one frame at a time
- Switch has multiple parallel data paths
  - Can handle multiple frames at a time
- Bridge uses store-and-forward operation
- Switch can have cut-through operation
- Bridge suffered commercially
  - New installations typically include layer 2 switches with bridge functionality rather than bridges

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**Problems with Layer 2 Switches (1)**

- As number of devices in building grows, layer 2 switches reveal some inadequacies
- Broadcast overload
- Lack of multiple links
- Set of devices and LANs connected by layer 2 switches have flat address space
  - All users share common MAC broadcast address
  - If any device issues broadcast frame, that frame is delivered to all devices attached to network connected by layer 2 switches and/or bridges
  - In large network, broadcast frames can create big overhead
  - Malfunctioning device can create broadcast storm
    - Numerous broadcast frames clog network
Problems with Layer 2 Switches (2)

- Current standards for bridge protocols dictate no closed loops
  - Only one path between any two devices
  - Impossible in standards-based implementation to provide multiple paths through multiple switches between devices
    - Limits both performance and reliability.
- Solution: break up network into subnetworks connected by routers
- MAC broadcast frame limited to devices and switches contained in single subnetwork
- IP-based routers employ sophisticated routing algorithms
  - Allow use of multiple paths between subnetworks going through different routers

Problems with Routers

- Routers do all IP-level processing in software
  - High-speed LANs and high-performance layer 2 switches pump millions of packets per second
  - Software-based router only able to handle well under a million packets per second
- Solution: layer 3 switches
  - Implement packet-forwarding logic of router in hardware
- Two categories
  - Packet by packet
  - Flow based
Packet by Packet or Flow Based

- Operates in same way as traditional router
- Order of magnitude increase in performance compared to software-based router
- Flow-based switch tries to enhance performance by identifying flows of IP packets
  - Same source and destination
  - Done by observing ongoing traffic or using a special flow label in packet header (IPv6)
  - Once flow is identified, predefined route can be established

Typical Large LAN Organization

- Thousands to tens of thousands of devices
- Desktop systems links 10 Mbps to 100 Mbps
  - Into layer 2 switch
- Wireless LAN connectivity available for mobile users
- Layer 3 switches at local network’s core
  - Form local backbone
  - Interconnected at 1 Gbps
  - Connect to layer 2 switches at 100 Mbps to 1 Gbps
- Servers connect directly to layer 2 or layer 3 switches at 1 Gbps
- Lower-cost software-based router provides WAN connection
- Circles in diagram identify separate LAN subnetworks
- MAC broadcast frame limited to own subnetwork
Summary

- LAN topologies and media
- LAN protocol architecture
- bridges, hubs, layer 2 & 3 switches