Data and Computer Communications

Chapter 15 – Local Area Network Overview

Eighth Edition
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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 (SANs)
  - separate network handling storage needs
  - detaches storage tasks from specific servers
  - shared storage facility
    - eg. hard disks, tape libraries, CD arrays
  - accessed using a high-speed network
    - eg. Fibre Channel
  - improved client-server storage access
  - direct storage to storage communication for backup
Storage Area Networks

(a) Server-based storage

(b) Storage area network
LAN Applications (3)

- high speed office networks
  - desktop image processing
  - high capacity local storage

- backbone LANs
  - interconnect low speed local LANs
  - reliability
  - capacity
  - cost
LAN Architecture

• Key elements of a LAN
  – topologies
  – transmission medium
  – wiring layout
  – medium access control

• These elements determine
  – Cost and capacity of the LAN
  – Type of data that may be transmitted
  – Speed and efficiency of communications
  – Kinds of applications that can be supported
LAN Topologies

(a) Bus

(b) Tree

(c) Ring

(d) Star
Bus and Tree

- used with multipoint medium
- transmission propagates throughout medium
- heard by all stations
- full duplex connection between station and tap
  - allows for transmission and reception
- need to regulate transmission
  - to avoid collisions and hogging
- terminator absorbs frames at end of medium
- tree a generalization of bus
- headend connected to branching cables
Frame Transmission on Bus LAN

C transmits frame addressed to A

Frame is not addressed to B; B ignores it

A copies frame as it goes by
Bidirectional Transmission (baseband transmission)
Broadband Transmission Using Two Frequencies, One Bus
Broadband Transmission Using One Frequency, Two Buses
Ring Topology

- a closed loop of repeaters joined by point to point links
- receive data on one link & 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 a station can insert frame
Frame Transmission
Ring LAN

(a) C transmits frame addressed to A

(b) Frame is not addressed to B; B ignores it

(c) A copies frame as it goes by

(d) C absorbs returning frame
Star Topology

- each station connects to central node
  - usually via two point to point links
- either central node can broadcast
  - physical star, logical bus
  - only one station can transmit at a time
- or central node can act as frame switch
Star Topology
Using a Hub in a Star Topology
Using a Switch in a Star Topology

Keep the data

Chap15:18
Choice of Topology

- reliability
- expandability
- performance
- needs considering in context of:
  - medium
  - wiring layout
  - access control
Chap15:20

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

Chap15:20
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

• less convenient compared to star topology twisted pair

• coaxial baseband still 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

- Voice grade unshielded twisted pair (UTP)
  - Cat 3 phone, cheap, low data rates
- Shielded twisted pair / baseband coaxial
  - more expensive, higher data rates
- Broadband cable
  - even more expensive, higher data rate
- High performance UTP
  - Cat 5+, very high data rates, witched star topology
- Optical fibre
  - security, high capacity, small size, high cost
IEEE 802 Layers (1)

- Physical
  - encoding/decoding of signals
  - preamble generation/removal
  - bit transmission/reception
  - transmission medium and topology
IEEE 802 Layers (2)

• Logical Link Control
  – interface to higher levels
  – flow and error control

• Media Access Control
  – on transmit assemble data into frame
  – on receive disassemble frame
  – govern access to transmission medium
  – for same LLC, may have several MAC options
LAN Protocols in Context

Application data

TCP segment

IP datagram

LLC protocol data unit

MAC frame
Logical Link Control

- transmission of link level PDUs between stations
- must support multiaccess, shared medium
- but MAC layer handles link access details
- addressing involves specifying source and destination LLC users
  - referred to as service access points (SAP)
  - typically higher level protocol
Media Access Control

• where
  – central
    • greater control, single point of failure
  – distributed
    • more complex, but more redundant

• how
  – synchronous
    • capacity dedicated to connection, not optimal
  – asynchronous
    • in response to demand
Asynchronous Systems

- **round robin**
  - each station given turn to transmit data

- **reservation**
  - divide medium into slots
  - good for stream traffic

- **contention**
  - all stations contend for time
  - good for bursty traffic
  - simple to implement
  - tends to collapse under heavy load
MAC Frame Handling

• MAC layer receives data from LLC layer
• fields
  – MAC control
  – destination MAC address
  – source MAC address
  – LLC
  – CRC
• MAC layer detects errors and discards frames
• LLC optionally retransmits unsuccessful frames
Bridge Function

Frames with addresses 11 through 20 are accepted and repeated on LAN B.

Frames with addresses 1 through 10 are accepted and repeated on LAN A.
Bridge Design Aspects

- no modification to frame content or format
- no encapsulation
- exact bitwise copy of frame
- minimal buffering to meet peak demand
- contains routing and address intelligence
- may connect more than two LANs
- bridging is transparent to stations
Bridge Protocol Architecture

- IEEE 802.1D
- MAC level
- bridge does not need LLC layer
- can pass frame over external comms system
  - capture frame
  - encapsulate it
  - forward it across link
  - remove encapsulation and forward over LAN link
  - e.g. WAN link
Connection of Two LANs

(a) Architecture

(b) Operation
Interconnected via WAN

- LANs are interconnected via the WAN.
Bridges and LANs with Alternative Routes
Fixed Routing

- complex large LANs need alternative routes
  - for load balancing and fault tolerance
- bridge must decide whether to forward frame
- bridge must decide LAN to forward frame to
- can use fixed routing for each source-destination pair of LANs
  - done in configuration
  - usually least hop route
  - only changed when topology changes
  - widely used but limited flexibility
Spanning Tree

- bridge automatically develops routing table
- automatically updates routing table in response to changes
- three mechanisms:
  - frame forwarding
  - address learning
  - loop resolution
Frame Forwarding

• maintain forwarding database for each port
  – lists 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 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
  – if not blocked, transmit frame through port Y
Address Learning

• can preload forwarding database
• when frame arrives at port X, it has come form the LAN attached to port X
• use source address to update forwarding database for port X to include that address
• have a timer on each entry in database
• if timer expires, entry is removed
• each time frame arrives, source address checked against forwarding database
  – if present timer is reset and direction recorded
  – if not present entry is created and timer set
Filtering Database Examples
Forwarding and Address Learning Algorithm
Address Learning Example

1. A -> E
2. B -> D
3. C -> B
4. D -> A
5. E -> C
Address Learning Example (A→E)
Address Learning Example (B→D)
Address Learning Example (C→B)
Address Learning Example (D→A)
Address Learning Example (E → C)
Loop of Bridges

• Loops provides reliability
• Loops make frames duplication
• Loops make wrong address learning
Spanning Tree Algorithm

• address learning works for tree layout
• in general graph have loops
• for any connected graph there is a spanning tree maintaining connectivity with no closed loops
• IEEE 802.1 Spanning Tree Algorithm finds this
  – each bridge assigned unique identifier
  – exchange info between bridges to find spanning tree
  – automatically updated whenever topology changes
Internetworking Devices

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Interconnecting LANs - Hubs

- active central element of star layout
- each station connected to hub by two UTP lines
- hub acts as a repeater
- limited to about 100 m by UTP properties
- optical fiber may be used out to 500m
- physically star, logically bus
- transmission from a station seen by all others
- if two stations transmit at the same time have a collision
Two Level Hub Topology

- HHUB
  - IHUB
    - Station
    - Station
    - Station
  - IHUB
  - Station

Two cables (twisted pair or optical fiber)

Transmit

Receive
Buses, Hubs and Switches

• 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
  – 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
• can improve performance using a layer 2 switch
  – can switch multiple frames between separate ports
  – multiplying capacity of LAN
Shared Medium Bus and Hub
Layer 2 Switch Benefits

• no change to attached devices to convert bus LAN or hub LAN to switched LAN
  – e.g. Ethernet LANs use Ethernet MAC protocol
• have dedicated capacity equal to original LAN
  – assuming switch has sufficient capacity to keep up with all devices
• 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 briefly, routes to destination port
  - see delay between sender and receiver
  - better integrity

- **cut-through switch**
  - use destination address at beginning of frame
  - switch begins repeating frame onto output line as soon as destination address recognized
  - highest possible throughput
  - risk of propagating bad frames
Layer 2 Switch vs Bridge

- Layer 2 switch can be viewed as full-duplex hub
- incorporates logic to function as multiport bridge
- differences between switches & bridges:
  - bridge frame handling done in software
  - switch performs frame forwarding in hardware
  - bridge analyzes and forwards one frame at a time
  - switch can handle multiple frames at a time
  - bridge uses store-and-forward operation
  - switch can have cut-through operation
- hence bridge have suffered commercially
Layer 2 Switch Problems

• broadcast overload
  – users share common MAC broadcast address
  – broadcast frames are delivered to all devices connected by layer 2 switches and/or bridges
  – broadcast frames can create big overhead
  – broadcast storm from malfunctioning devices

• lack of multiple links
  – limits performance & reliability
Router Problems

• typically use subnetworks connected by routers
  – limits broadcasts to single subnet
  – supports multiple paths between subnet

• 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
Layer 3 Switches

• 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

- **packet by packet**
  - operates like a traditional router
  - order of magnitude increase in performance compared to software-based router

- **flow-based switch**
  - enhances performance by identifying flows of IP packets with same source and destination
  - by observing ongoing traffic or using a special flow label in packet header (IPv6)
  - a predefined route is used for identified flows
Typical Large LAN Organization Diagram
Summary

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