Chapter 9:

Circuit Switching and Packet Switching
Switching Networks

- Long distance transmission is typically done over a network of switched nodes
- Nodes not concerned with content of data
- End devices are stations — Computer, terminal, phone, etc.
- A collection of nodes and connections is a communications network
- Data is routed by being switched from node to node
Nodes

- Nodes may connect to other nodes only, or to stations and other nodes
- Node to node links usually multiplexed
- Network is usually partially connected
  - Some redundant connections are desirable for reliability
- Two different switching technologies
  - Circuit switching
  - Packet switching
Simple Switched Network

Diagram showing a network with a mainframe connected to personal computers and server nodes.
Circuit Switching

- Dedicated communication path between two stations
- Three phases
  - Establish
  - Transfer
  - Disconnect
- Must have switching capacity and channel capacity to establish connection
- Must have intelligence to work out routing
Circuit Switching

- Inefficient
  - Channel capacity dedicated for duration of connection
  - If no data, capacity wasted
- Set up (connection) takes time
- Once connected, transfer is transparent
- Developed for voice traffic (phone)
Public Circuit Switched Network
Telecom Components

• Subscriber
  — Devices attached to network

• Subscriber line
  — Local Loop
  — Subscriber loop
  — Connection to network
  — Few km up to few tens of km

• Exchange
  — Switching centers
  — End office - supports subscribers

• Trunks
  — Branches between exchanges
  — Multiplexed
Circuit Establishment

End office

Intermediate exchange

Trunk

Trunk
Circuit Switching Concepts

- Digital Switch
  - Provide transparent signal path between devices
- Network Interface
- Control Unit
  - Establish connections
    - Generally on demand
    - Handle and acknowledge requests
    - Determine if destination is free
    - Construct path
  - Maintain connection
  - Disconnect
Circuit Switch Elements
Blocking or Non-blocking

• Blocking
  — A network is unable to connect stations because all paths are in use
  — A blocking network allows this
  — Used on voice systems
    • Short duration calls

• Non-blocking
  — Permits all stations to connect (in pairs) at once
  — Used for some data connections
Space Division Switch

Input Lines

Output Lines
Space Division Switching

- Developed for analog environment
- Separate physical paths
- Crossbar switch
  - Number of cross-points grows in $n^2$
  - Loss of cross-point prevents connection
  - Inefficient use of cross-points
    - All stations connected, only a few cross-points in use
    - Non-blocking
Multistage Switch

- Reduced number of cross-points
- More than one path through network
  - Increased reliability
- More complex control
- May be blocking
Three Stage Space Division Switch

FIRST STAGE

SECOND STAGE

THIRD STAGE

5 \times 2 switch

2 \times 2 switch

2 \times 5 switch

1
2
3
4
5
6
7
8
9
10
Interconnection Networks

- Omega Network
Interconnection Networks

- Butterflies
  - isomorphic to Omega (a composition of shuffle-exchange networks with programmable switches) and SW-Banyan switch
  - closely related to hypercube and shuffle-exchange network
  - number of nodes $N = (k + 1)2^k$
    - this means $k + 1$ rows (or ranks) consisting of $n = 2^k$ nodes each
  - Let node($i,j$) refer to the $j$-th node in the $i$-th row, where $i$ is in $[0,k]$
  - Then node($i,j$) in row $i>0$ is connected to two nodes in row $i-1$
    - node($i-1,j$) and node($i-1,m$) where $m$ is the integer found by inverting the $i$-th most significant bit in the binary representation of $j$.
  - Note that if node($i,j$) is connected to node($i-1,m$), then node($i,m$) is connected to node($i-1,j$).
  - Benes network is consisting of two butterflies back to back
Interconnection Networks

- Butterflies

row 0

row 1

row 2

row 3
Time Division Switching

- Modern digital systems rely on intelligent control of space and time division elements
- Use digital time division techniques to set up and maintain virtual circuits
- Partition low speed bit stream into pieces that share higher speed stream
Interconnection Networks

An Application: ATM switch architecture

Hal96 fig.10.8

Two extremes
Interconnection Networks

—Delta Switch Matrix

• non-blocking/blocking
• self routing

Delta switch matrix

IC 0
IC 1
IC 2
IC 3
IC 4
IC 5
IC 6
IC 7

OC 0
OC 1
OC 2
OC 3
OC 4
OC 5
OC 6
OC 7

Routing tag bits
msb
lsb

Hal96 fig.10.9
Control Signaling Functions

- Audible communication with subscriber
- Transmission of dialed number
- “Call cannot be completed” indication
- “Call ended” indication
- Signal to ring phone
- Billing info
- Equipment and trunk status info
- Diagnostic info
- Control of specialist equipment
Control Signal Sequence

• Both phones on hook
• Subscriber lifts receiver (off hook)
• End office switch signaled
• Switch responds with dial tone
• Caller dials number
• If target not busy, send ringer signal to target subscriber
• Feedback to caller
  — Ringing tone, engaged (busy) tone, unobtainable
• Target accepts call by lifting receiver
• Switch terminates ringing signal and ringing tone
• Switch establishes connection
• Connection release when Source subscriber hangs up
Switch to Switch Signaling

- Subscribers connected to different switches
- Originating switch seizes inter-switch trunk
- Send “off hook” signal on trunk, requesting digit register at target switch (for address)
- Terminating switch sends “off hook” followed by “on hook” (wink) to show register ready
- Originating switch sends address
Location of Signaling

- Subscriber to network
  - Depends on subscriber device and switch

- Within network
  - Management of subscriber calls and network
  - more complex
In Channel Signaling

- Use same channel for signaling and call
  - Requires no additional transmission facilities
- Inband
  - Uses same frequencies as voice signal
  - Can go anywhere a voice signal can
  - Impossible to set up a call on a faulty speech path
- Out of band
  - Voice signals do not use full 4kHz bandwidth
  - Narrow signal band within 4kHz used for control
  - Can be sent whether or not voice signals are present
  - Need extra electronics
  - Slower signal rate (narrow bandwidth)
Drawbacks of In Channel Signaling

- Limited transfer rate
- Delay between entering address (dialing) and connection
- Overcome by use of common channel signaling
Common Channel Signaling

- Control signals carried over paths independent of voice channel
  - One control signal channel can carry signals for multiple subscriber channels
    - Common control channel for these subscriber lines
  - Associated Mode
    - Common channel closely tracks inter-switch trunks
  - Disassociated Mode
    - Additional nodes (signal transfer points)
    - Effectively two separate networks
Common v. In Channel Signaling

(a) Inchannel

(b) Common channel

CCIS SIG: Common-channel interoffice signaling equipment
SIG: Per-trunk signaling equipment
Common Channel Signaling Modes

(a) Associated

(b) Disassociated

- Signaling links
- Speech links
- Switching point (speech)
- Switching point (signal transfer point)
Signaling System Number 7

- SS7 is an open-ended common channel signaling standard

- Common channel signaling scheme
  - Especially designed to be used in ISDN (Integrated Services Digital Network)
  - Optimized for 64kbps digital channel network
  - Call control, remote control, management and maintenance
  - Reliable means of transfer of info in sequence
  - Will operate over analog and below 64kbps
  - Point to point terrestrial and satellite links
SS7

Signaling Network Elements

• Signaling point (SP)
  — Any point in the network capable of handling SS7 control message

• Signal transfer point (STP)
  — A signaling point capable of routing control messages

• Control plane
  — Responsible for establishing and managing connections

• Information plane
  — Once a connection is set up, info is transferred in the information plane
Transfer Points

STP = Signaling transfer point
SP = Signaling point
TC = Transit center
LE = Local Exchange
Signaling Network Structures

• STP capacities determine
  — Number of signaling links that can be handled
  — Message transfer time
  — Throughput capacity

• Network performance affected by
  — Number of SPs
  — Signaling delays

• Availability and reliability
  — Ability of network to provide services in the face of STP failures
Softswitch Architecture

- General purpose computer running software to make it a smart phone switch
- Lower costs
- Greater functionality
  - Packetizing of digitized voice data
  - Allowing voice over IP
- Most complex part of telephone network switch is software controlling call process
  - Call routing
  - Call processing logic
  - Typically running on proprietary processor
- Separate call processing from hardware function of switch
- Physical switching done by media gateway
- Call processing done by media gateway controller
Traditional Circuit Switching

(a) Traditional circuit switching
Softswitch

Supervisory events e.g., off-hook, on hook

Request to generate progress tones, e.g., ringback, engaged. Instructions to establish switch fabric connections.

(b) Softswitch architecture
Packet Switching Principles

- Circuit switching designed for voice
  - Resources dedicated to a particular call
  - Much of the time a data connection is idle
  - Data rate is fixed
    - Both ends must operate at the same rate
Packet Switching: Basic Operation

- Data transmitted in small packets
  - Typically 1000 octets
  - Longer messages split into series of packets
  - Each packet contains a portion of user data plus some control info

- Control info
  - Routing (addressing) info

- Packets are received, stored briefly (buffered) and past on to the next node
  - Store and forward
Use of Packets

Application data

Packet-Switching Network

control information (packet header)

packet
Advantages

• Line efficiency
  — Single node to node link can be shared by many packets over time
  — Packets queued and transmitted as fast as possible

• Data rate conversion
  — Each station connects to the local node at its own speed
  — Nodes buffer data if required to equalize rates

• Packets are accepted even when network is busy
  — Delivery may slow down

• Priorities can be used
Switching Technique

• Station breaks long message into packets
• Packets sent one at a time to the network
• Packets handled in two ways
  — Datagram
  — Virtual circuit
**Datagram**

- Each packet treated independently
- Packets can take any practical route
- Packets may arrive out of order
- Packets may go missing
- Up to receiver to re-order packets and recover from missing packets
Virtual Circuit

• Preplanned route established before any packets sent
• Call request and call accept packets establish connection (handshake)
• Each packet contains a virtual circuit identifier instead of destination address
• No routing decisions required for each packet
• Clear request to drop circuit
• Not a dedicated path
Virtual Circuit Diagram
Virtual Circuits vs. Datagram

• Virtual circuits
  — Network can provide sequencing and error control
  — Packets are forwarded more quickly
    • No routing decisions to make
  — Less reliable
    • Loss of a node looses all circuits through that node

• Datagram
  — No call setup phase
    • Better if few packets
  — More flexible
    • Routing can be used to avoid congested parts of the network
Packet Size

(a) 1-packet message
(b) 2-packet message
(c) 5-packet message
(d) 10-packet message

CS420/520 Axel Krings
Circuit vs Packet Switching

• Performance
  — Propagation delay
  — Transmission time
  — Node delay
Event Timing

(a) Circuit switching
(b) Virtual circuit packet switching
(c) Datagram packet switching

Call request signal
propagation delay
processing delay
Call accept signal
User data

Acknowledge signal

link

sequence 10

CS420/5 Nodes: ① ② ③ ④

Pkt1
Pkt2
Pkt3
Pkt1
Pkt2
Pkt3
Pkt1
Pkt2
Pkt3
Pkt1
Pkt2
Pkt3
X.25

- We will only briefly cover this as an overview
**X.25**

- 1976
- Interface between host and packet switched network
- Almost universal on packet switched networks and packet switching in ISDN
- Defines three layers
  - Physical
  - Link
  - Packet
X.25 - Physical

- Interface between attached station and link to node
- Data terminal equipment DTE (user equipment)
- Data circuit terminating equipment DCE (node)
- Uses physical layer specification X.21
- Reliable transfer across physical link
- Sequence of frames
**X.25 - Link**

- Link Access Protocol Balanced (LAPB)
  - Subset of HDLC
  - see chapter 7
X.25 - Packet

- External virtual circuits
- Logical connections (virtual circuits) between subscribers
X.25 Use of Virtual Circuits

Solid line = physical link
Dashed line = virtual circuit

Packet-Switching Network
Virtual Circuit Service

- Logical connection between two stations
  - External virtual circuit

- Specific preplanned route through network
  - Internal virtual circuit

- Typically one to one relationship between external and internal virtual circuits

- Can employ X.25 with datagram style network

- External virtual circuits require logical channel
  - All data considered part of stream
X.25 Levels

- User data passes to X.25 level 3
- X.25 appends control information
  - Header
  - Identifies virtual circuit
  - Provides sequence numbers for flow and error control
- X.25 packet passed down to LAPB entity
  - recall LAPB = Link Access Procedure Balanced
- LAPB appends further control information
User Data and X.25 Protocol Control Information

![Diagram showing User Data, X.25 packet, LAPB frame, Layer 3 header, LAPB header, and LAPB trailer]
Frame Relay

- Designed to be more efficient than X.25
- Developed before ATM
- Larger installed base than ATM
- ATM now of more interest on high speed networks
Frame Relay Background - X.25

- Call control packets, in band signaling
- Multiplexing of virtual circuits at layer 3
- Layer 2 and 3 include flow and error control
- Considerable overhead
- Not appropriate for modern digital systems with high reliability
Frame Relay - Differences

- Call control carried in separate logical connection
- Multiplexing and switching at layer 2
  - Eliminates one layer of processing
- No hop by hop error or flow control
- End to end flow and error control (if used) are done by higher layer
- Single user data frame sent from source to destination and ACK (from higher layer) sent back
Advantages and Disadvantages

- Lost link by link error and flow control
  -- Increased reliability makes this less of a problem
- Streamlined communications process
  -- Lower delay
  -- Higher throughput
- ITU-T recommend frame relay above 2Mbps
Protocol Architecture

![Diagram of Protocol Architecture]

Figure 10.18  Frame Relay User-Network Interface Protocol Architecture
Control Plane

- Between subscriber and network
- Separate logical channel used
  - Similar to common channel signaling for circuit switching services
- Data link layer
  - LAPD (Q.921)
  - Reliable data link control
  - Error and flow control
  - Between user (TE) and network (NT)
  - Used for exchange of Q.933 control signal messages
User Plane

- End to end functionality
- Transfer of info between ends
- LAPF (Link Access Procedure for Frame Mode Bearer Services) Q.922
  - Frame delimiting, alignment and transparency
  - Frame mux and demux using addressing field
  - Ensure frame is integral number of octets (zero bit insertion/extraction)
  - Ensure frame is neither too long nor short
  - Detection of transmission errors
  - Congestion control functions
User Data Transfer

• One frame type
  — User data
  — No control frame

• No inband signaling

• No sequence numbers
  — No flow nor error control
Summary

• circuit verses packet switching network approaches
• X.25
• frame relay