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 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

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 - Applications
- 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

- 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

Telecomms Components

Circuit Establishment

- End office
- Connecting Trunk
- InterCity Trunk
- Connecting Trunk
- Digital PBX
- Subscriber Loop

Circuit Switch Elements

- Control Unit
  - Establish connections
  - Generally on demand
  - Handle and acknowledge requests
  - Determine if destination is free
  - Construct path
  - Maintain connection
  - Disconnect

Circuit Switching Concepts

- Digital Switch
  - Provide transparent signal path between devices
- Network Interface
- Control Unit

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 Switching**
- Developed for analog environment
- Separate physical paths
- Crossbar switch
  - Number of crosspoints grows as square of number of stations
  - Loss of crosspoint prevents connection
  - Inefficient use of crosspoints
    - All stations connected, only a few crosspoints in use
  - Non-blocking

**Multistage Switch**
- Reduced number of crosspoints
- More than one path through network
  - Increased reliability
- More complex control
- May be blocking

**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

**Space Division Switch**

**Three Stage Space Division Switch**

**Control Signaling Functions**
- Audible communication with subscriber
- Transmission of dialed number
- Call can not 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 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 interswitch 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 a number of subscriber channels
- Common control channel for these subscriber lines
- Associated Mode
  - Common channel closely tracks interswitch trunks
- Disassociated Mode
  - Additional nodes (signal transfer points)
  - Effectively two separate networks
Common v. In Channel Signaling

Common Channel Signaling Modes

Signaling System Number 7
- SS7
- Common channel signaling scheme
- ISDN
- Optimized for 64k digital channel network
- Call control, remote control, management and maintenance
- Reliable means of transfer of info in sequence
- Will operate over analog and below 64k
- 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

Signaling Network Structures
- STP capacities
  - Number of signaling links that can be handled
  - Message transfer time
  - Throughput capacity
- Network performance
  - 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**

**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

**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**
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

Datagram Diagram

Virtual Circuit Diagram
Virtual Circuits v 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

Circuit v Packet Switching

- Performance
  - Propagation delay
  - Transmission time
  - Node delay

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

Packet Size

Event Timing

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**

**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
- LAPB appends further control information

**User Data and X.25 Protocol Control Information**
# 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

<table>
<thead>
<tr>
<th>Control Plane</th>
<th>User Plate</th>
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<tr>
<td>Q.931/Q.933</td>
<td>User-selectable functions</td>
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<td>LAPP core (Q.922)</td>
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## 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

**Required Reading**

- Stallings Chapter 10
- ITU-T web site
- Telephone company web sites (not much technical info - mostly marketing)
- X.25 info from ITU-T web site
- Frame Relay forum