CSIS 625 Week 9

Switching Technology

I. Overview

A. Switching Technology

1. Circuit Switching
2. Circuit Switching Topologies
3. Circuit Switching Technologies (ISDN)
4. Packet Switching
5. Packet Switching Technologies

II. Switching

A. Generic Switching technology

1. A switched network has both end stations or nodes and switching nodes.
2. Switching nodes may connect to
    a. only other switching nodes -or-
    b. other switching nodes and end stations
3. Connections between switching nodes can handle multiple circuits or sessions using TDM or FDM
4. Often not enough resources in the network for all nodes to be communicating simultaneously.
5. Switching nodes don't have direct connections to all other switching nodes
6. Usually there is more than one way to get between any two switching nodes
    a. This improves reliability
7. Circuit switching is common in the public telephony networks
8. Packet switching is common in data networks.
9. Latency - the amount of time it takes a signal to propagate from one node to another.
10. Jitter - the amount of variance in the latency

B. Circuit Switching

1. Circuit Switching - A dedicated path is established between two stations for communication
2. Once a connection is established it appears to the attached devices as if they are directly connected.
3. Switching and transmission resources are reserved for the exclusive use of the circuit for the duration of the connection.
4. Circuit Lifespan
    a. Circuit Establishment
        (1) Node has to signal to switching nodes who it wants to talk to.
        (2) Switching node finds and establishes path through network
        (3) Success or failure of circuit setup is communicated back to originating node
    b. Data transfer
        (1) typically full duplex communication of data
    c. Circuit disconnect

(1) Both ends informed of disconnect and resources in network released for another user.

5. Circuit Switching - pros & cons
   a. Pathway in place even if data isn't being sent
      (1) Not the best efficiency
   b. There may be some delay in getting a circuit set up, but once done:
      (1) latency is typically minimal
      (2) jitter is very small

C. Circuit Switching Topologies

1. Space Division Switches
   a. Space division switching uses space to separate the paths of different circuits
   b. Cross bar switches have n inputs and m outputs and a switch at every intersection
      (1) Simplest cross bar has n inputs and m outputs
      (2) needs n * m switches
      (3) See Week 8 - Figure 1
   c. Folded Cross bar switch
      (1) A folded cross bar switch has inputs and outputs wrapped around to allow full duplex any to any connections
      (2) Requires less switches than a crossbar switch
      (3) See Week 8 - Figure 2
   d. Multistage switches
      (1) Combine multiple smaller crossbar switches
      (2) May be blocking or non-blocking based on number of input lines and stages and size of different stages
      (3) Also called Clos switches after Charles Clos of Bell Laboratories who published analysis of these type of switches
      (4) Usually has multiple paths increasing reliability of equipment
      (5) Three stage switch Example in Week 8 – Figure 3
      (6) Multi-stage switches pros and cons
         (a) Allows for a far greater number of lines to be serviced with a far smaller number of cross connect switches
         (b) If blocking is allowable, even smaller number of switches
         (c) See Example in Week 8 Figure 4
2. Time Division circuit switches
   a. By using TDM techniques, switching can be achieved
   b. Time-slot Interchange (TSI) technique
      (1) Mux and demux on ends with the TSI in the middle
      (2) The TSI buffers all inputs and then re-sends it in a different output
   c. TDM bus technique
      (1) Mux and demux are "smart" and can take any timeslot to any I/O port
   d. Time Division pros and cons
      (1) With higher clocking speeds possible with modern silicon, it is possible to build TDM switches much larger and cheaper than crossbar switches
      (2) The clock rates after the TDM operation may get very high when high speed inputs or high number of inputs are used.

3. Circuit Switches - combinations
    a. For very large circuit switches a combination of TDM and crossbar switches is often the best.
    b. Multiple stage switches using different techniques in different stages

D. Circuit Switching Technology

1. ISDN - Integrated Services Digital Network
    a. What is ISDN?
        (1) Circuit-switched digital network
            (a) In reality, extension of T hierarchy to the subscriber
        (2) A misfired attempt by the circuit-switched network operators (TELCOs) to get on the “data” bandwagon
            (a) Implemented based on carrier’s perceptions of customer needs
            (b) Total user panacea (based on TELCO view)
        (3) Designed to provide fully integrated digital services to the user
            (a) Broadband, nonswitched
            (b) Broadband, switched
            (c) Packet switched
            (d) Signaling
                (1) Per-call, per-customer feature selection
    b. Brief history of ISDN
        (1) Initially, phone networks were analog
        (2) Local loops were analog as well
        (3) Modems were developed to allow digital communication over analog networks
        (4) Analog and digital services to subscribers
            (a) Transition to digital services is gradual
            (b) Analog services remain in place
            (c) Customer classification emerged
                (1) Traditional POT users
                (2) Modem users
                (3) Digital service users
        (5) Integrated Digital Networks - IDN
            (a) Created to meet customer demands
            (b) Combination of networks available for different needs
            (c) Access to IDN
                (1) Analog local loop
                (2) Digital local loop (Switched/56)
                (3) High-speed dedicated pipes (leased lines)
        (6) ISDN
            (a) Integrates IDN with customer services
            (b) Replaces Analog Local Loop with digital subscriber loop

            (1) Voice transmission is digitized at the source
            (2) Voice, data and digital video can thus be send over any digital network (provided it is capable of handling it)
            (3) All services are digital, available on customer demand
            (4) ISDN also introduced unified, standardized interface for all the services

c. Subscriber access to ISDN
    (1) To support flexibility (and sell-ability), ISDN defines 3 channel types of different sizes
        (a) Bearer – 64 Kbps (clear-channel DS0)
            (1) Basic user channel
            (2) Carries any type of digital information in full-duplex mode
            (3) Supports multiplexing (non-addressable)
            (4) Carries data end-to-end
        (b) Data – 16 or 64 Kbps (DS0 or fractional DS0)
            (1) Carries control information for B channels
            (2) Implements common-channel signaling
            (3) Carries control signals for all channels in the given path
            (4) Used to connect to the network and allocate a B channel
        (c) Hybrid channels
            (1) High data rate channels – 384 Kbps, 1536 (H11) Kbps, 1920 Kbps (H12)

d. User Interfaces
    (1) Basic Rate Interface (BRI)
        (a) 2B+D
            (1) 2 B channels (initially 1)
            (2) 1 16Kbps D channel
        (b) Designed to meet residential and small (tiny) business offices
        (c) Existing twisted pair is used
    (2) Primary Rate Interface (PRI)
        (a) 23 B channels
        (b) 1 64Kbps D channel
        (c) 8 Kbps overhead
        (d) Total: 1.544 Mbps -- Low and behold, a T1 Line!
        (e) All travel in a single path to an ISDN office
        (f) PRI can be divided into many different combinations
        (g) D channel is used to allocate network capacity accordingly

e. ISDN Access Devices
    (1) ISDN Reference Points
        (a) Used to identify interfaces between individual ISDN devices
        (b) R – connection between a TE2 and TA
        (c) S – connection between a TA or TE1 and NT1 or NT2
        (d) T – connection between NT2 and NT1

(e) U – connection between NT1 and ISDN office

(2) See Week 8 - Figure 5

E. Packet Switching

1. Packet Switching - a packet of data is transferred from one node to another
2. Packet switching is designed to be more efficient for data than circuit switching.
3. Datagram Packet Switching - Each packet of data is treated independently from all others
4. Virtual Circuit Packet Switching - all packets of data that are part of a session are sent via a single route
5. Packets allow for greater usage of trunks between nodes
    a. Packets may be queued and transmitted as quickly as possible
    b. May create more latency and much more jitter than circuit switched systems
    c. Unused Bandwidth in circuit switched networks can be used.
6. On circuit switched networks, calls may be blocked, but on packet switching the packets are just delayed
7. Packet switching - prioritization
    a. In packet switched networks, some packets can be given higher priority than others.
    b. This allows for those packets to be sent before lower priority ones reducing their latency and jitter.
    c. May allow for some packets to be sent different (faster) paths than others.
8. Datagram packet switching
    a. Every packet is treated independently.
    b. Every switching node must examine every packets destination and decide on where to send it next.
    c. If any node disappears it takes with it a few packets, but data keeps flowing.
9. Virtual circuit packet switching
    a. A path is set up that each packet between two nodes always follows the same path
    b. Makes switching node’s job easier because it always knows where to send a packet to next.
    c. If any node disappears, that session must be torn down and a new one created
10. Virtual circuit types
    a. Switched virtual circuit - a virtual circuit is set up for each session independently
        (1) Requires a circuit setup before data flows
        (2) Adds to time required to transfer a message
    b. Permanent virtual circuit
        (1) Requires provisioning of path when creating network.
        (2) May mean that any node failure requires human intervention.

F. Packet Switching Technologies:

1. What is X.25
    a. A protocol suite defined in ITU standards
    b. Covers Physical, Data Link and Network layers
    c. Called Physical, Frame or Link, and Packet layer
    d. Defines DTE ↔ DCE interface
    e. Has both link layer and packet layer error detection and retransmission

f. Very robust - developed for high-noise and unreliable communications links.
g. The nodes inside the X.25 cloud are PSE - Packet Switching Exchanges

2. X.25 Layers
   a. Physical Layer
      (1) X.21 is the defined standard
      (2) RS-232 (EIA-232) is often used
      (3) V.35 is often used
   b. Link Layer
      (1) LAPB - Link Access Protocol - Balanced
      (2) LAPB is a subset of HDLC
      (3) I-Frames - encapsulates packet layer data
      (4) S-Frames - Flow and error control
      (5) U-Frames - set up and disconnect link layer
   c. Packet Layer
      (1) PLP - Packet Layer Protocol
      (2) Responsible for End-to-end delivery of packets
      (3) Virtual Circuits
         (a) Packet layer multiplexes multiple virtual circuits over the link.
         (b) Up to 4095 virtual circuits
   d. Virtual Circuits
      (1) LCN - Logical Channel Number - the arbitrary number that identifies the virtual circuit
      (2) One LCN is established for the local or near-end DTE↔DCE interface and another for the remote or far-end DTE↔DCE interface
      (3) Permanent Virtual Circuit -PVC
         (a) Established by the network operator.
         (b) Use LCNs starting at 0 and going up
      (4) Switched Virtual Circuits - SVC
         (a) Established by DTE signaling to the DCE that it wishes to establish a connection to the remote DTE.
         (b) Uses X.121 addresses plan (14 digits - kind of like phone number)
         (c) DTE picks local LCN number (starts with 4095 and works down)
         (d) DCE picks far-end LCN numbers (starts with numbers above PVCs)
   e. X.25 PAD
      (1) PAD - Packet assembler/disassembler
      (2) A device that connects to X.25 network as a DTE, and has connections for dumb-terminal type devices.
      (3) Device knows how to take individual characters and put them into a packet
         (a) And the inverse
         (b) PAD knows how to handle Enter key, arrow keys, etc.
         (c) PAD can handle local echo, line buffering, etc.
      (4) A PAD is a DTE to the X.25 network
      (5) A PAD is a DCE for a dumb-terminal

3. Frame Relay
    a. Also a packet Switched Service, like X.25
    b. Derived initially from ITU-T I.122 ISDN frame-mode bearer services
    c. Decoupled from ISDN by The Group of Four, Cisco, Stratacom, DEC and Northern Telecom, which became the initial Frame Relay proposal group
    d. Currently Frame Relay Forum handles all of the FR-related standardization work
    e. Designed to hide network specifics from the user
    f. The only standardized parts are the UNI, or User-Network Interface, and LMI, or Logical Management Interface
    g. Designed to provide flexible service -- Bandwidth on Demand
    h. Takes into account modern, "intelligent" computer systems and reliable communication systems
    i. FRAD - Frame Relay access device.
        (1) Like X.25 PAD
        (2) FRAD is a DTE to the Frame Relay network
        (3) FRAD is a DCE for the computers connection to the Frame Relay network
    j. Frame Relay Switch
        (1) node inside the frame relay cloud.
    k. Frame Relay Layers
        (1) Physical Layer
            (a) No specification provided
        (2) Data Link Layer
            (a) Employs a simplified version of HDLC frame
            (b) Handles flow control
            (c) Has facilities to perform congestion notification
            (d) Uses DLCI -- Data Link Layer Identifier -- as an address
        (3) Utilizes primarily PVCs, although some proprietary versions support SVCs as well
        (4) Uses end-to-end error recovery, implemented either by upper layer protocols in user's application or the router
            (a) Bad packets are discarded by the network.
    l. Frame Relay - Routing
        (1) Based on DLCI, Data Link Layer Control Identifier
        (2) Although switching is a Network Layer functionality, it is generally accepted that Frame Relay does not implement true switching, and thus "relaying" is treated as Data Link Layer function
        (3) Switch accepts a DLCI on an input port, and, using internal tables, routes it to the output port, modifying the DLCI in the process.
    m. Frame Relay - Policing
        (1) CIR - Committed Information Rate is a guaranteed level of service between two points.
        (2) Typically frame relay service is purchased with a CIR, and some burst rate allowed.
        (3) Frames that exceed the CIR have the Discard Eligibility (DE) bit in the header set.
        (4) Frames with the DE bit set may be discarded by switching nodes that encounter congestion.

(5) The Frame Relay switch must set the DE bit
    (a) Can't trust a FRAD owned by the subscriber.
(6) Burst rate is the maximum rate that information can be sent at.
    (a) Sender may use the burst rate for up to some time limit (2 seconds for example)
(7) It may not be wise for a service provider to allow high burst rates
    (a) When network is initially set up, the subscriber gets all their burst data through because congestion is very rare.
    (b) Subscriber gets used to this kind of service.
    (c) More subscribers sign on.
    (d) Congestion starts to occur and packets get dropped
    (e) Subscriber is irate because they aren't getting the service they are used to.

4. ATM
   a. Goal of ATM is to allow all data: voice video and data to co-exist on the same network.
      (1) The be-all and end-all of networking protocols
   b. Everything in ATM is based on Cells.
      (1) A cell is 53 bytes long
          (a) 5 bytes for header
          (b) 48 bytes of data
              (1) 32 bytes wanted by Europeans and
              (2) 64 bytes wanted by Americans.
              (3) 32 bytes => 4 milliseconds which means no need for echo cancellation
              (4) Americans have to do echo cancellation anyway because of distance, and wanted something more efficient for data applications
              (5) Typical committee, they compromised so no one is happy
   c. ATM - Why short fixed length cells?
      (1) The use of relatively short cells makes sure that if high priority traffic comes in, it doesn't have to wait very long behind a big packet.
      (2) Fixed length cells allow for easier hardware implementations.
      (3) Easier implementations means that very high speed circuits can be created to allow higher speed applications to work.
      (4) Fixed length cells mean that buffer memory is always efficient.
   d. ATM - why short, fixed length cells aren't important
      (1) Now with much higher speed interfaces the amount of time to wait, is very small even for "big" packets.
      (2) Memory and processor power is much cheaper now
      (3) Variable size packets are more efficient for data traffic
          (a) Data traffic now makes up as much traffic as voice, and it it growing rapidly
   e. ATM – UNI & NNI
      (1) UNI – User-to-Network Interface
      (2) NNI – Network-to-Network Interface

(3) In ATM networks, a distinction is made between an end point connecting to an ATM switch (UNI) and two ATM switches connecting together (NNI)

f. ATM – VPI/VCI
   (1) In an ATM network, a virtual circuit identifier is identified by a pair of numbers, the VPI and VCI.
      (a) VPI – Virtual Path Identifier
      (b) VCI – Virtual Circuit Identifier
   (2) Some ATM switches switch only on VPI
      (a) A cell comes in, and the switch sends it to another port based on it's VPI
      (b) A new VPI is written into the cell
      (c) The VCI is left untouched in this process.
   (3) Some ATM switches switch on VPI & VCI
      (a) A cell comes in and the switch sends it to another port based on both the VPI and VCI
      (b) A new VPI and VCI is written into the cell

g. ATM – Header fields (UNI)
   (1) 5 bytes in the header. The fields are:
      (a) GFC (4 bits) – General Flow Control Identifier
         (1) Used for flow control between the network and the DTE
      (b) VPI (8 bits) – Virtual Path Identifier
      (c) VCI (16 bits) – Virtual Circuit Identifier
      (d) PTI (3 bits) - Payload Type Indicator
      (e) CLP (1 bit) – Cell loss priority
         (1) Marked with a 0 means that it is to be discarded before cells marked with a 1.
      (f) HEC (8bits) – Header Error Control
         (1) An 8-bit CRC to catch errors in the header
         (2) Does not catch errors in the data body

h. ATM – Header fields (NNI)
   (1) 5 bytes in the header. The fields are:
      (a) VPI (12 bits) – Virtual Path Identifier
      (b) VCI (16 bits) – Virtual Circuit Identifier
      (c) PTI (3 bits) - Payload Type Indicator
      (d) CLP (1 bit) – Cell loss priority
      (e) HEC (8bits) – Header Error Control
   (2) NNI interfaces have more VPIs, based on the idea that inside of the ATM cloud, there might be more VPI switches than full VPI/VCI switches.
   (3) This is all nice and good – but not normally used

i. Payload Type
   (1) 3 bits
   (2) First one defines management or not
   (3) Enumerated out:
      (a) 000 –no congestion, no signaling
      (b) 010 – no congestion, signaling
      (c) 001 – congestion encountered, no signaling

(d) 001 – congestion encountered, signaling
(e) 100 – Management, link associated management
(f) 101 – Management, end to end management
(g) 110 – Management, resource management
(h) 111 – reserved

j. ATM – Service Classes
  (1) CBR – Constant Bit Rate
    (a) For real-time audio or video
    (b) Similar to that service of a dedicated T1 line
  (2) VBR – Variable Bit Rate
  (3) VBR-RT – Variable Bit Rate – Real Time
    (a) For those services that use compression to create a variable bit rate stream, but still need real-time characteristics.
  (4) VBR-NRT – Variable Bit Rate – Non-real time
    (a) Ditto – but don't require real-time
  (5) ABR – Available Bit Rate
    (a) Delivers a minimum cell rate
    (b) If network capacity is available, higher cell rates are achievable.
  (6) UBR – Unspecified Bit Rate
    (a) Best effort delivery that doesn't guarantee anything

k. ATM – QOS attributes
  (1) Different service classes allow specifying some or all of these attributes.
    (a) SCR – Sustained Cell Rate
    (b) PCR – Peak Cell Rate
    (c) MCR – Minimum Cell rate
    (d) CVDT – Cell variation delay tolerance

l. ATM Adaptation Layers - AAL
  (1) AAL's are standards that specify how the 48 byte data payload is used.
  (2) AAL1 – Supports constant bit rate applications such as T1, T3, etc.
    (a) Has a 1 byte header and 47 bytes of data
  (3) AAL2 – support for variable bit rate applications (like compressed voice)
    (a) Has a 1 byte pointer and 47 bytes of data
    (b) The 47 bytes contain variable length packets that each have a 3 byte header.
  (4) AAL3/4 – combined #3 and #4
    (a) Support for data services
    (b) Each cell has a 2 byte header and 2 byte trailer
    (c) The data packet (up to 64k bytes) is given a 4 byte header and 4 byte trailer and padded to a multiple of 44.
    (d) The data packet is then sliced into 44 byte chunks to be put into each cell
    (e) Supports sequencing and error control
  (5) AAL5 – data applications that don't require sequencing and error control of AAL3/4

(a) Data packet (up to 64k bytes) has an 8 byte trailer added and padded up to multiple of 48 bytes.
(b) Data packet is then sliced into 48 byte chunks to be put into each cell.
(c) The PTI signaling bit in the header indicates when the end of a packet occurs.