18.6 SUMMARY

- Virtual-circuit switching is a data link layer technology in which links are shared.
- A virtual-circuit identifier (VCI) identifies a frame between two switches.
- Frame Relay is a relatively high-speed, cost-effective technology that can handle bursty data.

- Both PVC and SVC connections are used in Frame Relay.
- The data link connection identifier (DLCI) identifies a virtual circuit in Frame Relay.
- Asynchronous Transfer Mode (ATM) is a cell relay protocol that, in combination with SONET, allows high-speed connections.
- A cell is a small, fixed-size block of information.
- The ATM data packet is a cell composed of 53 bytes (5 bytes of header and 48 bytes of payload).
- ATM eliminates the varying delay times associated with different-size packets.
- ATM can handle real-time transmission.
- A user-to-network interface (UNI) is the interface between a user and anATM switch.
- A network-to-network interface (NNI) is the interface between two ATM switches.
- In ATM, connection between two endpoints is accomplished through transmission paths (TPs), virtual paths (VPs), and virtual circuits (VCs).
- In ATM, a combination of a virtual path identifier (VPI) and a virtual-circuit identifier identifies a virtual connection.
- The ATM standard defines three layers:
  a. Application adaptation layer (AAL) accepts transmissions from upper-layer services and maps them into ATM cells.
  b. ATM layer provides routing, traffic management, switching, and multiplexing serVIces.
  c. Physical layer defines the transmission medium, bit transmission, encoding, and electrical-to-optical transformation.
- TheAAL is divided into two sublayers: convergence sublayer (CS) and segmentation and reassembly (SAR).

- There are four different AALs, each for a specific data type:
  a. AALI for constant-bit-rate stream.
  b. AAL2 for short packets.
  c. AAL3/4 for conventional packet switching (virtual-circuit approach or datagram approach).
  d. AAL5 for packets requiring no sequencing and no error control mechanism.
- ATM technology can be adopted for use in a LAN (ATM LAN).
- In a pure ATM LAN, an ATM switch connects stations.
- In a legacy ATM LAN, the backbone that connects traditional LANs uses ATM technology.
- A mixed architecture ATM LAN combines features of a pure ATM LAN and a legacy ATM LAN.
- Local-area network emulation (LANE) is a client/server model that allows the use of ATM technology in LANs.
- LANE software includes LAN emulation client (LECS), LAN emulation configuration server (LECS), LAN emulation server (LES), and broadcast/unknown server (BUS) modules.

Review Questions

1. There are no sequence numbers in Frame Relay. Why?

1. ***Frame Relay*** does not use *flow* or *error control*, which means it does not use the sliding window protocol. Therefore, there is no need for ***sequence numbers***.

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2. Can two devices connected to the same Frame Relay network use the same DLCIs?

2. ***DLCIs*** are unique only for a particular interface. A switch assigns a DCLI to each virtual connection in an interface. This way two different connections belonging to two different interfaces may have the same DLCI.

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3. Why is Frame Relay a better solution for connecting LANs than T-llines?

3. ***T-lines*** provide point-to-point connections, not many-to-many. In order to connect several LANs together using T-lines, we need a mesh with many lines. Using Frame Relay we need only one line for each LAN to get connected to the Frame Relay network.

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4. Compare an SVC with a PVc.

4. In a ***PVC***, two end systems are connected permanently through a virtual connection. In a ***SVC***, a virtual circuit needs to be established each time an end system wants to be connected with another end system.

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5. Discuss the Frame Relay physical layer.

5. ***Frame Relay*** does not define a specific protocol for the physical layer. Any protocol recognized by ANSI is acceptable.

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6. Why is multiplexing more efficient if all the data units are the same size?

6. If data packets are different sizes there might be variable delays in delivery.

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7. How does an NNI differ from a UNI?

7. A ***UNI*** (user network interface) connects a user access device to a switch inside the ATM network, while an ***NNI*** (network to network interface) connects two switches or two ATM networks.

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8. What is the relationship between TPs, VPs, and VCs?

8. A ***TP*** (transmission path) is the physical connection between a user and a switch or between two switches. It is divided into several ***VPs*** (virtual paths), which provide a connection or a set of connections between two switches. VPs in turn consist of several ***VCs*** (virtual circuits) that logically connect two points together.

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9. How is an ATM virtual connection identified?

9. An ATM virtual connection is defined by two numbers: a ***virtual path identifier (VPI)*** and a ***virtual circuit identifier (VCI).***

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10. Name the ATM layers and their functions.

10. The ***Application Adaptation Layer (AAL)*** allows existing networks to connect to ATM facilities by mapping packet data into fixed-sized ATM cells. The ***ATM layer*** provides routing, traffic management, switching, and multiplexing services.

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11. How many virtual connections can be defined in a UNI? How many virtual connections can be defined in an NNI?

11. In an UNI, the total length of VPI+VCI is 24 bits. This means that we can define $\mathbf{2^{24}}$ virtual circuits in an UNI. In an NNI, the total length of VPI+VCI is 28 bits. This means that we can define $\mathbf{2^{28}}$ virtual circuits in an NNI.

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12. Briefly describe the issues involved in using ATM technology in LANs.

12. We can briefly summarize the most important issues:

a. Traditional LANs are ***connectionless*** protocols; ATM is a ***connection-oriented*** protocol.

b. Traditional LANs define the route of a packet through ***source and destination addresses***; ATM defines the route of a cell through ***virtual connection identifiers***.

c. Traditional LANs can do ***unicast***, ***multicast***, and ***broadcast*** transmission; ATM is designed only for ***unicast*** transmission.

Exercises

13. The address field of a Frame Relay frame is 1011000000010111. What is the DLCI (in decimal)?

13. We first need to look at the EA bits. In each byte, the EA bit is the last bit (the eight bit from the left). If EA bit is 0, the address ends at the current byte; if it 1, the address continues to the next byte.

Address → **10110000 00010111**

The first EA bit is 0 and the second is 1. This means that the address is only two bytes (no address extension). DLCI is only 10 bits, bits 1 to 6 and 9 to 12 (from left).

Address → 10110000 00010111
DLCI → **1011000001** → **705**

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14. The address field of a Frame Relay frame is 101100000101001. Is this valid?

The given address field of a frame relay frame is 101100000101001 is not valid because actual address field of a frame relay frame has 16bits but given frame is 15 bits.

14. The address field in Frame Relay is 16 bits. The address given is only 15 bits. It is **not valid**.

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15. Find the DLCI value if the first 3 bytes received is 7C 74 E1 in hexadecimal.

15. We first need to look at the EA bits. In each byte, the EA bit is the last bit (the eight bit from the left). If the EA bit is 0, the address ends at the current byte; if it 1, the address continues to the next byte.

Address → **0x7C74E1** → **01111100 01110100 11100001**

The first two EA bit are 0s and the last is 1. This means that the address is three bytes (address extension). DLCI is 16 bits, bits 1 to 6, 9 to 12, and 17 to 22.

Address → 01111100 01110100 111000
DLCI → **0111110111111000** → **32248**

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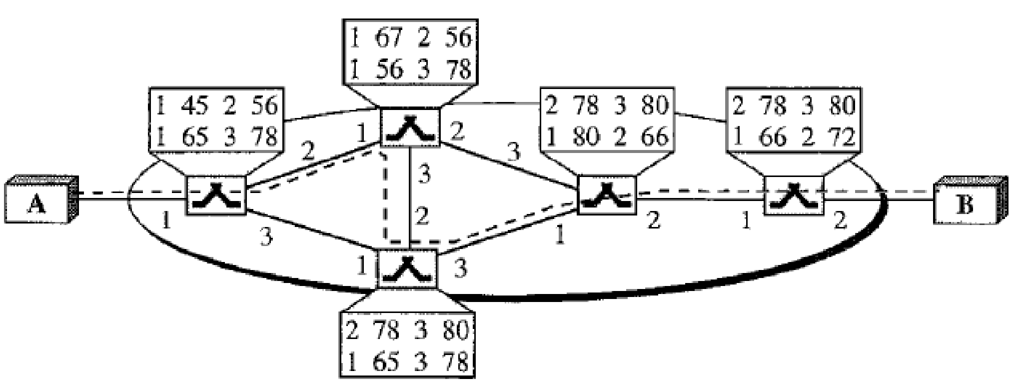
16. Find the value of the 2-byte address field in hexadecimal if the DLCI is 178. Assume no congestion.

16. We first change the number 178 to 10-bit binary **0010110010**. We then add separate DLCI into a 6-bit and a 4-bit and add extra bits. Note that the first EA bit is 0; the second is 1.

DLCI → **0010110010**

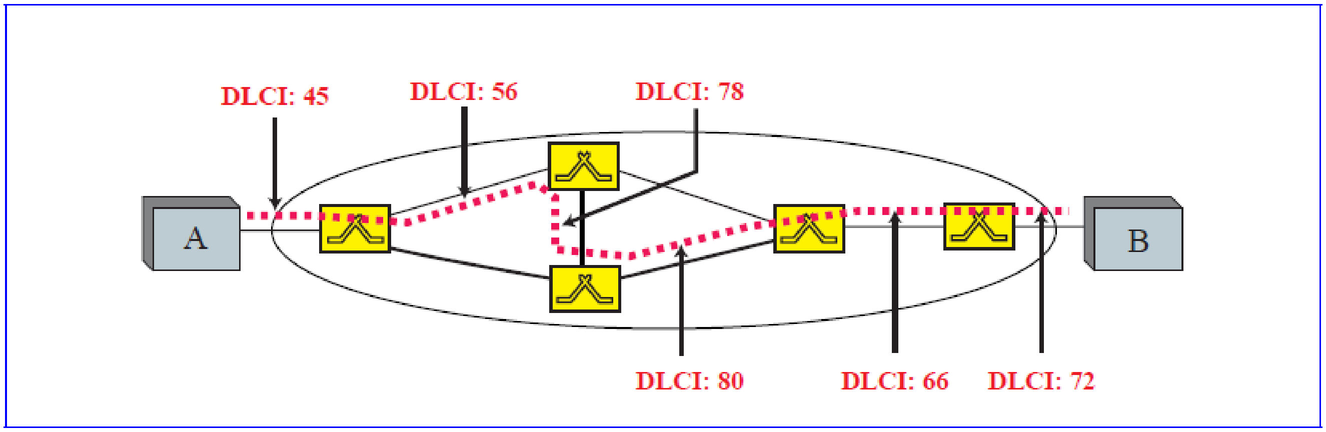
Address → 00101100 00100001 → **0x2C21**

17.* In Figure 18.30 a virtual connection is established between A and B. Show the DLCI for each link.

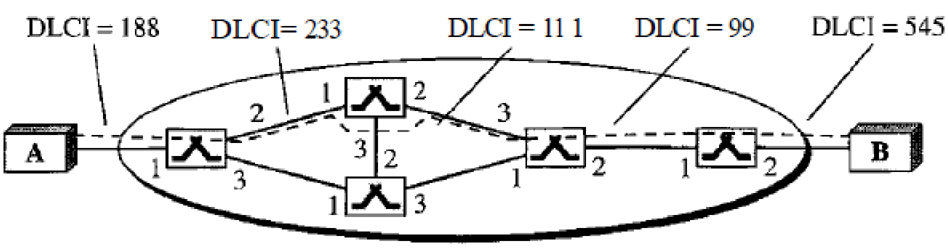


17. See Figure 18.1.

Figure 18.1 *Solution to Exercise 17*

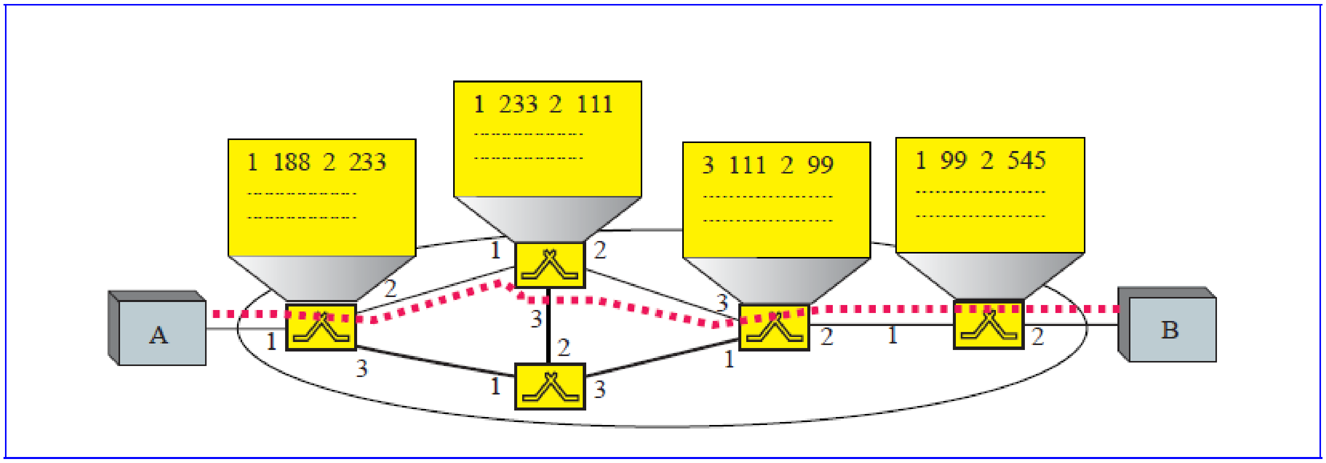


18. In Figure 18.31 a virtual connection is established between A and B. Show the corresponding entries in the tables of each switch.



18. See Figure 18.2.

Figure 18.2 *Solution to Exercise 18*



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19. An AAL1layer receives data at 2 Mbps. How many cells are created per second by the ATM layer?

19. In AAL1, each cell carries only 47 bytes of user data. This means the number of cells sent per second can be calculated as [(2,000,000/8)/47] ≈ **5319.15**.

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20. What is the total efficiency of ATM using AAL1 (the ratio of received bits to sent bits)?

20. In AAL1, each 53-byte cell carries only 47 bytes of user data. There are 6 bytes of overhead. The efficiency can be calculated as 47/ 53 ≈ **89%**.

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21. If an application uses AAL3/4 and there are 47,787 bytes of data coming into the CS, how many padding bytes are necessary? How many data units get passed from the SAR to the ATM layer? How many cells are produced?

21.

a. In AAL3/4, the CS layer needs to pass 44-byte data units to SAR layer. This means that the total length of the packet in the CS layer should be a multiple of 44. We can find the smallest value for padding as follows:

$$H + Data + Padding + T = 0 \bmod 44$$
$$4 + 47{,}787 + Padding + 4 = 0 \bmod 44$$
$$Padding = \mathbf{33\ bytes}$$

b. The number of data unit in the SAR layer is

$$(4 + 47787 + 33 + 4) / 44 = \mathbf{1087}$$

c. In AAL3/4, the number of cells in the ATM layer is the same as the number of data unit in the SAR layer. This means we have **1087 cells**.

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22. Assuming no padding, does the efficiency of ATM using AAL3/4 depend on the size of the packet? Explain your answer.

22. If we assume that there is no need for padding, the efficiency of the AAL3/4 depends on the size of the packet because of the 8 bytes of overhead in the CS layer. A larger packet is more efficient than a smaller packet. A packet of size 8 bytes has an efficiency of 8/16 = 50% while a packet of size 1000 bytes has an efficiency of 1000/1008 ≈ 99%.

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23. What is the minimum number of cells resulting from an input packet in the AAL3/4 layer? What is the maximum number of cells resulting from an input packet?

23.

a. The minimum number of cells is **1**. ***This happens when the data size ≤ 36 bytes***. Padding is added to make it exactly 36 bytes. Then 8 bytes of header creates a data unit of 44 bytes at the SAR layer.

b. The maximum number of cells can be determined from the maximum number of data units at the CS sublayer. If we assume no padding, the maximum size of the packet is 65535 + 8 = 65543. This needs 65543 / 44 ≈ 1489.61. The maximum number of cells is **1490**. ***This happens when the data size is between 65,509 and 65,535 (inclusive) bytes.*** We need to add between 17 to 43 (inclusive) bytes of padding to make the size 65552 bytes. The 8 byte overhead at the CS layer makes the total size 65560 which means 1490 data units of size 44.

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24. What is the minimum number of cells resulting from an input packet in the AAL5 layer? What is the maximum number of cells resulting from an input packet?

24.

a. The minimum number of cells is **1**. ***This happens when the data size ≤ 40 bytes***. Padding is added to make it exactly 40 bytes. Then 8 bytes of header creates a data unit of 48 bytes at the SAR layer.

b. The maximum number of cells is **1366**. It can be determined from the maximum number of data units at the CS sublayer. If we assume no padding, the maximum size of the packet is 65535 + 8 = 65543. This needs 65543 / 48 ≈ 1365.48 or 1366 cells. ***This happens when the data size is between 65,513 and 65,535 (inclusive) bytes***. We need to add between 25 to 47 (inclusive) bytes of padding to make the size 65560 bytes. The 8 byte overhead at the CS layer makes the total size 65568 which means 1366 data unit of size 48.

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25. Explain why padding is unnecessary in AAL1, but necessary in other AALs.

25. AAL1 takes a ***continuous stream*** of bits from the user without any boundaries. There are always bits to fill the data unit; there is no need for padding. The other AALs take a bounded packet from the upper layer.

26. Using AAL3/4, show the situation where we need of padding.

a. 0 bytes (no padding)

b. 40 bytes

c. 43 bytes

26. In AAL3/4 the number of bytes in CS, after adding header, padding, and trailer must be multiple of 44.

a. When user (**4** + **user data** + **4**) mod 44 = 0.

b. When user (**4** + **user data** + **40** + **4**) mod 44 = 0.

c. When user (**4** + **user data** + **43** + **4**) mod 44 = 0.

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27. UsingAAL5, show the situation where we need of padding.

a. 0 bytes (no padding)

b. 40 bytes

c. 47 bytes

27. In AAL5 the number of bytes in CS, after adding padding and trailer must be multiple of 48.

a. When user (**user data** + **8**) mod 48 = 0.

b. When user (**user data** + **40** + **8**) mod 48 = 0.

c. When user (**user data** + **43** + **8**) mod 48 = 0.

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28. In a 53-byte cell, how many bytes belong to the user in the following (assume no padding)?

a. AALI

b. AAL2

c. AAL3/4 (not the first or last cell)

d. AAL5 (not the first or last cell)

28. For AAL1 we can calculate the exact number of bytes; for AAL2, AAL3/4, and AAL5, we cannot calculate the portion of the overhead in CS sublayer.

a. AAL1 → 53 − **5** − 1 = **47**

b. AAL2 → 53 − **5** − 1 − (CS header) < **47**

c. AAL3/4 → 53 − **5** − 4 − (CS header) < **44**

d. AAL3/4 → 53 − **5** − (CS header) < **48**