SWITCHING

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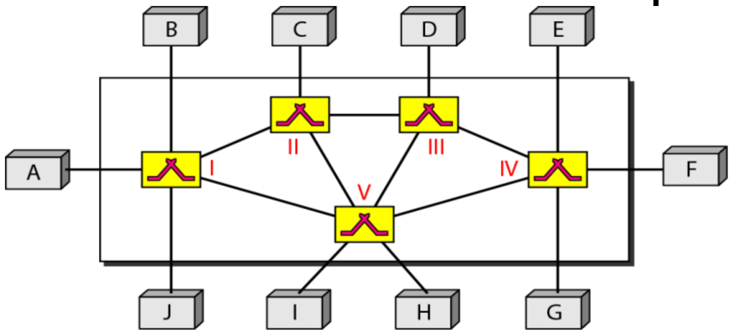
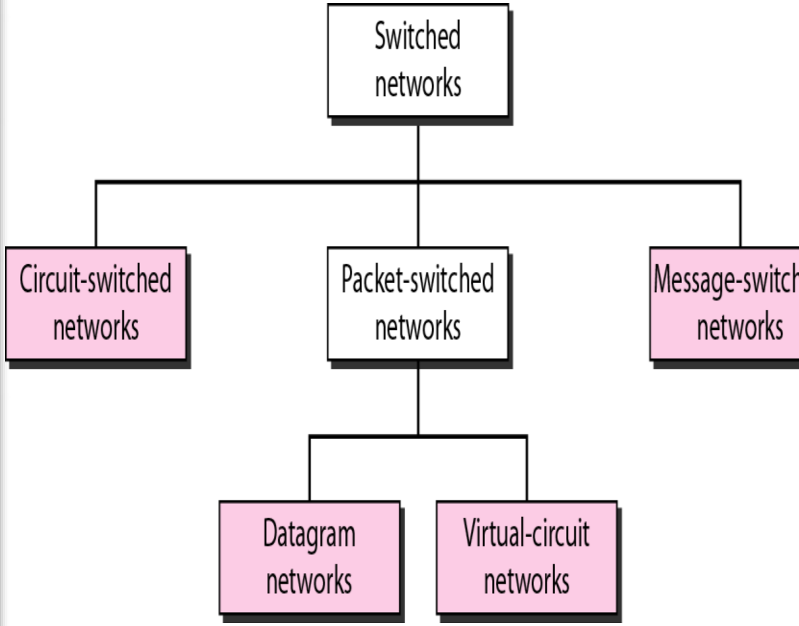
- A network is a set of connected devices. Whenever we have multiple devices, we have the problem of how to connect them to make one-to-one communication possible. One solution is to make a **point-to-point** connection between each pair of devices (a **mesh topology**) or between a central device and every other device (a star topology). These methods, however, are impractical and **wasteful** when applied to very large networks. The number and length of the links require too much infrastructure to be cost-efficient, and the majority of those links would be idle most of the time. Other topologies employing **multipoint** connections, such as a bus, are ruled out because the distances between devices and the total number of devices increase **beyond the capacities** of the media and equipment.
- A better solution is **switching.** A switched network consists of a series of interlinked nodes, called switches. **Switches are devices capable of creating temporary connections between two or more devices linked to the switch.** In a switched network, some of these nodes are connected to the end systems (computers or telephones, for example). Others are used only for routing. Figure shows a switched network.
- The end systems (communicating devices) are labeled A, B, C, D, and so on, and the switches are labeled I, II, III, IV, and V. Each switch is connected to multiple links.



- Traditionally, three methods of switching have been important: circuit switching, packet switching, and message switching. The first two are commonly used today. The third has been phased out in general communications but still has networking applications. We can then divide today's networks into three broad categories: circuit-switched networks, packet-switched networks, and message-switched. Packet-switched networks can further be divided into two subcategories- virtual-circuit networks and datagram networks

	MESSAGE SWITCH	PACKET SWITCH
1	No limit on block size	Tight upper limit on block size
2	Routers must have disks to buffer long blocks	Packets buffered on the main memory instead of on disk
3	Single user may tie up a router(for minutes)	No user monopolize(<milliseconds)
4	Each block is received in its entirety and then retransmitted	The first packet of a multi packet can be forwarded before the second one is fully arrived, reducing delay and improving throughput



Circuit-Switched networks

- A circuit-switched network **consists of a set of switches connected by physical links.** A connection between two stations is a **dedicated path** made of one or more links. However, each connection uses only one dedicated channel on each link. Each link is normally divided into *n* channels by using FDM or TDM . A circuit-switched network is made of a set of switches connected by physical links, in which each link is divided into *n* channels.

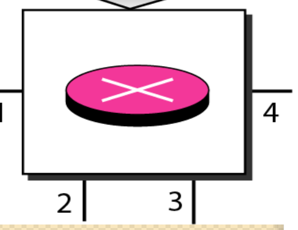
  Three Phases-The actual communication in a circuit-switched network requires three phases**: connection setup, data transfer, and connection teardown.**
- ***Setup Phase-*** Before the two parties (or multiple parties in a conference call) can communicate, a dedicated circuit (combination of channels in links) needs to be established. The end systems are normally connected through dedicated lines to the switches, so connection setup means creating dedicated channels between the switches.
- ***Data Transfer Phase-*** After the establishment of the dedicated circuit (channels), the two parties can transfer data
- ***Teardown Phase-*** When one of the parties needs to disconnect, a signal is sent to each switch to release the resources.
- **Efficiency**- It can be argued that circuit-switched networks are not as efficient as the other two types of networks because resources are allocated during the entire duration of the connection. These resources are unavailable to other connections.
- **Delay-** Although a circuit-switched network normally has low efficiency, the delay in this type of network is minimal. During data transfer the data are not delayed at each switch; the resources are allocated for the duration of the connection

Item	Circuit-switched	Packet-switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
When can congestion occur	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

SL	ITEM	CIRCUIT SWITCHED	PACKET SWITCHED
1	Dedicated copper path	YES	NO
2	Reserves Resources(bandwidth, time slot, switches)	YES	NO
3	Unused bandwidth	YES	NO
4	Each Packet follows the same root	YES	NO
5	Call setup	YES	NO
6	Transparent	YES	NO
7	Addressing	NO	YES
8	Out of order packets(loss packets)	NO	YES
9	Store and forward transmission	NO	YES
10	Over whelm a router	NO	YES
11	Delay or congestion occur	At setup time, data transfer, disconnect	On every Switch
12	Charging	Based on time and distance	No of packets/bytes and connect time
13	Takes place at	Physical layer	Network layer
14	Example	Rail road	Road

Datagram Networks

Destination address	Output port
1232	1
4150	2
⋮	⋮
9130	3



- In data communications, we need to send messages from one end system to another. If the message is going to pass through a packet-switched network, it needs to be divided into packets of fixed or variable size. The size of the packet is determined by the net work and the governing protocol.
- In packet switching, there is no resource allocation for a packet. This means that there is no reserved bandwidth on the links, and there is no scheduled processing time
- **Each packet is treated independently even if it is a part of a multi packed transmission, the network treat as though it exited alone.**
- **Routing Table-** The destination addresses and the corresponding forwarding output ports are recorded in the tables. This is different from the table of a circuit switched network in which each entry is created when the setup phase is completed and deleted when the teardown phase is over.
- **Destination Address- Every packet** in a datagram network carries a header that contains, among other information, the **destination address of the packet. When the switch receives the packet, this destination address is examined; the routing table is consulted to find the corresponding port through which the packet should be forwarded**. This address, unlike the address in a virtual-circuit-switched network, **remains the same during the entire journey of the packet.**
- **Efficiency-** The efficiency of a datagram network is better than that of a circuit-switched network; resources are allocated only when there are packets to be transferred.
- **Delay**- There may be greater delay in a datagram network than in a virtual-circuit network. Although there are no setup and teardown phases, each packet may experience a wait at a switch before it is forwarded.
- Switching in the Internet is done by using the datagram approach to packet switching at

Virtual Ciruit networks

- A virtual-circuit network is a cross between a circuit-switched network and a datagram network. It has some characteristics of both.
- As in a circuit-switched network, there are setup and teardown phases in addition to the data transfer phase.
- Resources can be allocated during the setup phase, as in a circuit-switched network, or on demand, as in a datagram network.
- As in a datagram network, data are packetized and each packet carries an address in the header. However, the address in the header has local jurisdiction (it defines what should be the next switch and the channel on which the packet is being carried), not end-to-end jurisdiction. The reader may ask how the intermediate switches know where to send the packet if there is no final destination address carried by a packet. The answer will be clear when we discuss virtual-circuit identifiers in the next section.
- As in a circuit-switched network, all packets follow the same path established during the connection.
- A virtual-circuit network is normally implemented in the data link layer, while a circuit-switched network is implemented in the physical layer and a datagram network in the network layer. But this may change in the future.

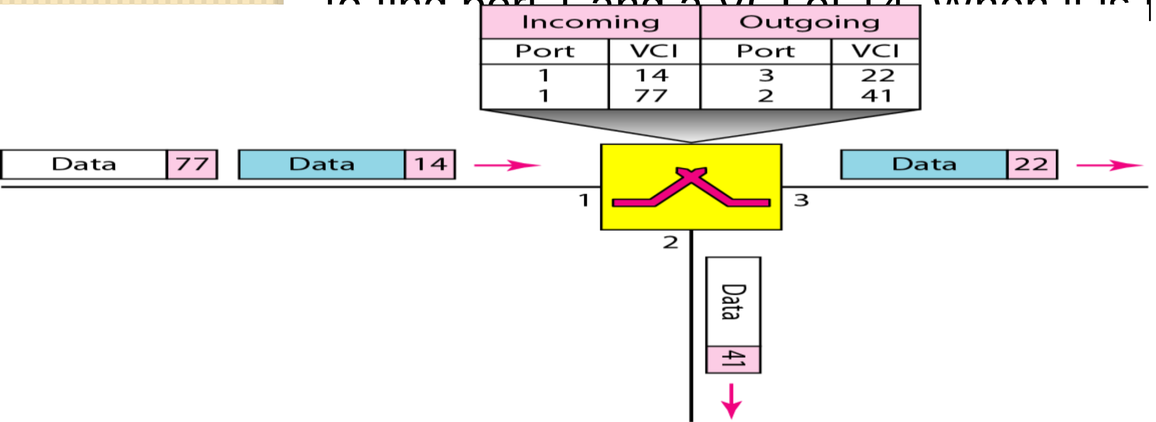
Path-Versus Route

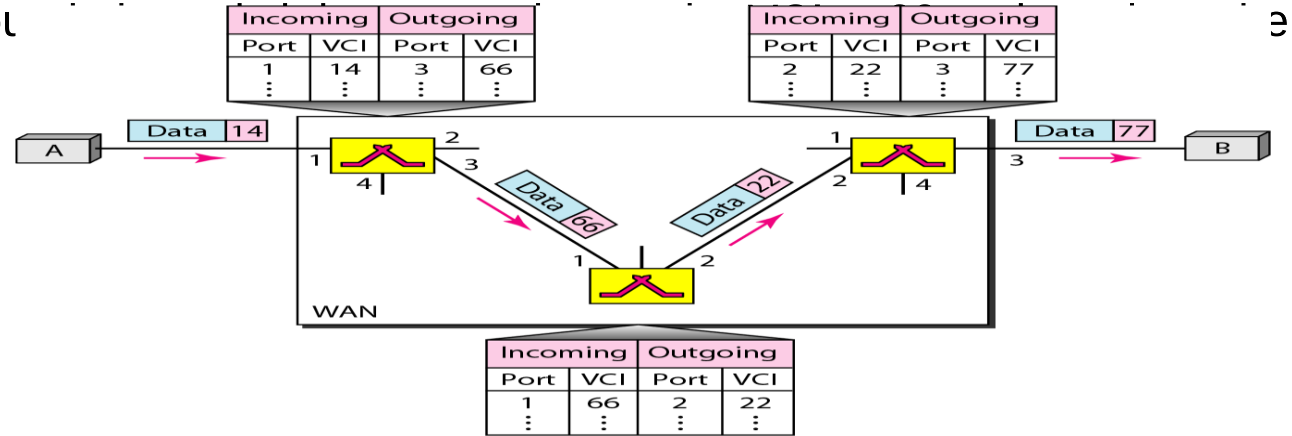
A Circuit Switched connection creates **a physical path** for the duration of the dial(dial up line). All switches are closed in such away that create a path between A and B and the **path is dedicated-they cannot be used by other connection.**

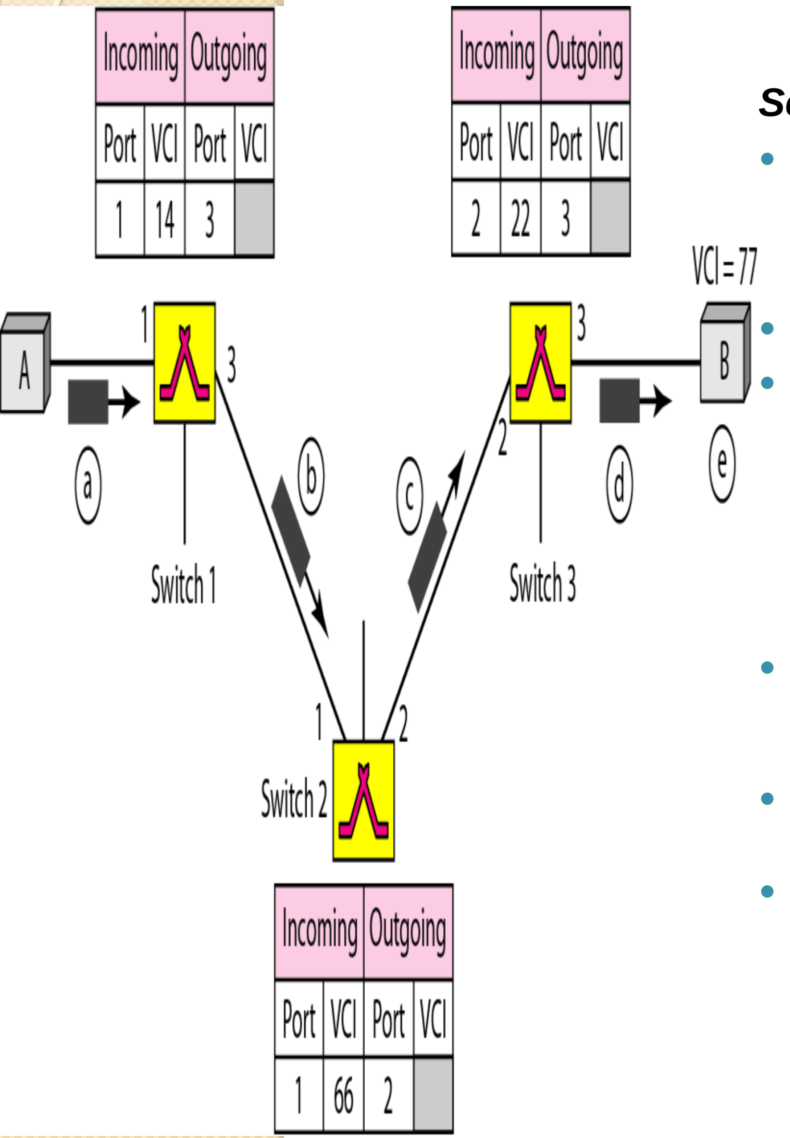
Here a **Virtual Circuit is created whenever it is needed and exists only for the duration of the specific exchange also called Switched Virtual Circuits(SVC) or** duration of the lease(leased lines). **The circuit is dedicated to specific users on continuous basis- Permanent Virtual circuits(PVC)**

A Virtual Circuit creates **a route** between two points. **This means each switch creates an entry in its routing table for the duration of the session(SVC) or duration of the lease(PVC).** All switches create an entry in such a way create a route for this connection. **The link that make a route can be shared by**

- **Addressing-** In a virtual-circuit network, two types of addressing are involved: global and local (virtual-circuit identifier).
- ***Global Addressing-*** A source or a destination needs to have a **global** address-an address that can be unique in the scope of the network or internationally. A global address in virtual-circuit networks is used only to create a virtual-circuit identifier, as discussed next.
- ***Virtual-Circuit Identifier-*** The identifier that is actually used for data transfer is called the virtual-circuit identifier (VCI). A VCI, unlike a global address, is a **small number that has only switch scope**; it is used by a frame between two switches. **When a frame arrives at a switch, it has a VCI; when it leaves, it has a different VCI.** Figure shows how the VCI in a data frame changes from one switch to another. Note that a VCI does not need to be a large number since each switch can use its own unique set of VCIs.
- **Three Phases-** As in a circuit-switched network, a source and destination need to go through three phases in a virtual-circuit network: **setup, data transfer, and teardown**. In the setup phase, the source and destination use their global addresses to help switches make table entries for the connection. In the teardown phase, the source and destination inform the switches to delete the corresponding entry. Data transfer occurs between these two phases.
- ***Data Transfer Phase-*** To transfer a frame from a source to its destination, all switches need to have a table entry for this virtual circuit. The table, in its simplest form, has four columns. This means that the switch holds four pieces of information for each virtual circuit that is already set up. We show later how the switches make their table entries, but for the moment we assume that each switch has a table with entries for all active virtual circuits. Figure shows such a switch and its corresponding table.
- Figure shows a frame arriving at port 1 with a VCI of 14. When the frame arrives, the switch looks in its table to find port 1 and a VCI of 14. When it is fou







Setup request in a virtual-circuit network

- Figure. shows how a frame from source A reaches destination B and how its VCI changes during the trip. Each switch changes the VCI and routes the frame. The data transfer phase is active until the source sends all its frames to the destination. The procedure at the switch is the same for each frame of a message. The process creates a virtual circuit, not a real circuit, between the source and destination.

Setup Phase

- In the setup phase, a switch creates an entry for a virtual circuit. For example, suppose source A needs to create a virtual circuit to B. Two steps are required: the setup request and the acknowledgment. Setup Request A setup request frame is sent from the source to the destination.
- Source A sends a setup frame to switch 1.
- Switch 1 receives the setup request frame. It knows that a frame going from A to B goes out through port 3.The switch, in the setup phase, acts as a packet switch; it has a routing table which is different from the switching table. For the moment, assume that it knows the output port. The switch creates an entry in its table for this virtual circuit, but it is only able to fill three of the four columns. The switch assigns the incoming port (1) and chooses an available incoming VCI (14) and the outgoing port (3). It does not yet know the outgoing VCI, which will be found during the acknowledgment step. The switch then forwards the frame through port 3 to switch 2.
- Switch 2 receives the setup request frame. The same events happen here as at switch 1; three columns of the table are completed: in this case, incoming port (l), incoming VCI (66), and outgoing port (2).
- Switch 3 receives the setup request frame. Again, three columns are completed: incoming port (2), incoming VCI (22), and outgoing port (3).
- e. Destination B receives the setup frame, and if it is ready to receive frames from A, it assigns a VCI to the incoming frames that come from A, in this case 77. This VCI lets the destination know that the frames come from A, and not other sources.

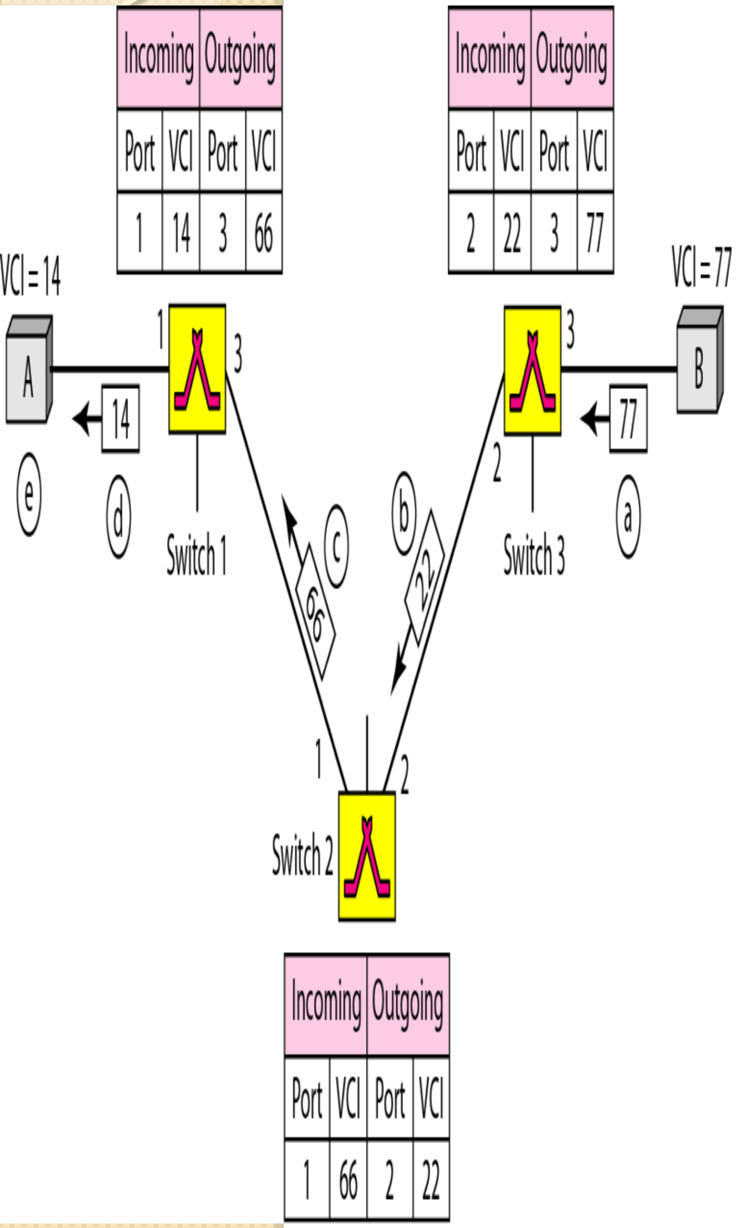


Fig Setup acknowledgment in a virtual-circuit network

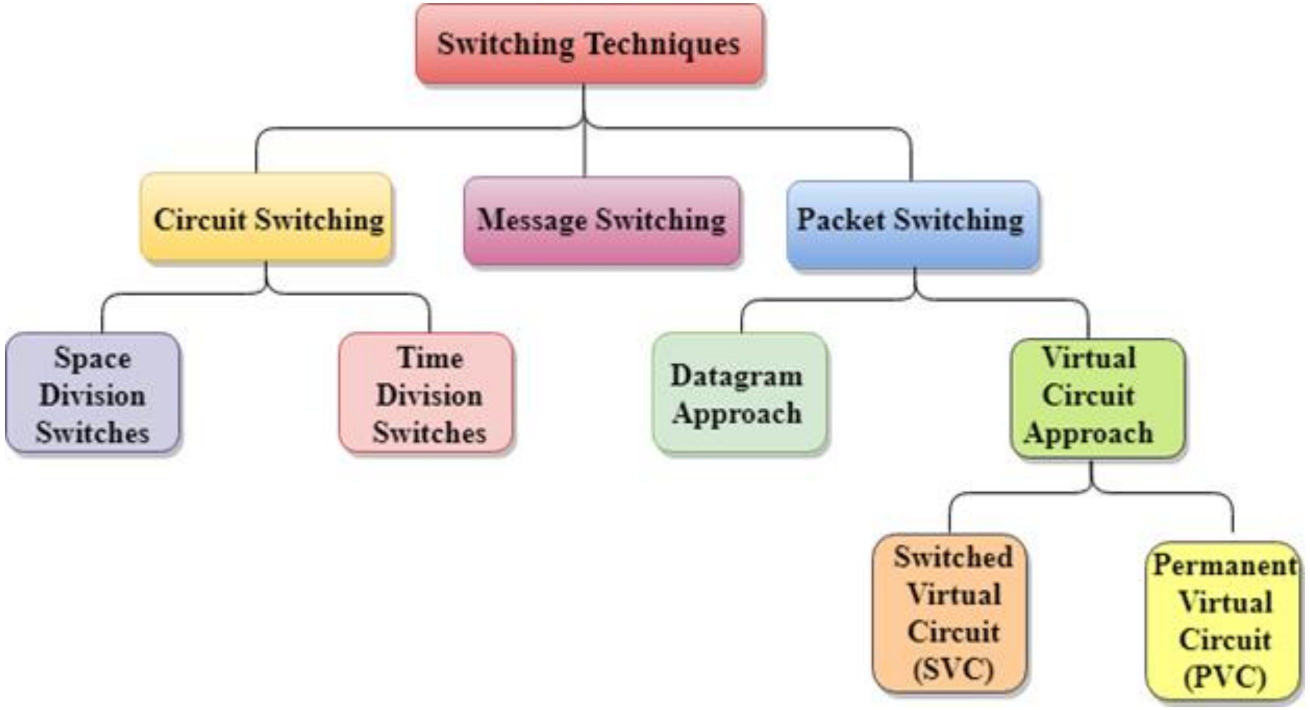
- **Acknowledgment** A special frame, called the acknowledgment frame, completes the entries in the switching tables. Figure
- The destination sends an acknowledgment to switch 3. The acknowledgment carries the global source and destination addresses so the switch knows which entry in the table is to be completed. The frame also carries VCI 77, chosen by the destination as the incoming VCI for frames from A. Switch 3 uses this VCI to complete the outgoing VCI column for this entry. Note that 77 is the incoming VCI for destination B, but the outgoing VCI for switch 3.
- Switch 3 sends an acknowledgment to switch 2 that contains its incoming VCI in the table, chosen in the previous step. Switch 2 uses this as the outgoing VCI in the table.
- Switch 2 sends an acknowledgment to switch 1 that contains its incoming VCI in the table, chosen in the previous step. Switch 1 uses this as the outgoing VCI in the table.
- Finally switch 1 sends an acknowledgment to source A that contains its incoming VCI in the table, chosen in the previous step.
- The source uses this as the outgoing VCI for the data frames to be sent to destination B.

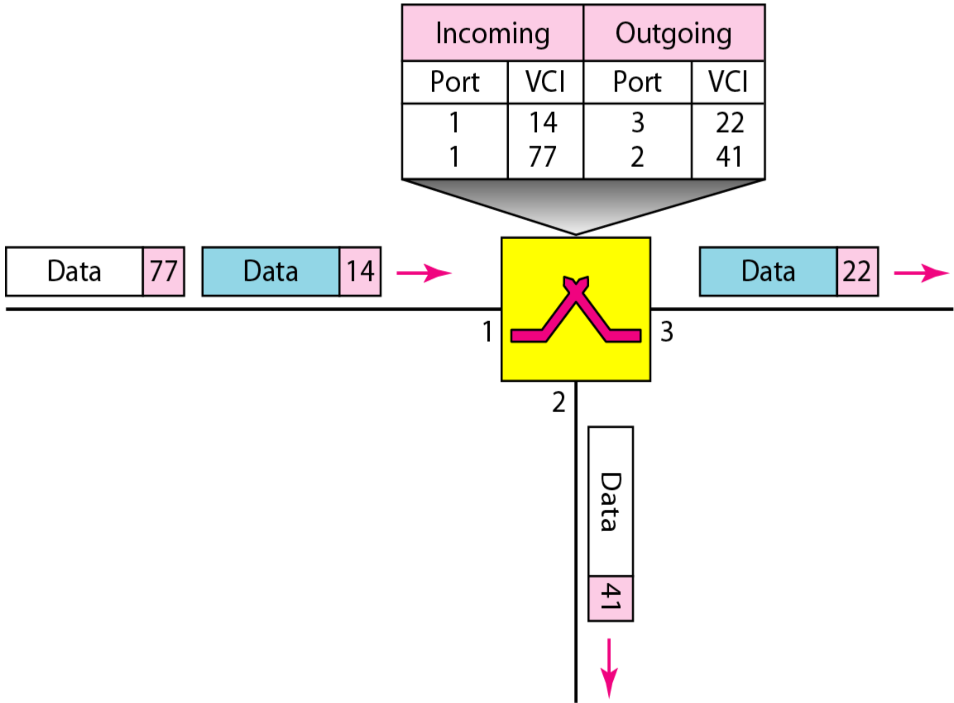
Teardown Phase

- In this phase, source A, after sending all frames to B, sends a special frame called a ***teardown request***. *Destination B responds with a teardown* ***confirmation frame.*** *All* switches delete the corresponding entry from their tables.

Efficiency

- Resource reservation in a virtual-circuit network can be made during the setup or can be on demand during the data transfer phase. In the first case, the delay for each packet is the same; in the second case, each packet may encounter different delays. There is one big advantage in a virtual-circuit network even if resource allocation is on demand. The source can check the availability of the resources, without actually reserving it. Consider a family that wants to dine at a restaurant. Although the restaurant may not accept reservations (allocation of the tables is on demand), the family can call and find out the waiting time. This can save the family time and effort.
- **Delay in Virtual-** Circuit Networks- In a virtual-circuit network, there is a one-time delay for setup and a one-time delay for teardown



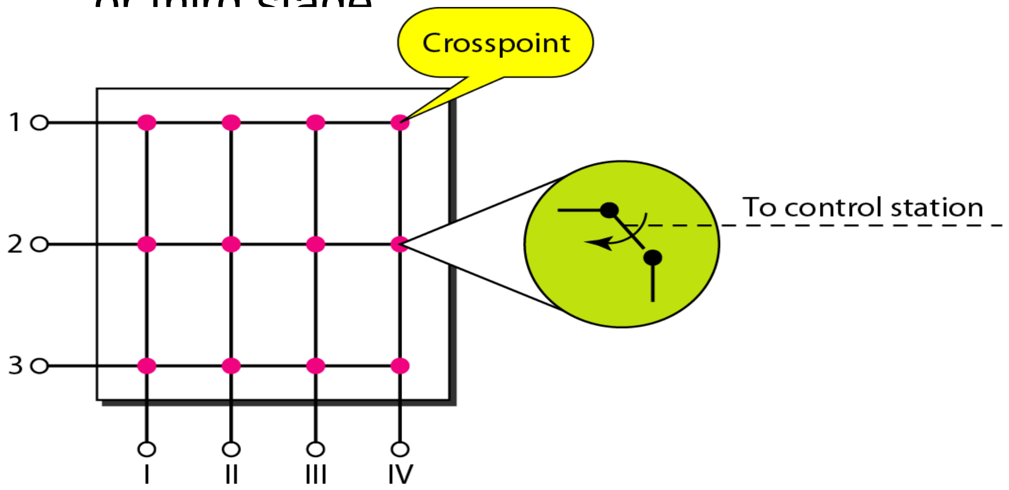


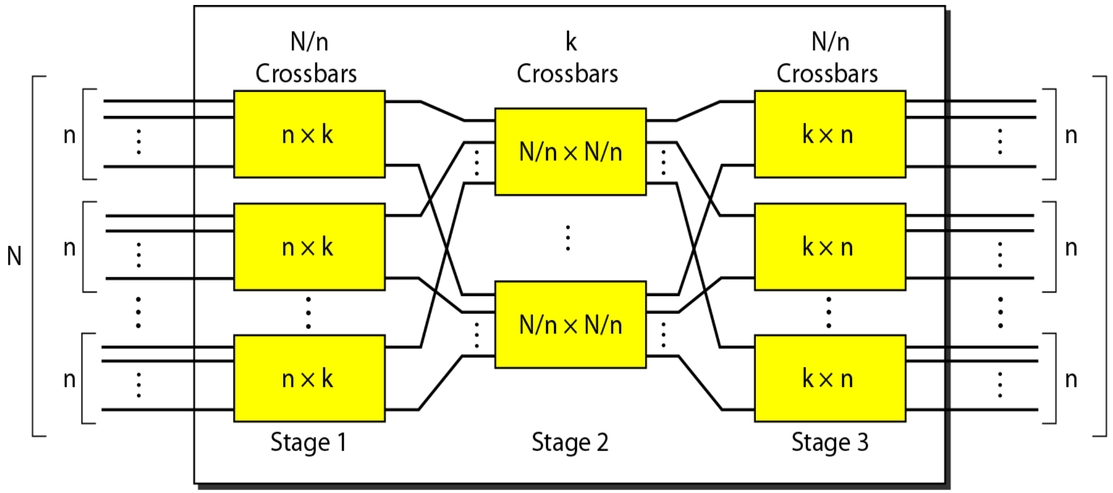
Structure of a switch

- We use switches in circuit-switched and packet-switched networks. In this section, we discuss the structures of the switches used in each type of network.

Space-Division Switch

- In space-division switching, the paths in the circuit are separated from one another spatially. This technology was originally designed for use in analog networks but is used currently in both analog and digital networks. It has evolved through a long history of many designs.
- Crossbar Switch A crossbar switch connects *n* inputs to *m* outputs in a grid, using electronic micro switches (transistors) at each crosspoint (see Figure). The major limitation of this design is the number of cross points required. To connect *n* inputs to *m* outputs using a crossbar switch requires *n* x *m* crosspoints.
- Multistage Switch The solution to the limitations of the crossbar switch is the multistage switch, which combines crossbar switches in several (normally three) stages, as shown in Figure . In a single crossbar switch, only one row or column (one path) is active for any connection. So we need *N x N crosspoints. If we can allow* multiple paths inside the switch, we can decrease the number of crosspoints. Each crosspoint in the middle stage can be accessed by multiple crosspoints in the first or third stage





Time-Division Switch

- Time-division switching uses time-division multiplexing (TDM) inside a switch. The most popular technology is called the time-slot interchange (TSI). Figure shows a system connecting four input lines to four output lines. Imagine that each input line wants to send data to an output line according to the following pattern: 1 3 2 4 3 1 4 2
- The figure combines a TDM multiplexer, a TDM demultiplexer, and a TSI consisting of random access memory (RAM) with several memory locations. The size of each location is the same as the size of a single time slot. The number of locations is the same as the number of inputs (in most cases, the numbers of inputs and outputs are equal). The RAM fills up with incoming data from time slots in the order received. Slots are then sent out in an order based on the decisions of a control unit.

Time- and Space-Division Switch Combinations

- When we compare space-division and time-division switching, some interesting facts emerge. The advantage of space-division switching is that it is instantaneous. Its disadvantage is the number of crosspoints required to make space-division switching acceptable in terms of blocking.
- The advantage of time-division switching is that it needs no crosspoints. Its disadvantage, in the case of TSI, is that processing each connection creates delays. Each time slot must be stored by the RAM, then retrieved and passed on.
- In a third option, we combine space-division and time-division technologies to take advantage of the best of both. Combining the two results in switches that are optimized both physically (the number of crosspoints