Module 4

Switched Communication Networks

Lesson
1

Switching Techniques: Circuit Switching

Specific Instructional Objectives

At the end of this lesson the student will be able to:

- Understand the need for circuit switching
- Specify the components of a switched communication network
- Explain how circuit switching takes place
- Explain how switching takes place using space-division and time-division switching
- Explain how routing is performed
- Explain how signalling in performed

4.1.1 Introduction

When there are many devices, it is necessary to develop suitable mechanism for communication between any two devices. One alternative is to establish point-to-point communication between each pair of devices using **mesh topology.** However, mesh topology is impractical for large number of devices, because the number of links increases exponentially (n(n-1)/2, where n is the number of devices) with the number of devices. A better alternative is to use switching techniques leading to switched communication network. In the **switched network** methodology, the network consists of a set of interconnected nodes, among which information is transmitted from source to destination via different routes, which is controlled by the switching mechanism. A basic model of a switched communication is shown in Fig. 4.1.1. The end devices that wish to communicate with each other are called *stations*. The switching devices are called *nodes*. Some nodes connect to other nodes and some are to connected to some stations. Key features of a switched communication network are given below:

- Network Topology is not regular.
- Uses FDM or TDM for node-to-node communication.
- There exist multiple paths between a source-destination pair for better network reliability.
- The switching nodes are not concerned with the contents of data.
- Their purpose is to provide a switching facility that will move data from node to node until they reach the destination.

The switching performed by different nodes can be categorized into the following three types:

- Circuit Switching
- Packet Switching
- Message Switching

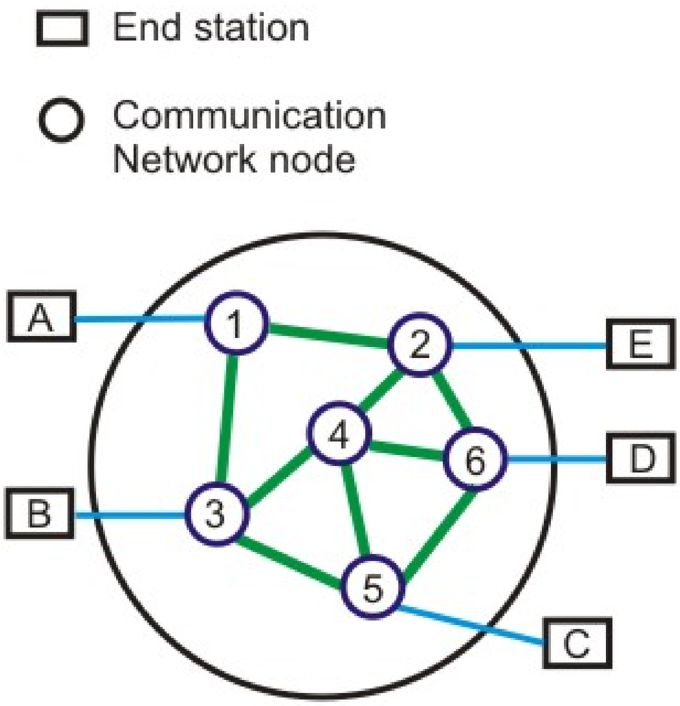


Figure 4.1.1 Basic model of a switched communication network

In this lesson we shall discuss various aspects of circuit switching and discuss how the Public Switched Telephone Network (PSTN), which is based on circuit switching, works.

4.1.2 Circuit switching Technique

Communication via circuit switching implies that there is a dedicated communication path between the two stations. The path is a connected through a sequence of links between network nodes. On each physical link, a logical channel is dedicated to the connection. Circuit switching is commonly used technique in telephony, where the caller sends a special message with the address of the callee (i.e. by dialling a number) to state its destination. It involved the following three distinct steps, as shown in Fig. 4.1.2.

Circuit Establishment: To establish an end-to-end connection before any transfer of data. Some segments of the circuit may be a dedicated link, while some other segments may be shared.

Data transfer:

- Transfer data is from the source to the destination.
- The data may be analog or digital, depending on the nature of the network.
- The connection is generally full-duplex.

Circuit disconnect:

- Terminate connection at the end of data transfer.
- Signals must be propagated to deallocate the dedicated resources.

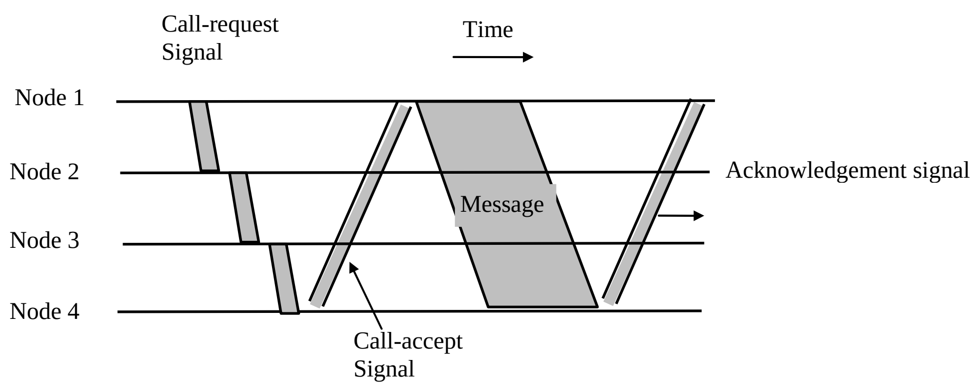


Figure 4.1.2 Circuit Switching technique

Thus the actual physical electrical path or circuit between the source and destination host must be established before the message is transmitted. This connection, once established, remains exclusive and continuous for the complete duration of information exchange and the circuit becomes disconnected only when the source wants to do so.

4.1.3 Switching Node

Let us consider the operation of a single circuit switched node comprising a collection of stations attached to a central switching unit, which establishes a dedicated path between any two devices that wish to communicate.

Major elements of a single-node network are summarized below:

- *Digital switch*: That provides a transparent (full-duplex) signal path between any pair of attached devices.
- *Network interface:* That represents the functions and hardware needed to connect digital devices to the network (like telephones).
- *Control unit:* That establishes, maintains, and tears down a connection.

The simplified schematic diagram of a switching node is shown in Fig. 4.1.3. An important characteristic of a circuit-switch node is whether it is *blocking* or *non-blocking*. A blocking network is one, which may be unable to connect two stations because all possible paths between them are already in use. A non-blocking network permits all stations to be connected (in pairs) at once and grants all possible connection requests as long as the called party is free. For a network that supports only voice traffic, a blocking configuration may be acceptable, since most phone calls are of short duration. For data applications, where a connection may remain active for hours, non-blocking configuration is desirable.

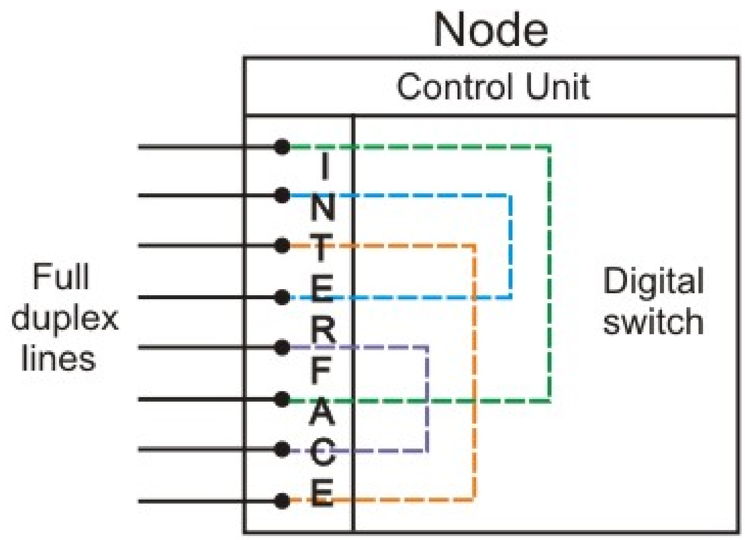


Figure 4.1.3 Schematic diagram of a switching node.

Circuit switching uses any of the three technologies: **Space-division** switches, **Time-division** switches or a **combination of both**. In Space-division switching, the paths in the circuit are separated with each other spatially, i.e. different ongoing connections, at a same instant of time, uses different switching paths, which are separated spatially. This was originally developed for the analog environment, and has been carried over to the digital domain. Some of the space switches are crossbar switches, Multi-stage switches (e.g. Omega Switches). A **crossbar** switch is shown in Fig. 4.1.4. Basic building block of the switch is a metallic crosspoint or semiconductor gate that can be enabled or disabled by a control unit.

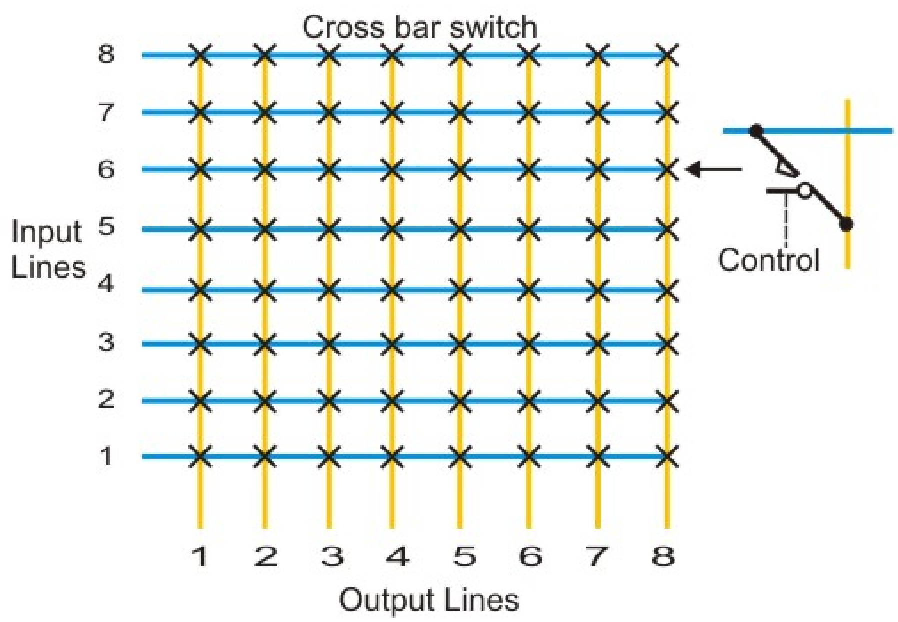


Figure 4.1.4 Schematic diagram of a crossbar switch

Example: Xilinx crossbar switch using FPGAs. It is based on reconfigurable routing infrastructure. It is a high-speed high capacity nonblocking type switch with sizes varying from 64X64 to 1024X1024 and data rate of 200 Mbps.

Limitations of crossbar switches are as follows:

- The number of crosspoints grows with the square of the number of attached stations.
- Costly for a large switch.
- The failure of a crosspoint prevents connection between the two devices whose lines intersect at that crosspoint.
- The crosspoints are inefficiently utilized.
- Only a small fraction of crosspoints are engaged even if all of the attached devices are active.

Some of the above problems can be overcome with the help of *multistage space division* switches. By splitting the crossbar switch into smaller units and interconnecting them, it is possible to build multistage switches with fewer crosspoints.

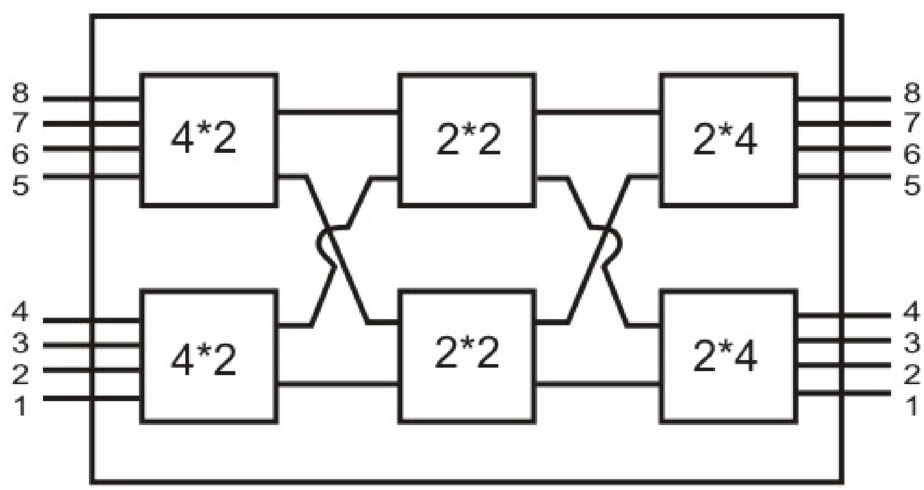


Figure 4.1.5 A three-stage space division switch

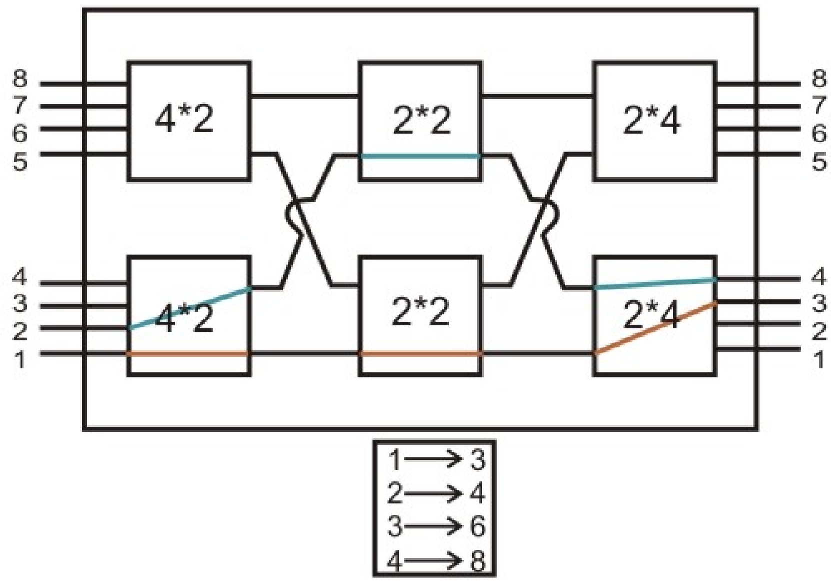
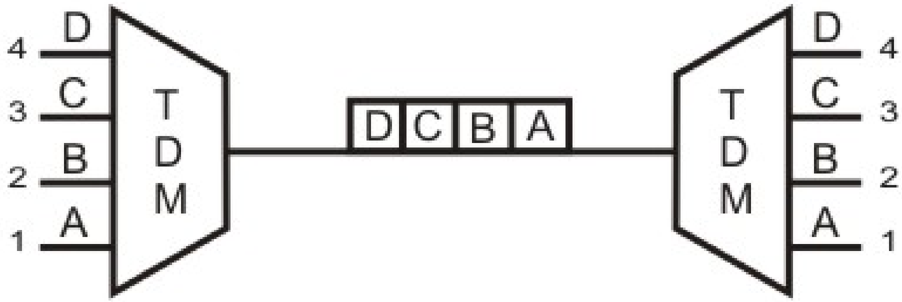


Figure 4.1.6 Block nature of the switch

Figure 4.1.5 shows a three-stage space division switch. In this case the number of crosspoints needed goes down from 64 to 40. There is more than one path through the network to connect two endpoints, thereby increasing reliability. Multistage switches may lead to *blocking*. The problem may be tackled by increasing the number or size of the intermediate switches, which also increases the cost. The blocking feature is illustrated in Fig. 4.1.6. As shown in Fig. 4.1.6, after setting up connections for 1-to-3 and 2-to-4, the switch cannot establish connections for 3-to-6 and 4-to-5.

Time Division Switching

Both voice and data can be transmitted using digital signals through the same switches. All modern circuit switches use digital time-division multiplexing (TDM) technique for establishing and maintaining circuits. Synchronous TDM allows multiple low-speed bit streams to share a high-speed line. A set of inputs is sampled in a round robin manner. The samples are organized serially into slots (channels) to form a recurring frame of slots. During successive time slots, different I/O pairings are enabled, allowing a number of connections to be carried over the shared bus. To keep up with the input lines, the data rate on the bus must be high enough so that the slots recur sufficiently frequently. For 100 full-duplex lines at 19.200 Kbps, the data rate on the bus must be greater than 1.92 Mbps. The source-destination pairs corresponding to all active connections are stored in the control memory. Thus the slots need not specify the source and destination addresses. Schematic diagram of time division switching is shown in Fig. 4.1.7.



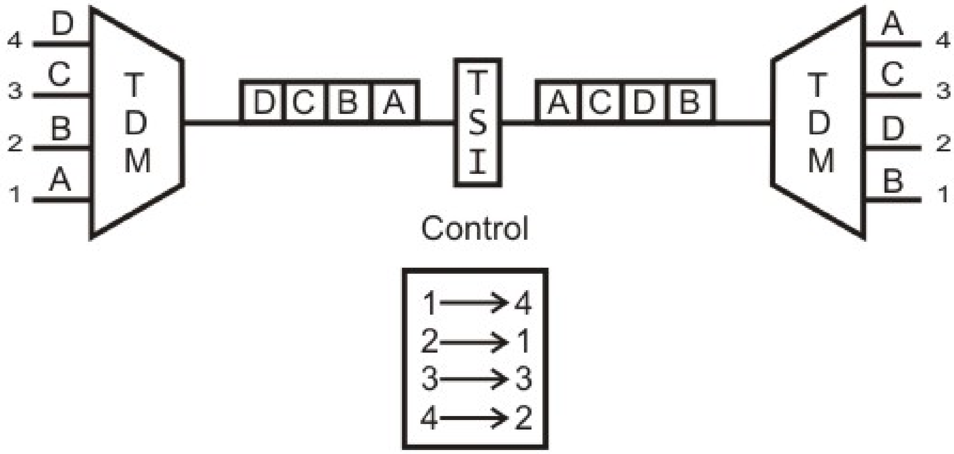


Figure 4.1.8 TDM with Switching using TSI

Time-division switching uses time-division multiplexing to achieve switching, i.e. different ongoing connections can use same switching path but at different interleaved time intervals. There are two popular methods of time-division switching namely, Time-Slot Interchange (TSI) and the TDM bus. TSI changes the ordering of the slots based on desired connection and it has a random-access memory to store data and flip the time slots as shown in Fig. 4.1.8. The operation of a TSI is depicted in Fig. 4.1.9. As shown in the figure, writing can be performed in the memory sequentially, but data is read selectively. In TDM bus there are several input and outputs connected to a high-speed bus. During a time slot only one particular output switch is closed, so only one connection at a particular instant of time as shown in Fig. 4.1.10.

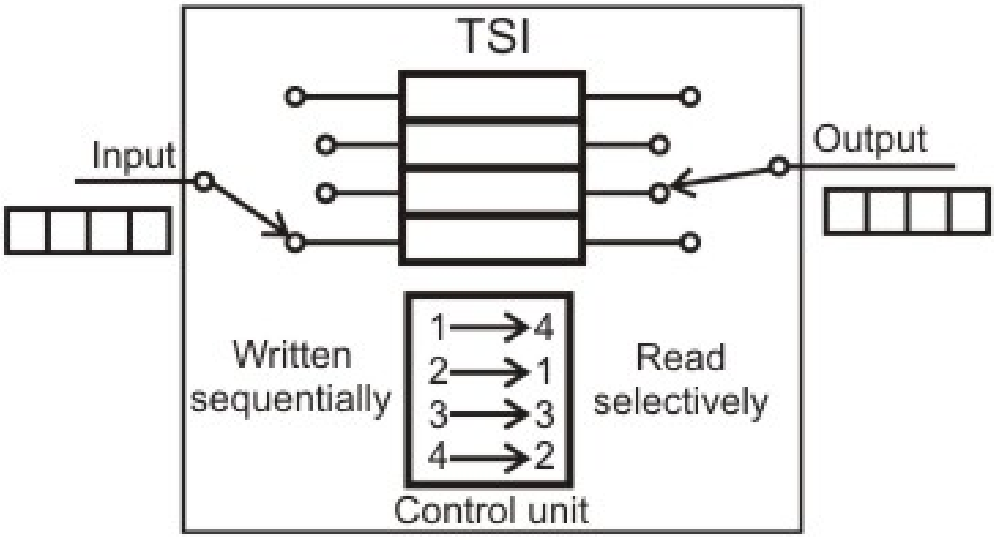


Figure 4.1.9 Operation of a TSI

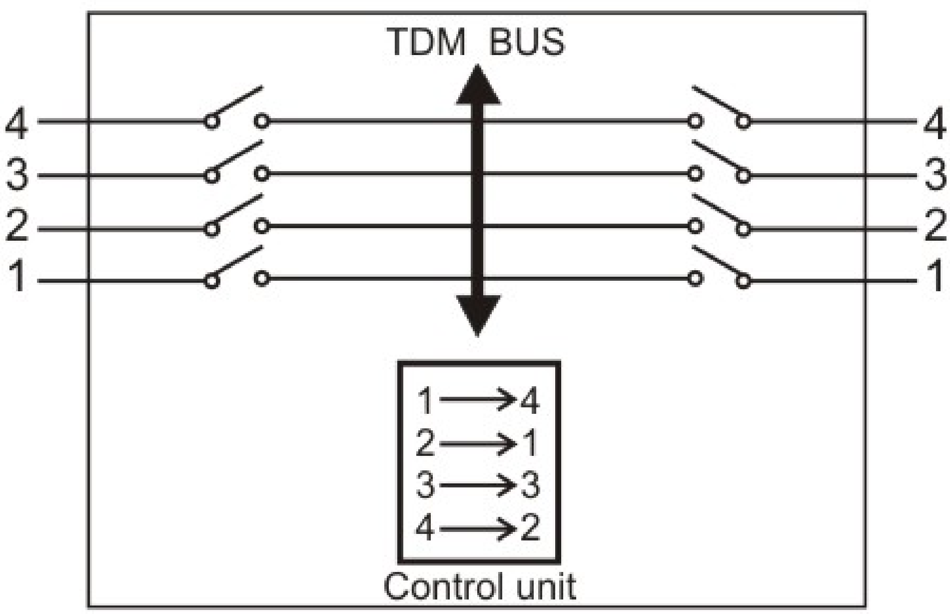


Figure 4.1.10 TDM bus switching

4.1.4 Public Switched Telephone Networks

Public switched telephone network (PSTN) is an example of circuit-switched network. It's also known as Plain Old Telephone Service (POTS). The switching centres used for the switching are organised in different levels, namely: Regional offices (class 1), Section offices (class 2), primary offices (class 3), Toll offices (class 4) and finally End offices (class 5) as shown in Fig. 4.1.11. Level 1 is at the highest level and Level 5 is the lowest level. Subscribers or the customers are directly connected to these end offices. And each office is connected directly to a number of offices at a level below and mostly a single office at higher level.

Subscriber Telephones are connected, through **Local Loops** to end offices (or central offices). A small town may have only one end office, but large cities have several end offices. Many end offices are connected to one Toll office, which are connected to primary offices. Several primary offices are connected to a section office, which normally serves more than one state. All regional offices are connected using mesh topology. Accessing the switching station at the end offices is accomplished through dialling. In the past, telephone featured rotary or pulse dialling, in which digital signals were sent to the end office for each dialled digit. This type of dialling was prone to errors due to inconsistency in humans during dialling. Presently, dialling is accomplished by Touch-Tone technique. In this method the user sends a small burst of frequency called dual tone, because it is a combination of two frequencies. This combination of frequencies sent depends on the row and column of the pressed pad.

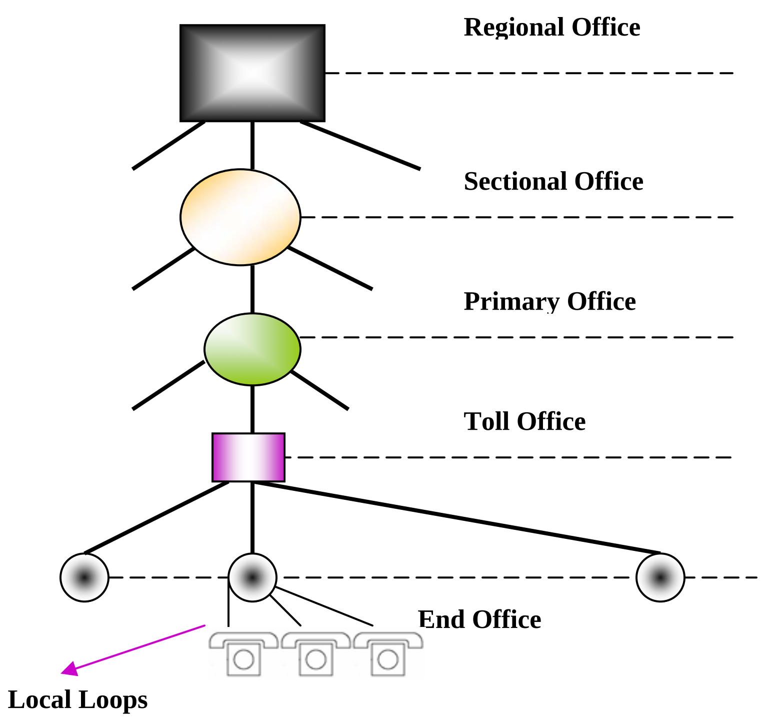


Figure 4.1.11 Basic organization of a Public Switched Telephone Network (PSTN)

The connections are multiplexed when have to send to a switching office, which is one level up. For example, Different connections will be multiplexed when they are to be forwarded from an end-office to Toll office. Figure 4.1.12 shows a typical medium distance telephone circuit.

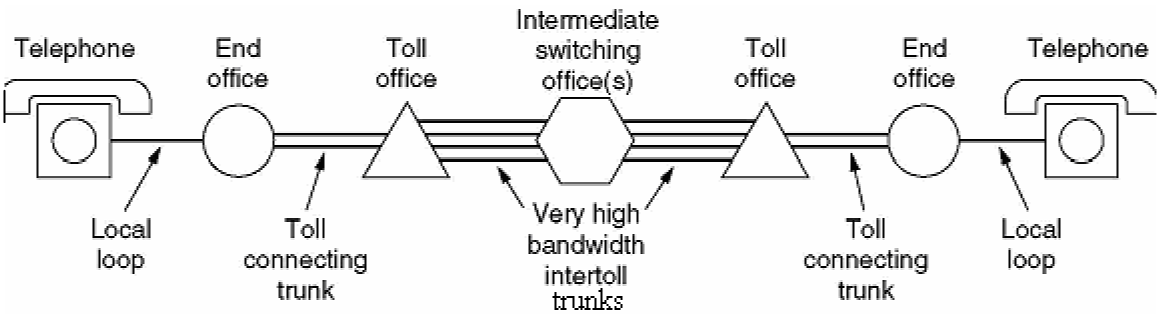


Figure 4.1.12 Typical medium distance telephone circuit

Fill In the Blanks:

1. ________ uses the entire capacity of the link.
2. In ________ switching, each packet of a message need not follow the same path from sender to receiver.
3. In ________ switching all the datagrams of a message follows the same channel of a path.
4. PSTN is an example of _______________ network.
5. PSTN is also known as ____________.

Ans:

1. Circuit switching
2. Datagram packet
3. virtual circuit
4. circuit switching
5. plain old telephone service (POTS)

Short Answer Questions

Q-1. What are the three basic steps involved in data communication through circuit switching?

Ans: The steps are:

- i) Circuit establishment (before data transfer)
- ii) Circuit maintenance (When data transfer is going on)
- iii) Circuit disconnect (When data transfer is over)

Q-2. Mention the key advantages and disadvantages of circuit switching technique.

Ans: Advantages:

- i) After path is established, data communication without delay.
- ii) Very suitable for continuous traffic.
- iii) It establishes a dedicated path.
- iv) No overhead after call setup.
- v) It is transparent and data passes in order.

Disadvantages:

i) Provide initial delay for setting up the call.
ii) Inefficient for bursty traffic.
iii) Data rate should be same because of fixed bandwidth.
iv) When load increases, some calls may be blocked.

Q-3. Why data communication through circuit switching is not efficient?

Ans: In data communication, traffic between terminal and server are not continuous. Sometimes more data may come or sometimes there is no data at all. Circuit switching is not efficient because of its fixed bandwidth.

Q-4. Compare the performance of space-division single-stage switch with multi-stage switch.

Ans: Space-division single-stage switch requires more number of crosspoints, nonblocking in nature but provides no redundant path. On the other hand multi-stage switches require lesser number of crosspoints, blocking in nature but provides redundant paths.