LESSON 29: SWITCHING HIERARCHY AND ROUTING, TRANSMISSION PLAN

Objective

The objective here is to learn Switching hierarchy and routing, transmission plan.

Introduction

Switching Hierarchy And Routing

Telephone networks require some form of interconnection of switching exchanges to route traffic effectively and economically. Exchanges are interconnected by groups of trunk lines, usually known as trunk groups that carry traffic in one direction. Two trunk groups are required between any two exchanges. Three basic topologies are adopted for interconnecting exchanges: mesh, star and hierarchy. Mesh is fully connected network. The number of trunk groups in a mesh network is proportional to the square of the exchanges being interconnected. As, results, mesh connections are used only when there is heavy traffic among exchanges, as may happen in a metropolitan area. A star connection utilizes an intermediate exchange called a tandem exchange through which all other exchanges communicate. A star configuration is shown in Fig. 29.1 (a). Star network are used when traffic levels are comparatively low. Many star networks may be interconnected by using an additional tandem exchange, leading to a two-level star network as shown in fig.29.1 (b). An orderly construction of multilevel star networks leads to hierarchical networks.

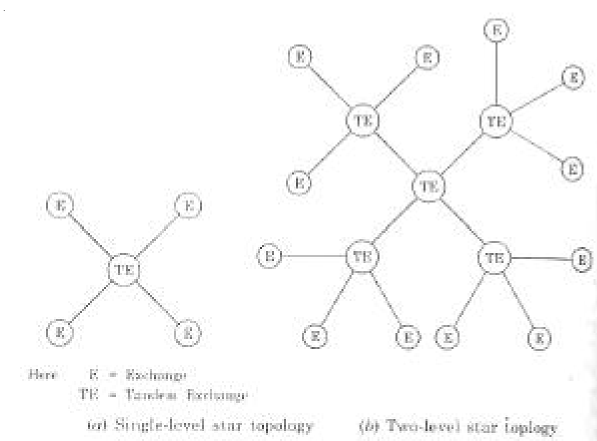

Fig. 29.1 Telecommunication network star topology

Hierarchical networks are capable of handling heavy traffic where required, and at the same time use minimal number of trunk groups. A 5-level switching hierarchy is recommended by CCITT as shown in fig.29.2. In a strictly hierarchical network, traffic from subscriber A to subscriber B and vice versa flows through the highest level of hierarchy, viz. quaternary centers in fig. 29.2. A traffic route via the highest level of hierarchy is known as the final route. However, if there is high traffic intensity between any of exchanges, direct truck groups may be established between them as shown as shown by dashed lines in fig. 29.2. These direct routes are known as high usage routes. Wherever high usage routes exist, the traffic is primarily routed through them. Overflow traffic, if any, is routed along the hierarchical path. No flow is permitted from the final route. In fig. 29.2, the first choice routing for traffic between subscribers A and B is via the high usage route across the primary centers. The second and third choice routes and the final route are also indicted in fig. 29.2. A hierarchical system of routing leads to simplified switch design.

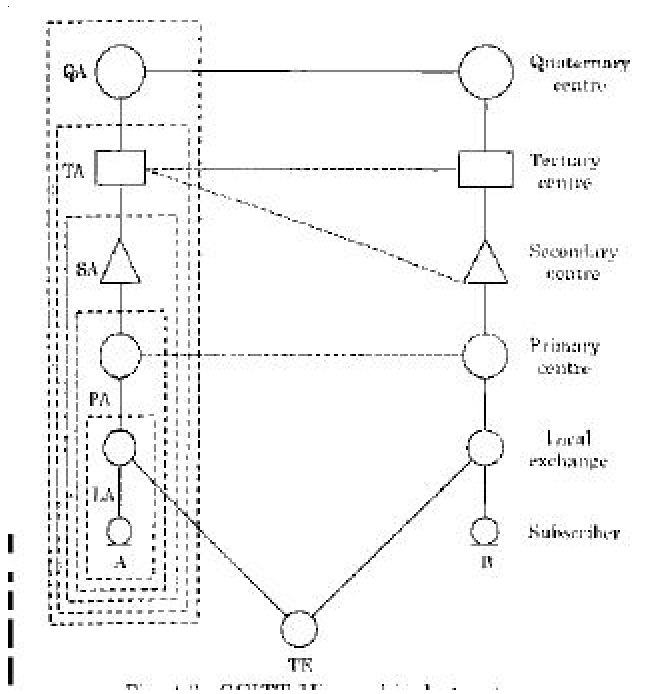

Fig.29.2 CCITT Hierarchical structure

Three methods are commonly used for deciding on the route for particular connections:

1. Right-through routing
2. Own-exchange routing
3. Computer-controlled routing

Now we will discuss each routing one-by-one in subsequent subsections.

Right-through routing

In right-through routing the originating exchanges determines the complete route from the source and destination. No routing decisions are taken at the intermediate routes. In the absence of a computer, only a predetermined route can be chosen by the originating exchange. However, there may be more than one predetermined route and the originating node may select one out of these, based on certain criteria like time of the day, even distribution of traffic etc.

Own-exchange routing

Own-exchange routing or distributed routing allows alternative routes to be chosen at the intermediate nodes. Thus the strategy is capable of responding to changes in traffic loads and network configurations. Another advantage of distributed routing is that when new exchanges are added, modifications required in the switch are minimal.

Computer Controlled Routing

Computers are used in telephone networks with common channel signalling (CCS) feature. A separate computer-controlled signalling network is used in common channel signalling (CCS)

With computers in position, a number of sophisticated route selection methods can be implemented. Computer-based routing is a standard feature of the data networks.

A strictly hierarchical network suffers from one serious drawback, i.e. its poor fault tolerance feature. A good network design should maintain communication, though may be with reduced capability and increased blockage, even in the event of a failure of a failure of one or the several links due to causes such as fire, explosion, sabotage and natural disaster. Total breakdown of the network should never occur unless under calamity.

In a hierarchical network, as we go higher in the hierarchy, the nodes of each rank become fewer and fewer. A failure of a node or communication links at higher levels might seriously jeopardize communications. Alternative routing paths and redundant nodes have to be provided for in higher levels. The current tendency is to reduce the number of levels in the hierarchy, and fully interconnect the high level nodes to provide a large number of alternative routes. It is expected that the future national networks may be built with only three levels of hierarchy.

Transmission Plan

1. For satisfactory operation it is essential that the transmission performance of any switched telephone network be properly planned so that an acceptable quality of signal (speech or data) is achieved for all possible types of call connection.
2. Other network operators are encouraged to develop their transmission plans in accordance with ITU-T Recommendations to enable the full range of digital services to be switched nationally and internationally through a mix of networks as selected by the customer.
3. Telecom will continue to update the Plan as technology and customer service requirements develop.

The objectives of the transmission Plan are to:

(a) Minimise the number of customers experiencing difficulty on any connection through the network.

(b) Maximise the number of connections falling within the customers' range of preferred losses.

(c) Provide for a digital switched network capable of terminating both the integrated services digital network (ISDN) lines and the existing analogue customers' lines.

For reasons of transmission quality and efficiency of operation of signalling, it is desirable to limit the number of circuits connected in tandem. In tandem chain, the apportionment of links between national and international circuits is necessary to ensure quality telecommunications. CCITT lays down certain guidelines in the regard in its recommendations:

1. The maximum number of circuits to be used in an international call is 12.
2. No more than 4 international circuits be used in tandem between the originating and the terminating international switching centres.
3. In exceptional cases and for low number of calls, the total number of circuits may be 14, but even in this case, the international circuits are limited to a maximum of four.

Taking the guidelines (1) and (2), we have 8 links available for national circuits, which implies a limit of 4 for each national circuit. Designs of national network should take into account this limit.

The transmission loss is defined in terms of reference equivalents TRE, RRE and ORE.

Attenuation limits arise from the a.c. response of the subscriber loop and refers to subscriber loop loss in decibels (dB). The criterion here is to ensure that the quality of reception at the subscriber end is satisfactory. This is a subjective criterion. A rating system standardized by CCITT to grade customer satisfaction is known as the Reference Equivalent (RE). In this system, RE of a telephone set or subscriber loop is arrived at by comparing its performance with a standard. The standard set up consisting of a telephone transmitter, receiver and network is established in the ITU laboratory in Geneva and is known as NOSFER.

NOSFER stands for "Nouveau Systame Fundamental Pour La Determination des Equivalents de Reference". NOSFER setup is illustrated in Fig.29.3. Tests are conducted for both transmit and receive qualities and the corresponding REs are called Transmit Reference Equivalent (TRE) and Receive Reference Equivalent (RRE), respectively. Since the transmitter and the receiver technologies have evolved differently. Therefore, the TRE and RRE are usually, unequal. The REs for cables are measured at standard frequency of 800 Hz as specified by CCITT. This standard frequency in American Standard is 1000 Hz. Trained listeners and talkers are engaged to 1 judge the quality of reception and to transmit speech signal using a standard test language.

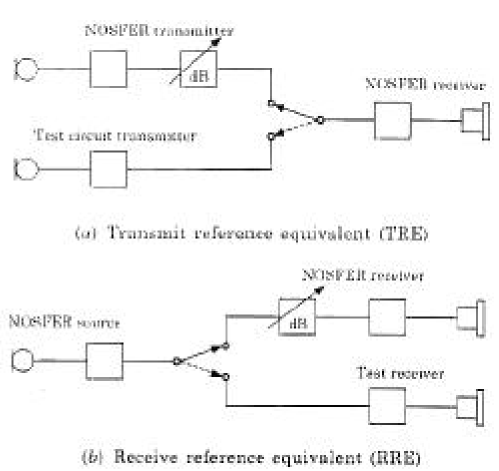

Fig.29.3 NOSFER reference equivalent systems

Calibrated attenuations are inserted into the system until the speech quality of the test circuit is judged to be equal to that of the NOSFER. The value of the balancing attenuation is the RE. If 5 dB losses are added to the NOS FER system for balancing, the test connection is said to have an RE of 5 dB.

If 5 dB is taken out of the NOSFER system for balancing, the test connection is said to have an RE of-5 dB. Negative value for RE indicates that the test circuit performs better than the laboratory standard. The standard language is made up of logatoms. A logatom is a 1-syllable word comprising a constant, a vowel and another consonant in that sequel.

Example 29.1: Find the reference equivalent (RE) of a local call circuit given the following REs:

For the telephone set, TRE = 3 dB

RRE = -3 dB

For the subscriber line loop, TRE = 10 dB

RRE = 8 dB

For the exchange switch, RE = 1 dB.

Solution:

Overall Reference Equivalent (ORE) is illustrated in a Figure below

Therefore, ORE = 3 + 10 + 1 + 8 + (- 3) = 19 dB

Some times, it is convenient to specify symmetric values for reference equivalents

$$RE = \frac{TRE + RRE}{2}$$

CCITT recommends that for 97% of the connections the maximum TRE be limited to 20.8 dB and RRE to 12.2 dB between the subscriber and the international interface in the natural network. This gives an overall reference equivalent (ORE) of 33 dB. Telephone administrations and companies attempt to design networks in such a way as to reduce as much as possible the ORE to improve subscriber satisfaction. From country to country OREs range from 6 dB to 26 dB.

We know that a hybrid is required to convert a 2-wire circuit into a 4-wire circuit between the subscriber and a digital exchange. The 2 wire circuits are used to establish the local calls in analog exchanges. But, long distance calls require 2-wire to 4-wire conversion at the subscriber line-trunk interfaces. Interexchange or intercity trunk lines carry a number of conversations on a single bearer circuit.

A single bearer circuit may be derived from a coaxial cable, microwave or satellite system. Due to long distances, the bearer circuits need amplifiers or repeaters at appropriate intervals to boast the signals. The amplifiers are almost one-way devices and cannot handle bi-directional signals. Since the telephone conversation calls for signal transmission both ways, long distance trunks require separate circuits for each direction, leading to 4-wire circuits. Hence, 2-wire to 4-wire conversion is required in long distance connections. Such type of conversion is done by the hybrids.

An important function of the hybrid is to ensure that the received signal is not coupled. The coupling is zero only when the 2-wire circuit and 4-wire circuit impedances are perfectly matched.

We can easily control the impedances of the trunk circuits. The subscriber loop impedances vary from subscriber to subscriber depending on the distance at which a subscriber is located from the exchange. As a result, an impedance mismatch occurs for most of the connections at the subscriber link-trunk interface. Due to mismatching of impedances, some part of the incoming speech signal is reflected to the outgoing circuit, which returns to the speaker as echo.

The echo may be loud enough to annoy the speaker as it is amplified like other signals in the return path. Echo as reflected signal is shown in Fig.29.4.

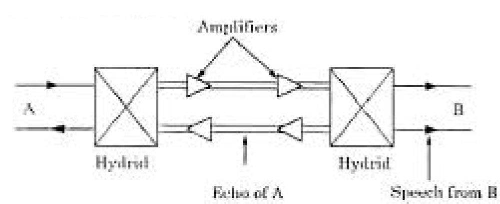

Fig.29.4 Echo as reflected signal.

If the distances are short, the round trip delay experienced by the echo is small such that the echo superimposes on the speaker's own voice and becomes unnoticeable. In fact, the side tone may be considered as echo with zero time delay. As the time delay increases, the echo becomes noticeable and annoying to the speaker.

Short delay echos are controlled by using attenuators. But long delay echos are controlled by echo suppressors or echo cancellers. CCITT recommends the use of echo suppressors or echo cancellers if the round trip delay exceeds 50 ms. Use of each suppressors is mandatory in satellite circuits as the round trip delay involved is several hundred milliseconds.

For short delays upto 50 ms, simple attenuators in the transmission path limit the loudness of echo to a tolerable level. The attenuation required increases as the delay increases. Attenuation verses echo delay are shown in Fig. 29.5.

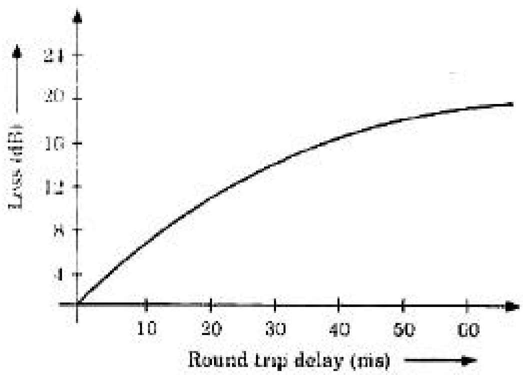

Fig. 4.6 Attenuation Vs echo delay.

For instance, if the echo path delay is 20 ms, 11-dB attenuators must be introduced in the transmission paths. Here, we can note that this loss must be accounted for the overall transmission loss budget, i.e. in ORE.

The operation of an echo suppressor is shown in Fig. 29.6. Echo suppressors are voice activated attenuators. Normally, the echo suppressors remain in a deactivated state, i.e. the attenuators are bypassed, Speech in one channel activates the echo suppressor in the return path. In Fig. 29.6, A's speech activates the echo suppressor E_B and B's speech activates the echo suppressor E_A.

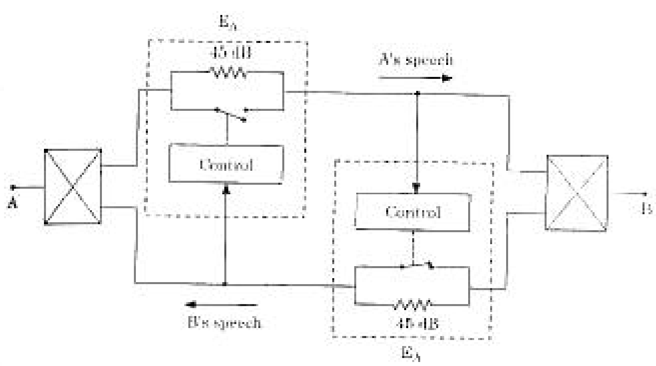

Fig.29.6 Operation of echo suppressor

Fig. 29.6 depicts the situation when B is talking and A is silent. Speaker 'A' can attempt to talk at this juncture, his talk is also attenuated. However, he can turn off the echo suppressor by interrupting B loudly. The echo suppressor is deactivated automatically a few milliseconds after the talker stops speaking.

Echo suppressor has one drawback that they may clip the beginning portion of speech segments.

If subscriber A begins talking at the tail end of B's speech, his talk spirit is not transmitted until the echo suppressors have had time to reverse directions. New designs of echo suppressors attempt to minimise the time required to reverse directions. Typical reversal times are in the range of 2-5 ms.

The operation of a system with echo suppressors is clearly half duplex. When telephone circuits are used for data transmission, full duplex operation is required. Moreover, with several milliseconds of interruption while an echo suppressor in one direction is turned off and one in other direction is turned on. Therefore, it is very difficult to organise data transmission. Hence, each suppressor is usually disabled while the circuits are used for data transmission. This is done by providing a disabler feature in the echo suppressor and trigging the same with special signal.

Usually, a 2025-Hz or 2100-Hz tone is used to trigger the disabler. The duration of signal is atleast of 300 ms with a signal level not less than 5dBm. Once disabled, an echo suppressor remains so, as long as signals in the frequency range of 300 to 3000 Hz are being transmitted in either direction. A no-signal interval of 100 ms or more switches the echo suppressor back into the circuit.

Due to recent developments in electronic technology, we have new form of echo control by echo cancellation. Echo cancellers do not physically insert attenuators or bypass them. But they process the incoming signal to eliminate the reflected component from it. Transmitted speech is stored for a period of time equal to the round trip delay of the circuit. The stored signal is attenuated by a quantity equal to the loop loss and then subtracted from the incoming signal.

Now we can note that echo cancellers eliminate speech clipping. I Therefore it allows full duplex operation.

Upto now we have discussed that only one reflection of the signal at the listener's end is echoed at the talker's end. This echo is called "talker echo". If a second reflection takes place at the talker's end, 'listener echo' occurs.

If repeated multiple reflection occurs oscillations are produced and a condition known as 'Singing' occurs. Under this condition, the circuit is said to experience instability. If the loop gain at some frequency is greater than unity, then singing condition occurs. If the loop gain is close to but less than unity, damped oscillations or near signing conditions result. Singing or near singing conditions have a disturbing effect on both the talker and the listener. In general, procedures used to control echos also control signing. But in some short connections where no control is necessary for echos, singing may become a problem. Singing can occur in idle circuits. But echo cannot occur in idle circuits. For controlling signing under such circumstances, the 4-wire circuits must have a certain minimum loss. CCITT recommends a minimum loss of 10 dB on natural networks to avoid singing.

The amount by which the reflected signal is attenuated is known as return loss.

Return loss in terms of impedances is given by

$$L_R = 20 \log \frac{Z_4 + Z_2}{Z_4 - Z_2}, \text{ dB} \quad \text{……….Eq.1}$$

where, L_R = Return loss

Z_4 = Impedance of the 4-wire circuit

Z_2 = Impedance of the 2-wire circuit

Return loss in terms of power is given by

$$L_R = 10 \log \frac{P4}{P_4 - P_2}, \text{ dB} \quad \text{………..Eq.2}$$

where, P_4 = Incoming power on the 4-wire circuit

P_2 = Incoming power on the 2-wire circuit.

$P_4 - P_2$ = Power reflected on to the return path

Return loss in terms of signal voltages is given by

$$L_R = 20 \log \frac{V_4}{(V_4 - V_2)}, \text{dB} \quad \text{..…….Eq.3}$$

Or $$L_R = 20 \log \frac{1}{r_c}, \text{dB} \quad \text{..…….Eq.4}$$

where, r_c = Reflection coefficient

It is defined as

$$r_c = \frac{\text{Reflected signal}}{\text{Incident signal}}$$

If the two networks are perfectly balanced, then $Z_4 = Z_2$. Therefore, eq.1 becomes

$$L_R \text{ (balanced)} = 20 \log \frac{2 Z_2}{0} = \infty$$

The return loss is infinite. It means that the return signal experiences an infinite attenuation and hence there is no reflected signal.

Example 4.2. In a national transmission system the characteristic impedances of the 4-wire circuit and the 2-two wire circuit are 1000 W and 1200 W, respectively. The average phase velocity of the signal in the circuit is 3 x 107 m/s. If the largest distance of a connection is 300 km. find the attenuation to be inserted in the circuit.

Solution. Return loss in terms of impedance is given by

$$L_R = 20 \log \frac{Z_4 + Z_2}{Z_4 - Z_2}, \text{ dB}$$

$$L_R = 20 \log \frac{1000 + 1200}{1000 - 1200}, \text{ dB}$$

$$L_R = 20 \log \frac{2200}{200}, \text{ dB}$$

$$= 20.8 \text{ dB}$$

$$\text{Round trip delay for echo} = \frac{\text{Largest distance of connection}}{\text{Average phase velocity of the signal}}$$

$$= \frac{300 * 10^3}{3 * 10^7}$$

$$= 10 \text{ ms}$$

From Fig.29.5, for a round trip delay of 10 ms, we need about 7 dB loss to contain the echo. As per the CCITT recommendations, the circuits would have been provided with a loss of 10 dB to control singing. Hence no addition attenuator needs to be inserted in the circuit to control echos.

Notes