LESSON :20
COMBINATION SWITCHING AND MULTISTAGE SWITCHING

Objective

To provide a detailed understanding of the concepts combination switching and multistage switching

Introduction

We a1ready studied that time Multiplexed Time Division Space Switches do not offer full availability as they are not capable of performing time slot interchange (TSI) switches are not capable of switching sample values across the trunks without the help of some space switching matrices. Therefore a combination of the time and Space switches gives a configuration which provides both timeslot interchange (TSI) and sample switching across trunks, combination switches also permit; a large number of simultaneous connection to be supported for given technology. A combination switch can be built by using a number of stages of time, and space switches.

Two-Stage Combination switching

A two-stage combination switch can be organised with time switch as first stage and the space switch as the second stage. The order of the time switch and the space switch may be changed. These two switch configurations are known by nomenclature Time-Space (TS), or Space-Time (ST) switches, respectively.

A TS switch is shown in Fig.20.1. The first stage of this TS switch consists of one time slot interchange per inlet and the second stage a NXN space switch.

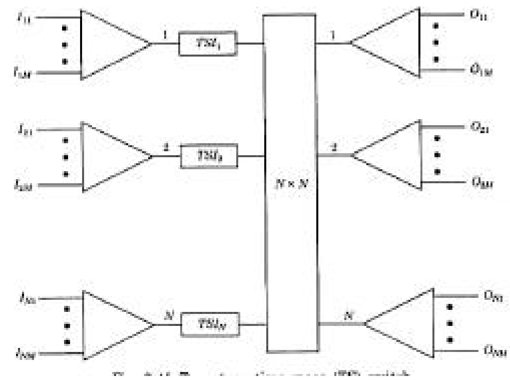
We have not shown control memories of TSI and space switch in the Fig. 20.1. Each time multiplexed inlet/outlet stream carries M channels. A subscriber on the input side is assigned one of the inlets and a time slot in that inlet.

An input subscriber assigned to line 4 at time slot 7 is identified by the label I_{47}. Similarly, a subscriber connected to the outlet 5 and time slot 6 is identified by O_{56}. The corresponding time slots are identified as IS_{47} and OS_{56}. Suppose that a communication is to be established between these two subscribers. The input sample from IS_{47} is first moved to IS_{46} at the output of ISI switch. During the time slot 6, a connection is established between the inlet 4 and the outlet 4 at the space switch. While this switch configuration provides full availability, it is non-blocking.

Now we consider two connections. These connections are to be established between I_{47} and O_{29} and between I_{43} and O_{69}. Both the samples originate from the same inlet and are destined to the same time slot in different outlets. Both input samples require to be switched to time slot 9, which is not possible. Only one of them can be switched to slot 9.

In general, blocking occurs if two inputs I_{ij} and I_{jk} are destined to outputs O_{pq} and $O_{rq.}$ In other words, we can say that it is only possible to set up a single connection between any of the subscribers connected to the same time slot on the output side.

Fig.20.1 Two-stage time-space (TS) switch



Now we let the traffic intensity in erlangs per inlet trunk = ρE

Probability that a subscriber X is active

$$= \frac{\rho}{M}$$

Probability that any other subscriber is active on the same inlet

$$= \frac{(M-1)\rho}{M}$$

Probability that a particular outlet subscriber is chosen by subscriber X

$$= \frac{1}{MN}$$

Probability that the same time slot on a different outlet is chosen by the other subscriber on the same inlet

$$= \frac{(M-1)\rho(N-1)}{M(MN-1)}$$

Therefore, the blocking probability P_B is given by

$$P_B = \frac{\rho}{M \times MN} \frac{(M-1)(N-1)}{M(MN-1)} \quad \text{Eq.1}$$

If M >> 1 and N >> 1, then eq.1 can be written as

PB = ...Eq.2

$M^3 N$

Theoretically, the Time-space (TS) switch can be made non-blocking by using an expanding time switch and a concentrating space switch.

In the first case, all subscribers in one line may want to set up connection to the same output time slot. All the subscribers can be accommodated without blocking. We need (M -1) additional slots for each time slot.

The space switch must be able to set up M connections for each input time slot. Therefore, we require M^2 time slots on the outputs side of TSI. An expansion type time switch which provides expansion from M inlet time slots to M^2 outlet time slots, is very expansive.

Moreover, the space switch (at the second stage) has to concentrate the time slots on the output side. Design of such a space switch is very complicated.

A Space-Time (ST) switch configuration is shown in Fig. 20.2. Now, we consider a connection between I_{47} and O_{69}. During the time slot 7, the input sample is switched from inlet 4 to outlet 6 by space switch. It is then switched to time slot 9 by time switch. This switch is blocking same TS switch. This happens when the input samples originate from two different inlets design the same time slot and are destined to the same outlet though too different time slots. For example, we consider 175 and 185 to be switched to O_{96} and O_{92} respectively. Only one of the inputs can be space switched during time slot 5 to the output line 9 and the other is blocked.

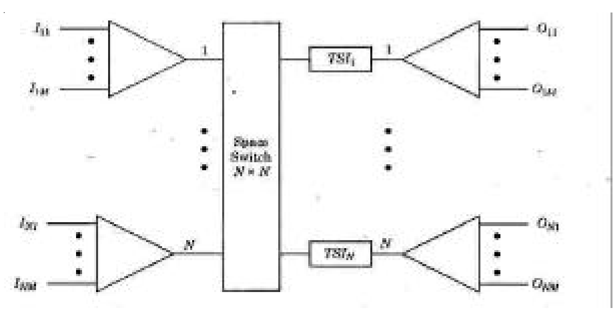


Fig.20.2 A Space- Time (ST) switch

The calculation of PB is done in a manner similar to the TS switch the performance of ST and TS switches are identical. Since two switches are in series in these configurations, the time constraint is the sum of the two constraints for time switch and space switch.

Time constraint for TS or ST switch

= Time constraint for space switch + Time constraint for time switch

or $125 = 2NMt_m + N M t_m$

or $125 = 3NMt_m$ ……..Eq.3

In this eq.3, we assume that $t_s = t_m$

Three-stage Combination Switching

Three-stage time and space combination switches are more flexible than two-stage time and space combination switches. The most common three-stage configurations are:

1. Time-Space-Time (TST) configuration
2. Space-Time-Space (STS) Configuration

Now we discuss above configurations one-by-one.

Time-Space-Time (TST) Configuration

Fig.20.3 illustrates a TST network configuration. The two-time stage exchange information between external channels and the internal space array channels. The first flexibility offered by this arrangement is that there is no need to have a fixed space stage time slot for a given input or output time slot. For example, IS_{47} may be moved to OS_{96} via an intermediate time slot 5.

An incoming channel time slot may be connected to an outgoing channel time slot using any possible space array time slot. A two- stage TS or ST network has only one fixed path but a three-stage TST network has many alternative paths between a prescribed input and output. This factor reduces the value of the blocking probability P_B of a three-stage combination switches.

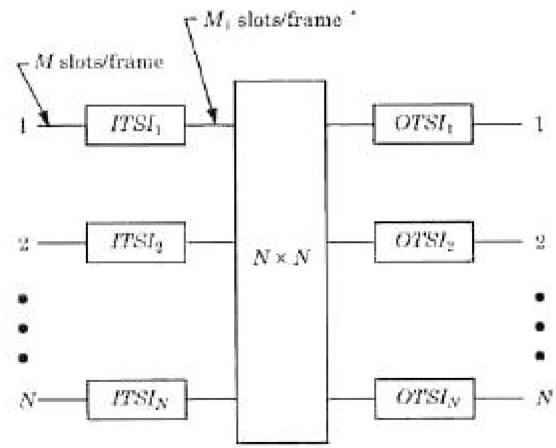


Fig.20.3 A Time-Space-Time (TST) switch

Three-stage combination switches are still blocking. Now we a situation when (M -1) slots in an inlet I_j are all busy. Let arrive in the M slot destined to a time slot outlet Ok It possible that during the time slot M, the outlet Ok is busy some other, output. As a result, blocking occurs.

When (M -1) time slot of Ok are busy and the outlet is for this purpose during (M -1) slots when the inlet *Ii* is free. The worst case When this worst case occurs, we would need one more additional time slot to establish a connection between the free time slots of I_j and O_k. Now, we need a total of (M- 1) + (M- 1) slots, i.e., 2M -1 time slots in the intermediate space stage. We have also assumed similar consideration in case of three stage division networks.

Functionally, a TST switch is identical to a three-stage division network. An equivalent Lee's probability graph of TST in shown in Fig.21.4. The general expression for the blocking of a TST switch is given by

$PB = [1 - (1 - I_T/L)]^{M1}$ ……..Eq.4

where,

M_1 = No. of time slots on the output side of the TSI switch

$L = M_1 / M$ = Expansion or Concentration factor

I_T = Traffic Intensity on an inlet

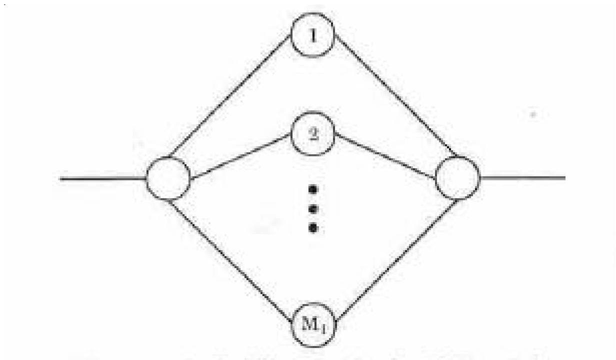


Fig. 20.4 Probability graph of a TST switch.

Space-Time-Space (STS) Configuration

A STS configuration consists of an N x K space matrix at the input, an array of K TSI switches in middle and a K x N space matrix at the output. It is shown in Fig.20.5. In this architecture, the choice of input and output time slot is fixed for a given connection.

Here the flexibility is provided by the ability to utilize any free TSI switch by space switching on the input and the output side. There are so many alternative paths for a given connection same as there are TSI switches.

For example, I_{79} may be connected to O_{84} by passing through $TSI_{3.}$

The sequence is as follows:

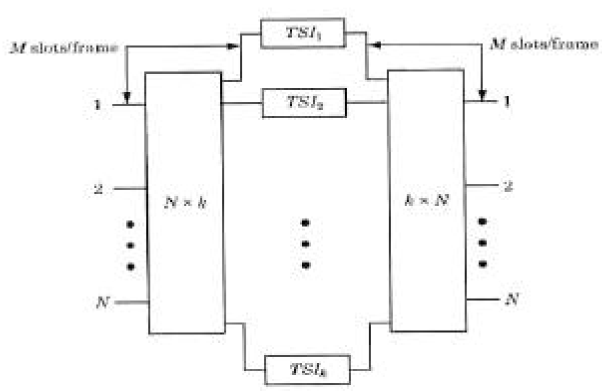


Fig.20.5 A space-time-space (STS) switch

where, IS' and OS' represent the input and output time slots of the TST switch. The expansion and concentration take place at the space switch level and not at the time slot level. The time slots are symmetrical throughout the switch. A STS switch is non-blocking if K = (2N –1). The blocking probability P_B is governed by an expression similar to the one given in eq.4

The comparison of cost of a STS switch and a TST switch gives the following important points.

The cost of a space switch is given by C = 2N + MN. This switch uses 2(N * 1) space matrices.

Modifying this cost for a space switch that uses a N * K space matrix, we have the cost as,

$$C_S = NK + MN \quad \text{……….Eq.5}$$

Therefore, the cost of the STS switch is,

$$C_{STS} = 2\,(NK * MN) + 2MN$$
$$= 2NK + 4MN \quad \text{…………..Eq.6}$$

From eq. C = 2M units for TSI switch and Eq.6 we have the cost of a TST switch as,

$$C_{TST} = 2N\,(2M) + (N_2 + MN)$$
$$= 5MN + N_2 \quad \text{……………..Eq.7}$$

It is important to note that a TST switch uses N TSI switches. Now we compare the following eqns.:

$$C_{STS} = 2NK + 4MN$$

and $C_{TST} = 5MN + N_2$

for different values of M and K, keeping N fixed.

1. For concentration switches, we have $M_1 < M$ for TST switch and

K < N for STS switch.

For M = K = N / 2, we have

$C_{STS} = 3\,N^2$

$C_{TST} = 3.5\,N^2$

2. For symmetric switches, M = N = K, then

$C_{STS} = 6\,N^2$

$C_{TST} = 6\,N^2$

3. For expanding the switches, $M_1 > M$ and K > N,

Say $M_1 = K = 2N$

$C_{STS} = 12\,N^2$

$C_{TST} = 11\,N^2$

The above calculations bring out that for small switches STS architecture. It is to be favoured and for large switches. A TST configuration is better.

Switches are designed to be concentrating when the utilization of the input links is low. As the input traffic intensity increases, less and less concentration is acceptable.

When the input loading becomes sufficiently high, space expansion in the STS switch and time expansion in the TST switch are required to maintain low blocking probabilities. Calculations shown above indicate that time expansion is cheaper than space expansion. Hence, TST architecture is more cost effective than STS architecture for higher loads. There are, of course, other factors like modularity, testability and maintainability, which must also be taken into account before deciding on a particular architecture.

Multistage Combination Switching

Very large time division switches, supporting 40,000 lines or more, can be economically designed by using more than three stages of time and space combination switching. We call this n-stage switching where n is greater than three. N-stage combination networks may also be designed to provide better flexibility and less blockage. Basically, two approaches are seen in designing n-stage switches:

- Expanding a TST switch with additional space stages

- Modular design using a number of time-space (TS) modules

Typical configurations include TSST, TSSSST and TSTSTSTS. Examples of practical combination switches with their salient features are presented in table. 20.1

Table 21.1 Examples of practical multistage combination switches.

System	Configuration	Traffic capacity (erlangs)	Maximum number of trunks
E 10 B (France)	TST	1600	3600
No.4 ESS (USA)	TSSSST	47,000	107,520
C-DOT MAX-XL (India)	TST	16,000	40,000
DMS 100 (Folded) (Canada)	TSTS	39,000	61,000
System 12 (USA)	TSTSTSTSTSTS	25,000	60,000
NEAX 61 (Japan)	TSST	22,000	60,000

When the space stage of a TST switch is large enough to justify additional control complexity, multiple space stages can be used to reduce the total cross-point count. As an example of this approach, we consider the no.4 ESS switch, which has TSSSST architecture. The no. 4 was developed by Bell laboratories and was the first digital switch in the U.S. telephone network when it became operational in 1976. Even today, it is one of the largest capacity switches developed in the world.

It is capable of supporting a maximum of 107,520 voice channels with a blocking probability of less than 0.005 at a traffic intensity of 0.7 E per channel. The no.4 ESS is designed to be a transit or tandem exchange providing significant cost savings by being capable of replacing several of the largest space division switches available previously, in particular no.4A crossbar system.

A block diagram of the different time and space in no.4 ESS is shown in the fig.20.6. The interface between the no.4 ESS and the transmission system is based on analog 12 or 24 group trunks, which carry 120 time slots each (12 * 10 = 120 or 24* 5 = 120).

Internally, the no.4 ESS has design parameter values that are powers of two to take advantage of the efficiencies allowed by binary digital systems. The time stage uses 128-time slot. TSI switches.

The time stages at the input and output consist of 128 time modules each. A time module comprises 8 of 128 time slots each. Thus we get TSI switches giving a total capacity of 128 * 8 * 128 =131,072 voice channels. However, the capacity is limited by the incoming trunks, each of which carries only 120 channels. There are seven trunks input to each time module giving a maximum capacity of 7 * 120 * 1218 = 107,520 terminations. In order to ensure low blocking, a decorrelator is used, which performs an expansion function by spreading the traffic from 120-time slot streams to eight 128-time slot streams. The distribution or expansion function is performed by using a fixed writing pattern. There is a corresponding recorrelator at the end of the network to concentrate traffic from eight lines to seven lines.

The first and the fourth space stages consist of 128, 8 * 8 space switches each. The eight TSI switch outputs are connected to the eight inputs of the 8 * 8 space switch in the second stage of the network. The third and the fourth stages of the network, i.e. second and third space stages, contain four, 256 * 256 space matrices each. These 256 * 256 space matrices are built using 16, 16 * 16 space arrays. With 128 time slots in one 125ms frame, each time slot has duration of 976ns. During every time slot the four-stage space switch is clocked 16 times giving 16 different possible paths to each of the time slot sample. The clock duration works out to be 61 ns requiring a basic clock frequency of 16.384 MHz. With 128 possible time slots and 16 space matrix paths for each sample, there are 2048 alternative paths available for each connection in the network ensuring a low blocking probability even at high loads.

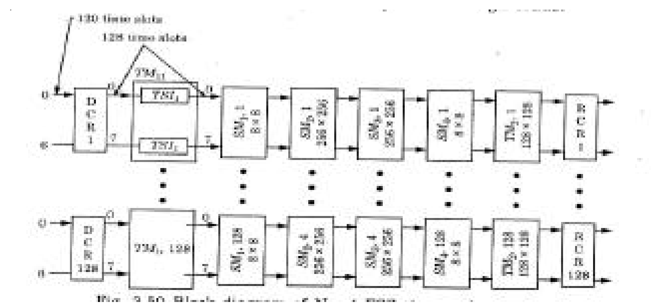


Fig.20.7 Block diagram of No.4 ESS time and space stage.

In order to achieve high system availability, reliability and maintainability, hot standby is provided for the entire switching network. To detect faults and aid diagnostics, we Use comparator is provided in a number of appropriate points between the dupliq1ted units. If any path fails, the system control can switch to the hot standby unit which maintains the identical path configuration details. Faulty unit can be repaired while the services are maintained by the functional unit. All memory modules are provided with parity checking feature for both address and data used with 8 bit PCM samples, one for enabling space matrices to be switched between time slots and the other as party bit.