# Telecommunication Networks
# 15B11EC611

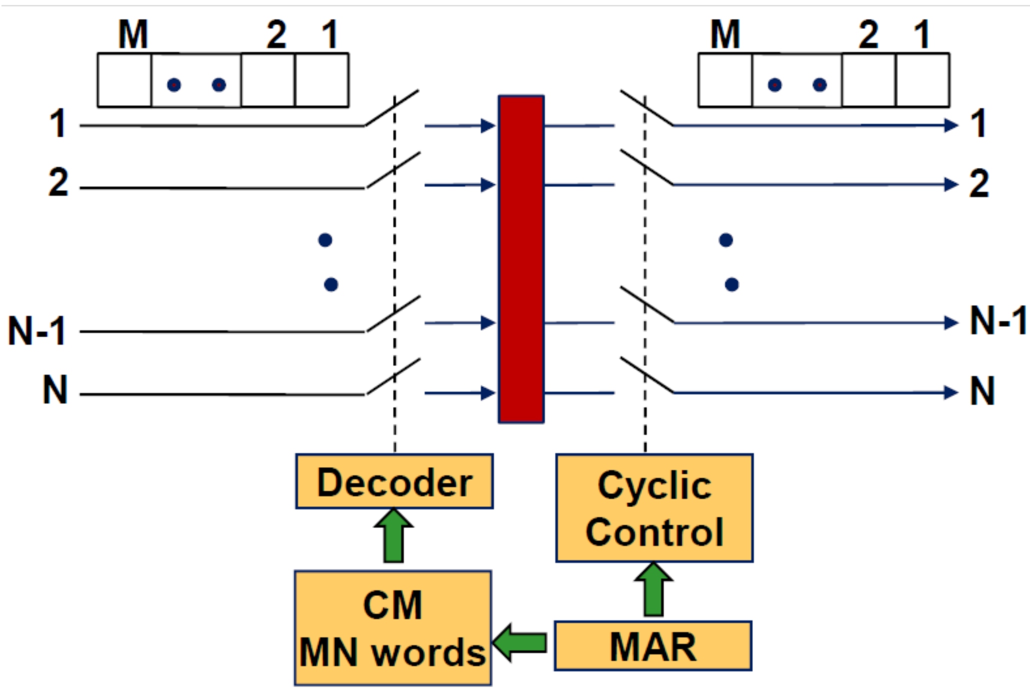
# Time Division Switching

**Till now, we discussed time division switches where an inlet or outlet corresponded to a single subscriber line with one speech sample appearing every 125 μs on the line. Such switches are used in local exchanges.**

- **Time multiplexed switches ➔**
  - **Switches required in transit exchanges.**
  - **Inlets and outlets are trunks which carry time division multiplexed data**

- **Time multiplexed switches:**
  1. **Time multiplexed space switching**
  2. **Time multiplexed time switching**

# Time Multiplexed Space Switching




- Time multiplexed space switch has
  – N time-multiplexed trunks as inlets and outlets.

  – There are M time slots in a frame carrying PCM voice samples.

- Being a space switch, there is no time shift of voice samples.

# Time Multiplexed Space Switching

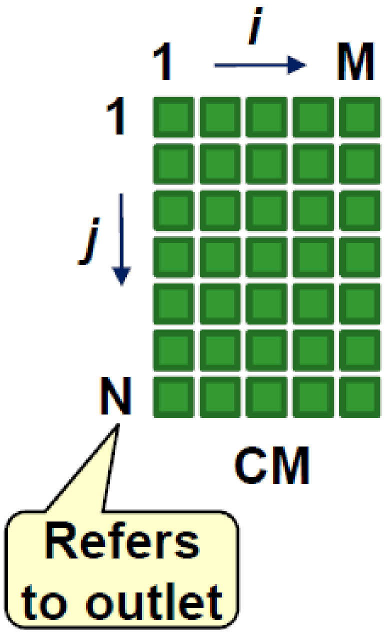
- CM has MN locations, one for each time slot.

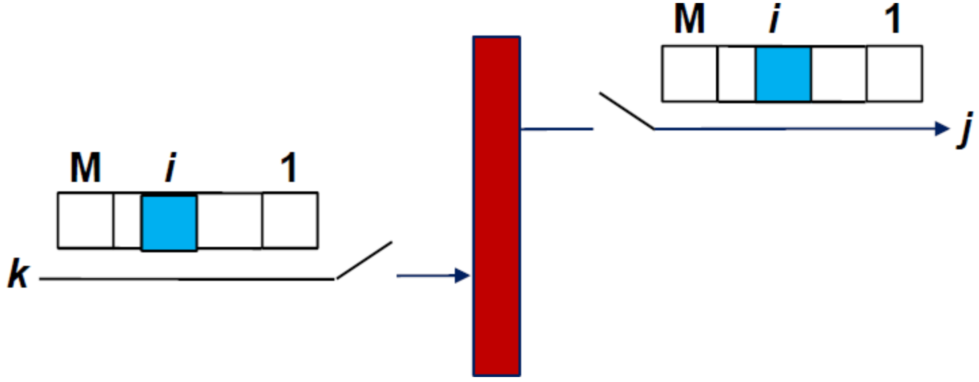
– A memory location is specified as (*i, j*).

– Location (*i, j*) corresponds to time slot *i of outlet j.*

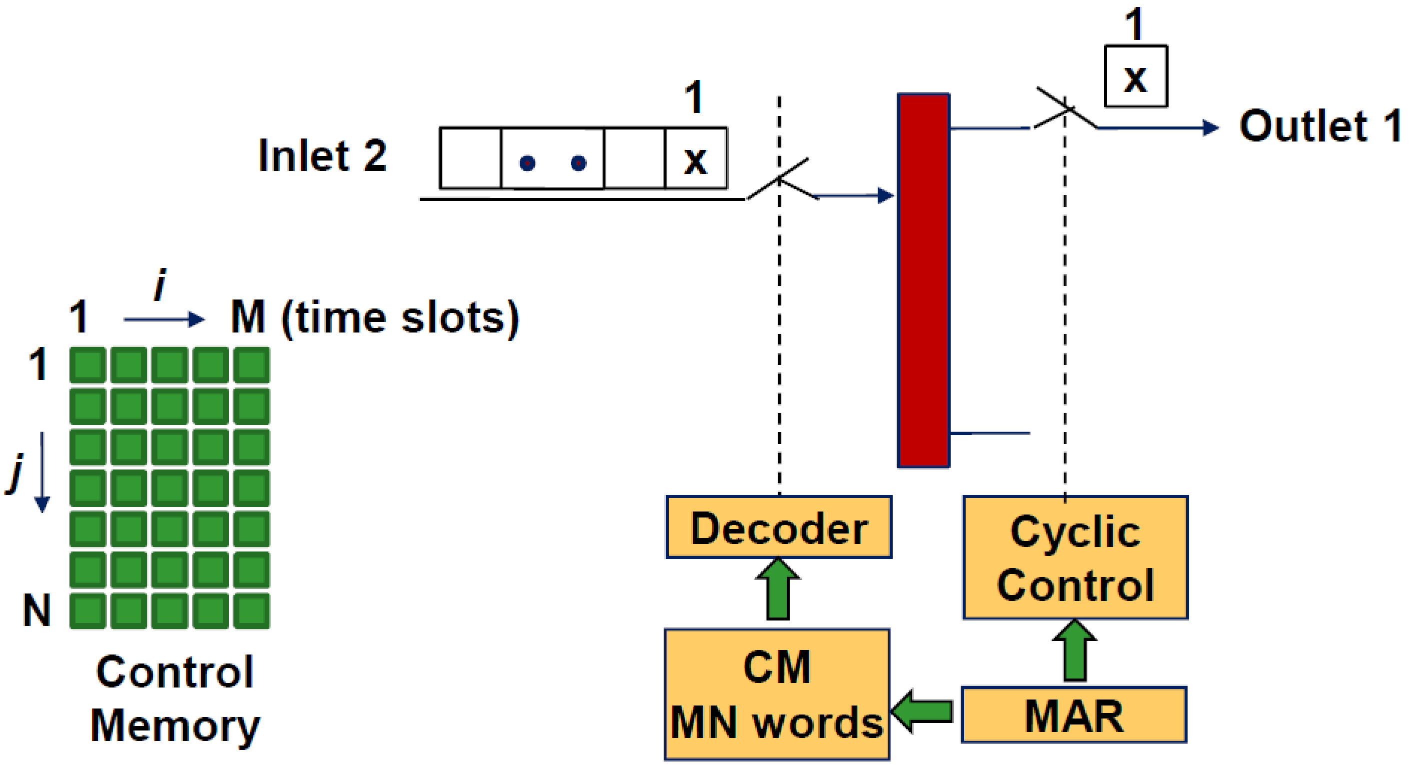
– Location (*i, j*) contains address *k* which corresponds to inlet *k*.

✓ It implies that voice sample in *i th* time slot of inlet *k will be switched to i th time slot of outlet j.*



# Time Multiplexed Space Switching




- ➢ **CM is read column-wise and from top to bottom.**
- ➢ **If (1, 1) location in CM contains 2,**

  **→ 2nd inlet is connected to outlet 1 and 8-bit data (x) of time slot 1 of inlet 2 is switched to outlet 1 at the output.**

# Time Multiplexed Space Switching

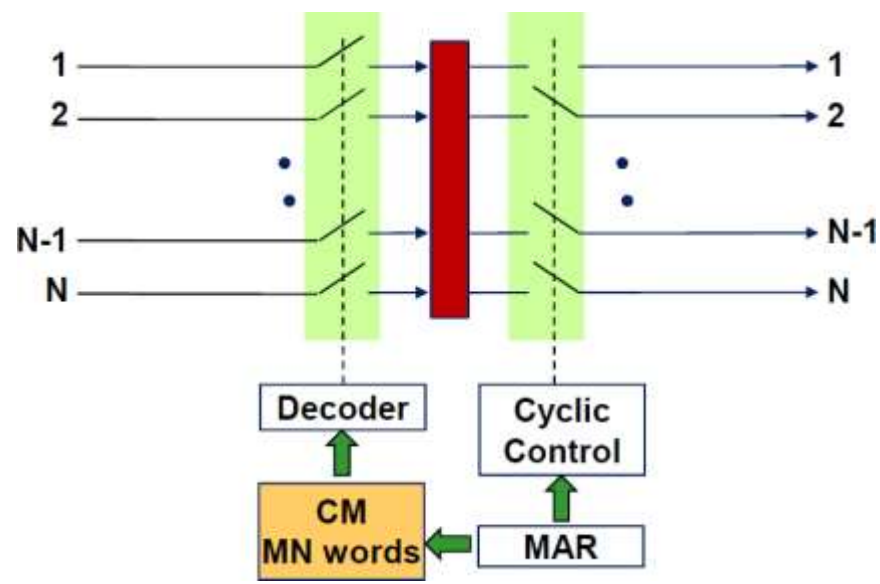
If $t_s$ is the switching time,

The number of trunks (N) that can be supported by the switch is

$N = 125/(M\ t_s)$ , M = time slots

The Switch cost C can be estimated as

- C = Number of switches + Number of memory words
- C = 2N + MN



# Time Multiplexed Space Switching

**Example**

**Calculate the number of trunks that can be supported on a time multiplexed space switch, given that**

**a) 32 channels are multiplexed in each stream,**

**b) Control memory access time is 100 ns,**

**c) Bus switching and data transfer time is 100 ns per transfer.**

**Solution:**

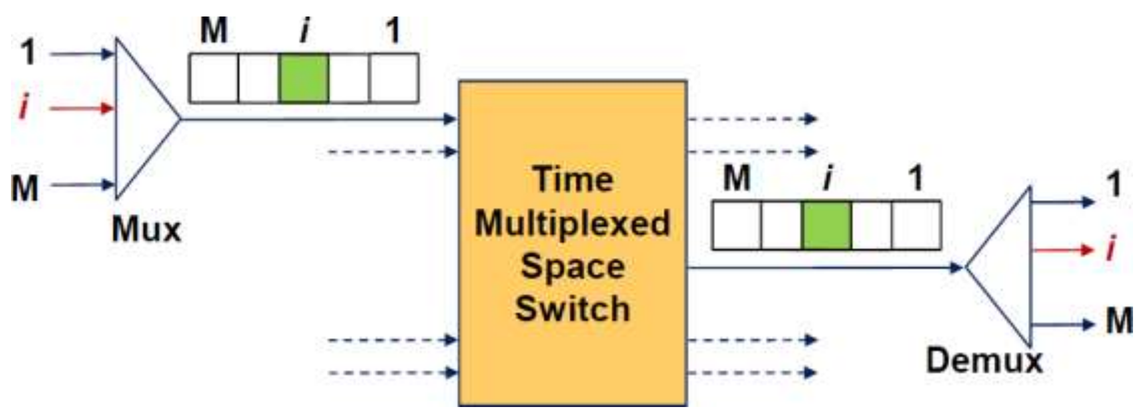
**The total switching time $t_s$ = 100 ns + 100 ns = 200 ns**

**$N = 125/(32 \times 200 \times 10^{-3}) = 19.53 \approx 20$**

# Time Multiplexed Space Switching

- Time multiplexed space switch **does not provide full availability** as it does not permit time-slot interchange (TSI).

- ***i th*** time slot of input trunk can only be switched as ***i th*** time slot of any output trunk.



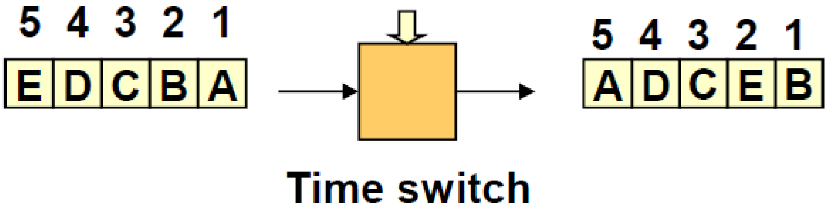

- Thus for any voice channel, there are only N possible time slots out of total MN time slots at the outlets.

- Rest MN-N = N(M-1) outlets cannot be reached.

# Time Multiplexed Time Switching

- **Time multiplex time switch is based on time slot interchange (TSI).**

**– Speech sample of a time slot is switched to different time slot .**

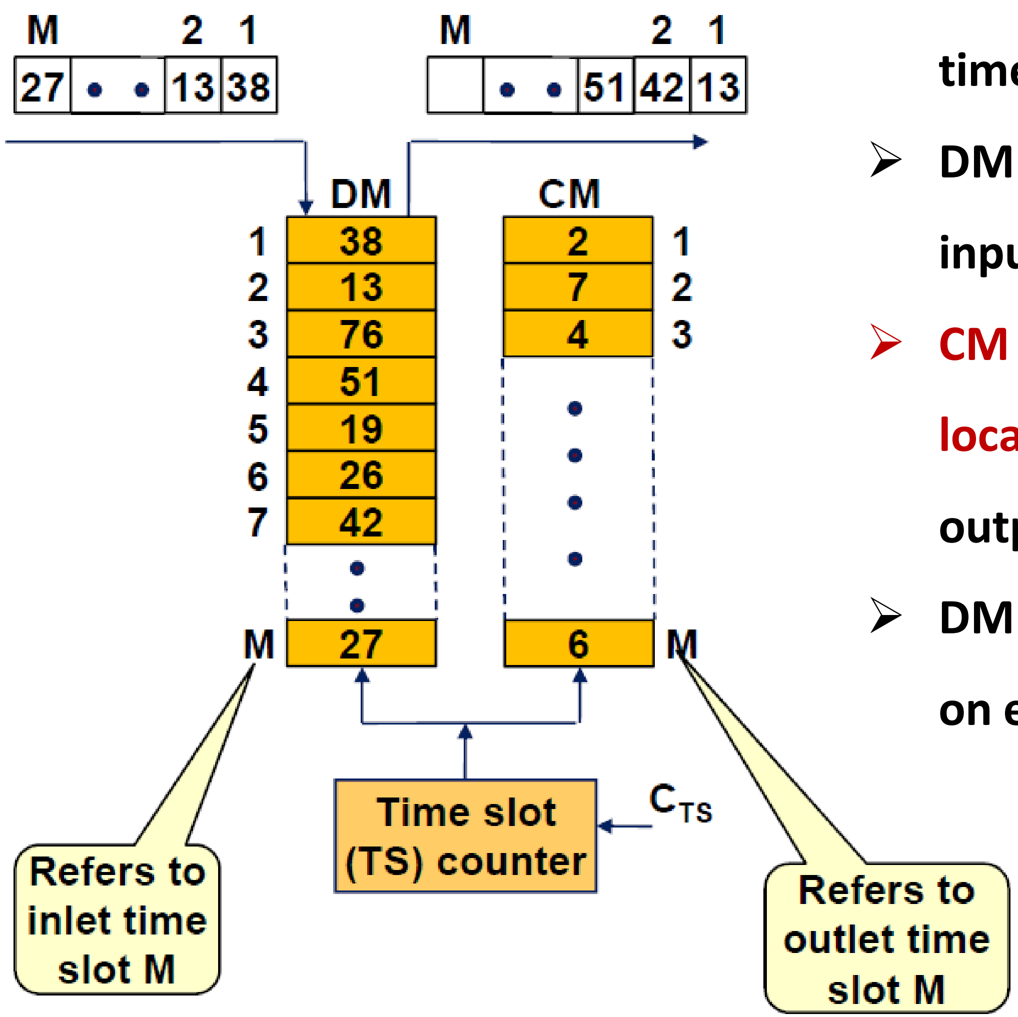



- **Time switching necessarily involves delay.**

**– A time multiplexed frame must first be stored.**

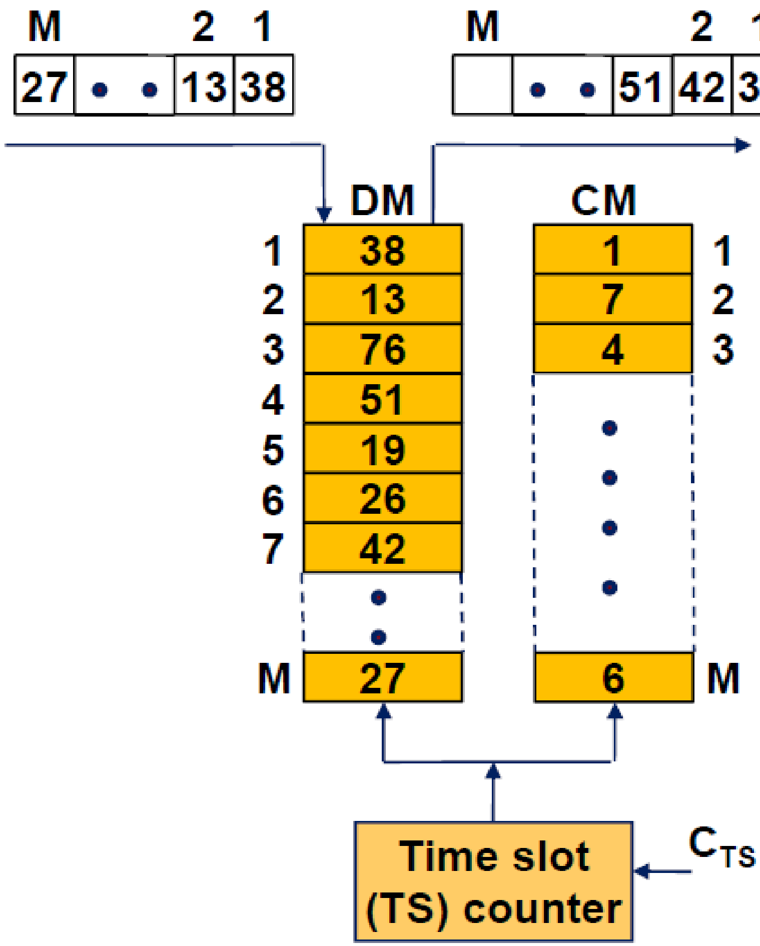
**– Contents of its time slots can then be switched and transmitted.**

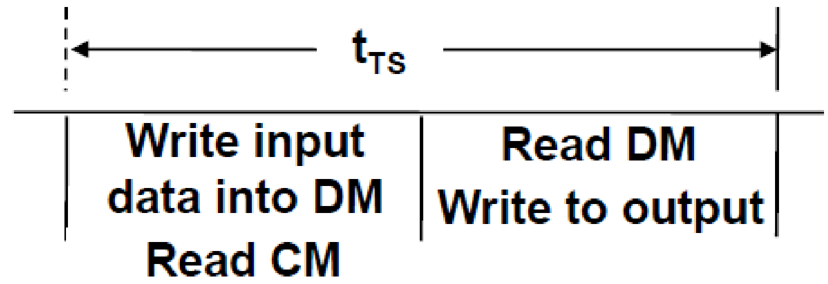
# Time Multiplexed Time Switching




- Time slot counter runs at $1/ t_{TS}$ rate, where time slot $t_{TS} = 125/M$
- DM contains voice data of time slots of the input in locations 1 to M.
- CM contains addresses of the DM locations. CM addresses 1 to M pertain to output time slots.
- DM and CM are simultaneously accessed on each Time Slot counter pulse.

# Time Multiplexed Time Switching




## Example

- At time slot instance 2

1. Content (13) of time slot 2 of input is written into DM at location 2.
2. Location 2 of CM is read simultaneously. It gives the DM address 7.
3. DM location 7 is read and its content (42) is sent as output in TS 2 .

There two sequential memory accesses per time slot.

$t_{TS} = 2t_m$ $\qquad$ $125 = 2Mt_m$

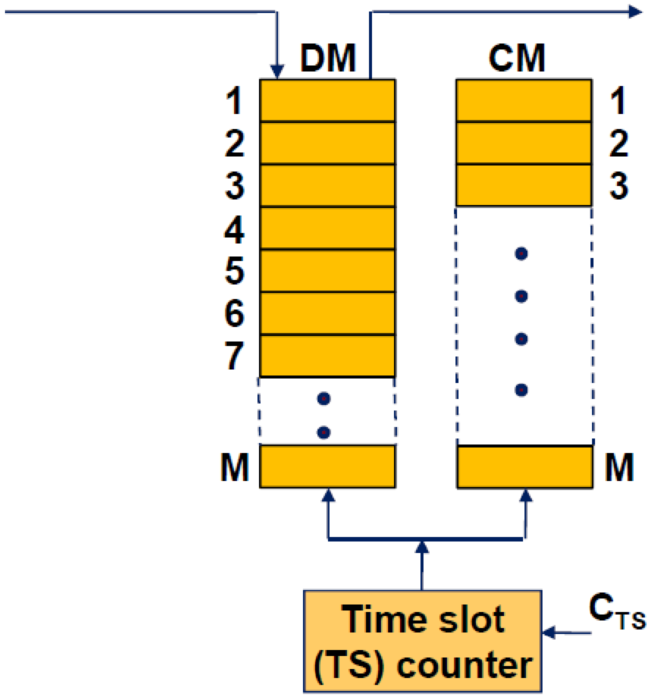
where $t_m$ is memory access time in µs.

# Time Multiplexed Time Switching

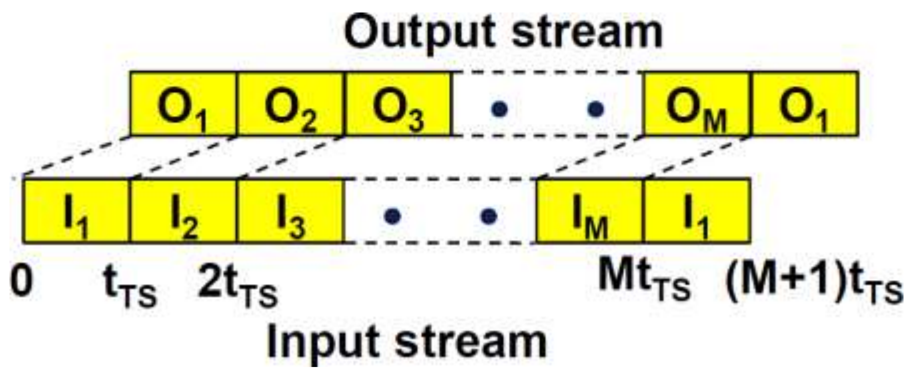
- Since there are no switching elements, switch cost C is based on memory locations.

C = Data memory locations + Control memory locations

C = M + M = 2M



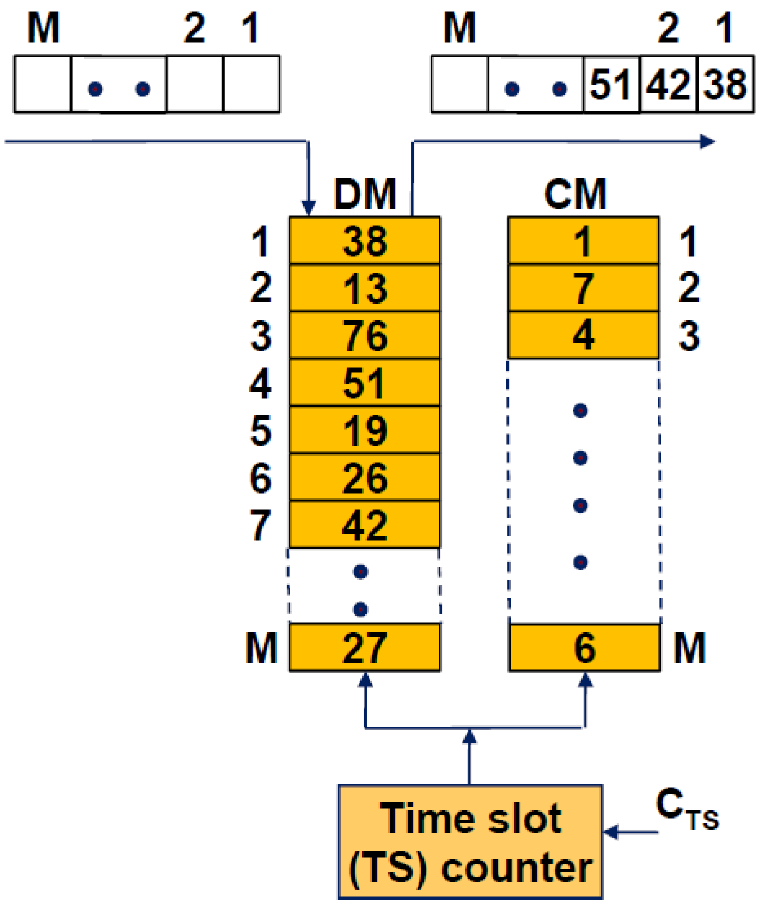
# Time Multiplexed Time Switching




- Time switch has inherent delay of one time slot.
  - All the 8 bits of a time slot become available at the end of the time slot.
  - Then these 8 bits are written into DM.

- The voice channels may have delay ranging from 1 to M time slots.
  - Delay depends on output time slot to which an input time slot content is switched.

# Time Multiplexed Time Switching




**Example**

- 2nd location of CM contains 7.
- 7th location of DM has data 42 that was written during previous frame during 7th time slot.
- Delay $= [M-7+2+1]t_{TS}$
  $= (M-4)$ Time slots
  - 2 is added as 42 is being read in 2nd timeslot of current frame.
  - 1 is added as there is delay of one TS between input and output streams.

**In general, Delay = M – Inlet + Outlet + 1**

**Example:** For a TSI switch with 1 trunk and 24 slots, working in sequential write/random read mode. Find out the delay in getting sample at outlet for following connections:

2 --------------- 7 , 3 ----------------- 4 , 1 ---------------- 1

**Solution:**

Trunk , N = 1

Channel / Slots , M = 32

Time slot duration, $t_{TS}$ = 125 μs/M =

→ Inherent delay = 1 $t_{TS}$

→ For 2 – 7, Delay = [M – 2 + 7 + 1] $t_{TS}$

→ For 3 – 4, Delay = [M – 3 + 4 + 1] $t_{TS}$

→ For 1 – 1, Delay = 1 $t_{TS}$

# Combination Switching

- Time multiplexed time division space switch does not provide full availability as it cannot do time slot interchange.
- Time multiplexed time division Time switch cannot switch time slot data across different trunks.

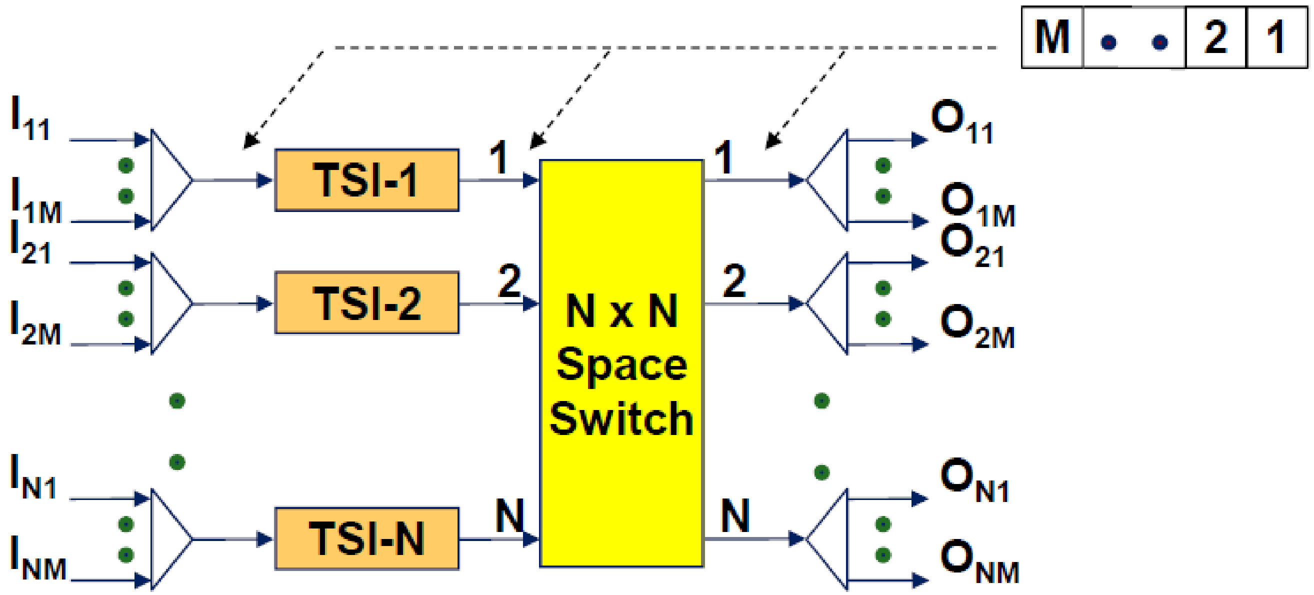
- A combination of time and space switches can achieve both time switching (i.e. time slot interchange) & space switching (i.e. Sample switching across trunks).

- A combination switch can be build using several stages of time and space switching.

  2 stage switch: TS (Time-Space)
  ST (Space-Time)

  3 stage switch: TST (Time-Space-Time)
  STS (Space-Time-Space)

# Time-Space Switch




❖ 1st Stage consists → 1 time slot interchanger per inlet

❖ 2nd Stage consists → a N x N space switch

❑ Each time-multiplexed inlet/outlet carries M channels.

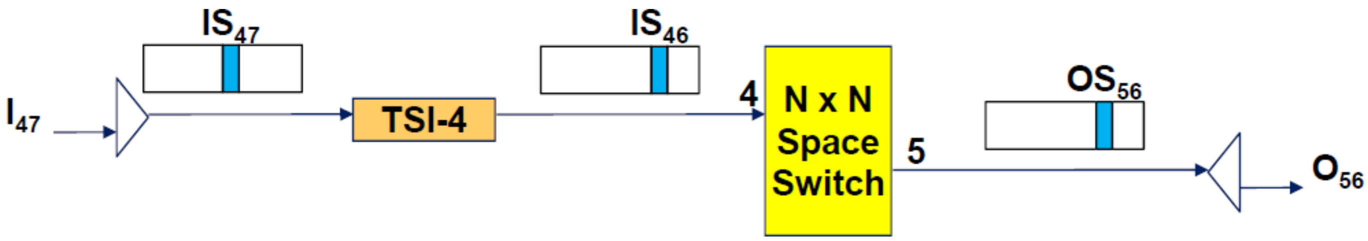
Notation for subscribers for input and output side

- $I_{47}$ ➔ A input subscriber assigned to line 4 (TSI-4) at time slot 7.
- $O_{56}$ ➔ A subscriber connected to the outlet 5 and time slot 6.

❖ The respective time slots are identified as $IS_{47}$ and $OS_{56}$.

# Time-Space Switch

**Suppose $I_{47}$ is to be connected to $O_{56}$.**



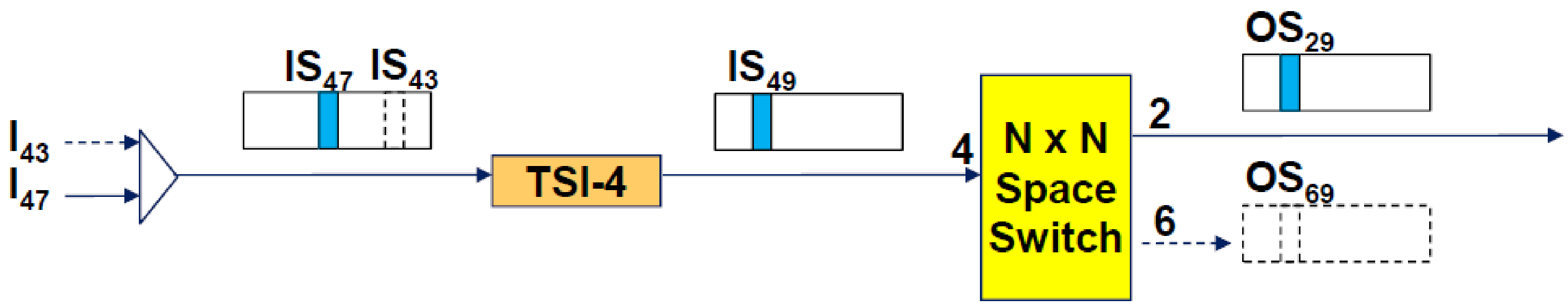

1. **Data of time slot $IS_{47}$ is moved to $IS_{46}$ by TSI-4.**
2. **Data of time slot $IS_{46}$ of inlet 4 is moved to $OS_{56}$ of outlet 5 by the space switch.**
   - ✓ **Note that time slot location remains same '6' in space switch.**

❖ **Connection between $I_{47}$ and $O_{56}$ established.**

**Note that any inlet $I_{xy}$ can be connected any outlet $O_{mn}$. Thus, 2-stage TS switch provides Full Availability.**

# Time-Space Switch

- Consider that connection $IS_{47} \rightarrow OS_{29}$ is already established.
  – Note that time slot location is ‘9’ in outlet 2.



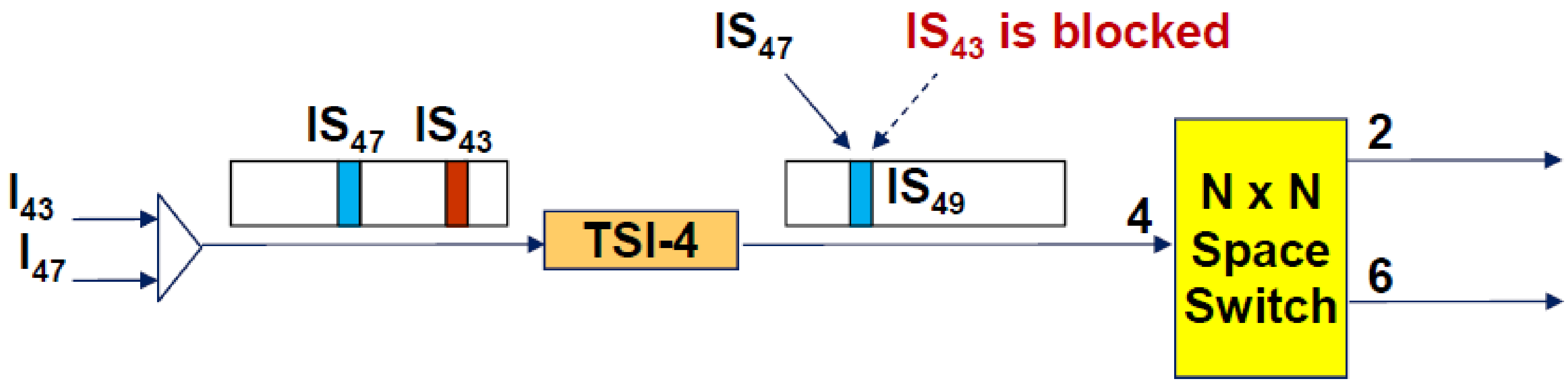

- There is request for another connection $IS_{43} \rightarrow OS_{69}$.

Note that time slot location required is ‘9’ in outlet 6, a different outlet.

# Time-Space Switch

✓ For the new connection, TSI-4 needs to switch data of time slot $IS_{43}$ to time slot $IS_{49}$.

➢ As $IS_{49}$ is already engaged for $IS_{47}$, the new connection request $IS_{43} \rightarrow OS_{69}$ will be blocked by the switch.



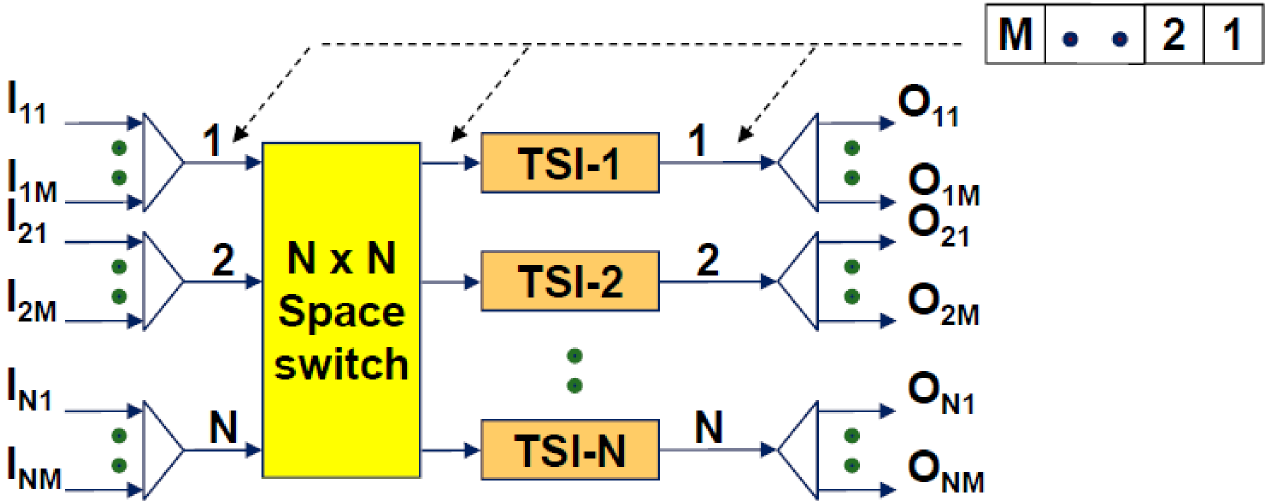

➢ This situation always occurs when two or more inlets of a time frame are to be connected to the same timeslot in different outlets.

➢ 2-stage TS switch provides Full availability but it is Blocking switch.

# Space-Time Switch

# Space-Time Switch

- Space switch has N-inlets/outlets each carrying time-multiplexed M channels.
- Each outlet of the space switch has TSI switch that interchanges the time-slot data.
- Notation for inputs, outputs & time-slots is same as before.

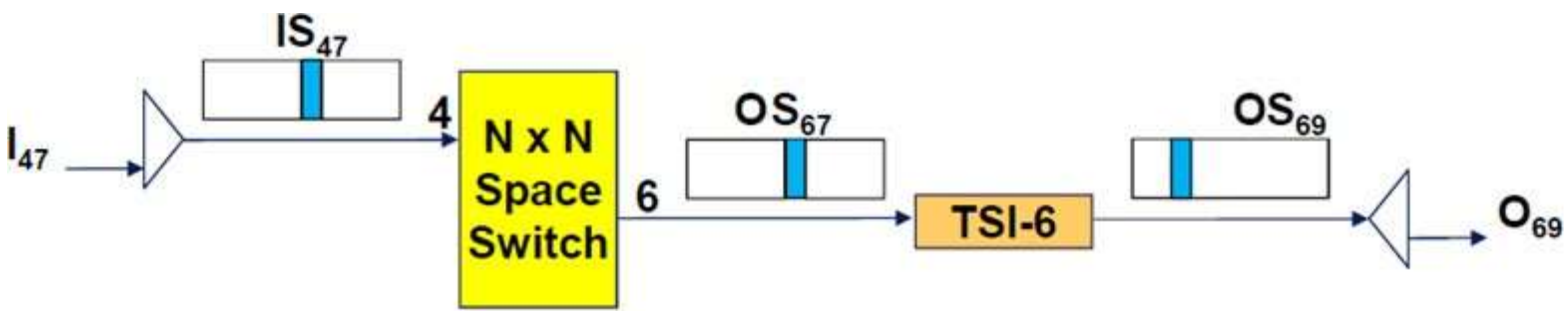


# Space-Time Switch

❖ **Suppose $I_{47}$ is to be connected to $O_{69}$.**

1. **Data of time slot $IS_{47}$ is switched from inlet 4 to outlet 6.**
2. **It is then switched to time slot 9 by TSI-6 and the connection is established.**

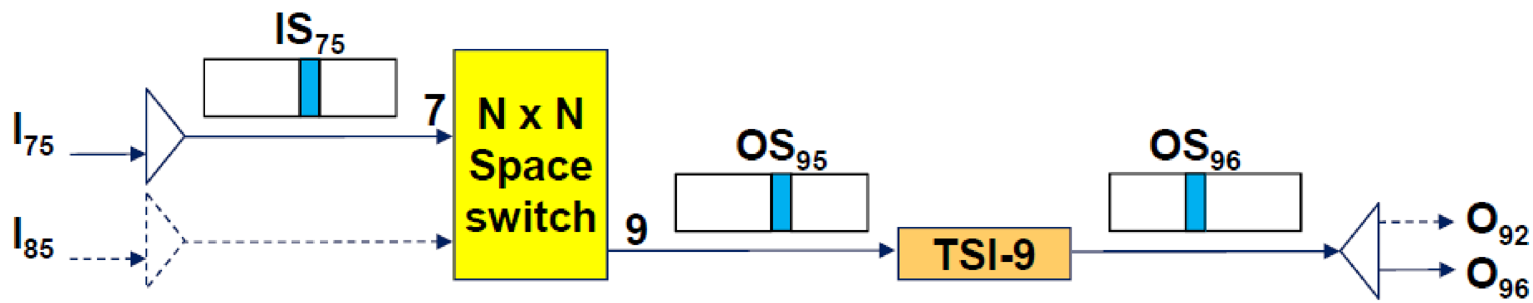
✓ **As in case of TS switch, this switch has Full Availability.**



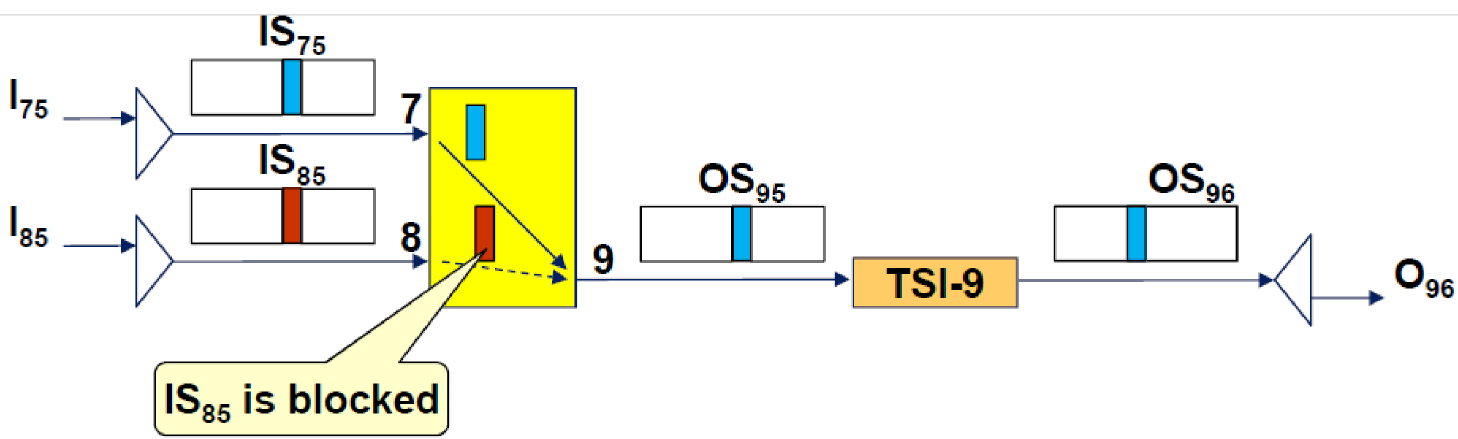
# Space-Time Switch

- Consider that connection $IS_{75} \rightarrow OS_{96}$ is already established.
  - $IS_{75}$ is space switched as $OS_{95}$.
  - $OS_{95}$ is time switched as $OS_{96}$.

- There is request for another connection $IS_{85} \rightarrow OS_{92}$.




- $IS_{85}$ is to be space switched as $OS_{95}$.
- But $OS_{95}$ is already engaged by the connection $IS_{75} \rightarrow OS_{96}$.
- The new connection request $IS_{85} \rightarrow OS_{92}$ is blocked.

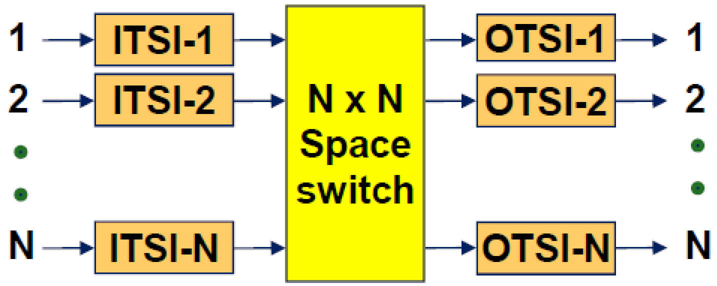



✓ ST switch has Full Availability but it is a Blocking switch.

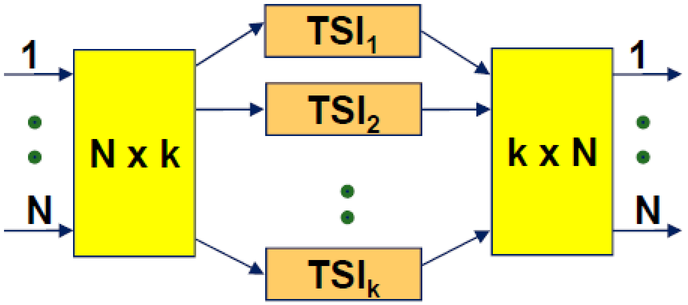
# Three-Stage Combination Switching

# Three-Stage Combination Switching

❖ 3-stage time and space combination switches are more flexible than 2-stage




Time-Space-Time (TST) Switch

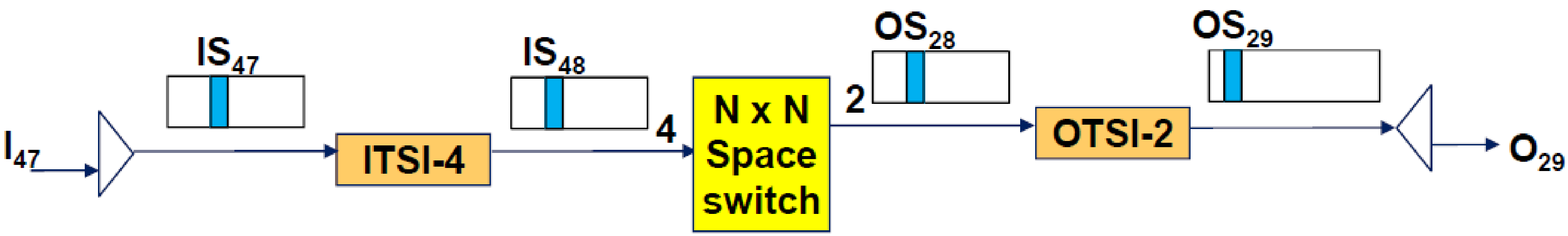



Space-Time-Space (STS) Switch

- 3-stage combination switch architecture has the two configurations:
  - – Time-Space-Time (TST) switch.
  - – Space-Time-Space (STS) switch.
- The middle switch introduces the flexibility of switching a incoming channel to
  - – a free intermediate time slot (in case of TST)
  - – A free intermediate outlet (in case of STS).
- Subsequently, the intermediate time slot/outlet is switched to the desired time slot/outlet.

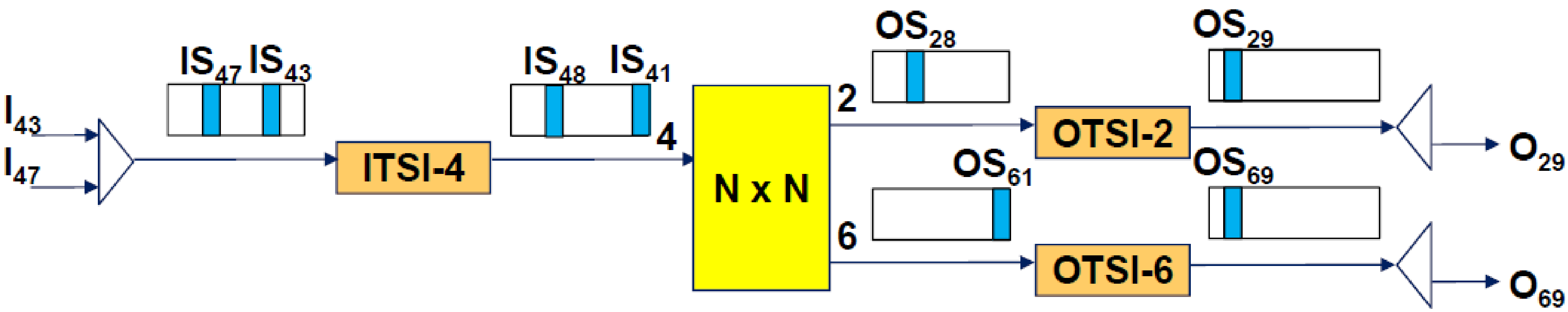
# Time-Space-Time (TST) switch

- ❖ Let us say there is request for connection $I_{47} \rightarrow O_{29}$
  - – ITSI-4 switches the data of $IS_{47}$ to a free intermediate time slot $IS_{48}$ that has path through the space switch to outlet 2.
  - – Space switch switches time slot ($IS_{48}$) data to outlet 2 ($OS_{28}$).
  - – OTSI-2 switches the data of $OS_{28}$ to the desired location $OS_{29}$.




- Let us say there is working connection $I_{47} \rightarrow O_{29}$. There is request for another connection $I_{43} \rightarrow O_{69}$.
- 2-stage TS switch will block this call because intermediate time slot $IS_{49}$ would be engaged by the first call.
  1. $IS_{47} \rightarrow IS_{49} \rightarrow OS_{29}$
  2. $IS_{43} \rightarrow IS_{49} \rightarrow OS_{69}$
- 3-stage TST does not block this call as there are alternative intermediate time slots .

# Time-Space-Time (TST) switch




- ❖ $IS_{47} \rightarrow IS_{48} \rightarrow OS_{28} \rightarrow OS_{29}$
- ❖ $IS_{43} \rightarrow IS_{41} \rightarrow OS_{61} \rightarrow OS_{69}$

✓ **So long as alternative free intermediate time slot that has path through the space switch is available, the next call will not be blocked.**

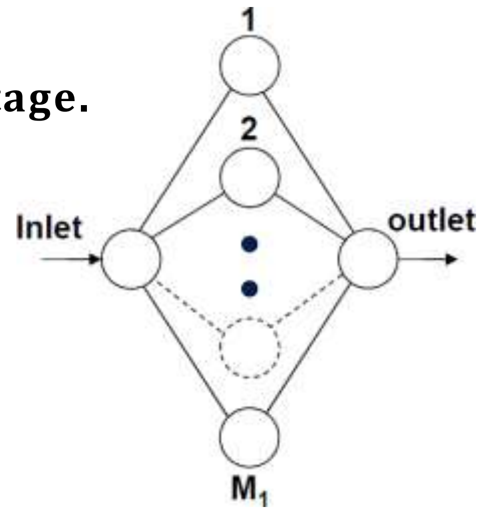
# Blocking in (TST) switch

**For some specific situation, TST switch can be blocking.**

- **Consider a situation:**
  - **(M-1) slots in an inlet $I_j$ are all busy.**
  - **Let traffic arrive in the *M-th* slot destined to a time slot outlet $O_k$.**
  - **It is possible that during the time slot M, the outlet $O_k$ is busy receiving some other output.**
  - **As a result, blocking occurs.**
- **If this happens, we need one more additional slot to establish a connection.**
- **This means that we need a total of $2M - 1$ time slots in the intermediate space stage.**

# Blocking in (TST) switch

- In a functional sense, a TST switch is identical to a 3-stage space division network.
- An equivalent Lee's graph of TST switch is shown.
  – M1 number of time slots of a frame in the middle stage.




- Recall that for blocking space switch blocking probability is
  $P_B = [1 - (1 - \alpha/k)^2]^s$
- For non-blocking space switch, s = 2p – 1
  – p is number of inlets in input module.

**IN SIMILAR FASION**

- The expression for the blocking probability of a TST switch is given by

$$P_B = (1 - (1 - \alpha/L)^2)^{M_1}$$

Where $M_1$ = number of time slots on the output side of the TSI switch
$L$ = expansion or concentration factor = $M_1 / M$
$\alpha$ = traffic intensity on an inlet

✓ Non blocking TST switch has frame size of $M_1$= 2M-1 for the middle stage.

**Example:** A TST switch supports 32 trunks of 32 channels each. A time expansion/concentration factor of 2 and a single stage space switch are used. What is the blocking probability of the switch if the channel loading is 0.9E per channel?

**Solution:**

- **the blocking probability of a TST switch is given by**

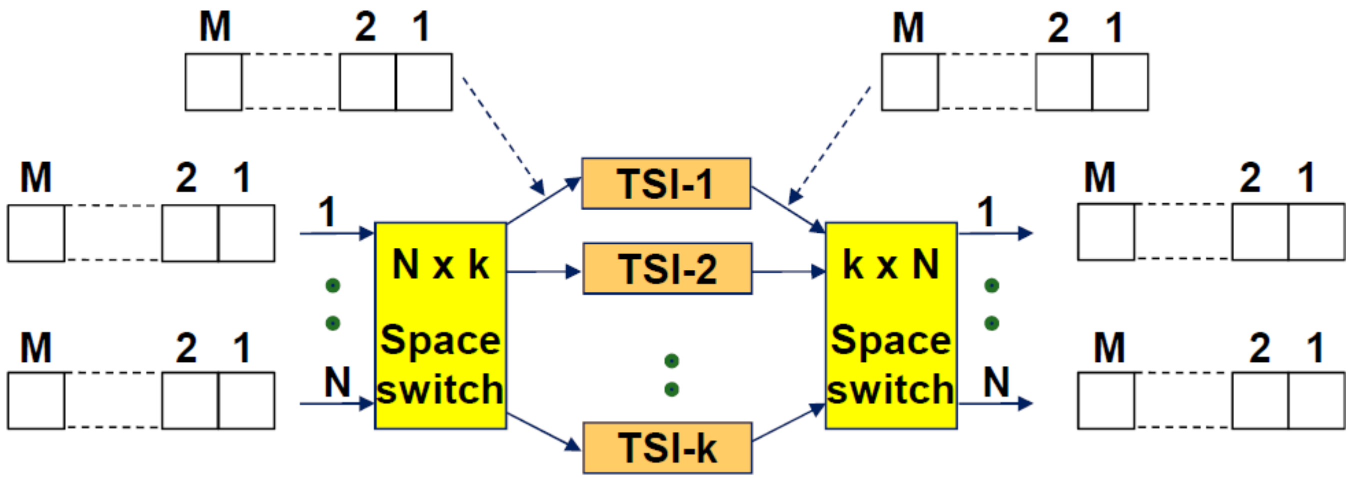
$$P_B = (1 - (1 - \alpha/L)^2)^{M_1}$$

**Where $M_1$ = number of time slots on the output side of the TSI switch**
**$L$ = expansion or concentration factor = $M_1 / M$**
**$\alpha$ = traffic intensity on an inlet**

**Given, $\alpha = 0.9$ E**
**M = 32**
**L = 2 = $M_1 / M$ ➔ M1 = 2*32 = 64**

$$P_B = (1 - (1 - \alpha/L)^2)^{M_1}$$
$$P_B = (1 - (1 - 0.9/2)^2)^{64}$$
$$P_B = 9.7 \times 10^{-11}$$

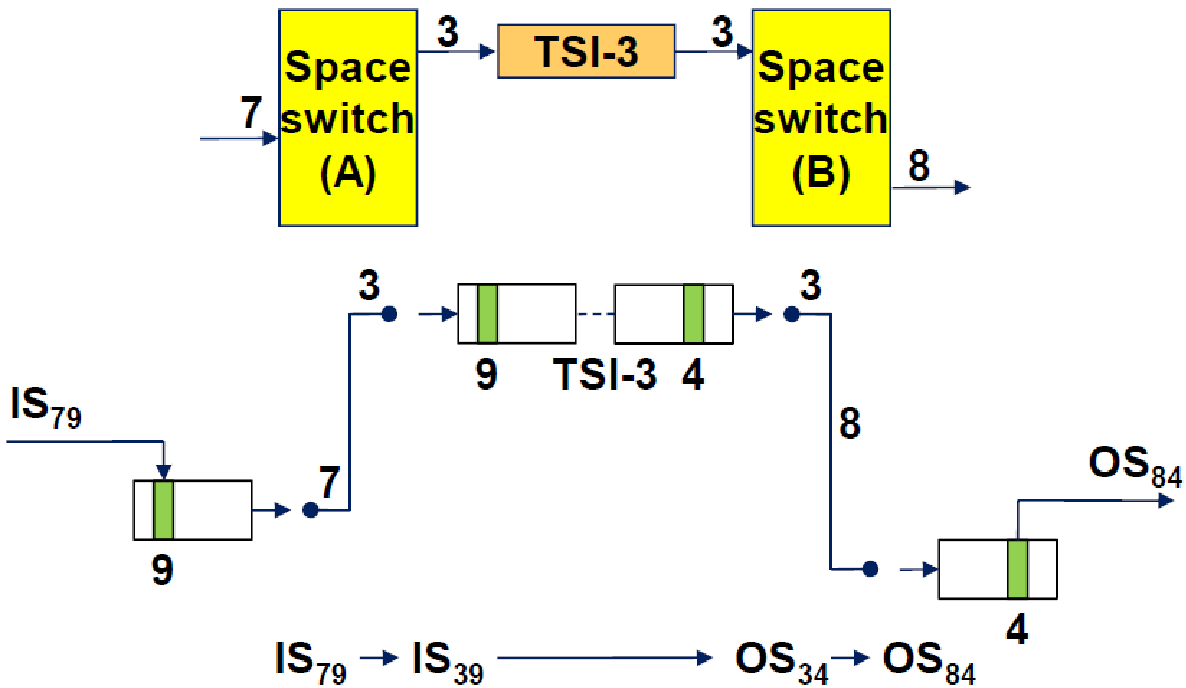
# Space-Time-Space (STS) switch




- A Space–Time–Space (STS) switch consists of-
  - An $N \times k$ space matrix at the input
  - $k$ TSI switches in middle
  - A $k \times N$ space matrix at the output

# Space-Time-Space (STS) switch

For example, consider a connection $I_{79} \rightarrow O_{84}$




- Space switch (A) switches data (x) of $IS_{79}$ from 7th inlet to 3rd outlet. Time slot location within frame remains same (9).
- Time switch TSI-3 switches data (x) from time slot 9 to time slot 4.
- Space switch (B) switches data (x) from its 3rd inlet to its 8th outlet. Time slot location within frame remains same (4).

# Blocking in STS Switch

- For some specific situation, STS switch can be blocking.
- Blocking can be overcome by having expansion / compression (concentration) space switches.

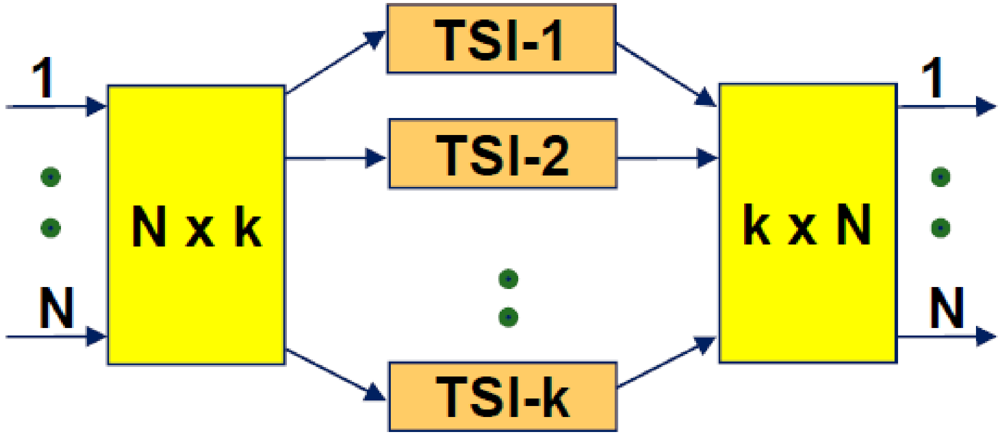
✓ **Blocking probability**

$$P_B = [1 - (1 - \alpha / L)^2]^k$$

where expansion factor $L$ = k/N

✓ **It can reasoned out that the STS switch is non-blocking when $k \geq (2N - 1)$.**

# Cost Analysis




## Cost of STS switch

- Cost of a $N \times k$ space-switch with MN memory locations

  $C_s = Nk + MN$

  Cost of 2 space-switches

  $2C_s = 2Nk + 2MN$

- Cost of k time-switches is determined by memory required for MN data elements and MN addresses.

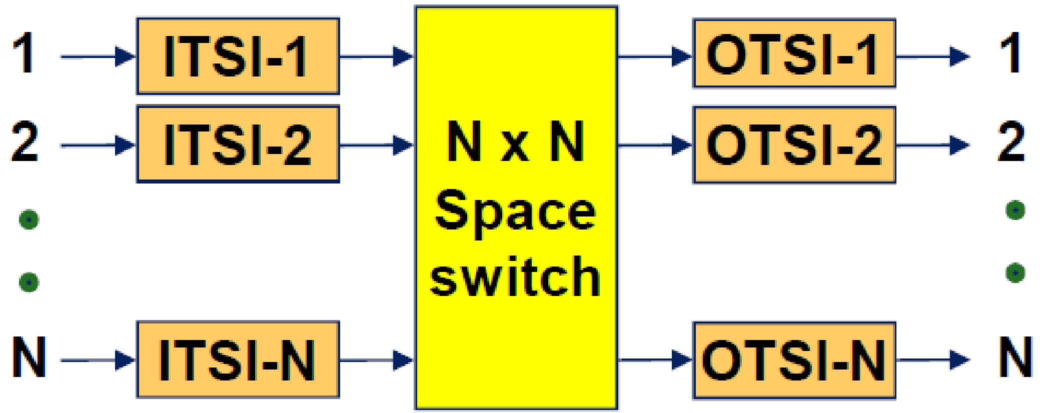
  $C_T = 2MN$

- Cost of STS switch

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

# Cost Analysis

## Cost of TST switch




- Cost of N × N space-switch with MN memory locations
  - $C_s = N*N + MN$
- Cost of 2N time-switches
  - $2C_T = 2N \times 2M = 4MN$
- Cost of TST switch
  - $C_{TST} = N^2 + 5MN$

# Cost Analysis

- For concentrating switches,
  - TST → $M_1 < M$
  - STS → $k < N$

  - For $M = k = N/2$, we have

    $$C_{STS} = 3N^2, \qquad C_{TST} = 3.5N^2$$

  - For symmetric switches, $M = k = N$

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

- For expanding switches,
  - TST → $M_1 > M$
  - STS → $k > N$,

  - $M_1 = k = 2N$

    $$C_{STS} = 12N^2, \qquad C_{TST} = 11N^2$$

**Example**: **A STS switch support 16 trunks and 16 channels each, and expansion factor of 2 is used. Calculate the blocking probability if the channel traffic intensity is 60 %.**
**Also calculate the cost of switch.**

**Solution:**

**Blocking probability**

$$P_B = [1 - (1 - \alpha / L)^2]^k$$

**where expansion factor $L$ = k/N**

**Given,** $N = 16$ **trunks**

$\alpha = 60\ \% = 0.6$

$L = 2 = k/N \Rightarrow k = L*N = 2*16 = 32$

$P_B = [1 - (1 - 0.6 / 2)^2]^{32}$

$P_B = 4.387 \times 10^{-10}$

**Cost of STS switch,** $CSTS = 12*N^2$

$CSTS = 12*16^2$

$CSTS = 3072$

# TST vs STS Switch

- ✓ TST switches have distinct advantages
  - – TST switch is more cost effective than STS switch because time expansion is less costly than space expansion.
  - – TST switch can handle larger volume of traffic.
- ✓ STS architecture is used for smaller switches.

# THANK YOU