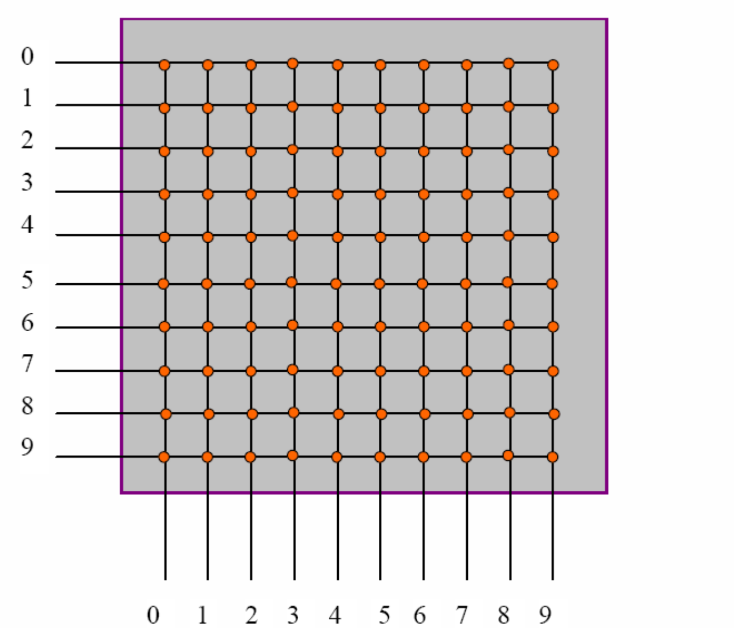
Digital Switching

Switching

- A switch transfers signals from one input port to an appropriate output.
- A basic problem is then how to transfer traffic to the correct output port.
- In the early telephone network, operators closed circuits manually. In modern circuit switches this is done electronically in digital switches.
- If no circuit is available when a call is made, it will be blocked (rejected). When a call is finished a connection teardown is required to make the circuit available for another user.

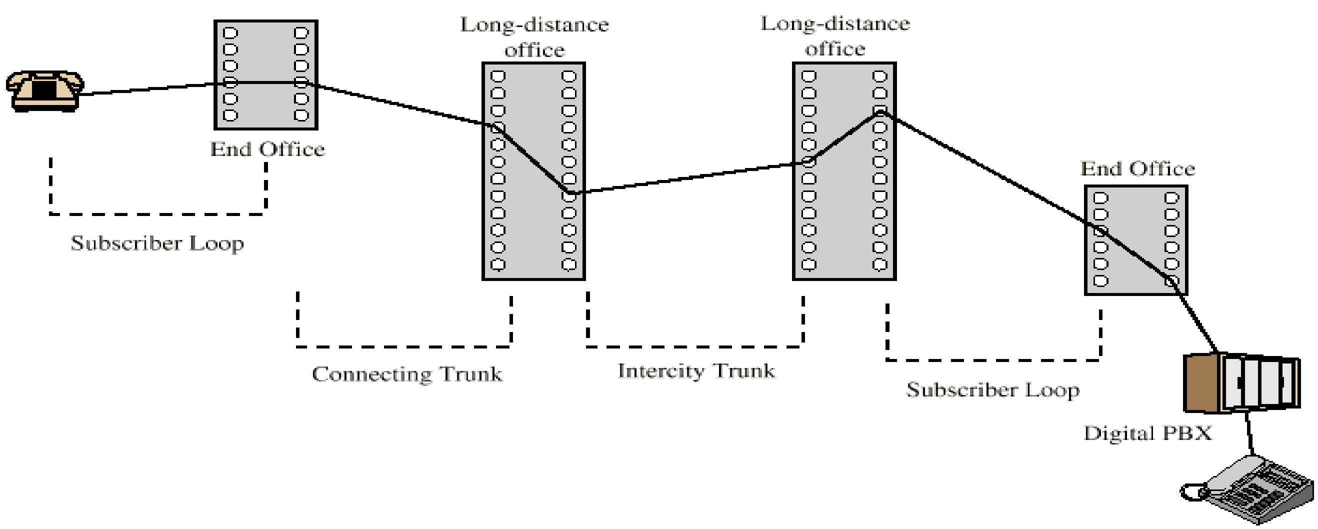
Crossbar Switch

- A crossbar switch with *N input lines and N output lines* contains an *N x N array of cross points that connect each input line to one* output line. In modern switches, each cross point is a semiconductor gate.



Switching Functions

- Recall basic elements of communications network:
  - Terminals, transmission media, and switches
- Basic function of any switch is to set up and release connections between transmission channels on an "as-needed basis"
- Computers are used to control the switching functions of a central office



Switching Types

- Two different switching technologies
  - Circuit switching
  - Packet switching

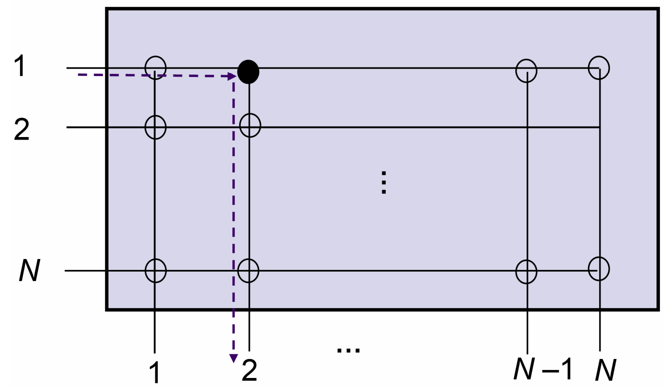
Circuit-Switched Network

- Circuit-Switched network assigns a dedicated communication path between the two stations. It involves
  - Point to Point from terminal node to network
  - Internal Switching and multiplexing among switching nodes.
  - Data Transfer.
  - Circuit Disconnect.
- Advantages
  - Once connection is established
  - Network is transparent.
  - Nodes seems to be directly connected.
  - Fixed data rate with no delay.
- Disadvantages
  - Can be inefficient
  - Resources are dedicated to
  - Connection even if no data is sent.
  - Delay prior to usage of connection

- Blocking Networks (voice)
- Non-Blocking Networks (computer)

Space Division Switching

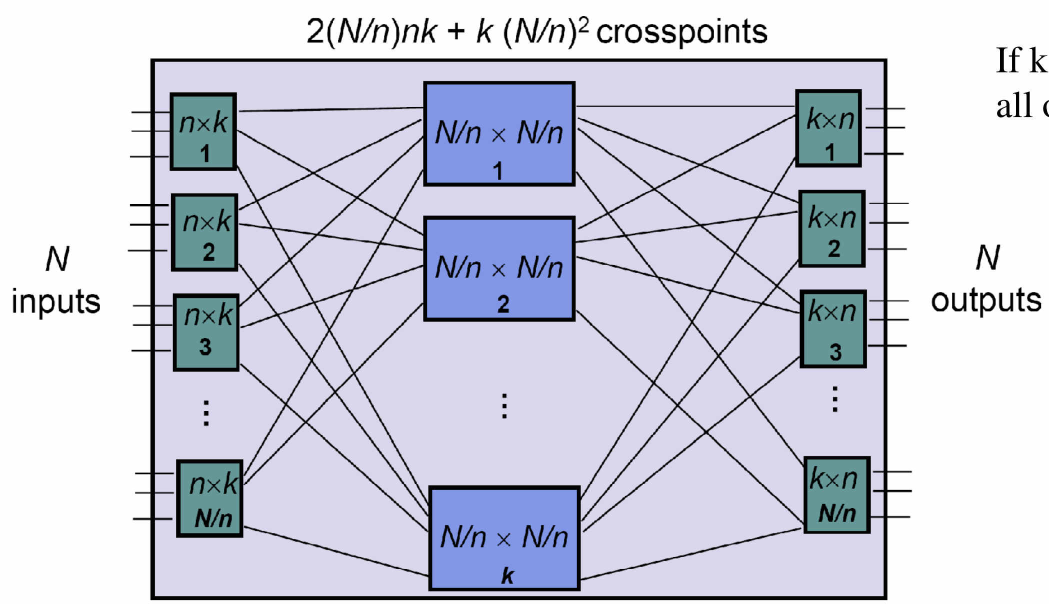
- Developed for analog environment
- Separate physical paths



- Recall Cross bar switch
  - The no. of cross points grows with square of the lines attached. N×N array of crosspoints
  - The loss of cross point means the loss of connection between the corresponding points.
  - Only fraction of the cross points are used even when all the points are fully active. (sqrt of cross points)
  - Non-blocking switching type.
  - Less signaling requirement from the network.

Multistage Switches

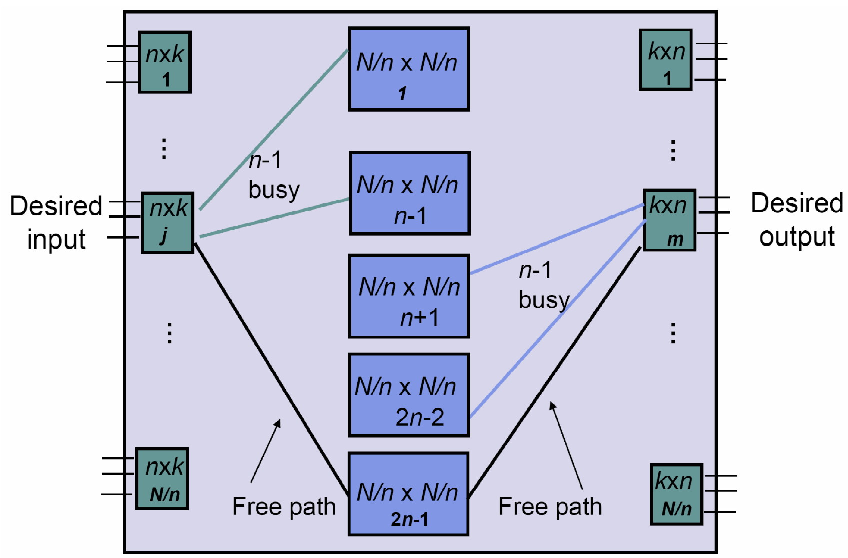
- Multistage switch
  - Less no. of cross points are needed.
  - More than one route for a connection.
  - More signaling from the network.
  - A blocking switching type (voice)

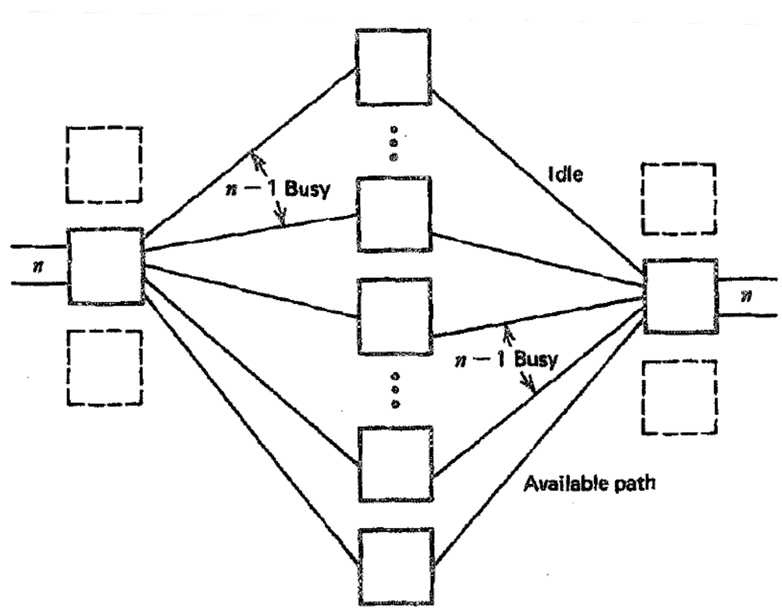


If k<n, if the first stage has k connections, all other connections will be blocked

Nonblocking Switching

- When a multistage switch becomes nonblocking?
  - The multistage switch with k=2n-1 is nonblocking
- The number of crosspoints required in a three stage switch is the sum of the following components
  - $N/n \times nk + k \times (N/n)^2 + N/n \times nk = 2Nk + k(N/n)^2$





Blocking Probabilities

- Strictly nonblocking switches are rarely needed in most voice telephone networks.
  - Switching systems and the number of circuits in interoffice trunk groups are sized to service most requests (not all) as they occur
  - Economics dictates that network implementations have limited capacities that occasionally exceeded during peak-traffic situations
- Equipment for the public telephone network is designed to provide a certain maximum probability of blocking for the busiest hour of the day.
- Grade of service of the telephone company depends on the blocking probability, availability, transmission quality, and delay
- Residential lines are busy 5-10% of the time during the busy hour
- Network-blocking occurrences on the order of 1% during the busy hour do not represent a significant reduction in the ability to communicate since the called party is much more likely to have been busy anyway.

Evaluation of Blocking Probability

- Probability graphs as proposed C. Y. Lee
  - Simplifying approximations are needed
  - Formulas directly relate to the underlying network structures
- Notation
  - *p*→ represents the fraction of the time that a particular link is in use (or *p* is the probability that a link is busy)
  - $q=1-p$ is the probability that the link is idle.
- When any one of n parallel links can be used to complete a connection, the composite blocking probability *B* is the probability that all links are busy

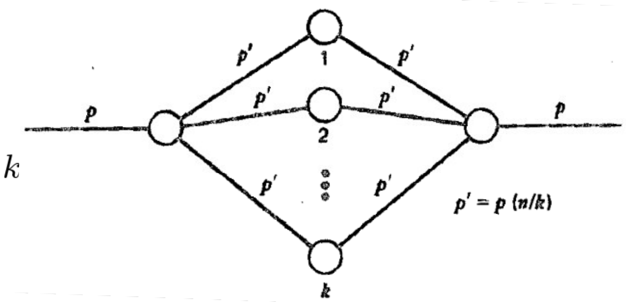
$$B = p^n$$

- When a series of n links are all needed to complete a connection, the blocking probability is mostly determined as 1 minus the probability that they are all available

$$B = 1 - q^n$$

Probability Graph

- Any particular connection can be established with *k* different paths
  - One through each center-stage array



$$
\begin{aligned}
B &= \text{probability that all paths are busy} \\
&= \text{probability that an arbitrary path is busy} \\
&= \text{probability that at least one link in a path is busy})^k \\
&= (1-(q')^2)^k
\end{aligned}
$$

where *k*=number of center-stage arrays

q'=probability that an interstage link is idle, =*1-p'*

- If the probability *p* that an inlet is busy is known, the probability *p'* that an interstage link is busy can be determined as

$$p' = \frac{p}{\beta} \quad (p < \beta) \quad \text{where} \quad \beta = k/n$$

- There are β=k/n times as many interstage links as there are inlets and outlets. The percentage of interstage links that are busy is reduced by the factor β. If β is less than 1, then the first stage is concentrating the incoming traffic.

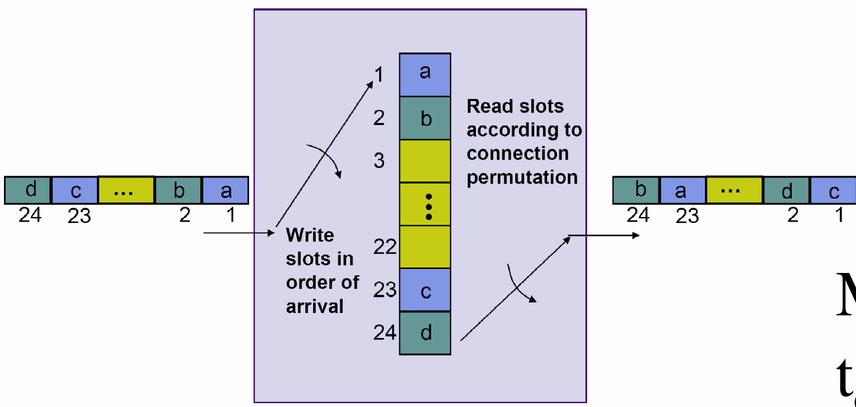
Three-Stage Switch Design

- The blocking probability of a three-stage switch in terms of the inlet utilization p:

$$B = \left[1 - \left(1 - \frac{p}{\beta}\right)^2\right]^k$$

Time-Division Switching

- Mostly all modern circuit switches are time-division switches.
- Time-slot interexchange (TSI)
- It is based on synchronous TDM.
- Multiple low speed inputs share a high speed line.
- There is no need for address bits in each slot (synchronous)
  - The slot could be a bit, a byte or a longer block.



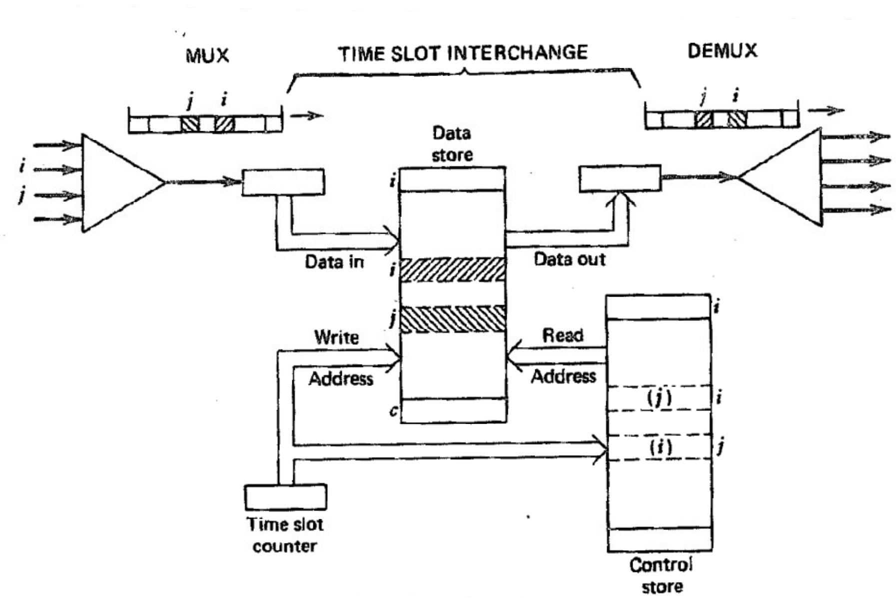
Time-slot interchange

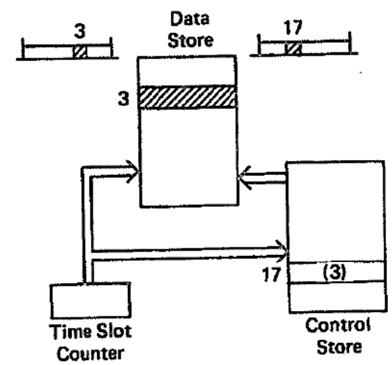
Maximum # of slots=$125/(2\times t_c)$

t_c=memory cycle time (μ sec)

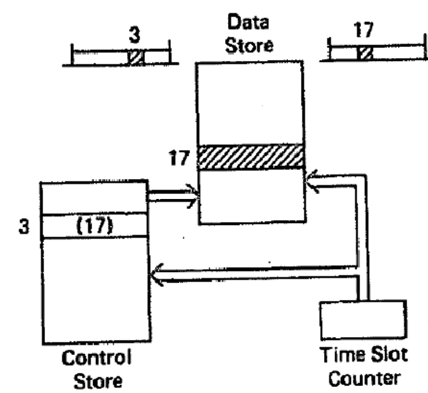
MUX/TSI/DEMUX

- Incoming data slots are written into sequential locations of the data store memory.
- Data words fro outgoing time slots, are read from addresses obtained from a control store





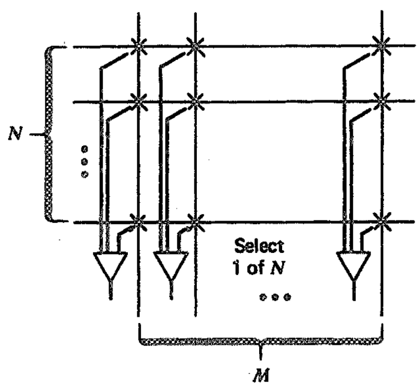
Sequential writes/
random reads



random writes/
sequential reads

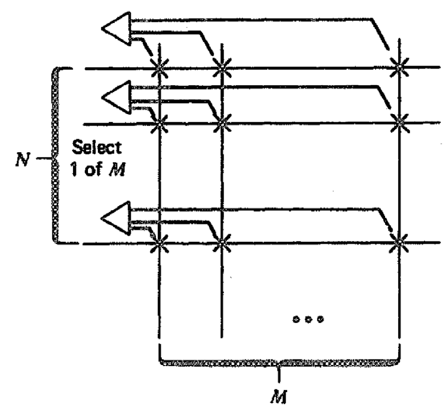
Switch Matrix Control

- Crosspoint selection within a matrix is accomplished in one of two ways.
- Input-associated control
- Output-associated control



Output associated

# of bits=$M\log_2 N$

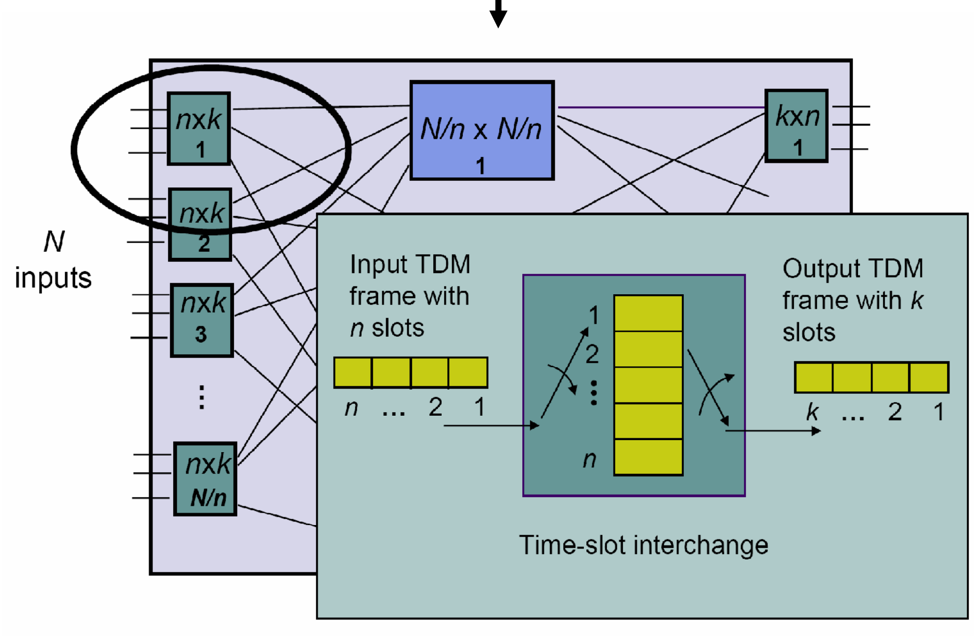


Input associated

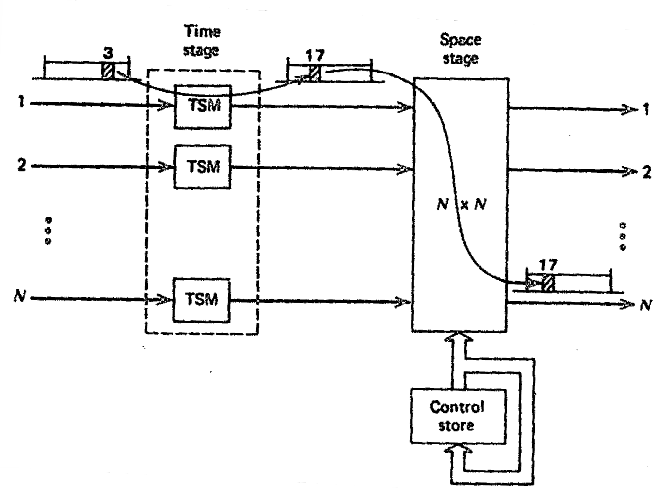
# of bits = $N\log_2 M$

Hybrid Switches

- Hybrid switch design (or two dimensional switching)
  - Time-Space switch
  - Space-Time-Space switch
  - Time-Space-Time switch



Time-Space switch



Implementation Complexity of TDS

- Total number of crosspoints alone is a less meaningful measure of implementation cost
- We have to include cost of the implementation including control bits
- Cost of number bits vs cost of crosspoints, (we use the ratio as 100)
- Complexity = $N_x + N_B/100$
  - N_X= Number of space stage crosspoints
  - N_B is number of bits of memory and control

Implementation Complexity Example

- Determine the implementation complexity of the TS switch shown in previous slide:
  - # of TDM input lines N=80
  - Each input contains a single DS1 signal (24 channels).
  - Assume a one-stage matrix is used for the space stage
- Number of cross points: $N_x = 80^2 = 6400$

Implementation Complexity

- Total number of memory bits
  - space stage control store → N_{BX}=(number of links)(number of control words)(number of bits per control word)
  - N_{BX}=(80)(24)(7)=13,440
  - Time stage N_{BT}= time slot interchange memory + control = (number of links)*number of channels)(number of bits per channel)+(number of links)(number of control words)(number of bits per control word)

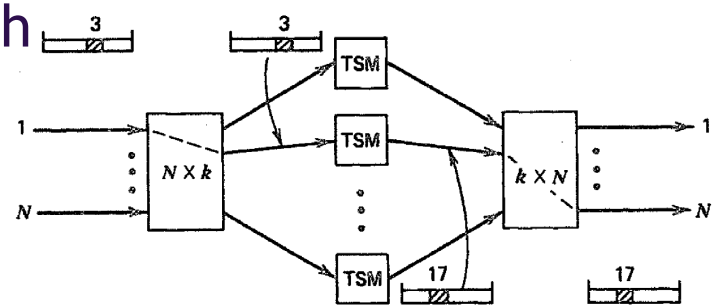
    N_{BT} =(80)(24)(8)+(80)(24)(5)=24960
- Complexity=N_X+(N_{BX}+N_{BT})/100=6784 equivalent crosspoints

Space-Time-Space Switch

- Blocking probability of an STS switch

$$B = (1 - (q')^2)^k$$

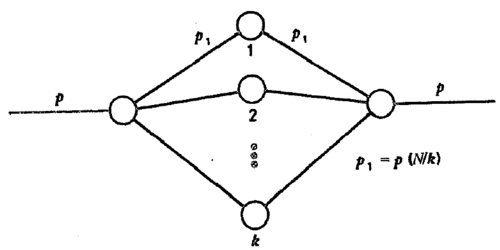
  - where q'=1-p'=1-p/β β=k/N
  - k=number of center-stage time switch arrays



- Assume that each TDM link has c message channels

  Complexity of STS switch= number of space stage crosspoints + (number of space stage control bits + number of time stage memory bits+ number of time stage control bits)/100

  Complexity=2kN+(2kclog$_2$N+kc(8)+kclog$_2$ c)/100

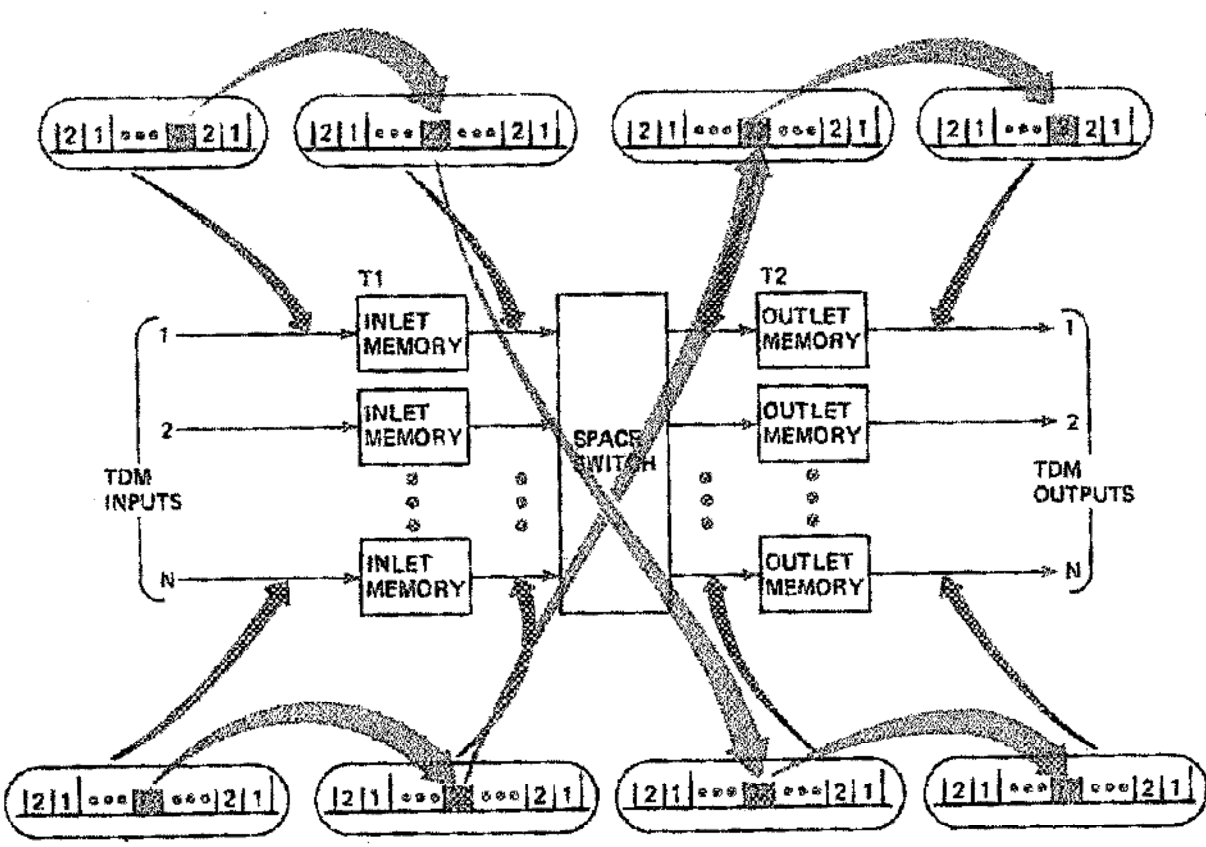


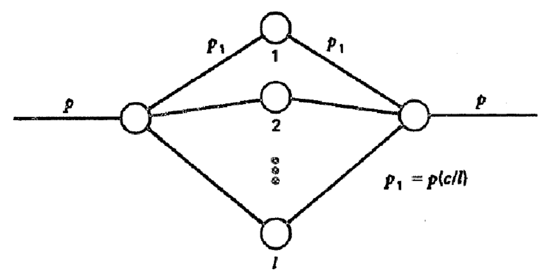
Example

- Determine the implementation complexity of a 2048-channel STS switch implemented for 16 TDM links with 128 channels on each link. The desired maximum blocking probability is 0.002 for channel occupancies of 0.1
- k=7, B=0.002
- $N_X=(2)(7)(16)=224$
- $N_B=(2)(7)(128)(4)+(7)(128)(8)+(7)(128)(7)=20608$
- $N=N_X+N_B/100=430$

TST Switch

- TST switch structure



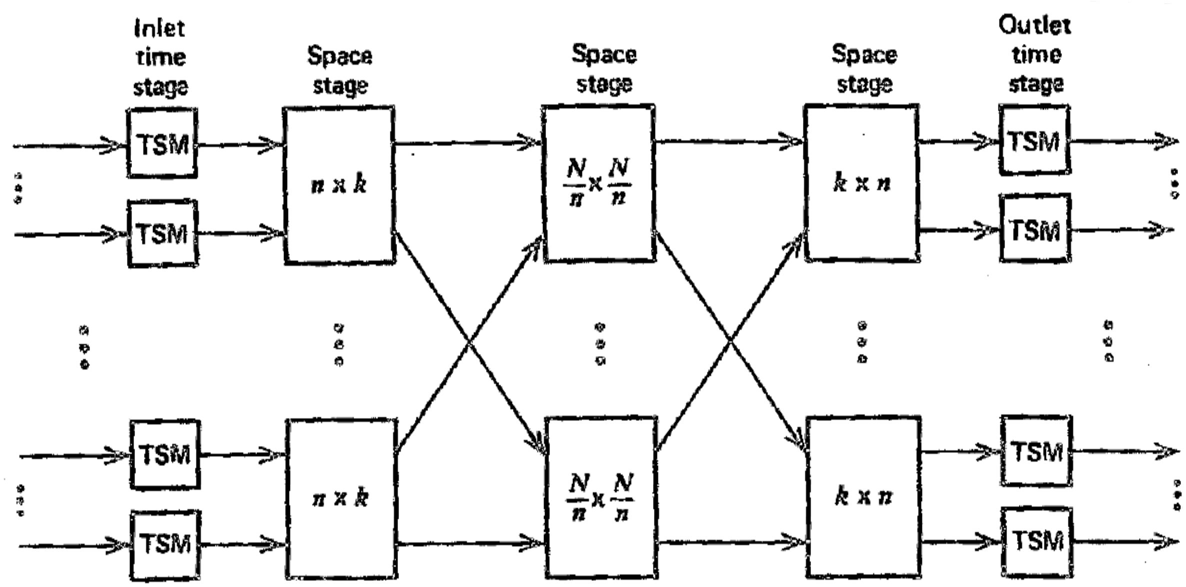


$$B = (1 - (q_1)^2)^k$$

where $q_1 = 1 - p_1 = 1 - p/\alpha$
α = time expansion (l/c)
l = number of space stage time slots

TSSST Switching Structure

- Multistage switches



No. 4 ESS Toll Switch

- Electronic Switching System
- Time-space-time with four stages in the space switch