Telecommunication Networks
15B11EC611

LECTURE:
SWITCHING SYSTEMS

Evolution of Telecommunication

- In March 1876, Alexander Graham Bell demonstrated his telephone set i.e. long distance voice transmission.

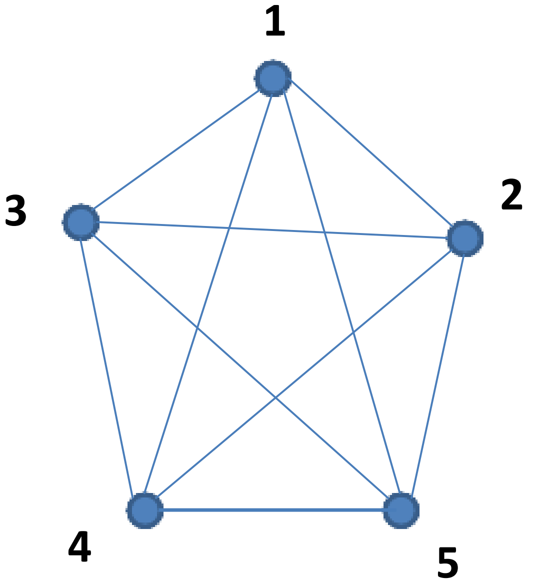
- Graham Bell demonstrated a point-to-point telephone connection.

- In Figure, there are 5 entities and 10 point-to-point links

- In general case with n entities, there are $n(n-1)/2$ links

Fully connected networks: Networks with point-to-point links among all the entities

Note: In this network, number of pairs of wires, number of switching system (or switching office or the exchange) required is large.

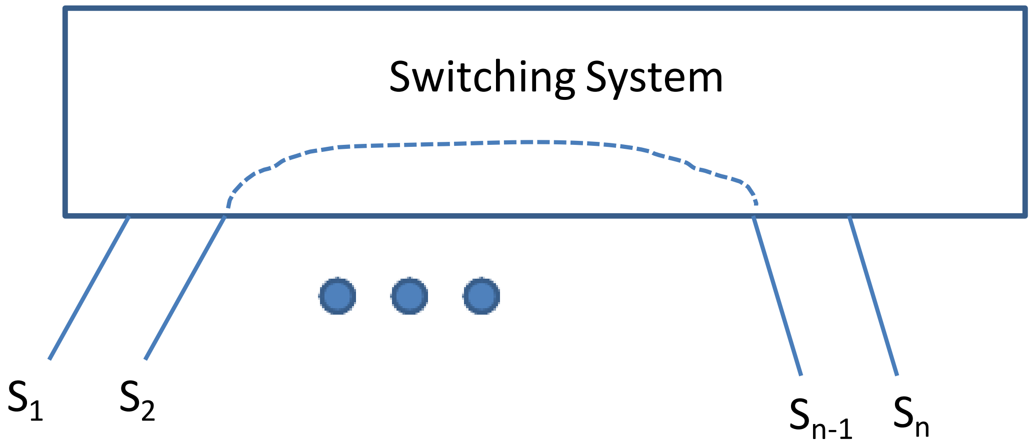


A network with point-to-point links

Switching System

Switching: The process of establishing an active connection between telecommunication devices

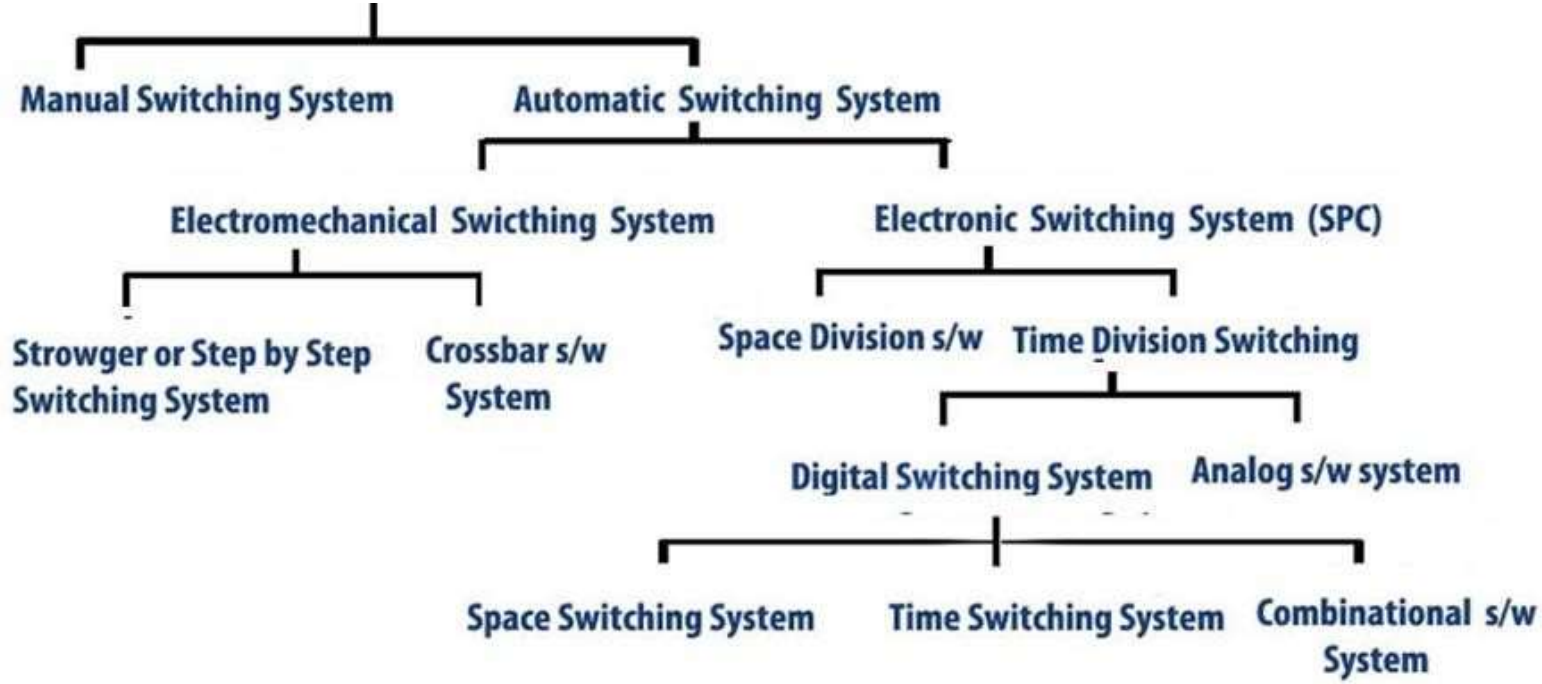
- With the introduction of switching system, the subscribers are not directly connected to one another.
- Instead, they are connected to the switching system (Figure)



Subscriber interconnection using a switching system

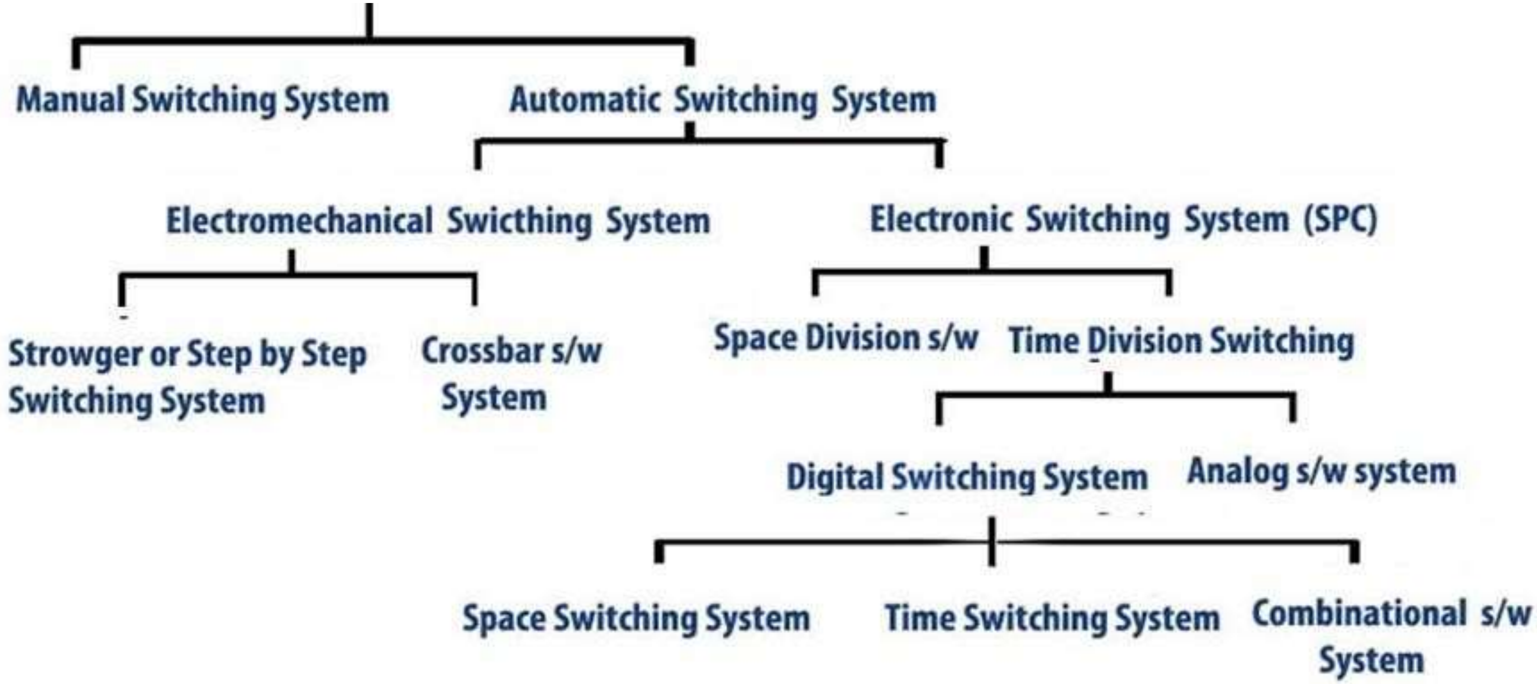
- In this configuration, total number of links required is equal to the total number of subscribers. But, here
- **Signalling** is required to draw the attention of the switching system to establish or release the connection.
- **Control Functions:** The functions performed by a switching system

Switching System (SS) : Classification



- Early SS were manual and operator oriented. Due to so many limitations, Automatic SS came into existence.
- Step-by-step system (also known as Strowger system: inventor A.B. Strowger): The control functions in a Strowger system are performed by circuits associated with the switching elements in the systems.
- Crossbar systems have hard-wired control subsystems which use relays and latches. These subsystem have limited capability and difficult to modify them to provide additional functionalities

Switching System (SS) : Classification

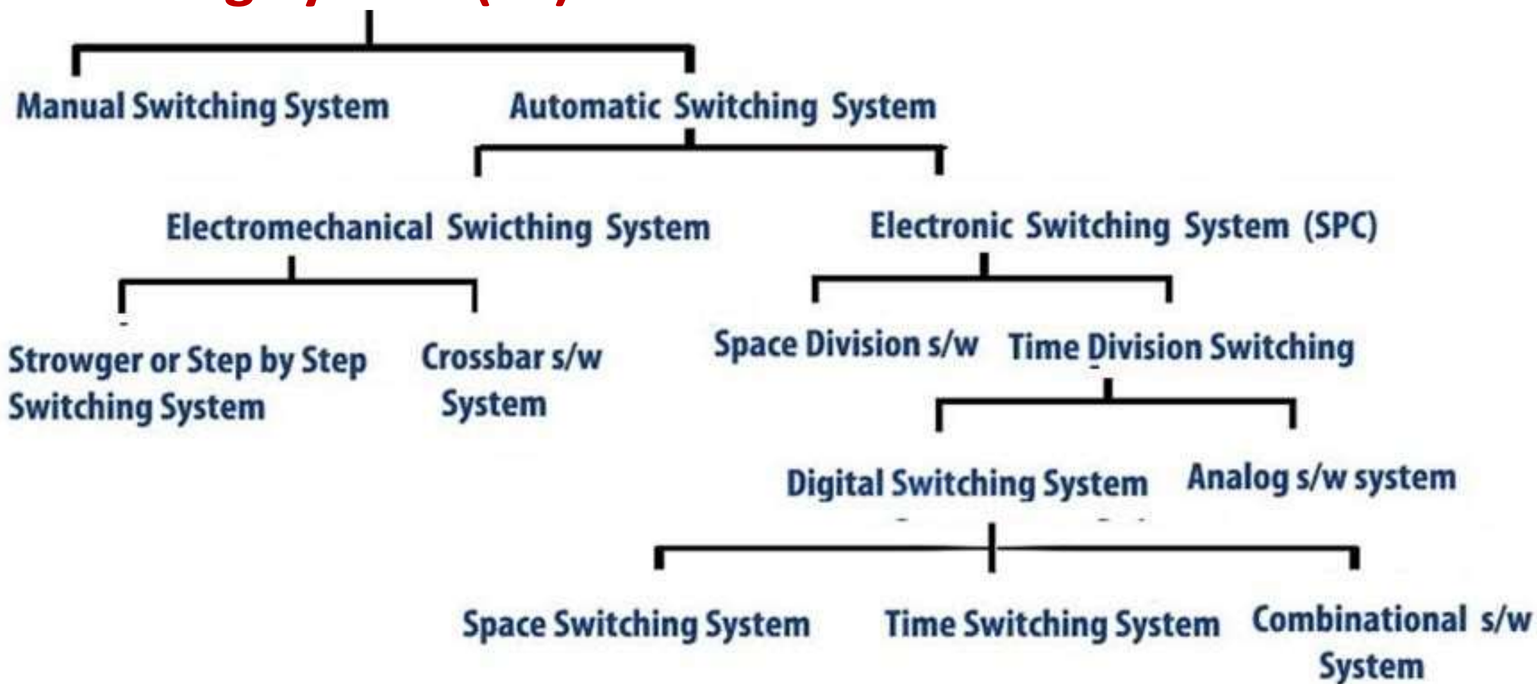


- **In Electronic SS, the control functions are performed by a computer or a processor → that's why it is called stored program control (SPC) systems.**
  - **New facilities can be added to a SPC system by changing the control program**

- **In Space Division Switching, a dedicated path is established between the calling and called subscribers for the entire duration of the call.**

- **In Time Division Switching, sampled values of speech signals are transferred at fixed intervals**

Switching System (SS) : Classification

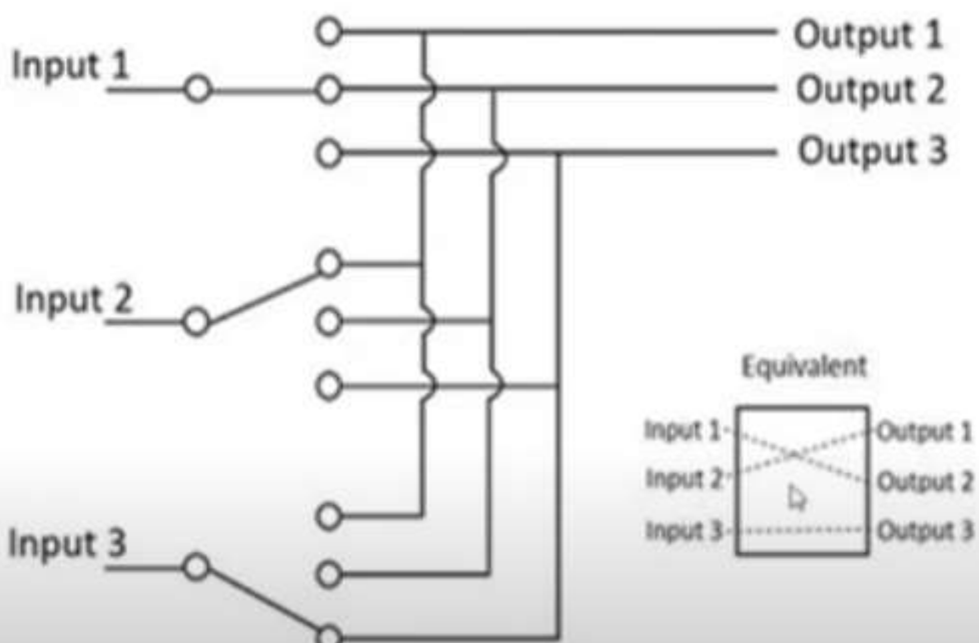


- Time Division switching may be analog or digital
- In Analog switching, the sampled voltage levels are transmitted as they are
- In Digital switching, they are binary coded and transmitted.
- Space switching: If the coded values are transferred during the same time interval from input to output, the technique is called space switching.
- Time switching: If the values are stored and transferred to the output at a later time interval, the technique is called time switching.
- A time division digital switch may be designed by using a combination of space and time switching techniques.

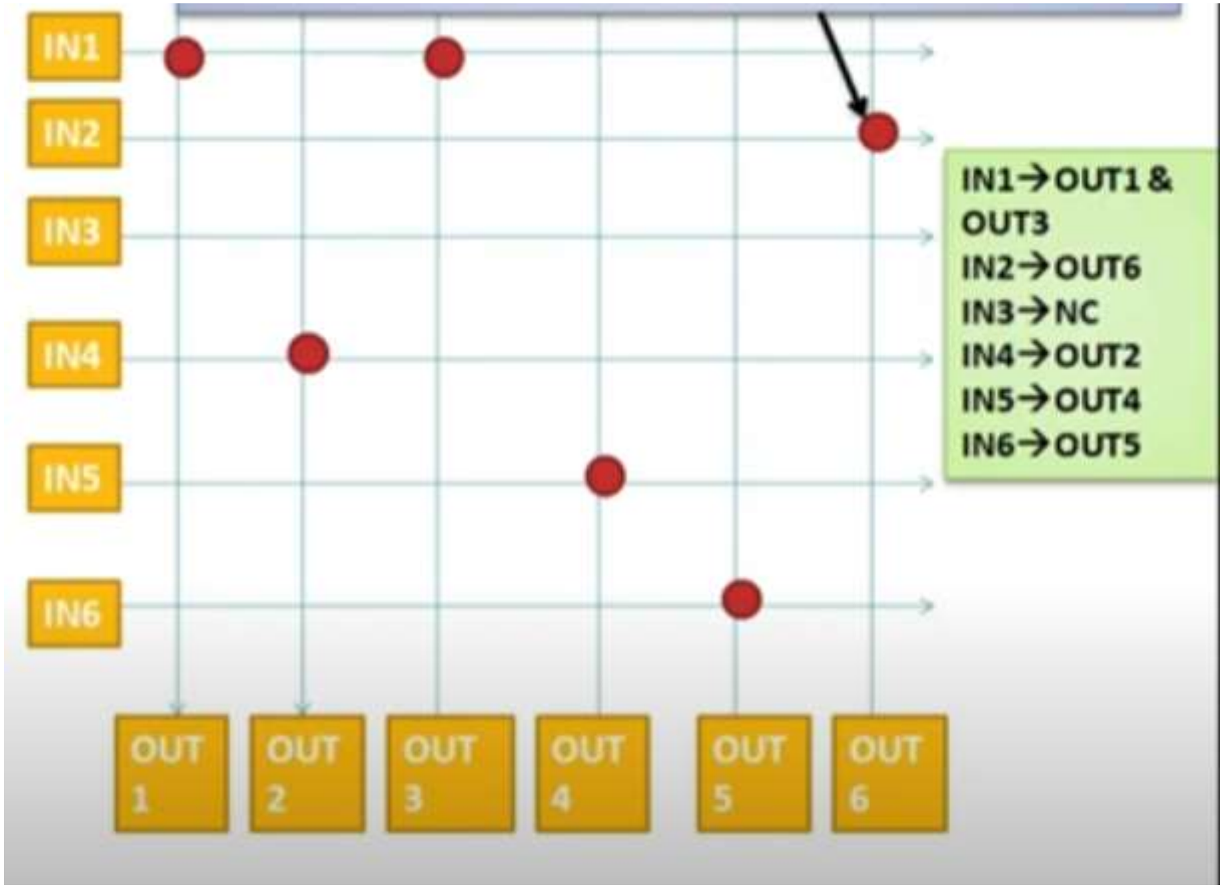
Space division switching

- dedicated path is established b/w calling & called subscribers for the entire duration of the call.
- instantaneous transmission from i/p to o/p. (no delay)
- cross point not shared.

BLOCK DIAGRAM FOR SPACE DIVISION SWITCHING



When this switch cell is activated, then it connects IN2 to OUT6



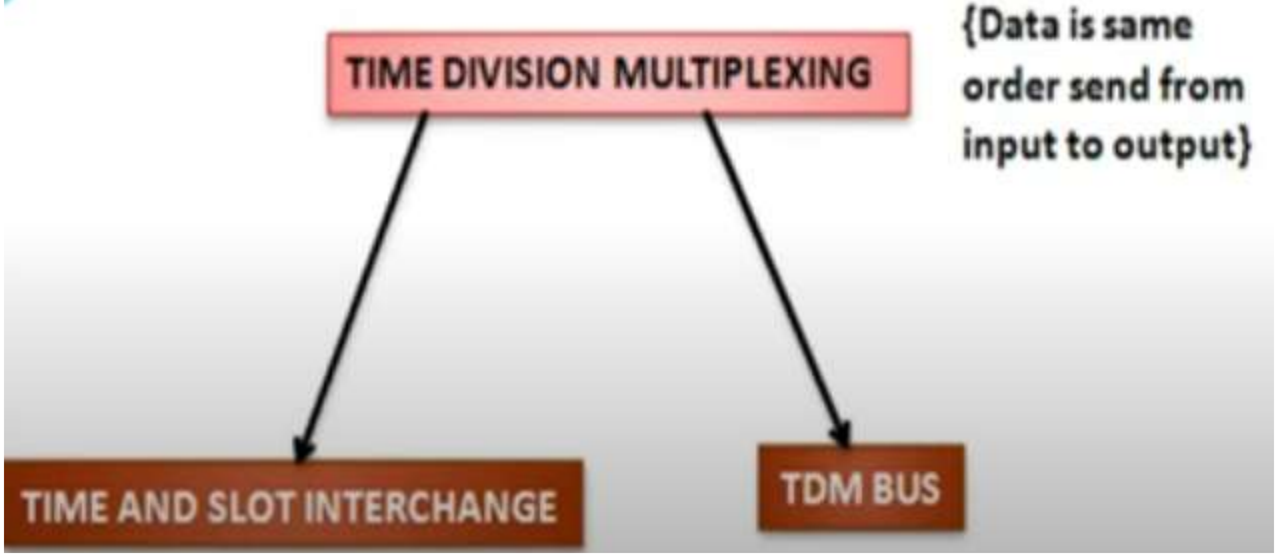
6 x 6 Crosspoint switch

Time Division Switching

- Pulse code modulated signals are mostly present at i/p & o/p ports.
- i/ps of any PCM highway can be connected to the o/ps of any PCM highway, to establish a call.
- incoming & outgoing signals when recieved & retransmitted in a different time slot, This is called time-division switching.
- sharing of cross points.

- Time division switches use time division multiplexing, in switching.
- The two popular methods of TDM are

1. TSI (Time and Slot Interchange)
2. TDM bus

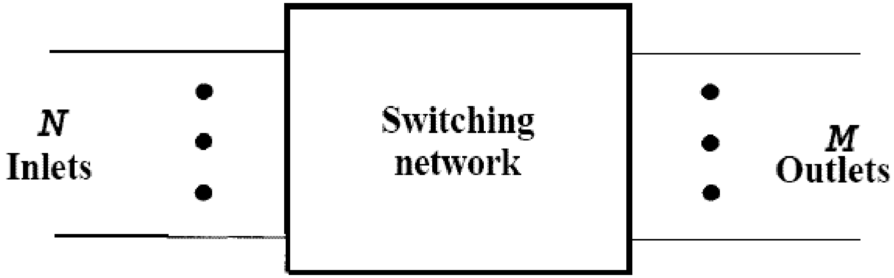


Basics of a Switching System

Different components and terms used in switching systems:

1. Inlets and Outlets

- The set of input circuits of an exchange are called Inlets and the set of output circuits are called the Outlets.
- Usually, N indicates the inlets and the outlets are indicated by M. So, a switching network has N inlets and M outlets.
- The primary function of a switching system is to establish an electrical path between a given inlet-outlet pair.

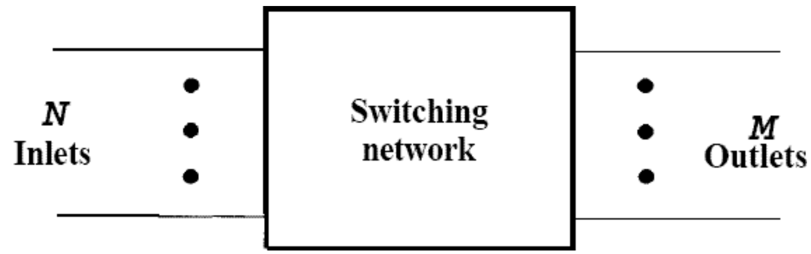


Model of switching network

2. Switching Matrix/Switching Network

- The hardware used to establish connection between inlets and outlets is called the Switching Matrix or the Switching Network.

Basics of a Switching System



Symmetric Network

- When N = M, the switching network is called a **symmetric network**.
- The inlets/outlets may be connected to local subscriber lines or to trunks from or to other exchanges as illustrated in Figure.

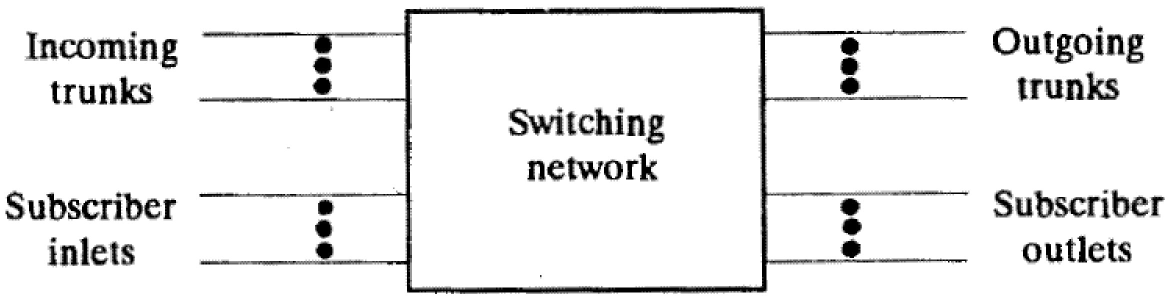


Figure. Model of a telephone switching Network

In the Figure, four types of connections can be established:

1. Local call connection between two subscribers in the system
2. Outgoing call connection between a subscriber and an outgoing trunk
3. Incoming call connection between an incoming trunk and a local subscriber
4. Transit call connection between an incoming trunk and an outgoing trunk.

Basics of a Switching System

Folded Network

- When all the inlets/outlets are connected to the subscriber lines.
- The output lines are folded back to the input and hence the network is called a folded network.

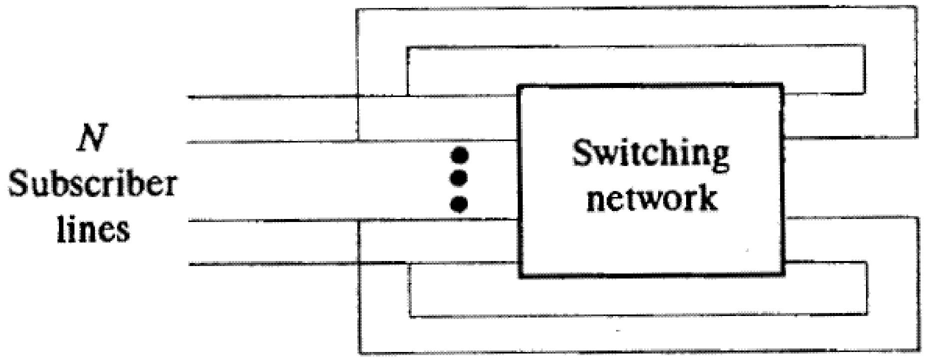


Figure. A folded Network

- In a folded network with N subscribers, there can be a maximum of N/2 simultaneous calls.
- The switching network may be designed to provide N/2 simultaneous switching paths, in which case the network is said to be non-blocking.

Basics of a Switching System

Non-Folded Network

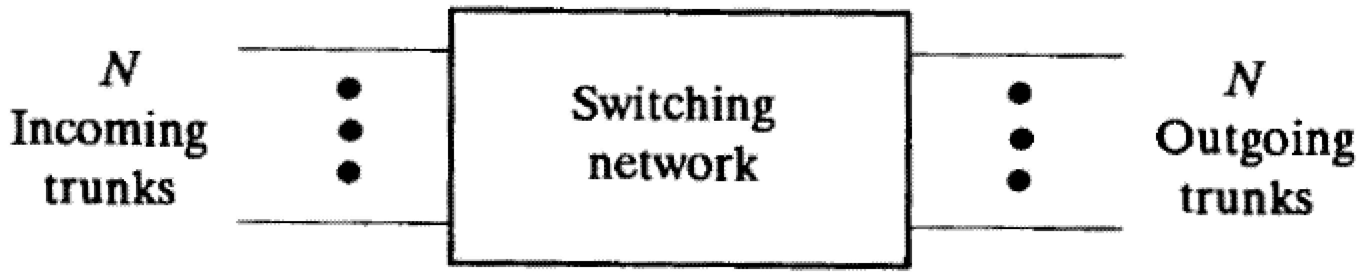


Figure. A Non-folded Network

- In a switching network, all the inlet/outlet connections may be used for inter-exchange transmission.
- In such a case, the exchange does not support local subscribers and is called a transit exchange and a network of this kind is called a non-folded network.
- In a non-folded network with N inlets and N outlets, N simultaneous information transfers are possible.
- Consequently, for a non-folded network to be non-blocking, the network should support N simultaneous switching paths.

Direct and Common/Indirect Control

Direct Control

The switching systems in which the control subsystem is an integral part of the switching network itself are known as direct control switching systems.

Example: Strowger Switch

Common/Indirect Control

The switching systems in which the control subsystem is outside the switching network are known as common control switching systems.

Example: crossbar and electronic exchanges, in general all SPC systems

Electronic Switching (SPC)

- ❖ **Application of electronics in the design of control and signalling subsystems → to improve the speed of control and signalling between exchanges**

Stored Program Control (SPC)

- ✓ **Modern digital computers use the stored program concept.**
- ✓ **A program or a set of instructions to the computer is stored in its memory and the instructions are executed automatically one by one by the processor.**
- ✓ **Carrying out the exchange control functions through programs stored in the memory of a computer led to the nomenclature stored program control (SPC).**

Single-Stage Networks

- In a large single-stage network, number of crosspoint switches required is very large i.e. $N (N - 1)/2$

- Single-stage networks suffer from a number of disadvantages which can be overcome by adopting a multistage network

Table 4.3 Single Stage vs. Multistage Networks

S.No.	Single stage	Multistage
	single	multiple
1.	Inlet to outlet connection is through a single crosspoint.	Inlet to outlet connection is through multiple crosspoints. crosspts.
2.	Use of a single crosspoint per connection results in better quality link.	Use of multiple crosspoints may degrade the quality of a connection. quality
3.	Each individual crosspoint can be used for only one inlet/outlet pair connection.	Same crosspoint can be used to establish connection between a number of inlet/outlet pairs.
4.	A specific crosspoint is needed for each specific connection.	A specific connection may be established by using different sets of crosspoints.
5.	If a crosspoint fails, associated connection cannot be established. There is no redundancy.	Alternative cross-points and paths are available.
6.	Crosspoints are inefficiently used. Only one crosspoint in each row or column of a square or triangular switch matrix is ever in use, even if all the lines are active.	Crosspoints are used efficiently.
7.	Number of crosspoints is prohibitive. Less no. of crosspts read.	Number of crosspoints is reduced significantly. More no. of crosspts. read
8.	A large number of crosspoints in each inlet/outlet leads to to capacitive loading.	There is no capacitive loading problem.
9.	The network is nonblocking in character. no blocking	The network is blocking in character. blocking
10.	Time for establishing a call is less. Less	Time for establishing a call is more. Time to establish call More

Two-Stage Networks

Theorem

- For any single stage network, there exists an equivalent multistage network.
- A NxN single stage network with a switching capacity of K connections can be realized by a two-stage network of NxK and KxN.

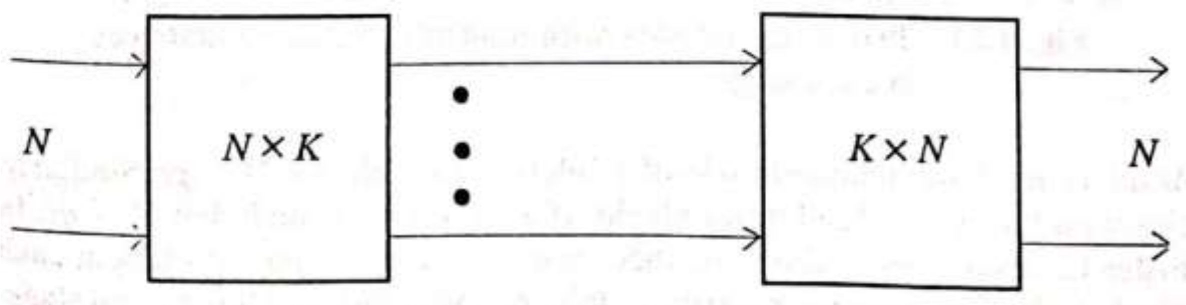


Figure: A two-stage representation of an N X N network.

- **First Stage**: Any of the N inlets can be connected to any of the K outputs. **NK switching elements.**
- **Second Stage**: Any of the K inputs can be connected to any of the N outlets. **NK switching elements.**
- There are K alternative paths for any inlet/outlet pair connection.
- For large N, switching matrix N x K difficult to realize practically.
- Hence, use smaller size switching matrices

Two-Stage Networks

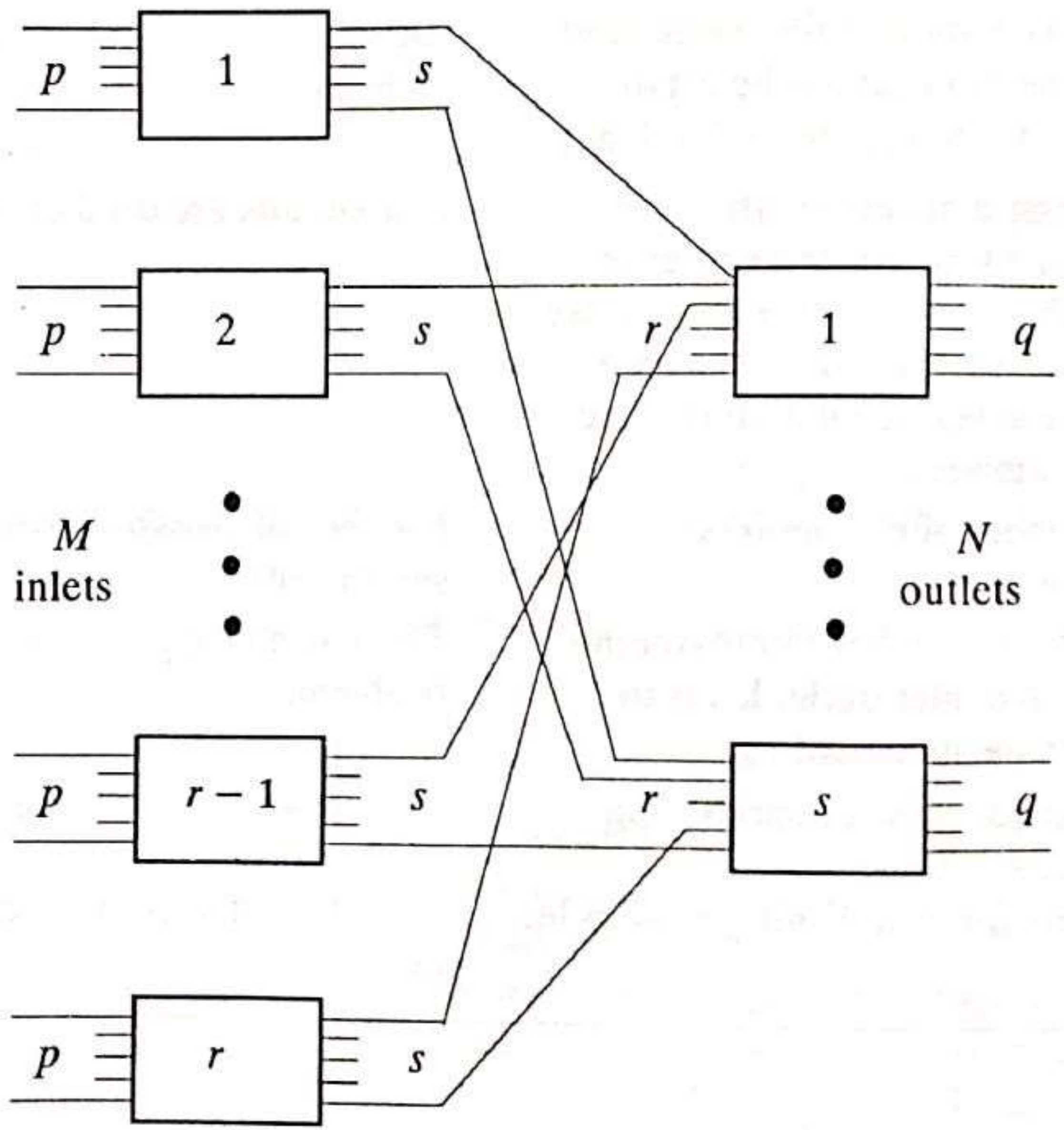
- M inlets are divided into r blocks of p inlets
  ➔ M = pr

- N outlets are divided into s blocks of q outlets
  ➔ N = qs

- Switching Capacity (SC) → The no. of simultaneous calls that can be supported by the network.

- SC is equal to number of links between the first and second stage.

- SC = rs



Two stage network with multiple switching matrices in each stage

This determines the block sizes as $p \times s$ and $r \times q$ for the first and second stages respectively. Total number of switching elements S is given by

$$S = psr + qrs$$

Substituting for p and q in terms of M, N, r and s, we get

$$S = Ms + Nr \tag{4.9}$$

The number of simultaneous calls that can be supported by the network, i.e. the switching capacity, SC, is equal to the number of links between the first and the second stage. Hence,

$$SC = rs \tag{4.10}$$

... to be simultaneously active, the active inlets and ... be s active

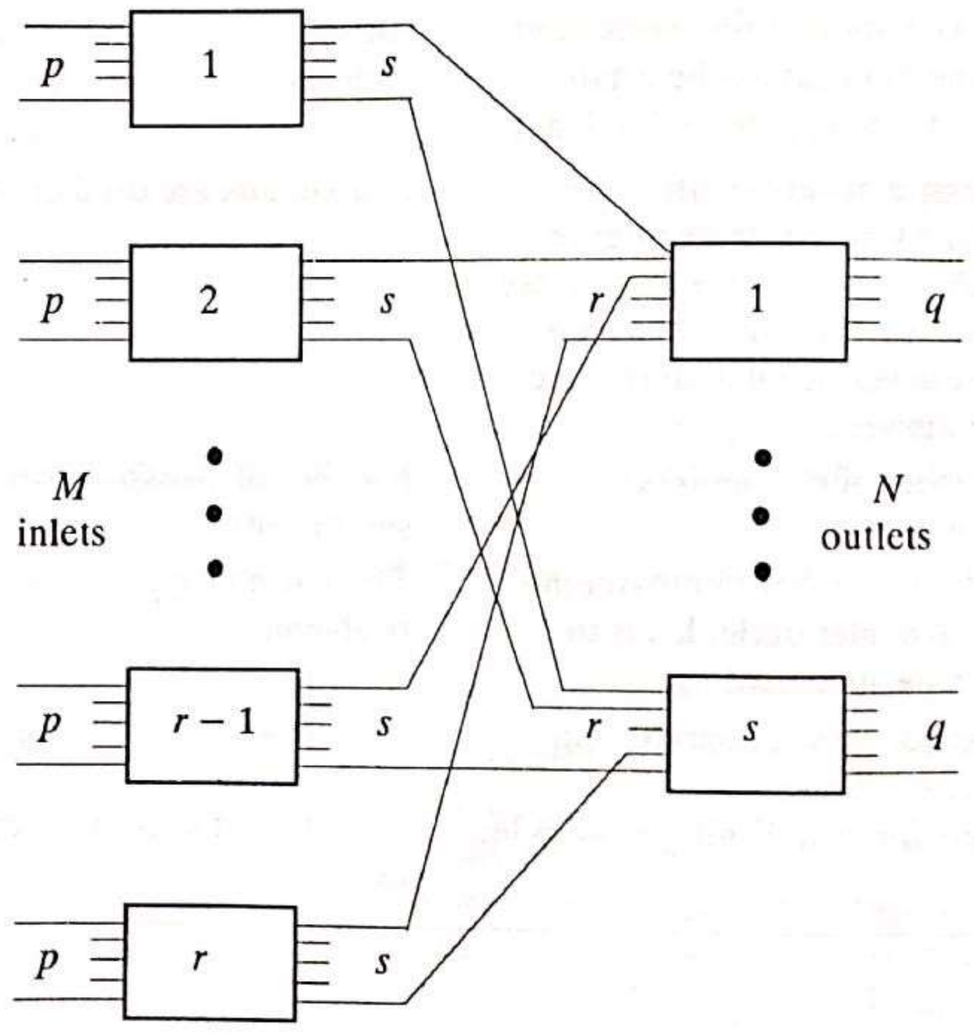
Two-Stage Networks

- This network is blocking is nature & blocking may occur under two conditions:

  1. The calls are uniformly distributed; i.e. rs calls are in progress and the (rs + 1)th call arrives. P_B is dependent upon traffic statistics.

  2. The calls are not uniformly distributed; there is a call in progress from I-th block in first-stage to J-th block in second stage, and another call originates in the I-th block destined to the J-th block.

For rs connections to be simultaneously active, the active inlets and outlets must be uniformly distributed. There must be s active inlets in each of the r blocks in the 1st stage and r active outlets in each of the s blocks in the 2ns stage.



Let α be the probability that a given inlet is active. Then, the probability that an outlet at the I-th block is active is

$$\beta = (p\alpha)/s$$

The probability that another inlet becomes active and seeks an outlet other than the one which is already active is given by

$$(p-1)\alpha/(s-1)$$

The probability that the already active outlet is sought is, therefore,

$$P_B = \frac{p\alpha}{s}\left[1 - \frac{(p-1)\alpha}{s-1}\right]$$

Substituting $p = M/r$, we have

$$P_B = \frac{M\alpha(s-1) - ((M/r) - 1)\alpha}{rs(s-1)}$$

If s and r decrease then S can be minimized

But if we decrease s and r we are increasing blocking probability!

So, we have to choose values for s and r as small as possible but giving sufficient links to provide a reasonable grade of service.

M inlets vs N outlets

If N > M, network is expanding traffic

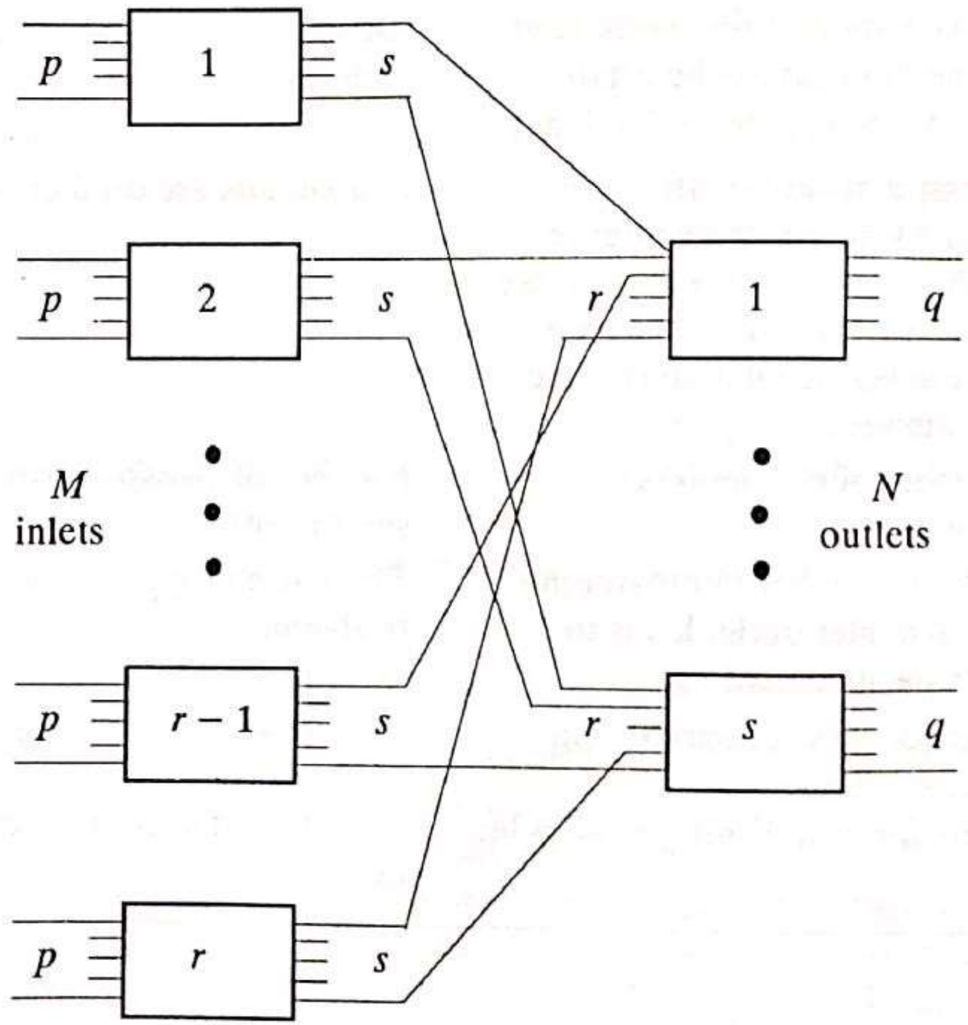
If M > N, concentrating the traffic

If N = M, matrix size is uniform

i.e. r=s, p=q

Two-Stage Networks

- There is only one link between a block in the 1st stage and a block in the 2nd stage → as a result, Link failure would cut-off connection between p inlets and q outlets
- This one-link structure gives rise to several blocking in the network.
- The Blocking performance can be improved →
  - by increasing the number of links between the blocks of the stages, and
  - by increasing the more stages.



Non-Blocking Network

- In order to make the network non-blocking, must have $K=\sqrt{N}$ and for $M=N$, $p=q=\sqrt{N}$ and $r=s=K\sqrt{N}$
- Now, $S = Ms+Nr=2Nr=2N^2$
- And, $SC = rs=\sqrt{N}x\sqrt{N}=N$
- So, a two-stage non-blocking network requires twice the number of switching elements as the single stage non-blocking network.

Three-Stage Networks

- The Blocking probability and the number of switching elements can be reduced significantly.

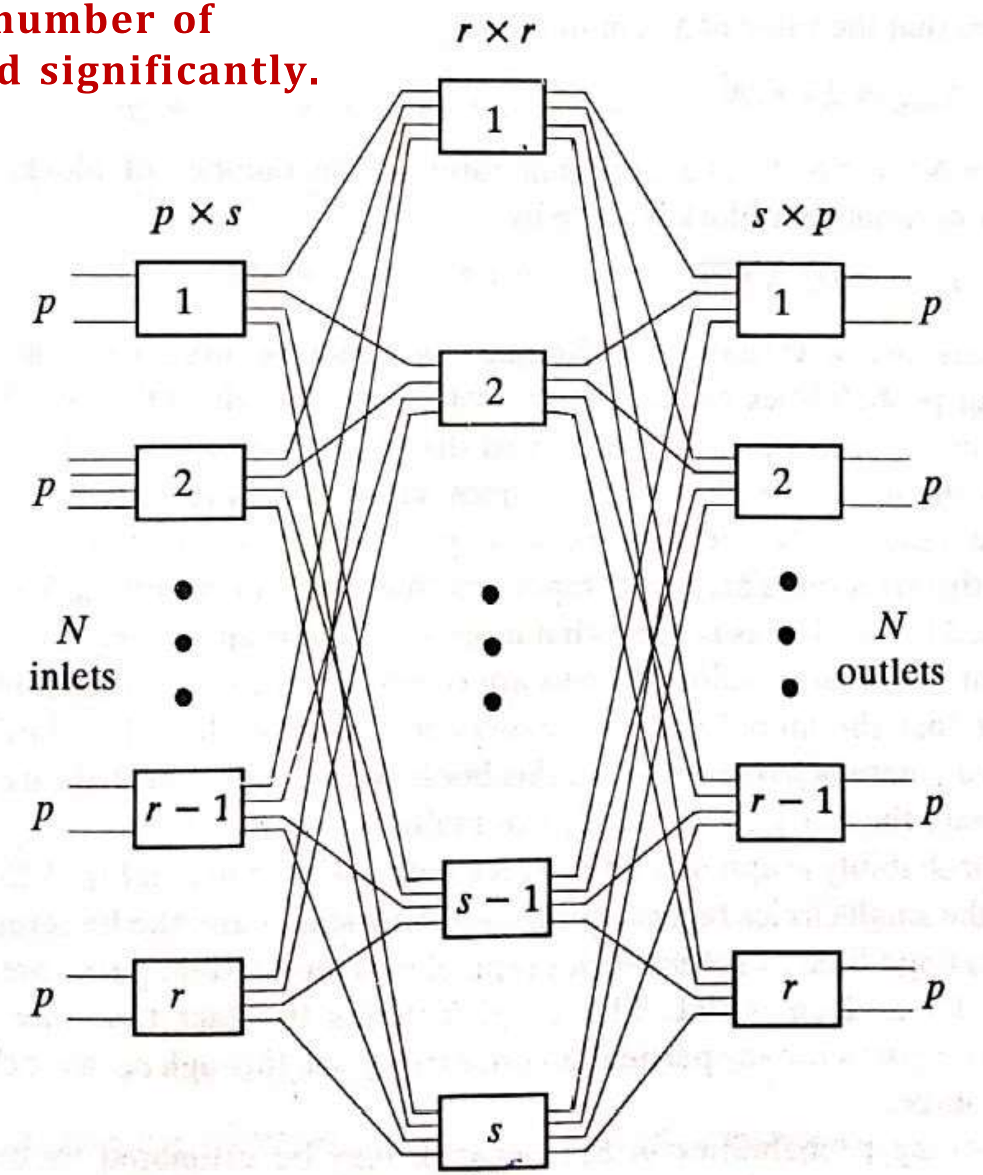
- N inlets are divided into r blocks, and each blocks is having p inlets

- N outlets are divided into r blocks, and each blocks is having p outlets

- Switching matrices size
  - 1st stage = p x s
  - 2nd stage = r x r
  - 3rd stage = s x p

- Total number of switching elements

  - $S = psr + r^2s + spr$
  - $S = 2prs + r^2s$
  - $S = 2Ns + r^2s = s\,(2N + r^2)$



N X N three-stage switching network

Three-Stage Networks

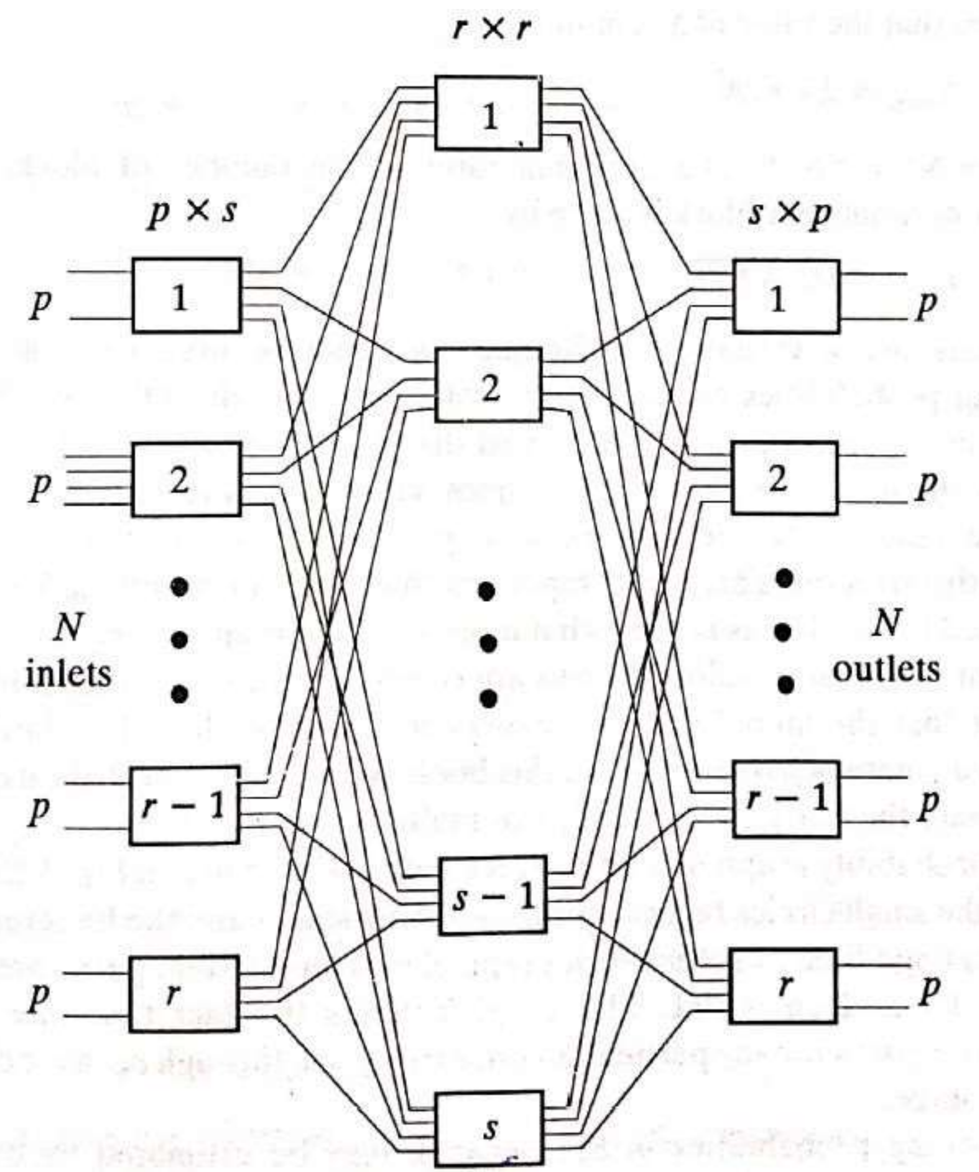
Note: If we use **square matrices** in the first and third stages, we have $p = s = (N/r)$

- **Total number of switching elements**

  - $S = 2Ns + r^2 s = s\,(2N + r^2)$
  - $S = 2N^2/r + Nr$

➔ This equation indicates for a given value of N, **there exists an optimal value of r** which minimizes the value of S.

- $dS/dr = -2N^2/r^2 + N = 0$
- $r = \sqrt{(2N)}$
- $d^2S/dr^2 = 4N^2/r^3 > 0$ ➔ value of S is minimum
- $S_{min} = 2N\sqrt{(2N)}$



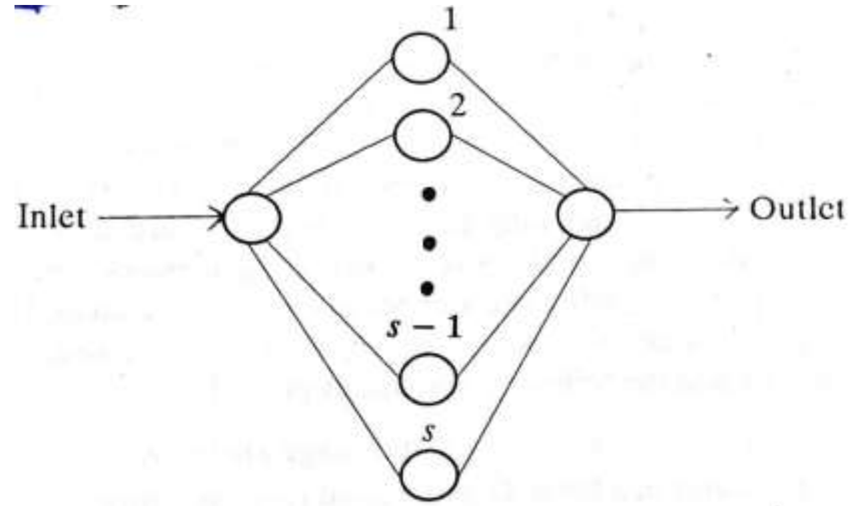
N X N three-stage switching network

Three-Stage Networks

Blocking Probability (P_B) = ?

- ❑ Use Lee,s probability graph to estimate the blocking probability.

➢ Probability graph of a 3-stage network ➔



- ❖ Small circle → switching stages
- ❖ Line → interstage links

- ❖ The network graph shows all possible paths between a given inlet and an outlet

- ❖ P_B may be estimated by breaking down a graph into serial and parallel paths.

Three-Stage Networks

Let
β = probability that a link is busy
β' = probability that a link is free

➔ $\beta = 1 - \beta'$

For S parallel links,
P_B = probability that all the links are busy
$P_B = \beta^S$, $Q_B = 1 - P_B$

For a series of S links,

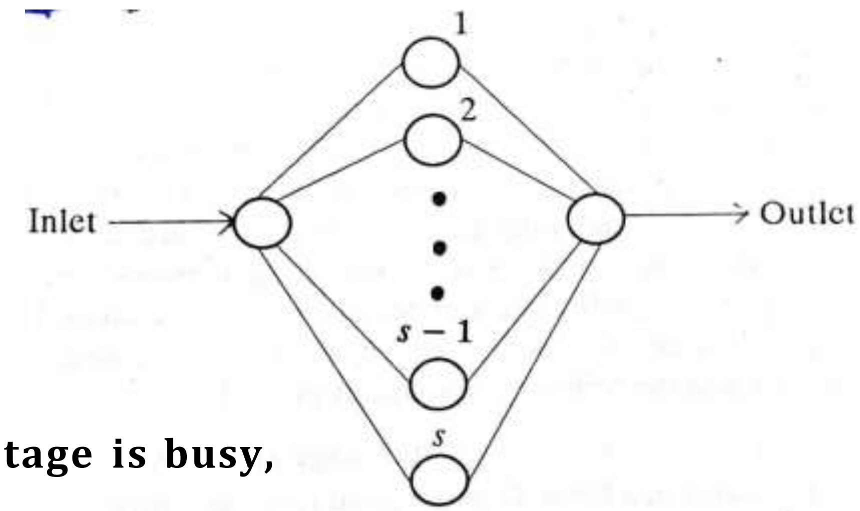
P_B = One minus the probability that all the links are available

$P_B = 1 - (\beta')^S = 1 - (1 - \beta)^S$,

Three-Stage Networks

Blocking Probability (P_B) = ?

For a 3-stage network ➔ two links in series for every path and there are s parallel paths.



$$P_B = [1 - (\beta')^2]^S = [1 - (1 - \beta)^2]^S$$

If α = probability that an inlet at the 1st stage is busy,

Then $\beta = p\alpha/s = \alpha/k$

Finally, $P_B = [1 - (1 - \alpha/k)^2]^S$

Where,

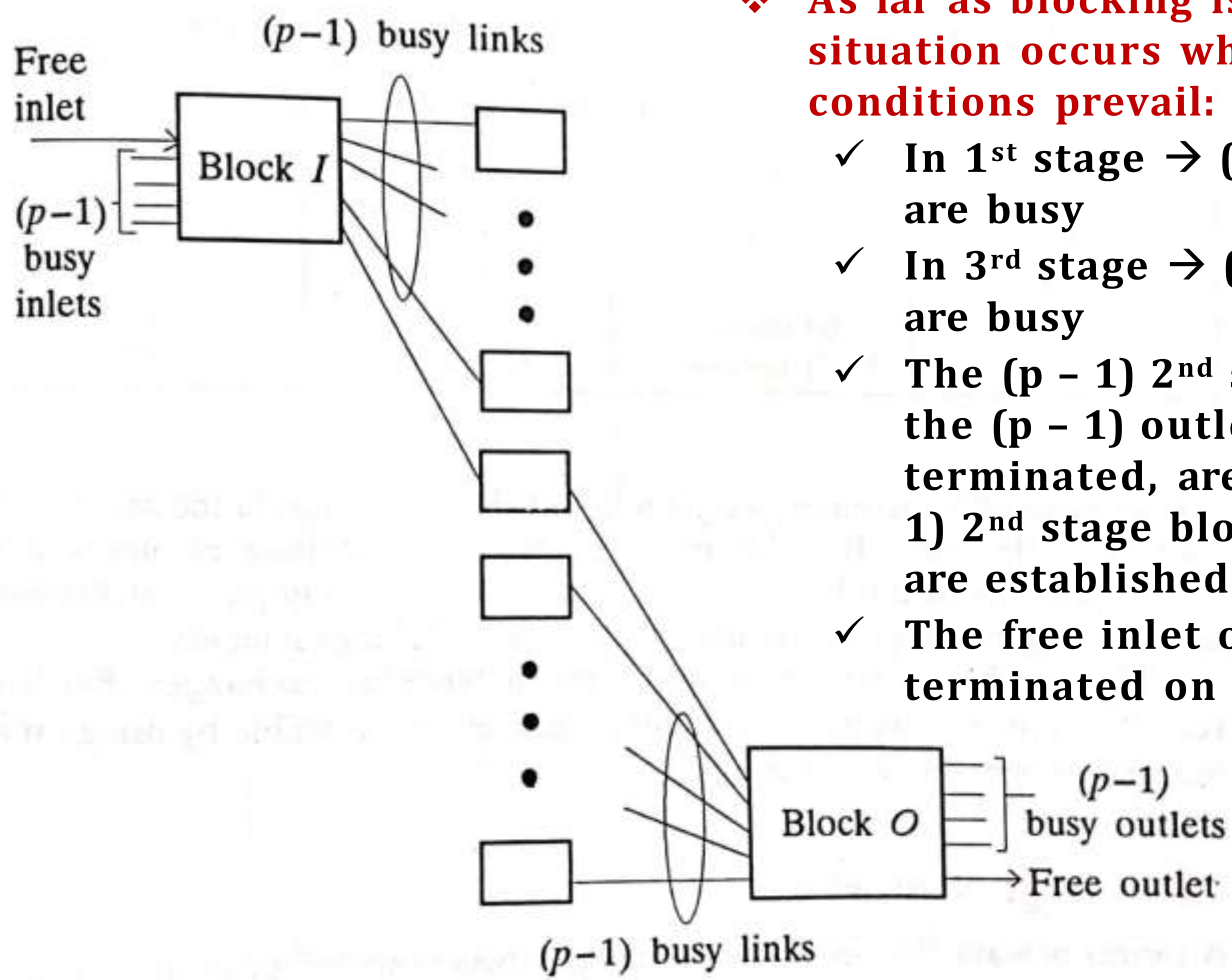
k = space expansion/concentration factor = s/p

If s > p ➔ 1st stage provide expansion

If s < p ➔ 1st stage provide concentration

Three-Stage Networks

- A 3-stage network can be made non-blocking by providing adequate number of blocks in the 2nd stage i.e. by increasing the value of s

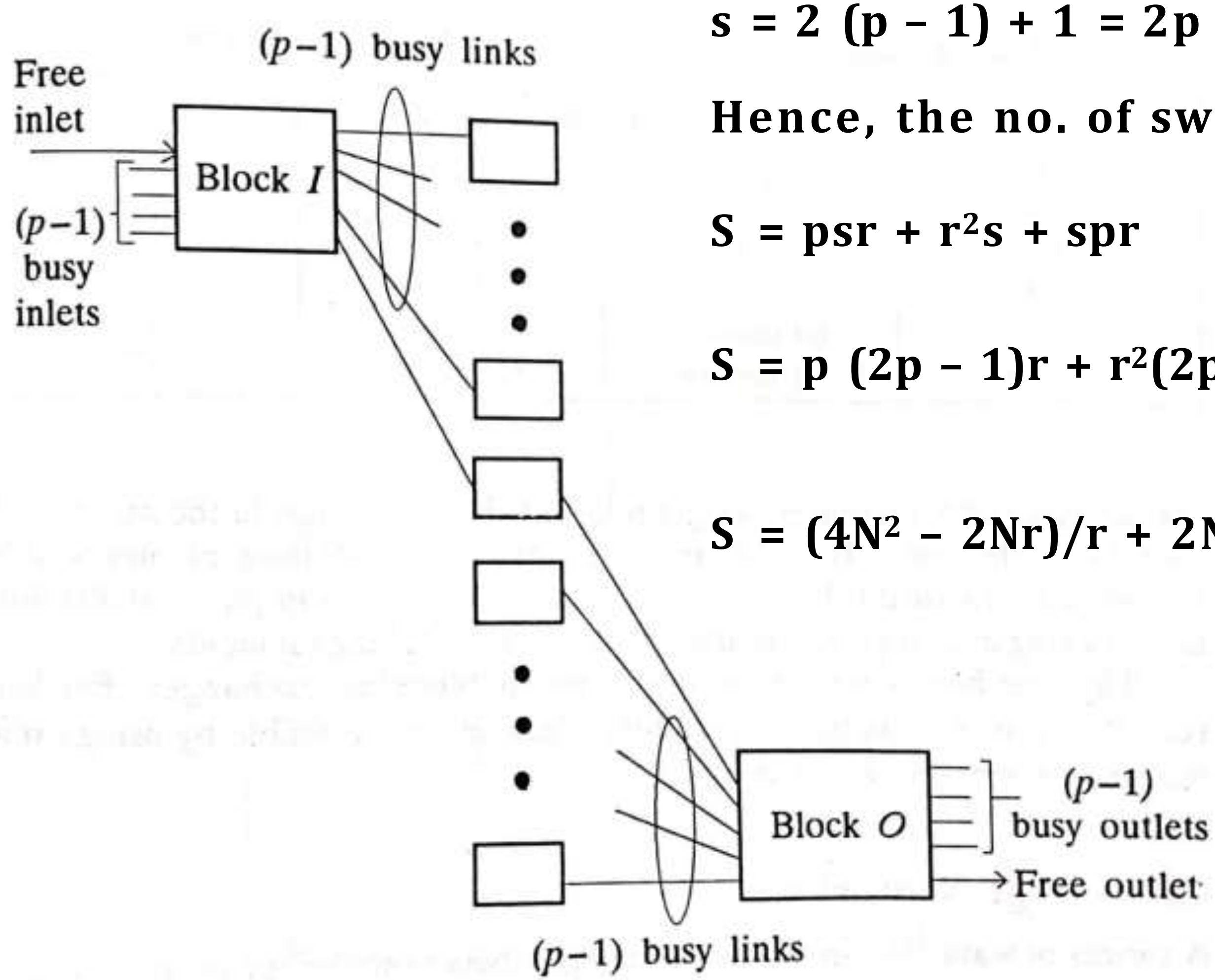


- As far as blocking is concerned, the worst situation occurs when the following conditions prevail:
  - ✓ In 1st stage → (p – 1) inlets in block *I* are busy
  - ✓ In 3rd stage → (p – 1) outlets in block *O* are busy
  - ✓ The (p – 1) 2nd stage blocks, on which the (p – 1) outlets from block I are terminated, are different from the (p – 1) 2nd stage blocks from which the links are established to the block O
  - ✓ The free inlet of block I needs to be terminated on the free outlet of block O

Figure: 3-stage non-blocking configuration

Three-Stage Networks

Under these circumstances, we require an additional block in the 2nd stage.



The number of blocks required in 2nd stage

$$s = 2\,(p - 1) + 1 = 2p - 1$$

Hence, the no. of switching elements

$$S = psr + r^2s + spr$$

$$S = p\,(2p - 1)r + r^2(2p - 1) + (2p - 1)\,pr$$

$$p = s = (N/r)$$

$$S = (4N^2 - 2Nr)/r + 2Nr - r^2$$

Three-Stage Networks – Non-blocking

$S = (4N^2 - 2Nr)/r + 2Nr - r^2$

Now find optimum value of r for minimizing the number of switching elements

$dS/dr = -4N^2/r^2 + 2N - 2r = 0$

$r^2 (N - r) = 2N^2$

For large value of N, we have N – r = N, and hence

$r^2 = 2N \Rightarrow r = \sqrt{(2N)}$

Substitute the value of r

$S_{min} = 4N^2/ \sqrt{(2N)} - 2N + 2N \sqrt{(2N)} - 2N$

$S_{min} = 4N \sqrt{(2N)} - 4N = 4N (\sqrt{(2N)} - 1)$

$S_{min} = 4N \sqrt{(2N)}$

Comparison – Single-stage and Multi-stage Network

Parameters	Single-stage	Multi-stage
Inlet to outlet connection	Through a single crosspoint	Through multiple crosspoint
Quality of link	Better due to single crosspoint	Degrade due to multiple crosspoint
Redundancy	No, i.e. if a croospoint fails, associated connection cannot be established	Yes, i.e. alternative crosspoints and paths are available
Number of crosspoints	Large	Reduced significantly
Nature of blocking	Non-blocking	Blocking
Time to establishing a call	Less	More

Example: A three-stage switching structure supports 128 inlets and 128 outlets. It is supposed to use 16 first stage and third stage matrices. What is the number of switching elements in the network if it is non-blocking?

Solution:

$$S = 4N \left(\sqrt{(2N)} - 1 \right)$$
$$S = 512 \times 15 = 7680$$

THANK YOU