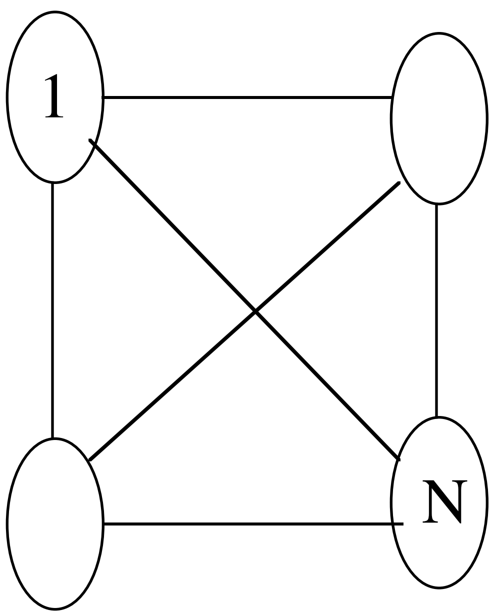
Telephone System

- Illustrate networking concepts
- Illustrate circuit switching
- Introduce ISDN
- Introduce Broadband-ISDN
- ATM

Switching

- Fully connected

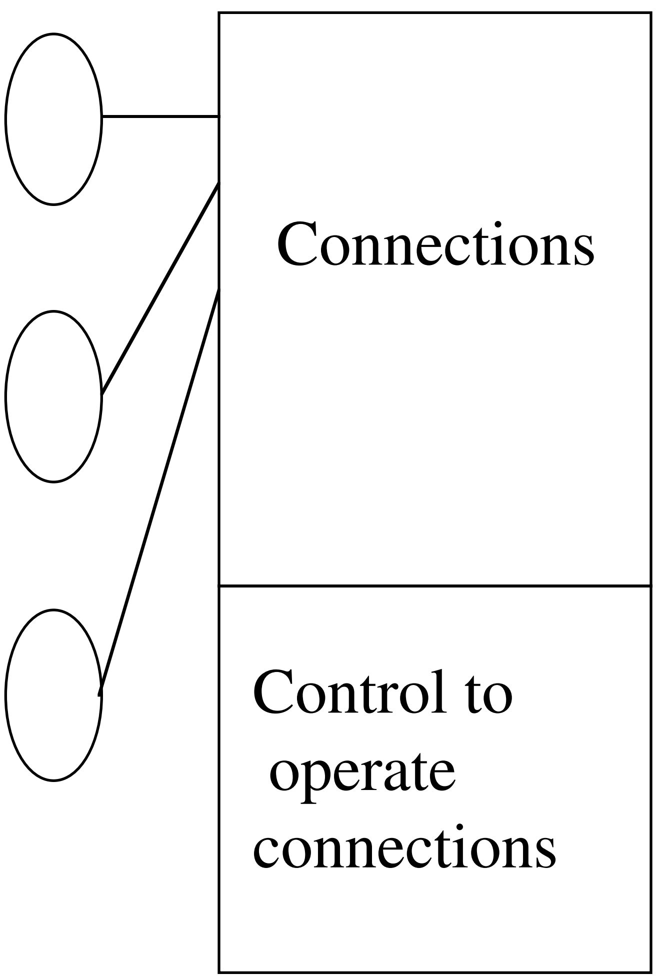


Number Nodes = N
Number of Lines = N(N-1)/2

Disadvantages: N is large
Long distances between nodes
Each node does switching

Switching

- Centralized switching



Number of Lines = N

Step-by-Step Switching

The Strowger Switch

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Step-by-Step Switching

- Calling-> Off-hook
  - Switch -> Connect to line finder to selectors
- Dial 5
  - Each pulse sends switch up one level, and it then scans around to find a free line, so can connect to any 5XXX number
- Dial 1
  - Pulse sends up one level, can connect to any 51XX

Step-by-Step Switching

- Dial 23
  - On last selector goes up to second level and around to third connection to connect to 5123
- Limited selectors means that calls can be blocked when a path is available
- Telephone number (address) is tied to the physical switch port

Crossbar Switch

Switch Architectures

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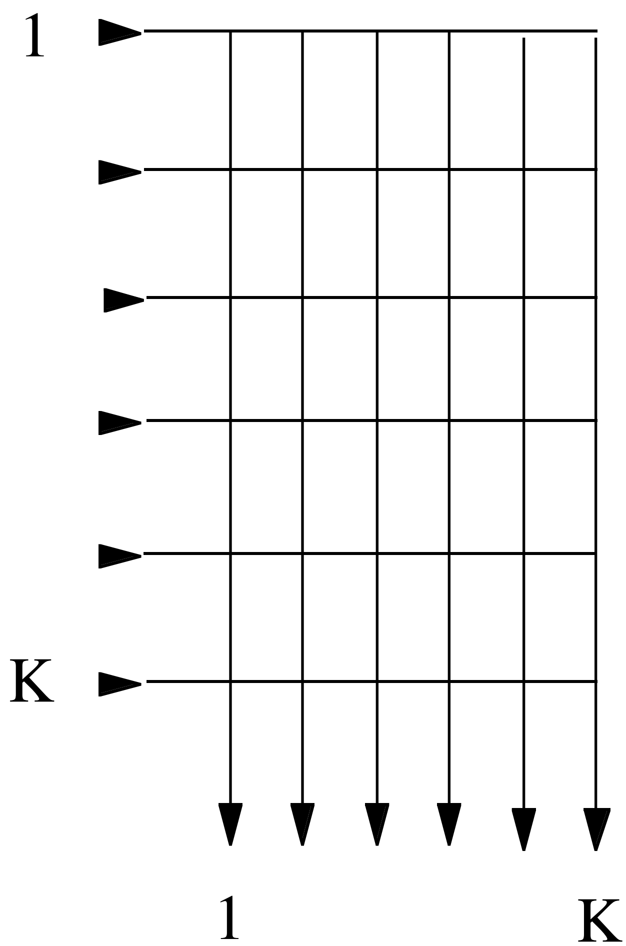

Distribution
Switch-toSwitch

Crossbar Switch

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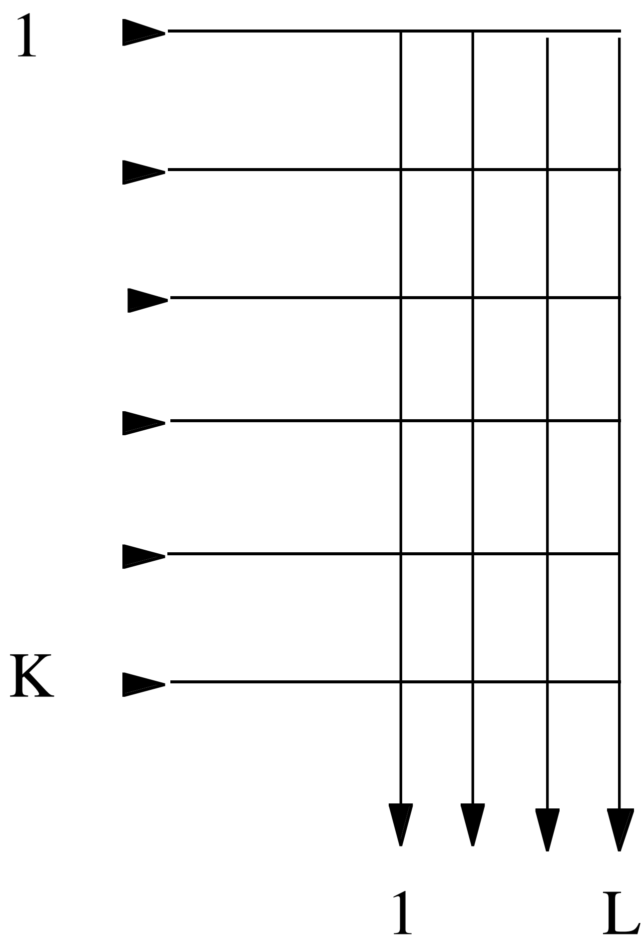
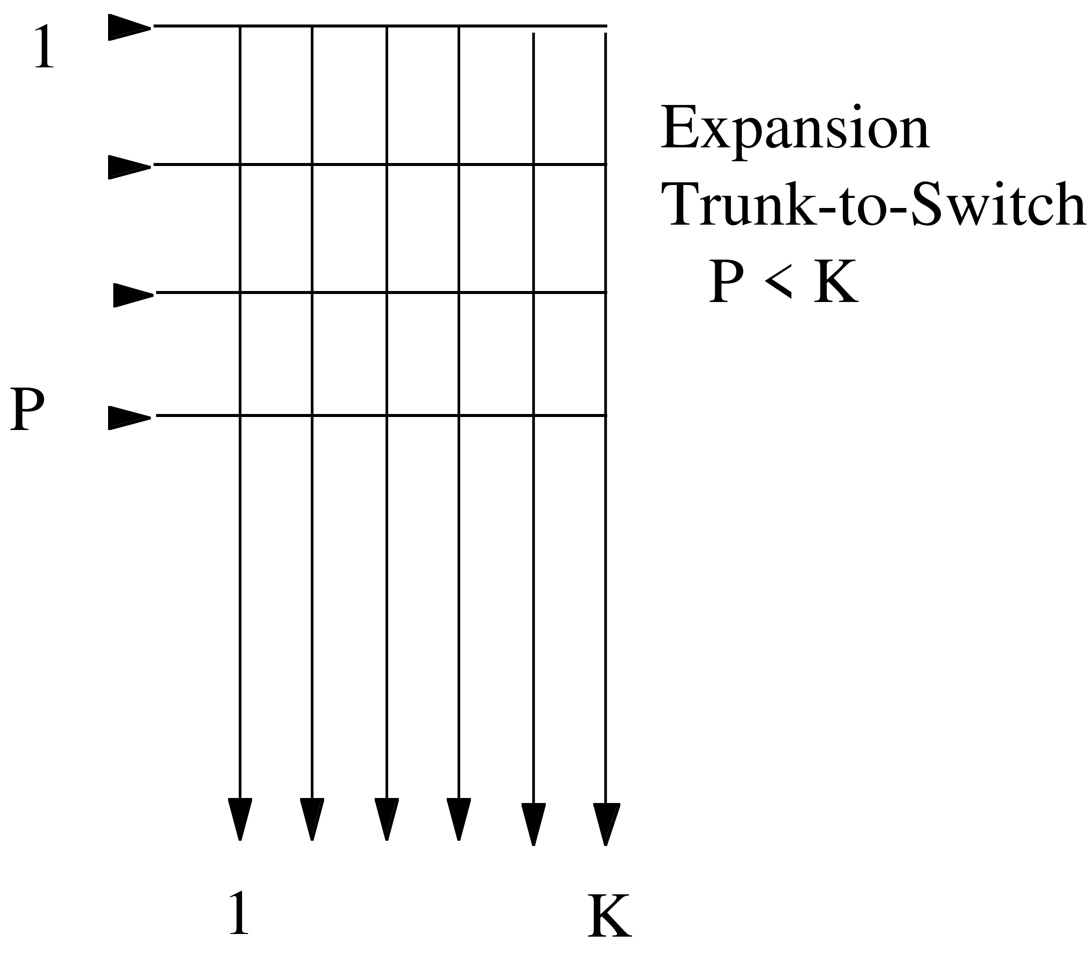


Concentration
K > L
Switch-to-Trunk

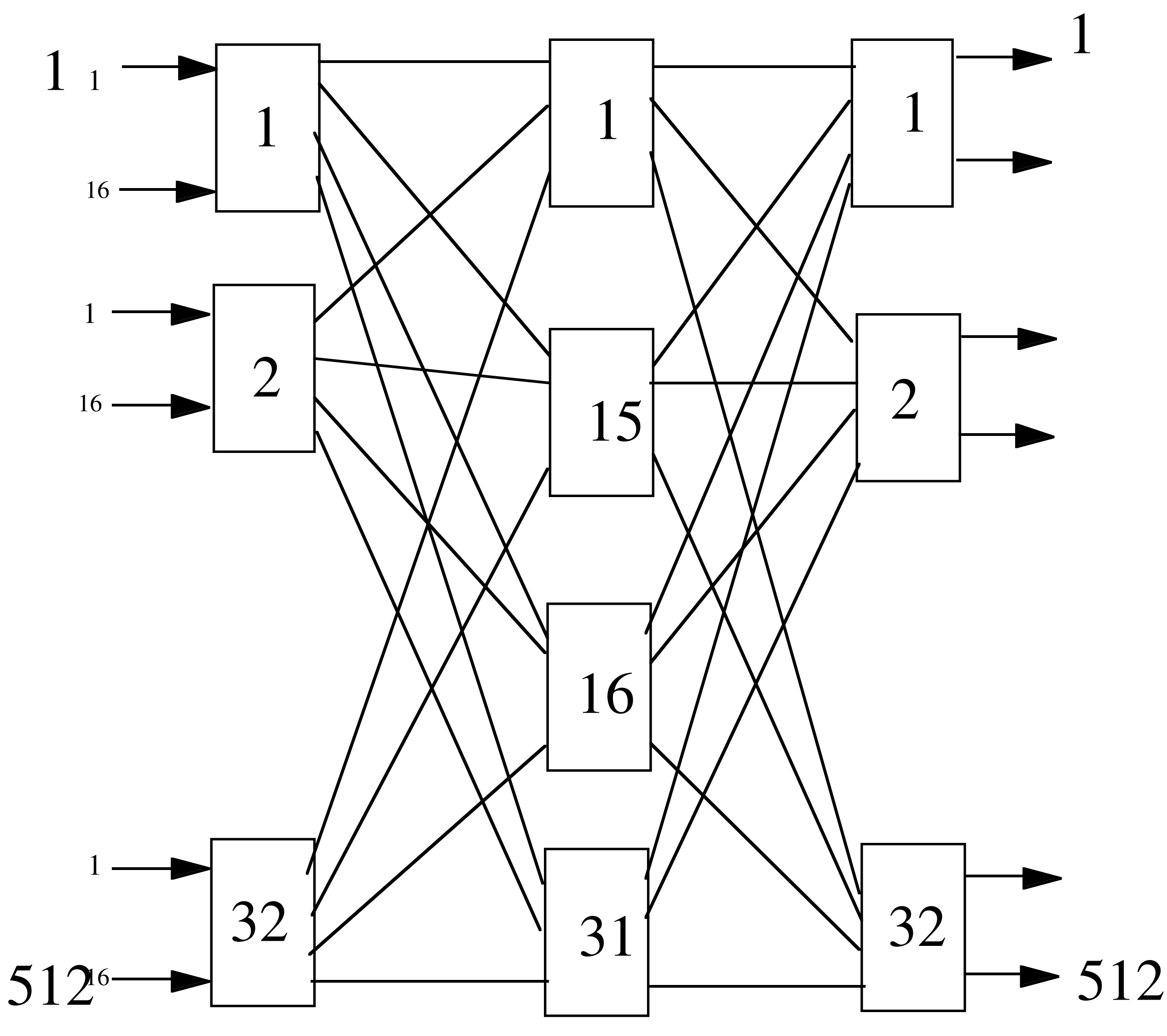
Crossbar Switch



Nonblocking Networks

- N ports need ~N*N switch connections or cross-points
- Using multistage switch architectures fewer cross points are needed
- Multistage switch architectures provide the model for the current generation of digital switches

Three Stage Spatial Switch Architectures

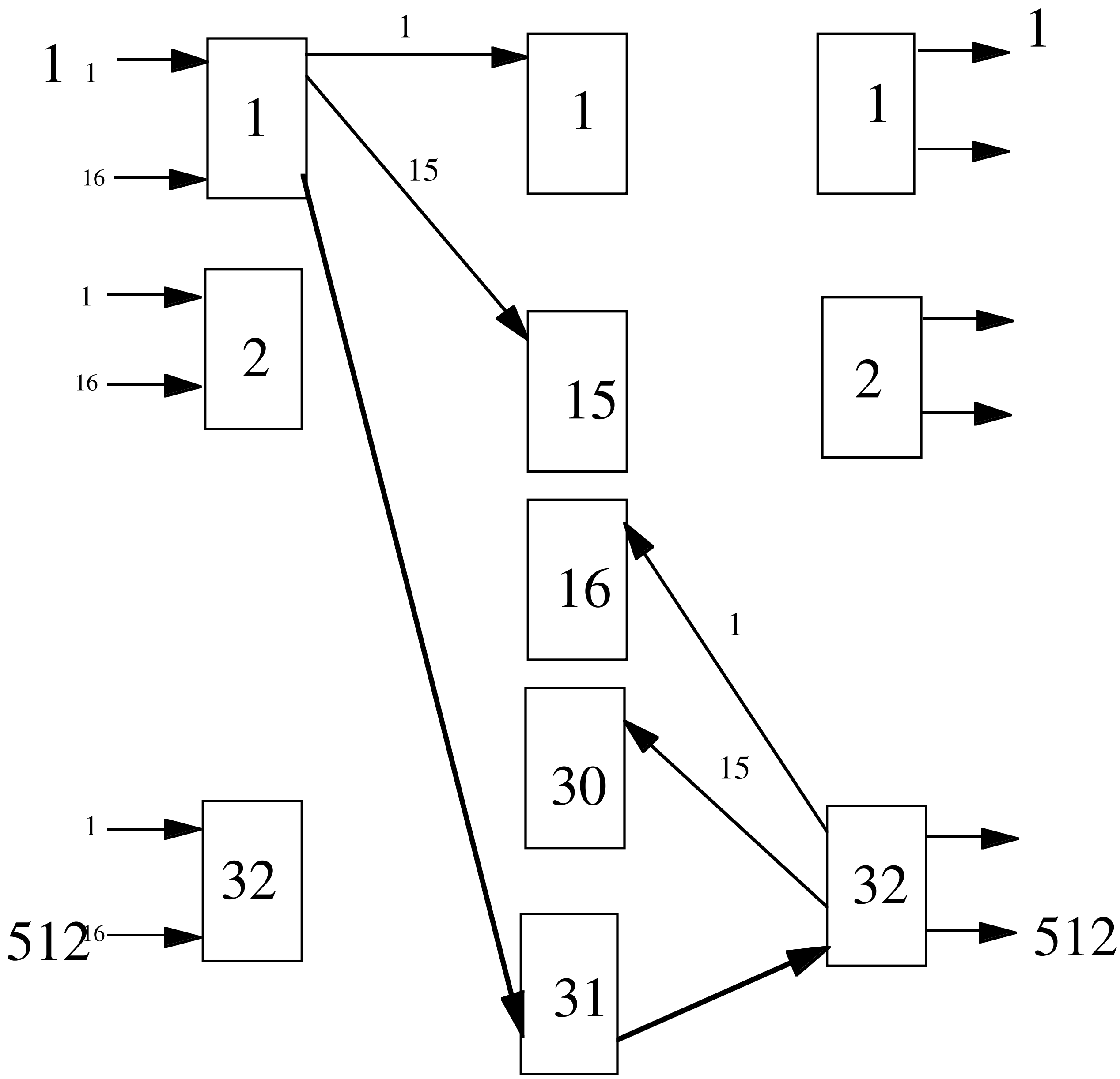


Three Stage Spatial Switch Architectures

- N input ports
- N output ports
- k center stage switches
- n input ports/first stage switch
- n output ports/last stage switch
- N/n first(last) stage switches

Three Stage Spatial Switch Architectures

Nonblocking Analysis



Three Stage Spatial Switch Architectures

Nonblocking Analysis

- n-1 (15) center stage switches busy serving output from stage 1 element
- n-1 (15) center stage switches busy serving
- input to stage 3 element
- Need one more center stage switch to serve the 16th input port on the stage one element
- $k = (n-1) + (n-1) + 1 = 2n - 1$ needed for nonblocking

Three Stage Spatial Switch Architectures

Non-blocking Analysis

Number of cross points

$$N_c = (N / n)(k \bullet n) \ + \ k(N / n) \ + \ (N / n)(k \bullet n)$$

$$= \ 2Nk \ + \ \frac{kN^2}{n^2}$$

For nonblocking $k \ = \ 2n - 1$, so

$$N_c \ = \ 2N(2n - 1) \ + \ (2n - 1)\left(\frac{N}{n}\right)^2$$

Minimum $N_c \ = \ 4N(\sqrt{2N} - 1)$

Example:

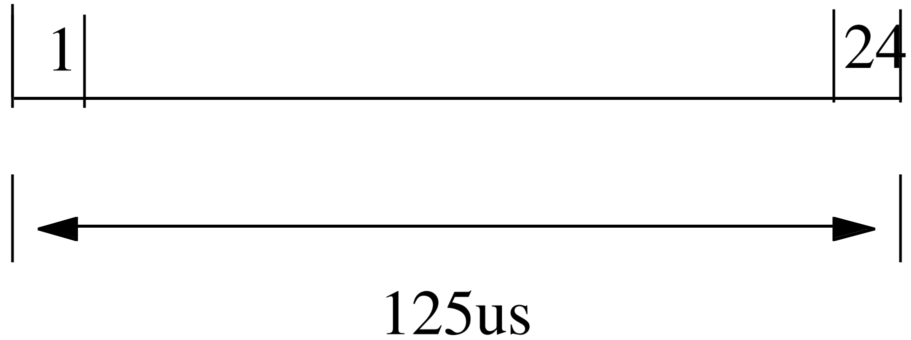
$N = 8{,}192$

Single Stage Switch N_c = 67 Million

Three Stage Switch N_c = 4.2 Million

Digital Switching

- All voice signals are digital
- TDM is used
- Sample rate is 8000 samples/ sec.
- Time between samples is 125us
- 8 bits/sample



Digital Switching

- Time Slot Interchanger (**T**)
  - Sequential write - random read
  - Random read - sequential write
  - Random read - random write
- Memory & speed requirements
  - Let N_s=Number of time slots/frame
  - Rate = $(N_s*8)/125us$ b/s
  - Memory requirement = (N_s*8) bits

Digital Switching

- Examples:
  - N_s=128
    - Rate = (128*8)/125us=8.192Mb/s
    - Memory = 128 bytes
  - N_s=131,072 (ESS #4)
    - Rate = 8.389 Gb/s
    - Memory 131,072 bytes

Digital Switching

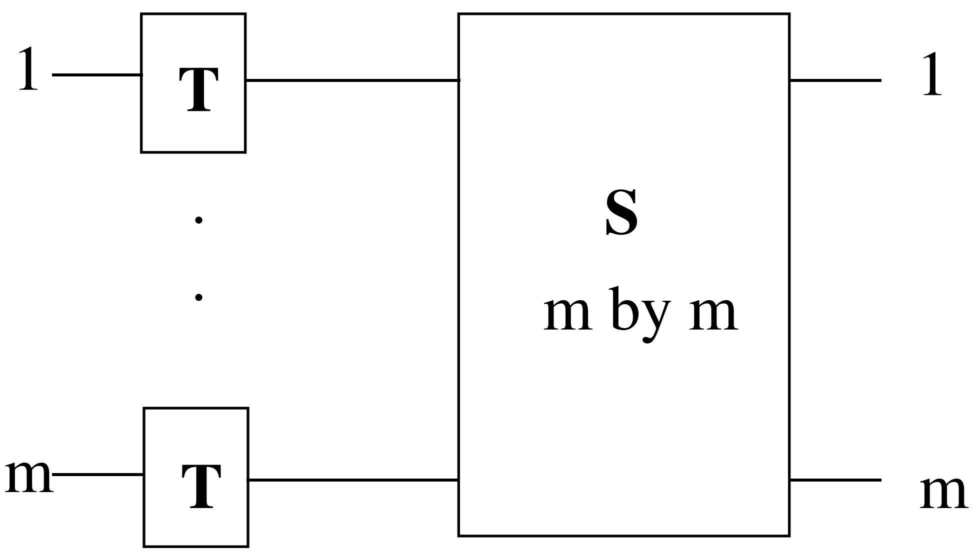
- Time shared space division switch (**S**)
  - Fast electronic crossbar switch
  - Switch configuration changes every time slot
  - Each input(output) is a TDM bus
  - Slot X on TDM input bus i can be switched to Slot X on TDM output bus j

Digital Switch Architectures

- One stage: TSI only (**T**)
- One stage: Time shared space division only (**S**)

Digital Switch Architectures

- T -S



User A on input TDM slot 3, bus 1 ==> User B on output TDM slot 6, bus 5

T stage does TSI

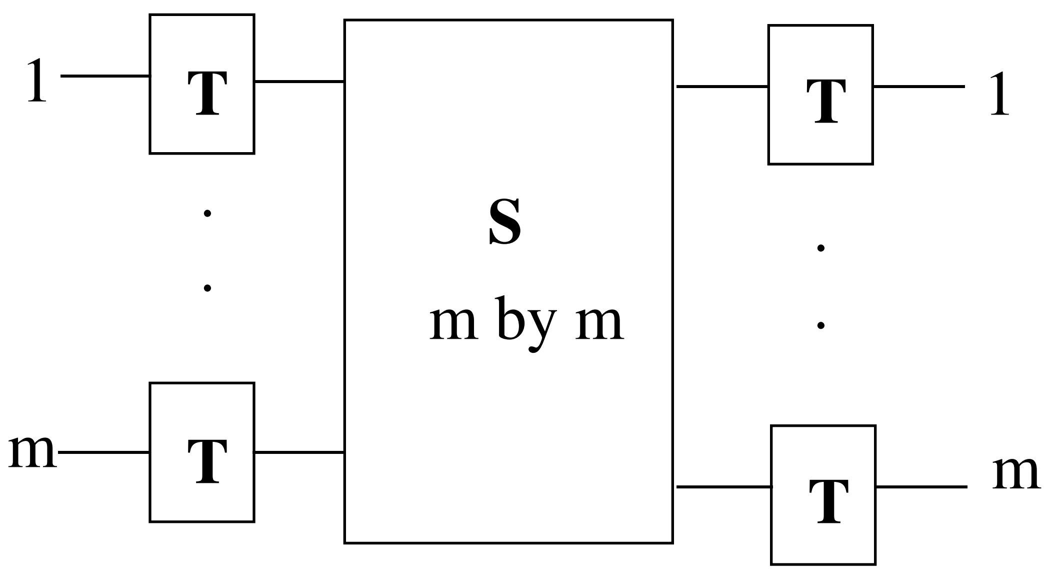
Input to S stage is slot 6 on bus 1

S stage does space switching

Output is slot 6 on bus 5

Digital Switch Architectures

- T -S- T



Digital Switch Architectures

- Slot 2 on bus 1 --> Slot 5 on Bus 10
  - Slot 2 on bus 1 (TSI) Slot 5 on bus 1 (input to S-stage)
  - Slot 5 on bus 1 (S) Slot 5 on bus 10
- Slot 3 on bus 1--> Slot 5 on Bus 20
  - Slot 3 on bus 1 (TSI) Slot 4 on bus 1 (input to S-stage)
  - Slot 4 on bus 1 (S) slot 4 on bus 20 (output from S-stage)
  - Slot 4 on bus 20 (TSI) slot 5 on bus 20

Digital Switch Architectures

Non-blocking Analysis

Let T_{in} = Total number on input time slots

= m(busses)T (slots / bus)

Let N_{in} = Total number of space stage time slots

= m (busses) N(slots / bus)

Using same analysis applied to the three stage switch, if $N_{in} = 2T_{in} - 1$ then the system is nonblocking.

Example:

Number of users = 2048, T = 128, m = 16

A 16 - by - 16 space switch at 8.192 Mb / s per bus.

$N_{in} = 2T_{in} - 1 = 2(128)16 - 1 \sim 4096$

$N = N_{in} / m = 4096 / 16 = 256$

A speed up of a factor of two in the space stage switch will make the TST switch nonblocking.