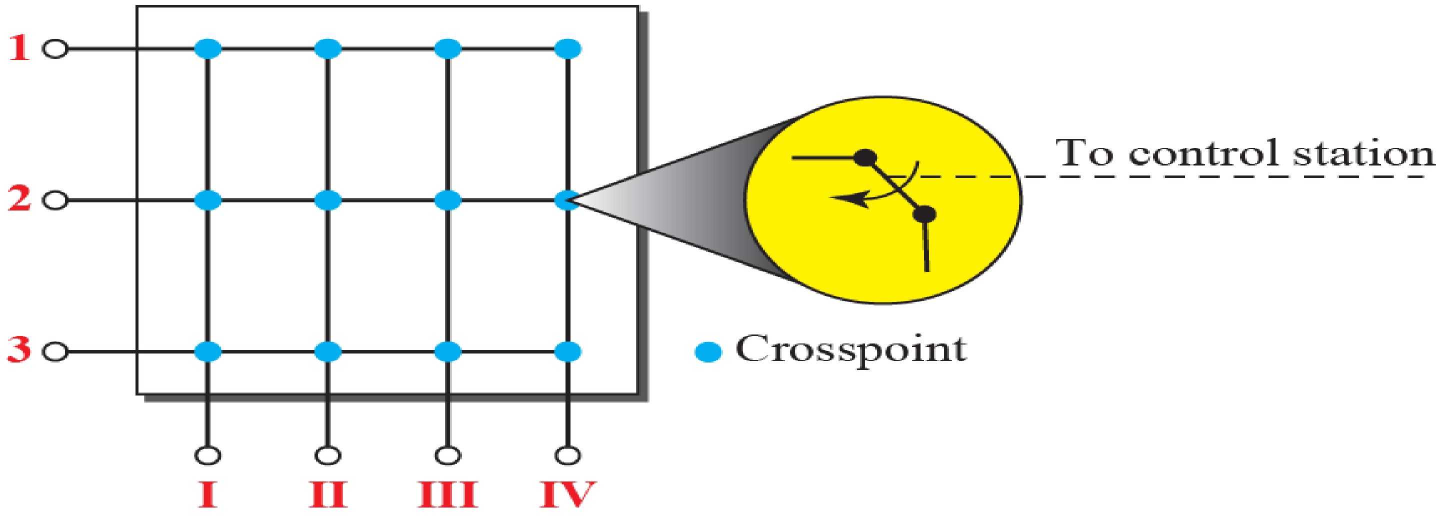
Structure of Circuit Switches

Circuit switching can use either of two technologies: the space-division switch or the time-division switch.

Crossbar Switch with 3 Inputs and 4 Outputs

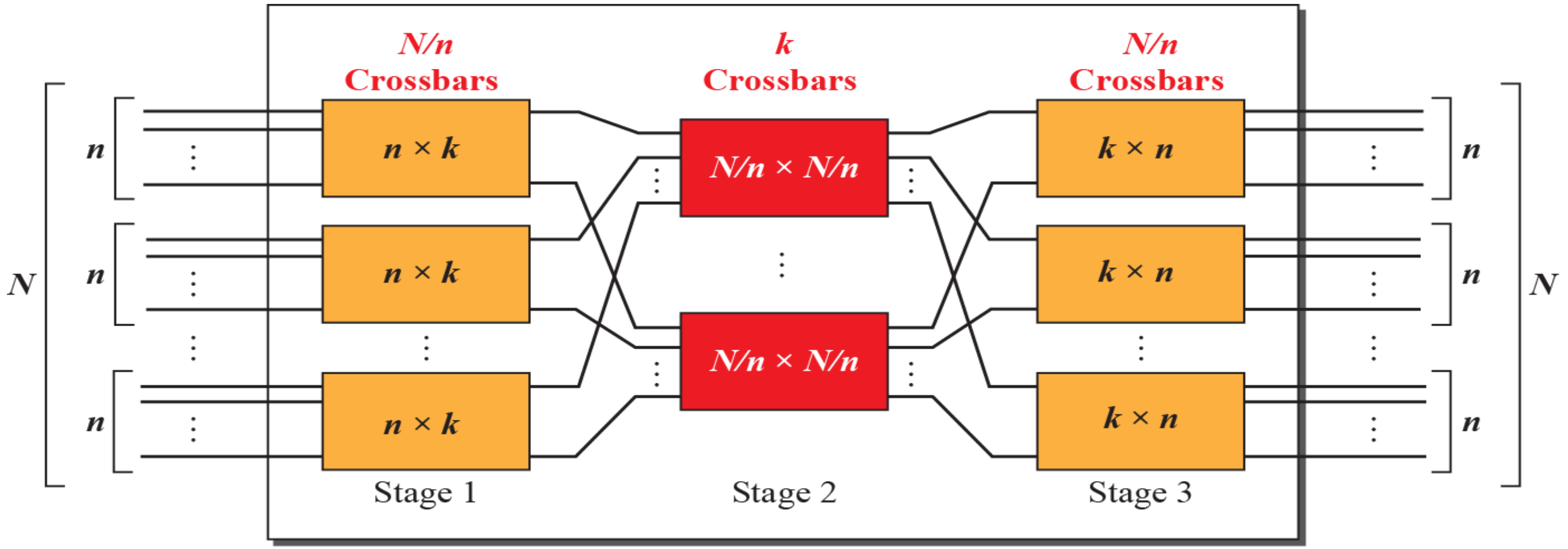


N^2 crosspoints

Most of the crosspoints may not be in use at any given time

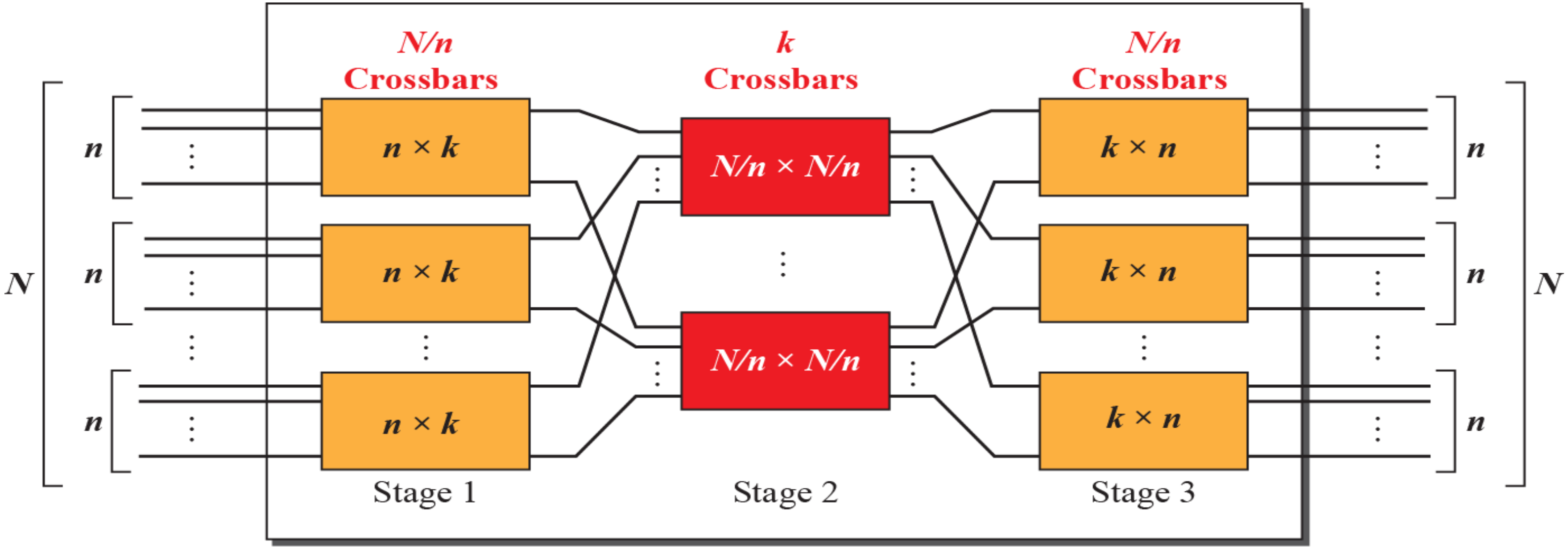
Non-blocking; connection never denied due to lack of crosspoints

Multistage Switch



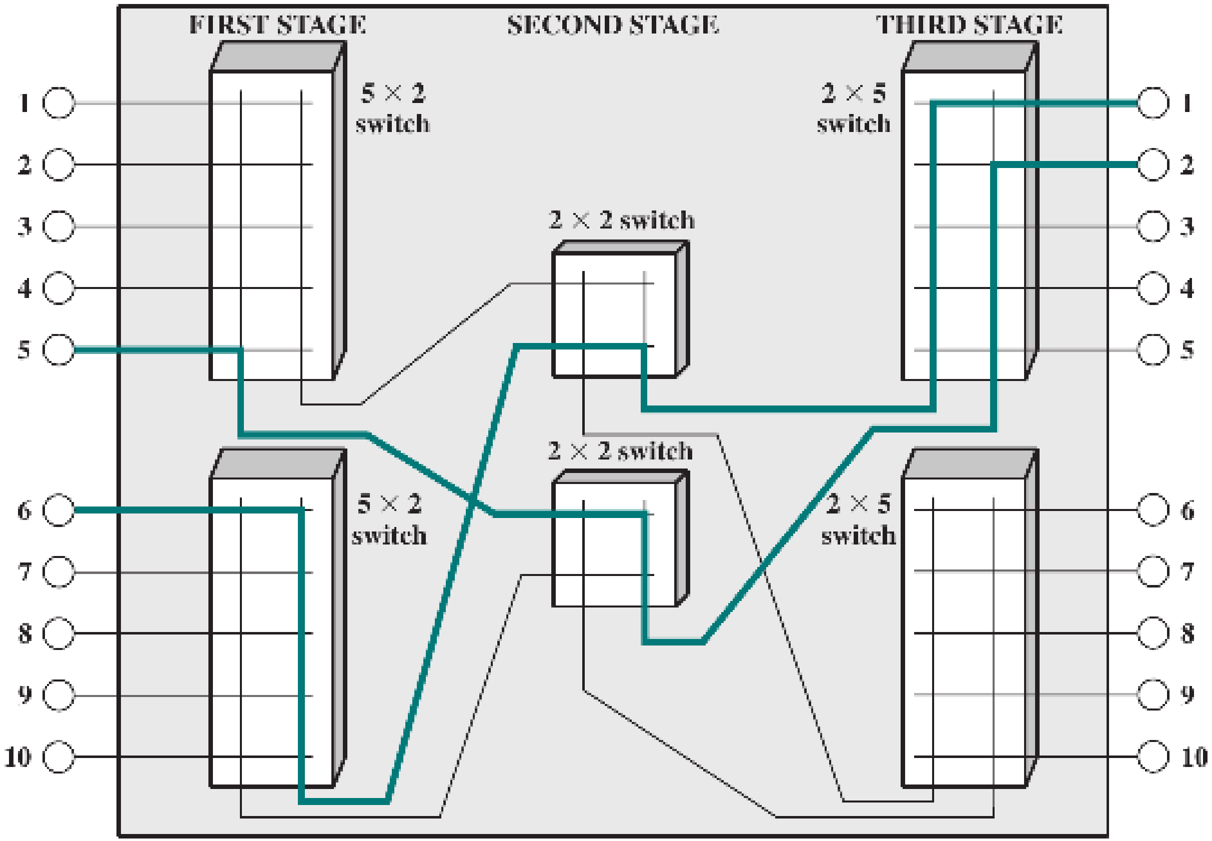
- Three stages of smaller space-division switches
- Each set of *n* input lines shares *k* paths to any one of the switches in the last stage

Multistage Switch



Total number of cross points: $\frac{N}{n}(n \times k) + k\left(\frac{N}{n} \times \frac{N}{n}\right) + \frac{N}{n}(k \times n) = 2kN + k\left(\frac{N}{n}\right)^2$

Multistage Switch



Example

Design a three-stage, 200 × 200 switch ($N = 200$) with $k = 4$ and $n = 20$.

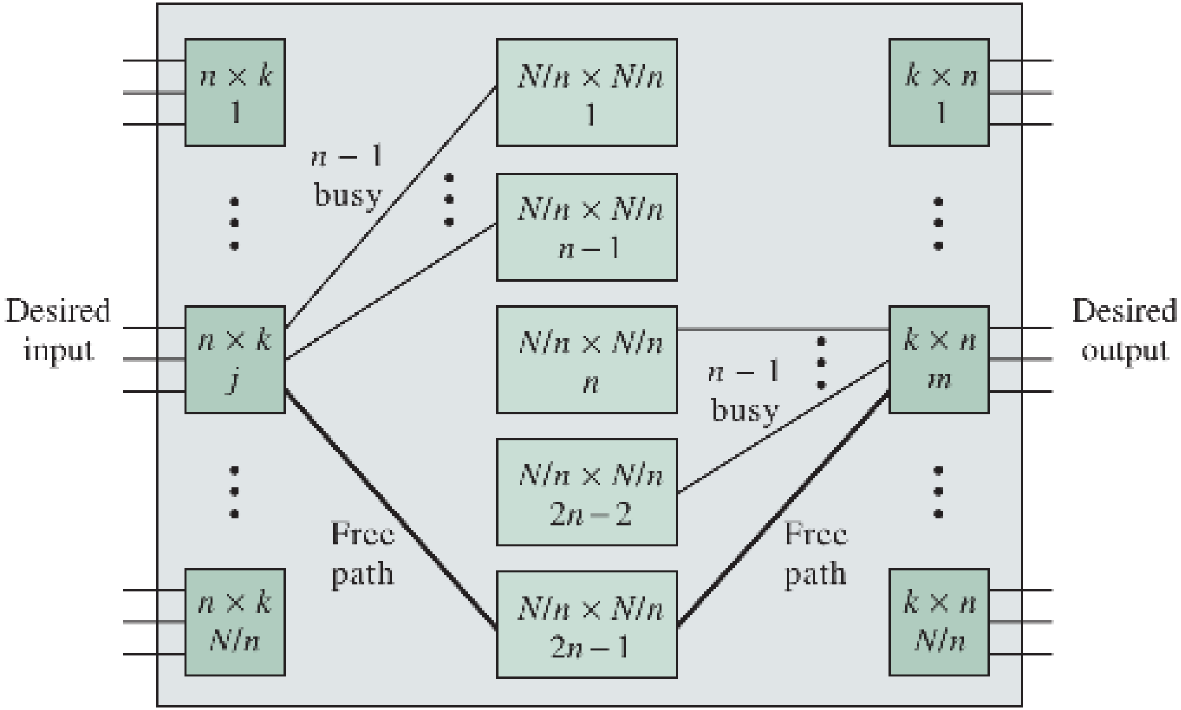
Solution

In the first stage we have N/n or 10 crossbars, each of size 20 × 4. In the second stage, we have 4 crossbars, each of size 10 × 10. In the third stage, we have 10 crossbars, each of size 4 × 20. The total number of crosspoints is

$$2kN + k(N/n)^2 = 2000 \text{ crosspoints.}$$

This is 5 percent of the number of crosspoints in a single-stage switch (200 × 200 = 40,000).

Clos Criterion for Non-blocking Switch



To avoid blocking: $k >= 2n-1$

Clos Criterion for Non-blocking Switch

Total number of cross points: $2Nk + k(N/n)^2$

With non-blocking criterion: $k = 2n - 1 \Longrightarrow 2N(2n-1) + (2n-1)(N/n)^2$

Min. number of n under non-blocking criterion: $n \approx (N/2)^{\frac{1}{2}}$

Min. number of non-blocking crosspoints: $4N([2N]^{\frac{1}{2}} - 1)$

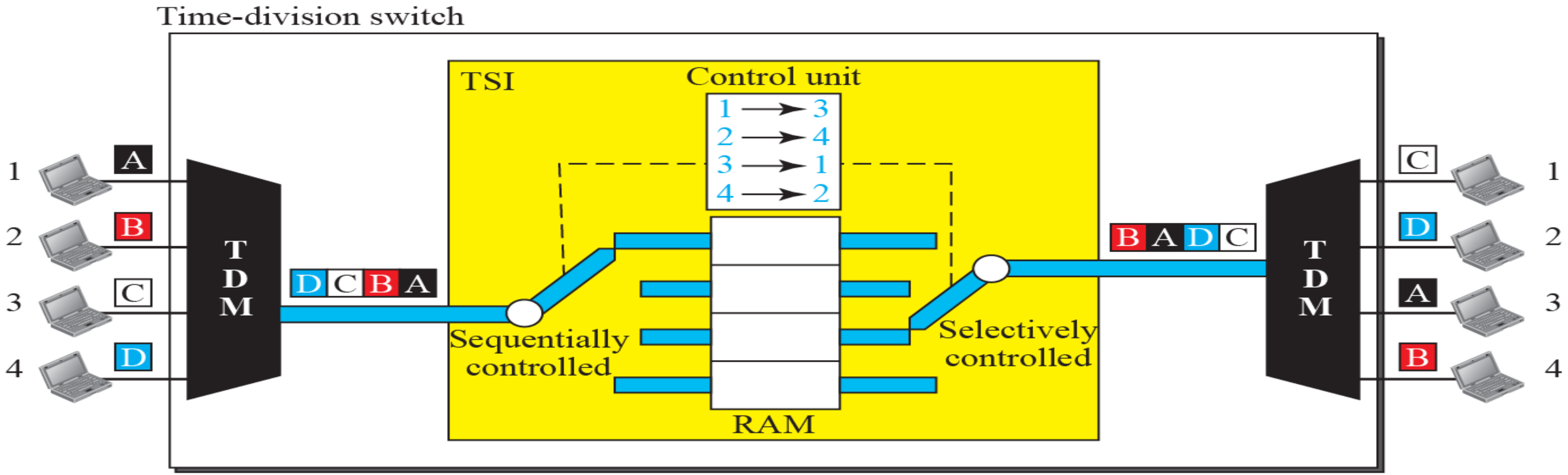
Example

Redesign the previous three-stage, 200 × 200 switch, using the Clos criteria with a minimum number of crosspoints.

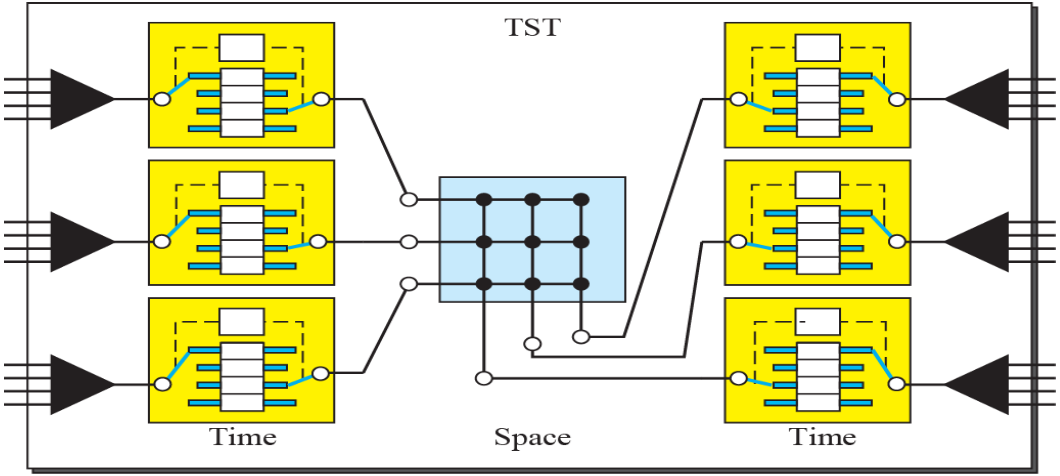
Solution

We let $n = (200/2)^{1/2}$, or $n = 10$. We calculate $k = 2n - 1 = 19$. In the first stage, we have 200/10, or 20, crossbars, each with 10 × 19 crosspoints. In the second stage, we have 19 crossbars, each with 10 × 10 crosspoints. In the third stage, we have 20 crossbars each with 19 × 10 crosspoints. The total number of crosspoints is 20(10 × 19) + 19(10 × 10) + 20(19 × 10) = 9500. If we use a single-stage switch, we need 200 × 200 = 40,000 crosspoints. The number of crosspoints in this switch is 24 percent that of a single-stage switch.

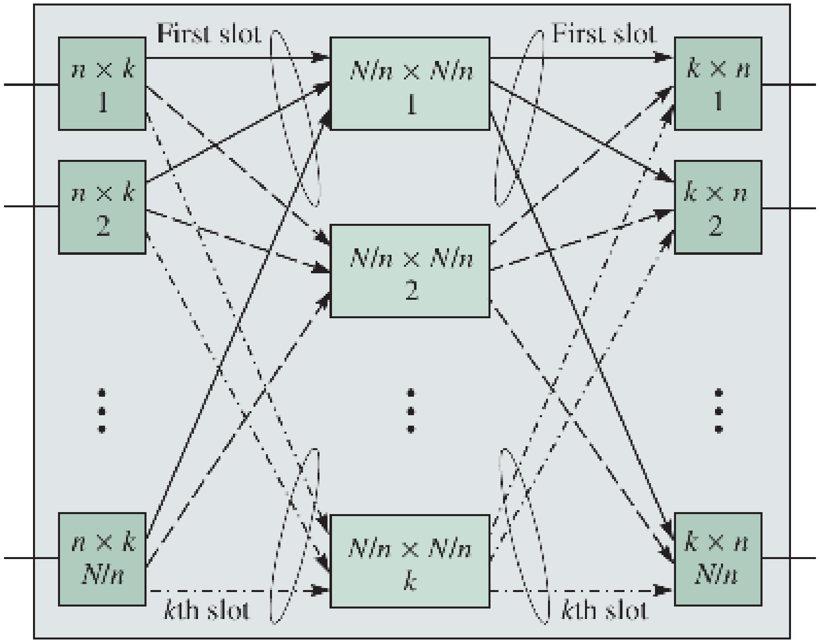
Time-slot Interchange

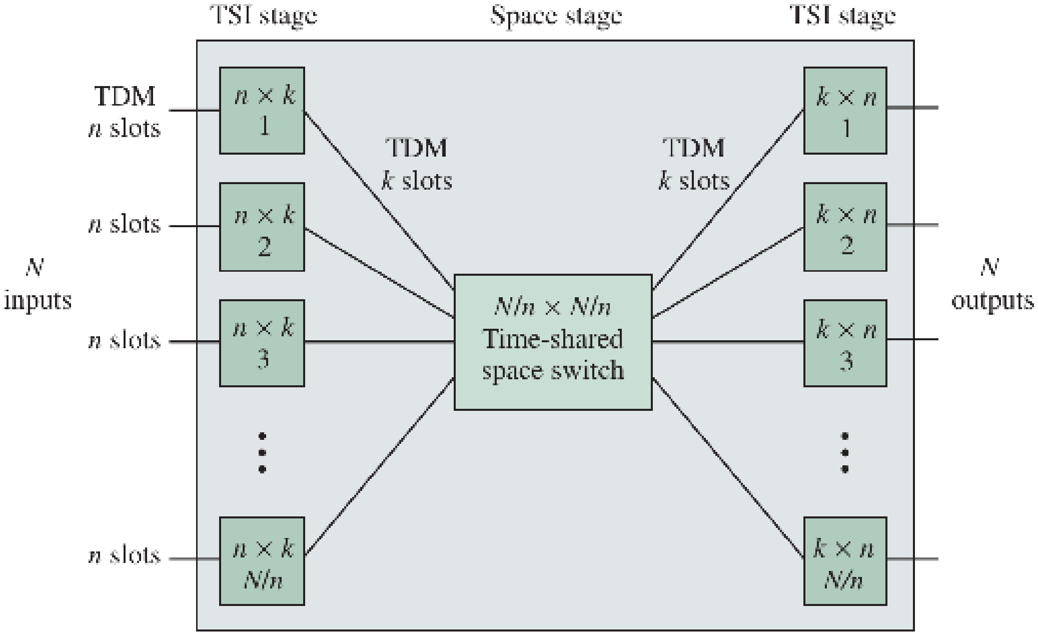


Time-Space-Time (Hybrid) Switch



Time Sharing of Crossbar Switch in TST



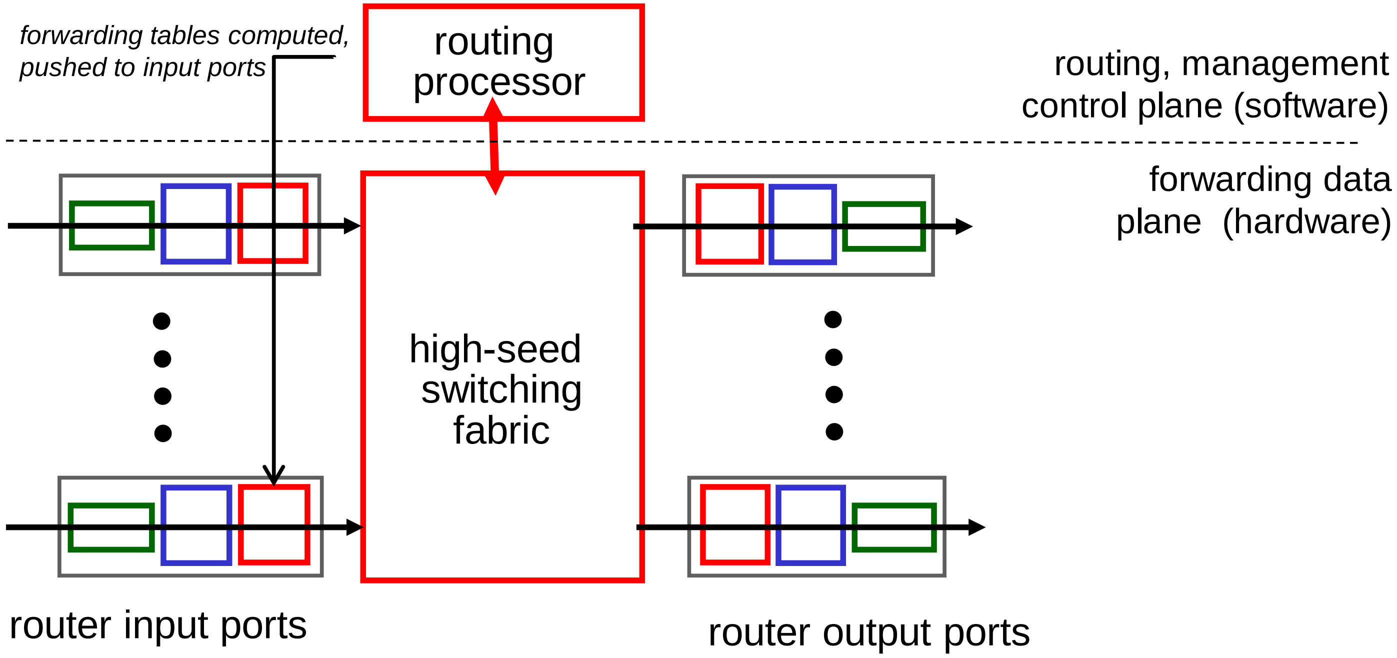


At any time-slot, only one intermediate switch is active

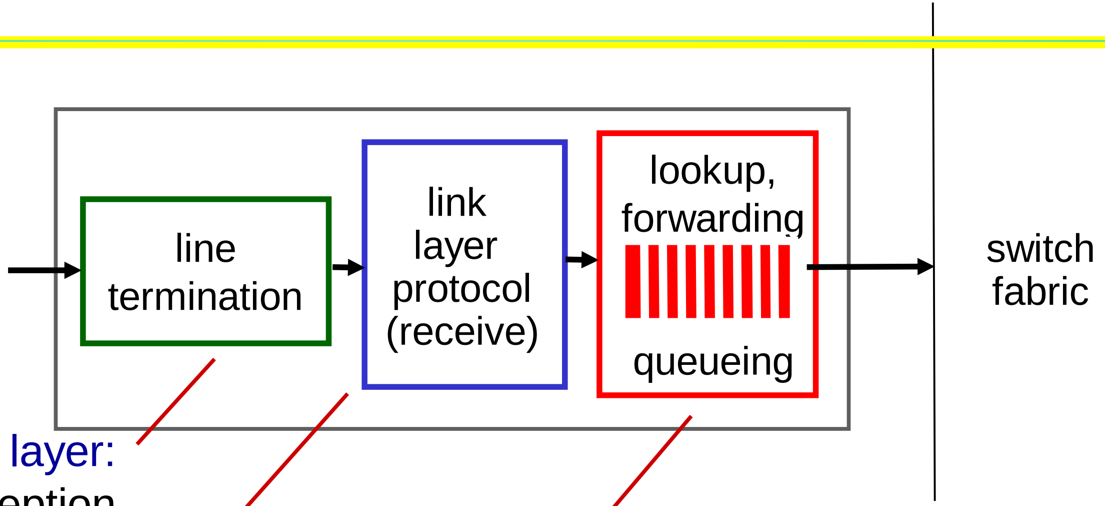
Structure of Packet Switches

four components: input ports, output ports, the routing processor, and the switching fabric.

- run routing algorithms/protocol
- *forwarding* datagrams from incoming to outgoing link



Input Port



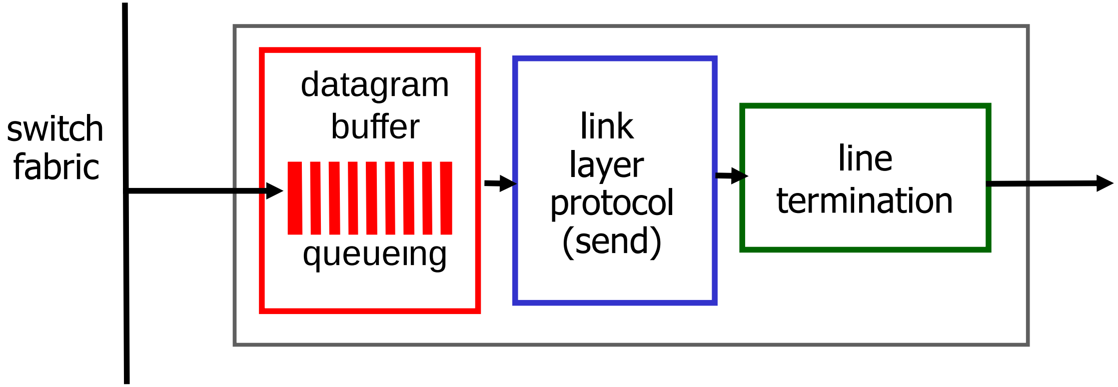
physical layer:
bit-level reception

data link layer:
e.g., Ethernet

decentralized switching:

- given datagram dest., lookup output port using forwarding table in input port memory
- goal: complete input port processing at 'line speed'
- queuing: if datagrams arrive faster than forwarding rate into switch fabric

Output Port



- *buffering* required from fabric faster rate

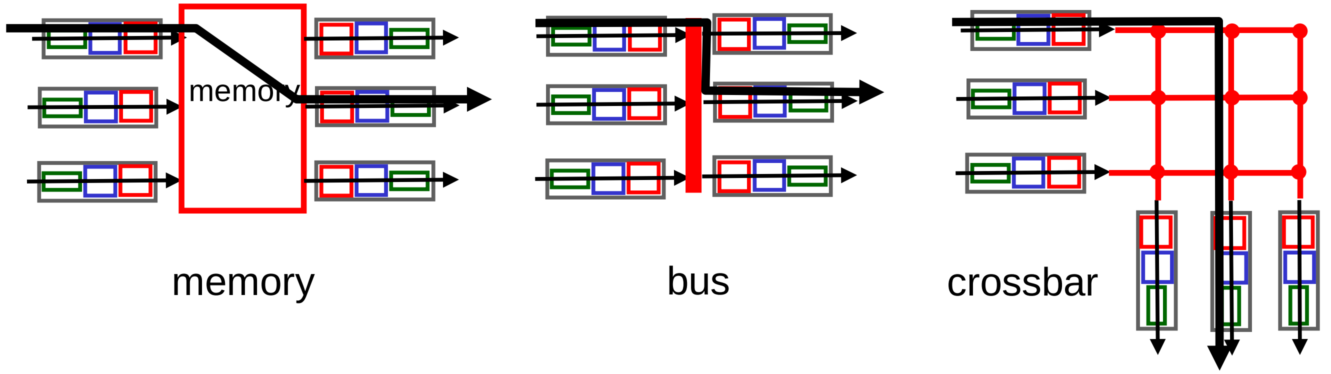
Datagram (packets) can be lost due to congestion, lack of buffers

- *scheduling* datagrams

Priority scheduling – who gets best performance, network neutrality

Switching Fabric

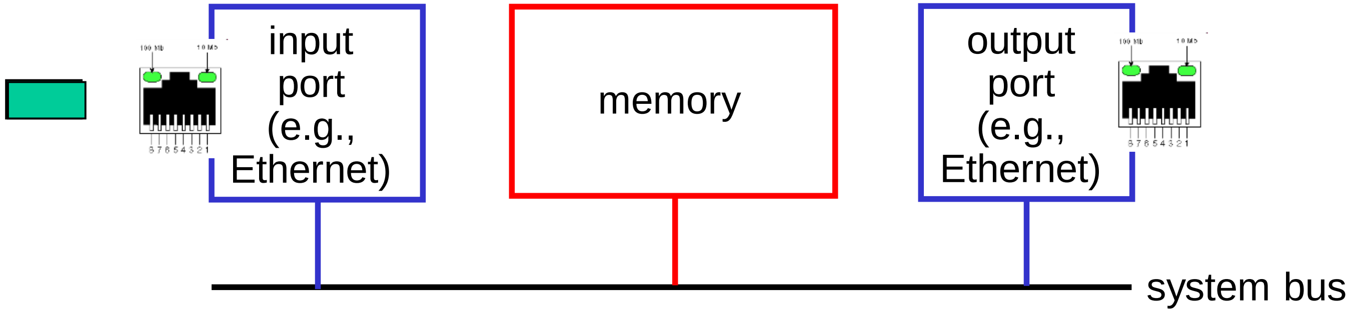
- transfer packet from input buffer to appropriate output buffer
- switching rate: rate at which packets can be transfer from inputs to outputs
  - often measured as multiple of input/output line rate
  - N inputs: switching rate N times line rate desirable
- three types of switching fabrics



Switching via Memory

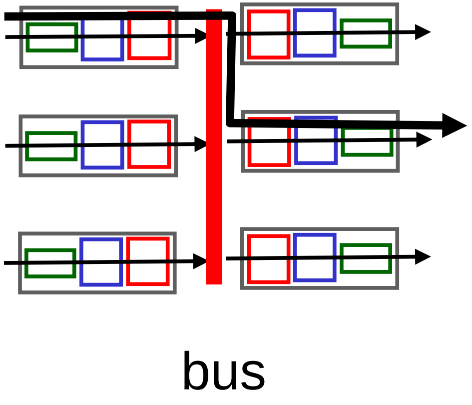
first generation routers:

- traditional computers with switching under direct control of CPU
- packet copied to system' s memory
- speed limited by memory bandwidth (2 bus crossings per datagram)



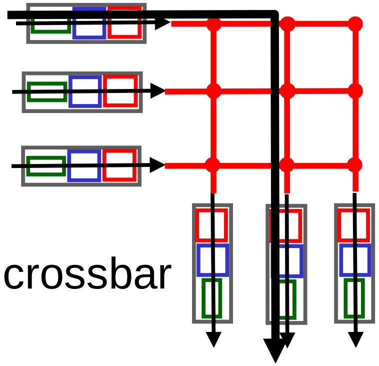
Switching via a Bus

- datagram from input port memory
 to output port memory via a shared bus
- *bus contention:* switching speed limited by bus bandwidth
- 32 Gbps bus, Cisco 5600: sufficient speed for access and enterprise routers

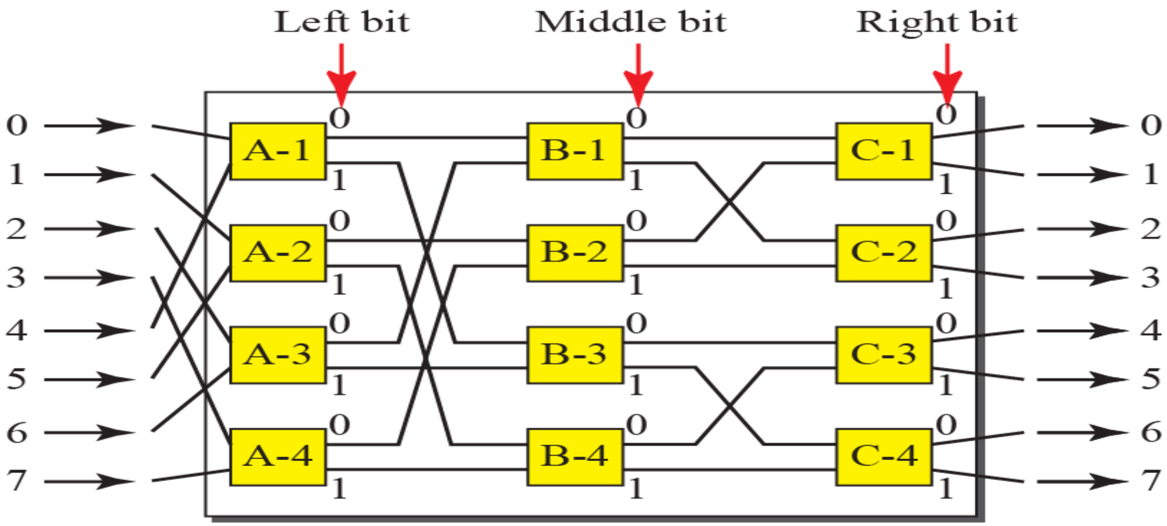


Switching via Interconnection Network

- overcome bus bandwidth limitations
- banyan networks, crossbar, other interconnection nets initially developed to connect processors in multiprocessor
- advanced design: fragmenting datagram into fixed length cells, switch cells through the fabric.
- Cisco 12000: switches 60 Gbps through the interconnection network



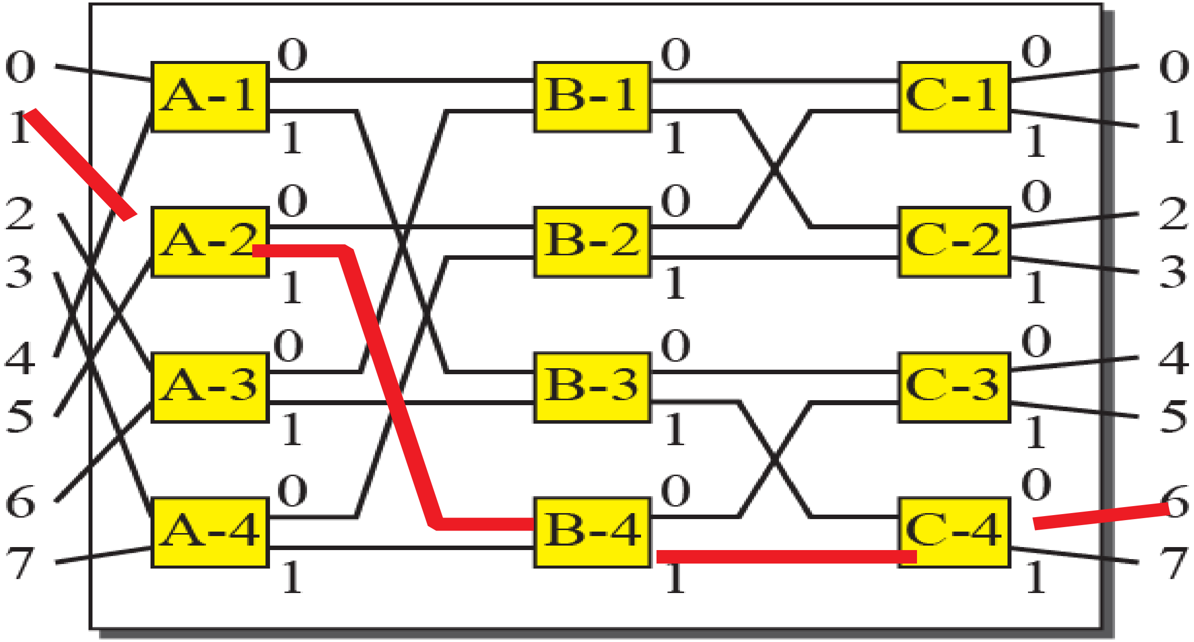
A Banyan Switch



- A banyan switch is a multistage switch with microswitches at each stage that route the packets based on the output port represented as a binary string.

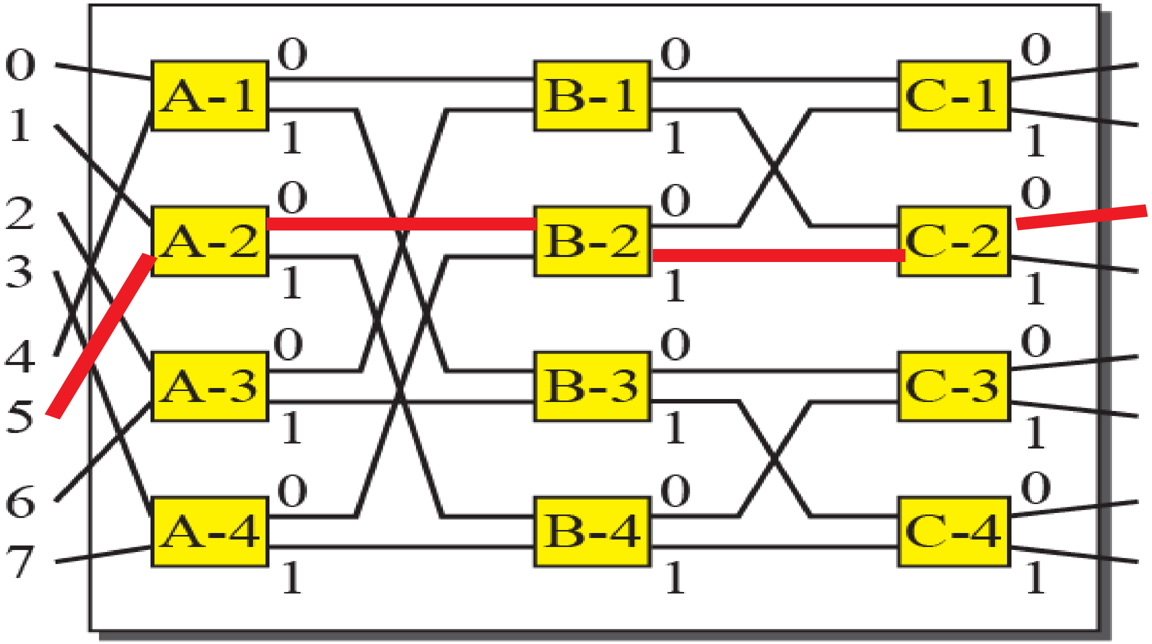
- For *n* inputs and *n* outputs, we have *log2(n)* stages with *n/2* microswitches at each stage.

Example of Routing in a Banyan Switch



a. Input 1 sending a cell to output 6 (110)

Example of Routing in a Banyan Switch



b. Input 5 sending a cell to output 2 (010)

Batcher-Banyan Switch