TSN: Lecture 2
Clos Network

Topics Covered

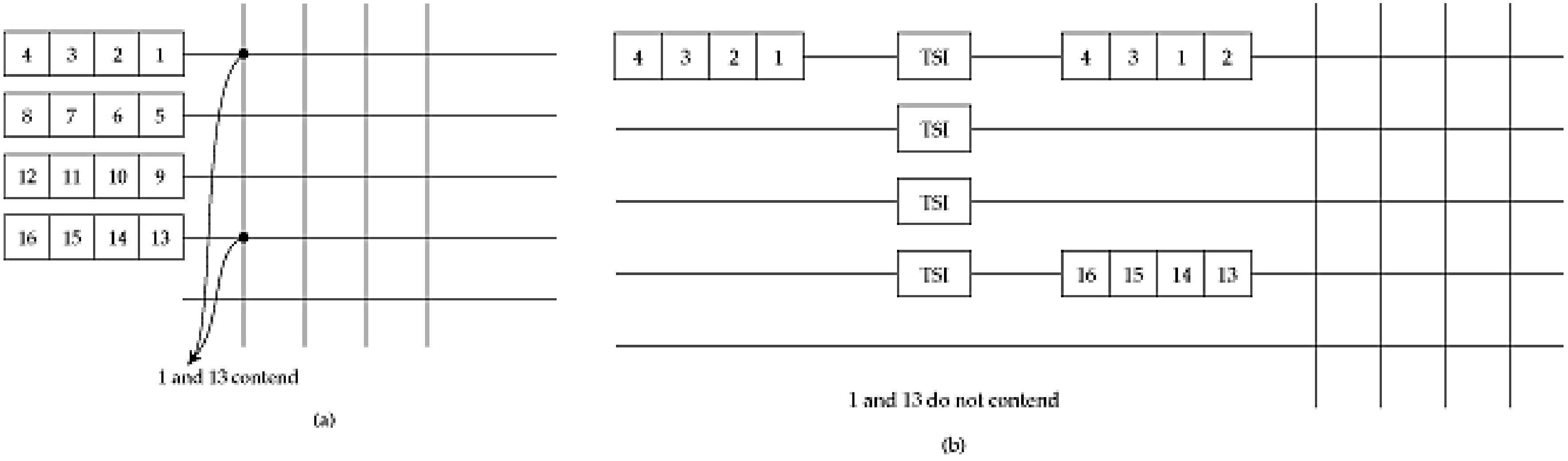
- Time –space switching
- Clos Network
- Time -space-Time switching

Clos Network

- How large should be *k* (# of center stages) for the switch to be internally non-blocking??
  - Clos [1953 paper] showed that if a switch controller is willing to *rearrange* existing connections when a new call is arrived, the condition is
    - $k \geq n$ (i.e., the number of center stages must be greater than the number of inputs in a group) ($k=2n-1$)
    - Also called *re-arrangably non-blocking switch*
    - In practice we cannot rearrange live calls (without breaking the circuit) - becomes complex (make before break)
  - Clos network of size *NxN* has $2N(2n-1)+(2n-1)x(N/n)^2$ cross points, way smaller than N^2

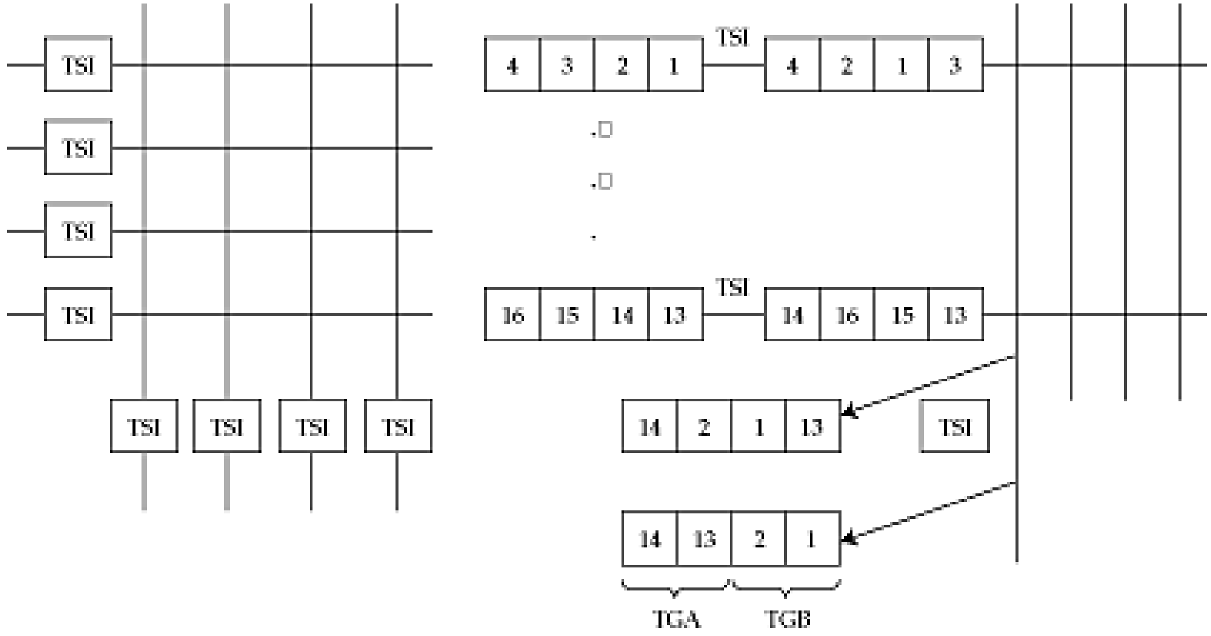
Time-space switching

- Precede each input trunk in a crossbar with a TSI
- Delay samples so that they arrive at the right time for the space division switch's schedule
- Re-orders samples within an input line and switches them to different output if there is output blocking



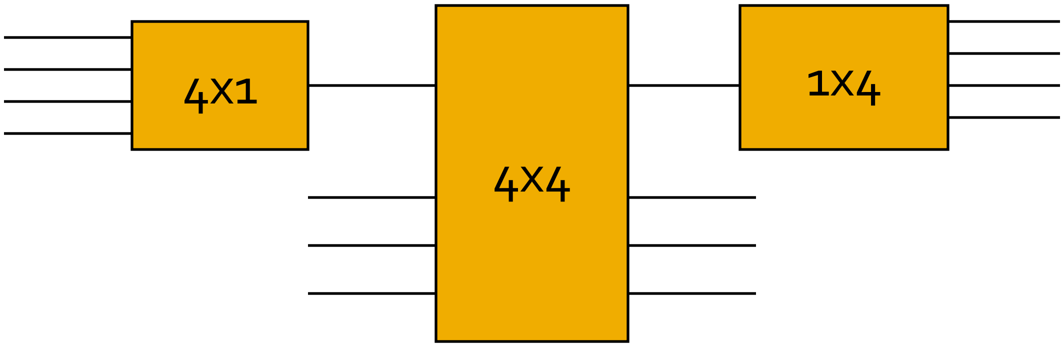
Time-space-time (TST) switching

- Similar to 3-stage crossbar except input and output cross bars use TSI
- Allowed to flip samples both on input and output trunk
  - samples in a TS switch may arrive out of order. Use output TSI to re-order
- Gives more flexibility => lowers call blocking probability

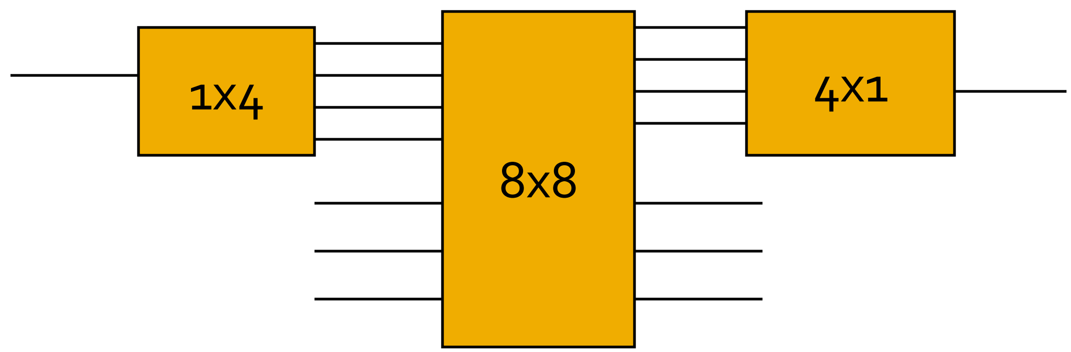


1,2,13,14 all switched to output 1; 1,2 also switched to Trunk Group B and 13,14 are switched to Trunk Group A

Line Heterogeneity



Low speed to
High speed



High Speed to
Low Speed

Traffic Engineering

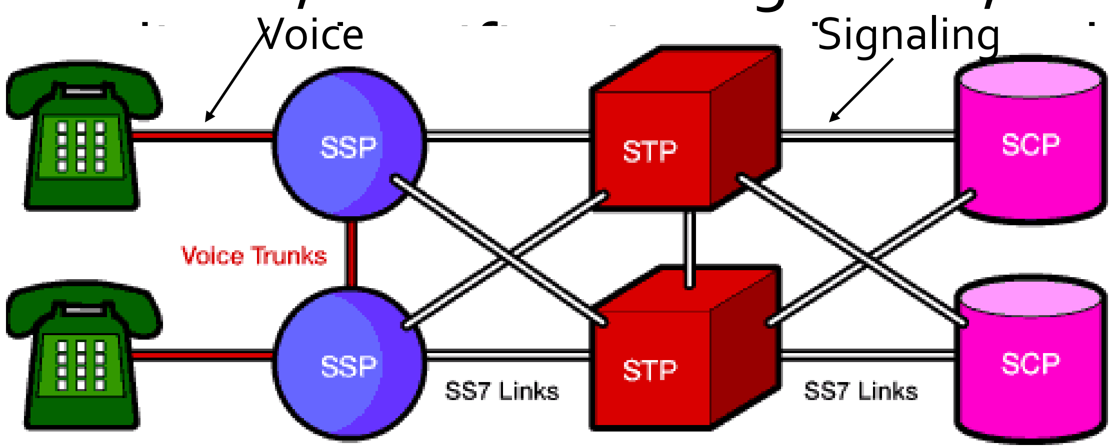
- For *MxN* switch, as M→∞, the probability of blocking (i.e., a call is lost) is given by Erlang-B formula

$$P_B = p_N = \frac{A^N / N!}{\sum_{n=0}^{N} A^n / n!}, \qquad \text{where} \quad A = \lambda / \mu$$

- λ is the call arrival rate (calls/sec)
- $1/\mu$ is the call holding time (3 minutes)
- Example: (For A = 12 Erlangs)
  - P_B = 1% for $N = 20$; $A/N = 0.6$
  - P_B = 8% for $N = 18$; $A/N = 0.8$
  - P_B = 30% for $N = 7$; $A/N = 1.7$

CCS7 Signaling

- Common channel signaling (out of band) for setup, administration, toll-free management, billing, calling-card, ers



- SSP: Service Switching Point (Telephone Switches)
- STP: Signal Transfer Point (Routing Management)
- SCP: Service Control Point (Database)

Outline

- Circuit switching
- Packet switching
  - Switch generations
  - Switch fabrics
  - Buffer placement
  - Multicast switches

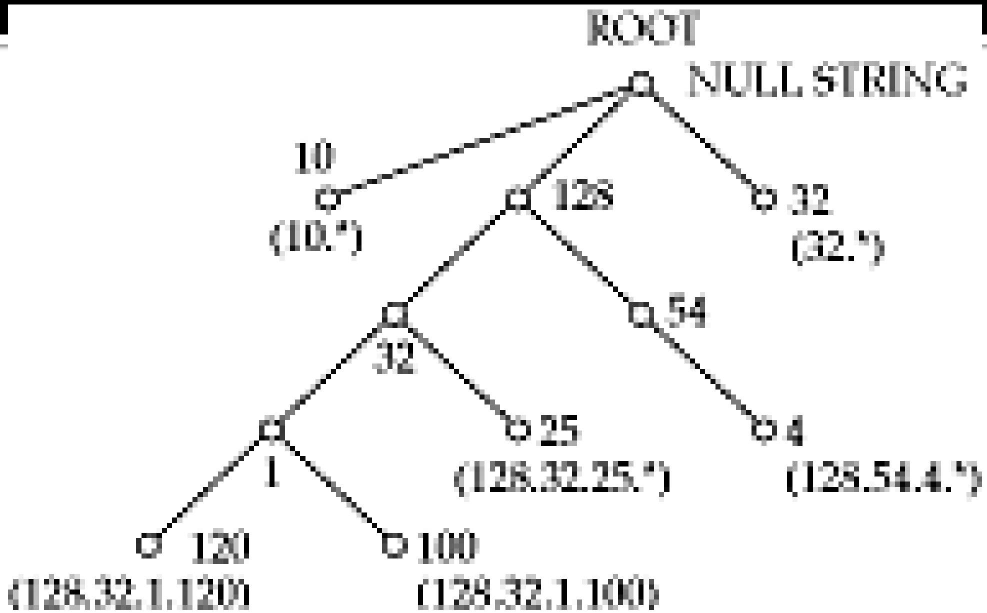
Packet switching

- In a circuit switch, path of a sample is determined at time of connection establishment
- No need for a sample header--position in frame is enough
- In a packet switch, packets carry a destination field
- Need to look up destination port on-the-fly
- Datagram
  - lookup based on entire destination address
- ATM Cell
  - lookup based on VCI
- MPLS Packet
  - Lookup based on label in the packet
- Other than that, very similar

Port mappers

- Look up output port based on destination address
- Easy for VCI: just use a table (Cross Connect)
- Harder for datagrams:
  - need to find *longest prefix match*
    - e.g. packet with address 128.32.1.20
    - entries: (128.32.*, 3), (128.32.1.*, 4), (128.32.1.20, 2)
- A standard solution: trie
  - A tree in which each node corresponds to a string that is defined by the path to that node from the root
  - *Alphabet* is a finite set of elements used to form address strings
  - Children of each node correspond to every element of the alphabet

Tries

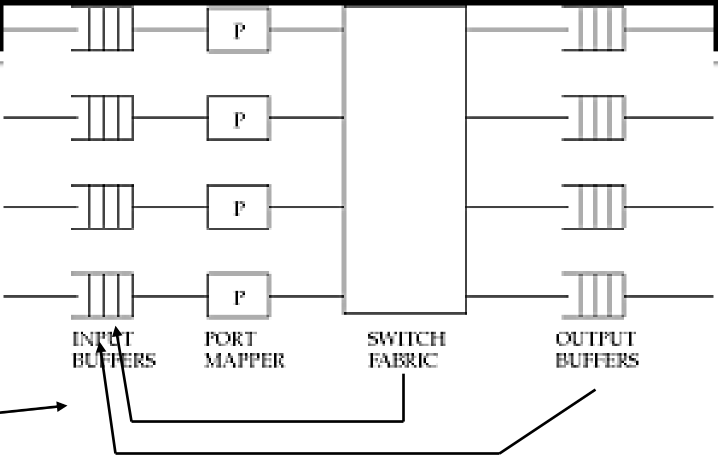


- Two ways to improve performance
  - cache recently used addresses (principle of locality) in a CAM
  - move common entries up to a higher level (match longer strings)

Blocking in packet switches

- Can have both internal and output blocking
- Internal
  - no path to output
- Output
  - trunk unavailable
- Unlike a circuit switch, cannot predict if packets will block (why?)
- If packet is blocked, must either buffer or drop it

Dealing with blocking



- Over-provisioning
  - internal links much faster than inputs
  - expensive, waste of resources
- Buffers
  - at input or output
- Backpressure
  - if switch fabric doesn't have buffers, prevent packet from entering until path is available, by sending signals from output to input quickly.
- Sorting and Randomization
  - For certain fabrics, sorting or randomization reduces internal blocking
- Parallel switch fabrics
  - increases effective switching capacity

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  - Buffer placement
  - Multicast switches