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

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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. $N \times N$ 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
  - $\frac{N}{n} \times nk + k \times (\frac{N}{n})^2 + \frac{N}{n} \times nk = 2Nk + k(\frac{N}{n})^2$
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 exceed 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

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

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

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

- There are \( \beta = k/n \) times as many interstage links as there are inlets and outlets. The percentage of interstage links that are busy is reduced by the factor \( \beta \). If \( \beta \) 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 $p$:

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

Maximum # of slots=125/(2×t_c)

\( t_c \) = memory cycle time (\( \mu \) sec)
MUX/TSI/DEMUX

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

Input TDM frame with \( n \) slots

Output TDM frame with \( k \) slots

Time-slot interchange

UTD

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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 = \(N_x + \frac{N_B}{100}\)
  - \(N_x\) = 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 \( N_{BX} = (\text{number of links})(\text{number of control words})(\text{number of bits per control word}) \)
  - \( N_{BX} = (80)(24)(7) = 13,440 \)
- Time stage \( N_{BT} = \text{time slot interchange memory + control} \)
  \[ = (\text{number of links})*\text{number of channels}(\text{number of bits per channel})+(\text{number of links})(\text{number of control words})(\text{number of bits per control word}) \]
  - \( N_{BT} = (80)(24)(8)+(80)(24)(5) = 24,960 \)
- 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 \( q' = 1 - p' = 1 - p / \beta \), \( \beta = k / N \)
- \( k = \) 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 = \( 2kN + (2kc \log_2 N + kc(8) + kc \log_2 c) / 100 \)
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
- \( k=7, \ B=0.002 \)
- \( N_x=(2)(7)(16)=224 \)
- \( N=N_x + N_B/100=430 \)
TST Switch

- TST switch structure

\[ B = (1 - (q_1)^2)^k \]

where \( q_1 = 1 - p_1 = 1 - p/\alpha \)
\( \alpha = \text{time expansion } (b/c) \)
\( l = \text{number of space stage time slots} \)
TSSST Switching Structure

- Multistage switches
No. 4 ESS Toll Switch

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