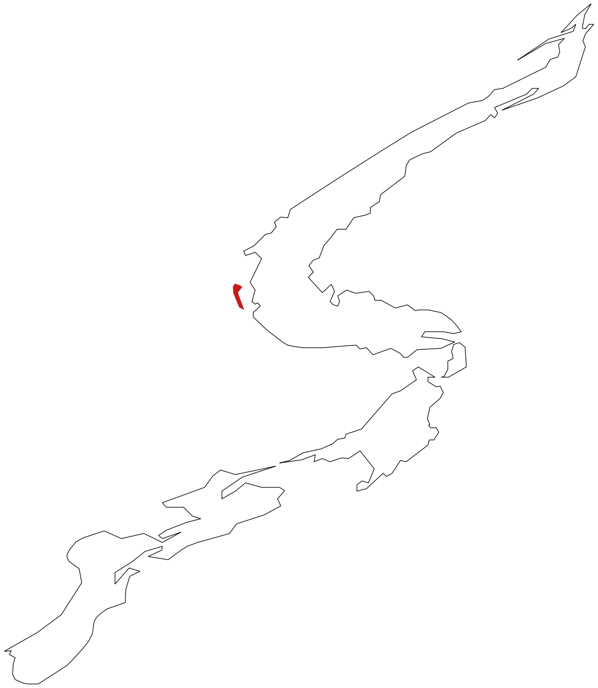


Lecture 2: Basic Concepts and the Physical Layer

Dr. G. A. Marin

Basic Concepts

- Computer Network: 2 or more computers interconnected by a computer network
- Connectivity: provided by a network
- Link: physical medium that interconnects 2 computers
  - Point to Point
  - Multiple access (broadcast)
- Node: computer (etc.) in the network
- Switched Network: nodes organized in a systematic way to forward data from a source node to a destination node.
  - Circuit Switched: used in telephony
  - Packet Switched: nodes send discrete blocks of data (called packets) among themselves
  - Store and forward: complete packet received, stored, fwd

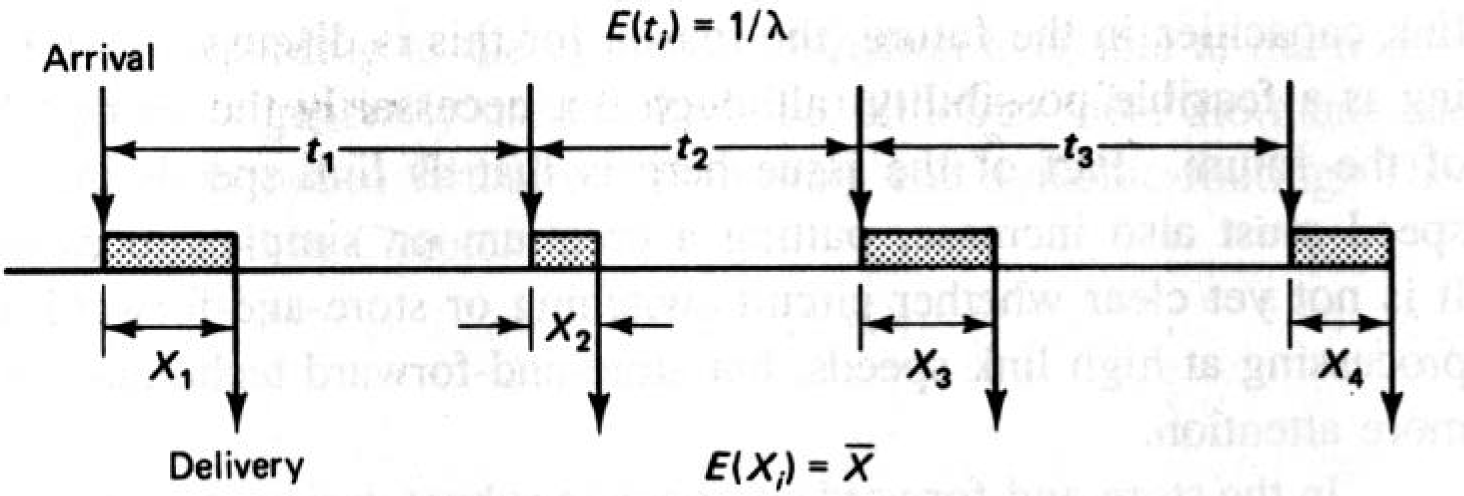
Transmission Media

- Twisted Pair
  - Two insulated copper wires twisted together to reduce electrical interference (cat 3, cat 5)
- Coaxial Cable
  - Stiff copper wire surrounded by insulator and plastic sheath (p84) (50 ohm, 75 ohm)
- Fiber Optics (capable of 50-100 gbps)
- Wireless
  - VLF, LF, MF via groundwave
  - HF, VHF via ionosphere reflection
  - UHF, EHF directional
  - ...

Circuit Switching vs Store-and-Forward

- Circuit Switching
  - Connection is allocated a given transmission rate (r bps).
  - Path created (fixed) from transmission site to destination
  - Each comm link dedicates bandwidth r to this connection.
  - If no path can be found having r bps on all links, call is rejected.

Ineefficient Link Utilization



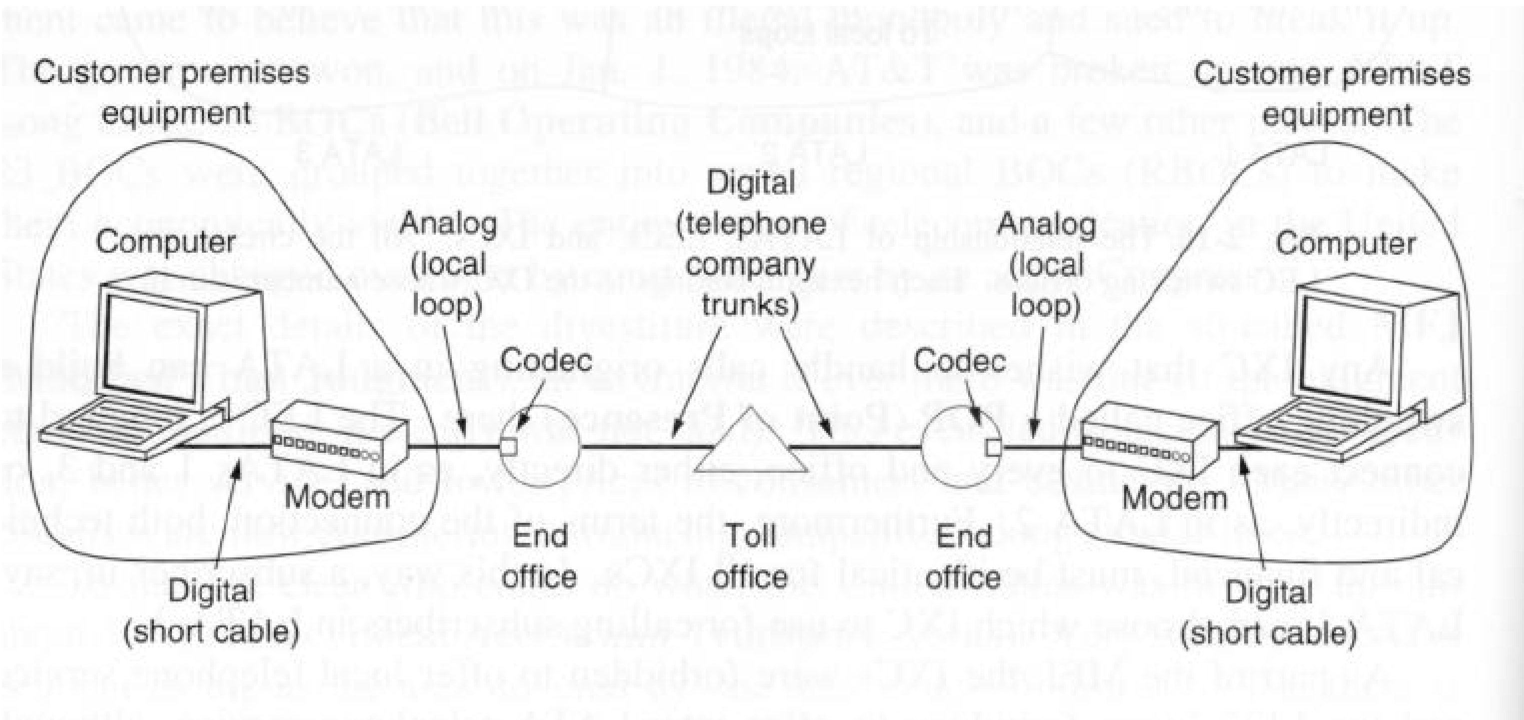
Store-and-Forward

- Session setup without (necessarily) reserving bandwidth across network.
- One msg/pkt/cell transmitted on link at a time using full bandwidth of link.
- Packet waits in queue if needed to be transmitted on next link (disadvantage).
- Advantage is that each link is fully utilized when there is traffic to send.

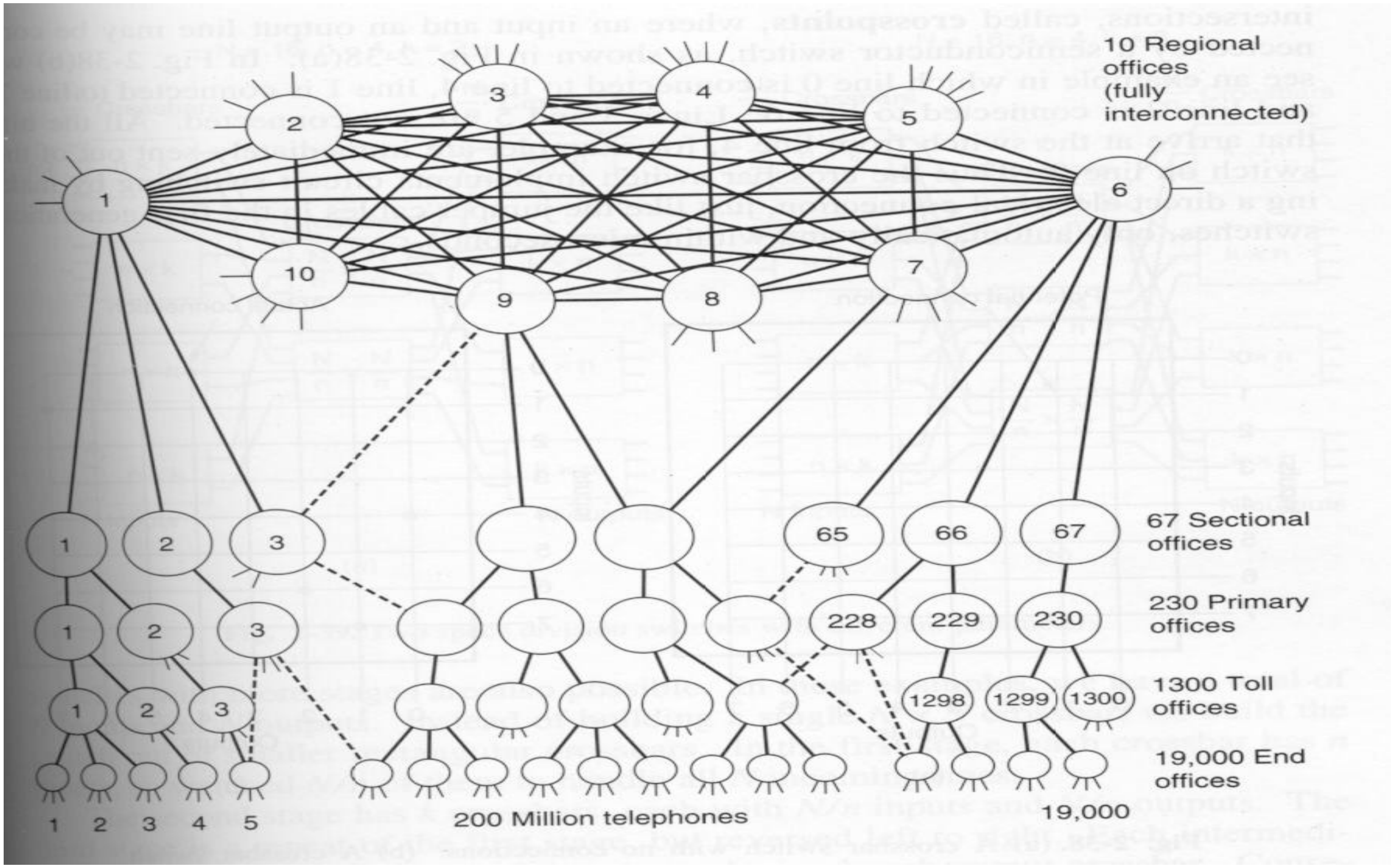
Basic Concepts (continued)

- Host: a node that uses the network (outside the network)
- Switch: a node that implements the network (inside the network)
- Internetwork: A set of independent networks that are interconnected
- Router/Gateway: a node connected to two or more networks
- Address: a byte string that identifies a node
- Routing: a process of forwarding packets across a network based on source and destination addresses.
- Unicast and Multicast Addresses: addresses assigned to single or multiple destinations.

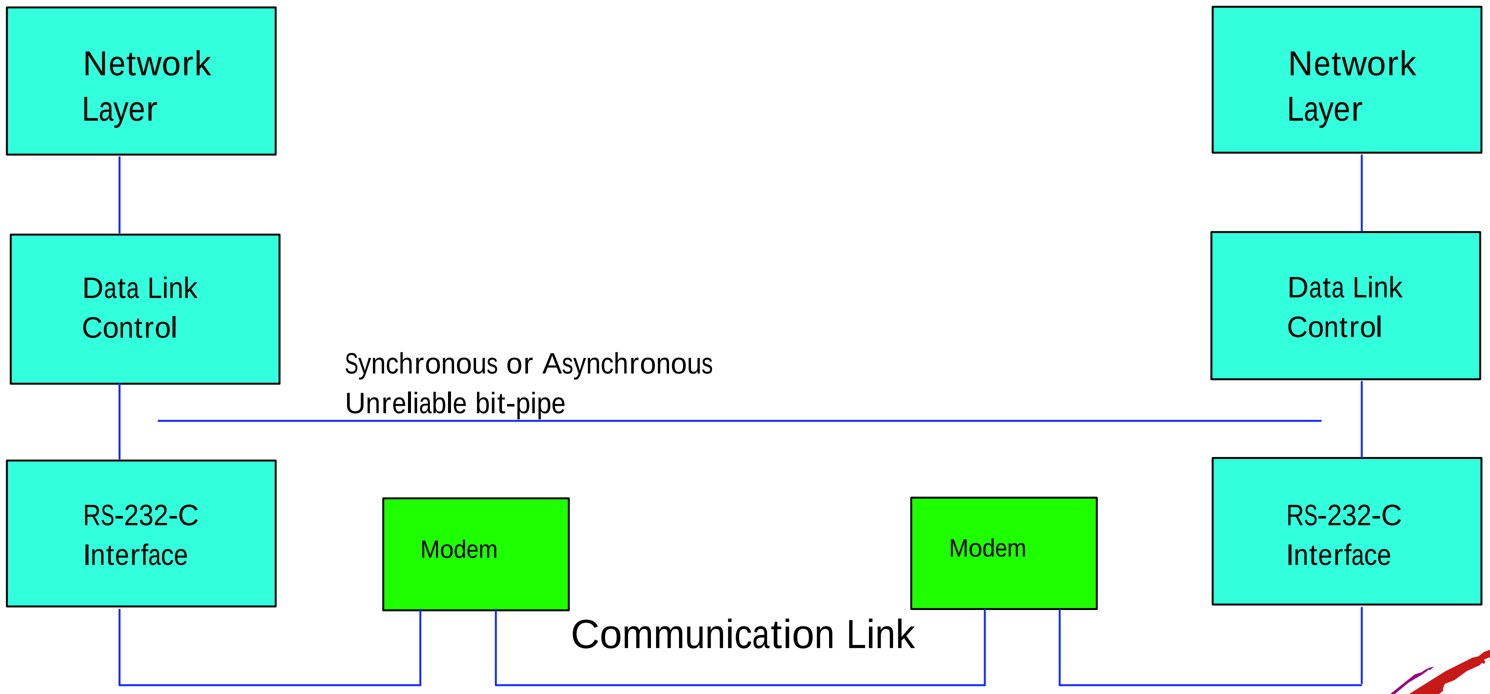
End-to-end analog-digital-analog



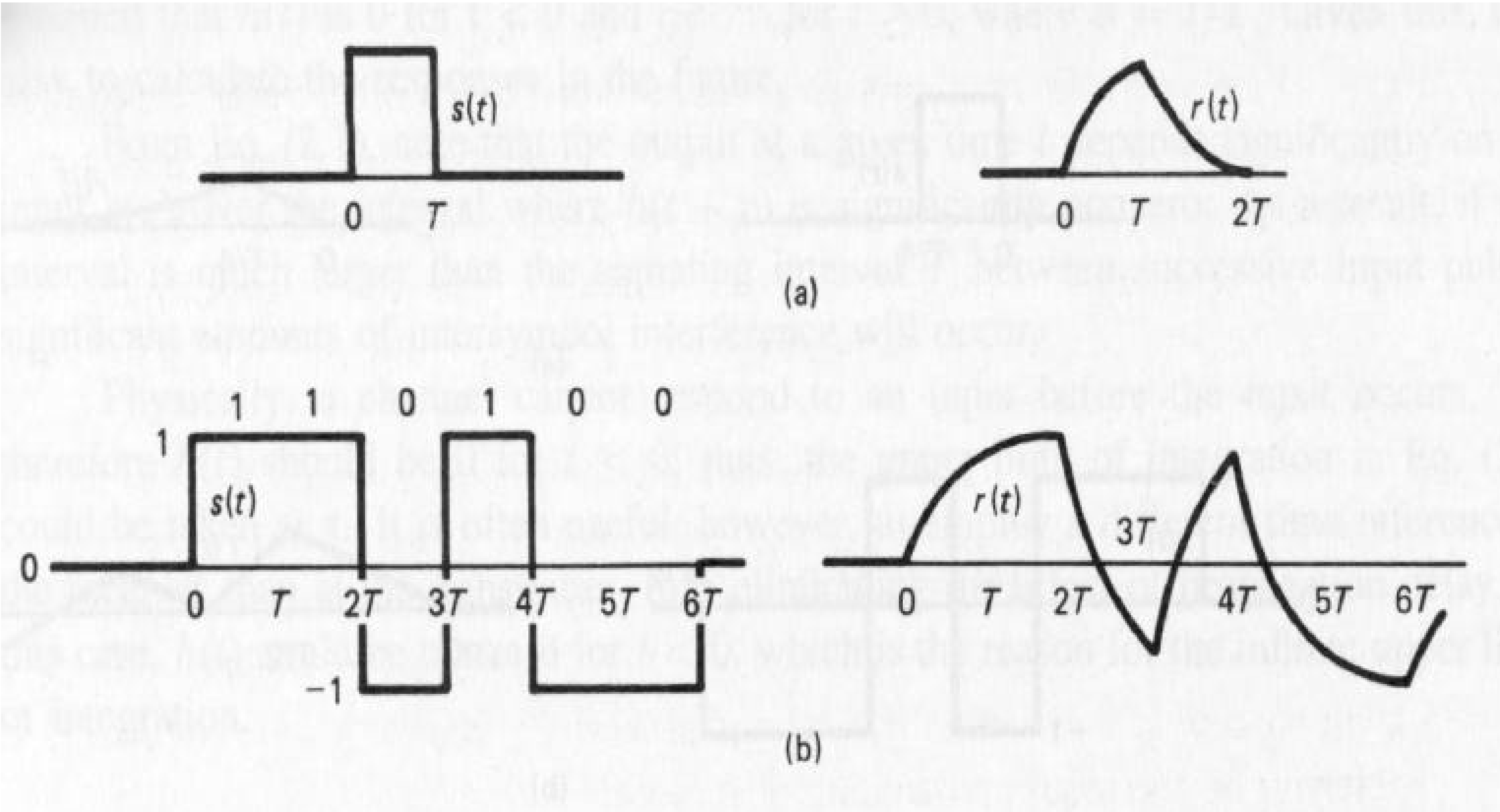
But inside the network...



The Communication Link or Channel



Digital Signal to Analog Waveform



note: baud rate vs bit rate

Bandwidth of Channel

- In early 19th Century Fourier showed that most periodic functions having period T can be represented as a sum of sines and cosines (p78)
- The coefficients in such a series represent the "harmonics" of the signal.
  - Frequency domain representation
- Any communication channel passes a minimum and maximum frequency that limits the number of harmonics that can be recovered.

Important Channel Concepts

- Bandwidth: the difference between the highest frequency and lowest frequency that a channel can carry. It is directly related to the <u>number of bits that can be transmitted over a network in a fixed time period.</u>

Max Data Rate of Noisy Channel

- Nyquist (1924) and Shannon (1948) showed that the maximum data rate of a noisy channel whose bandwidth is H Hz and whose signal-to-noise ratio is S/N, is given by:
  - max bits/sec = $2H\log_2(1+S/N)$
- Example, a channel of 3kHz bandwidth and a signal to noise ratio of 30 dB can never transmit more than 30kbps

Important Channel Concepts (continued)

- Bit Transmission Time: the amount of time it takes to transmit one bit onto the channel
- Propagation Delay: the amount of time it takes a bit to travel the length of the channel
- Throughput: Generally refers to measured bps over the channel (as opposed to bandwidth, the theoretical max).
  - depends on statistical characteristics of input to the channel
  - has its on statistical distribution with mean usually indicated by lambda.

Important Channel Concepts (continued)

- Delay or Latency: the time it takes a packet to travel end-to-end across the network (or link).
- Roundtrip Time (RTT): the time it takes a packet to travel across the network (link) and back.
- Characteristic throughput-delay curve

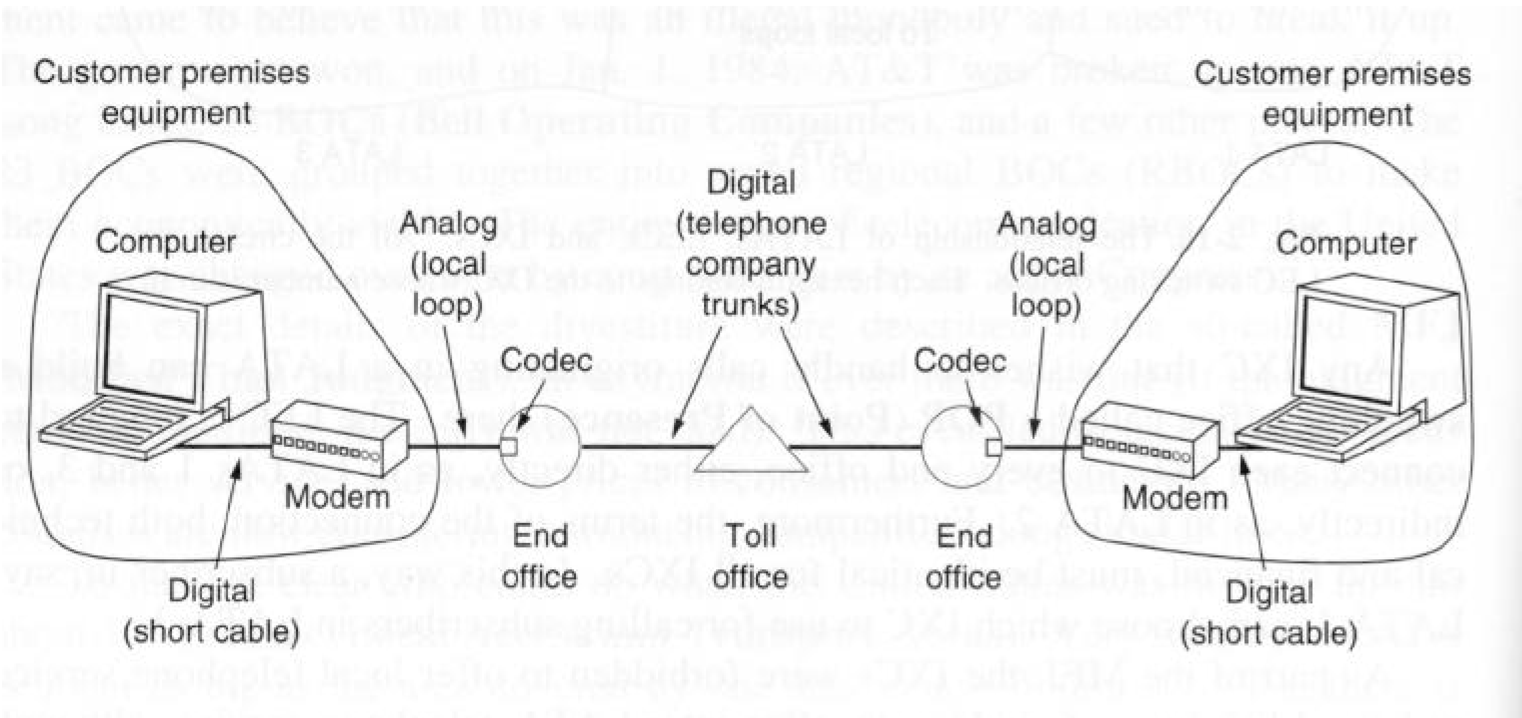
Components of Delay

- Propagation Delay (Speed of Light)
  - $3x10^8$ meters/sec in a vacuum
  - $2.3x10^8$ m/s on a cable
  - $2.0x10^8$ m/s on a fiber
- Transmission Time: packet length in bits divided by bps channel speed
- Queueing Delays: time spent waiting for service just like cars at a traffic light.

DelayXBandwidth Product

- delay (secs) x bandwidth (bits/sec) = bits
- represents the number of bits that a channel can "hold" before the first bit transmitted gets to the destination.
  - Ex. a transcontinental channel with a one-way latency of 50 ms and a bandwidth of 45 mbps can hold: 50×10^{-3} secs x 45×10^{6} bits/sec = 2.25×10^{6} bits or 280 kbytes (kB) of data.

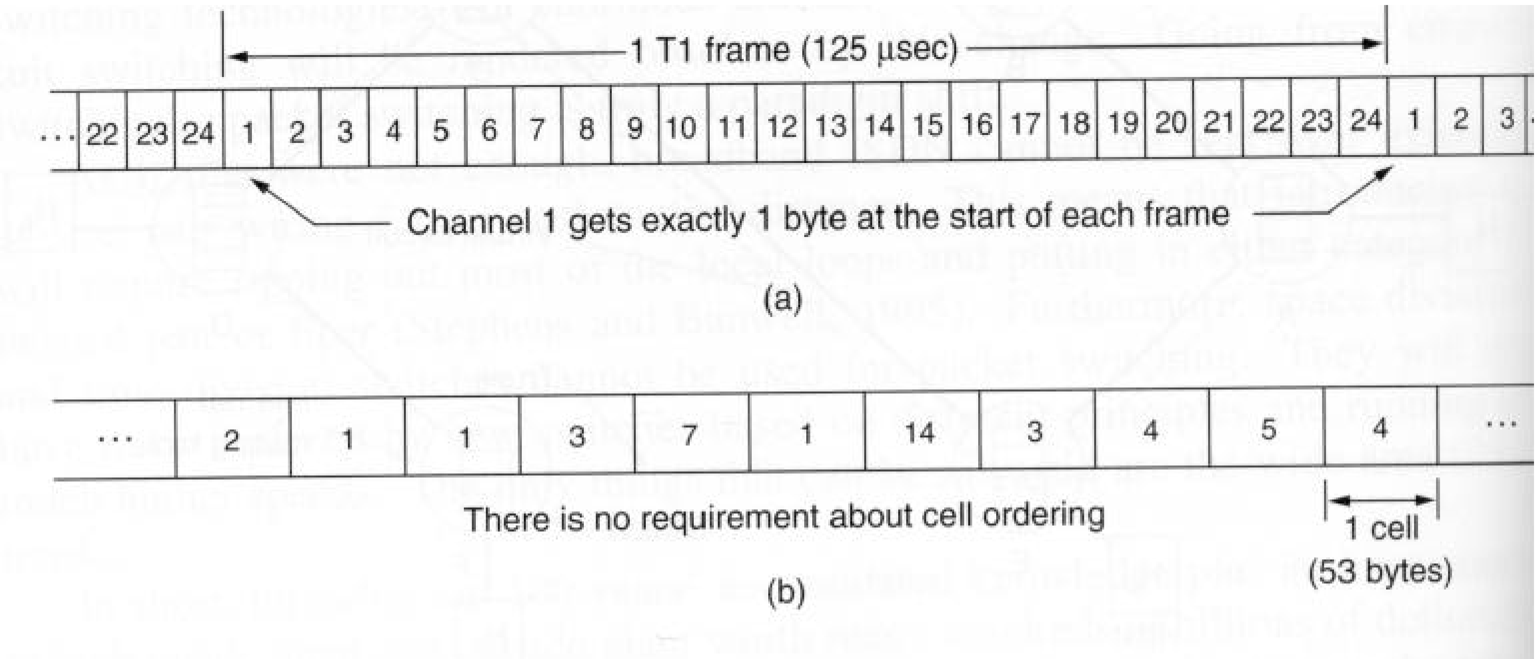
End-to-end analog-digital-analog



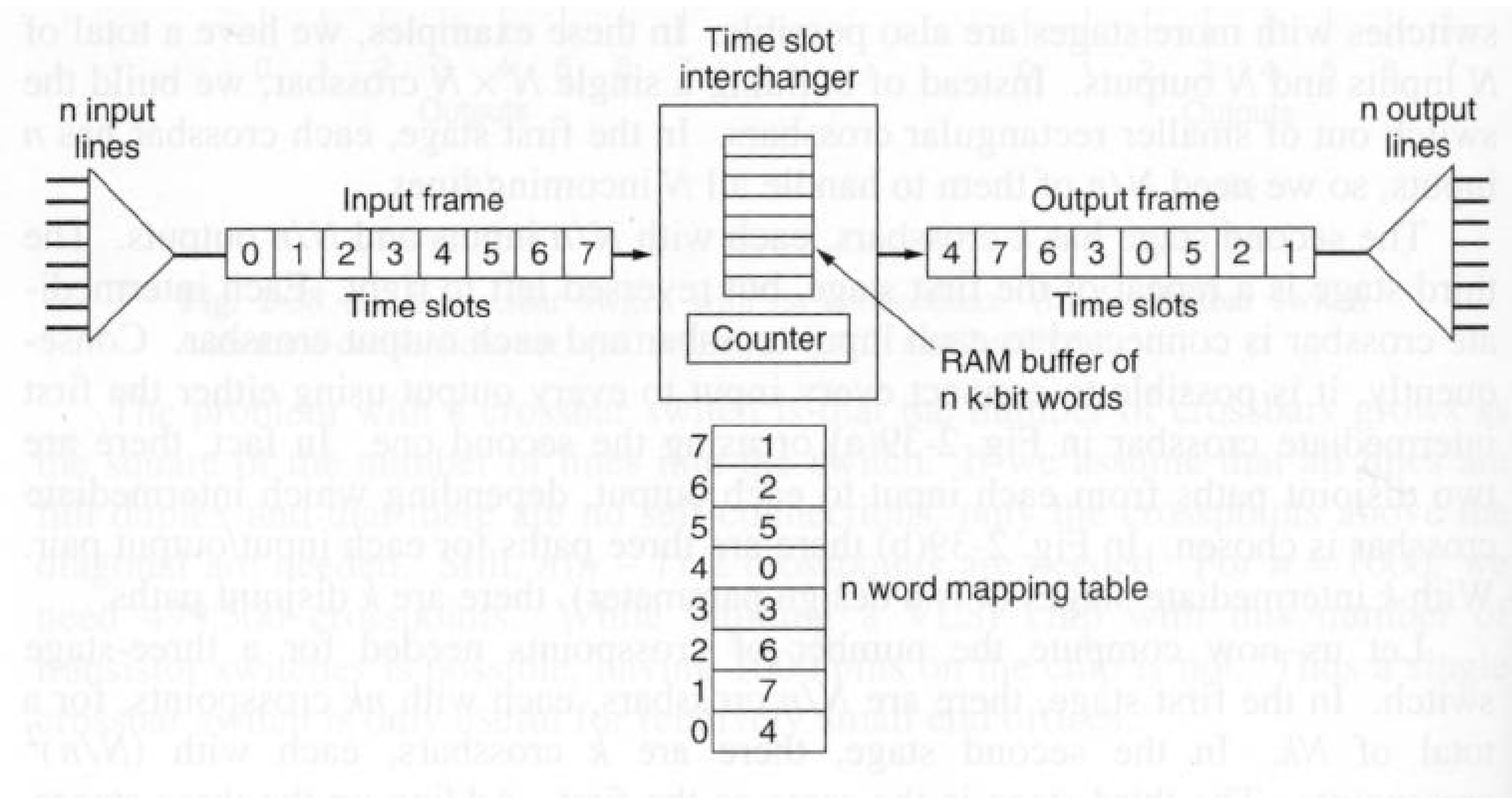
Pulse Code Modulation - telephony

- Analog signals digitized in end-office producing 8-bit sample.
- Codec samples 8000 per second at 125 microsecs per sample (7-bits data + check bit each sample)
  - 4 kHz bandwidth per channel (Nyquist)
  - 64 kbps transmitted per channel
  - 56 kbps data transmitted per channel
- T1 carrier has 24 voice channels multiplexed together (1.544 mbps)

T1 Carrier and ATM

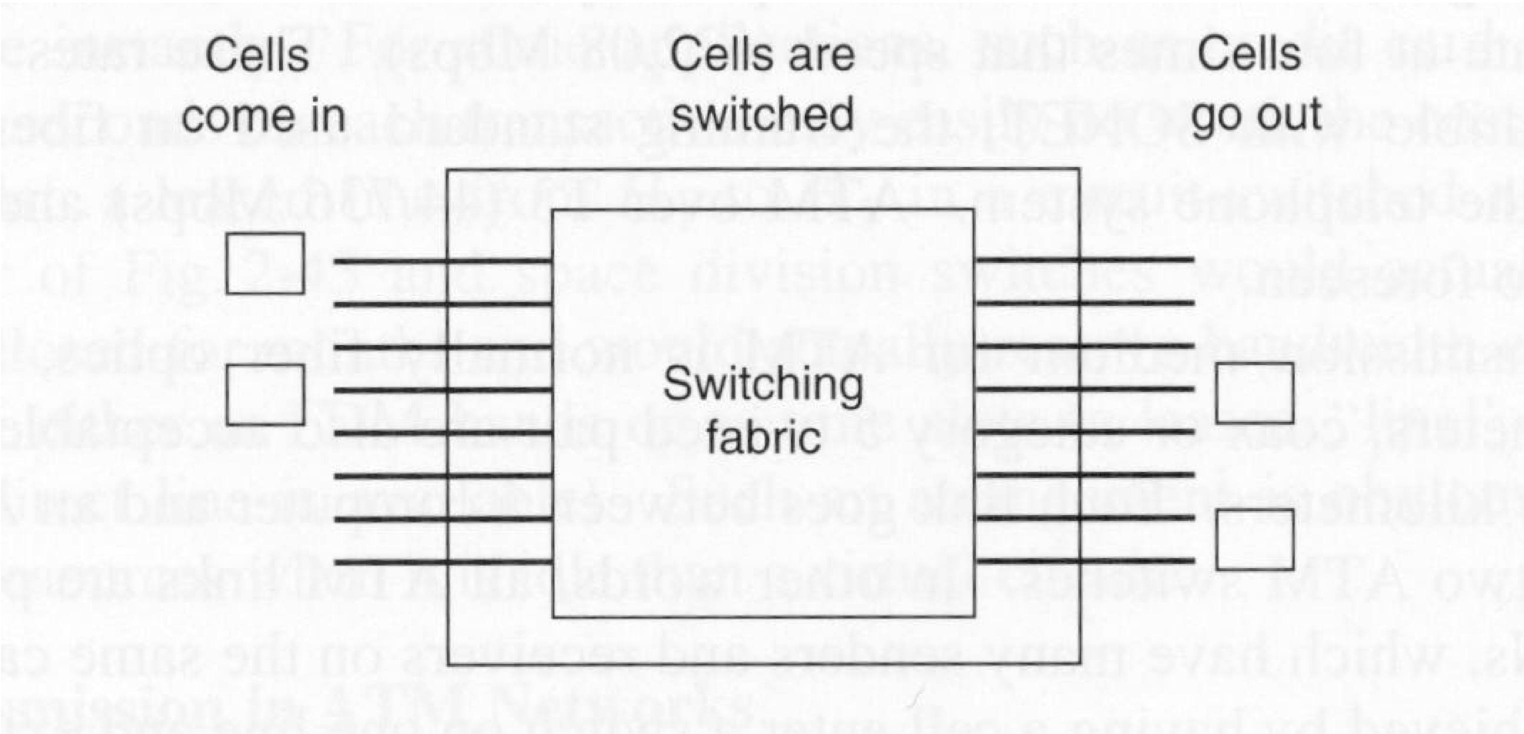


TDM Switch

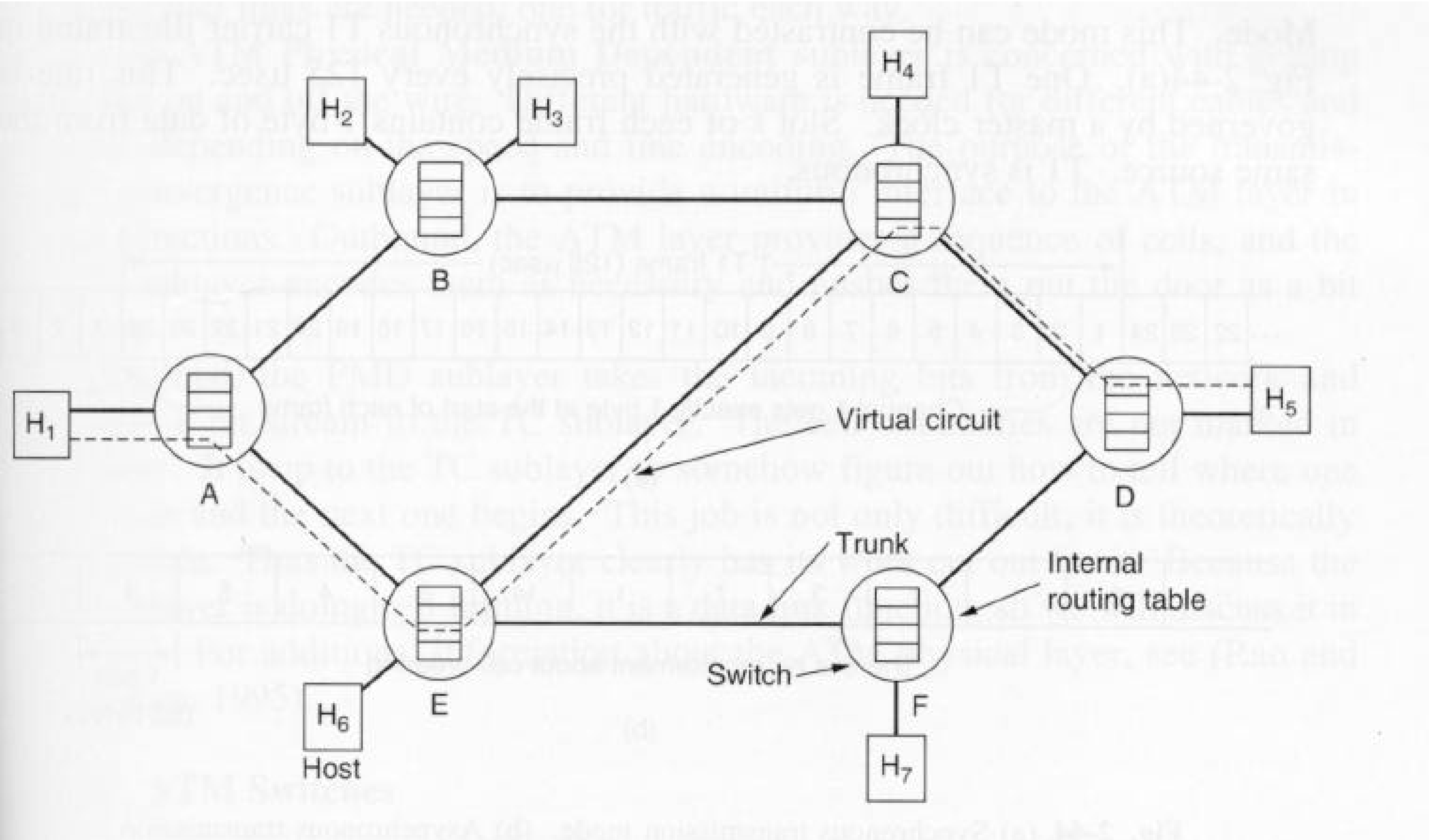


n input lines
Input frame
0 1 2 3 4 5 6 7
Time slots
Time slot interchanger
Counter
RAM buffer of n k-bit words
Output frame
4 7 6 3 0 5 2 1
Time slots
n output lines
7 1
6 2
5 5
4 0
3 3
2 6
1 7
0 4
n word mapping table

Generic ATM Switch

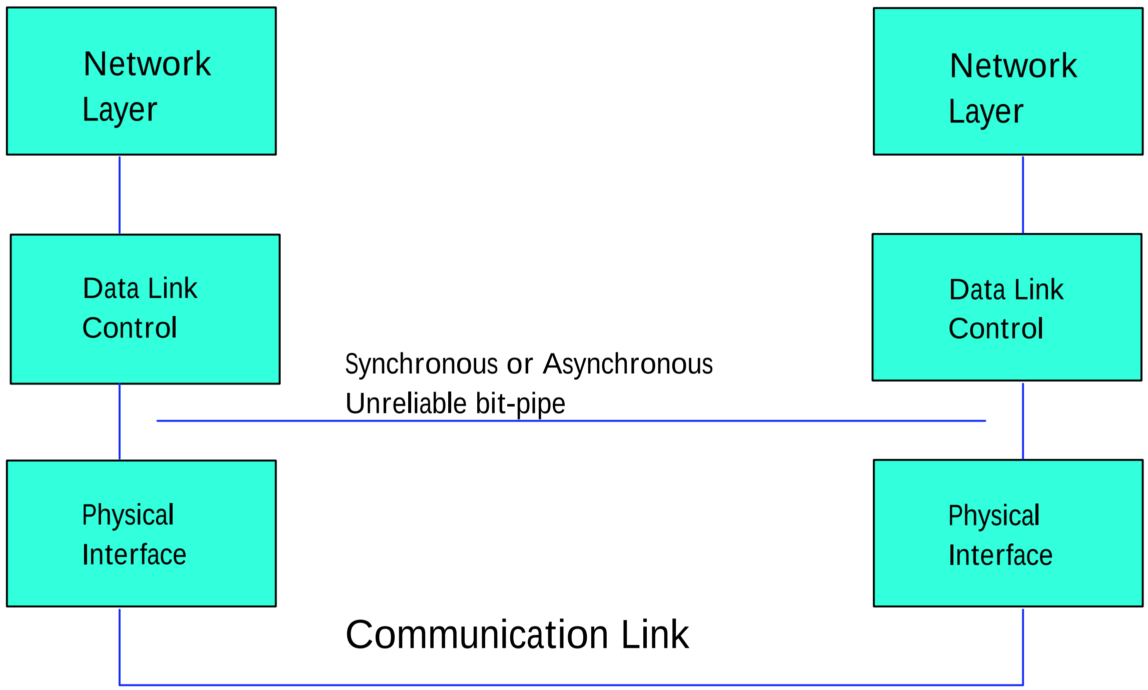


PVC and SVC



H_4
H_2
H_3
B
C
H_1
A
D
H_5
Virtual circuit
Trunk
Internal
routing table
E
Switch
F
H_6
Host
H_7

The Virtual bit-pipe



Types of Bit-pipes

- Synchronous virtual bit pipe
  - DLC feeds the modem one bit each T secs
  - Idle fill
- Intermittent synchronous virtual bit pipe
  - Data bits fed synchronously and no idle bits
  - Receiving modem must detect 1,0 and idle
- Asynchronous characters
  - Bits go at fixed rate
  - Variable delay between characters
  - Generally lowspeed

Linear Time-Invariant Filter

- If input s(t) yields output r(t), then for any u, input s(t-u) yields output r(t-u)
- If s(t) yields r(t), then for any real number a, a*s(t) yields a*r(t)
- If $s_1(t)$ yields $r_1(t)$ and $s_2(t)$ yields $r_2(t)$, then $s_1(t)+s_2(t)$ yields $r_1(t)+r_2(t)$