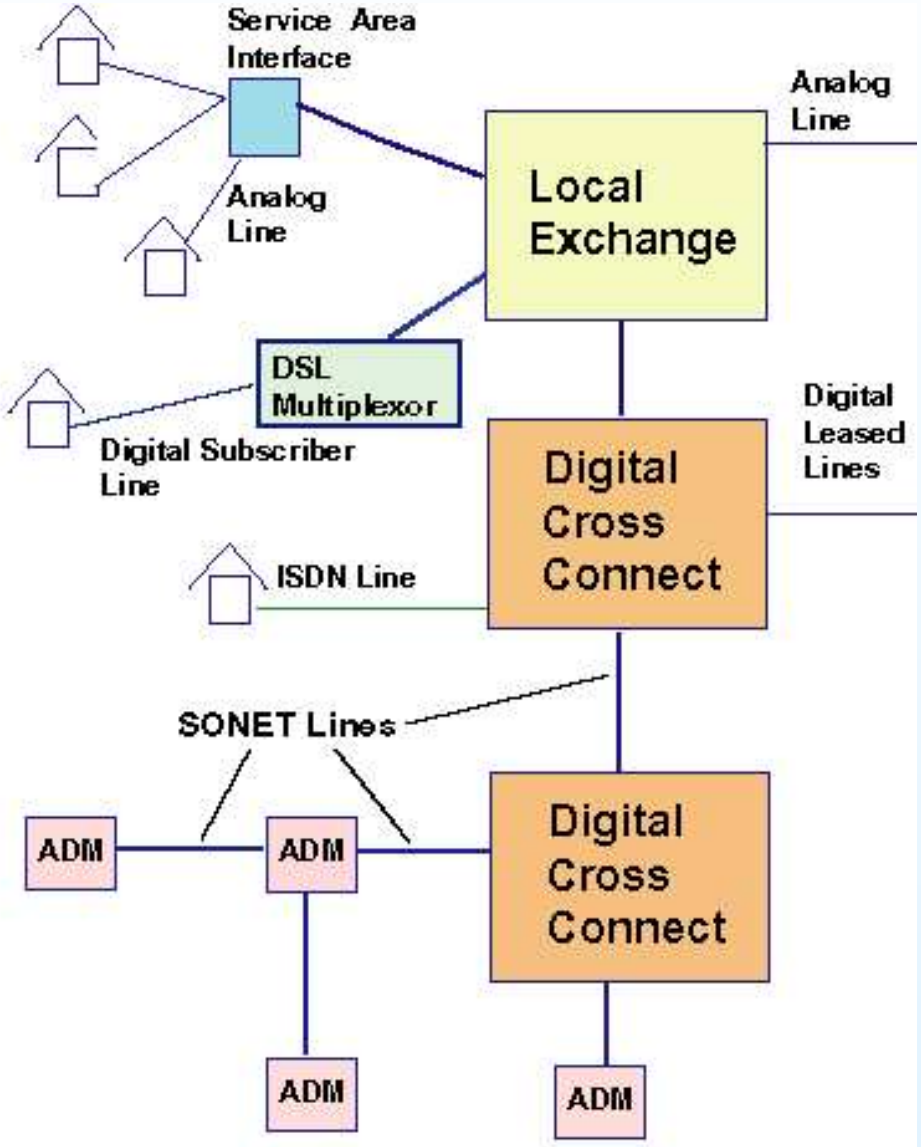
The Telephone System

- Locally, the Central Exchange connects to telephones, Private Branch Exchanges (PBX's) and to enhanced service equipment such as DSLAM's and ISDN nodes.
- Remotely, the local system connects to Digital Cross Connects which form a WAN for telephone traffic.
- Modern telephone WAN's use ATM switches and SONET signal carriers.

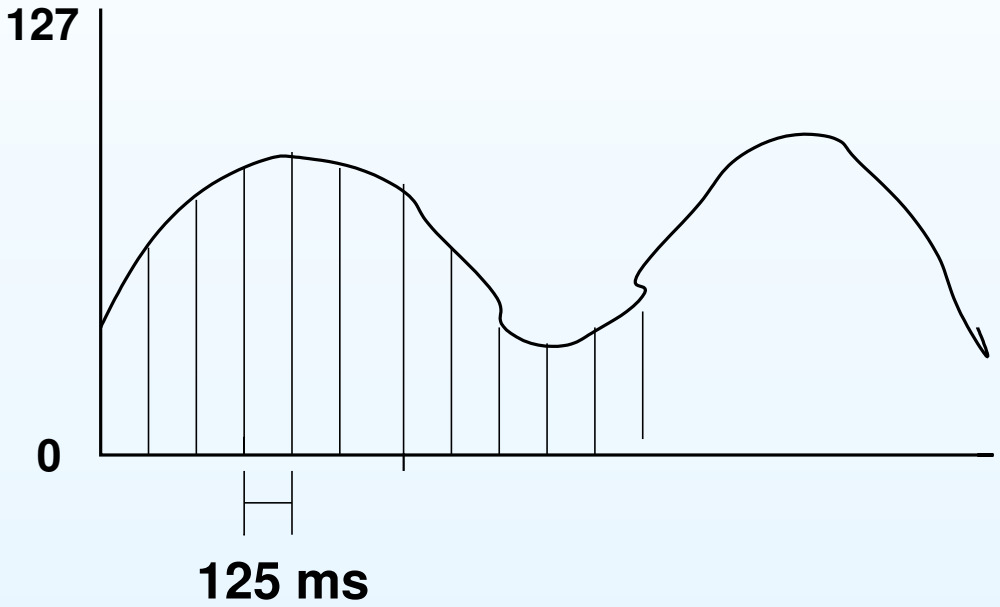
An Example Network



Telephone System Structure

Telephony Signaling

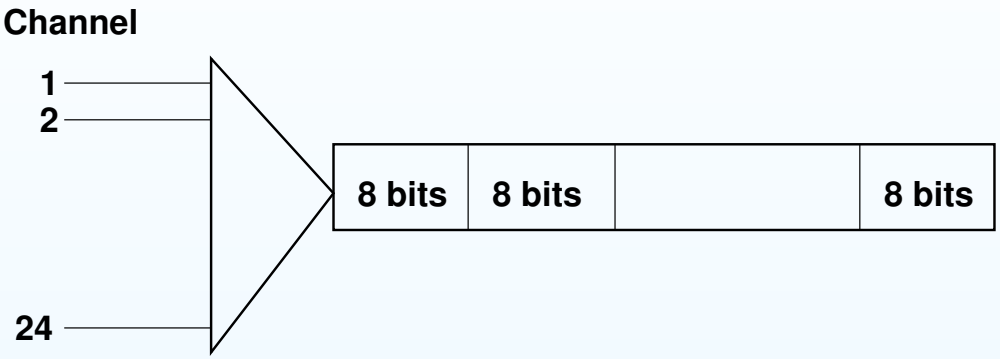
Pulse Code Modulation is used to produce a digitized signal from an analog voice line.



Pulse Code Modulation

7-bit samples 8000 times per second to encode 4000 Hz

The /it T Standards

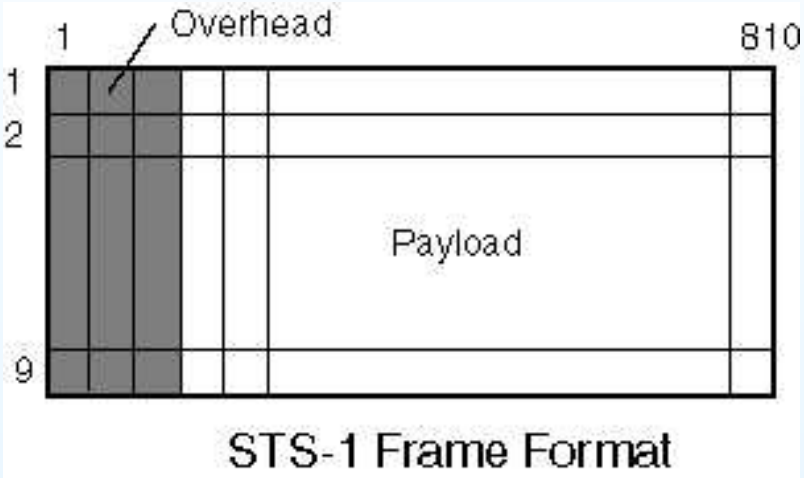


T1 Carrier Multiplexing

- Each channel (DS0) is (8000 x 8) 64,000 bps.
- DS0A is 56,000 bps for voice.
- DS1 or T1 is 24 PCM channels + 1 control bit = 1.544 Mbps
- DS3 or T3 is 24 T-1 channels = 37.056 Mbps
- ISDN channels have 2 DS0 subchannels and a 16 kbps signaling channel

SONET - Synchronous Optical Network

- Part of SDH (Synchronous Digital Hierarchy)
- The basic building block is a SONET frame.



- 90 bytes by 9 rows = 810 bytes (27 header, 783 data).
- $810 bytes/frame \times 8000 frames/sec = 51.84 Mbps$
- Each byte in a series is a 64 kbps channel.
- NRZ coding for header with xor to 127 bit string.

SONET Standard Rates

SONET Name	Optical Signal	Bit Rate
STS-1	OC-1	51.84 Mbps
STS-3	OC-3	155.52 Mbps
STS-9	OC-9	466.56 Mbps
STS-12	OC-12	622.08 Mbps
STS-18	OC-18	933.12 Mbps
STS-24	OC-24	1244.16 Mbps
STS-36	OC-36	1866.24 Mbps
STS-48	OC-48	2488.32 Mbps
STS-192	OC-192	8853.28 Mbps

An STS-n, $n > 1$ signal interleaves the bytes of each frame so that a receiver gets all the (0,0) bytes, then the (0,1) bytes column-by-column.

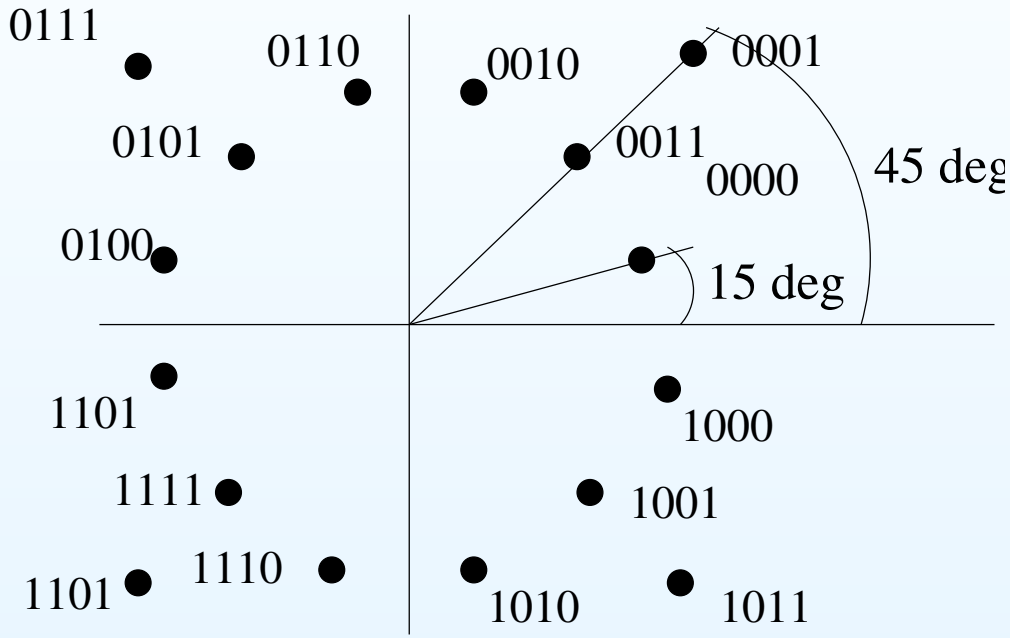
Modem Technology

Bell 103 for 120 character/second modems

- Orginator uses 1070 Hz for zero, 1270 for one
- Answerer uses 2025 Hz for zero, 2225 for one

Quadrature Amplitude Modulation

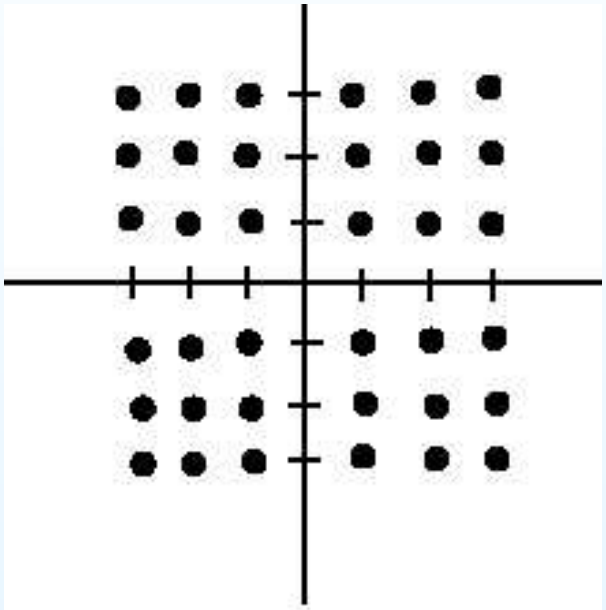
A mix of PSK and ASK to achieve 16 signal levels and 9600 b/s at 2400 baud.



16 OAM Constellation

Trellis Coding

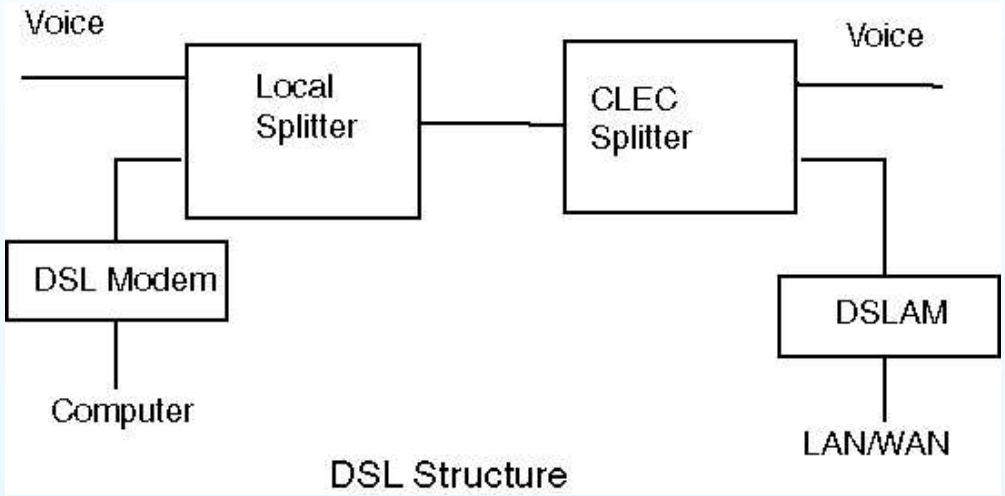
A QAM method, but it adds a sine and a cosine wave to get large numbers of states.



Trellis Coding

DSL - Digital Subscriber Line

DSL uses existing copper telephone lines to achieve high data rates (sometimes).



DSL Structure

- Voice gets the 0-4000 Hz band
- 4000 Hz - 1 GHz is divided into parallel bands so that the data rate is adaptable to any quality of carrier.
- Bit rates above 1.5 Mbps require higher quality media.
- Distance is a critical factor.

DSL Types

Name	Downstream Rate	Upstream Rate	Distance Media	Des
DSL	160 Kbps	160 Kbps	6000 m	Ba
ISDL	128 Kbps	128 Kbps	6000 m/24 ga.	ISI
DSL Lite	1.544 - 6 Mbps	1.544 - 6 Mbps	2500 m/24 ga.	Sp
HDSL	1.544 - 2 Mbps	1.544 - 2 Mbps	4000 m/24 ga.	T1
ADSL	16-640 Kbps	1.5 - 6 Mbps	3-6000 m/24 ga.	Int
VDSL	13-52.8 Mbps	1.5-2.3 Mbps	300-2000 m	AT