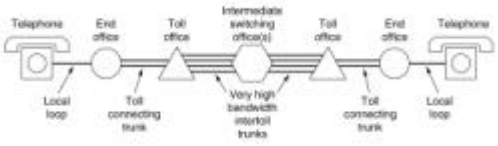
POTS

- Circuit Switched
  - Connection oriented, deterministic
  - Designed for voice
  - Local loop (last mile) – mostly still analogue
  - Exchanges/Trunks - digital
- Local loop
  - Voltage modulated by voice over imposed narrow frequency range within 0-4kHz band (300-3400 Hz)
  - Narrowband telephony
  - Human ear 20-20kHz
    - Wideband Telephony initiatives 6-7 KHz
    - Aimed at VoIP market



POTS Basics

Exchange

- Signal sampled 8000/sec ... every 125 usec
  - no point in sampling any faster as frequencies limited by LPF (Low Pass Filter)
- PCM (Pulse Code Modulation)
  - different types
- Simplest
  - Each sample converted into an 8-bit number
  - US T1: 7 + 1 data/signal
  - CCITT E1: 8 data bits
  - Quantisation error (ADC) limits fidelity
  - 8000 samples/sec * 8 bit/sample = 64 kbps

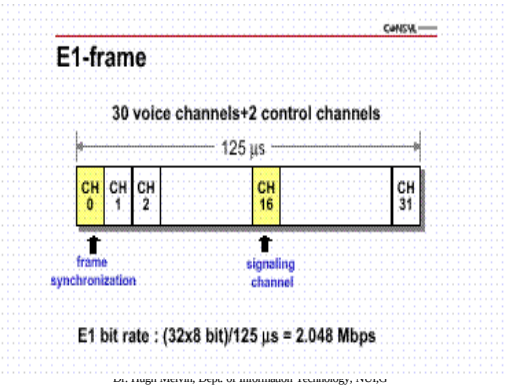
Multiplexing

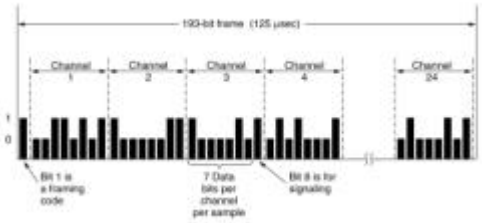
- Frequency Division Multiplexing FDM
  - Frequency bands allocated to different users
  - Potential wasted bandwidth
  - Radio Stations
    - Eg. 88.2MHz, 100.6 MHz
  - GSM: Each call utilises narrow freq band
- Time Division Multiplexing TDM
  - Full bandwidth allocated to each user for certain timeslots
  - Share b/w using time slots
  - GSM: Users share limited capacity
    - *'network busy'*

POTS

Trunks

- ITU-T E1 frame
  - Consists of 32 8-bit samples from 32 channels
    - 30 data plus 2 for signalling.
  - 32 x 64 kbps = 2.048 Mbps
- US T1 frame
  - Consists of 24 8-bit samples from 24 channels + 1 framing bit
    - 7 bit plus 1 bit signalling per channel
  - 24 * 64 kbps + 8 kbps framing = 1.544 Mbps



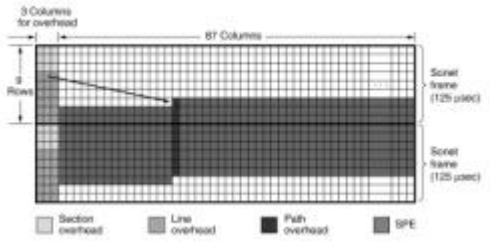


POTS

- E1 carriers multiplexed (TDM)
  - Successively higher bandwidth carriers
    - E2: 128 channels (120+8)...8.848 Mbps
    - E3: 512 channels (480+32) ..34.304 Mbps
    - E4: 2048 channels (1920+128)... 139.264 Mbps
    - Etc.. SONET/SDH
- T1 ➔ T4
  - Different ratios

SDH/SONET

- Synchronous Digital Hierarchy
  - ITU-T
- Synchronous Optical NETwork
  - USA /Canada
- Similar Technology:Aims
  - Global hi-speed data transmission
    - Compatibility
  - Future standard for data transmission
- Basic SONET frame
  - 810 bytes every 125 usec = 51.84 Mbps
  - Data plus signalling overhead



SONET		SDH	Data rate (Mbps)		
Electrical	Optical	Optical	Gross	SPE	User
STS-1	OC-1		51.84	50.112	49.536
STS-3	OC-3	STM-1	155.52	150.336	148.608
STS-9	OC-9	STM-3	466.56	451.008	445.824
STS-12	OC-12	STM-4	622.08	601.344	594.432
STS-18	OC-18	STM-6	933.12	902.016	891.648
STS-24	OC-24	STM-8	1244.16	1202.688	1188.864
STS-36	OC-36	STM-12	1866.24	1804.032	1783.296
STS-48	OC-48	STM-16	2488.32	2405.376	2377.728
STS-192	OC-192	STM-64	9953.28	9621.504	9510.912

POTS Operation

- Time Division Switches
  - Replaced the mechanical Crossbar switch
  - Basis of Modern Exchange
    - Mapping table details current circuits
    - Input Lines → Input frame
    - Input frame → RAM memory
    - RAM → Output frame based on mapping table
    - Output frame → Output lines
  - Effect of Software Glitches
    - Telecomunications Failure

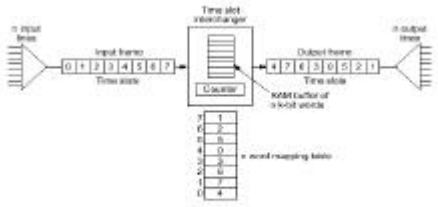


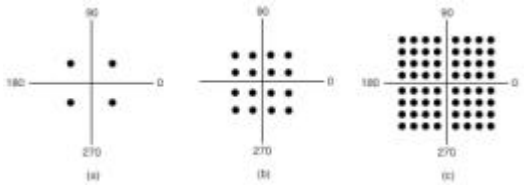
Fig. 2-40. A time division switch.

Data Transmission over POTS

- Classified by:
  - Distance & Required datarate
- Solutions
  - LAN
    - Local & hi datarate
  - WAN
    - Remote & hi datarate - Leased/Installed lines
  - Modem (POTS)
    - Remote & low datarate
  - ISDN / ADSL (POTS)
    - Remote & moderate datarate

Modems

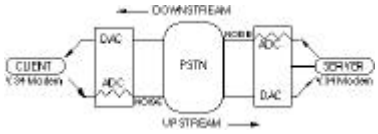
- Basic operation
  - Carrier signal (0- 4kHz band)
    - Limited by narrowband technology
  - Modulation Type (freq/ ampl/ phase)
    - latter 2 mostly
  - Recall Nyquist…no of levels per baud
    - 2 → bit rate = baud rate
    - 4 → 2 bits per baud → 4800 bps : QPSK (4 phase shifts)
    - 8 → 3 bits per baud → 7200 bps
    - 16 → 4 bits per baud → 9600 bps : QAM-16
    - 64 → 6 bits per baud → 14,400 bps: QAM-64



Modems

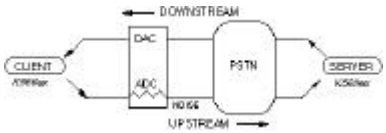
- QAM –16 (Quadrature Amplitude Modulation)
  - 9600 bps
  - Amplitude and phase modulation
  - At high bps, noise level critical
  - Error correction/compression features
- Datarate limited due to
  - Distance / wire quality
  - Noise
    - Shannon.. Rate = $H\log_2(1+S/N)$
  - Typically 30 kbps for conventional line
    - 2 x ADC quantisation
- V.90: 56 k modems

Conventional Modems



- ADC/DAC at both ends
- Quantisation noise at both ends (ADC)
- Limit to speed V.34 28.8 kbps typically

K56



- ISP connected digitally
- No ADC required at ISP end
- Less noise..faster speeds possible

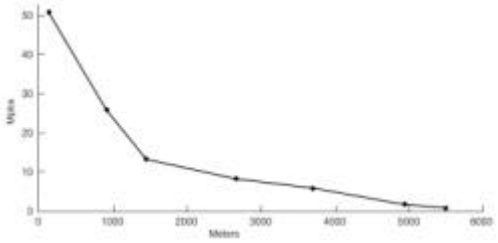
Higher Bandwidth POTS solutions

- ADSL
- ISDN
  - ..also known as N-ISDN

Asymmetric Digital Subscriber Line

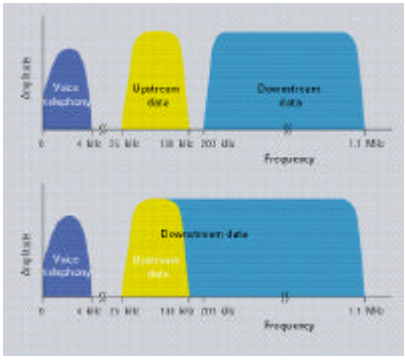
- Hi Speed
  - xDSL: Family of DSL systems
- Local Loop
  - Twisted pair capable of 1MHz bandwidth
    - 5 km limit typically
- Asymmetric
  - High Speed Downlink
    - 512 kbps - 1.5 Mbps -9Mbps
  - Uplink:
    - 64 to 640 kbps
  - Suited to WWW applications
  - Simultaneous phone access

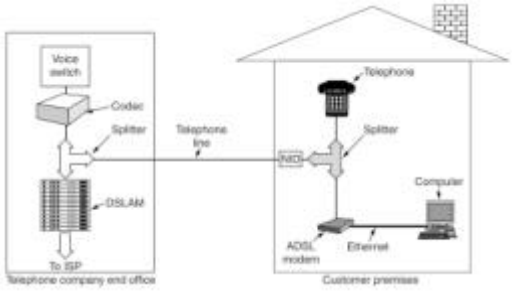
Category 3 UTP Characteristics



ADSL Operation

- Uses FDM
  - 0-25 kHz Voice
    - 4-25 kHz separation buffer
  - 25 - 1 MHz Data
    - 25 - 200 kHz Uplink
    - 250 kHz - 1MHz Downlink
    - Echo cancellation allows overlap of Uplink/Downlink spectrum
  - Splitter used to separate voice/ data at both ends
  - Digital Subscriber Line Access Multiplexer (DSLAM)
    - Reconstructs data stream to ISP
- See www.adslguide.org.uk

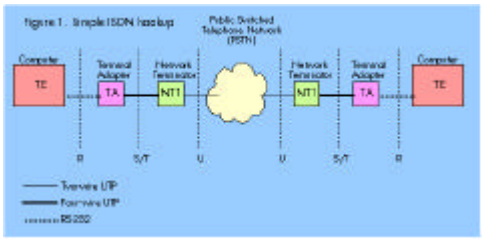




Integrated Services Digital Network

- Multiplexing of services
  - Realtime & Non-realtime
- Digital bit-pipe.
- Various rates
  - Basic
    - 2B + 1D (tw pair)
    - Simultaneous voice and data service
  - Primary
    - 30B + 1D (1984 kbps) ➔ fits into E1 carrier.
  - B = 64 kbps PCM channel for voice/data
  - D = 16 kbps channel for signalling
  - H = 1920 kbps

ISDN



- Basic rate 2B + 1D (Small business/Home user)
- TA..connects devices(Comp/Fax/Phone)
- Still commonly used