

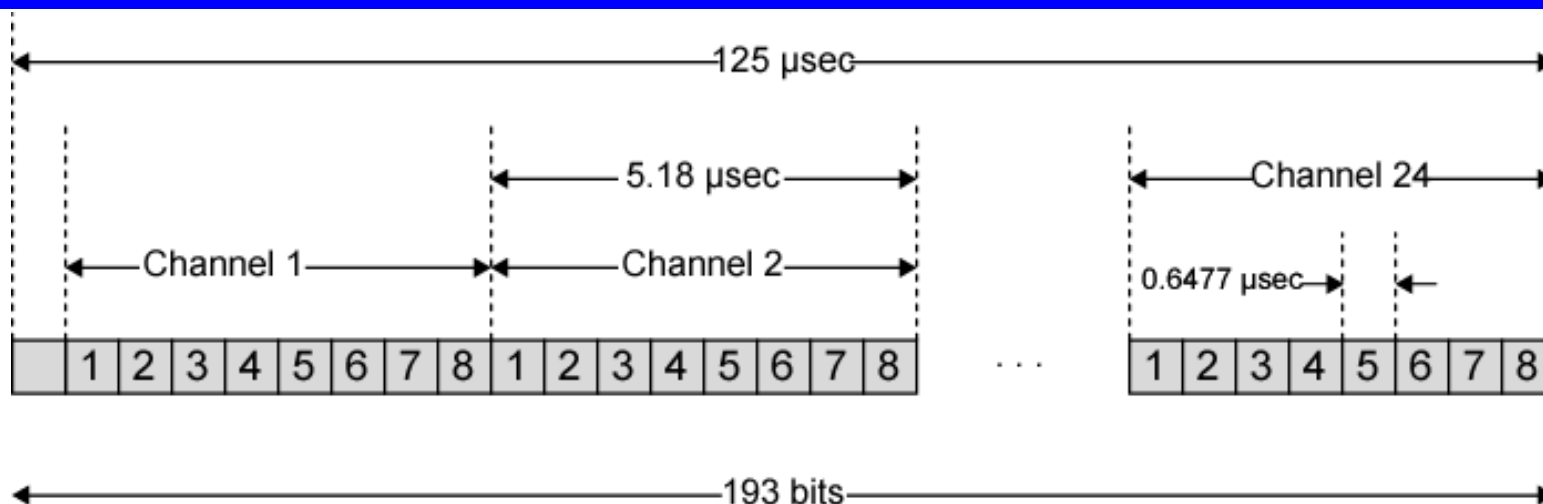
Digital Carrier Systems (2)

- For voice each channel contains one word of digitized data (PCM, 8000 samples per sec)
 - Data rate $8000 \times 193 = 1.544\text{Mbps}$
 - Five out of six frames have 8 bit PCM samples
 - Sixth frame is 7 bit PCM word plus signaling bit
 - Signaling bits form stream for each channel containing control and routing info
- Same format for digital data
 - 23 channels of data
 - 7 bits per frame plus indicator bit for data or systems control
 - 24th channel is sync

Mixed Data

- DS-1 can carry mixed voice and data signals
- 24 channels used
- No sync byte
- Can also interleave DS-1 channels
 - Ds-2 is four DS-1 giving 6.312Mbps

DS-1 Transmission Format



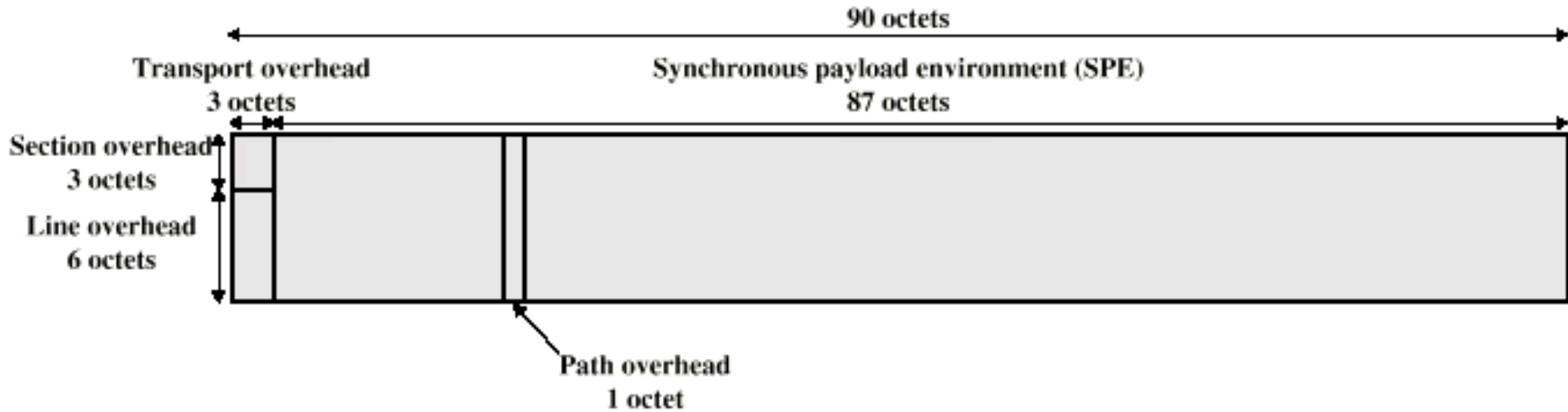
Notes:

1. The first bit is a framing bit, used for synchronization.
2. Voice channels:
 - 8-bit PCM used on five of six frames.
 - 7-bit PCM used on every sixth frame; bit 8 of each channel is a signaling bit.
3. Data channels:
 - Channel 24 is used for signaling only in some schemes.
 - Bits 1-7 used for 56 kbps service
 - Bits 2-7 used for 9.6, 4.8, and 2.4 kbps service.

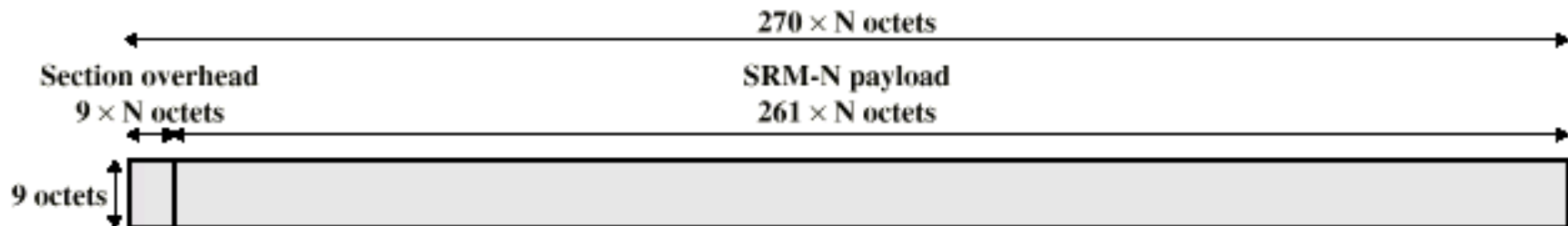
SONET/SDH

- Synchronous Optical Network (ANSI)
- Synchronous Digital Hierarchy (ITU-T)
- Compatible
- Signal Hierarchy
 - Synchronous Transport Signal level 1 (STS-1) or Optical Carrier level 1 (OC-1)
 - 51.84Mbps
 - Carry DS-3 or group of lower rate signals (DS1 DS1C DS2) plus ITU-T rates (e.g. 2.048Mbps)
 - Multiple STS-1 combined into STS-N signal
 - ITU-T lowest rate is 155.52Mbps (STM-1)

SONET Frame Format



(a) STS-1 frame format



(b) STM-N frame format

SONET STS-1 Overhead Octets

Section Overhead	Framing A1	Framing A2	STS-ID C1
	BIP-8 B1	Orderwire E1	User F1
	DataCom D1	DataCom D2	DataCom D3
Line Overhead	Pointer H1	Pointer H2	Pointer Action H3
	BIP-8 B2	APS K1	APS K2
	DataCom D4	DataCom D5	DataCom D6
	DataCom D7	DataCom D8	DataCom D9
	DataCom D10	DataCom D11	DataCom D12
	Growth Z1	Growth Z2	Orderwire E2

(a) Transport Overhead

Trace J1
BIP-8 B3
Signal Label C2
Path Status G1
User F2
Multiframe H4
Growth Z3
Growth Z4
Growth Z5

(b) Path Overhead

Statistical TDM

- In Synchronous TDM many slots are wasted
- Statistical TDM allocates time slots dynamically based on demand
- Multiplexer scans input lines and collects data until frame full
- Data rate on line lower than aggregate rates of input lines

Statistical TDM Frame Formats



(a) Overall frame



(b) Subframe with one source per frame

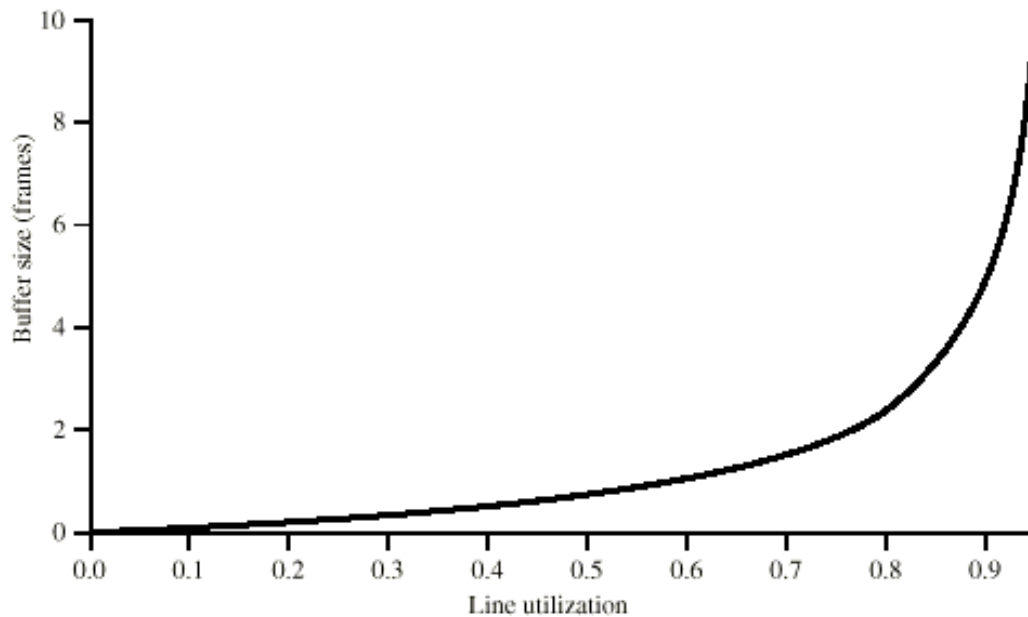


(c) Subframe with multiple sources per frame

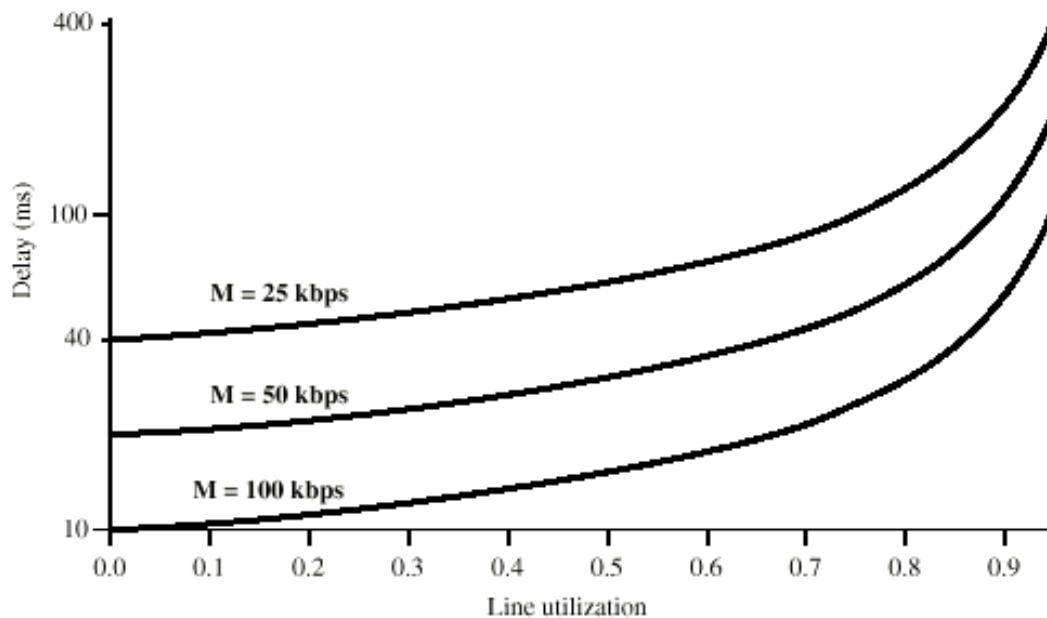
Performance

- Output data rate less than aggregate input rates
- May cause problems during peak periods
 - Buffer inputs
 - Keep buffer size to minimum to reduce delay

Buffer Size and Delay



(a) Mean buffer size versus utilization



(a) Mean delay versus utilization

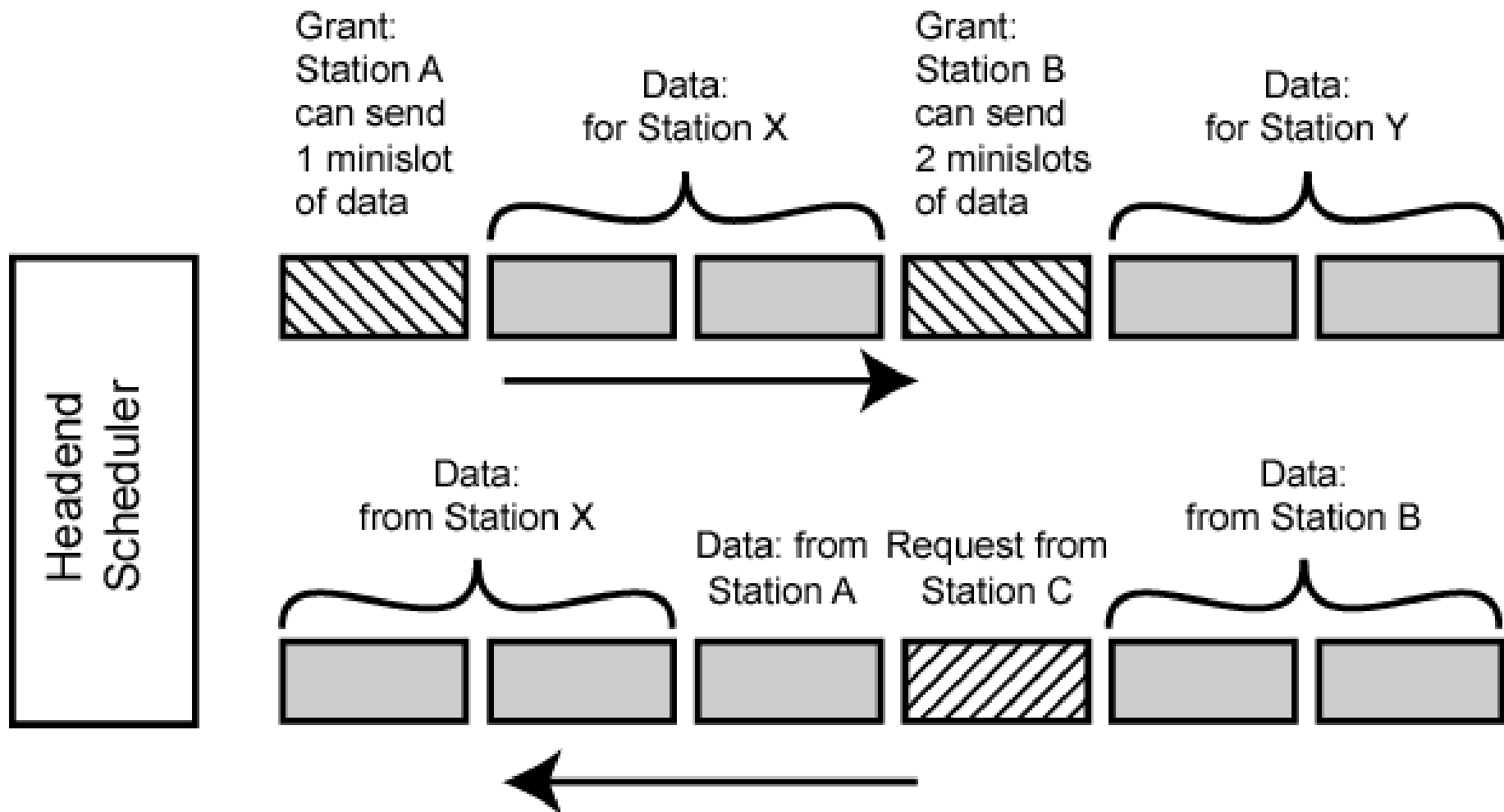
Cable Modem Outline

- Two channels from cable TV provider dedicated to data transfer
 - One in each direction
- Each channel shared by number of subscribers
 - Scheme needed to allocate capacity
 - Statistical TDM

Cable Modem Operation

- Downstream
 - Cable scheduler delivers data in small packets
 - If more than one subscriber active, each gets fraction of downstream capacity
 - May get 500kbps to 1.5Mbps
 - Also used to allocate upstream time slots to subscribers
- Upstream
 - User requests timeslots on shared upstream channel
 - Dedicated slots for this
 - Headend scheduler sends back assignment of future time slots to subscriber

Cable Modem Scheme



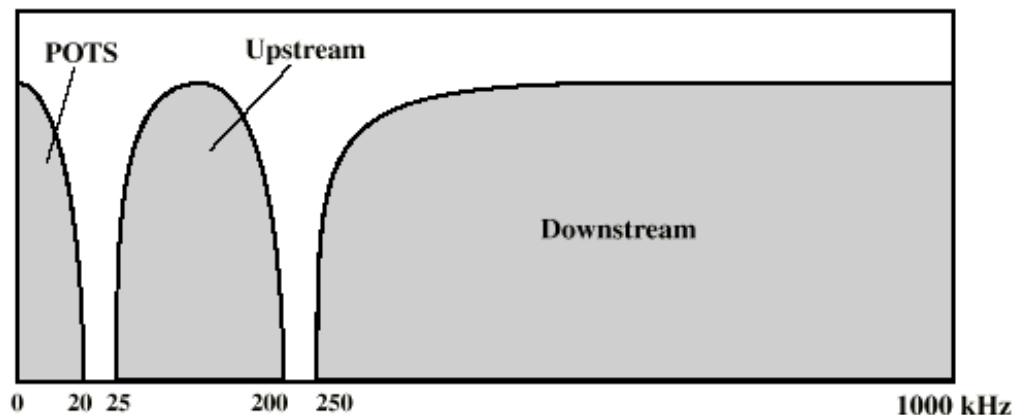
Asymmetrical Digital Subscriber Line

- ADSL
- Link between subscriber and network
 - Local loop
- Uses currently installed twisted pair cable
 - Can carry broader spectrum
 - 1 MHz or more

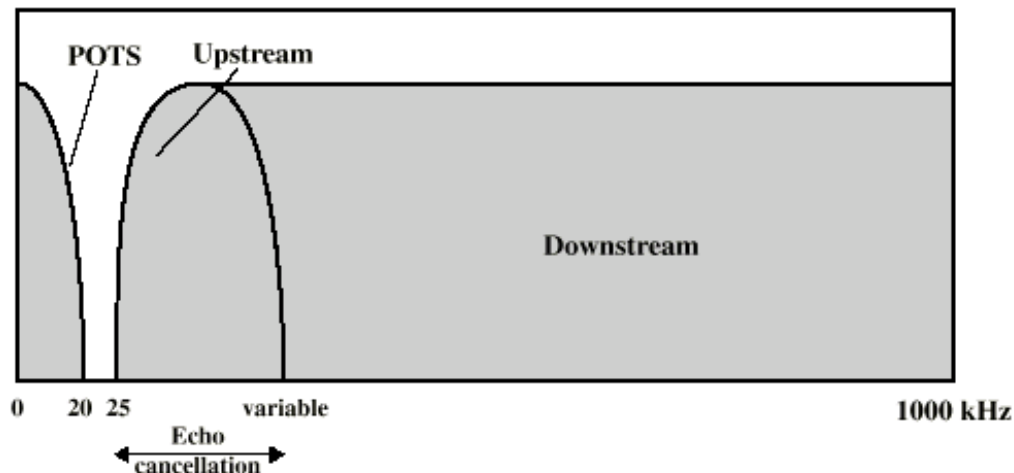
ADSL Design

- Asymmetric
 - Greater capacity downstream than upstream
- Frequency division multiplexing
 - Lowest 25kHz for voice
 - Plain old telephone service (POTS)
 - Use echo cancellation or FDM to give two bands
 - Use FDM within bands
- Range 5.5km

ADSL Channel Configuration



(a) Frequency-division multiplexing

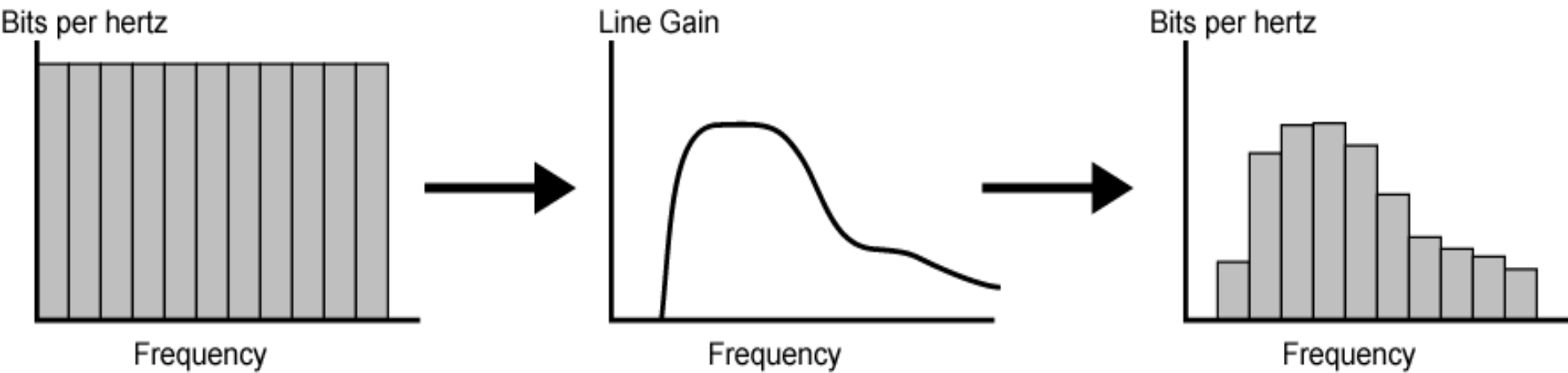


(b) Echo cancellation

Discrete Multitone

- DMT
- Multiple carrier signals at different frequencies
- Some bits on each channel
- 4kHz subchannels
- Send test signal and use subchannels with better signal to noise ratio
- 256 downstream subchannels at 4kHz (60kbps)
 - 15.36MHz
 - Impairments bring this down to 1.5Mbps to 9Mbps

DTM Bits Per Channel Allocation



DMT Transmitter

