Modems, DSL, and Multiplexing

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Outline

- Finish up Modems
- DSL
- Multiplexing

The fastest modems

- Last day, we say the combinations and phases used to code symbols on a 2400 baud line to get speeds up to 9600 bps (after error correction).
- The next step after this was QAM-128 which gives a speed with error correction of 14,400 bps.
- To additional standards after that V.34 and V.34bis achieved speeds up to 28,800 and 33,600 bps.
- This is closed to the Shannon limit due to noise on the line.
- However, if one puts the ISP end of the line on a digital loop rather than a traditional loop, the Shannon limit can be raised to about 70 kbps.
- The currently the best used standard V.90 achieves 56kbps because it uses some of the bits per symbol as control bits.
- A line is called **full duplex** if it allows traffic in both directions at the same time, **half duplex** if it allows traffic in both directions provided one has turn taking, and **simplex** if traffic in only one direction is allowed.
- Modern modems are full duplex.

Digital Subscriber Line

- To compete with cable broadband and with satellite transmission speeds, the phone companies needed a new approach to sending a signal over the local loop.
- So digital subscriber lines (DSL) were developed, the most common of these being ADSL (asymmetric DSL).
- The reason why modems are so slow is that at the end office the signal is passed through a filter which attenuates signal below 300Hz and above 3400 Hz. As the signal outside of these frequencies is not complete destroyed, one gets about 4000Hz of bandwidth on a good day.
- With DSL the incoming line is connected to a different kind of switch at the end office without this filter. (A filter is added to lines that will be used for phone: G.999.2 standard)
- The bandwidth then is limited by physical properties of the local loop, such as how far one is from the end office.

Bandwidth of DSL
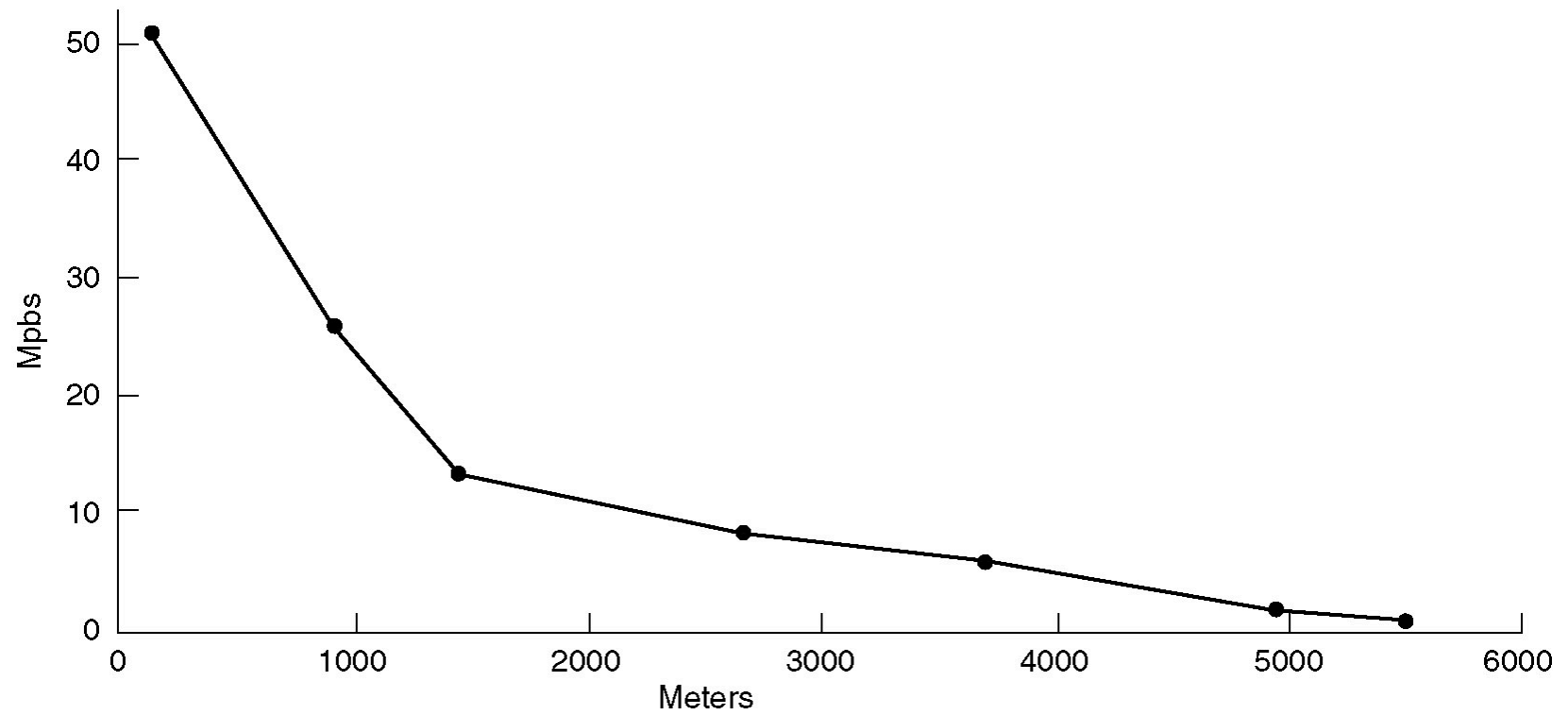
More on DSL

- The local loop has a typical spectrum of about 1.1 MHz.
- Initially, ADSL this is split into three bands, one for phone, one for upstream and one for downstream. The encoding to/decoding from these bands is called **frequency division multiplexing (FDM)**.
- Another approach is called **Discrete MultiTone (DMT)**, splits the total bandwidth into 256 independent channels each of bandwidth 4312.5Hz. Channel 0 is used for voice, Channels 1-5 are not used, and the remaining channels are for data and use V.34 at 4000 baud as the means of communication.
- The signal is reconstructed at the end office by a **digital subscriber line access multiplexer** (**DSLAM**), packets are formed and sent onto the ISP.
- In both schemes most of the bandwidth is allocated for downstream. This is where the A in ADSL comes from.
- The current standard allows speeds up to 8Mbps, if a splitter (rather than just subscriber installed filters) at the home is used.

Multiplexing

- The phone companies have developed a variety of schemes to send several phone calls over one trunk line.
- These fall into two basic categories: **Frequency Division Multiplexing** (**FDM**), which we've seen, and **Time Division Multiplexing** (**TDM**).
- In TDM, the users take turns in a round-robin fashion, each one periodically getting the entire bandwidth for a little burst of time
- As an example, the allocation of different frequencies for different AM radio channels is an example of FDM. The alternation between songs and advertisements is an example of TDM.

Frequency Division Multiplexing

- When many phone channels are multiplexed together 4000Hz is allocated to each channel.

- Frequencies of channels are translated by different amounts to put them all on the same line.

- Typically 60 channels are but into a 108kHz band called a **group**.

- For further bigger trunk line five groups are multiplexed into one **supergroup**. The highest level is when five or ten such groups are multiplexed together to create a **mastergroup**.
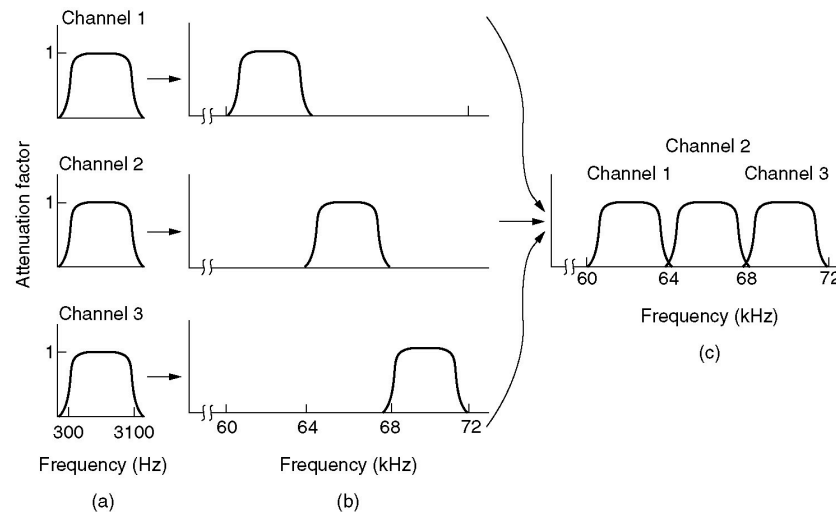
Wavelength Division Multiplexing

- FDM over optic fiber used a technique called Wavelength Division Multiplexing (WDM).

- In WDM, basically input signals at different wavelength are linearly added together by a combiner and at the other split out by a splitter.

- As of 2001, 96 channels were typically combined each with a capacity of 10Gbps.

- Such techniques allow one to use more of the capacity of fiber, which typically far exceeds the rate at which it can be driven by a single electrical to optical conversion.

Time Division Multiplexing

- FDM often requires analog circuitry which can be more complicated to drive from a computer.

- TDM on the other can be done completely electronically.

- A device at the end office called a codec (coder/decoder) encodes and decodes the signal as a sequence of 8 bit numbers.

- Sampling the phone line data is done at 8000 baud. Each sample 7bits +1 control bit of info is obtained from the Voltage level of the voice signal. Called **Pulse Code Modulation** (**PCM**).

- In a T1 carrier one then has frames of 193 bits which are sent in 125 microseconds.(So 8000 a sec)

- Each frame consists on one 8 bit value from each channel for 24 channels (can think of one channel = one phone call) and a framing bit.

- The framing bit has the pattern 01010… for odd frames and is used for signaling on even frames.

- T1 lines operate at 1.5 Mbps. Four of them can then be multiplexed into a T2, 7 of those into a T3, and 6 of these into a T4 line which has a capacity of 274 Mbps. (CCITT scheme has different capacities up to 565 Mbps).

SONET/SDH

- Two variants of TDM are used for Fiber Optics: SONET (Synchronous Optical Network) and SDH (Synchronous Digital Hierarchy). Both are very similar
- SONET uses a 1GHz master control clock
- Frames are 810 bytes (a rectangle of 9 x 90 bits)with 8000 frames/sec (STS-1 transport signal)
- Each frame is a rectangle which looks like:
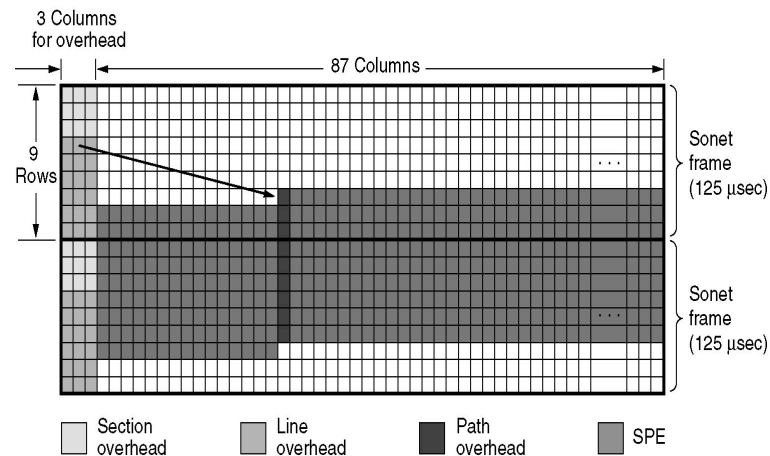
- SONET frames are sent back to back even when there is no data. A two byte sync pattern is used to start each frame.
- 87 columns are for user data.
- A **synchronous payload envelope** can occur anywhere is a frame it begins on a line with a path overhead marker. It might also cross frames

SONET Multiplex Rates

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