Long Distance Communication: Modulation, Modems and Multiplexing

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Introduction

- Sending signals over long distances
- Modulation and Modems
- Leased serial data circuits
- Optical, radio and dialup modems
- Multiplexing
- DSL and Cable modems

Signalling Across Long Distances

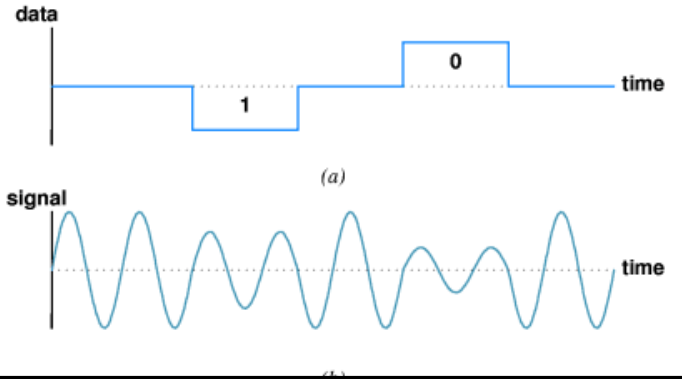
- Resistance in wires => signal loss => current cannot be propagated over long distances
- A continuous oscillating signal will propagate further than other signals

Modulation

- Send an oscillating carrier wave and then modulate it in some way
- Technique originated with radio and TV (stations use different carrier frequencies)
- Transmitter generates carrier and modulates according to data, receiver discards carrier
- Two approaches from radio are frequency modulation (FM) and amplitude modulation (AM)

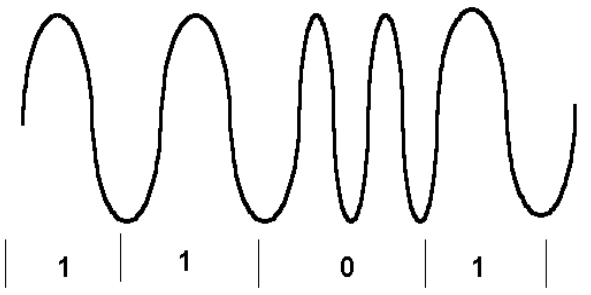
Amplitude Modulation (AM)

- Change amplitude of the carrier according to the data



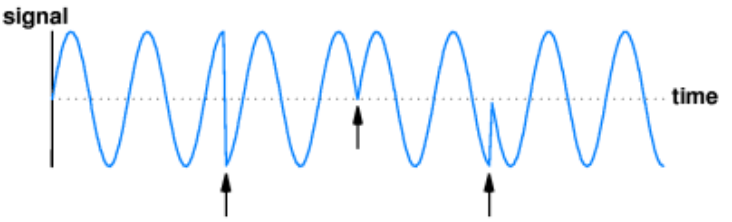
Frequency Modulation (FM)

- Slightly change frequency of the carrier according to the data



Phase Shift Keying (PSK)

- FM and AM require at least one wave cycle to send a bit
- Phase shift changes the timing of the carrier and can send several bits per cycle



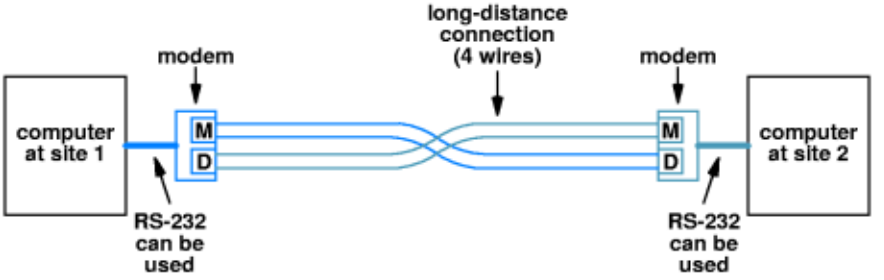
Phase Shift Modulation (2)

- *Amount* of phase shift can be measured
  - How much of sine wave is "skipped"
  - Example shows 1/4, 1/2 and 3/4 cycle
- Each phase shift can be used to carry more than one bit. For example:
  - 00 - no shift
  - 01 - 1/4 phase
  - 10 - 1/2 phase
  - 11 - 3/4 phase
- Thus, each phase shift carries 2 bits

Modems

- Hardware that takes bits and applies modulation is a *modulator*
- Hardware that takes a modulated wave and extracts bits is a *demodulator*
- Full duplex communication requires a combined modulator-demodulator (MODEM) at both ends

Example modem connection



Leased Serial Data Circuits

- Long distance four wire circuits can be leased from a phone company (spare circuits are often included in trunk cables for expansion purposes)
- Often called a serial line or serial data circuit

Optical, Radio and Dialup Modems

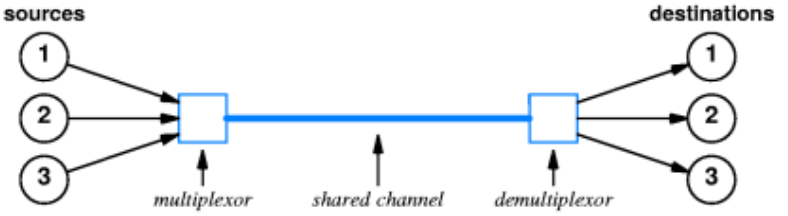
- Modems also used with optical fibre, radio and conventional phone connections
- Dial-up modems work with the existing phone system
  - mimic telephones
  - use a carrier that is an audible tone
  - use a single voice channel (2 wire circuit) and co-ordinate to achieve full duplex communication

Dial-up Modem Configuration

Multiplexing and Demultiplexing

- Multiplexing - Combining information streams from multiple sources for transmission over a shared medium
- Carried out by a multiplexor
- Demultiplexing – the separation of the combined information streams into their constituent streams

Multiplexing



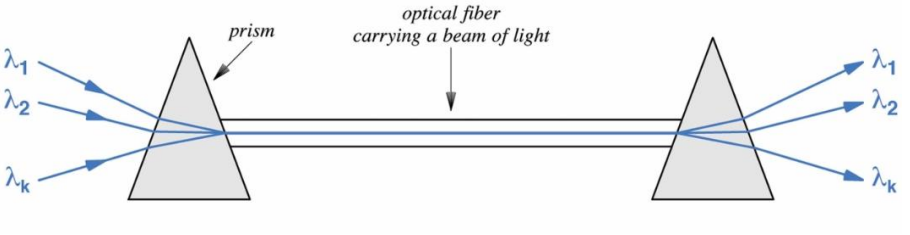
- Several logical connections share a single physical connection

Frequency Division Multiplexing (FDM)

- Two or more signals with different carrier frequencies transmitted over one medium
- Minimum frequency separation => requires high bandwidth connection
- Broadband (vs. baseband) technology
- Spread spectrum - use of multiple carriers to improve reliability
- Also, single logical channel may simultaneously use multiple carriers to improve performance

Wavelength Division Multiplexing (WDM)

- The application of FDM to optical fibre
- Uses prisms to combine beams of light of different wavelengths into a single beam



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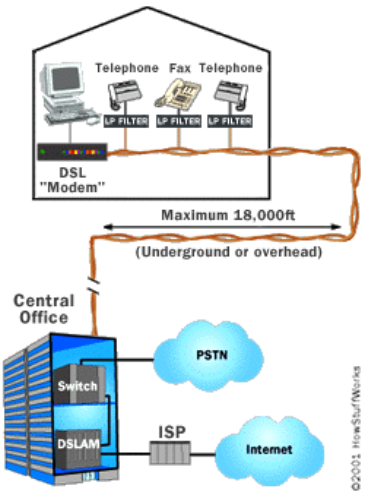
Time Division Multiplexing

- TDM is an alternative to FDM where the sources sharing the medium take turns
  - Synchronous Time Division Multiplexing
    - When TDM is applied to a synchronous network
    - No gap occurs between items
    - Uses a round robin order to select items to send
  - BUT – if a source doesn't have data to send?
    - Fill its slot with a value (e.g. Zero), set a bit to indicate value is invalid
    - Statistical Multiplexing – better alternative – skips a source if it does not have data to send

Inverse Multiplexing

- Commonly used on the Internet
- When service providers need higher bit rates than are available
  - Uses multiplexing in reverse
  - Spread a high-speed digital input over multiple lower-speed circuits for transmission
  - Combine them at the receiving end
  - Sender and receiver have to agree on how data arriving from the input will be distributed over the lower-speed connections

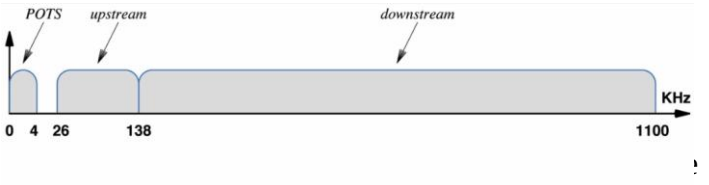
Digital Subscriber Line (DSL)



- Uses the two-wire local loop from telephone company end office to homes
- Normal telephone lines are limited to the frequency range of human voices (0-3400 Hz)
- DSL uses the entire bandwidth of the local loop
- However, capacity decreases with connection distance
  - limit 18,000 feet (5,460 m)

Digital Subscriber Line (DSL)

- Uses FDM
  - Data divided into separate channels, each 4 KHz wide
  - Bandwidth of the local loop divided into 3 regions:



  - Usually 80-90% of the rest of the channels are used for downstream communication (Asymmetrical DSL)

DSL Variants

Name	Expansion	General Use
ADSL	Asymmetric DSL	Residential Customers
ADSL2	Asymmetric DSL version 2	Approx. 3 times faster
SDSL	Symmetric DSL	Businesses that export data
HDSL	High bit rate DSL	Businesses up to 3 miles away
VDSL	Very-high bit rate DSL	Proposed version for 52 Mbps

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- Collectively known as xDSL

ADSL Data Rates

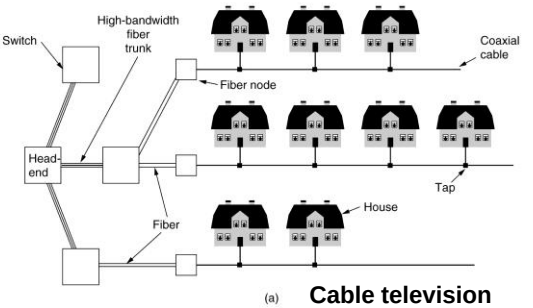
ADSL speed	Downstream	Upstream
Maximum	8Mbps	640 Kbps

- ADSL2 can download up to almost 20Mbps
- ADSL does not guarantee a data rate
  - Different line conditions affect data rates
  - ADSL modems use techniques to select frequencies and modulation techniques that yield the best results

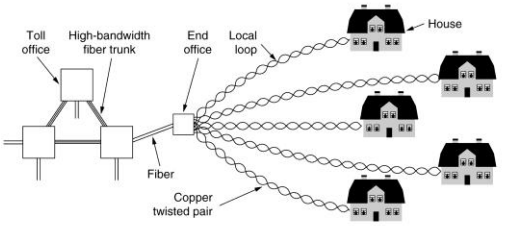
Cable Modem Technologies

- ADSL uses twisted pair cables
  - Inherently susceptible to EM interference
- Cable modem technologies - alternative to ADSL
  - Uses wiring already in place for cable TV
  - Coaxial cable
  - High bandwidth, less susceptible to EM interference
  - Use FDM and statistical multiplexing
- Theoretical data rate: 52Mbps downstream, 512 Kbps upstream (in practice can be much less)

Cable Connection



(a) **Cable television**



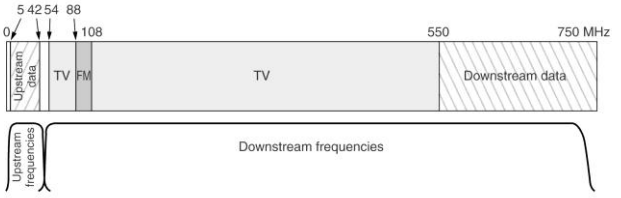
(b) **Fixed telephone system**

- A single cable is shared by many houses

+ Bandwidth of coax much higher than TP

Cable Connection (2)

- Sharing the cable for Internet and TV



- To cope with long coaxial cables analog modulation is needed
  - downstream channels – a form of AM
  - upstream channels – a form of PSK
- A cable modem connects a computer (through USB or Ethernet interface) to the cable network

Summary

- Modulation - FM, AM and phase shift keying (PSK)
- Modems, including dial-up modems
- Multiplexing – FDM, WDM, TDM
- DSL and Cable connection
- Reading:
  - Chapters 10 – 12 (parts of – as covered in lecture notes), Computer Networks and Internets, Comer, 5th Edition, 2009