Local Asynchronous Communication

CS442

Bitwise Data Transmission

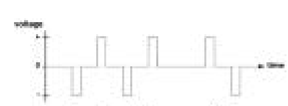
- Data transmission requires:
  - *Encoding* bits as energy
  - *Transmitting* energy through medium
  - *Decoding* energy back into bits
- Energy can be electric current, radio, infrared, light, smell, etc.
- Transmitter and receiver must agree on encoding scheme and transmission timing

Asynchronous Transmission

- One definition of *asynchronous*: transmitter and receiver do not explicitly coordinate each data transmission
  - Transmitter can wait arbitrarily long between transmissions
  - Used, for example, when transmitter such as a keyboard may not always have data ready to send
- Asynchronous may also mean no explicit information about where data bits begin and end
  - E.g. when we send individual ASCII characters

Using Electric Current to Send Bits

- Simple idea - use varying voltages to represent 1s and 0s
- One common encoding use negative voltage for 1 and positive voltage for 0
- In following figure, transmitter puts positive voltage on line for 0 and negative voltage on line for 1



Transmission Timing Problems

- Encoding scheme leaves several questions unanswered:
  - How long will voltage last for each bit?
  - How soon will next bit start?
  - How will the transmitter and receiver agree on timing?
    - Later : Self-clocking codes (e.g. Manchester Encoding)
- *Standards* specify operation of communication systems
- Devices from different vendors that adhere to the standard can *interoperate*
- Example organizations:
  - International Telecommunications Union (ITU)
  - Electronic Industries Association (EIA)
  - Institute for Electrical and Electronics Engineers (IEEE)

RS-232

- Standard for transfer of characters across copper wire
- Produced by EIA
- Full name is *RS-232-C*
- RS-232 defines *serial*, *asynchronous* communication
  - Serial - bits are encoded and transmitted one at a time (as opposed to *parallel* transmission)
  - Asynchronous - characters can be sent at any time and bits are not individually synchronized

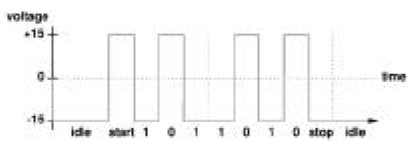
Details of RS-232

- Components of standard:
  - Connection must be less than 50 feet
  - Data represented by voltages between +15v and -15v
  - 25-pin connector, with specific signals such as data, ground and control assigned to designated pins
  - Specifies transmission of characters between, e.g., a terminal and a modem
  - Transmitter never leaves wire at 0v; when idle, transmitter puts negative voltage (a 1) on the wire

Identifying asynchronous characters

- Transmitter indicates start of next character by transmitting a one
  - Receiver can detect transition as start of character
  - Extra one called the *start bit*
- Transmitter must leave wire idle so receiver can detect transition marking beginning of next character
  - Transmitter sends a zero after each character
  - Extra zero call the *stop bit*
- Thus, character represented by 7 data bits requires transmission of 9 bits across the wire

Start, Stop Bits



Typically one of the data bits might be a parity bit (7N1, 8E1)…

Timing

- Transmitter and receiver must agree on timing of each bit
  - Agreement accomplished by choosing *transmission rate*
  - Measured in *bits per second*
- Detection of start bit indicates to receiver when subsequent bits will arrive
- Hardware can usually be *configured* to select matching bit rates
  - Switch settings
  - Software
  - Autodetection

Transmission Rates

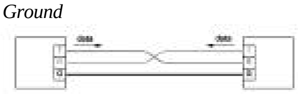
- *Baud* rate measures number of **signal changes** per second
- *Bits per second* measures number of **bits transmitted** per second
- In RS-232, each signal change represents one bit, so baud rate and bits per second are equal
- If each signal change represents more than one bit, bits per second may be greater than baud rate
  - This is the case with modems nowadays!
  - More on this when we look at modulation

Framing

- Start and stop bits represent *framing* of each character
- If transmitter and reciver are using different speeds, stop bit will not be received at the expected time
- Problem is called a *framing error*
- RS-232 devices may send an intentional framing error called a *BREAK*

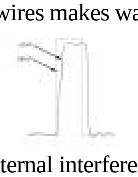
Duplex

- Two endpoints may send data simultaneously - *full-duplex* communication
  - Requires an electrical path in each direction
- If only one endpoint may send data – *half-duplex* communications or *simplex*
  - *Pin 2 - Receive (RxD)*
  - *Pin 3 - Transmit (TxD)*
  - *Pin 4 - Ready to send (RTS)*
  - *Pin 5 - Clear to send (CTS)*
  - *Pin 7 - Ground*



Limitations on Transmission

- Limitations on wires makes waveforms look like:



- Longer wire, external interference may make signal look even worse
- RS-232 standard specifies how precise a waveform the transmitter must generate, and how tolerant the receiver must be of imprecise waveform

Channel Capacity

- Data rate
  - In bits per second
  - Rate at which data can be communicated
- Bandwidth
  - In cycles per second, or Hertz
  - Amount of bandwidth constrained by transmitter and medium (and the feds!)
- For digital data: Want as high a data rate as possible given some slice of bandwidth! Limited by the error rate

Nyquist Bandwidth(1)

- If the rate of signal transmission is 2B then a signal with frequencies no greater than B is sufficient to carry the signal rate
- Converse: Given a bandwidth of B, the highest signal rate that can be carried is 2B
- Ex: Given 3000Hz (typical on phone lines), the capacity C of the channel is : C=2B = 6000bps

Nyquist Bandwidth(2)

- Wait! But given about 3000Hz our modems go much faster than 6000bps. How?
- The previous capacity assumes a binary signal element. If a signal element can represent more than one bit, the formulation becomes:
  - $C=2B(\log_2 M)$; M = # of signal elements
- If M=32, we get C=30,000bps

Shannon's Capacity

- Shannon's capacity includes the concept of error rates. At a given noise level, the higher the data rate, the higher the error rate. This is a theoretical maximum!
- Signal to Noise Ratio:
  - SNR = SignalPower/NoisePower
  - Ratio measured at the receiver
  - $SNR_{db} = 10\log_{10}(SNR)$
  - SNR of 100 = 20 dB
  - SNR of 1000 = 30 dB
- Capacity:
  - $C = B*\log_2(1+SNR)$

Shannon Capacity Examples

- If voice telephone has a SNR of 30 dB and bandwidth of 3000 Hz:
  - $C = 3000 \log_2(1 + 1000) = 30,000$ bps
- If our LAN technology has a SNR=251, B = 1Mhz
  - $C=10^6*\log_2(252)$ = 8Mbps
- Using Nyquist's formula, the number of symbols we would need to transmit this data per signaling element:
  - $8*10^6 = 2*10^6*\log_2 M$ $M = 2^4 = 16$