Lecture 1

* Routing
  + Paths
* Data Links – physical layer
  + Between 2 nodes (error detection, etc.)
* Narrow physical layer restriction:
  + Need to send data in small bits
* DNS – directory service -> name to ip address
* Network header
  + Routing info (all intermediary routers)
* Data link header
  + Only info about next router
* Physical layer
  + No header, splits DPDU (?) (frame) into bits
* At destination node, data link header is taken off, then the network header. Then, it sees final destination is this router and proceeds to take off other headers
* Data links – fiber, wireless, cable, Bluetooth, etc.
* TCP vs. UDP transport layer
  + UDP – no resending/retransmission
  + TCP – more reliable
* TCP abstraction
  + Sender and receiver have 2 connected queues and data reliably is sent from sender to receiver queue. No packets.
  + Uses data link to send packets between 2 routers, which sends bits at physical layer

Lecture 2

* TCP
  + Queue abstraction
* IP layer
  + IP header places source and destination
  + If IP addresses match, then we are at the right destination
  + Else, figure out the next router
* Data link
  + From mac address x to y
* Mac address
  + Unique 48 bit addresses uniquely identify everyone on a link
  + E.g., x->y z->l, y,z are mac addresses for the same router
* IP address
  + Temporarily assigned to device
* Physical
  + Bits
* RPC (remote procedure calls) vs TCP (Queue abstraction)
* Socket = queue
* Transmission
  + Bandwidth
    - Range of frequencies a particular signal is created from (infinite sum of which sine wave freqs)
  + Strict layering
    - Only read headers at current layer (e.g., IP only reads IP header)
    - Information can only be passed across interfaces
  + Physical layer
    - Frequency shifting vs amplitude shifting (baseband)
    - Bits to coded bits to add transitions
    - Send bits to modem to convert to energy
  + Channel
    - Physical medium to transmit from sender to receiver
    - A channel does not change frequency of sine waves (only maybe the amplitude and phase)
  + Any periodic function can be written as an infinite sum of sin waves with diff freqs
  + More harmonics/bandwidth -> better bit recovery
  + Harmonic = multiple of the fundamental frequency
  + Channels are sluggish (take time to respond to a change in the signal)
  + Channels have noise, resulting in a change in amplitude
  + Sample at middle points
  + Two limits
    - Bandwidth (Nyquist rate) – limit on symbols (signals)
      * Input: square wave, output: falling sine wave
        + When can be send the second signal such that it does not interfere with previous signal?

Bandwidth of input signal is 1/T

You can theoretically send signals every T/2 seconds (Send at frequency: 2 \* bandwidth = 2/T)

Max rate of sending symbols, not bits (baud rate)

* + - * Why not send multiple bits per symbol (6v – 11, 4v – 10, …)
        + Noise
    - Noise (Shannon) – limit on bits
      * Maximum number of noise to tolerate to distinguish 6V and 4V is 1V, which limits the number of bits per symbol
      * Shannon limit applies to any channel (wire, wireless, etc.)
      * S – max signal
      * N – noise
      * Signals must be spaced 2\*N
      * B – bandwidth
      * Shannon limit is B \* log (1 + S/2N) bits per second
* Channel needs to pass a range of frequencies in a range from highest to 0Hz
  + 010101010101 – highest
  + 000000000000 – 0 Hz
  + Non-periodic bit patterns

Lecture 4

Diagram

Description automatically generated

* Physical layer
  + Coding sublayer
    - Add transition bits
    - Initial training bits used to sync clock at the beginning
      * Physical clocks drift over time -> we need transition bits to keep them in sync
    - Example
      * Diagram

        Description automatically generated
      * Transition bits
        + Start detected by rising signal (edge detector)
        + Sample every 1 bit after that
      * Initial transition bit after each character being transmitted
    - Manchester
      * Sends double the number of bits (if Nyquist limit is B, we send B/2 amount of useful data)
      * 1->0 : 1
      * 0->1 : 0
      * Do not look at the signal for about 20-30%.
        + E.g., to send data 1111111
        + We need, 10-10-10-10-10-10-10
        + We must ignore the 01 transitions
        + No need to look at a specific point (middle of a peak), instead we watch for a transition from 0 to 1 or 1 to 0
      * The data 0101011 indicates start of the bit pattern (preamble phase)
      * Looking for rising and falling edges is dangerous due to noise
    - Phase Locked Loops (?)
    - Eye pattern (?)
      * Superimpose 2 signals together
    - Multiplexing (n times more bandwidth by sending more data at once)
      * Time
      * Frequency
      * Wavelength (visible light)
        + Send red, blue, etc. signals at the same time at the sender end
      * CDMA
        + Different frequencies at different times
    - Async vs sync
      * Async: Sender and receiver don’t have the same clock. Need start and stop bits and an accepted number of data bits (e.g., 1 byte)
      * Sync: Both the sender and receiver have synchronized clocks. Need transitions to ensure clocks do not drift.
  + Decoding sublayer
    - Clock recovery
  + Media transmission sublayer
    - Convert digital bits to energy (electricity or light)
  + Signal transmission sublayer
    - What the channel does to the signal (Nyquist and Shannon limits)

Lecture 5

* [www.google.com](http://www.google.com) -> DNS -> IP address
  + IP -> 32 bits
* HTTP atop TCP
  + HTTP header
* TCP adds sequence numbers to order data when received (after retransmission)
* Routing
  + Each router knows the next hop (forwarding table) and passes that to data link
* Data link
  + MAC in header
* RS-232
  + Interface between CPU and modem connected to twisted pair
* Cable
  + Twisted pair (last mile)
    - Signal is difference between both pairs -> signal gets cancelled out
    - Used to be low battery and low throughput and long distance
      * Now higher throughput less distance (cat 5/6 twisted pair)
    - Cable = coaxial
  + Cable is good at sending data to you
  + Coaxial
    - Used bw buildings
  + Twisted pair
    - Local
* Fibre
  + A lot of bandwidth
  + Each fibre cable is unidirectional
  + Total internal reflection – no refraction into the fibre cable
  + Multimode fibre
    - One part reflects (long path)
    - One part doesn’t (short path)
    - Limits bandwidth
  + Single mode -- Thin fibre
    - Wave will not be spread into parts... just one thin palse
    - Higher bandwidth because there is no dispersion (wave is not spread out)
  + Use monochromatic lasers so that the light waves do not interfere
* Wireless
  + Spectrum
    - Radio waves
      * Omnidirectional – goes in all direction
      * Goes through obstacles
    - Satiates, microwaves
      * Directional
      * Absorbed by obstacles
      * Signal to satellite from dish will be unidirectional
      * The signal back from satellite to its destination will have a larger direction range
      * Geosynchronous
        + Satellite should rotate around earth at same speed earth rotates itself

Antenna only needs to point in one directions

* + - * + Satellite needs to be far to achieve geosynchrony

Huge latency

Not as much bandwidth (cannot keep too many satellites in the sky)

* + - * Right of way
        + Satellites are not on the ground (bypass wires, …)
      * Low orbiting satellites
        + More latency
        + Cover earth with low orbiting satellites… handoff connection to closest satellite as one rotates away from dish
        + (satellites are not geosynchronous since they are too close)
        + Disadvantage: You need a lot of satellites that span around earth
* FMD = freq division multiplex
* TDM = time
* WDM = wavelength
* Interconnection
  + Router
    - More latency
    - Can redirect if a link goes down
    - Check for errors
  + Repeater (“hubs”)
    - Less latency
    - Cheaper
    - Physical layer
    - “Blindly” repeat bits
    - Fibre stays at the repeater level