CSE461: Introduction to Computer Communication Networks

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TODO

• Bits to signals and back again
• How does a wired protocol like Ethernet work?
• How do wireless protocols work?
• Machine learning + wireless
Ethernet

1980: 10Mb
1995: 100Mb
1999: Gigabit
2006: 10Gb

2010: 40Gb
2010: 100Gb
2017: 200/400 Gb
> 2020: Terabit
Baseband Data

10MBit Ethernet uses Manchester encoding
100MBit (Fast Ethernet)

4 bits → 4B/5B → Scramble → MLT-3

- At least 2 bit transitions per block for clock recovery
- Spread across multiple frequencies to reduce interference
- Reduce bandwidth

16 hex symbols
16 control symbols

The diagram shows a voltage waveform with peaks at 1V, 0V, and -1V.
0: no transition, 1: transition

1 → 0 → -1 → 0 → 1
4B/5B creates 125MBaud signal
MLT-3 reduces fundamental frequency to 31.25MHz
Gigabit Ethernet

- 125MBaud per twisted pair.
- 500MBaud in total (2 bits per symbol)
- 4D-PAM5 (5 voltage levels, spread across 4 channels)
- Trellis modulation for parity bit
Spread spectrum

Generate parity bit

Generate symbols

$5^4 = 625$ symbols in total

Encode 9 bit word: 8 data bits + 1 parity bit.
$2^9 = 512$ possible bitstrings

Remaining 113 symbols used for control or discarded

Channels are interdependent
Modulate data onto a carrier wave
Often 900MHz, 2.4GHz, 5GHz

Phase

Amplitude

Frequency shift keying (FSK)
Each symbol has a unique AMPLITUDE and PHASE

16QAM: 4 symbols per bit

Take the real value (x-axis) and the imaginary value (y-axis)

Create In-phase and Quadrature (IQ) waves

Multiply IQ waves by carrier wave frequency and transmit

\[ I(t) \cos(2\pi f_0 t) - Q(t) \sin(2\pi f_0 t) \]

At receiver low-pass filter signal to get back I/Q
After fading and multipath attenuation (loss over distance), points move closer. Noise points blur.
Many protocols use OFDM
Multiple streams of data over a channel
More robust to interference

Frequency-selective fading
Channel estimation: Estimate channel taps from packet preamble
Square-Root raised cosine filter: matched filtering, less ISI
Viterbi decoder: undo convolutional code (error correcting code)
Wi-Fi

NB - IoT

LoRa

Bluetooth

Z-Wave

ZigBee

PROTOCOLS

PROTOCOLS EVERYWHERE
ISM bands

- Reserved for industrial, scientific, medical purposes
- Originally not for communication
- But used for short-range communication
- Longer range like cellular, satellite, amateur radio, FM radio use other reserved bands
- Common bands: 900MHz, 2.4GHz, 5GHz
Combine transmissions over several frequency channels. Get Gigabit/s speeds.
Packet Collisions

- CSMA
  - Check channel, RTS/CTS
  - Exponential backoff
  - Standard for Wi-Fi, BLE, Zigbee
- What about other protocols?
Lora, Sigfox, NB-IoT

Long range + can be decoded BELOW the noise floor

Lora range: > 10 miles

No MAC protocols yet!

Lora, Sigfox and Z-wave are proprietary (unlike Wi-Fi)
Dimensionality reduction

SNR=-10

SNR=-20

SNR=-30
Machine learning
underneath the noise floor