Lecture 16: Low Power Networks, Narrowband vs Wideband, SIGFOX / LoRA / NB-IoT, Choir: Ideas & Eval

Low Power Motivation

- AAA battery capacity: 1.5 – 2 Wh
- Want to operate for 1 year
- 10 years?!
- How can we do this?
  - Duty Cycling
    - LTE radio takes 1 Watt -> 1.5 – 2h
    - Wi-Fi -> 100mW -> 15-20h
    - Duty cycle so we get that much time over a period of a year, multiple years, etc.
  - Lower power transmissions
    - 1 mW or μW

Long Range = Low deployment overhead

- Need to deploy less repeaters, etc. per unit area

LP-WAN: Low Power Wide Area Networks

Narrowband vs. Wideband

- Low power devices often operate at narrow bands (10s-100s of kHz)
  - 100-1000x lower bandwidth than WiFi
  - Narrowband devices can concentrate power in a specific band to get higher SNR
- What do you lose?
  - Data rate
  - More sensitive to channel
    - Reliability

Frequency

- Bigger wavelength – less attenuation over distance
  - $\frac{\lambda}{d}$
- LoRA operates at 400 MHz or 900 MHz
  - This allows longer-range transmission

BLE (Bluetooth Low Energy)

- Narrowband
- 2.4 GHz
    - Can have WiFi interference
- Frequency switching
    - Keeps jumping between different narrowband frequencies
    - Some bits may collide but most will get through
    - Somewhat of a security measure, only the devices paired know the frequency jump sequence
        - But you could still analyze all of it if you have a wideband radio

LoRA

- Uses a chirp
    - Linear increase in frequency over time
- Sends chirp from Tx device to Rx device
- Encoding data
    - Start frequency f_0 and end frequency f_1
        - Send from middle frequency to f_1 for bit 1 and from f_0 to middle frequency for bit 0
        - Have chirp segment bandwidth S?
        - By taking $f_1 + f_0 + S$ we can get a tone signal that will be different depending on the bit we want to send
    - What about clocks?
        - Use a preamble to calibrate
- Rate control
    - How can you increase data rate?
    - Have different levels / combinations of sweeps (different starting frequencies)
    - I.e. split your bandwidth into multiple segments, change the order over which you are sending chirps in those segments
        - Tx
            - Chirp
            - Shift starting frequencies
            - Transmit
        - Rx
            - Receive
            - Mix with downchirp

            - FT
            - Decode bits
    - Rate control 2: Change the slope of the chirp
        - "Spreading Factor"
            - How much the slope is spread over time
            - Slower (lower slope) are more robust
                - High SF (many samples for each chirp)
                - 7-12 samples?
            - Faster chirps have higher data rate
        - SF acts as medium access control
            - Slope that we expect, when received, will give tone
            - Other slopes will give us a chirp
            - So, we can identify the signal that we want

SIGFOX vs. LoRA

- SIGFOX uses narrowband transmitters
- Different deployment models
    - SIGFOX is like cellular networks
        - Have towers / base stations deployed
        - Have small number of packets (5-12 packets per day per device)
        - 30-40 km
    - LoRA is like WiFi
        - Deploy LoRA gateway
        - Figure out backhaul… where does data go from the gateway?
    - NB-IoT
    - Cellular Providers

Choir

- What happens when packets collide?
- How do you do medium access?
- Carrier sense is challenging, devices are spread over wide spaces
- Chirp collision
    - 2 colliding chirps will have slight offset due to frequency and/or clock offset
- How to decode bits over time?
    - Fractional offsets
        - Discrete / integer bins
            - These are what you set the frequencies to
        - Non-integer bins
            - What are received
        - These offsets are consistent over short periods of time
        - Use these offsets to decode
- Pros:
    - Decode despite collisions
    - No specialized hardware
- Cons
    - Need to sample more data
    - Only works at high SNR
    - Relies on random distribution of fractional offsets not colliding (too closely)
    - Offsets can change over time
        - Mobility