# Indoor Positioning

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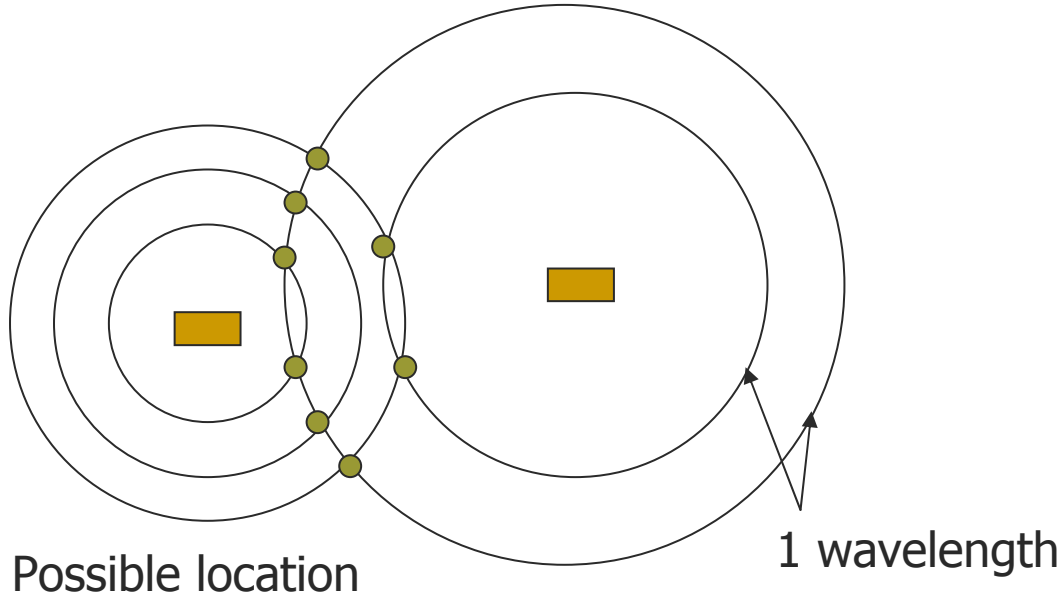
# Problem Description

- Determine position accurately indoors
- Cool because:
  - Unsolved problem!
  - Indoor robots, interactive maps, security
- Hard because:
  - GPS doesn't work indoors
    - Alternatives: Radio, ultrasonic, IR
    - Need *cheap* alternative (GPS atomic clocks ~ $100k)
    - Resolution: Better than room level … 1 foot possible?

# A Change of Heart

- After some research, decided:
  - Can use phase differences in sine waves
  - Receiver can solve for position



# Things Look Ugly

- Unfortunately…
  - Requires custom hardware
    - Which requires a custom OS
    - And custom software
    - And custom (i.e. no) debugging tools
  - A MIT Master's Thesis was on a similar subject
    - Unfortunately, couldn't get everything working

# Revelation

- Use *existing* hardware/software
  - Learned about Microsoft research using wireless networks (thanks to Michael Newman)
  - Can get a cheap wireless card & free software
  - Main idea: measure signal strengths at various locations
    - Create a table
    - Later, someone visits an unknown location
      - They record their current signal strength
      - Find closest match in table

# Bumps along the way

- Smaller problems
  - Needed access to device drivers to get signal strengths
    - Luckily, found some utilities
    - Netstumbler, Lucent's tools
      - Log signal strengths to a file
  - Now a matter of text extraction and manipulation
    - Time to learn Perl!
      - Built in hash tables

# Bigger, Better, Faster

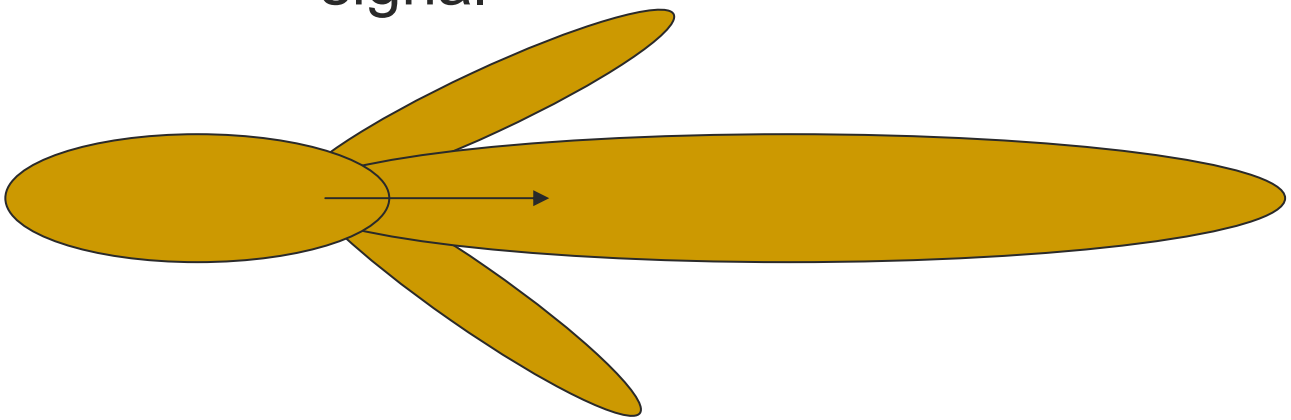
- Getting signals isn't enough
  - Need quality signals
    - Emphasize positioning, not just data transfer
  - Solution: an antenna
    - Found various "homebrew" antennas on the Web
    - Pringles can, soup can…
    - Work comparably to $100 commercial ones, cost < $10

# A Little Theory

- EM propagation hard, but main idea:
  - Antenna based on wavelength
    - 2.4 GHz (802.11b) roughly 12cm
    - Manageable size
      - If RF (MHz), could have been tens or hundreds of meters for a “perfect” antenna (i.e., a radio tower)
    - Sine wave peaks at ¼ wavelength (3 cm)
    - Set up a standing wave and tap it at 3 cm.
  - Still don’t understand all the details, but have books and learning more =)

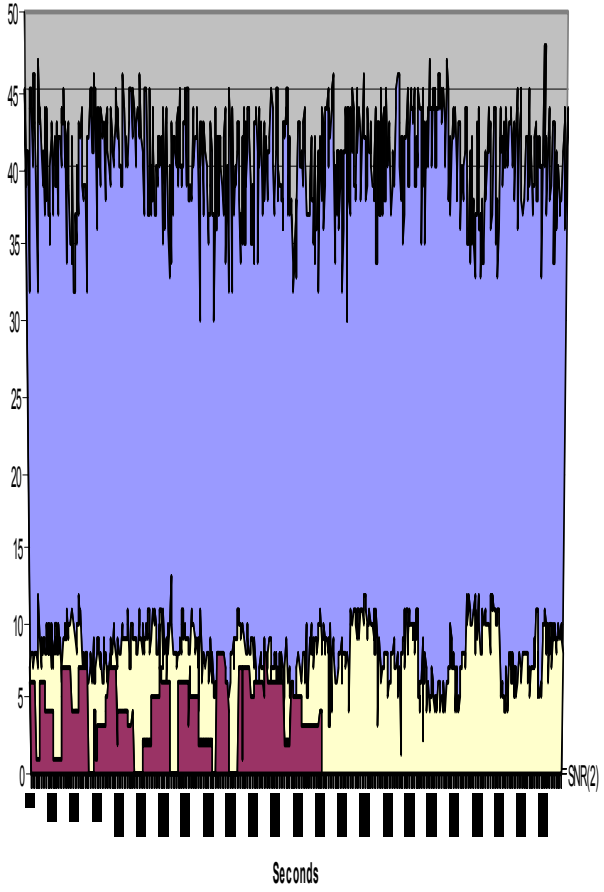
# How do they do?

- Pringles vs. soup?
  - Both directional antennas
    - “Amplify” signal in some directions, decrease it in others
    - Non-powered components, so can’t boost signal

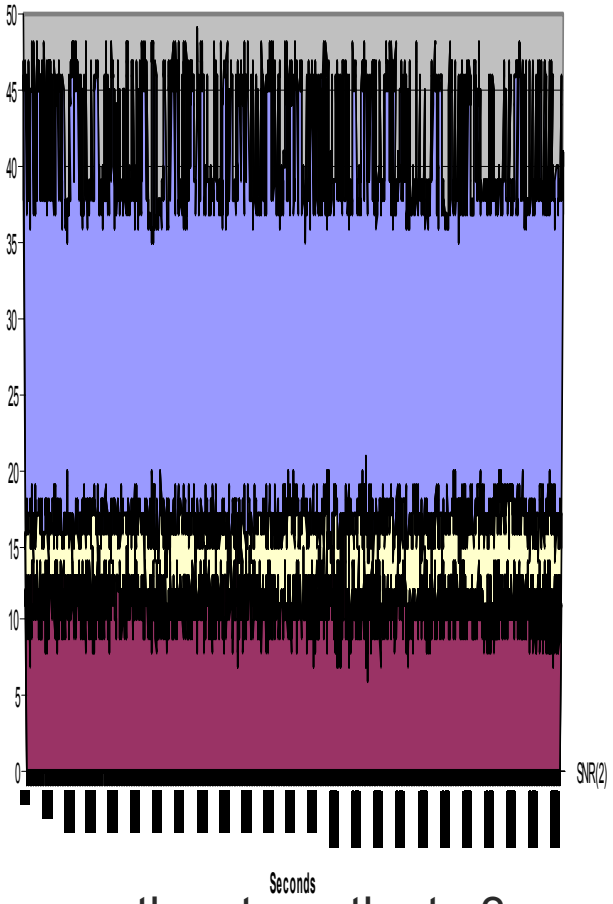


# Signal-to-noise ratio (1 second intervals)

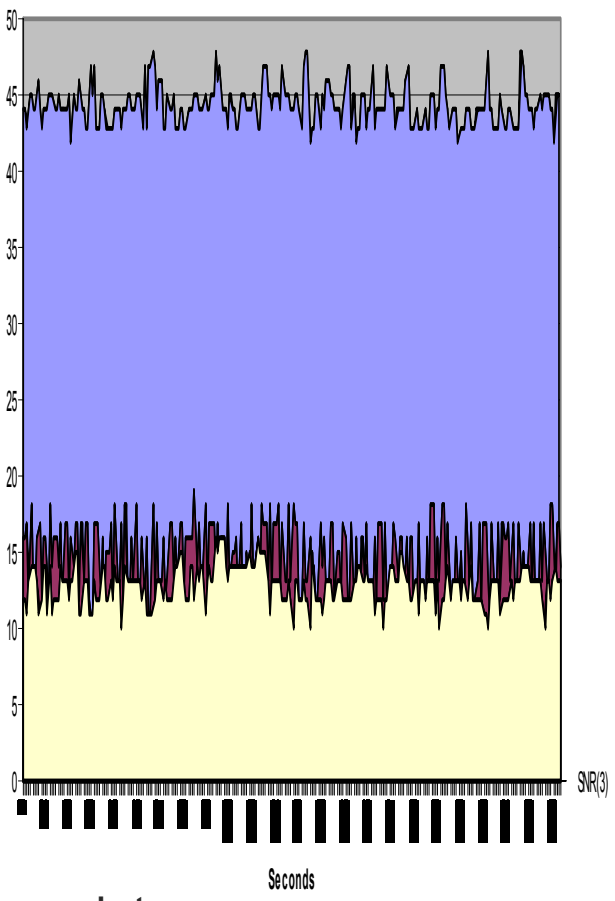
No antenna




Pringles




Can

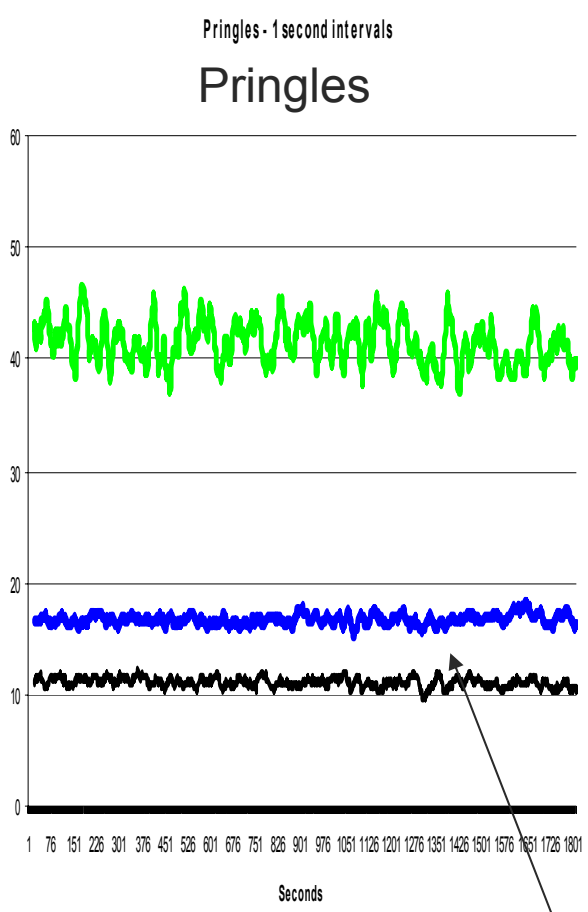



The colors are the strengths to 3 access points

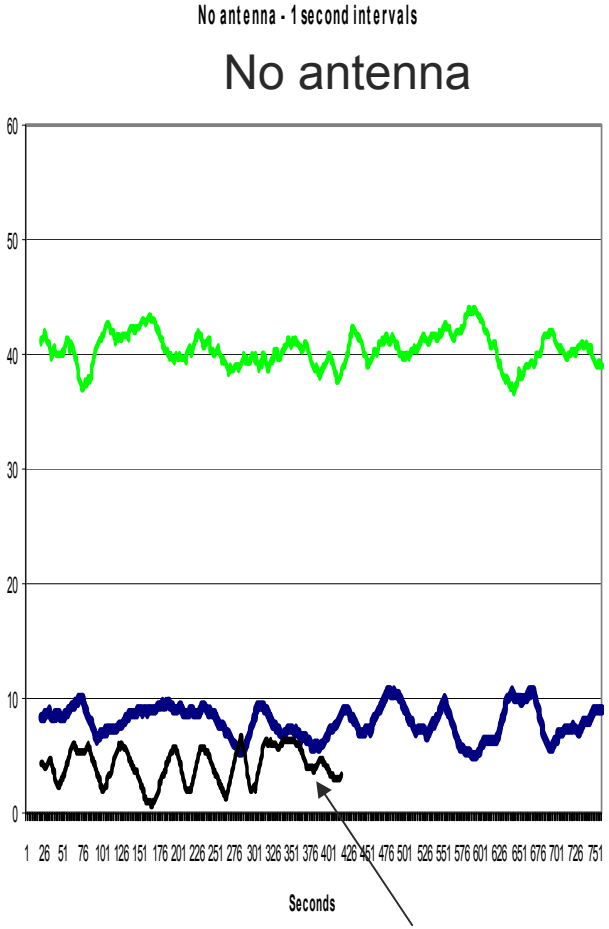
# Shaky - what if we average?

- Good idea – but...
  - How long will you stay in one place?
    - More than 10-20 seconds unreasonable
    - Enough time to get a decent sample?
- Does the signal vary too much, even for averaging?
  - Let’s see…

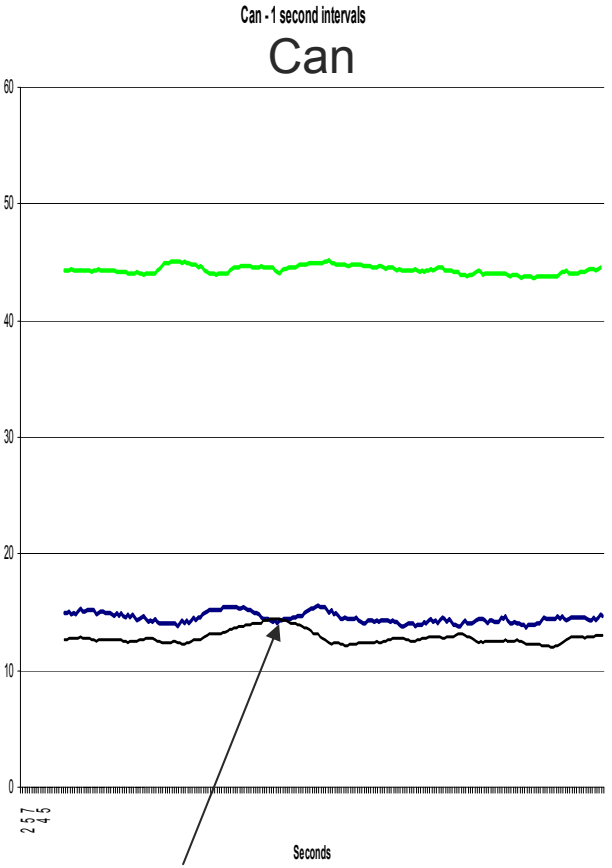
# 20 second moving avg.




Good

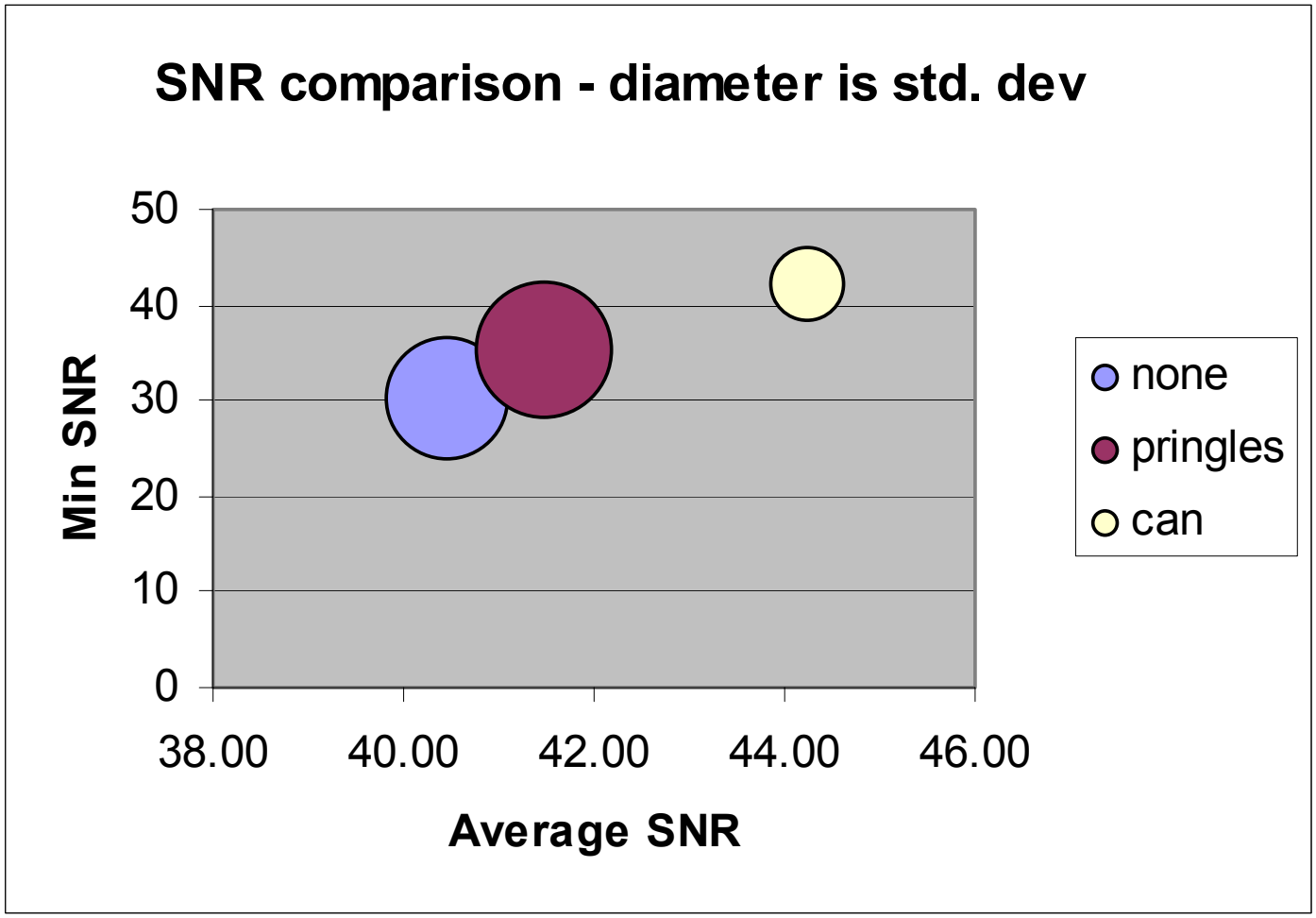



Ugly




Bad

# Signal-to-Noise ratio

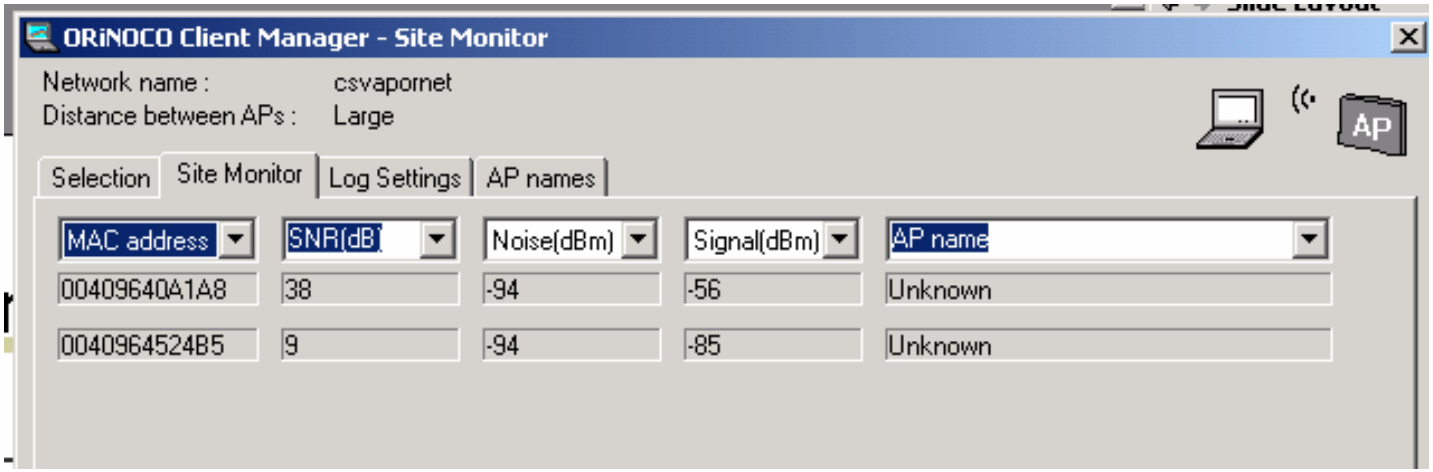


# Results

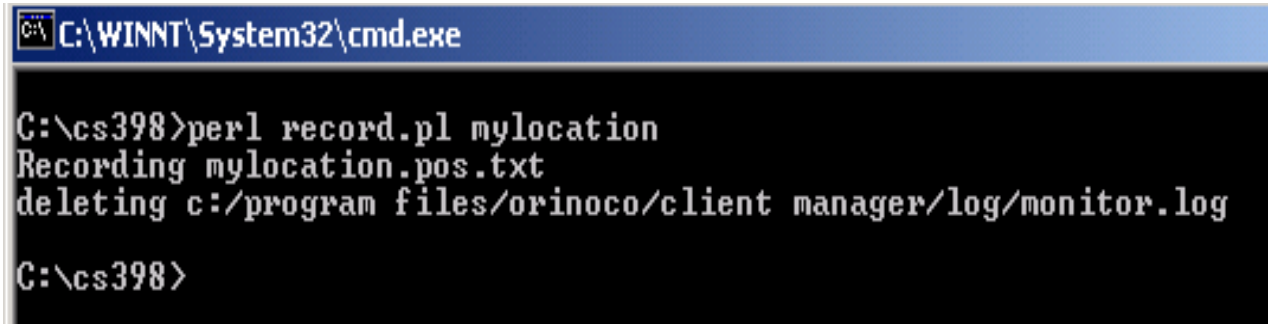
- Soup is the winner!
  - Usually has low range (max-min), highest avg.
    - Also, smaller size
    - Theory: soup is a waveguide, vs. the Pringles Yagi antenna – want to learn why soup wins
  - Pringles enhances signal…
    - …but still shaky over 20 seconds of averaging
    - Sometimes beat the can with std. deviation, but also had larger swings (max – min)
  - No antenna
    - Size (or lack thereof) is the sole advantage
    - Also a disadvantage – need roughly 6-12cm for an good antenna at 2.4 GHz

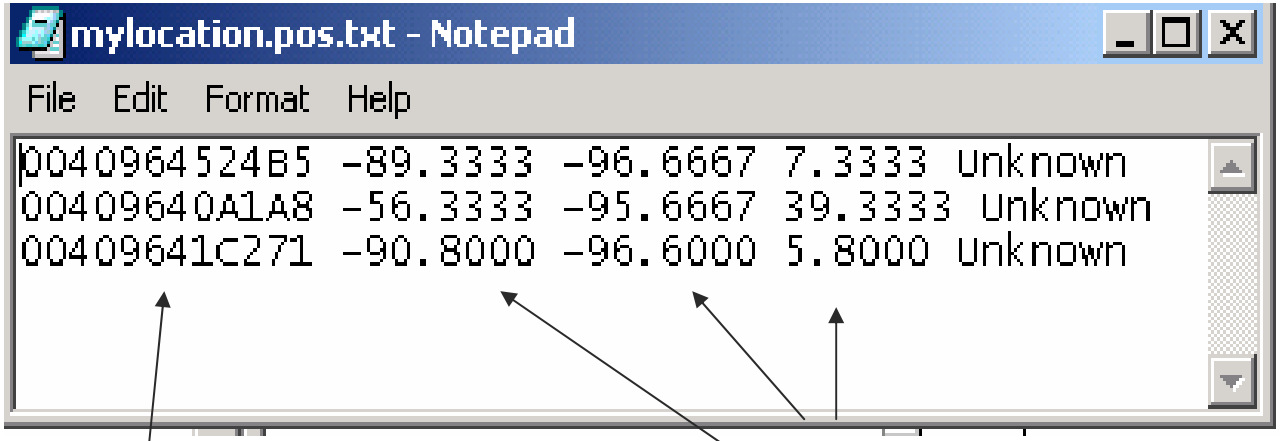
# My method

- Go to a location, log strength for ~30 seconds.



# Extract and average data to create a profile for the location




Acces point name

Average Values

# Log signals, and look it up…


```
----10 Closest Matches----
name: mylocation  distance: 16.5930
name: noa2  distance: 1974.0220
name: rm104  distance: 2050.5636
name: rm105_b  distance: 2073.9012
name: noa1  distance: 2260.7548
name: test  distance: 2399.2561
name: noa3  distance: 2443.7092
name: sq1  distance: 2471.7559
name: rm105_a  distance: 2473.8280
name: rm101  distance: 2560.6905
deleting c:/program files/orinoco/client manager/log/monitor.log

C:\cs398>
```

# A Long Journey…

- But learned a lot along the way
  - Perl for text extraction
  - EM theory & 802.11b
  - Some MySQL to manage database
  - How to quickly devour a can of Pringles to make an antenna
  - Lessons:
    - Cool things can be made from simple components, many of which already exist
      - Don’t build everything from scratch
    - You can find anything on the Internet! (drivers, utilities, theory explanations, design specs, hardware)

# Conclusions

- Only recently got it working, but…
  - Using the can, can distinguish to about 10 feet confidently
    - CS building has a lot of access points
    - Can resolve to about ~1 meter in the best case
      - Original goal achieved: better than room-level
      - Cheap, efficient, relatively simple, uses existing hardware
  - Need more tests to determine exact resolutions
    - Will most likely be a % error at that resolution
    - New metrics for comparison
      - Weighted avg: weight more for low std. dev.