I Am the Antenna: Accurate Outdoor AP Location using Smartphones

CSCI780 Sensors and Ubiquitous Computing

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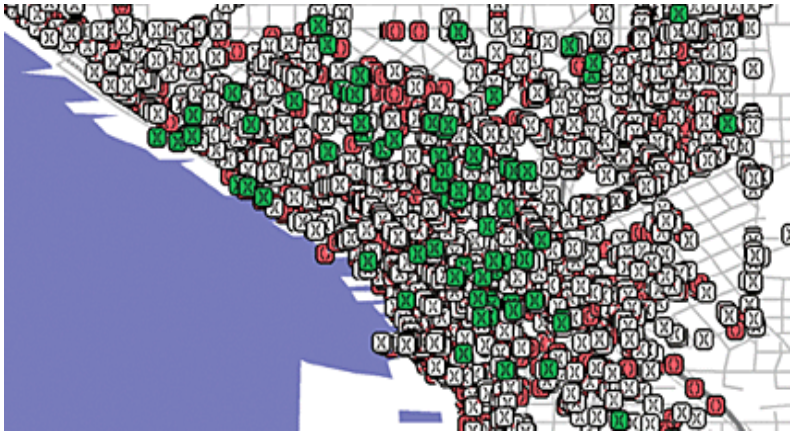
Based on slides from Zengbin Zhang

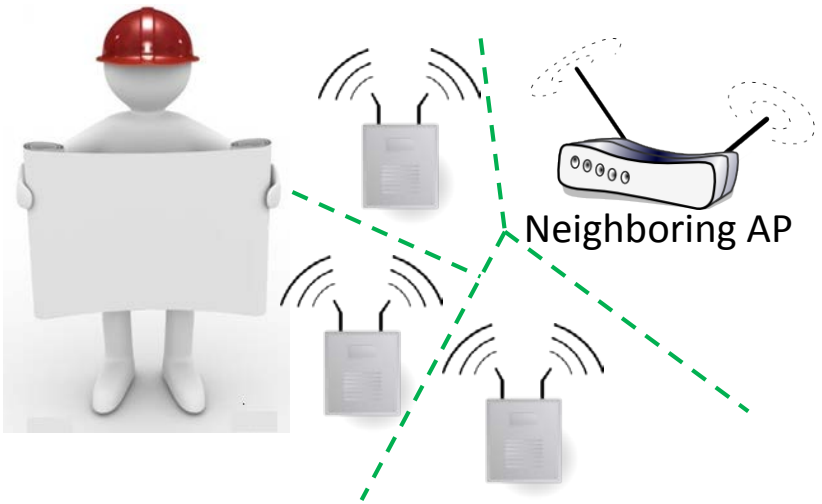
Ubiquitous WiFi Access



- WiFi network is growing rapidly
  - Cisco: WiFi traffic will surpass wired IP traffic in 2015
- High density
  - We need well tuned and managed WiFi networks!

It is Important to Locate APs

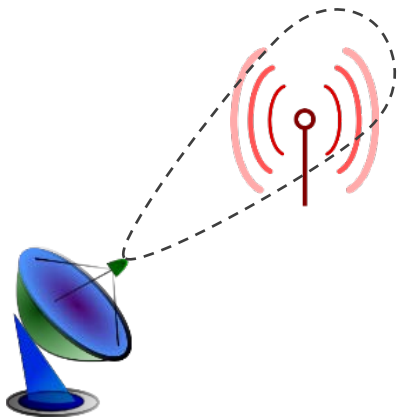
- Better network planning



- Finding rogue APs

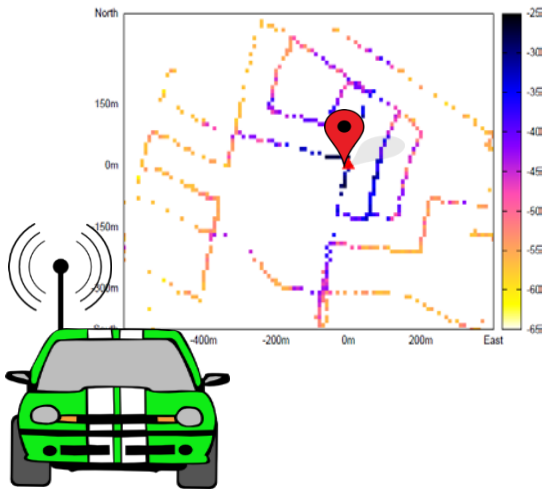
Methods for Locating APs

Directional Antenna



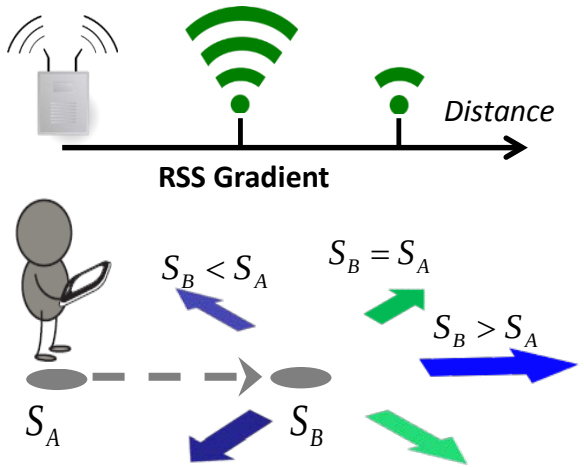
- ✓ Fast, very accurate (10˚)
- X
  - Expensive (hundreds to thousands of dollars)

Signal Map



- ✓ Simple method, easy to perform
- X Very time consuming

RSS Gradient



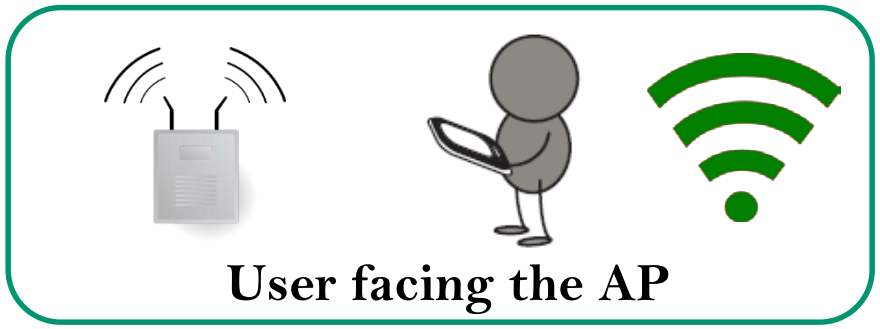
- ✓ Low measurement overhead
- X Low accuracy (often error > 45˚)

A new method is needed for accurate, cost-efficient, and time-efficient AP location?

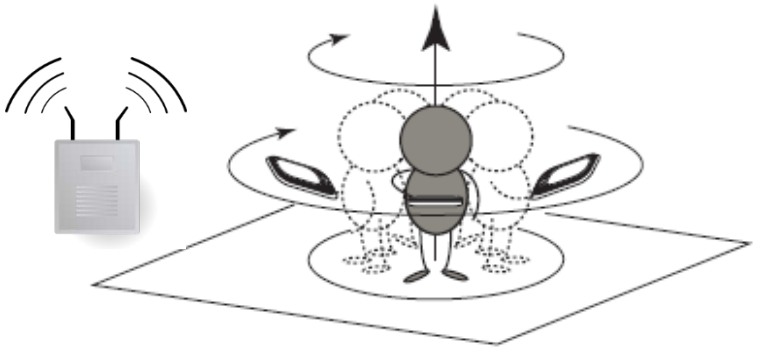
The New Idea

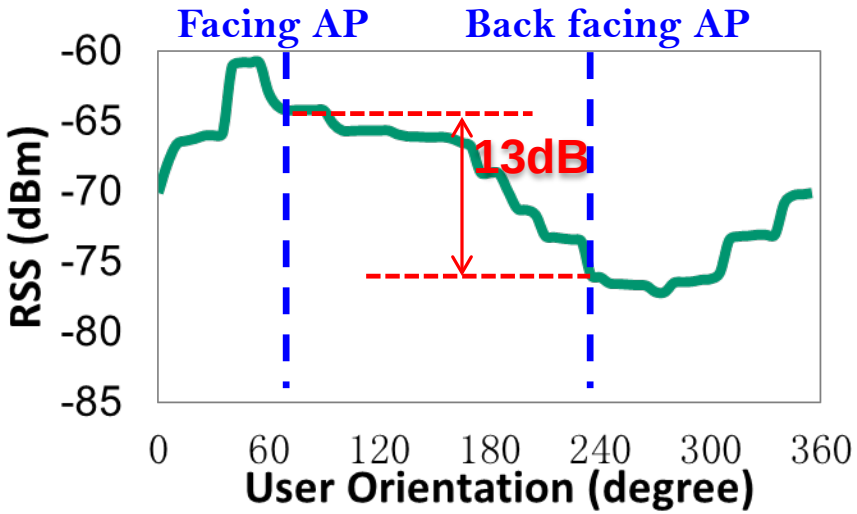
- Existing observation:
  - When wireless signal penetrates through a human body, up to 6dbm signal drop was observed. [IEEE TMC 2011]

- Can we use this to detect AP location?



The New Idea (continue)





- The difference is significant
  - User's body is much larger than the phone
  - User is close to the phone
- We can emulate a directional antenna just by
  - Rotating with Smartphones

Outline

- Motivation
- Measurement
- AP Location Design
- Performance Evaluation
- Conclusion & Discussions

Measurement

- Smartphone Devices
  - Motorola Droid, HTC G1(Android)
  - LG Fathom(Windows Mobile 6.5)
  - iPhone4 (iOS)
- WiFi Protocols
  - 802.11 b/g
  - 802.11n (MIMO)
- Human subjects
  - 7 users in their lab
  - Different phone orientations
- Environments
  - Outdoor LOS/Non-LOS
  - Different distances to AP

Anything else you want to add?

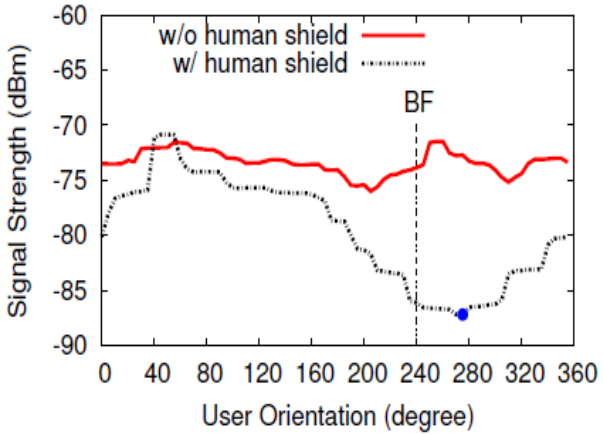
Measurement (continue)

Simple Line of Sight (Simple LOS)

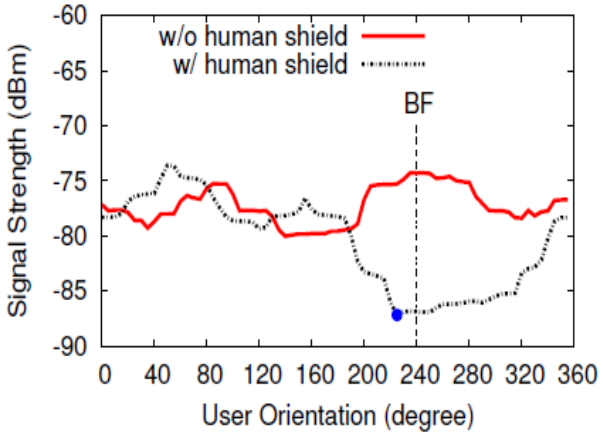
Complex Line of Sight (Complex LOS)

Non Line of Sight (NLOS)

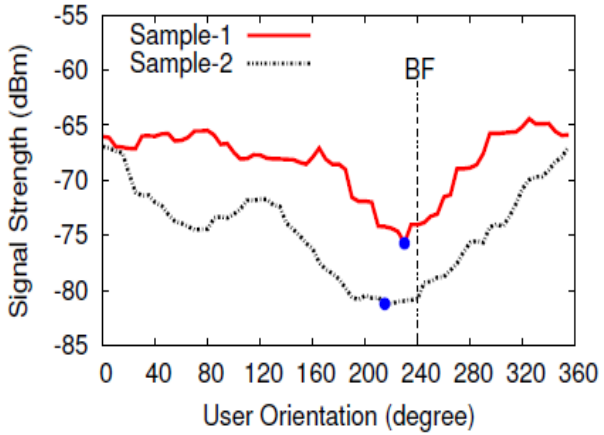
Measurement (continue)



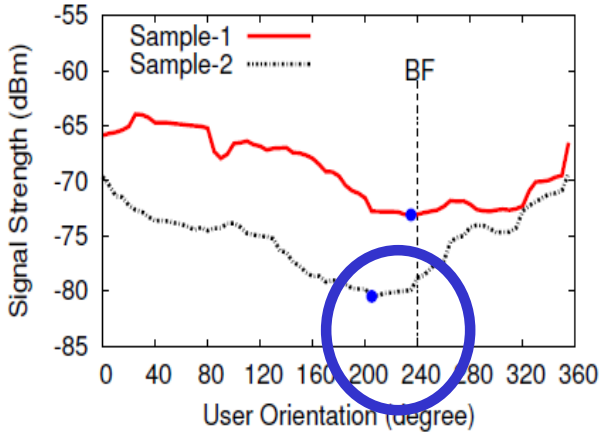
(a) Droid, Simple LOS



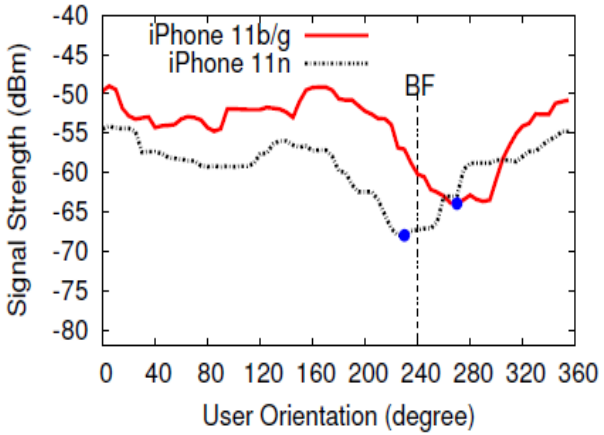
(b) G1, Simple LOS



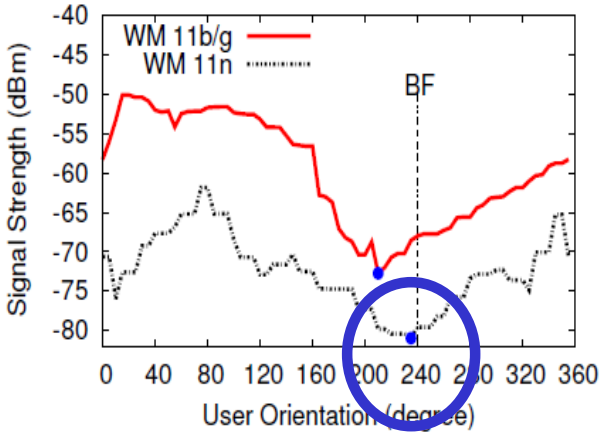
(c) Droid, Complex LOS



(d) Droid, NLOS



(e) iPhone, Simple LOS



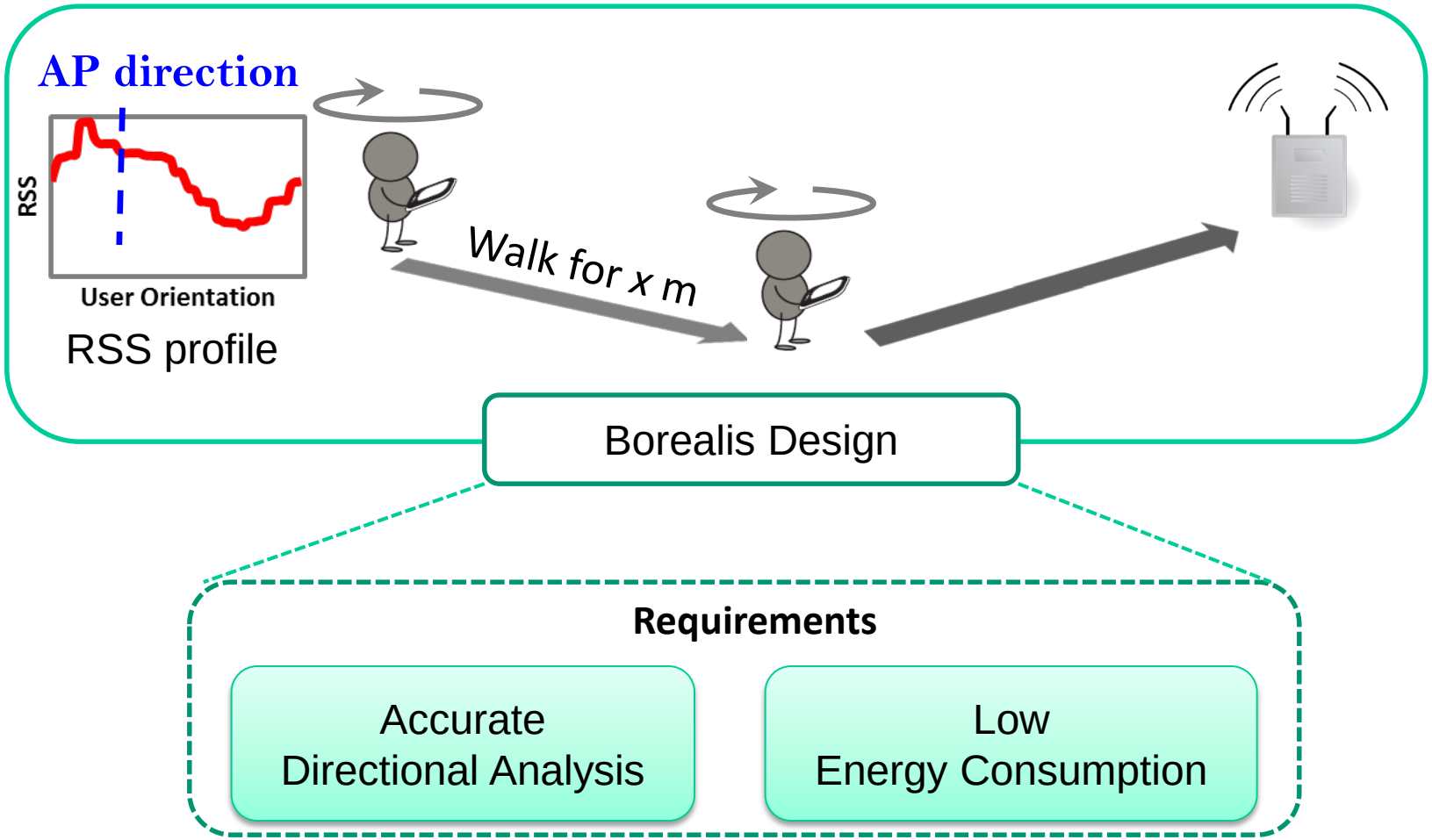
(f) Windows Mobile, Simple LOS

Human vs. Table

Complex LOS vs. NLOS

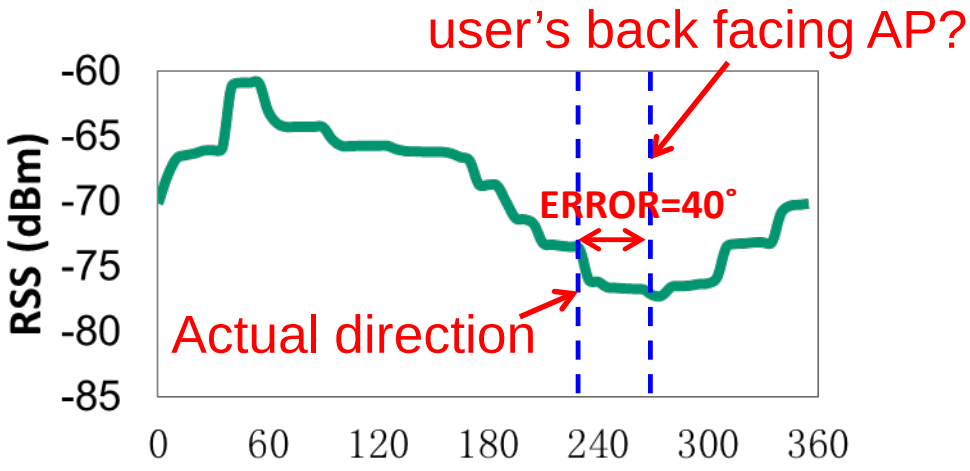
Phones & Protocols

The Borealis Design

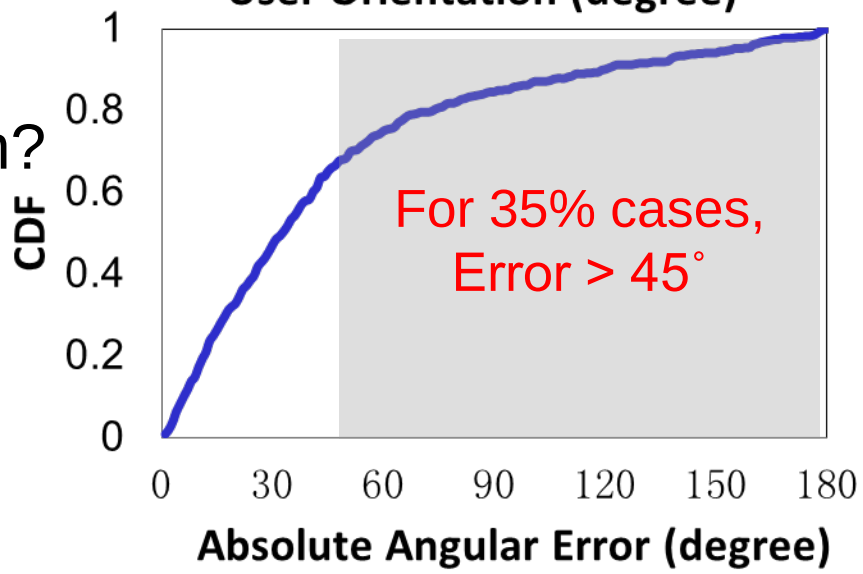


Directional Analysis

- Min RSS direction?

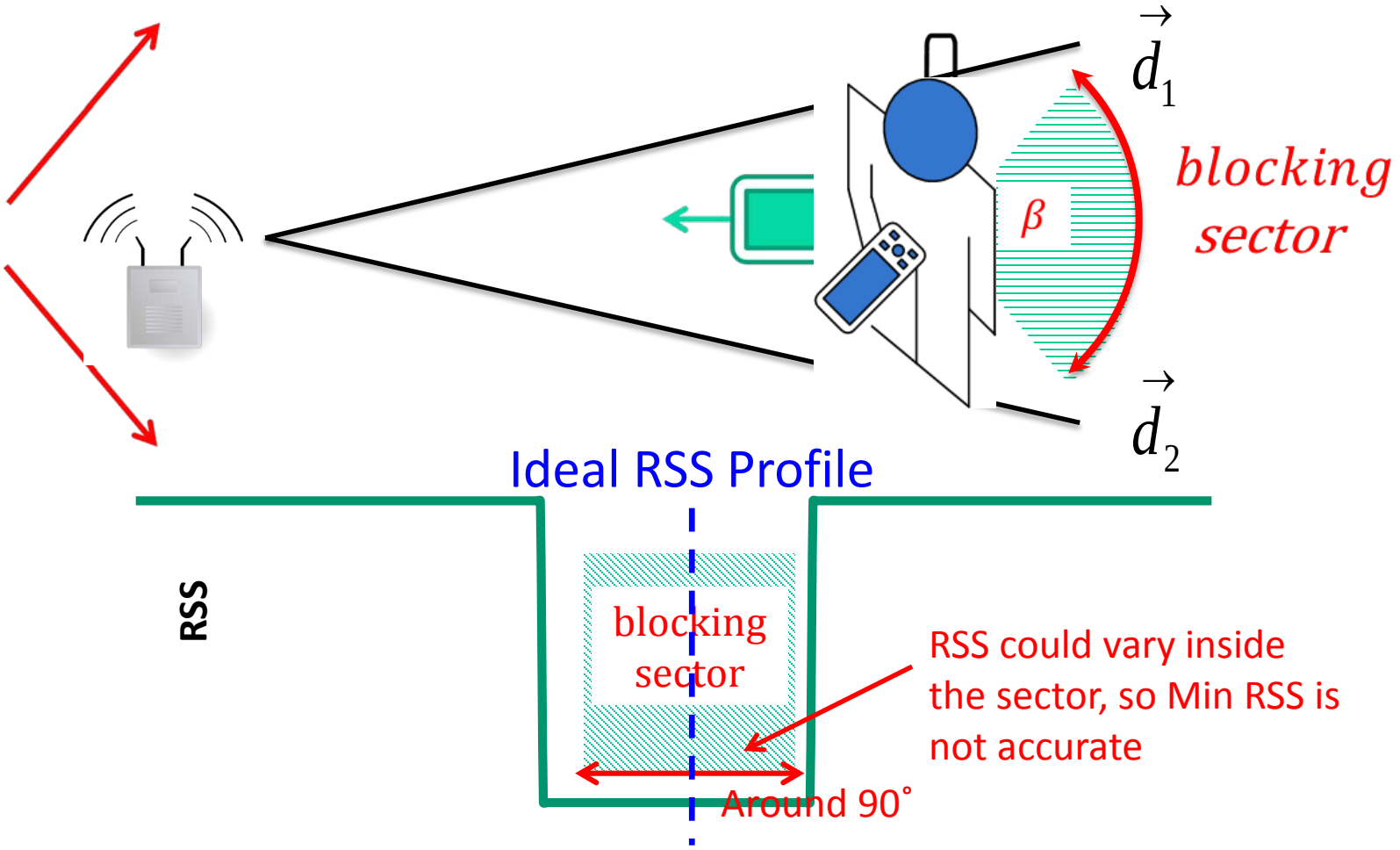


- How big is the error if using Min RSS direction?



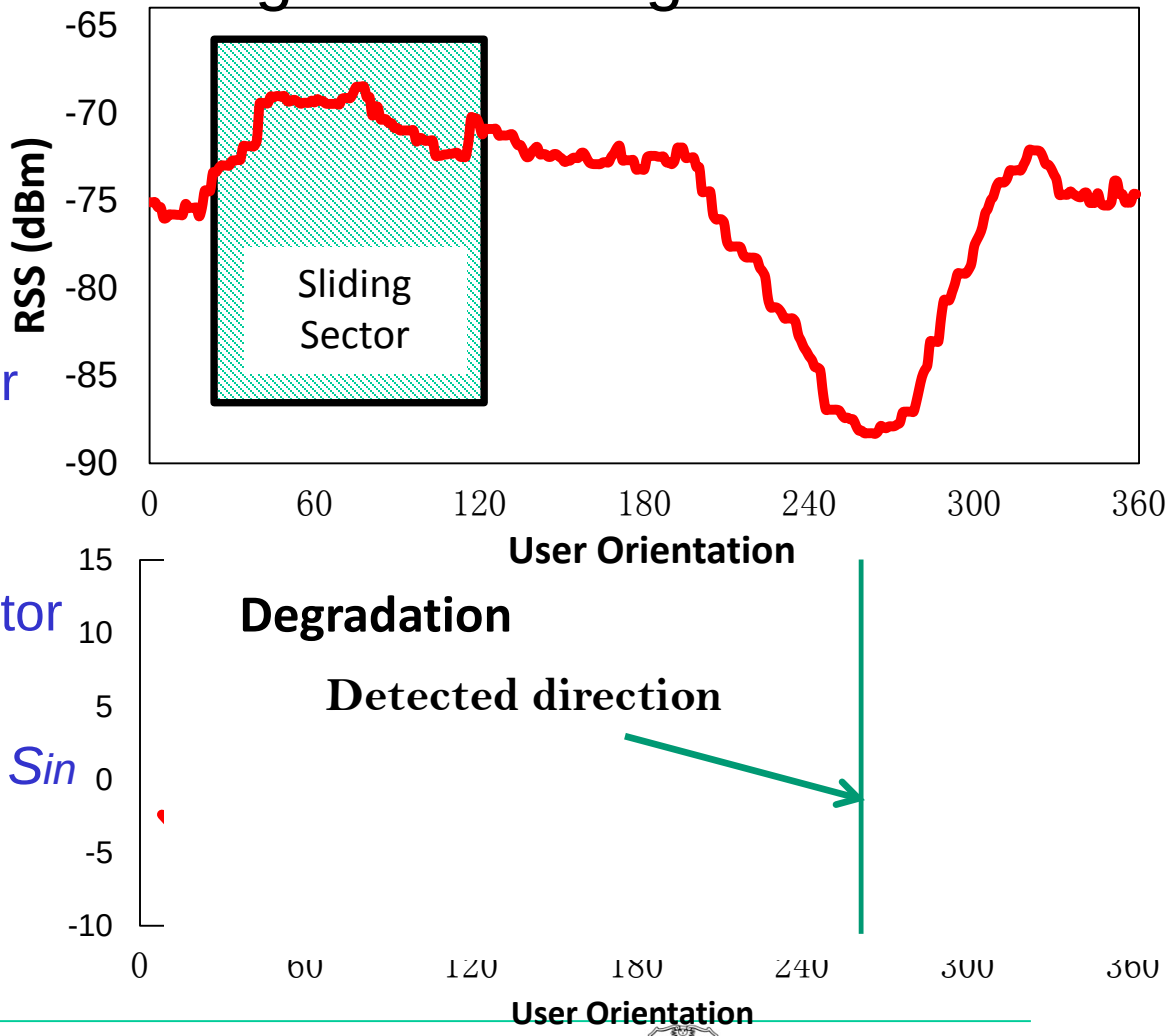
Directional Analysis (continue)

- Signal degradation occurs at a range of directions

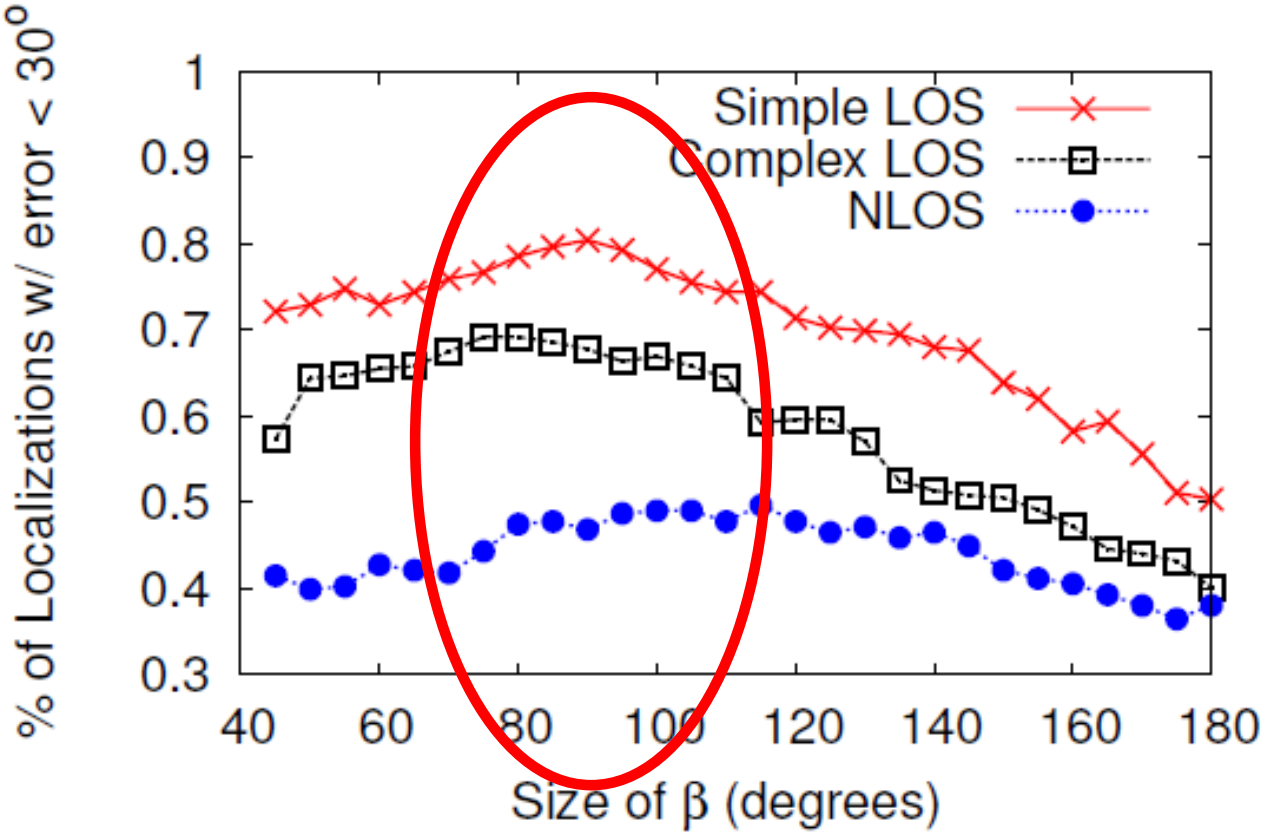


Directional Analysis (continue)

- Find the sector with the largest RSS degradation
  - Sliding window
  - *Sin*: average RSS inside the sliding sector
  - *Sout*: average RSS Outside the sliding sector
  - *degradation = Sout - Sin*



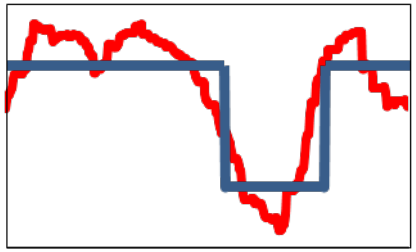
Impact of Blocking Sector Size



(b) Impact of Blocking Sector Size β

Navigation

- How does a user navigate using directional hints?
  - ➢ Strawman design: periodic
    - Refine AP direction every 20 meters
  - ➢ However, nothing is perfect
    - Temporal/spatial variation
- Our adaptive method
  - ➢ Measurement confidence
    - The similarity of measured RSS and ideal RSS profile



$$\rho = \frac{1}{m} \cdot \frac{\sum_{i \in [0, m-1]} (t_i - \bar{t})(r_i - \bar{r})}{\sigma_{\mathbf{T}} \cdot \sigma_{\mathbf{R}}}$$

  - ➢ If confidence is high
    - Walk further between measurements

Prototype Implementation

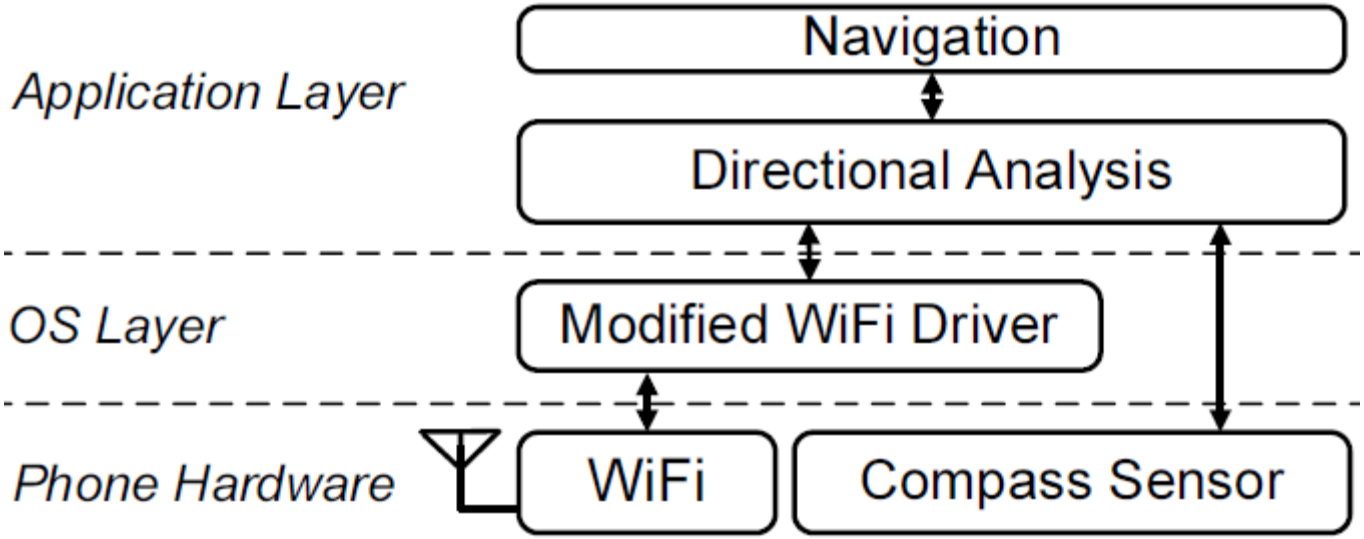
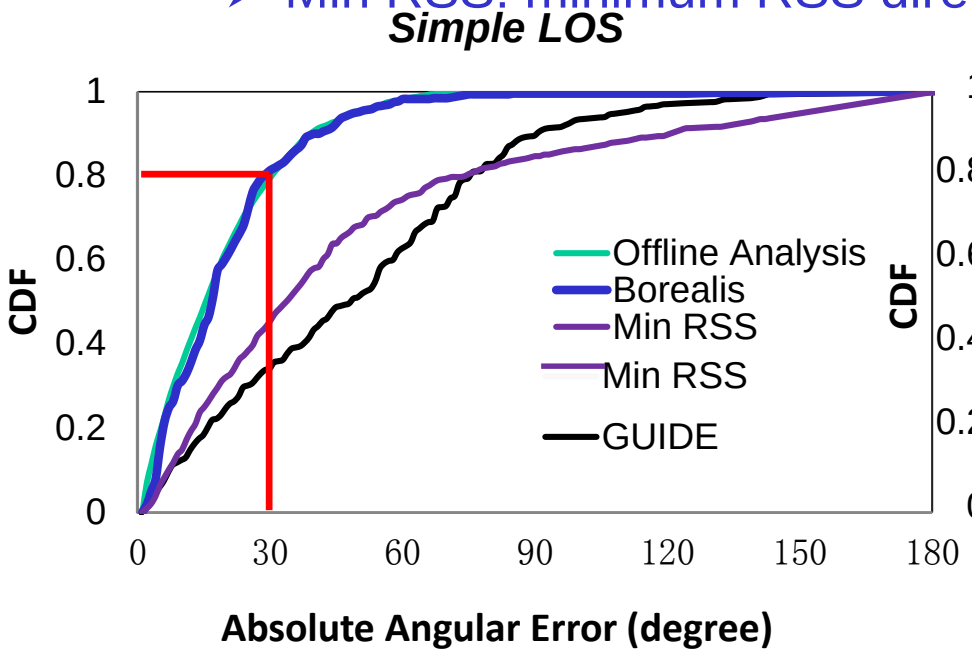


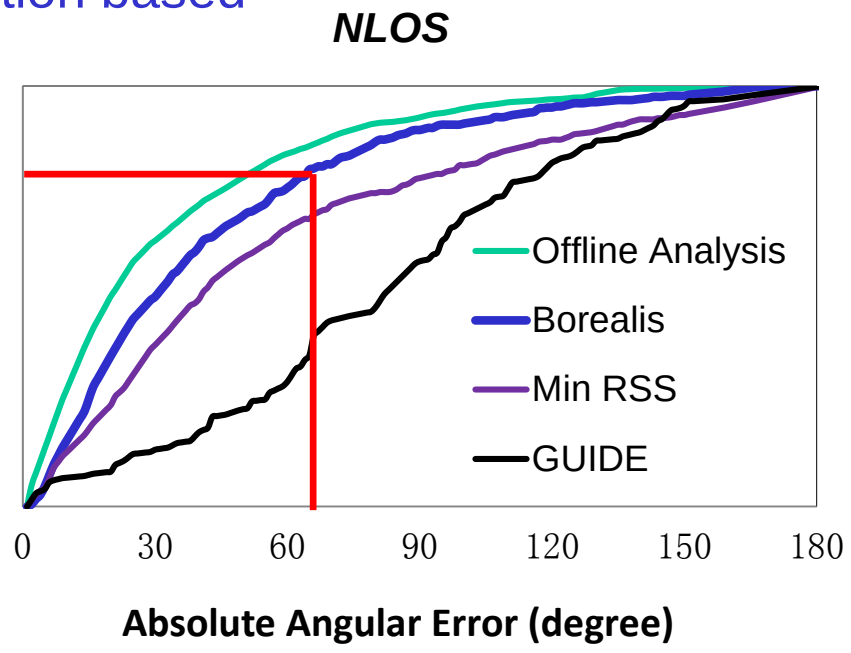
Figure 6: Borealis architecture overview.

Accuracy of Directional Analysis

- Compare Borealis to
  - Offline Analysis: clustering-based ML method
    - Claimed to be (?) upper bound of directional analysis
  - GUIDE: RSS gradient based
  - Min RSS: minimum RSS direction based



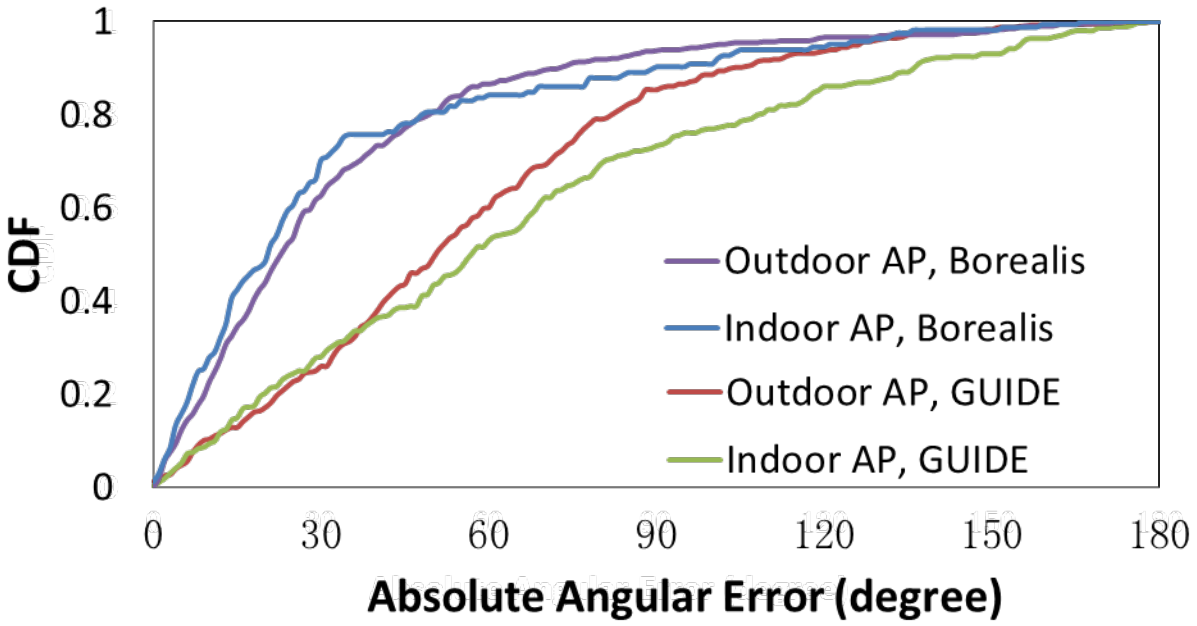
Error < 30˚ for 80%+ cases in Simple LOS



Error < 65˚ for 80%+ cases in NLOS

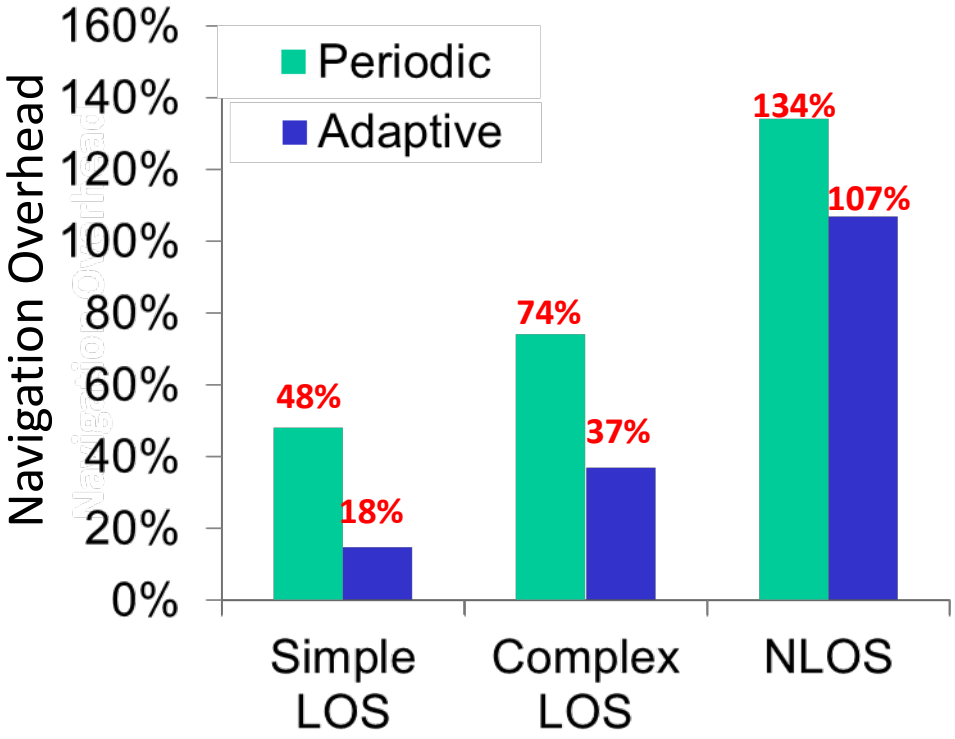
Locating Indoor APs?

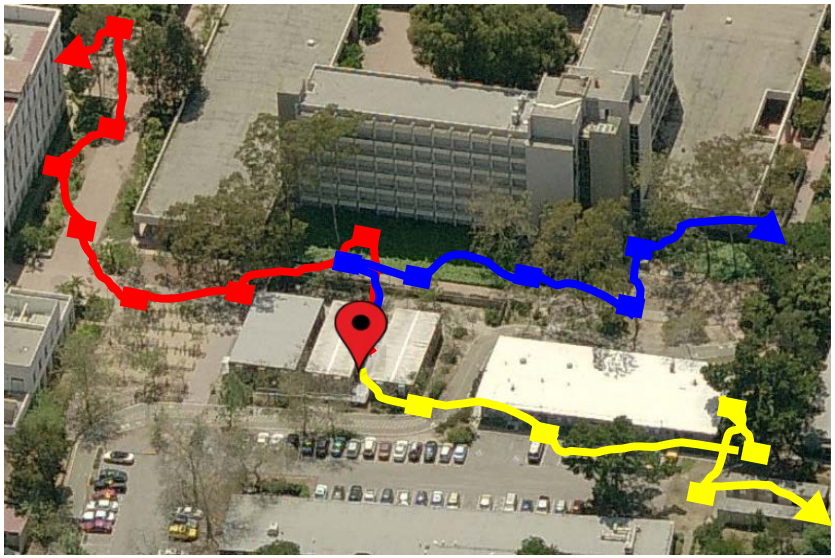
- Most APs are mounted inside buildings
- We mounted the AP on a table in our lab
  - Try to locate it outside in Complex LOS/NLOS environment



Efficiency

- Navigation Overhead: $\frac{Traveled\ distance - Real\ distance}{Real\ distance}$





NLOS Examples

Energy Consumption

	Droid	G1
% of battery consumed per Borealis operation	0.36%	0.78%
% of battery consumed ignoring Display and Standby	0.15%	0.29%

Distribution of Energy Usage across Components		
Display	54%	32%
Cell Standby	3%	31%
WiFi Radio	5%	12%
OS	21%	11%
Other Borealis Activity	17%	13%

Table 2: Energy consumption analysis of Borealis' directional analysis on Droid and G1 phones.

Conclusion & Discussions

Conclusion

- Propose, develop, and evaluate Borealis for WiFi AP location
  - Leveraging the **body fading** on smartphones
  - Evaluated in different scenarios

Discussions

- Are the goals achieved?
  - Accurate?
  - Time-efficient?
  - Cost-efficient?
- User's natural movements rather than in-place rotations?
- Other applications of body fading?
  - Human localization
  - Activity recognition
  - ???
- Other radios?
- Apps that need to locate APs?