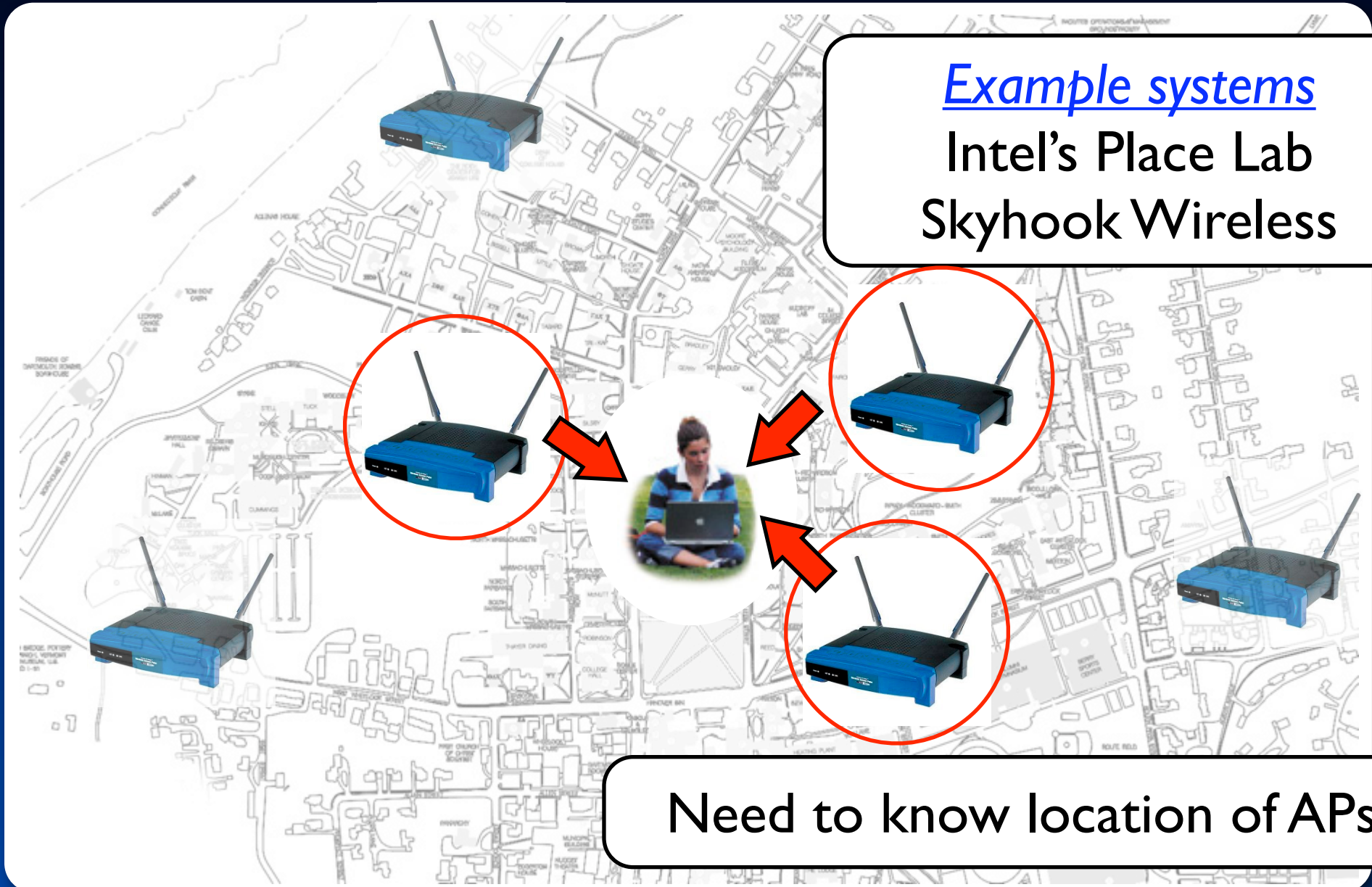


# Risks of using AP locations discovered through war driving

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Dartmouth College  
May 8, 2006

# Localization of wireless users



Example systems

Intel's Place Lab  
Skyhook Wireless

Need to know location of APs

# AP locations from war driving

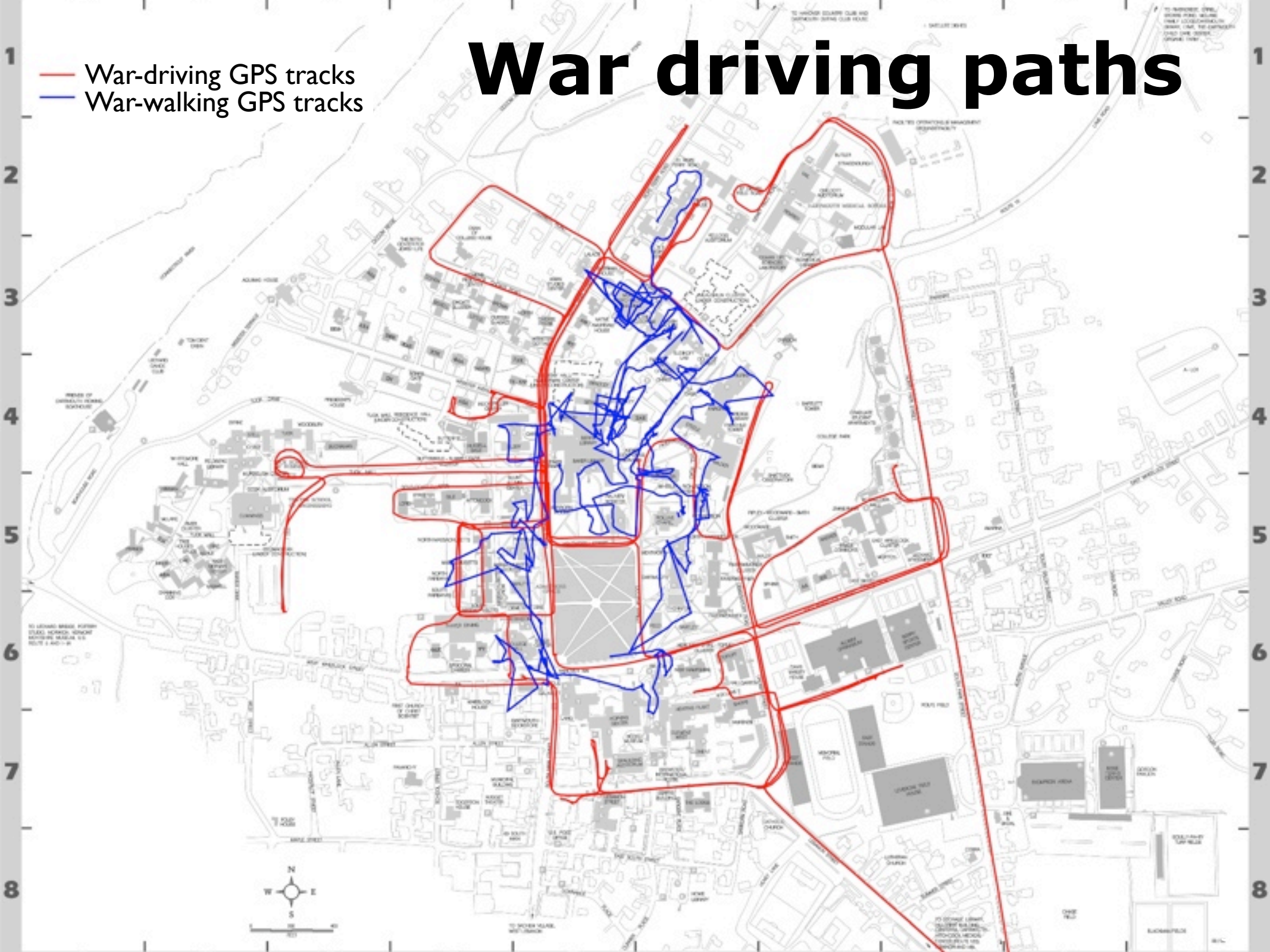
- Hard to collect actual AP locations
- AP locations from war driving are commonly used
  - ▶ War driving: Collecting Wi-Fi beacons by driving or walking to discover locations of APs
- Problem: AP locations from war driving are estimates rather than actual locations!
- Goal
  - ▶ Analyze error in AP location estimates
  - ▶ Understand effects of using estimated AP locations on **user localization** and **network analysis**

# Collecting AP locations

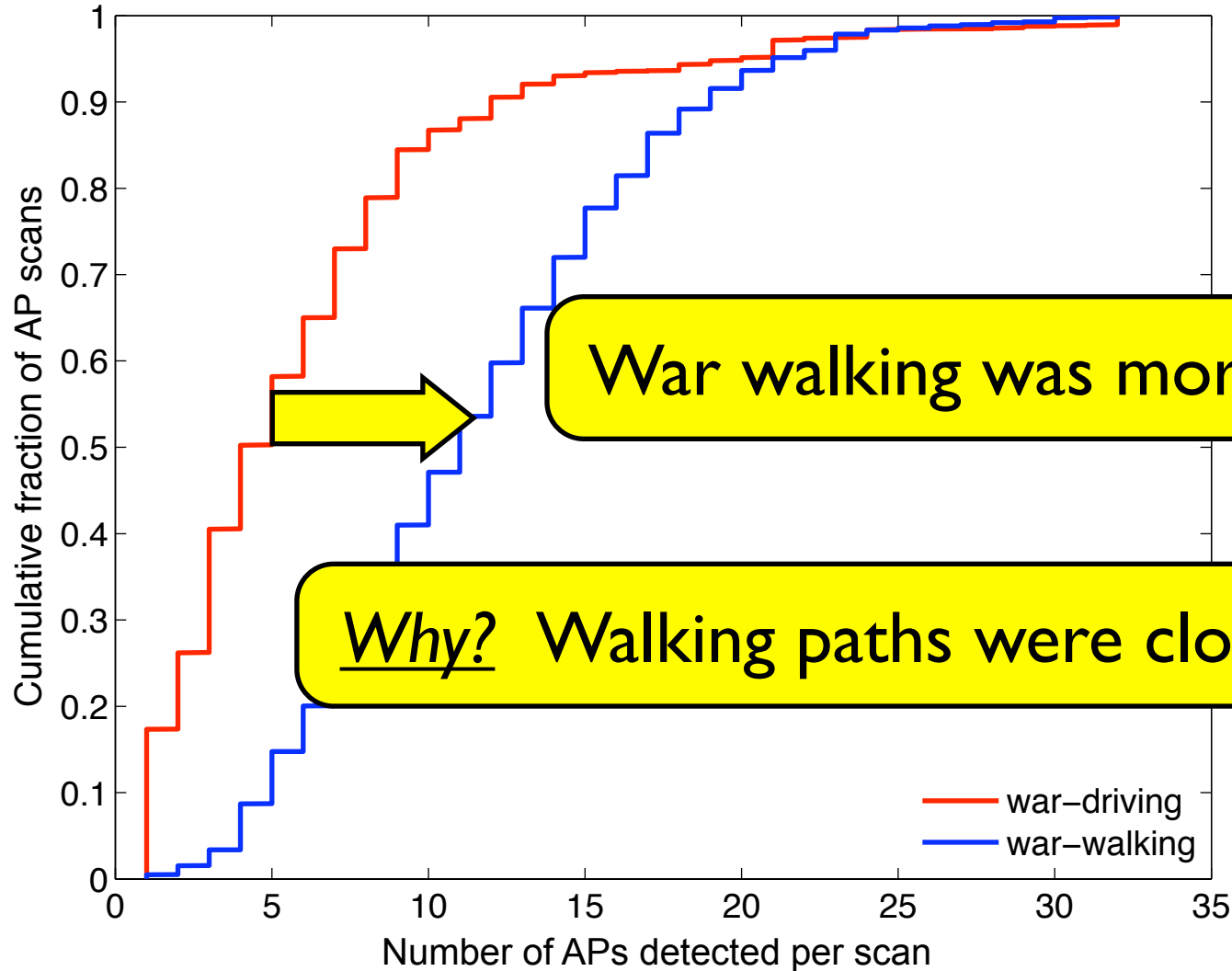
- Advantages of Dartmouth College
  - ▶ Wireless coverage everywhere
  - ▶ Centrally administrated network
  - ▶ Actual AP locations are available and up-to-date
- Tools for war driving and walking
  - ▶ Laptop with Cisco wireless card, Garmin GPS
  - ▶ Place Lab stumbler scans beacons periodically
- Duration of war driving and walking
  - ▶ War Driving at 10 miles/hour for 80 min
  - ▶ War walking for 200 min

# War driving paths

- War-driving GPS tracks
- War-walking GPS tracks



# APs detected per scan



# AP location estimation

- Wireless device scans beacons periodically
  - ▶ Estimate AP location using GPS readings from multiple locations where beacon was picked up
- Algorithms for AP location

## Centroid

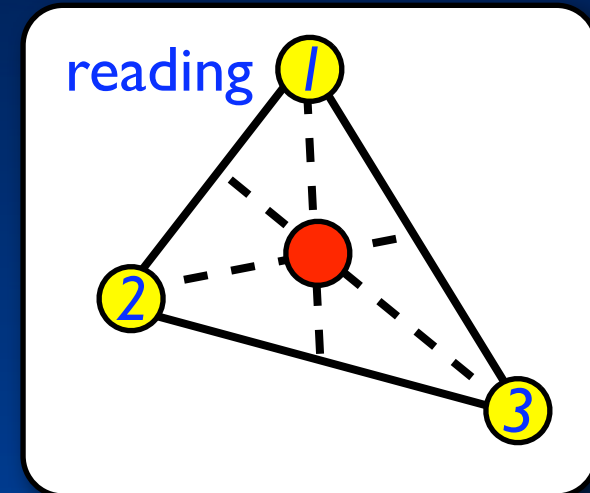
$$\bar{\mathbf{x}} = \sum_{i=1}^n \mathbf{x}_i / n$$

## Weighted centroid

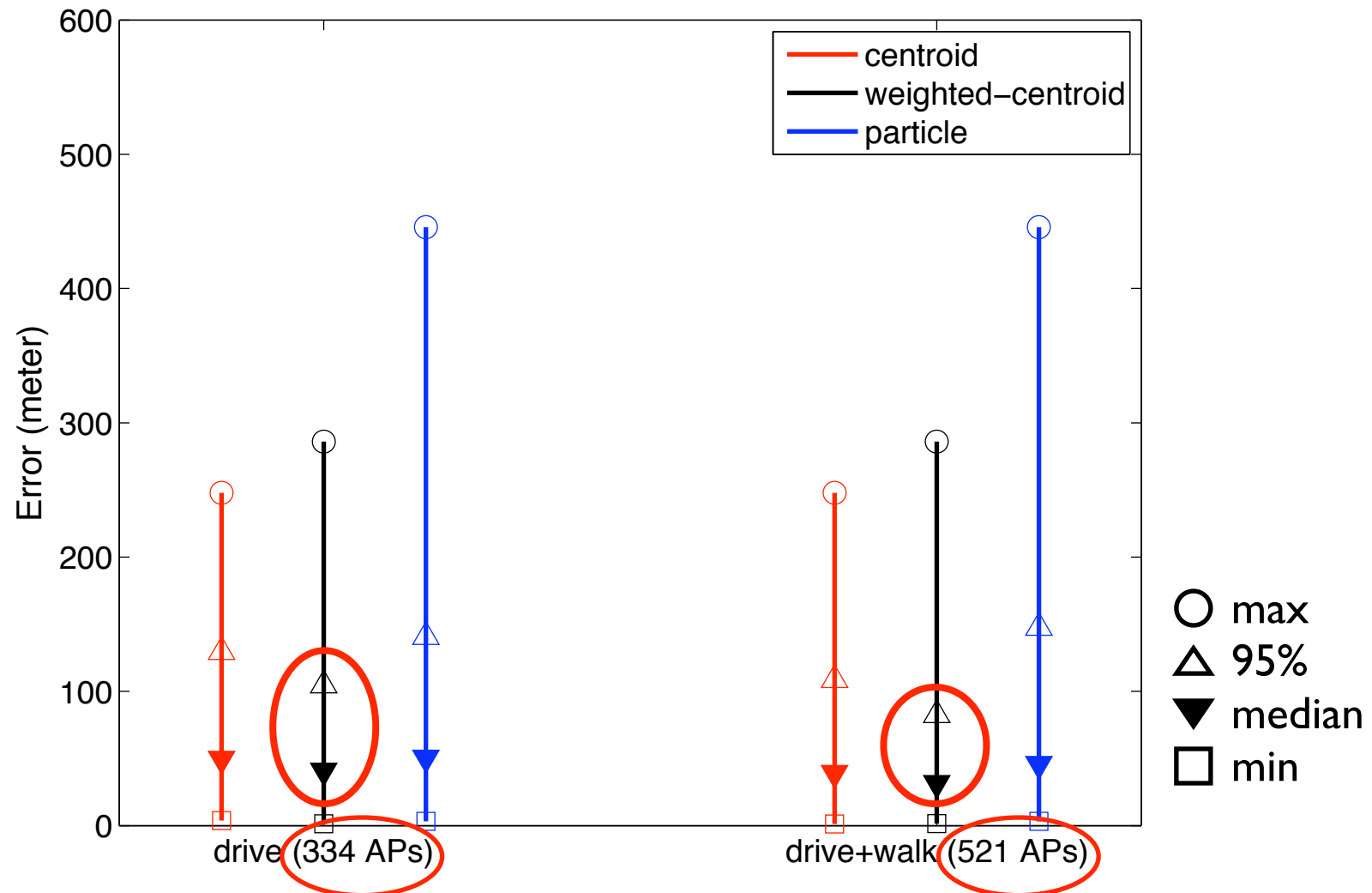
Signal strength as weight

## Particle filter

Location probability based on signal strength and distance from particle to observer

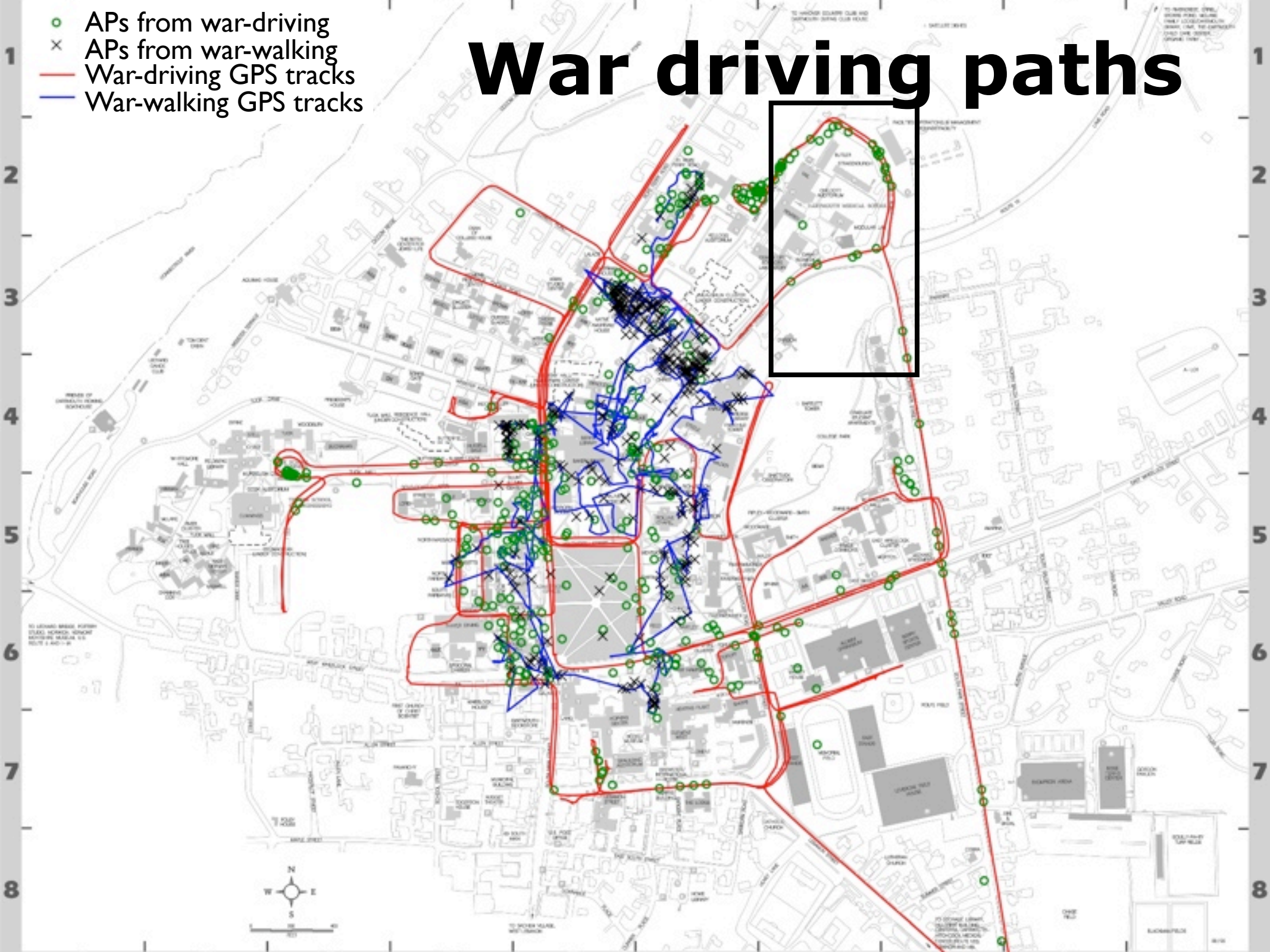


# Error in AP locations



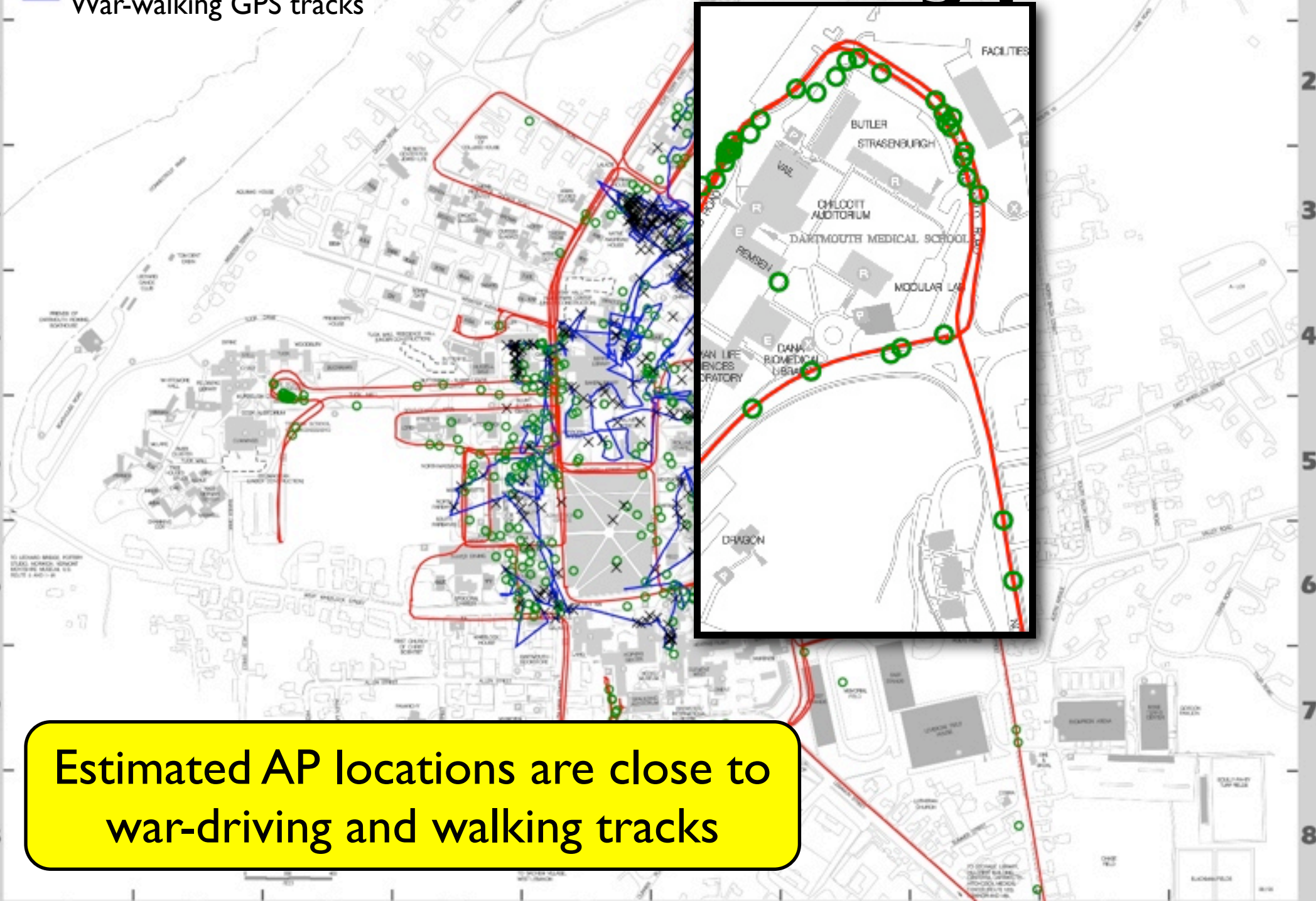
# War driving paths

- APs from war-driving
- × APs from war-walking
- War-driving GPS tracks
- War-walking GPS tracks



# War driving paths

- APs from war-driving
- × APs from war-walking
- War-driving GPS tracks
- War-walking GPS tracks



Estimated AP locations are close to war-driving and walking tracks

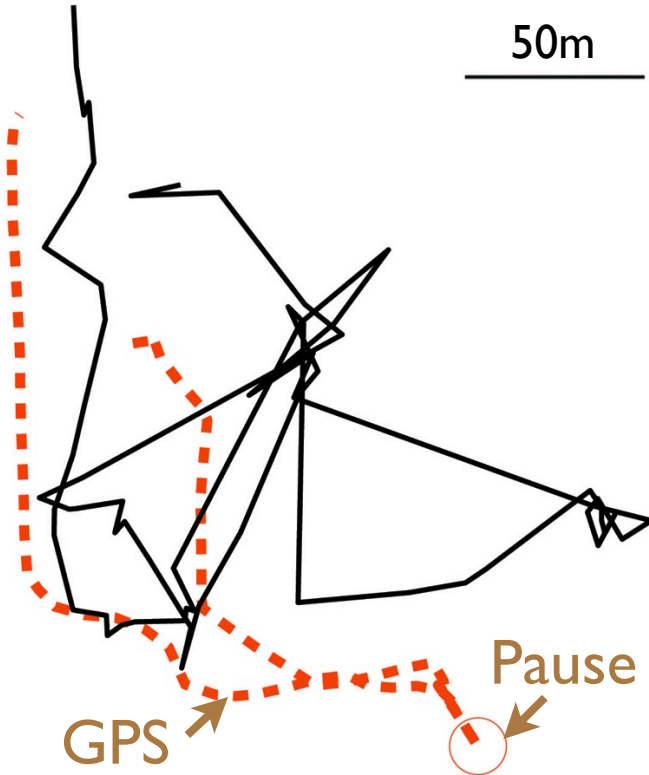
# User localization

- Particle filter from Place Lab
  - ▶ Sensor model: likelihood observing a set of APs
  - ▶ Motion model: random distance, random direction
- Four outdoor walks
  - ▶ Each lasted 10 min with 1 min pause
  - ▶ Truth: GPS recorded tracks
- Four indoor walks
  - ▶ Each covered three or more floors, lasting 6-14 min
  - ▶ Truth: User-drawn paths on digitized floor plans

# Outdoor user location

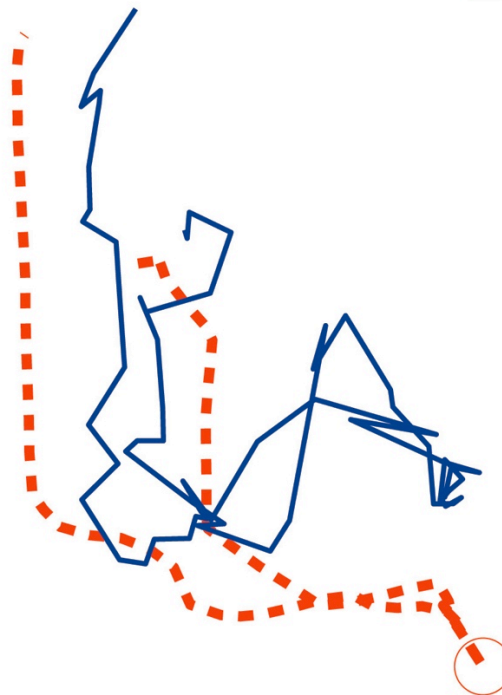
War drive

50m



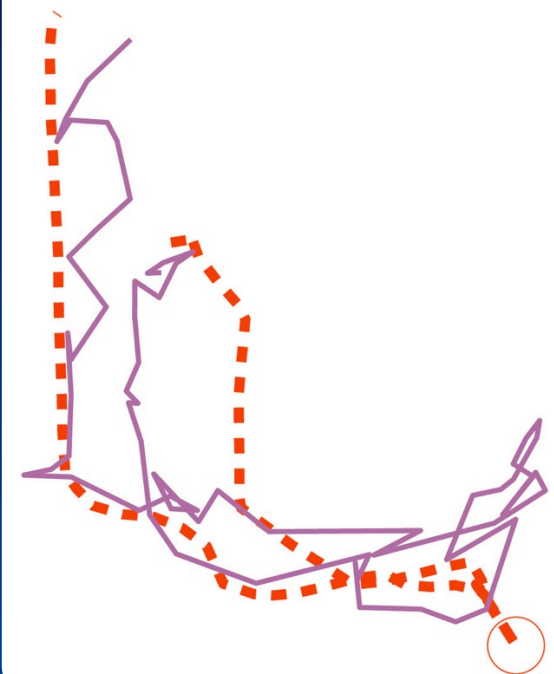
War drive & walk

50m

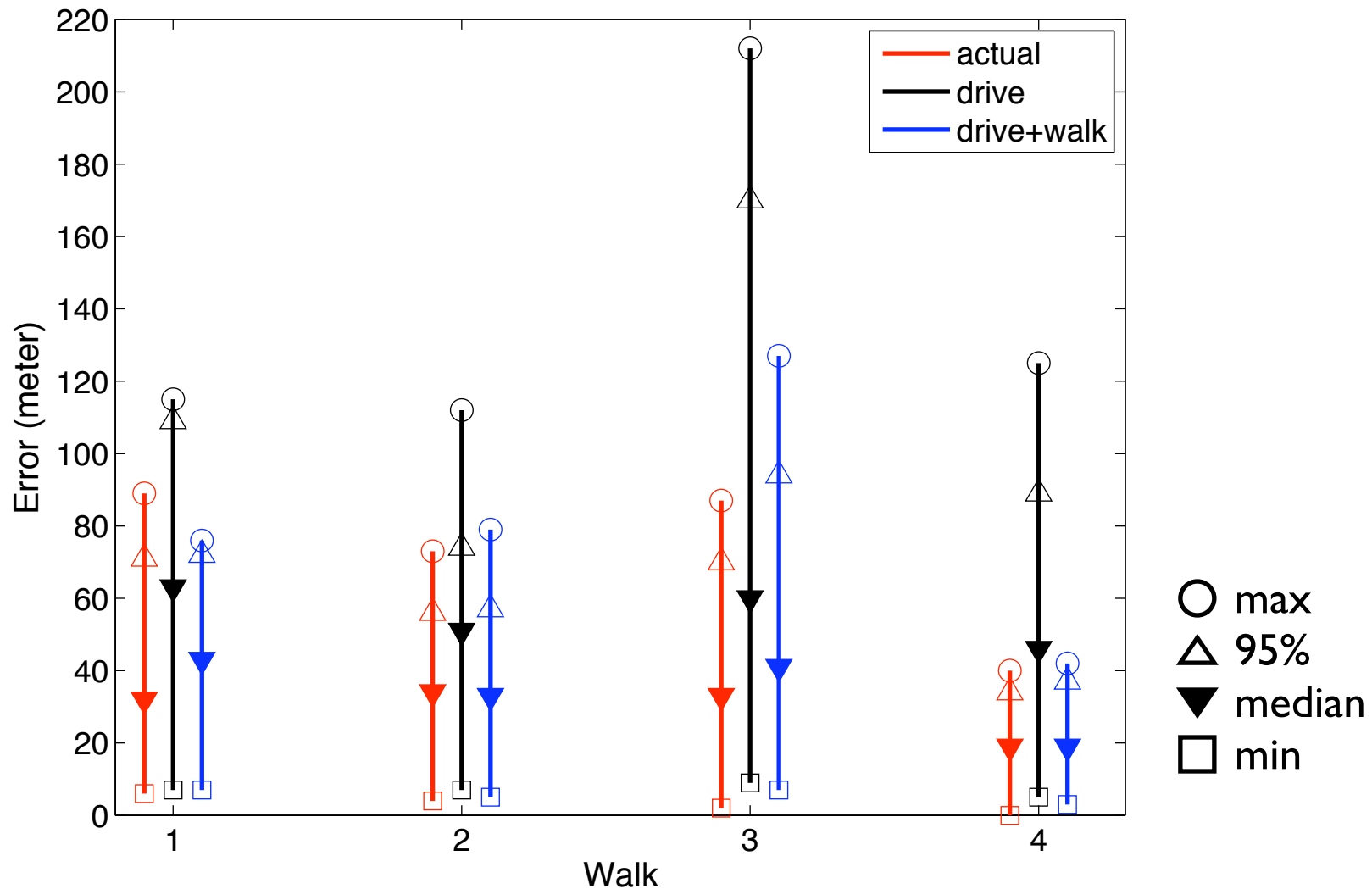


Actual locations

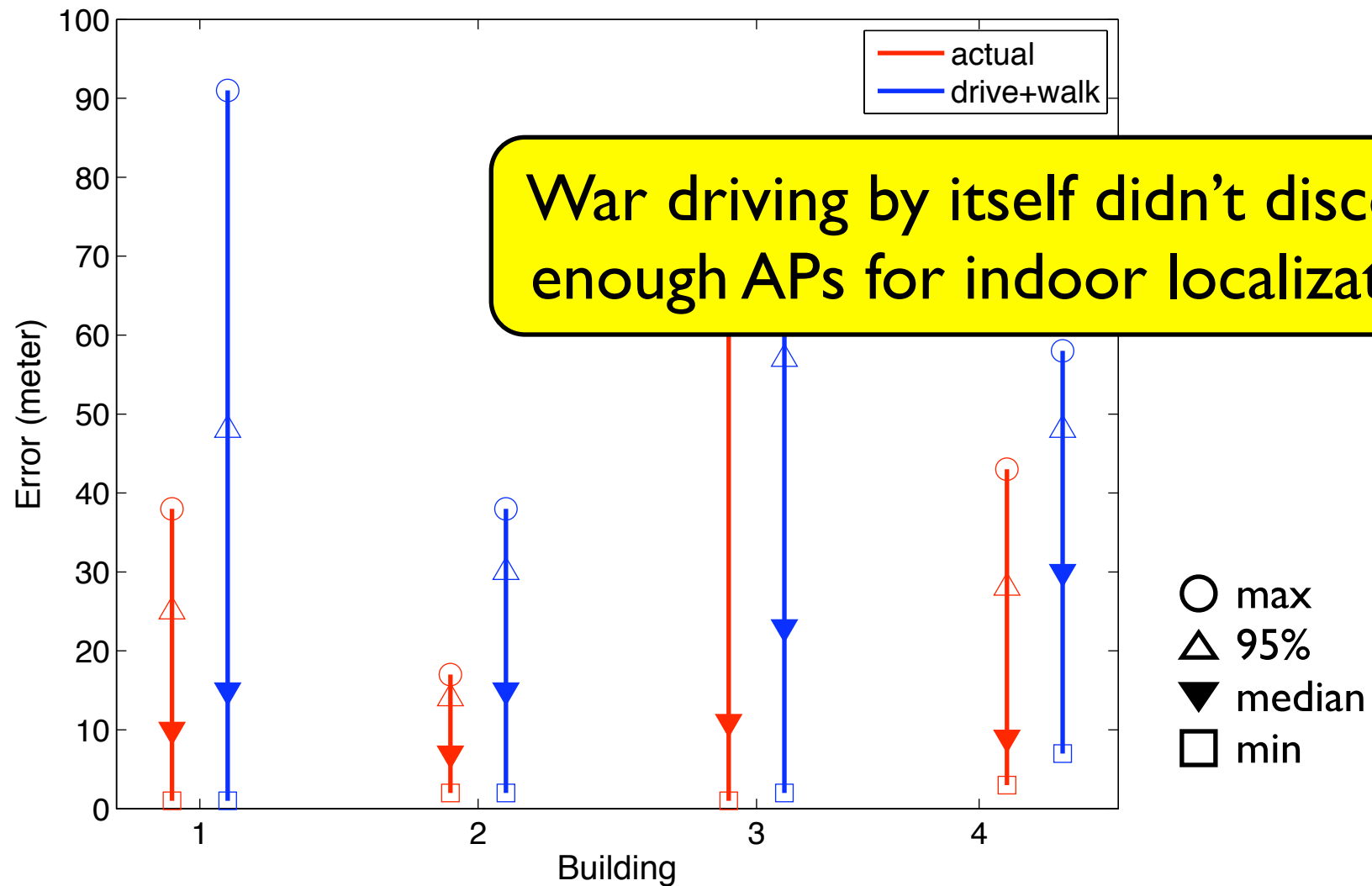
50m



# Outdoor user location



# Indoor user location



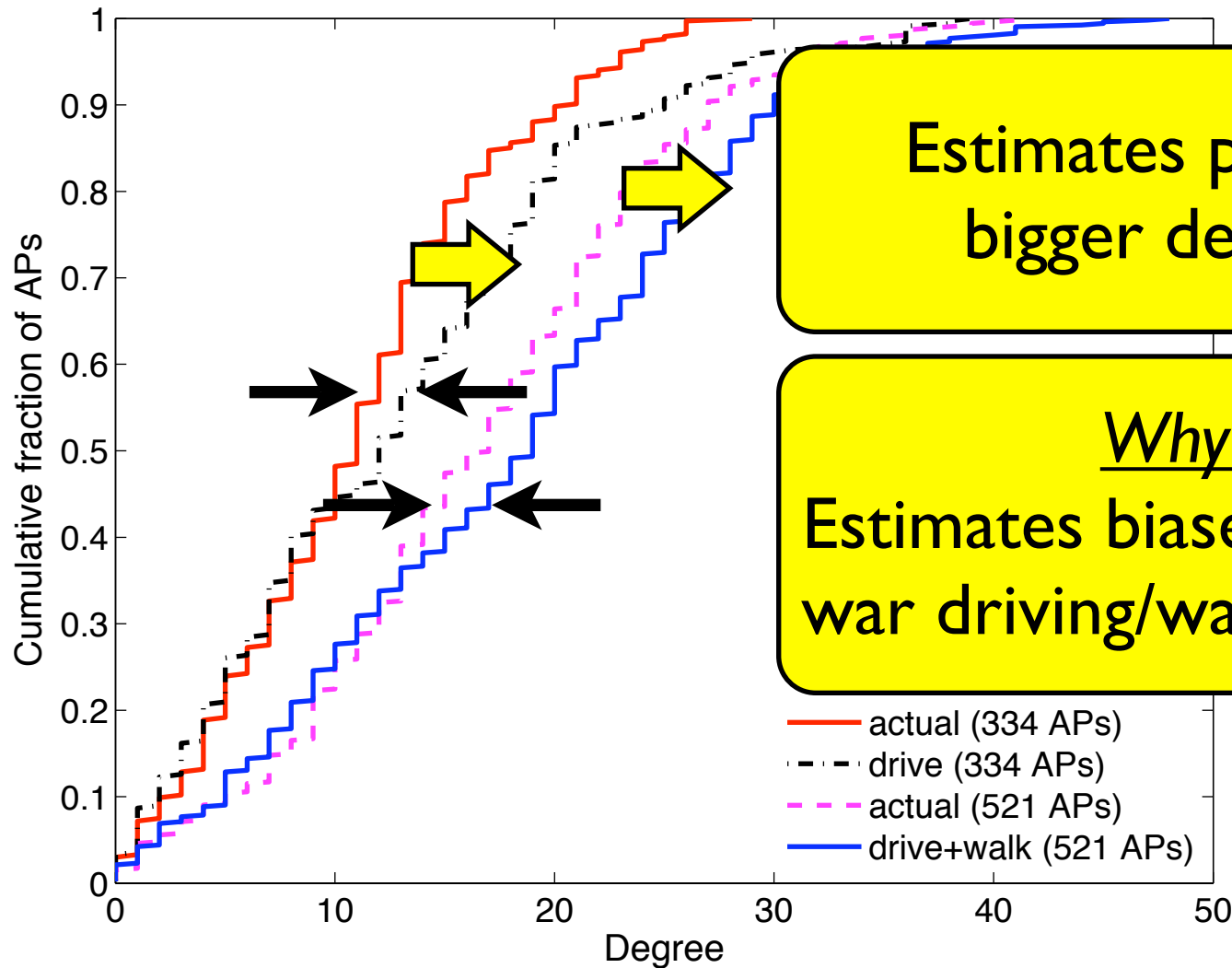
War driving by itself didn't discover enough APs for indoor localization!

# Network analysis

- Recently, AP locations from war driving used in network analysis: Akella *et al.* MobiCom 2005
  - ▶ Computed **AP interference** and **max signal coverage**
- AP interference
  - ▶ AP degree: number of interfering APs
  - ▶ APs interfere if they are less than 50 meters apart
- Three sets of data for comparison
  - ▶ Computed degrees using **estimated** AP locations
  - ▶ Computed degrees using **actual** AP locations
  - ▶ **Real** degrees detected by APs

}<sub>2</sub>}<sub>1</sub>

# Degree: actual vs. estimated

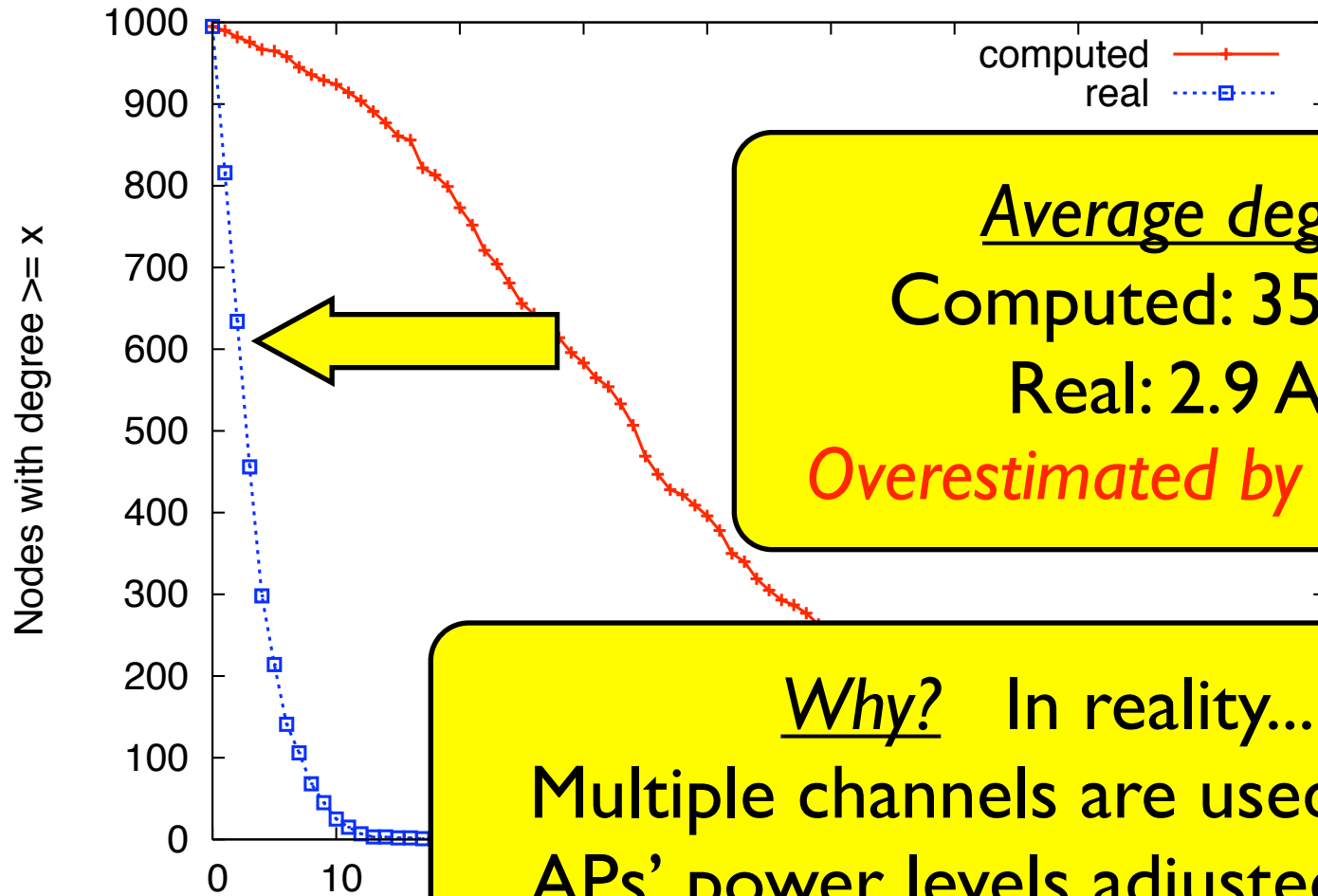


Estimates produce bigger degrees

Why?

Estimates biased towards war driving/walking paths

# Degree: computed vs. real



Average degree  
Computed: 35.0 APs  
Real: 2.9 APs  
*Overestimated by 12 times!*

Why? In reality...  
Multiple channels are used  
APs' power levels adjusted  
Obstructions prevent interference

# Summary

Analysis	Driving	Driving Walking	Actual
<u>Effectiveness of war driving</u> Average number of APs for each scan	6.1	11.5*	-
<u>AP location</u> Median error in AP locations (meter)	40.8	31.6	-
<u>Outdoor user location</u> Median error over four walks (meter)	46-63	19-43	19-34
<u>Indoor user location</u> Median error over four walks (meter)	-	15-30	7-11
<u>AP interference</u> Median degree difference=estimated-actual Computed: 35.0, real: 2.9	2	1	-

# Conclusion

- War walking is more effective than war driving
- Accurate AP locations are critical in user localization
- Need APs from war walking for indoor user localization
- AP locations biased towards war-driving paths
- Need to be cautious in making simple assumptions

# Thank you

For related papers and more info

<http://www.cs.dartmouth.edu/~minkyong/>

For traces used in this paper

<http://crawdad.cs.dartmouth.edu/>

