

A Walk on the Client Side: Monitoring Enterprise Wifi Networks Using Smartphone Channel Scans

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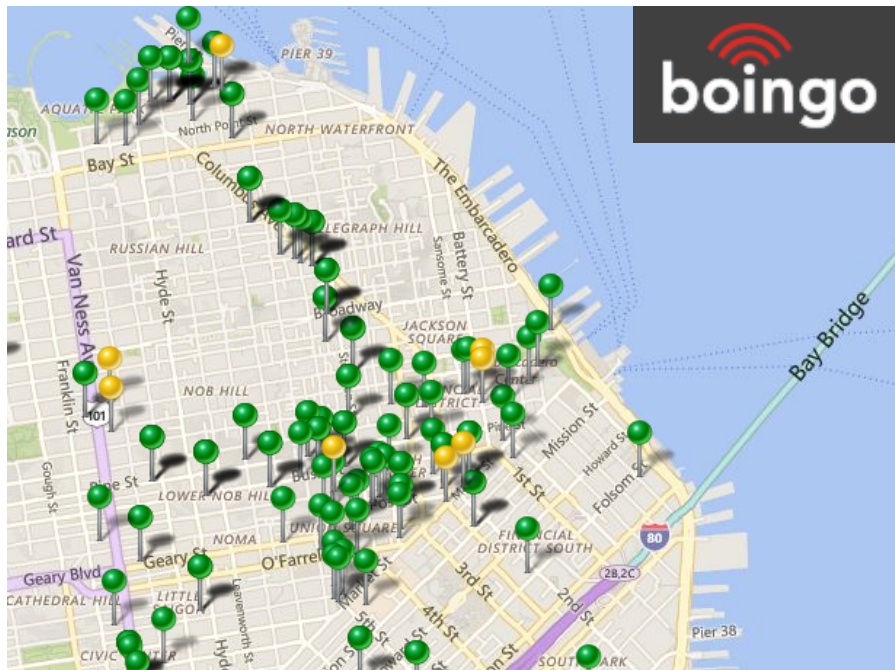


Centrally-Managed Wifi Networks



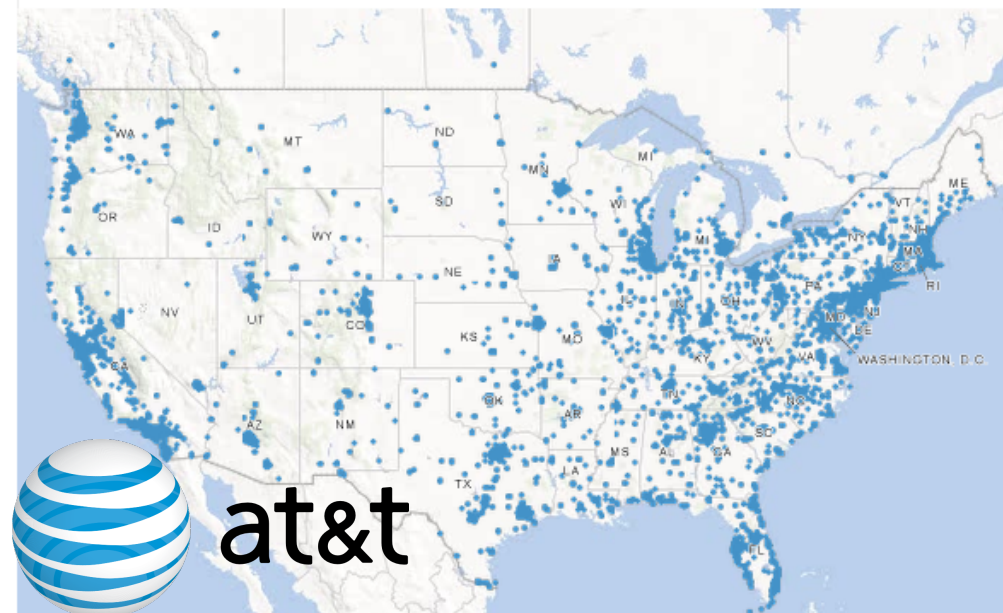
aruba[®]
NETWORKS

- ← Enterprise
- ↙ Commercial
- ↓ Wifi offloading



AT&T Wi-Fi Hot Spot locations

This map shows AT&T Basic Wi-Fi Hot Spots near your search location. To view hotspot details, click a pin.



Monitoring/Management



How's my network doing?

Site Surveys



- Detailed
- RF level



- Oneshot
- Expensive

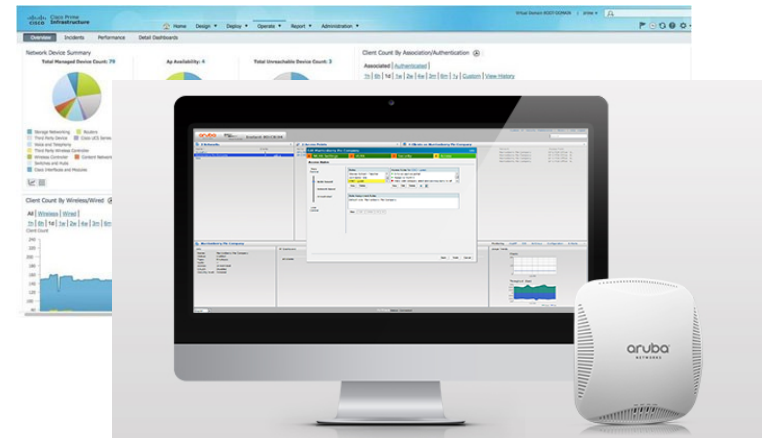


- Continuous
- Cross layer



Lack of client-side
feedback

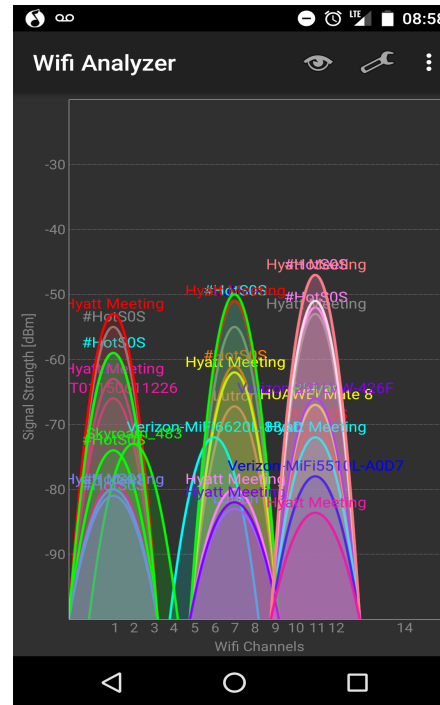
AP-Side Monitoring Software



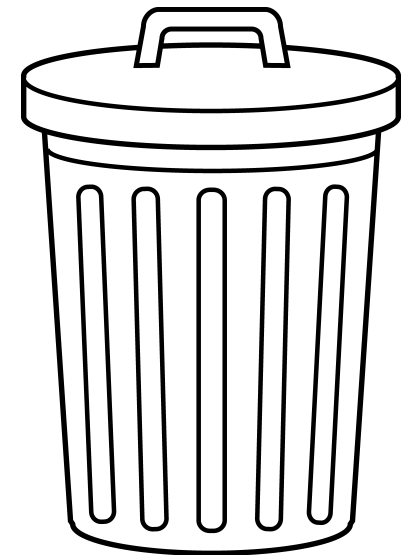
On the Other Hand...



2 billion
smartphones
keeps growing



Billions of
Wifi Scans
Network observation



...then
discarded
What a pity!

A Walk on the Client Side

- Explore smartphones as client-side monitoring tool for wireless networks
- Analysis already done (or can be done) at AP side (e.g., utilization, health, performance, etc.)

What unique insights can smartphone scans provide?

Why Smartphones?

Compared to other wireless devices

- ▶ Laptops, tablets, desktops w/ wireless adapters, etc.



Mobile

Good spatial coverage



Always On

Good temporal coverage



Mostly Idle

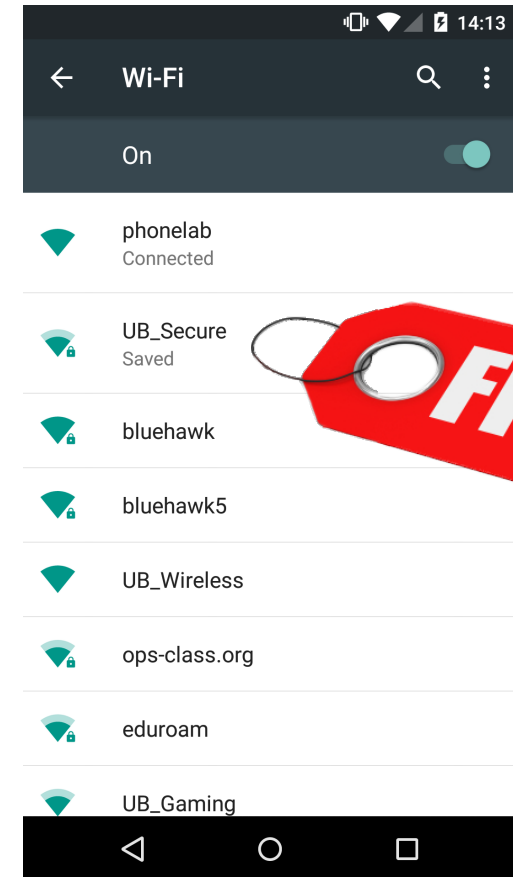
Less intrusive

Plus...Wifi Scans Are Free!

Aggressive scan behavior

- Fast roaming, localization, etc.
- Android median scan interval: 10s [1]

No energy or performance overhead w/ passive data collection



[1] Xueheng Hu, Lixing Song, Dirk Van Bruggen, and Aaron Striegel. 2015. Is There WiFi Yet?: How Aggressive Probe Requests Deteriorate Energy and Throughput. In Proceedings of the 2015 ACM Conference on Internet Measurement Conference (IMC '15). ACM, New York, NY, USA

The Datasets



PhoneLab

- 254 devices
- 147 days
- 5M scans
- 30K APs

University of Notre Dame

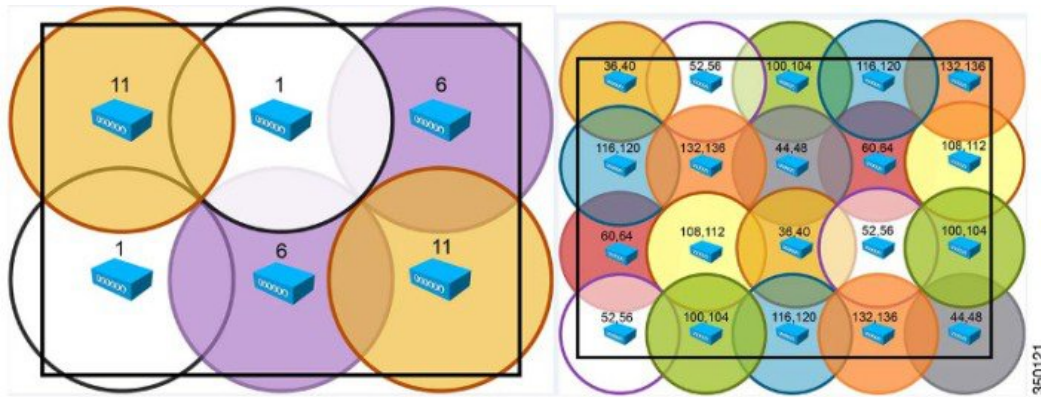
NetSense Project

- 120 devices
- 947 days
- 32M scans
- 72K APs

All data is collected passively.

Find detailed description in paper.

Case Studies

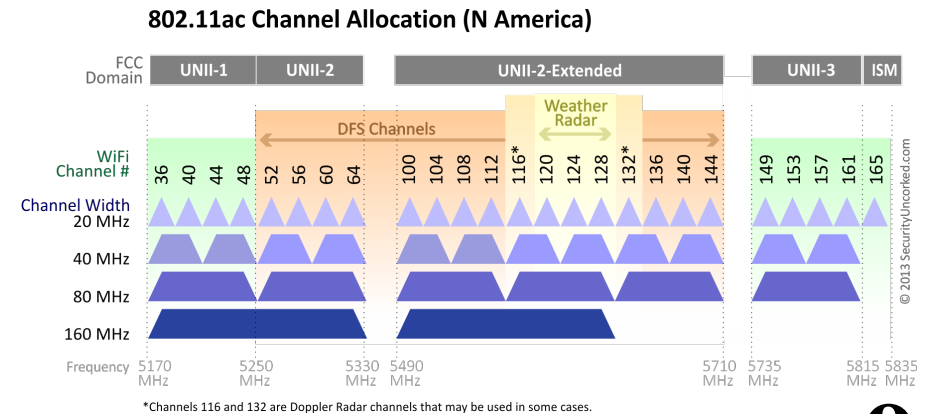
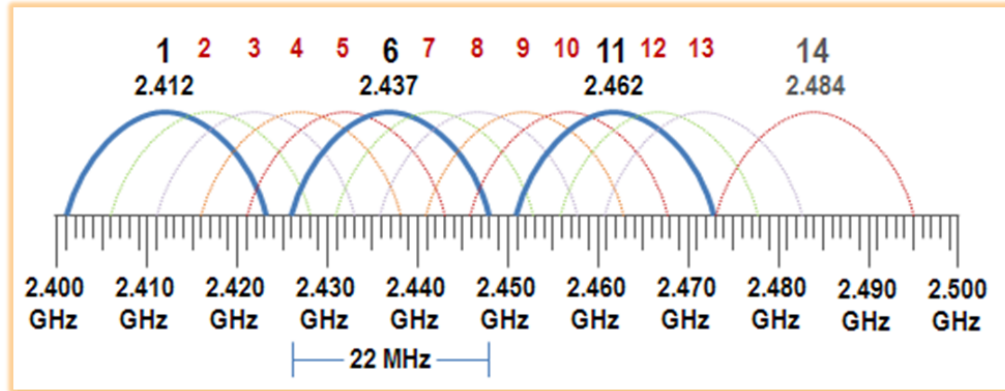


Spectrum Allocation Spatial Planning

- Why AP-side measurement is not enough
- How client-side feedback can help

Use 14 APs in department building as an example, see paper for full results

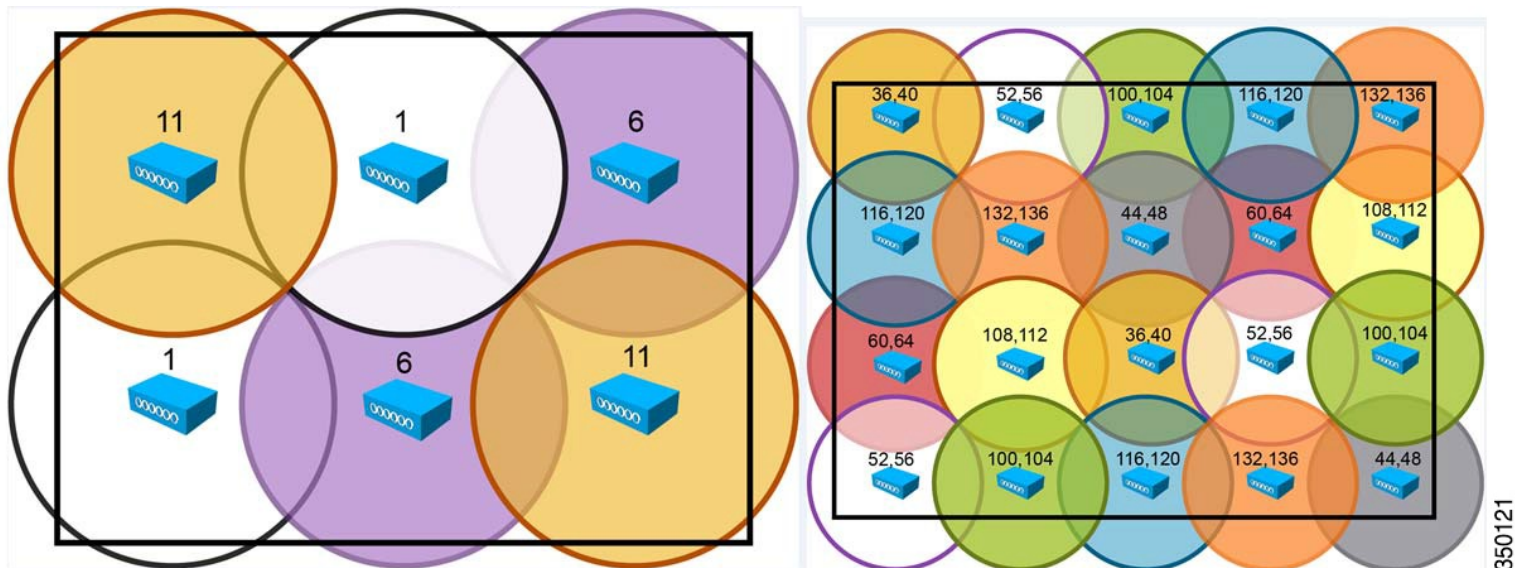
Spectrum Management



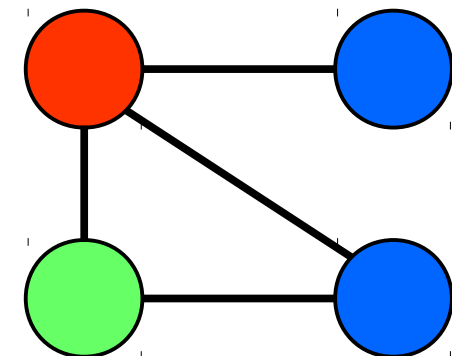
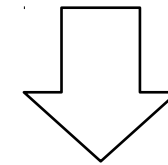
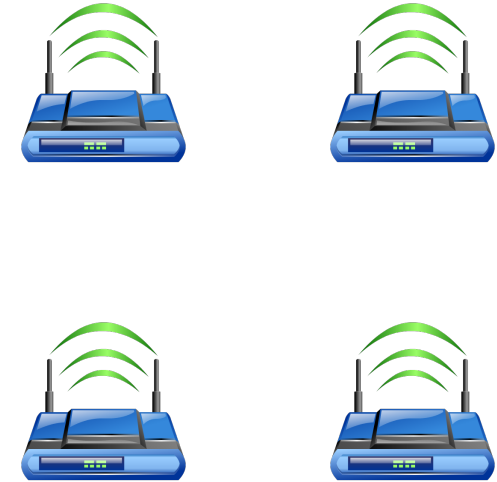
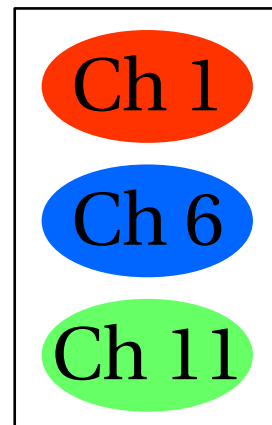
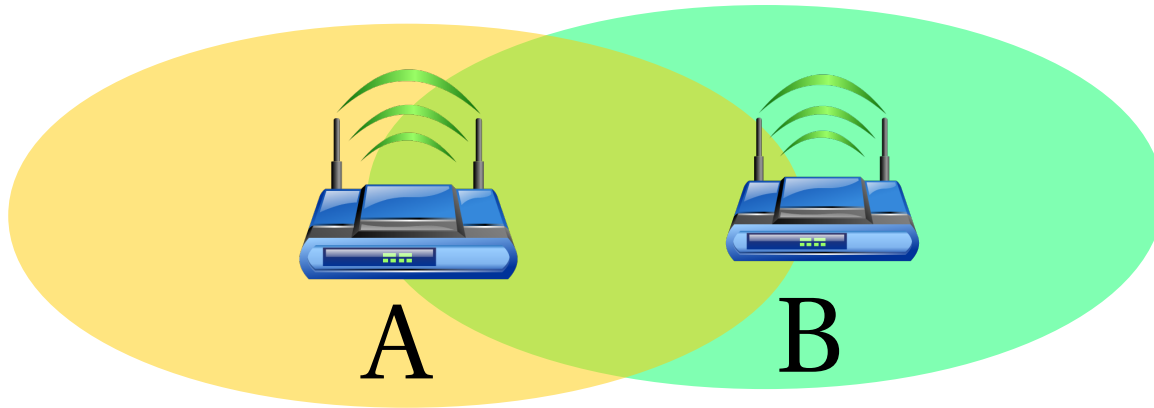
3

Limited # of orthogonal channels

9

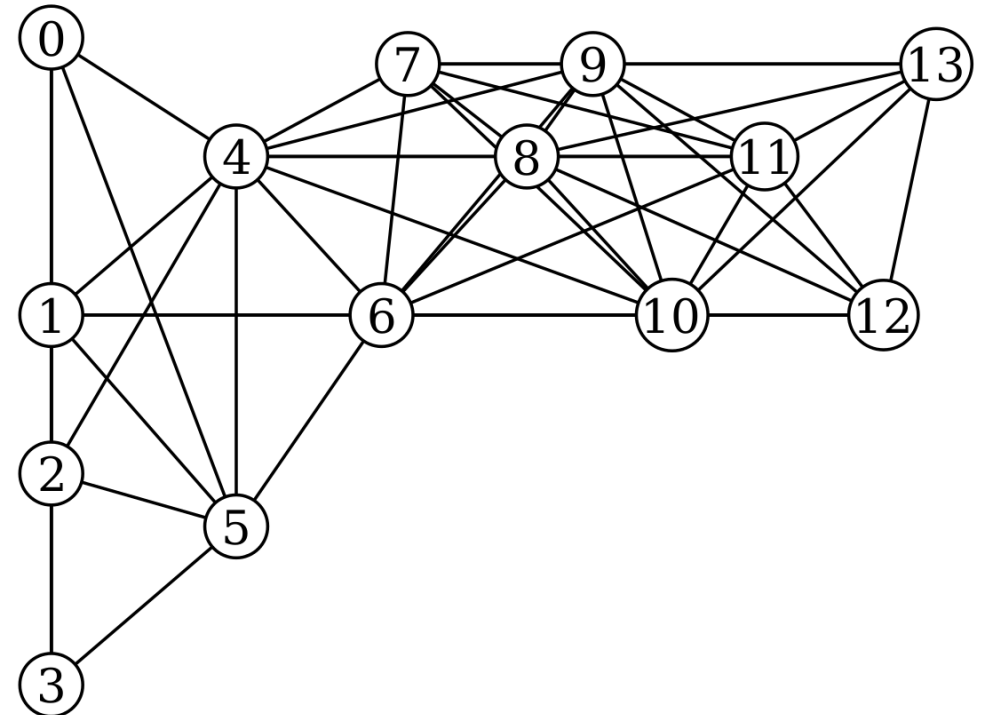
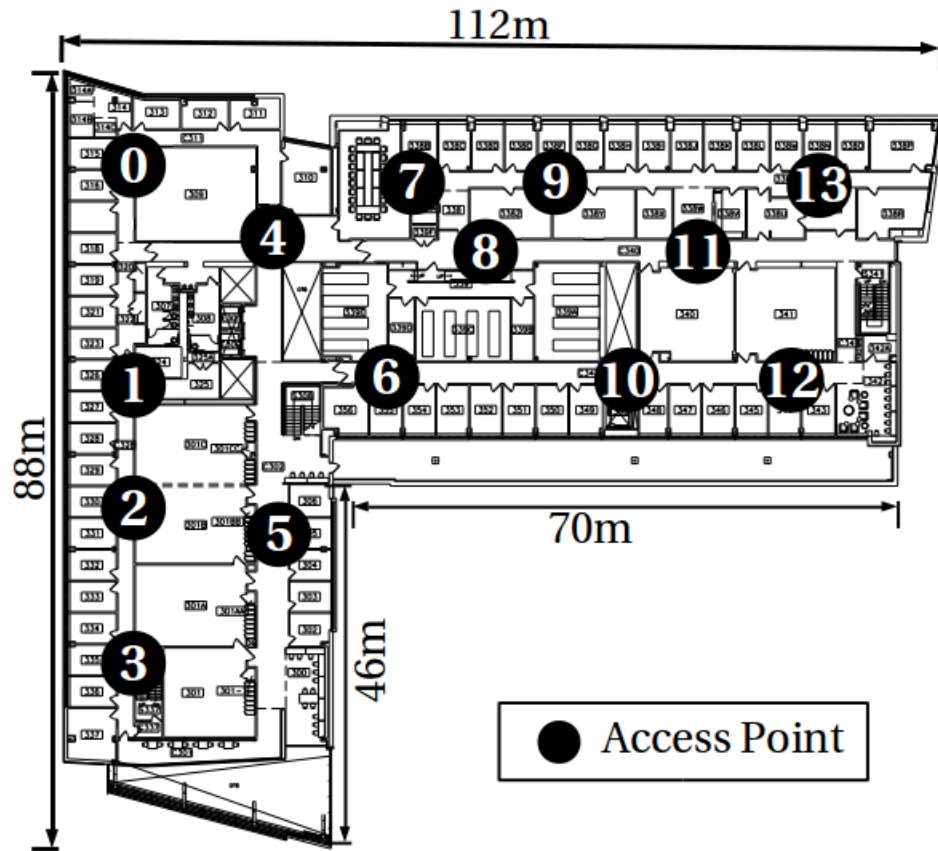


Graph Coloring Model



Conflict Graph

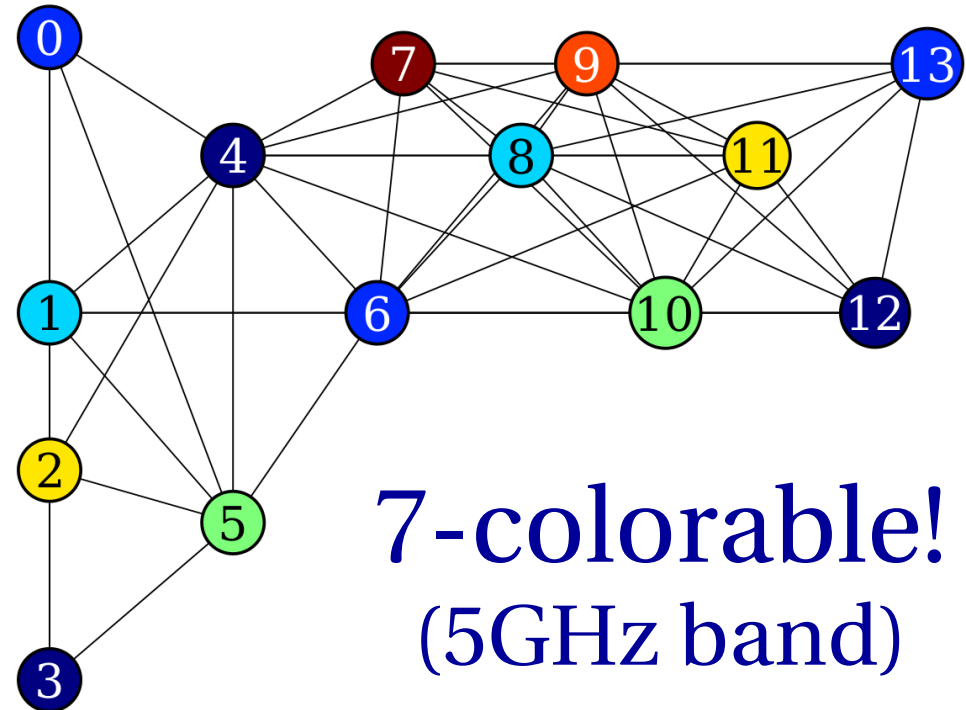
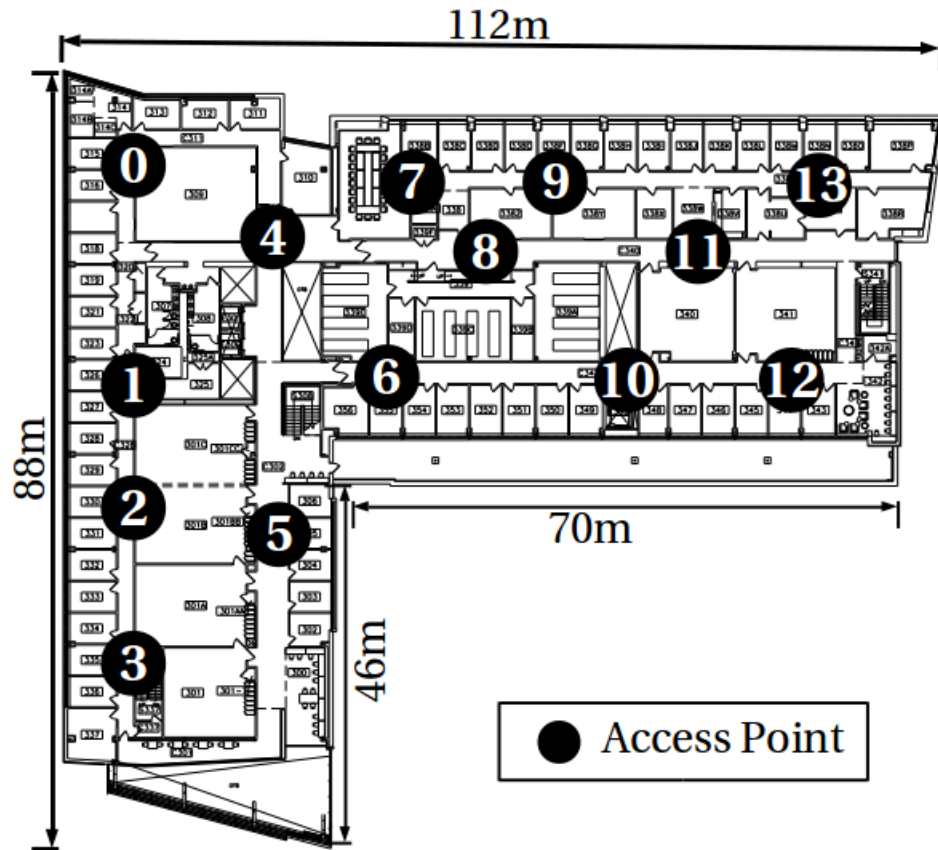
Conflict Graph From AP Scan



Floor Plan of Davis Hall 3rd @ UB

AP-Perceived Conflict Graph

Conflict Graph From AP Scan



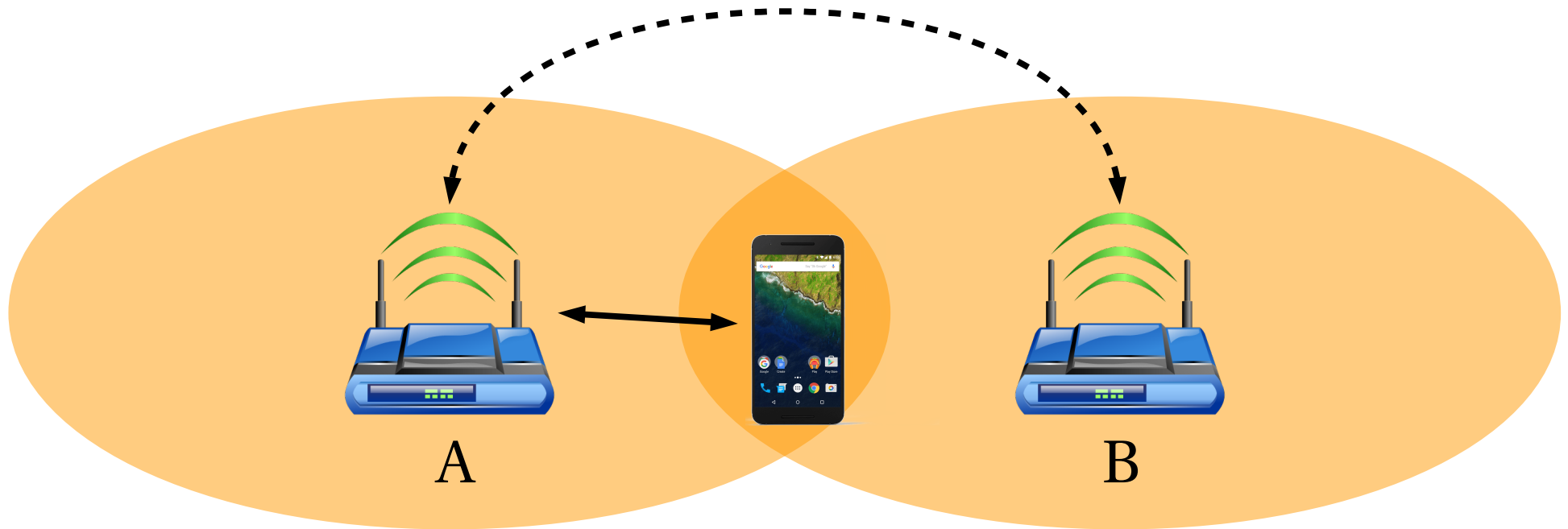
7-colorable!
(5GHz band)

Floor Plan of Davis Hall 3rd @ UB

AP-Perceived Conflict Graph

Hidden Terminals

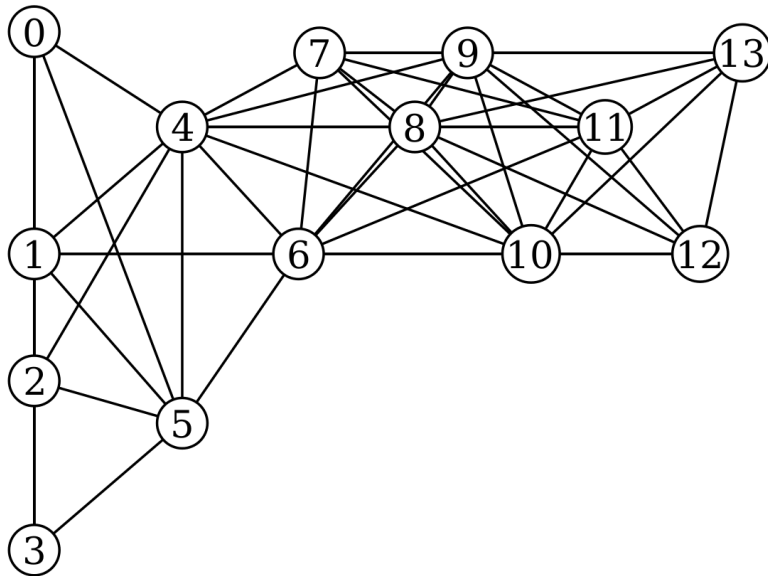
Hidden Conflict Edge



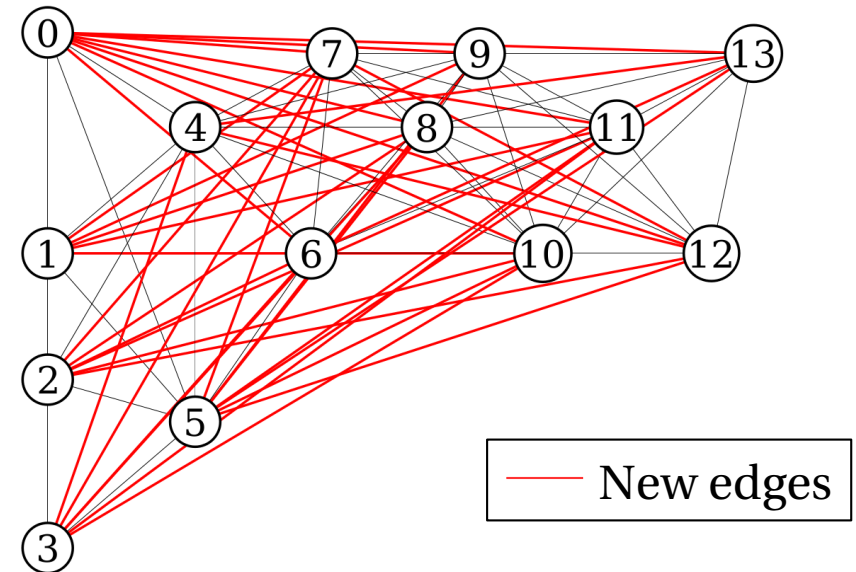
Clients-perceived conflicts may be different.

Client-Perceived Conflict Graph

What you think the network looks like What the network actually looks like



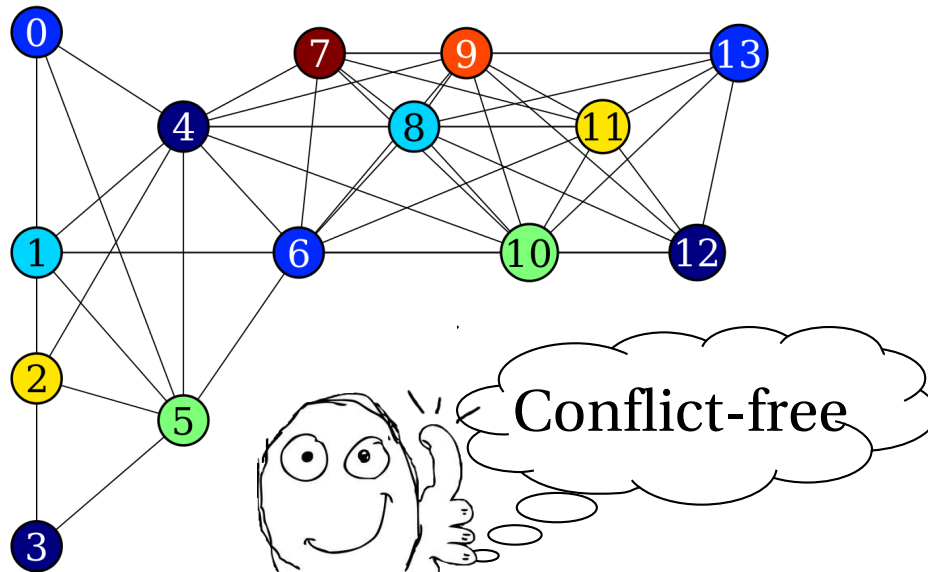
AP-Perceived Conflict Graph



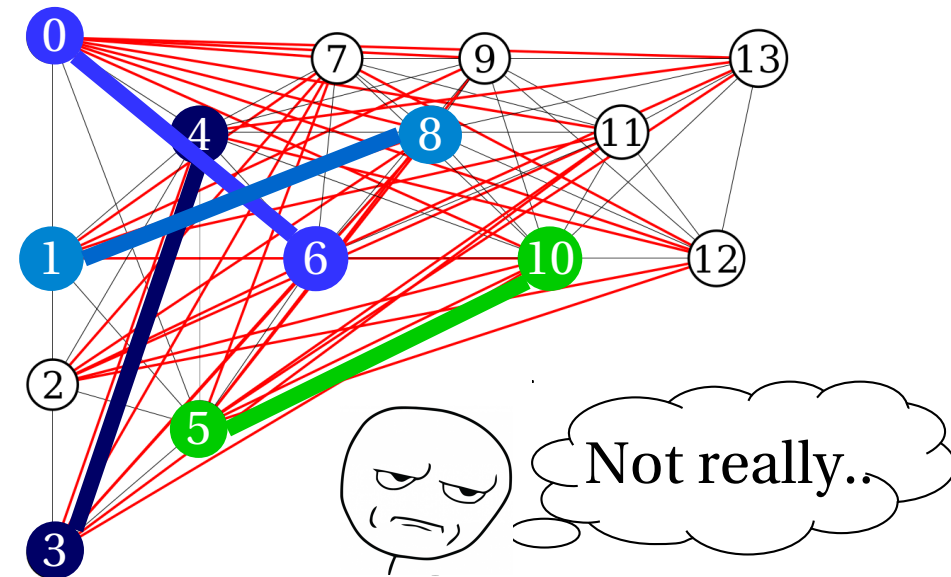
Client-Perceived Conflict Graph

Client-Perceived Conflict Graph

What you think the network looks like What the network actually looks like



AP-Perceived Conflict Graph

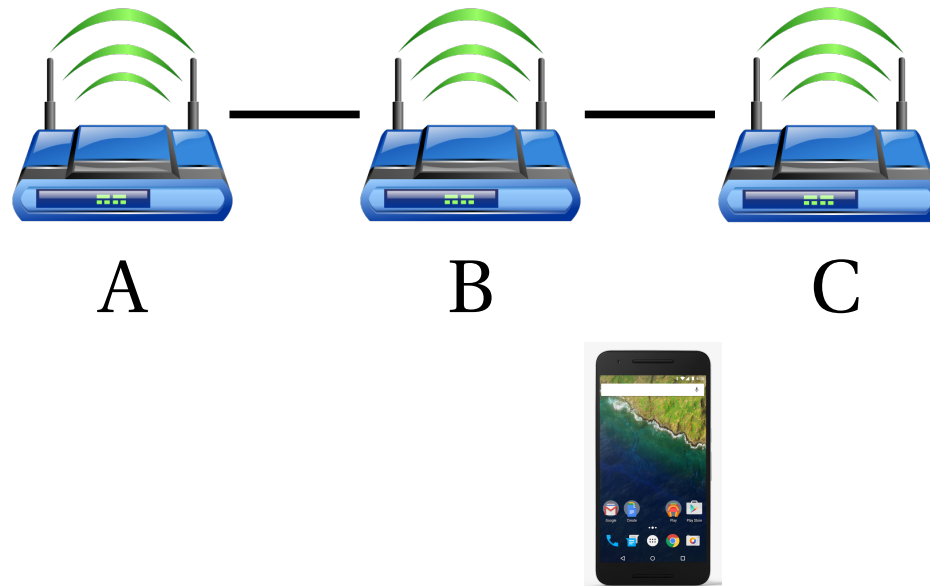


Client-Perceived Conflict Graph

Clients see more conflict edges!

...is there still hope?

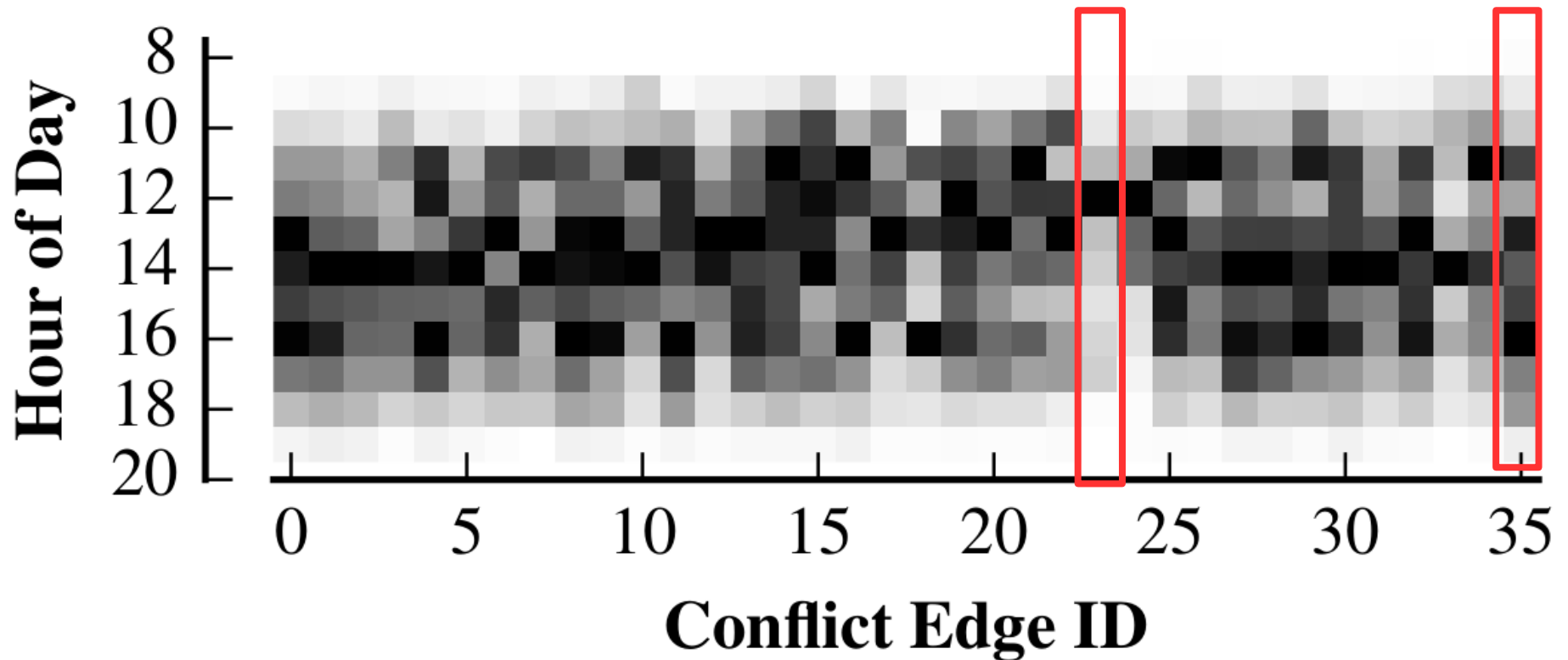
Time-Variant Conflict Graph



Conflict edge fluctuate w/ client distribution

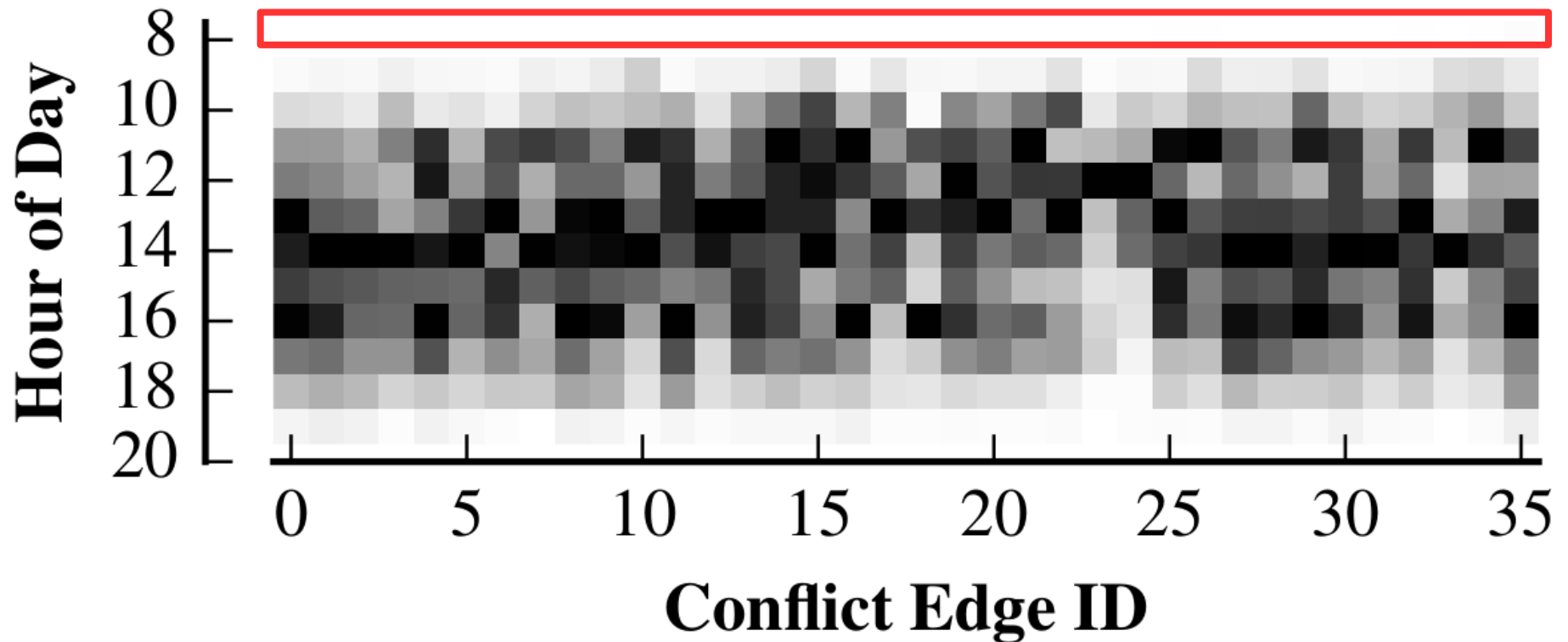
Time-Variant Conflict Graph

Temporal patterns can be learned

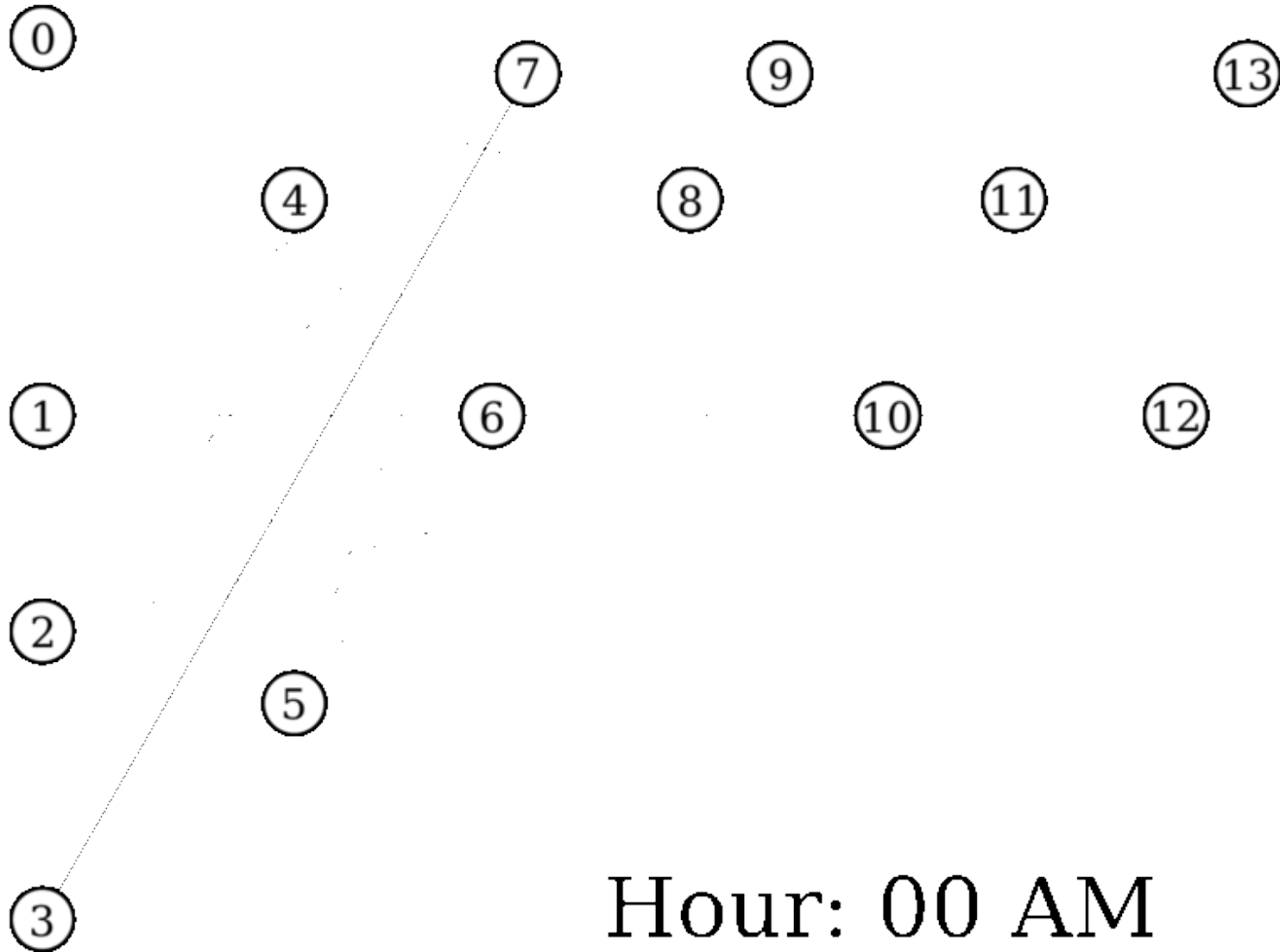


Time-Variant Conflict Graph

Temporal patterns can be learned



Time-Variant Conflict Graph



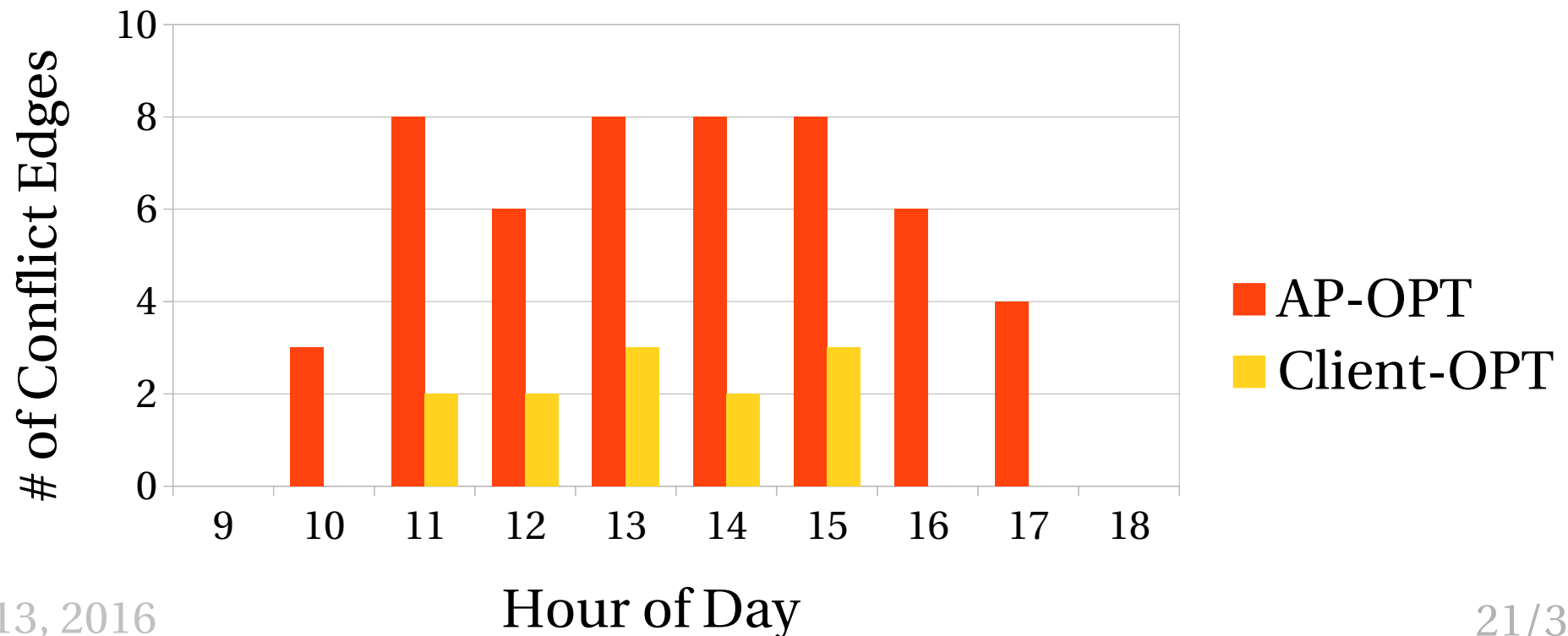
Coloring Algorithms

Client-OPT: optimal coloring on client conflict graph

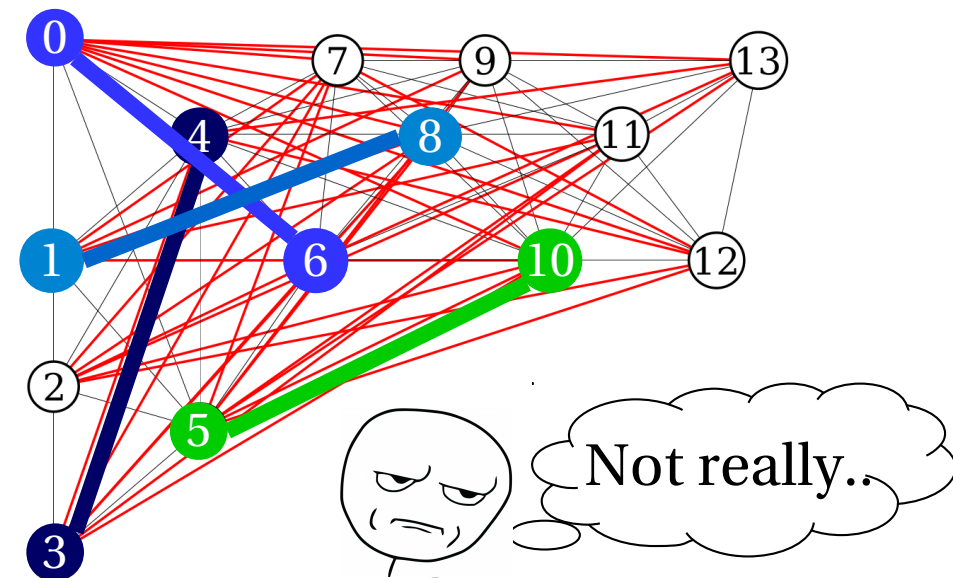
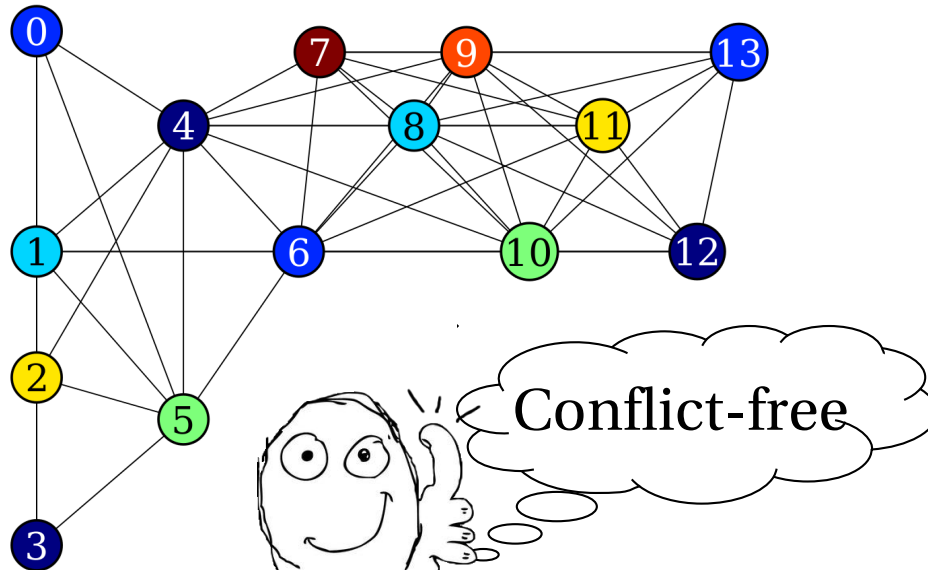
AP-OPT: optimal coloring in AP conflict graph

5 GHz band: 9 orthogonal channels

Metric: # of conflict edges in **client conflict graph**



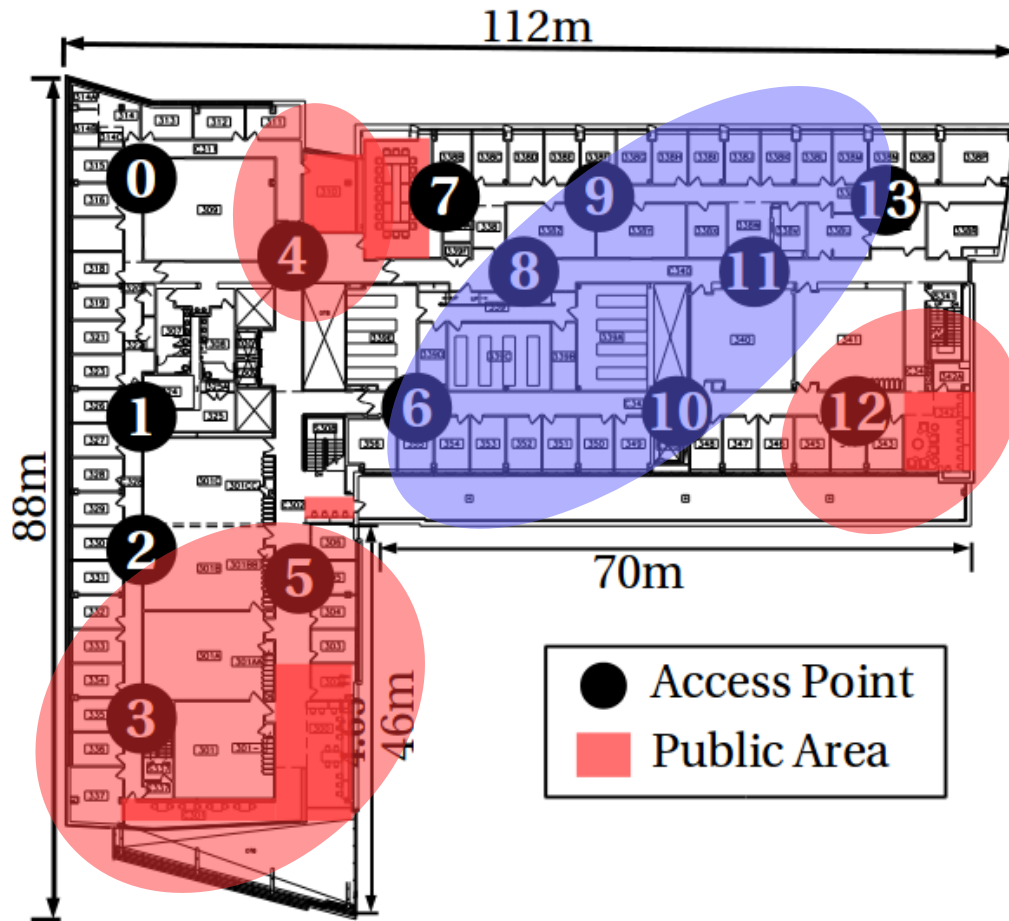
Take-Aways



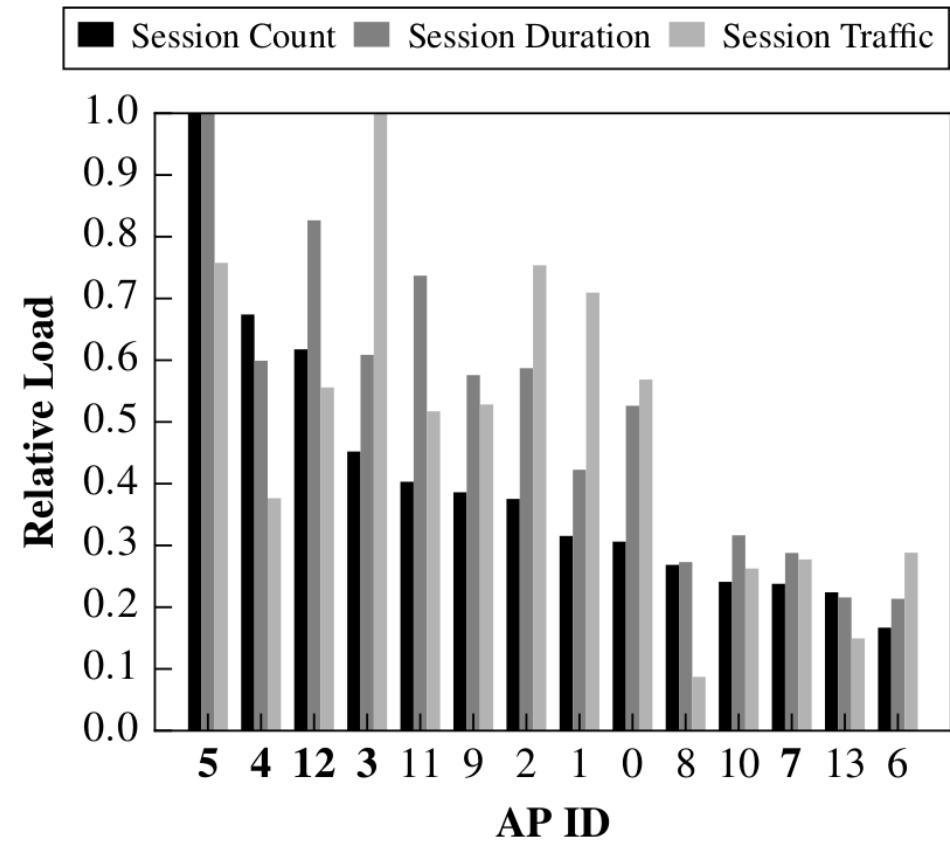
AP-Perceived Conflict Graph Client-Perceived Conflict Graph

- Infrastructure does not see all conflicts
- Client-side feedback helps reveal hidden conflicts, and improve spectrum allocation

Spatial Planning



Uneven AP Utilization

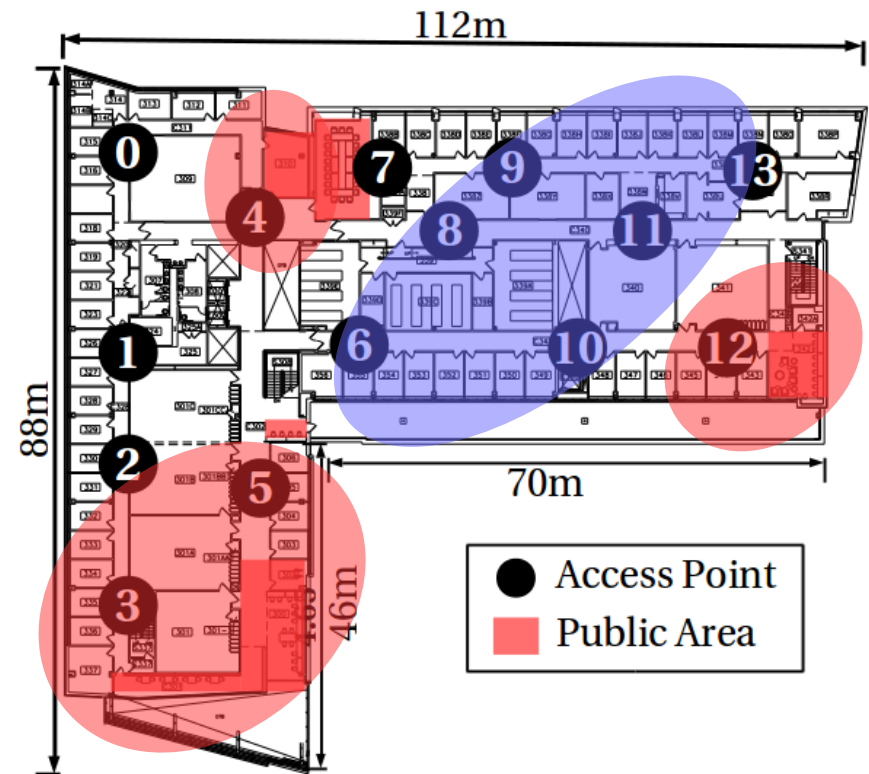


Questions



What to do with the underutilized APs?

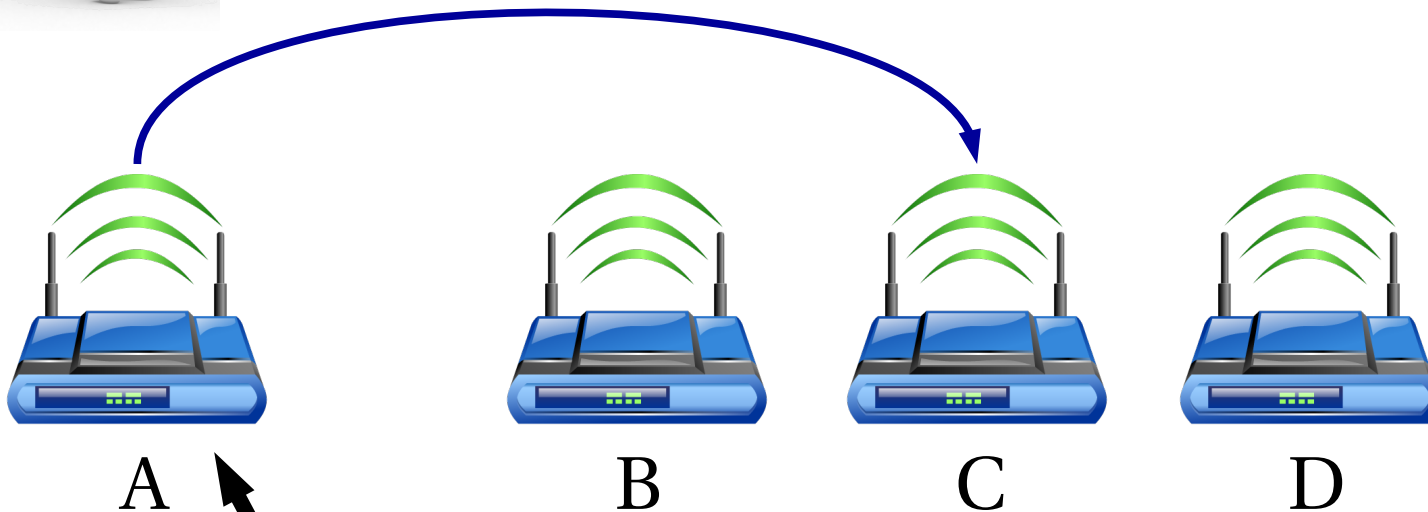
- Leave for load balancing?
 - ▶ Which neighbor AP to use?
 - ▶ Client signal quality?
- Reposition?
 - ▶ Load redistribution?
 - ▶ Coverage holes?



Load Balancing

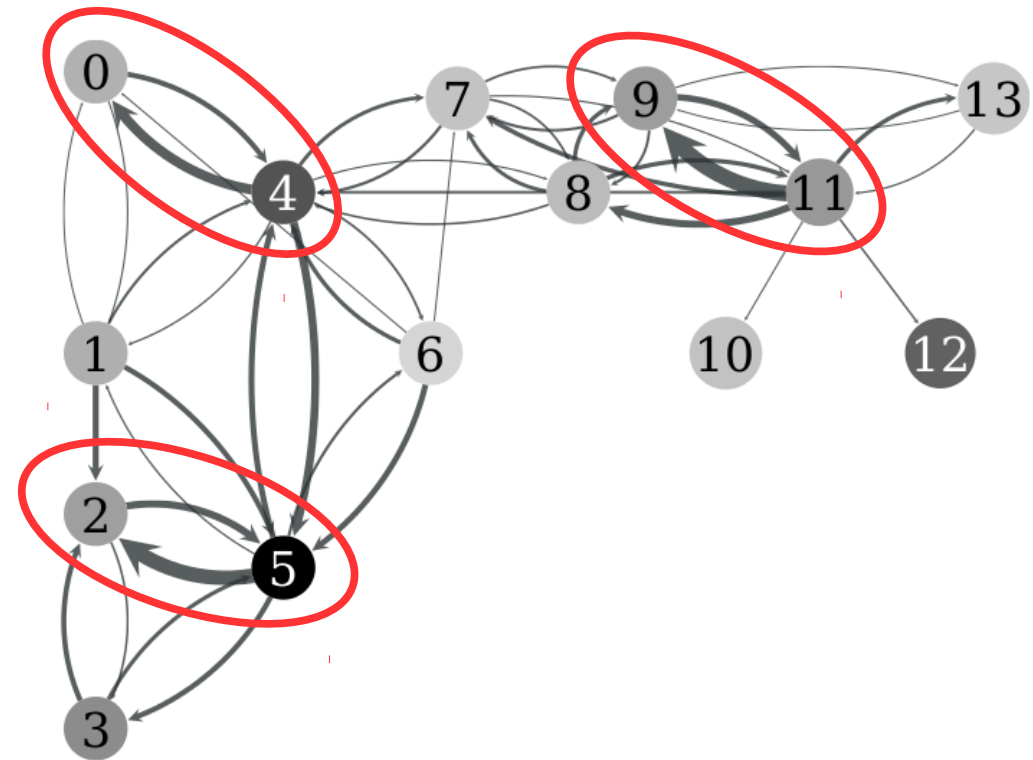
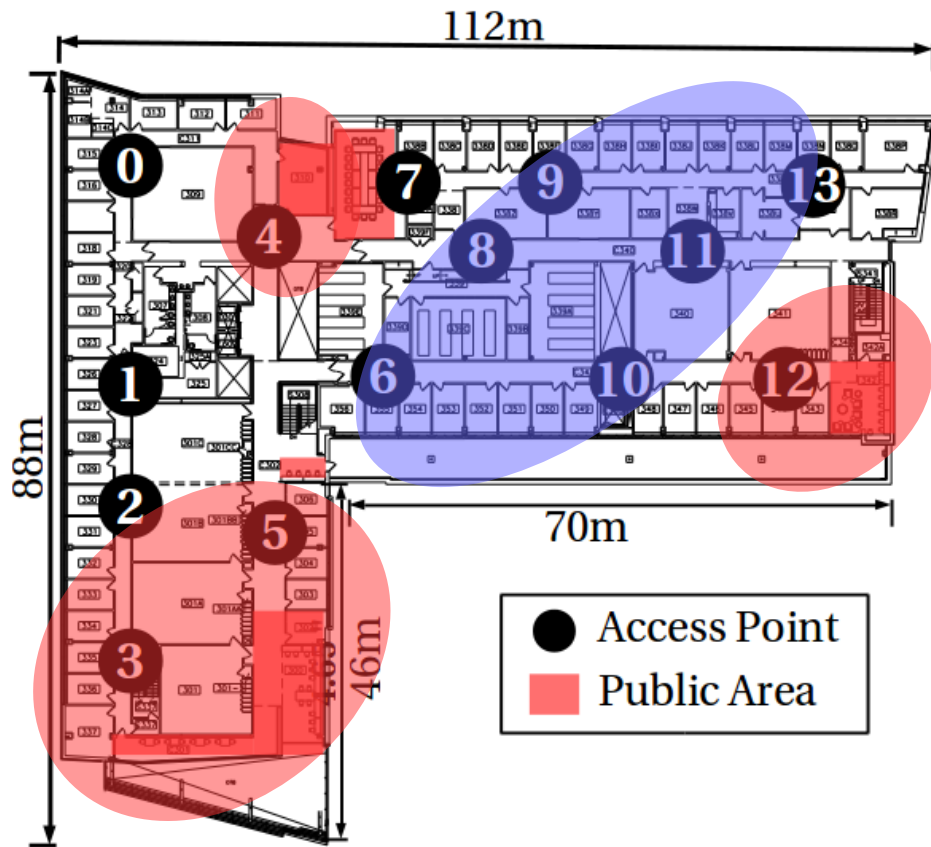


Which neighbor AP provides best signal for my client?



Scan results **during** Wifi session

Empirical Load Balancing Graph

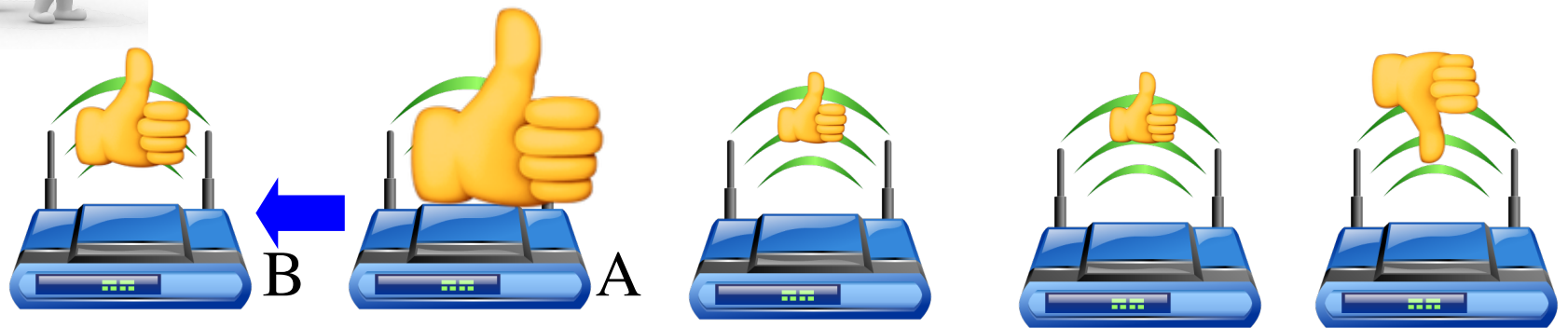


Load-balancing decisions

Load Redistribution



What happens when an AP is gone?



Scan results **before** Wifi session

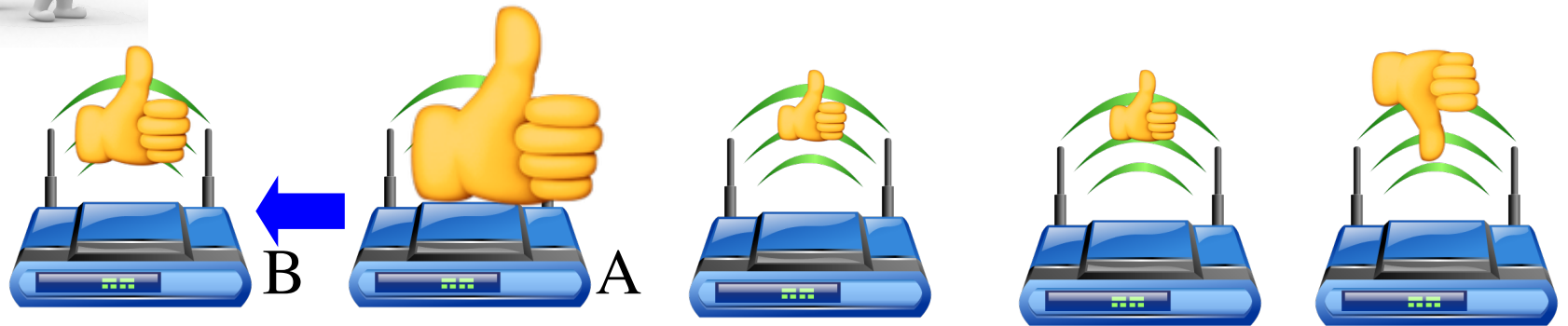
Second-best AP



Load Redistribution



What happens when an AP is gone?

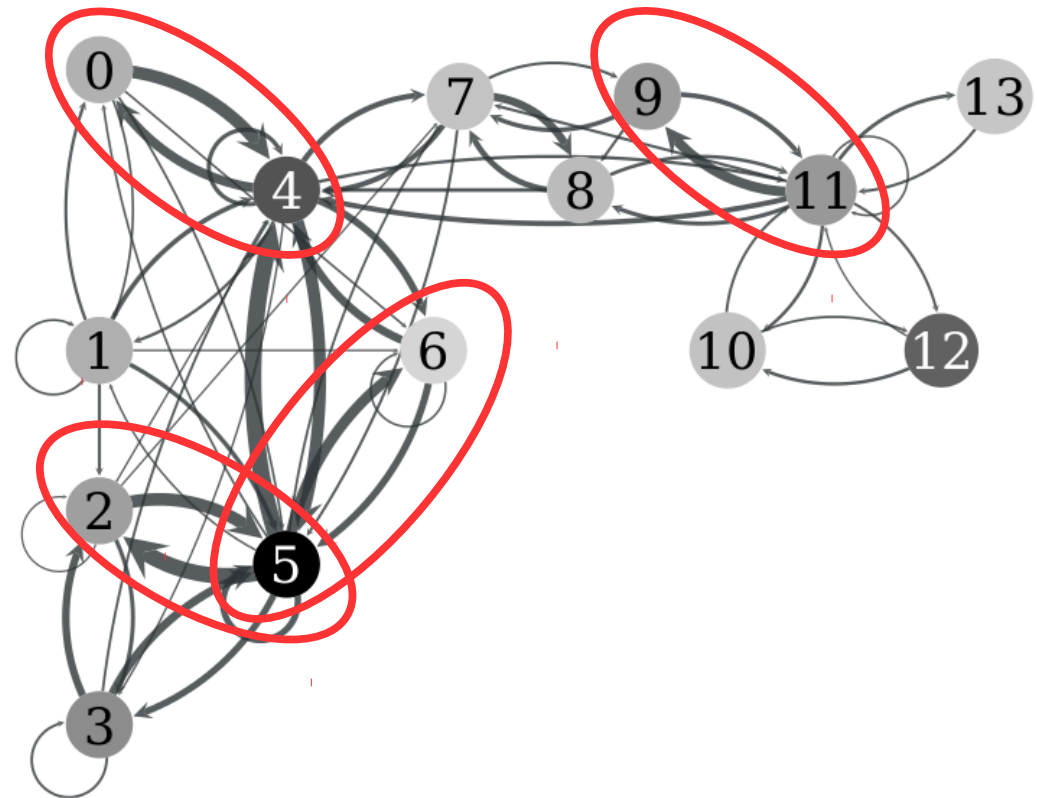
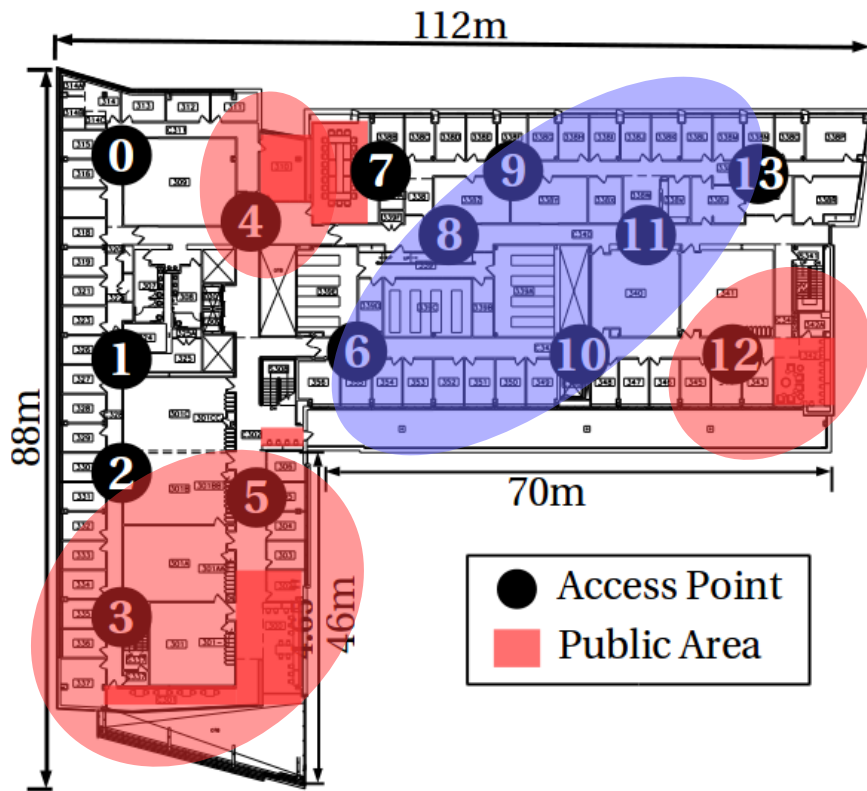


Scan results **before** Wifi session

Second-best AP

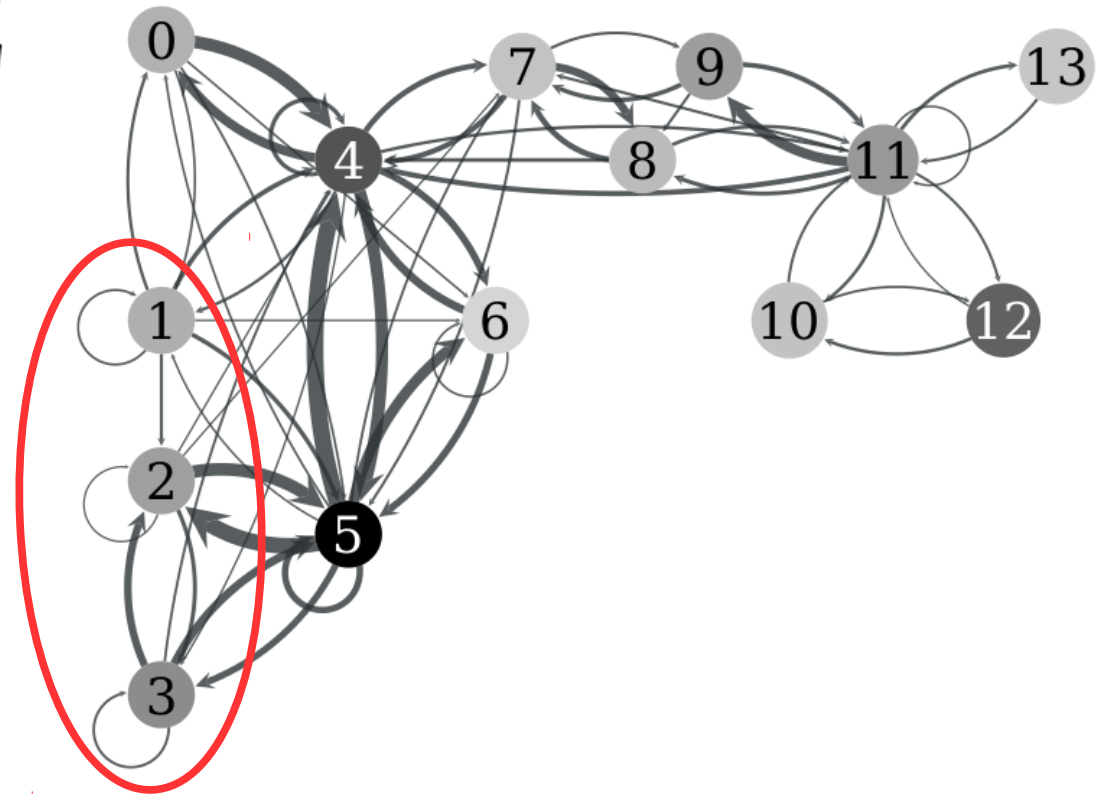
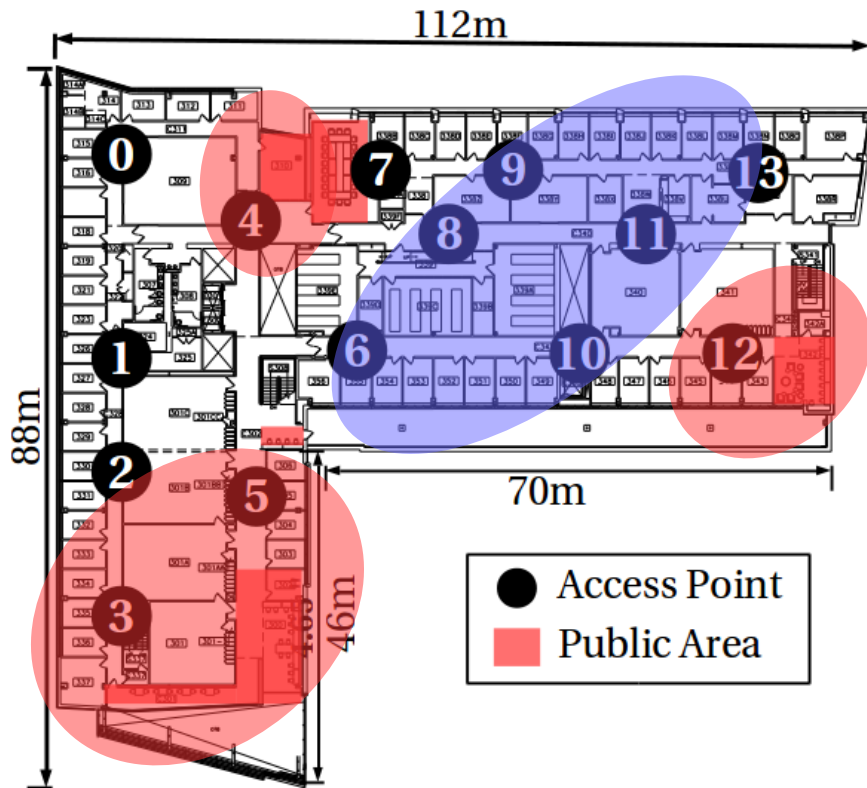


Load Redistribution Graph



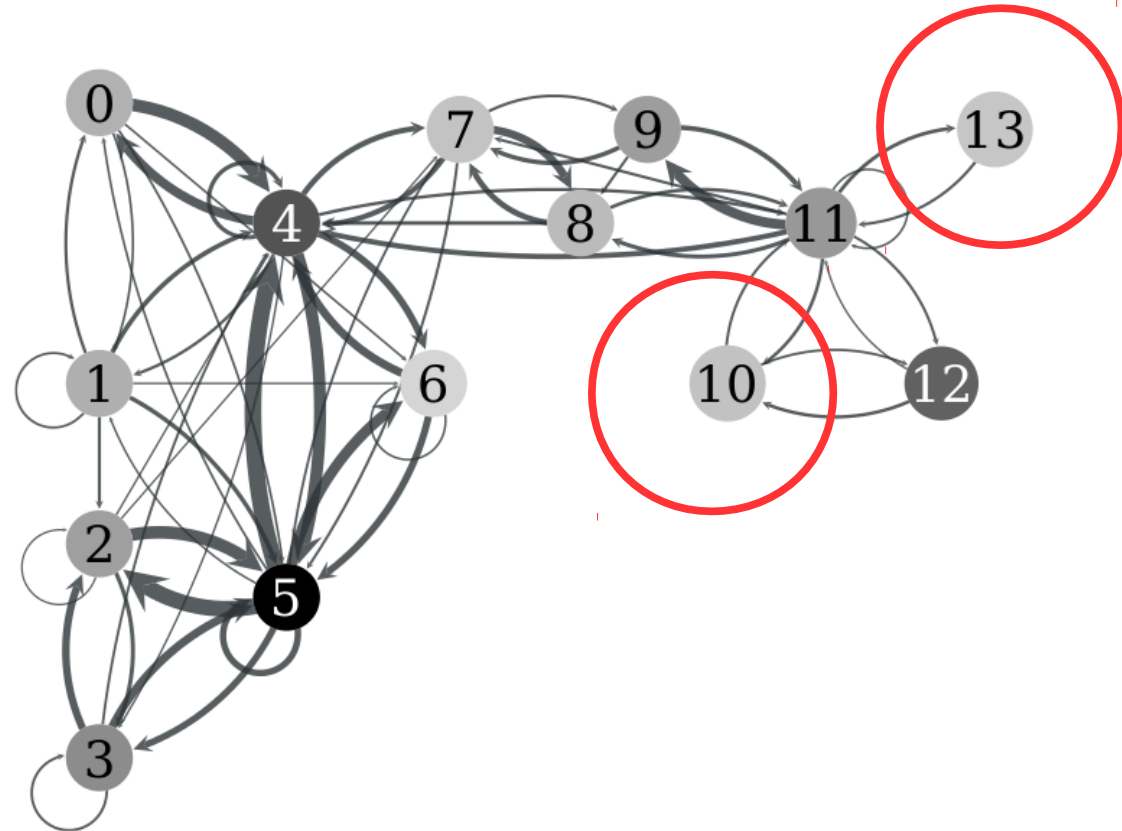
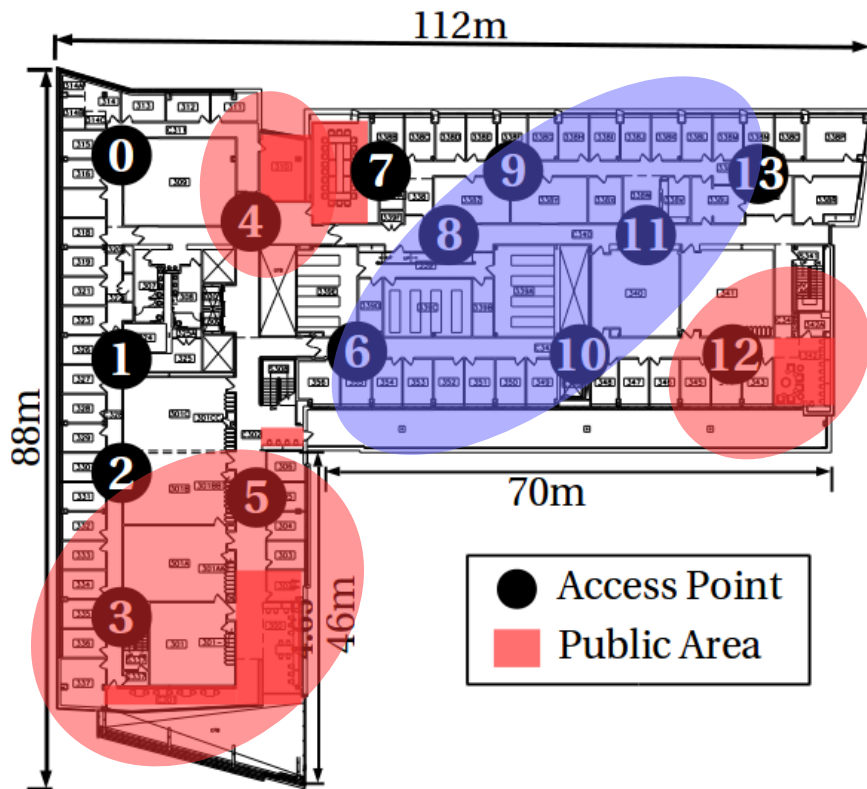
0, 2, 6, 9: better kept for backup

Load Redistribution Graph



0, 2, 6, 9: better kept for backup
 1, 2, 3: better kept to avoid coverage hole

Load Redistribution Graph



0, 2, 6, 9: better kept for backup

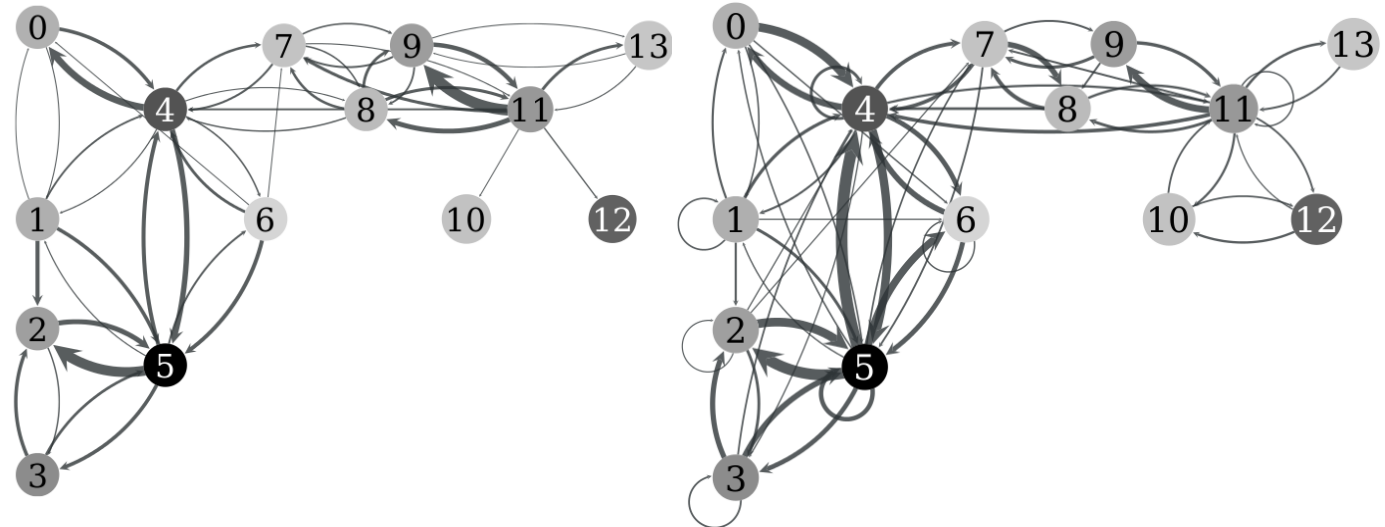
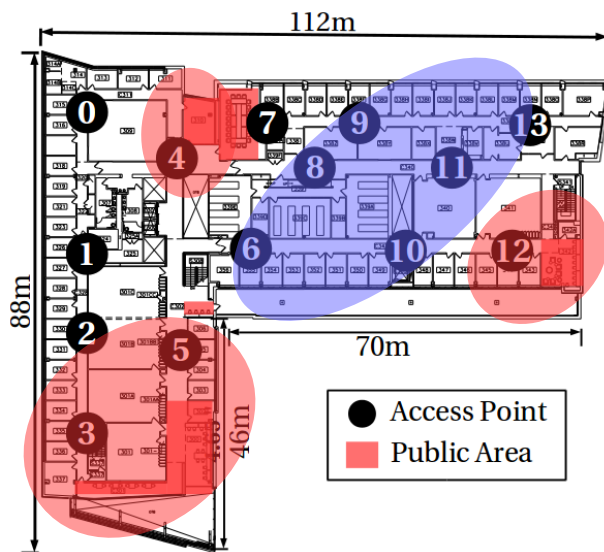
1, 2, 3: better kept to avoid coverage hole

10, 13: removal candidate

Take-Aways

Client-side view can help

- ▶ Decide load balancing candidates
- ▶ Predict load redistribution



Load balancing graph Load redistribution graph

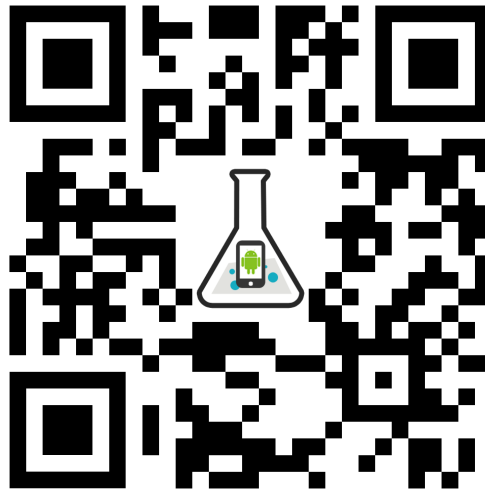
Summary

- Smartphone scan results are useful!
 - ▶ Spectrum management
 - ▶ Spatial planning
- Start collecting them already!



- 254 devices
- 147 days
- 5M scans
- 30K APs

<http://crawdad.org/buffalo/phonelab-wifi/>



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- 120 devices
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Per request to:

netsense@nd.edu