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

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Centrally-Managed Wifi 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

AP-Side Monitoring Software
- Continuous
- Cross layer

Oneshot
- Expensive
- Lack of client-side feedback
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

The Datasets

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

**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

Limited # of orthogonal channels
Graph Coloring Model

**A** conflict edge **B**

- Ch 1
- Ch 6
- Ch 11

Conflict Graph
Conflict Graph From AP Scan

Floor Plan of Davis Hall 3\textsuperscript{rd} @ UB  AP-Perceived Conflict Graph
Conflict Graph From AP Scan

Floor Plan of Davis Hall 3rd @ UB

AP-Perceived Conflict Graph

7-colorable! (5GHz band)
Hidden Terminals

Hidden Conflict Edge

Clients-perceived conflicts may be different.
Client-Perceived Conflict Graph

What you think the network looks like

AP-Perceived Conflict Graph

What the network actually looks like

Client-Perceived Conflict Graph

New edges
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

Hour: 00 AM
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

![Hour of Day vs. # of Conflict Edges](Image)
Take-Aways

Infrastructure does not see all conflicts

Client-side feedback helps reveal hidden conflicts, and improve spectrum allocation
Spatial Planning

Uneven AP Utilization

- **Access Point**
- **Public Area**

- **Legend**:
  - Black: Session Count
  - Gray: Session Duration
  - Light Gray: Session Traffic

- **Relative Load**

- **AP ID**
  - 5
  - 4
  - 12
  - 3
  - 11
  - 9
  - 2
  - 1
  - 8
  - 10
  - 7
  - 13
  - 6
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?

Second-best AP

Scan results before Wifi session
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!

[http://crawdad.org/buffalo/phonelab-wifi/]

Per request to:
[netsense@nd.edu]

[University of Notre Dame NetSense Project]
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