Outsourcing Coordination and Management of Home Wireless Access Points through an Open API

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Dense residential WiFi deployments...

Apartment Building

Apt 201

WiFi Access Points

Apt 202

WiFi Clients (e.g., laptops, smartphones)
What problems degrade residential WiFi experience today?
1. Channel congestion

Dark Knight

BitTorrent
Real Scenario in an apartment building

Traffic (in Mbps) (AP 1)

Airtime Utilization (AP 2)

Long periods with channel congestion
2. Hidden terminal WiFi interference

Dark Knight

Happy Feet
3. Non-WiFi interferers

- Cordless Phones
- Bluetooth Devices
- ZigBee
- Microwave Oven

> 50% throughput degradation due to non-WiFi interference (MobiCom’13)
4. Static and inefficient channel configuration

Spectrum Wastage: More than 50% of home APs used static WiFi channels (MobiCom’13)
How can we mitigate these residential WiFi problems?
Goal: Managing home Access Points (APs)

- Enable AP cooperation to improve performance
- Improve spectrum utilization
- Mitigate WiFi and non-WiFi interference
- Software-only solution for commodity WiFi APs
- Vendor neutral APIs for wider adoption
A central management control plane?
Enter COAP...

- COAP: Coordination framework for Open APs
  - A cloud based management service using OpenFlow SDN
Outline

- Introduction
- **COAP Framework Overview**
- COAP Applications
- Summary
COAP framework

Uses open-source OpenFlow SDN + Floodlight controller

Implemented OpenFlow wireless extensions to collect statistics from APs

Cloud-based COAP controller collects and coalesces statistics to configure APs

COAP enabled home Access Points

COAP Cloud Controller (Hosted by ISP or Building manager)
COAP API examples (at Access Point)

APConfigManager
- SetParameters(channel, power)
- SetAirtimeAccess(slotDur, xmitBitmap)

BasicStatsReporter
- GetAirtimeUtilization()
- GetLinkStatistics()
- GetNeighborInfo()

DiagnosticStatsReporter
- GetNonWiFiDevices() (Airshark, IMC’11)
- GetPacketSummaries() (WiSe, MobiCom’13)
Outline

• Introduction
• COAP Framework Overview
• **COAP Applications**
• Summary
Co-operative spectrum allocation

Interference mitigation

Context-aware configuration

Microwave oven activity
WiFi channel configuration

APs

Channel?

Channel?

Airtime Util Statistics

Channel Configuration

COAP Cloud Controller

Apartment Building
Using airtime-aware channel configuration

12 COAP APs in an apartment building

Apartment Building

COAP Enabled APs

Random vs “airtime-aware” channel config over 6 days (one day per scheme)
Using airtime-aware channel configuration

12 COAP APs: Random vs “airtime-aware” channel config over 6 days (one day per scheme)

Upto 42% reduction in median airtime utilization
Co-operative spectrum allocation

Interference mitigation

Context-aware configuration

Channel 1, 6 or 11?

Microwave oven activity
Hidden terminal WiFi interference

Dark Knight

Happy Feet
Slotting mechanism

AP 1 (Hidden terminal)

AP 2 (Hidden terminal)

10 ms

\( t_1 \)  \( t_2 \)  \( t_3 \)  \( t_4 \)

Time synchronization using common WiFi frames (error < 50 μs)

Slot(AP1, AP2):
AP1: SetAirtimeAccess(10ms, “1010”)
AP2: SetAirtimeAccess(10ms, “0101”)

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Example: Mitigate hidden terminal interference

Setup: 6 WiFi (802.11n) Links - 6 APs and clients

3 HTTP video streaming WiFi links (average 10 Mbps)

3 bulk download links (max 10 Mbps)

Used “Slotting” mechanism to mitigate interference
Mitigating hidden terminal interference

Slotting improved video throughput

Minor throughput drop for hidden terminals

HTTP video streaming links

Hidden terminals (Bulk downloads)
Impact on packet losses and video quality

50% reduction in packet losses
Better spectrum utilization

Almost zero frame drops with “Slotting”
Smooth video experience
Co-operative spectrum allocation

Interference mitigation

Context-aware configuration

Microwave oven activity
Context-aware configuration

• Predict future WiFi/non-WiFi activity

• Proactively configure APs based on predicted future activity

• Example inputs for modeling context:
  – Client device type (e.g., iPad, Google TV)
  – Traffic source (e.g., Netflix, YouTube)
  – Time of day
  – Activity statistics (session durations, bytes downloaded)
Example: “Time of day” microwave oven activity

How predictable is this activity for future time periods?
Building “Activity Vectors”

• **Activity Vector**: Represents time-series device activity

\[ V : < c_1, c_2, \ldots, c_n > \ \forall 1 \leq i \leq n \ \text{, } c_i \geq 0.0 \]

• Correlate activity vectors across “time-spans” (e.g., 1 day, 1 week etc.) to determine predictability

\[
\frac{1}{n - 1} \sum_{i=0}^{(d/k)-1} corr(V_i^k, V_{i+1}^k)
\]
Correlation between microwave oven activity across time spans

High predictability of microwave oven activity with 5 days of data
COAP demo screenshot
Summary

• Presented an **SDN framework** for managing home Access Points
  – Provides a **light-weight centralized control plane**

• Enabler for improving residential WiFi experience
  – Upto **42% reduction** in channel contention
  – Motivated “Airtime access APIs” to mitigate WiFi interference

• **Context-aware applications** can help with pro-active configuration of APs
Thanks!

http://research.cs.wisc.edu/wings/projects/coap/