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

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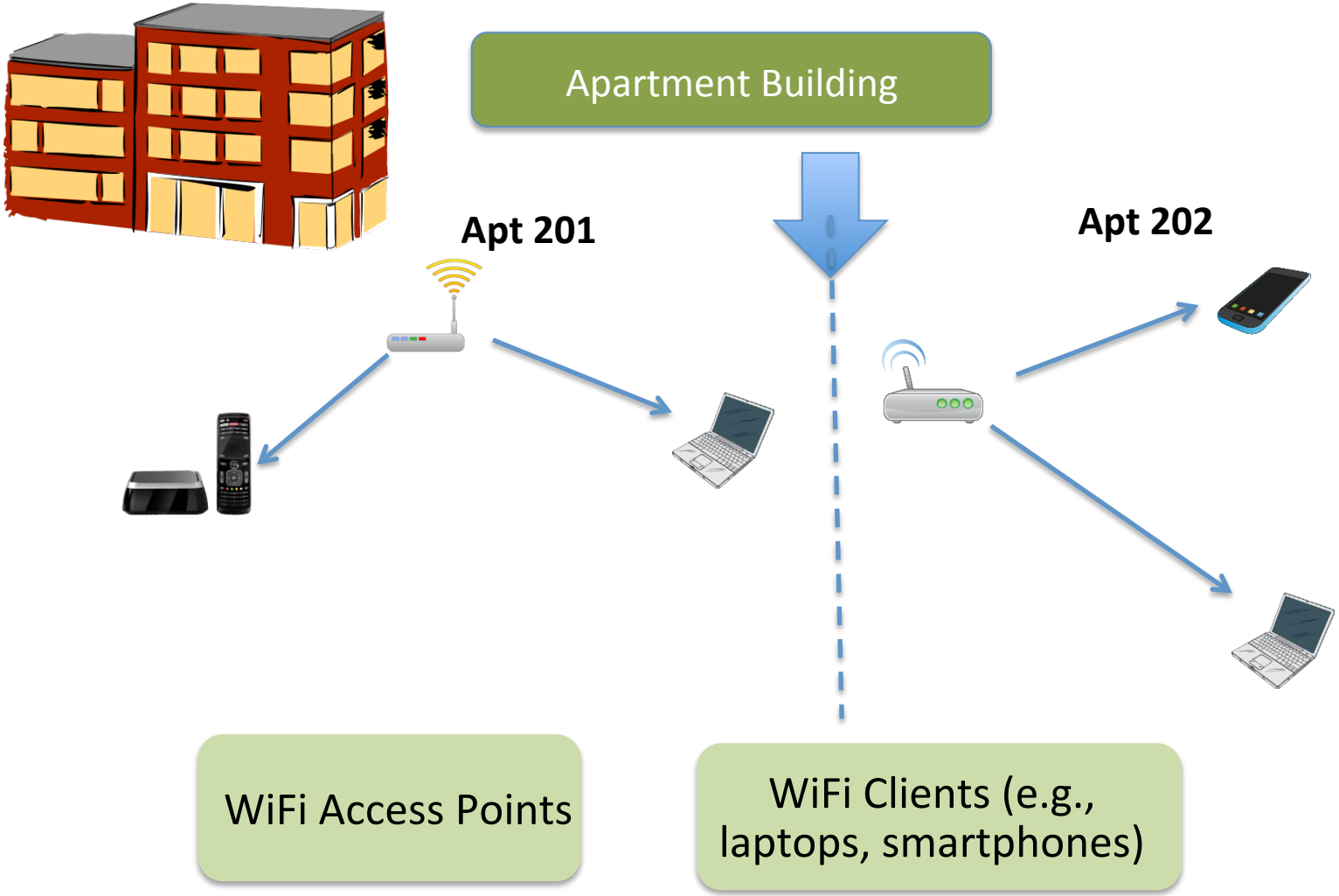
Dense residential WiFi deployments…



What problems degrade residential WiFi experience today?

Apartment Building

WiFi Access Points

1. Channel congestion

Dark Knight

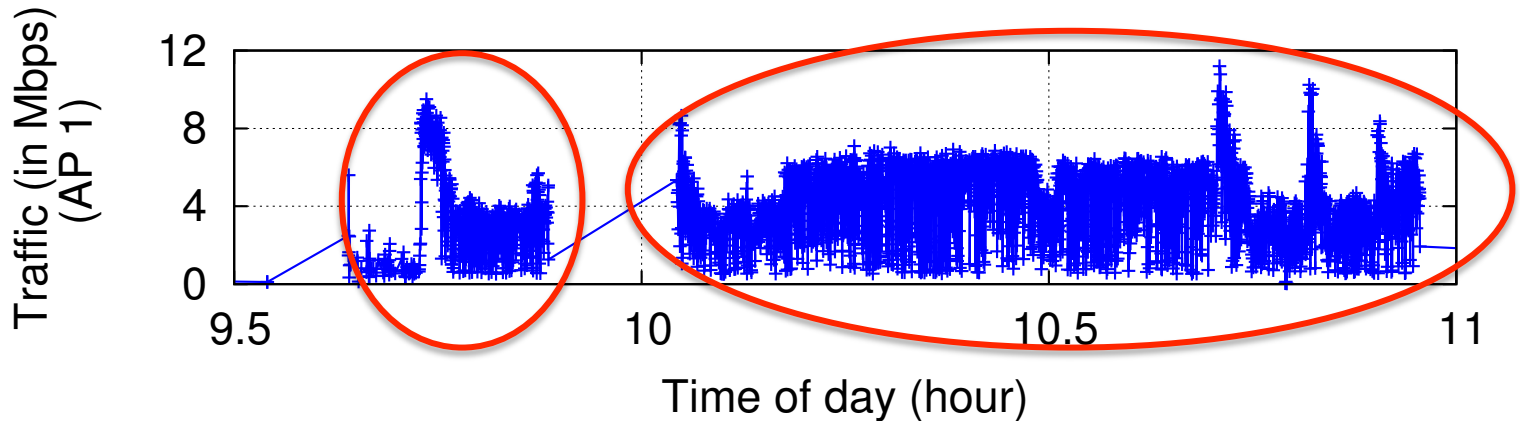
#@!*@

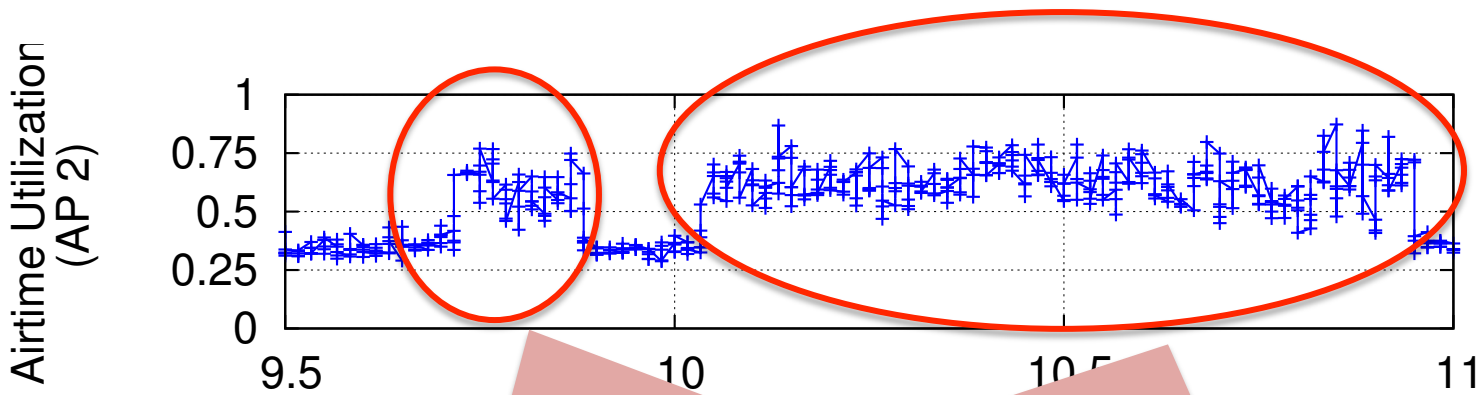
BitTorrent™

Real Scenario in an apartment building

AP 1

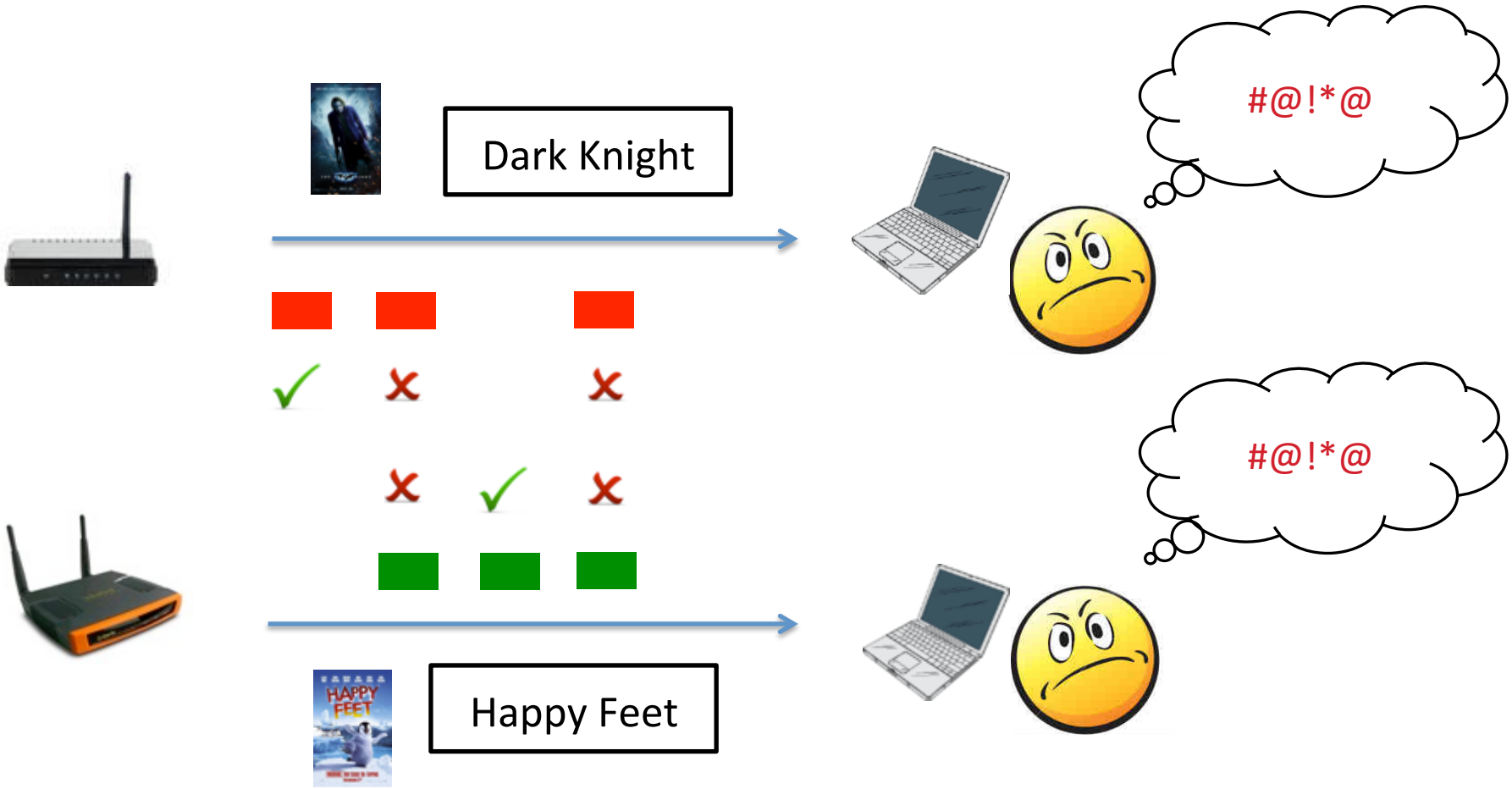
AP 2





Long periods with channel congestion

2. Hidden terminal WiFi interference



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

Home WiFi Access Points

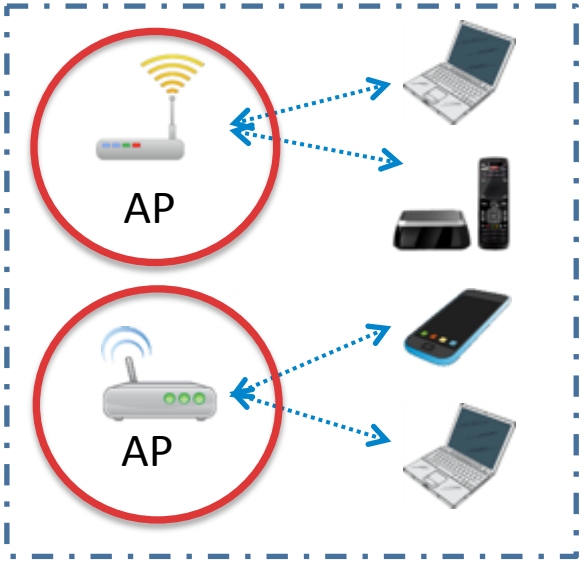
Spectrum Wastage: More than 50% of home APs used static WiFi channels (MobiCom'13)

How can we mitigate these residential WiFi problems ?

Apartment Building

WiFi Access Points

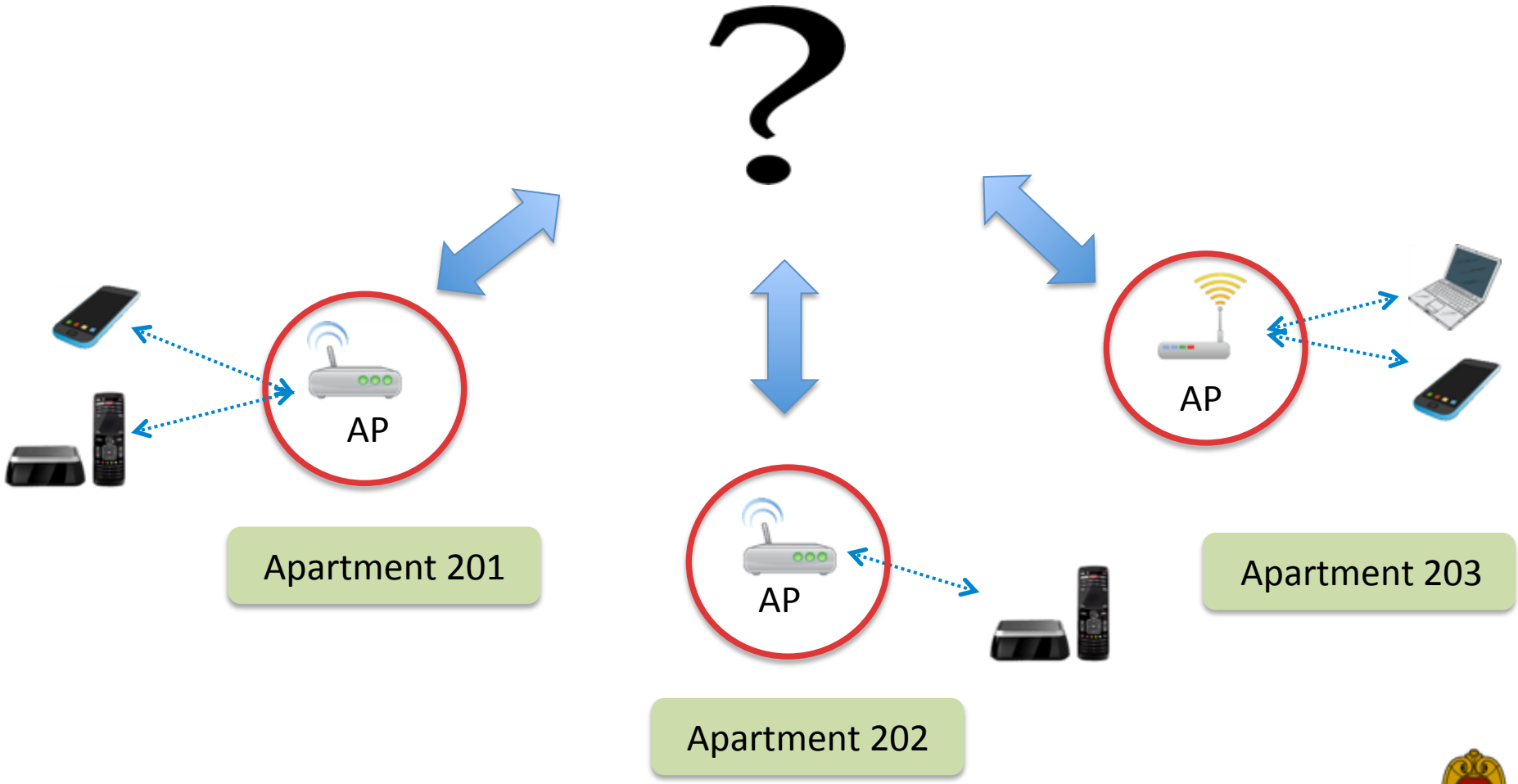
Goal: Managing home Access Points (APs)



Apartment Building

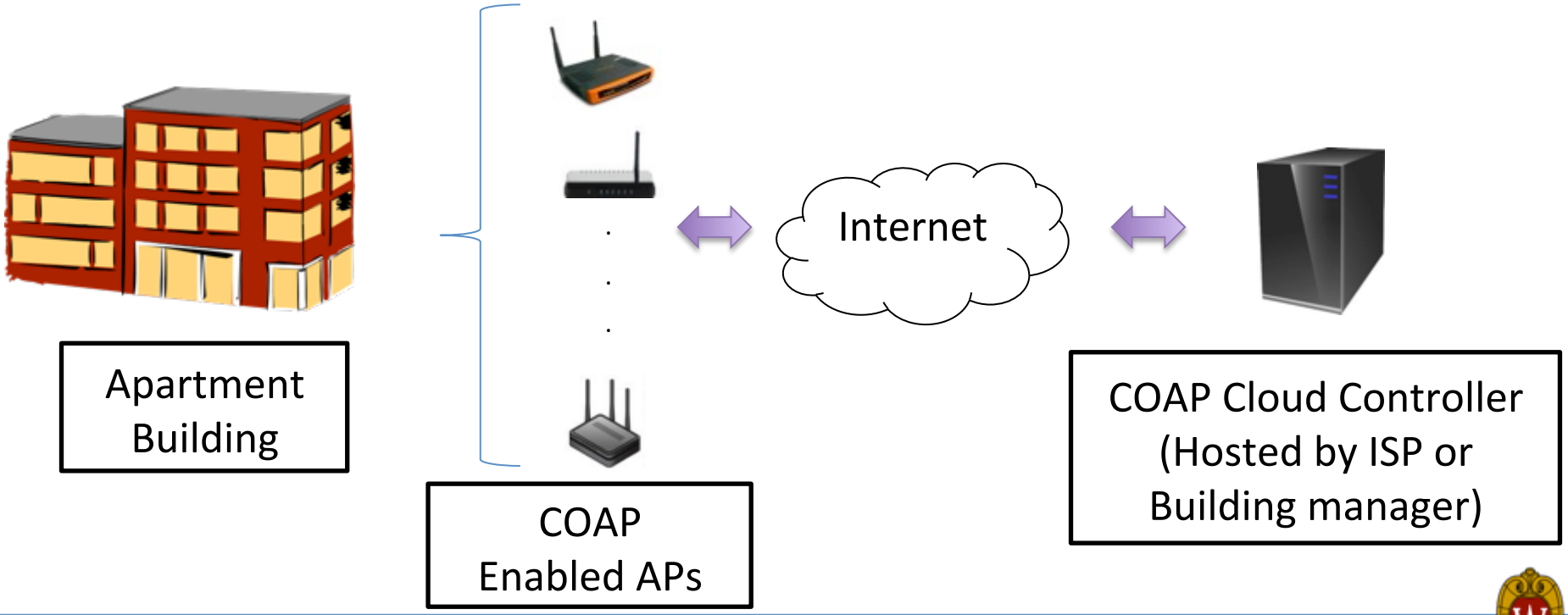
- Enable AP cooperation to improve performance
- Improve spectrum utilization
- Mitigate WiFi and non-WiFi interference
- Software-only solution for commodity WiFi APs
- Vendor neutral APIs for wider adoption

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

COAP enabled home Access Points

COAP Cloud Controller (Hosted by ISP or Building manager)

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 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)

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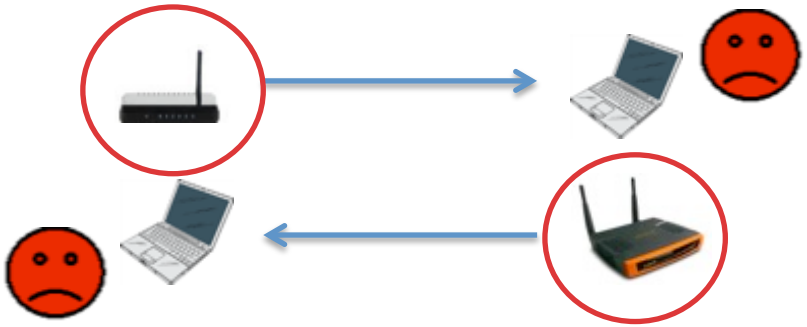
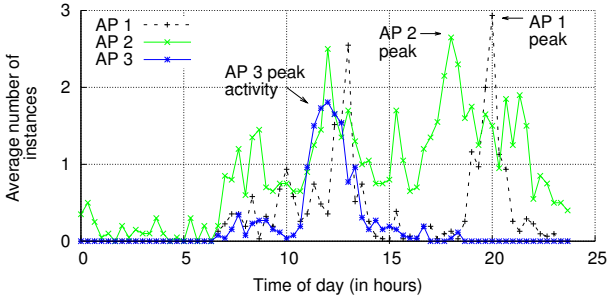
Co-operative spectrum allocation

Interference mitigation

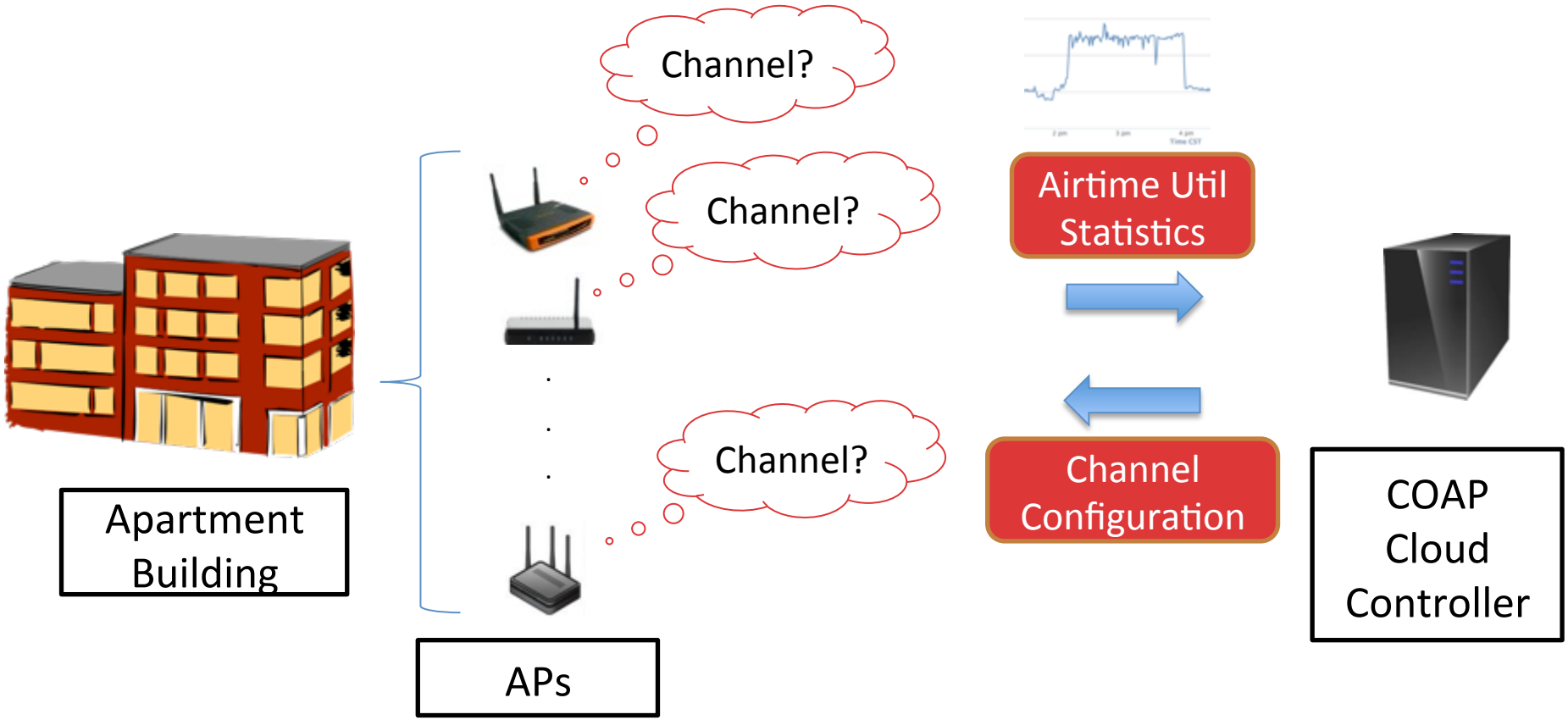


Context-aware configuration



Microwave oven activity

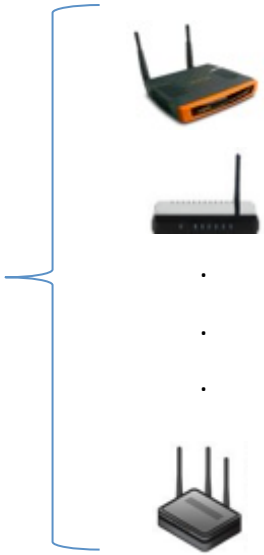
WiFi channel configuration



Using airtime-aware channel configuration

12 COAP APs in an apartment building

Apartment Building

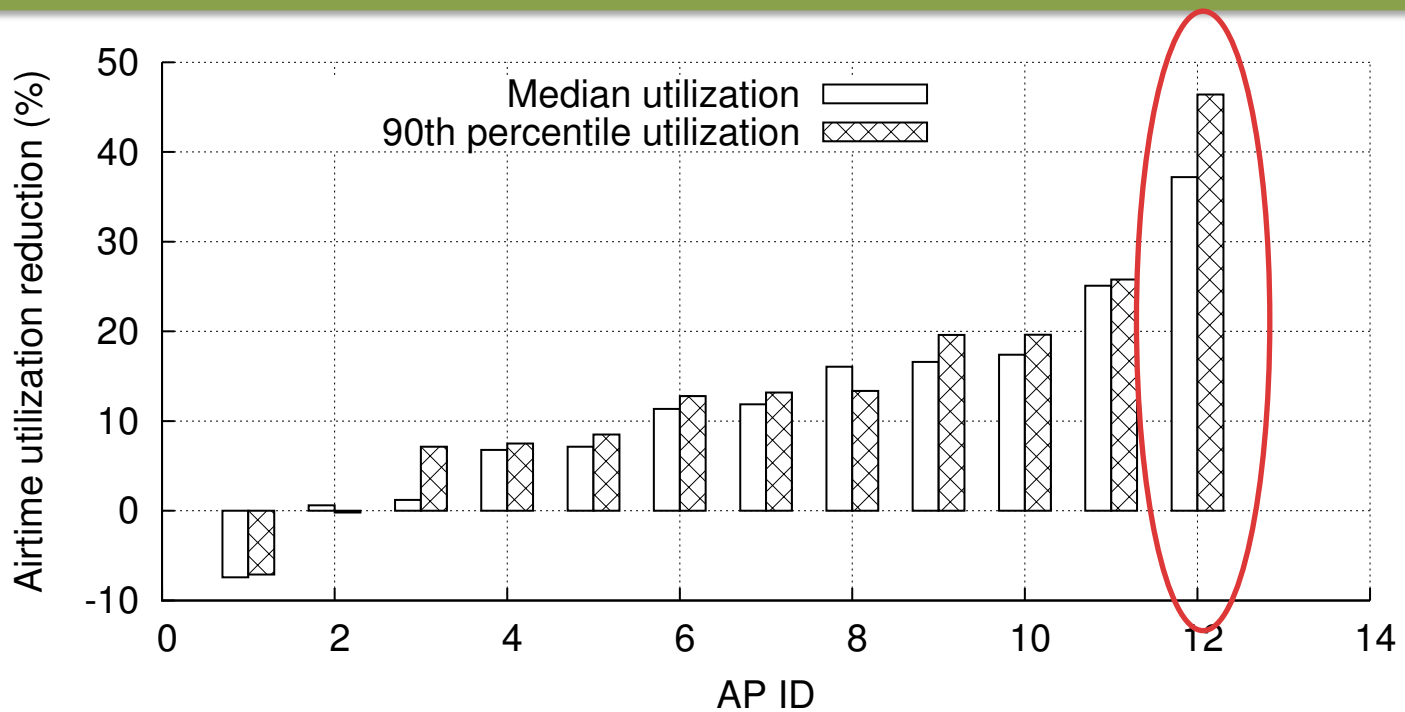


COAP Enabled APs

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

Using airtime-aware channel configuration

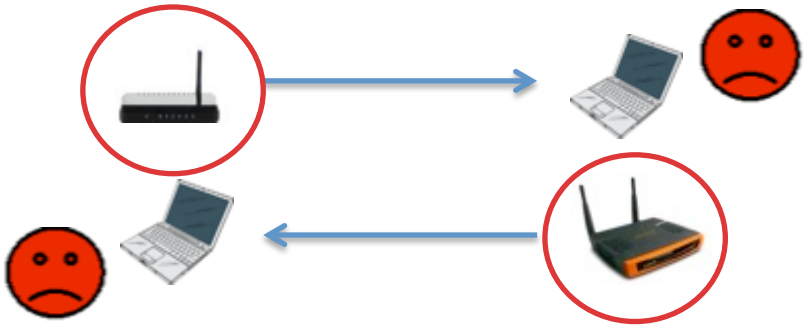
12 COAP APs: Random vs “airtime-aware” channel config over 6 days (one day per scheme)



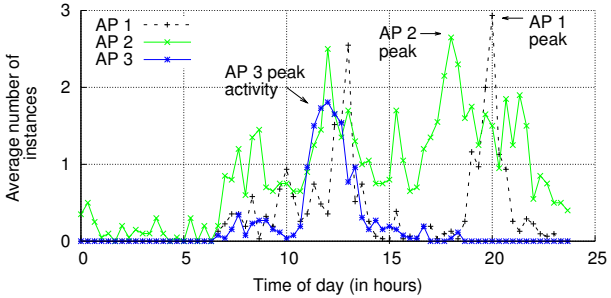
Upto 42% reduction in median airtime utilization

Co-operative spectrum allocation

Interference mitigation

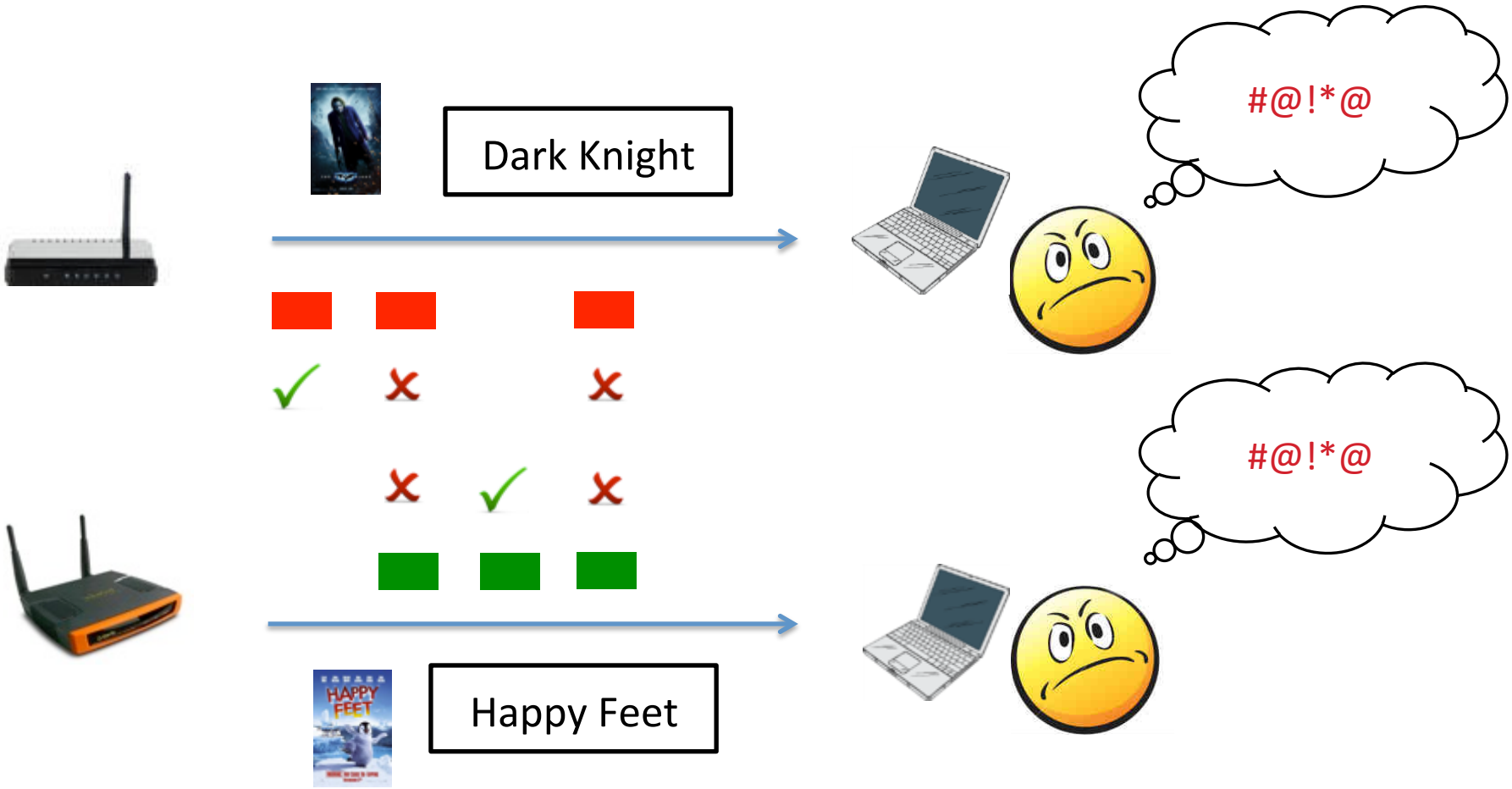


Context-aware configuration

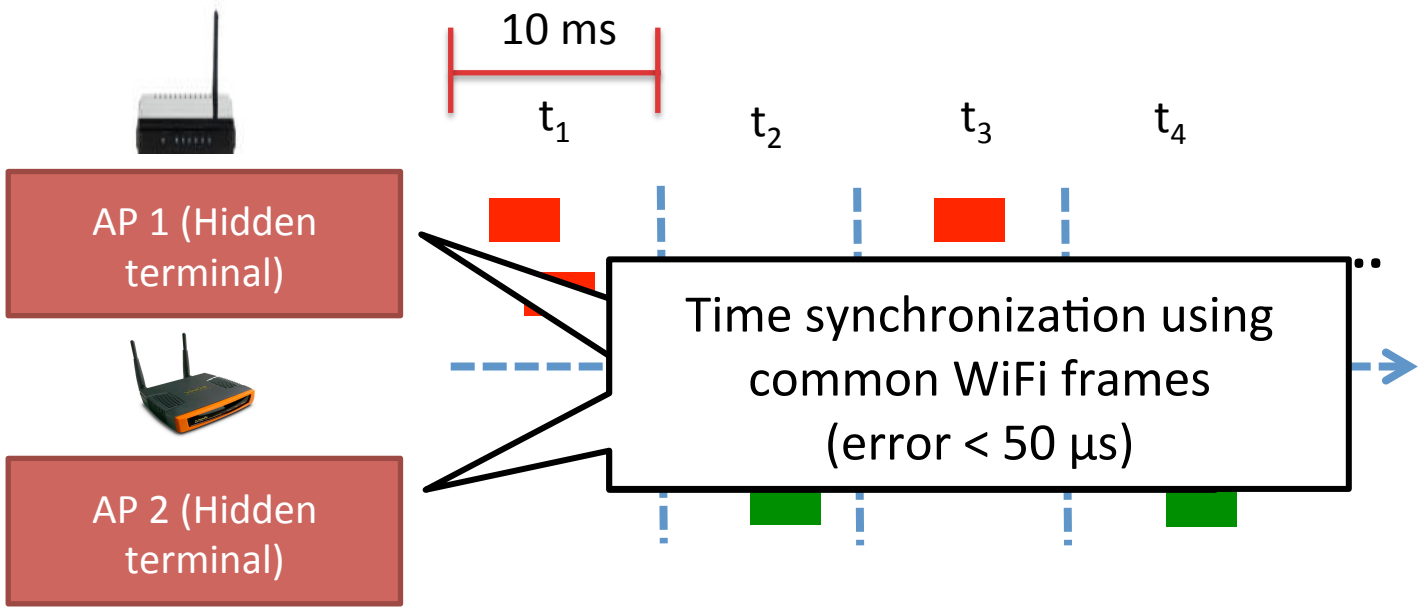


Microwave oven activity

Hidden terminal WiFi interference



Slotting mechanism

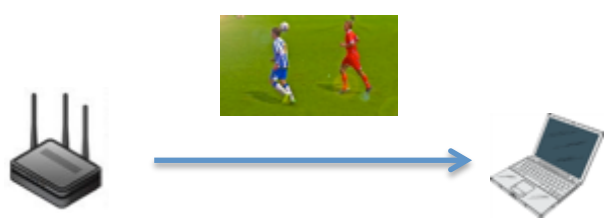


Slot(AP1, AP2):
AP1: SetAirtimeAccess(10ms, "1010")
AP2: SetAirtimeAccess(10ms, "0101")

Example: Mitigate hidden terminal interference

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

Setup as hidden terminals



3 HTTP video streaming WiFi links (average 10 Mbps)

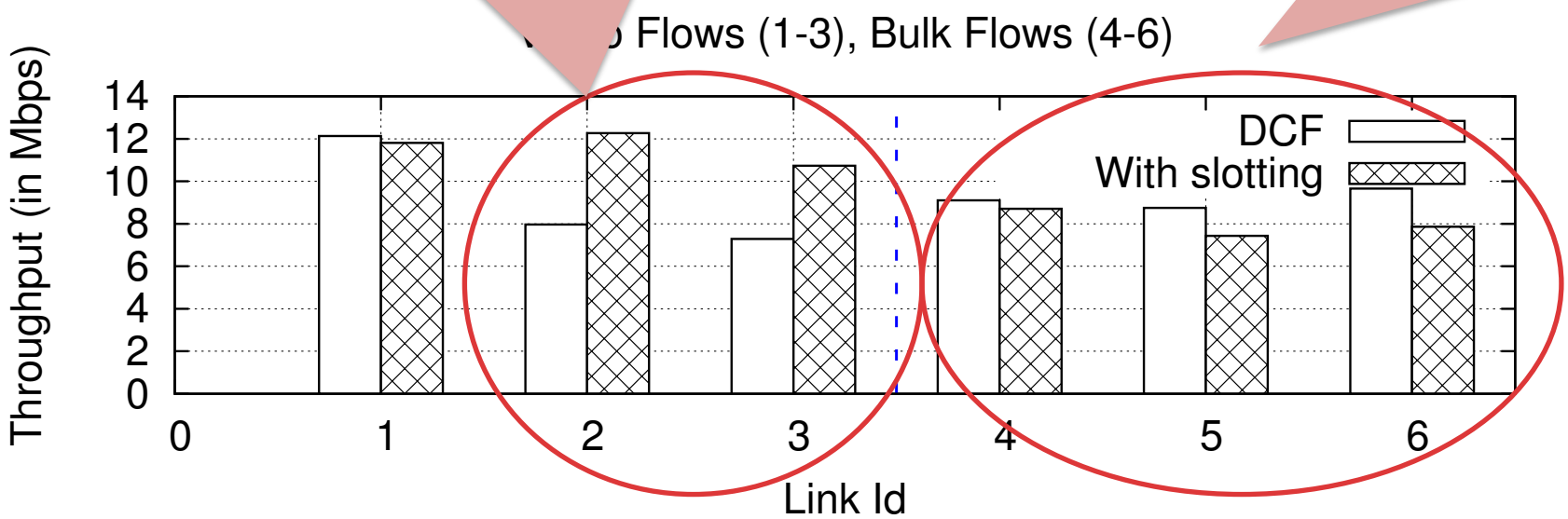
3 bulk download links (max 10 Mbps)

Used "Slotting" mechanism to mitigate interference

Mitigating hidden terminal interference

Slotting improved video throughput

Minor throughput drop for hidden terminals

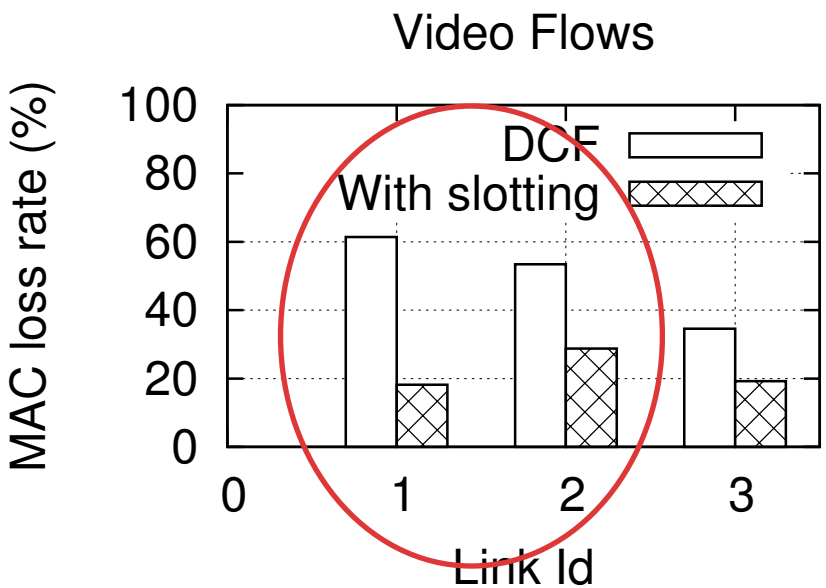


HTTP video streaming links

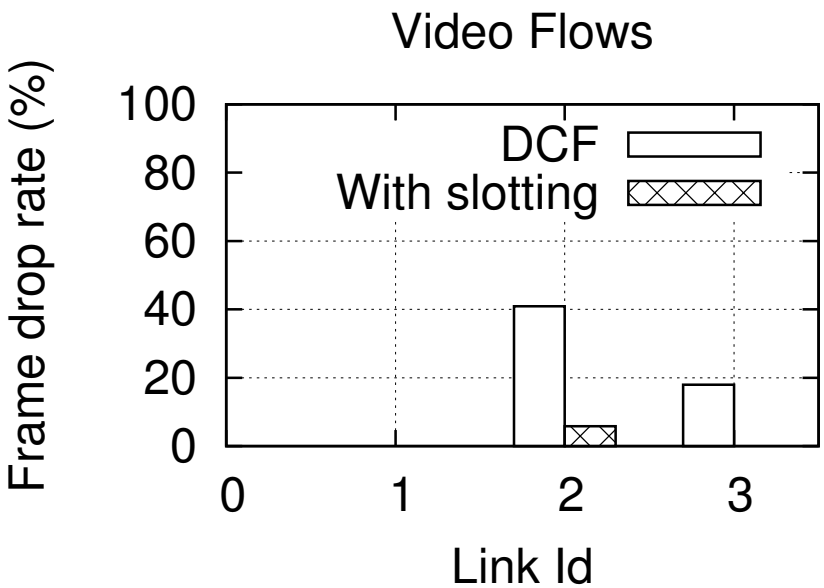
Hidden terminals (Bulk downloads)

Impact on packet losses and video quality

At Access Point



At Client

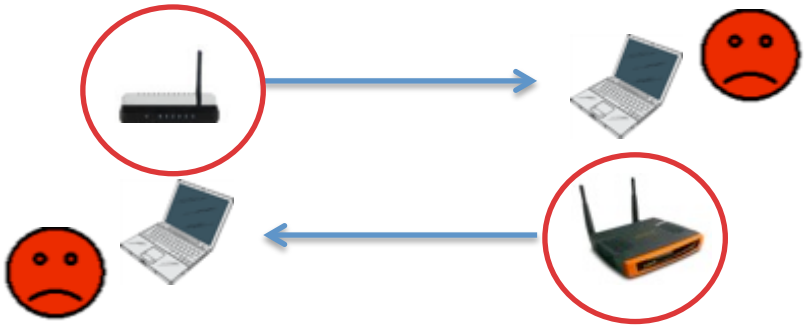


50% reduction in packet losses
Better spectrum utilization

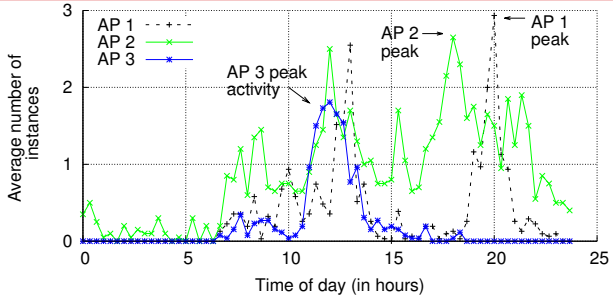
Almost zero frame drops with "Slotting"
Smooth video experience

Co-operative spectrum allocation

Interference mitigation



Context-aware configuration

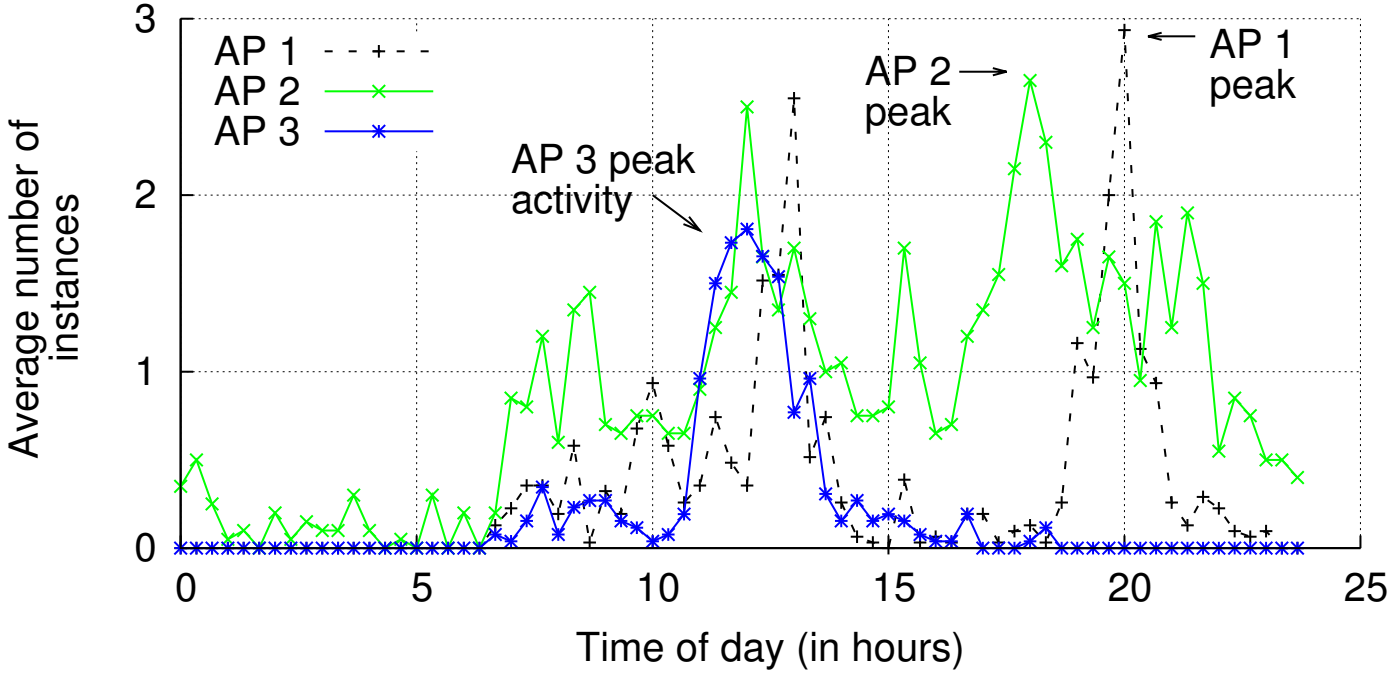


Microwave oven activity

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"

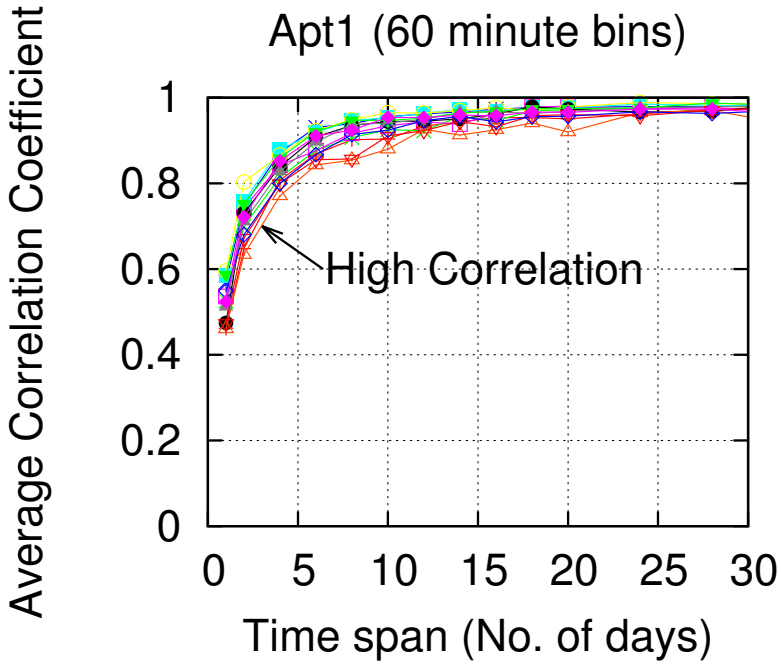
- Activity Vector: Represents time-series device activity

$$V :< c_1, c_2, ..., c_n > \forall 1 \leq i \leq n \ \ , c_i \geq 0.0$$

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

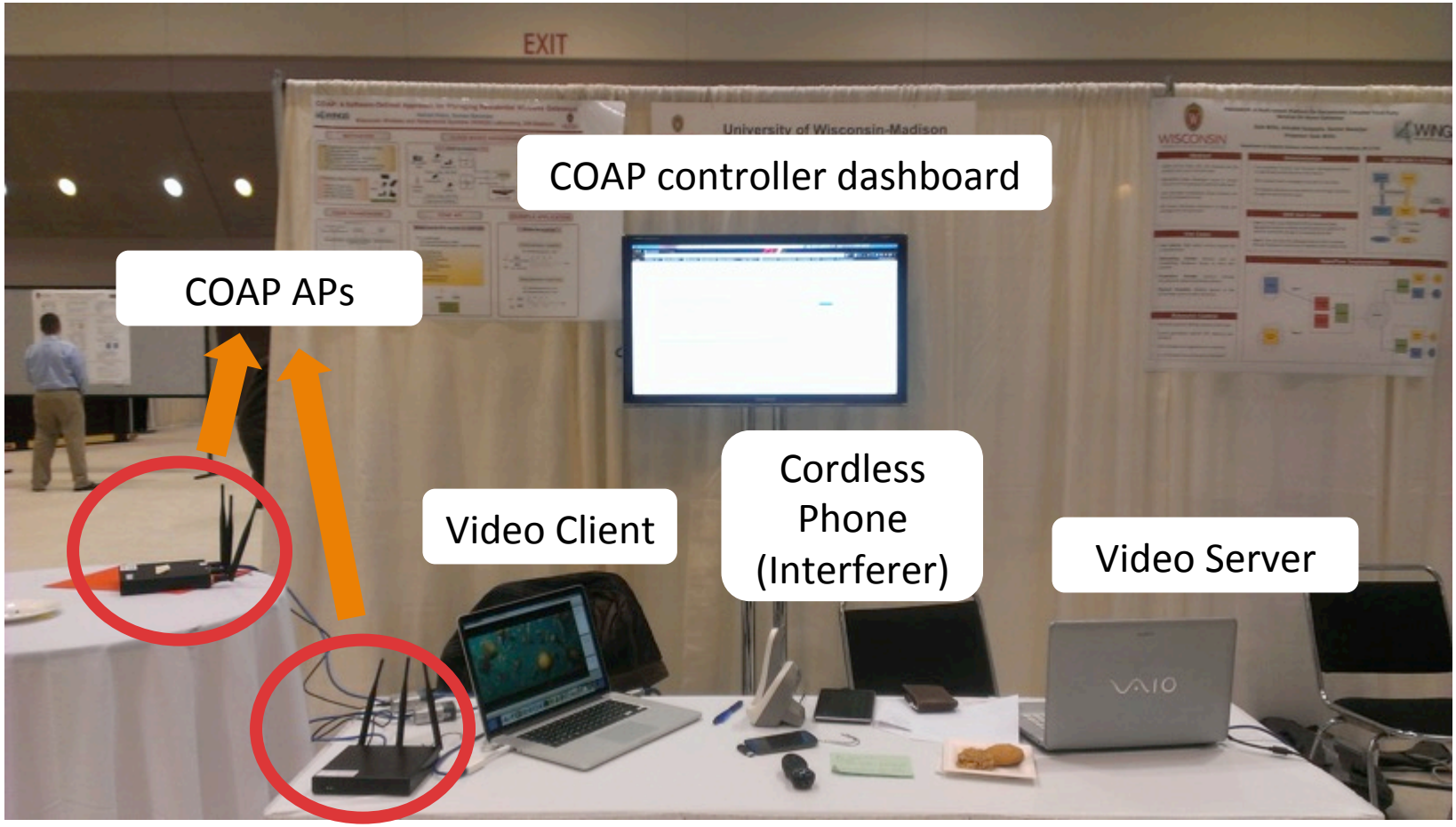
$$\frac{1}{n-1} \sum_{i=0}^{(d/k)-1} corr(V_i^k, V_{i+1}^k)$$

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/