OPEN NETWORKING INFRASTRUCTURE

BOOSTING WIRELESS NETWORKS IN THE ERA OF CLOUD COMPUTING

Ph.D. Proposal Defense

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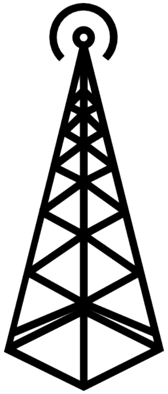
Evolution of Mobile Networks

- Mobile networks and devices are rapidly evolving
- Our daily life is on mobile

"More users may connect to the Internet via mobile devices than desktop PCs within 5 years"
– *Morgan Stanley, The Mobile Internet Report 2009*

New Challenges

- Fast growing demand of **ubiquitous network access**
- Cellular technology is facing critical challenges
  - High capacity **shared** by a large number of users
  - **Not scalable** as mobile population keeps growing
  - **High** maintenance/upgrade cost
- **New trend: Offload data to WiFi networks**
  - Carrier approach: AT&T, T-Mobile, China Mobile
    802.11u, hotspot 2.0
  - Community approach:
    FON encourages users to share their idle home bandwidth with others over millions of users



Advantage of WiFi

- WiFi **ubiquitous** in devices
- Much **wider spectrum** than cellular licensed band
  - 80MHz in 2.4GHz, 240MHz in 5GHz
- **Widely deployed**, “ready-to-use” infrastructure
- **Increasingly powerful** (CPU, RAM, Flash, Easy to upgrade, etc.)
  - Distributed storage service
  - Micro CDN nodes

Leverage **community WiFi** to provide better ubiquitous access to **wireless**, **data** and **computation**

Research Focus

BaPu

Harness the Idle Backbone Uplink Capacity through Neighboring WiFi

WiZi-Cloud

Reduce Energy Consumption with the Assistance of Urban WiFi Infrastructure

Outline

- Introduction
- Open Infrastructure Testbed
  A Residential Wi-Fi Research Testbed @ Boston
- BaPu
- WiZi-Cloud
- Task Schedule

Why Build Open Infrastructure Testbed?

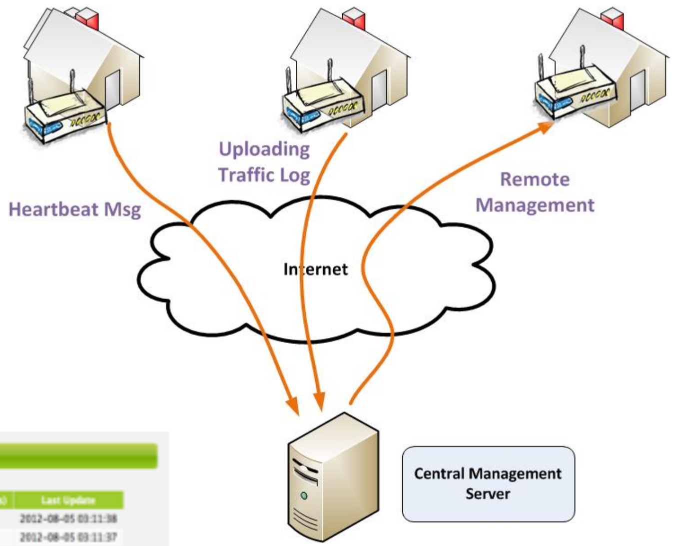
- Many testbeds run in university/enterprise environment

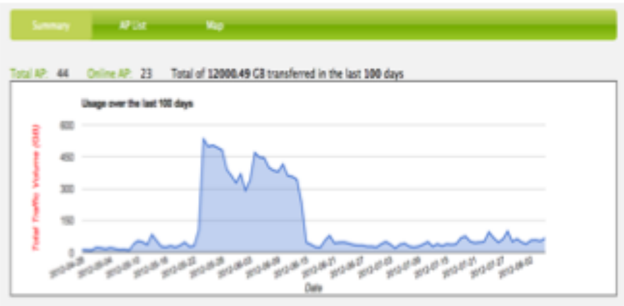
PLANETLAB

- Residential networks have unique characteristics
- We need a “**PlanetLab**” in residential networks
  - Provide first-hand information of residential networks (wireless & wired)
  - A realistic environment to try research ideas

Open Infrastructure Testbed

- 30 home WiFi APs in Boston (since 02/2011)
- Customized OpenWRT firmware
- 16GB USB Flash
- A suite of management tools
- Traffic monitoring at 10sec granularity
- 1.3TB full data trace (6 month)





Summary | AP List | Map

	version	IP	uptime (hr)	WiFi ESSID	PriBW (Kbps)	GuestBW (Kbps)	Last Update
•	0.63	129.10.115.200	3028.82		0.66	0.00	2012-08-05 03:11:38
•	0.63	65.96.165.130	1946.94		0.59	0.00	2012-08-05 03:11:37
•	0.63	71.232.32.247	1.22		10.49	0.00	2012-08-05 03:11:41
	0.61	129.10.115.200	0.04		0.00	0.00	2012-07-19 18:20:25
•	0.63	24.63.24.189	4117.74		0.59	0.00	2012-08-05 03:11:37
•	0.61	174.62.207.20	471.97		0.23	0.00	2012-08-05 03:11:39
	0.6	209.6.232.79	47.44		0.00	0.00	2012-04-12 19:41:07
•	0.63	76.175.169.116	773.54		10.30	0.00	2012-08-05 03:11:34
•	0.63	24.34.221.134	1434.77		0.80	0.00	2012-08-05 03:11:39
	0.63	24.147.69.225	4523.30		2086.77	0.00	2012-05-27 09:24:04
•	0.63	75.67.17.113	777.22		0.47	0.00	2012-08-05 03:11:42
	0.6	24.218.216.22	0.24		0.00	0.00	2012-02-26 16:12:48

OpenWrt
Wireless Freedom

Testbed Measurement Findings

- Residential broadband is mostly under utilized
  - Over 90% chance, DL bw. < 1Mbps, UL bw. < 100Kbps
- WiFi APs generally have good connectivity to Internet
  - inter-ISP, intra-ISP, ISP to major public servers
  - Latency: 24ms
  - Throughput: 2.3Mbps (off peak hrs) vs 2.5Mbps (peak hrs)
- Wardriving in Boston (Dec. 2011) to verify our findings in a large scale
  - 26K APs
  - Instrumented latency measurements with hundreds of them

Outline

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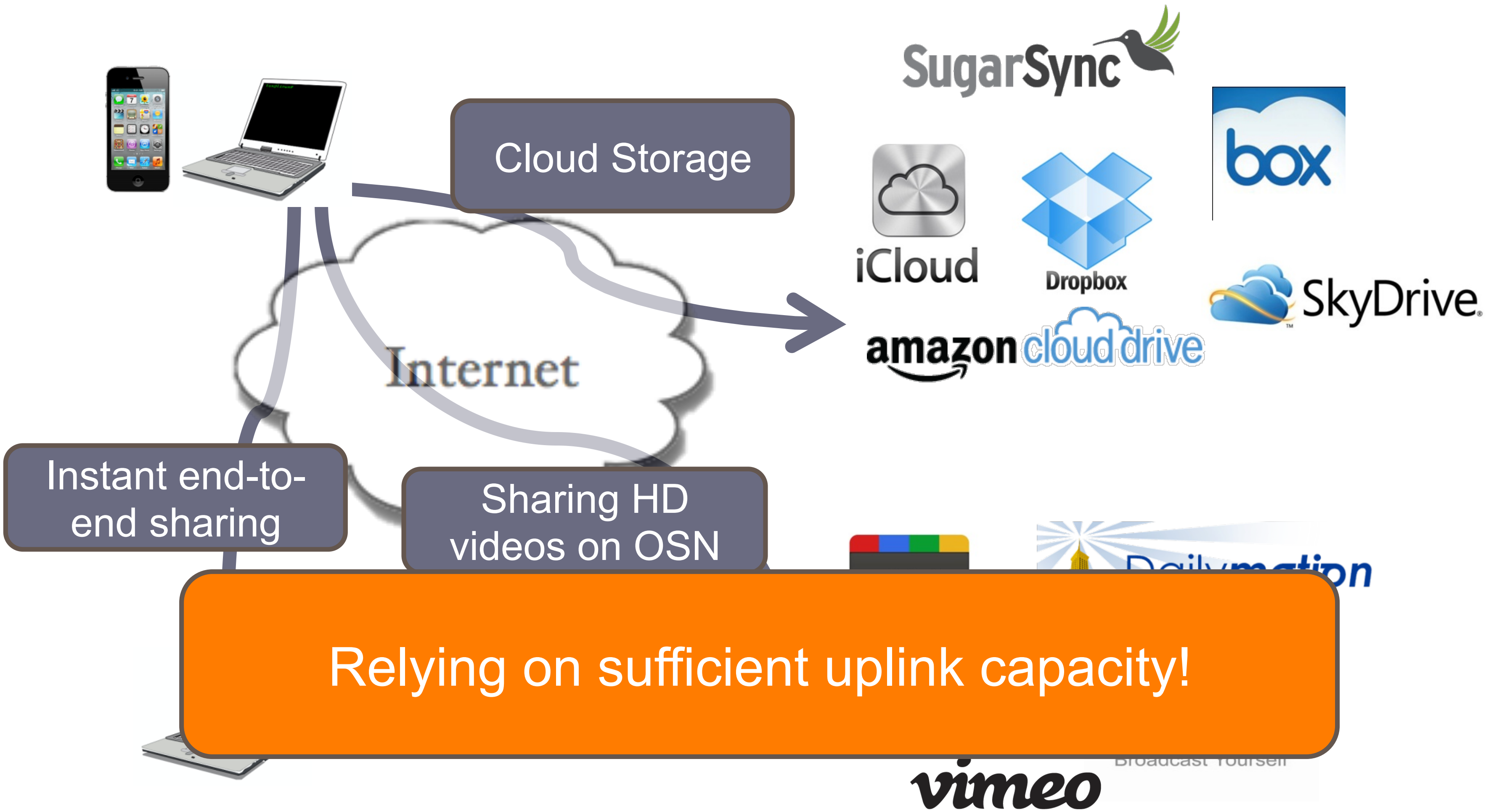
- Open Infrastructure Testbed
- BaPu

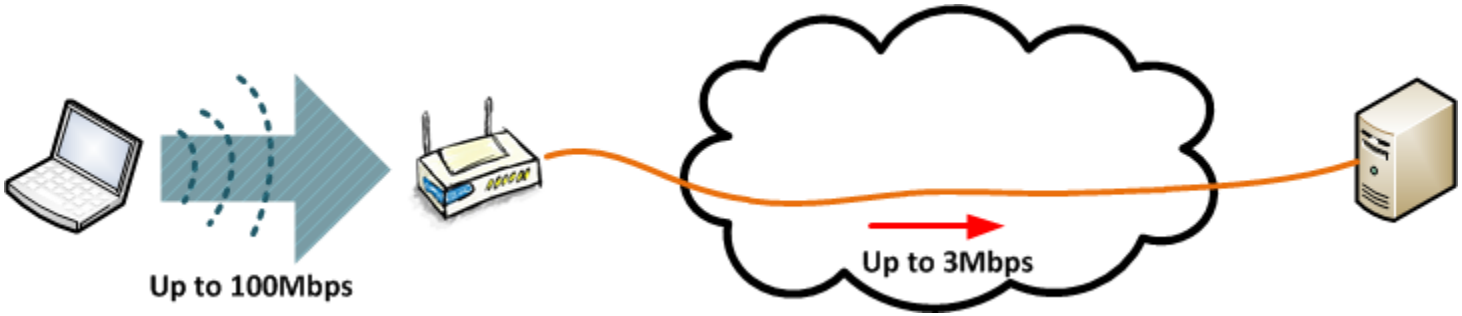
  Practical **B**unching of **A**ccess **P**oint **U**plinks
- WiZi-Cloud
- Task Schedule

Introduction



Relying on sufficient uplink capacity!

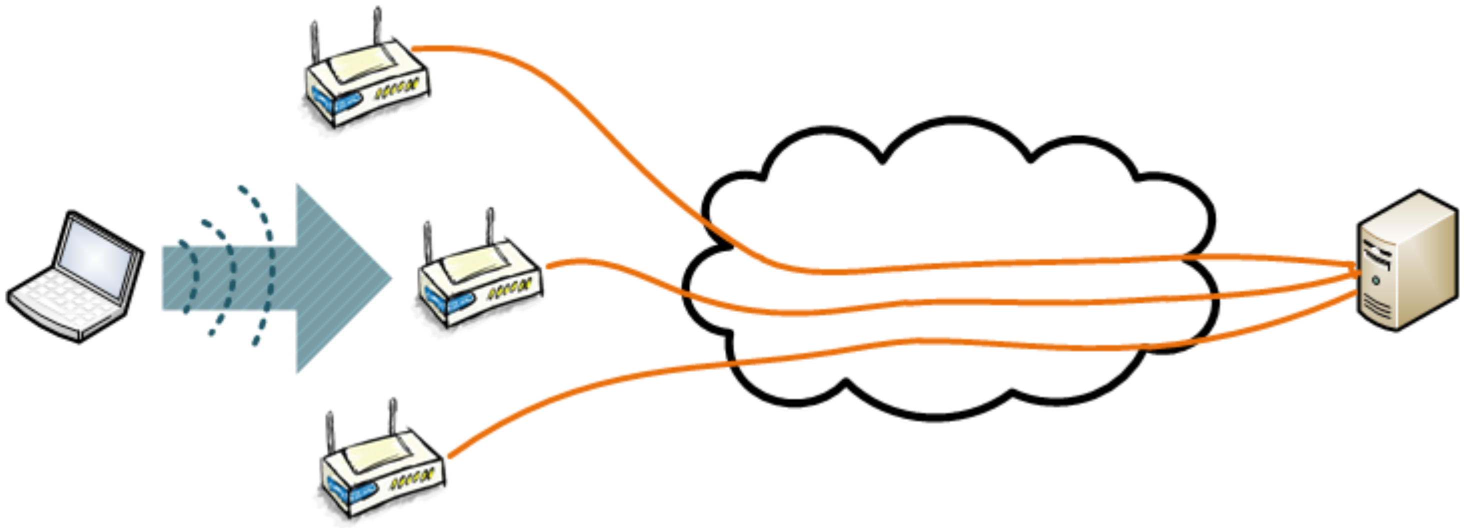
Uplink Bottleneck in Today's Residential Broadband



Backhaul broadband uplink is highly throttled

Proposed Research

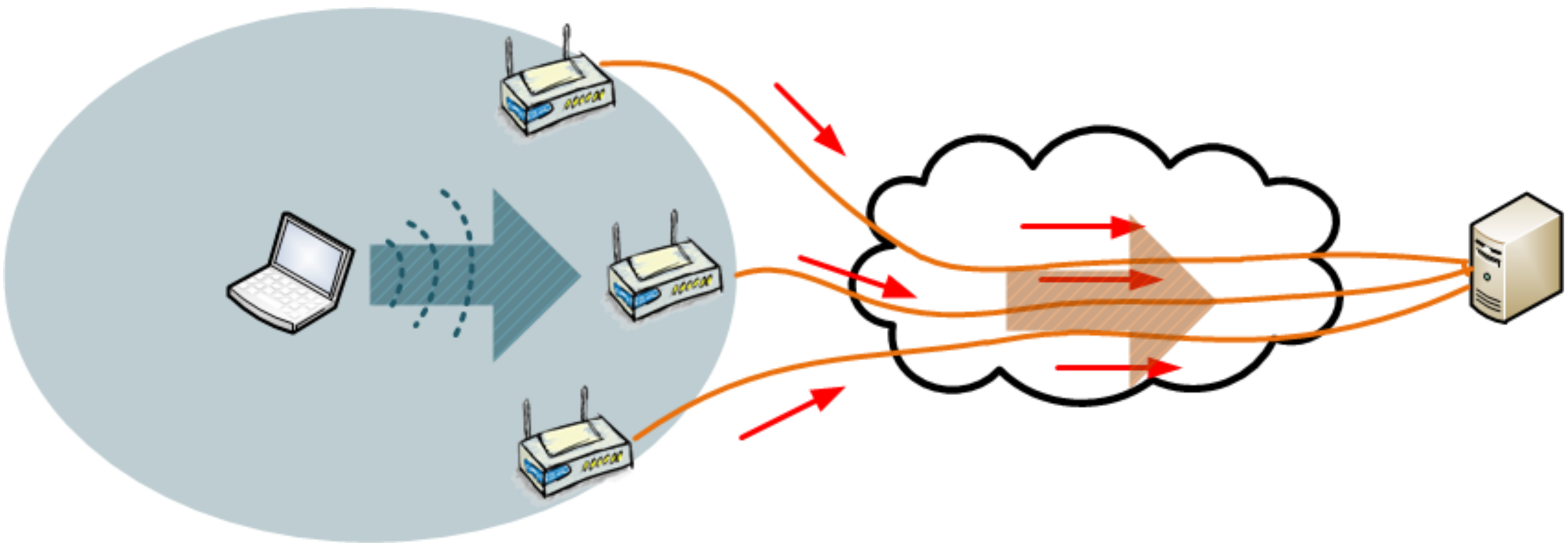
Backhaul Uplink Aggregation through WiFi



Generally, multiple proximate APs are available in residential area.

Proposed Research

Backhaul Uplink Aggregation through WiFi



All APs in communication range may each forward a share of the upload traffic

Why is Backhaul Uplink Aggregation Feasible?

- Rely on three observations
  - **Asymmetric** WiFi bandwidth and backhaul uplink
    WiFi BW. (54 ~ 600Mbps) >> Uplink BW. (1 ~ 3Mbps)
  - **High density** of WiFi APs (esp. in urban area)
    - On average 17 APs available per scanning
  - Internet backbone is **over provisioned**
  - **Under utilized** home broadband
    - Over 90% chance, uplink BW usage less than 100Kbps
    - Consistent with related study [Marcon et.al. *NOSSDAV* 2011]

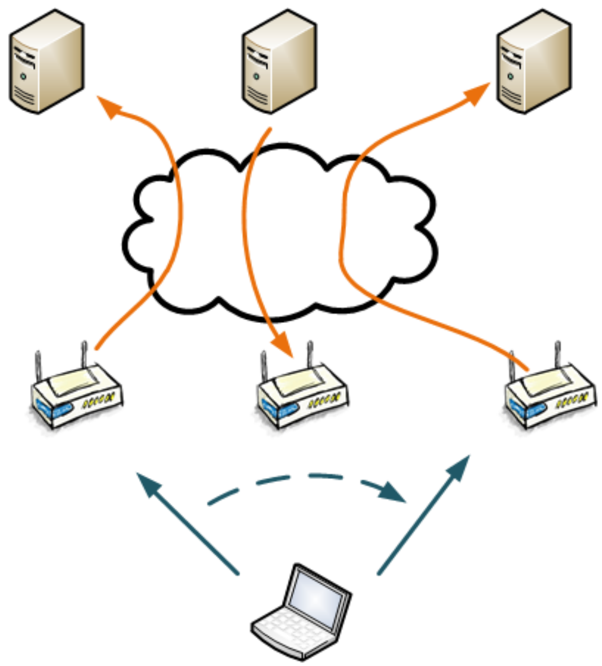
BaPu Design Goals

- Efficient harnessing of idle bandwidths
- Transparent to clients
- TCP/UDP friendly

  → Get existing network apps work out of the box
- Minimum modification required from current infrastructure → Easy incremental deployment
- Ensure fairness among APs → Better user incentive

Related Work
AP Grouping

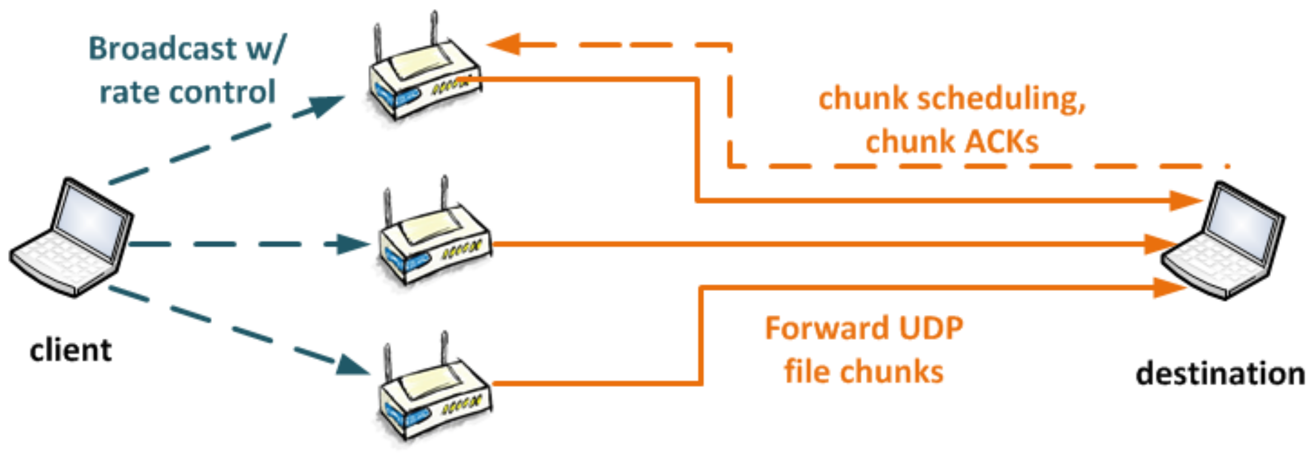
- FatVAP [Kandula et.al., *NSDI* ‘08]
  - custom client WiFi driver fast switching among legacy APs
  - multiplex sessions through different APs
  - **one session assigned to one AP (cannot overcome uplink bottlenck)**
  - FatVAP variants
    - fairness among APs
    - more efficient AP switching
    - security
    - ...



FatVAP architecture

Related Work
Uplink Aggregation

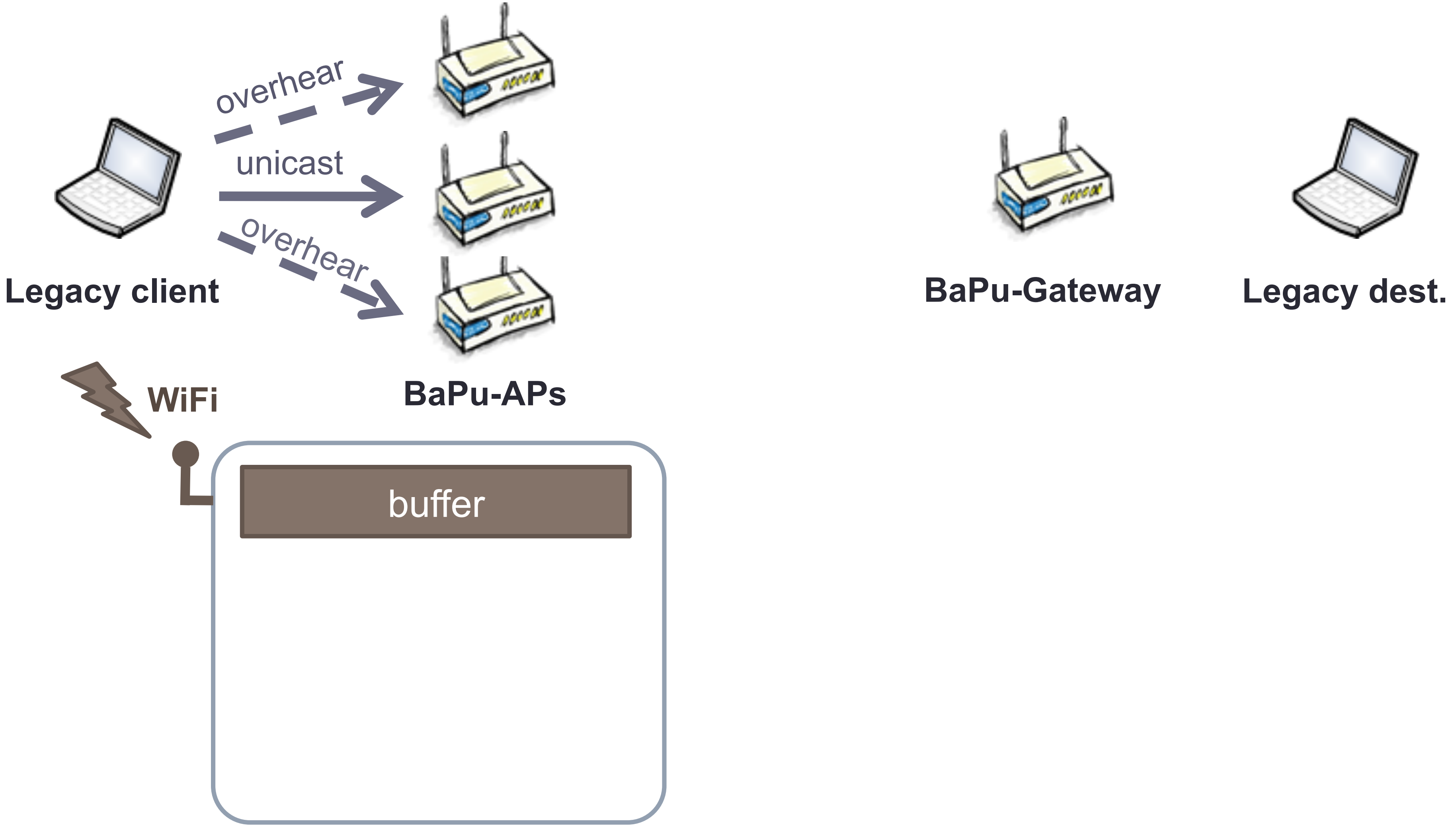
- Link-alike [Jakubczak et.al., *MC2R* ‘08]
  - designed for **UDP based large file transfer**
  - require modifications on **client, AP and destination**
  - central scheduling + rate control
  - **TCP unfriendly!**



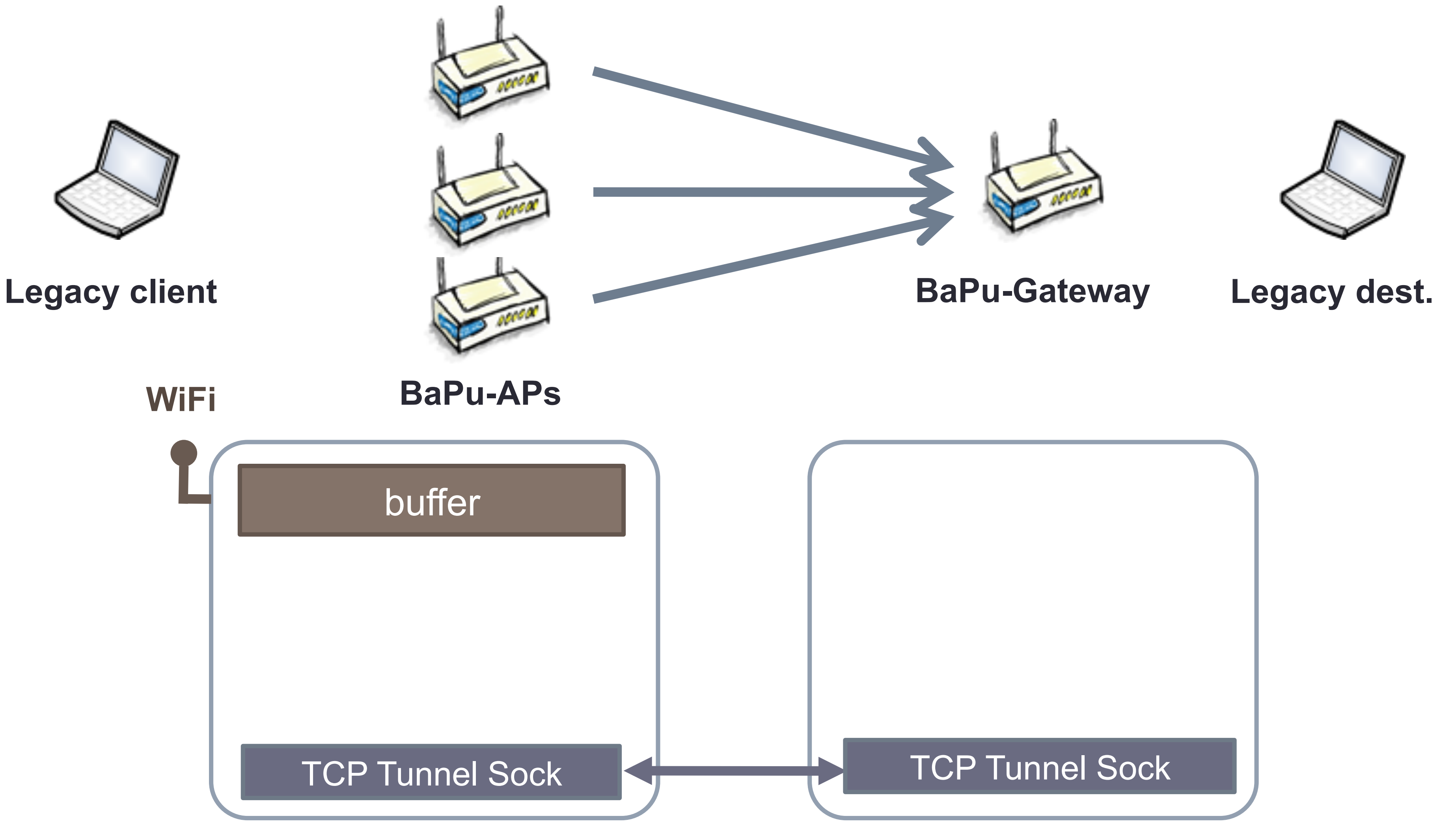
Link-alike architecture

Example Scenario

BaPu System Design



BaPu System Design



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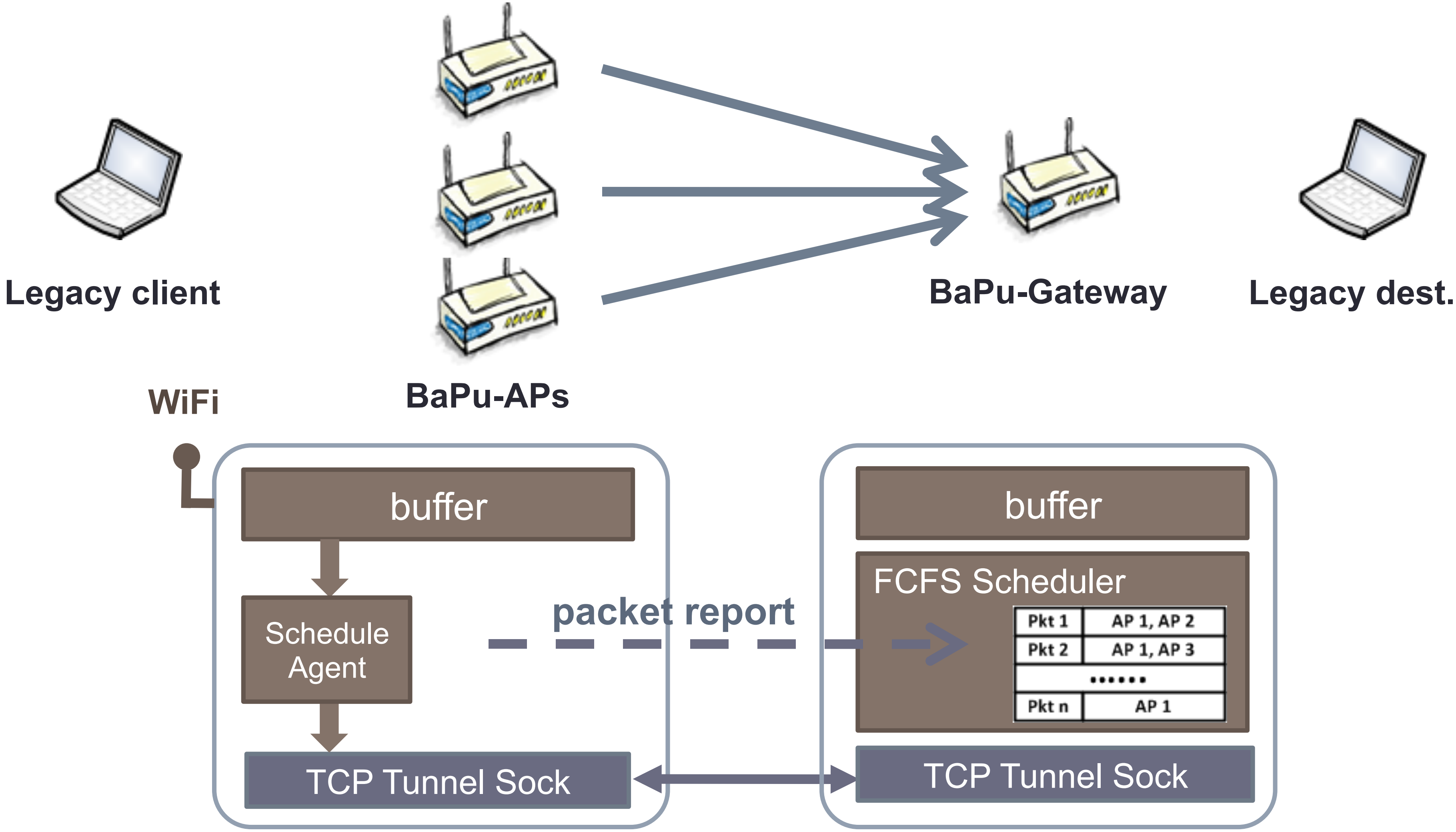

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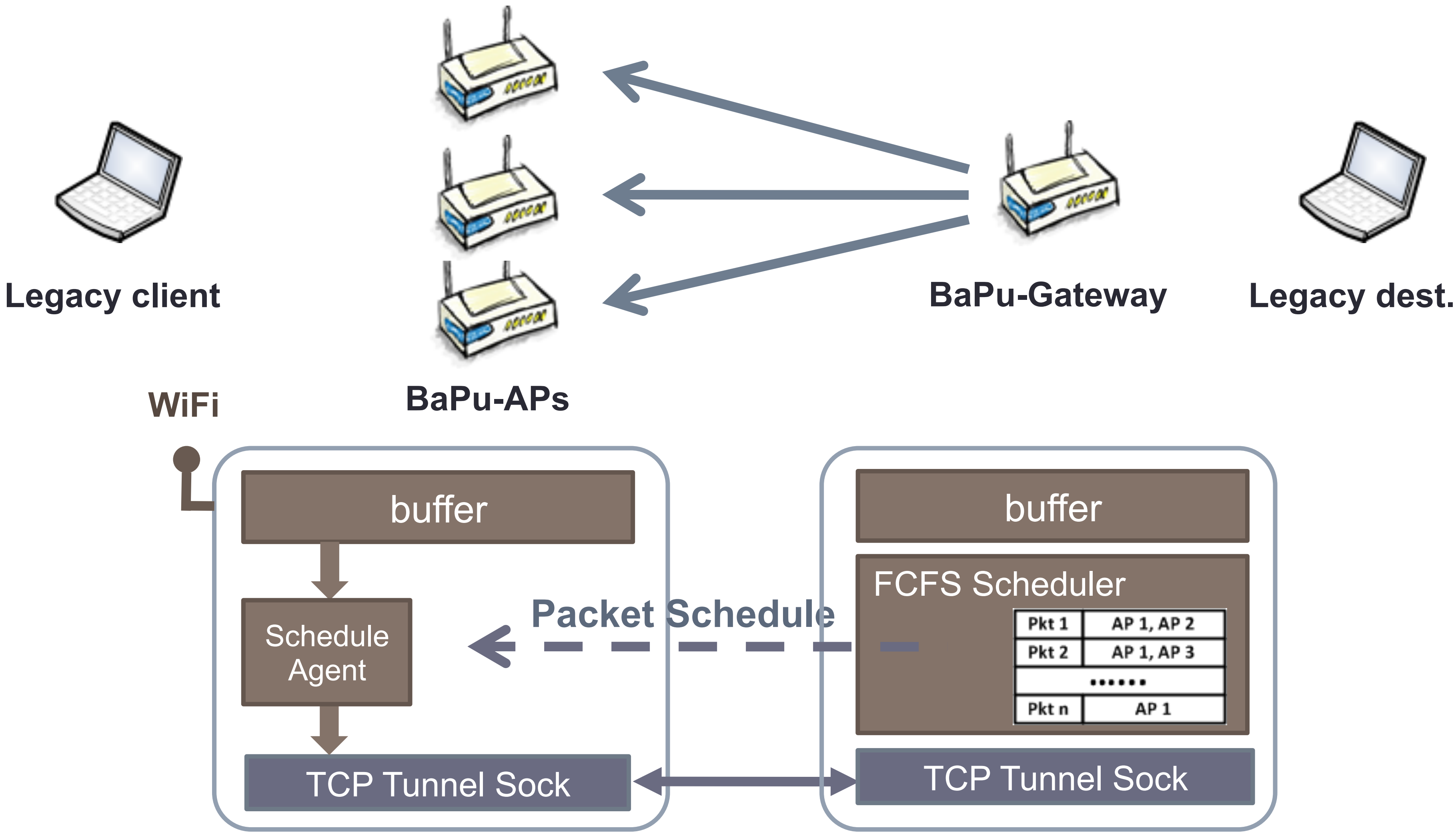

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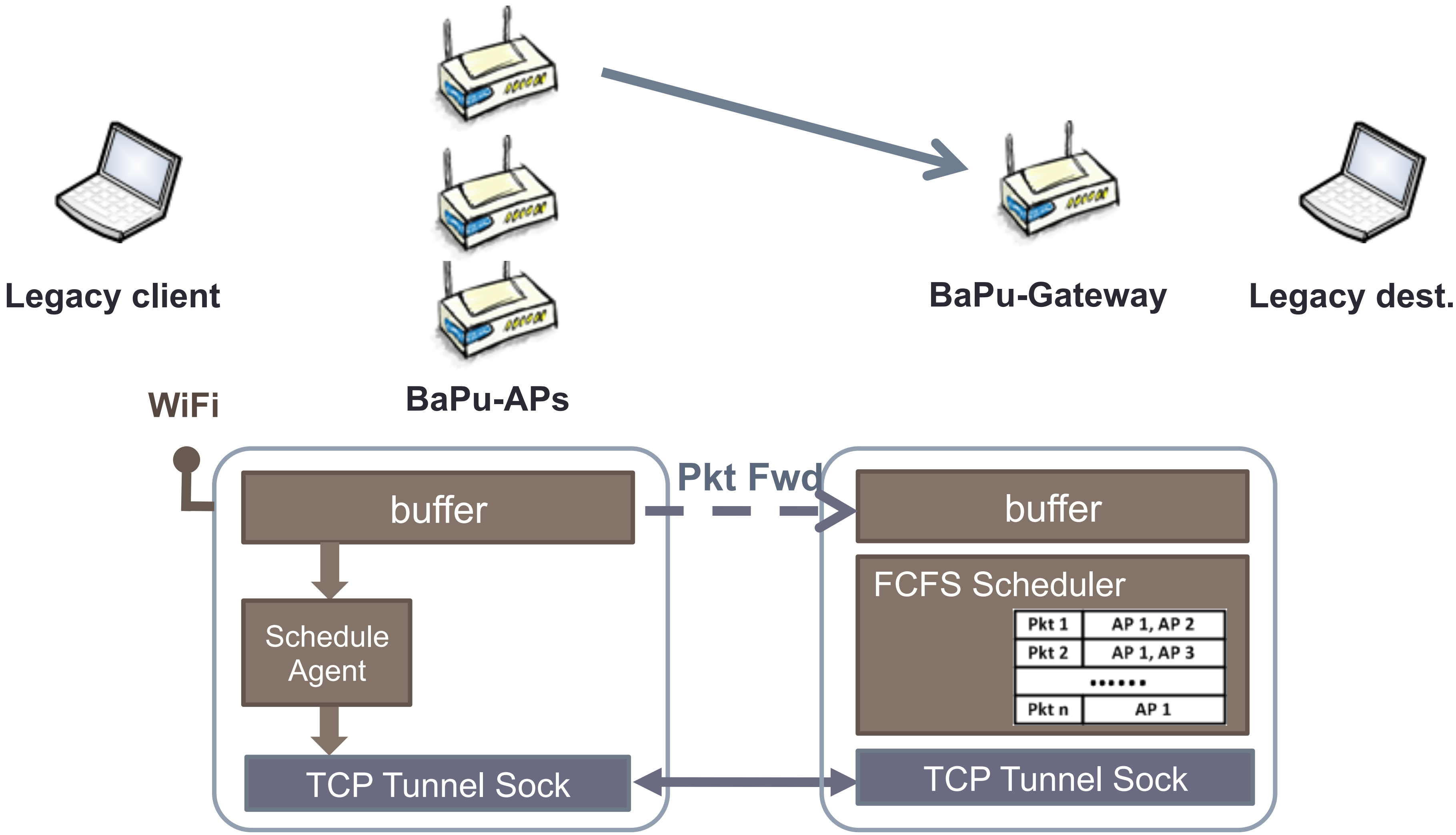

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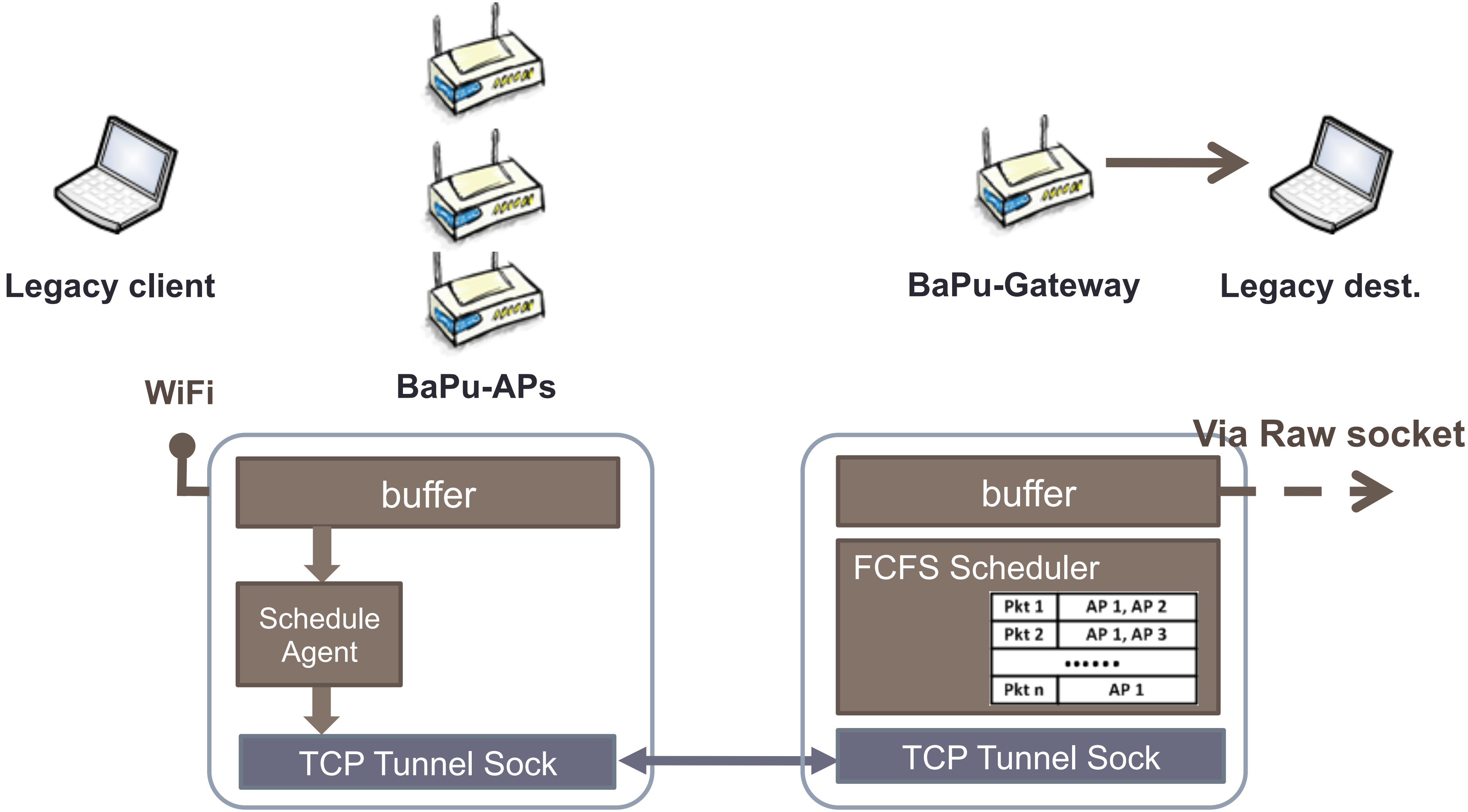
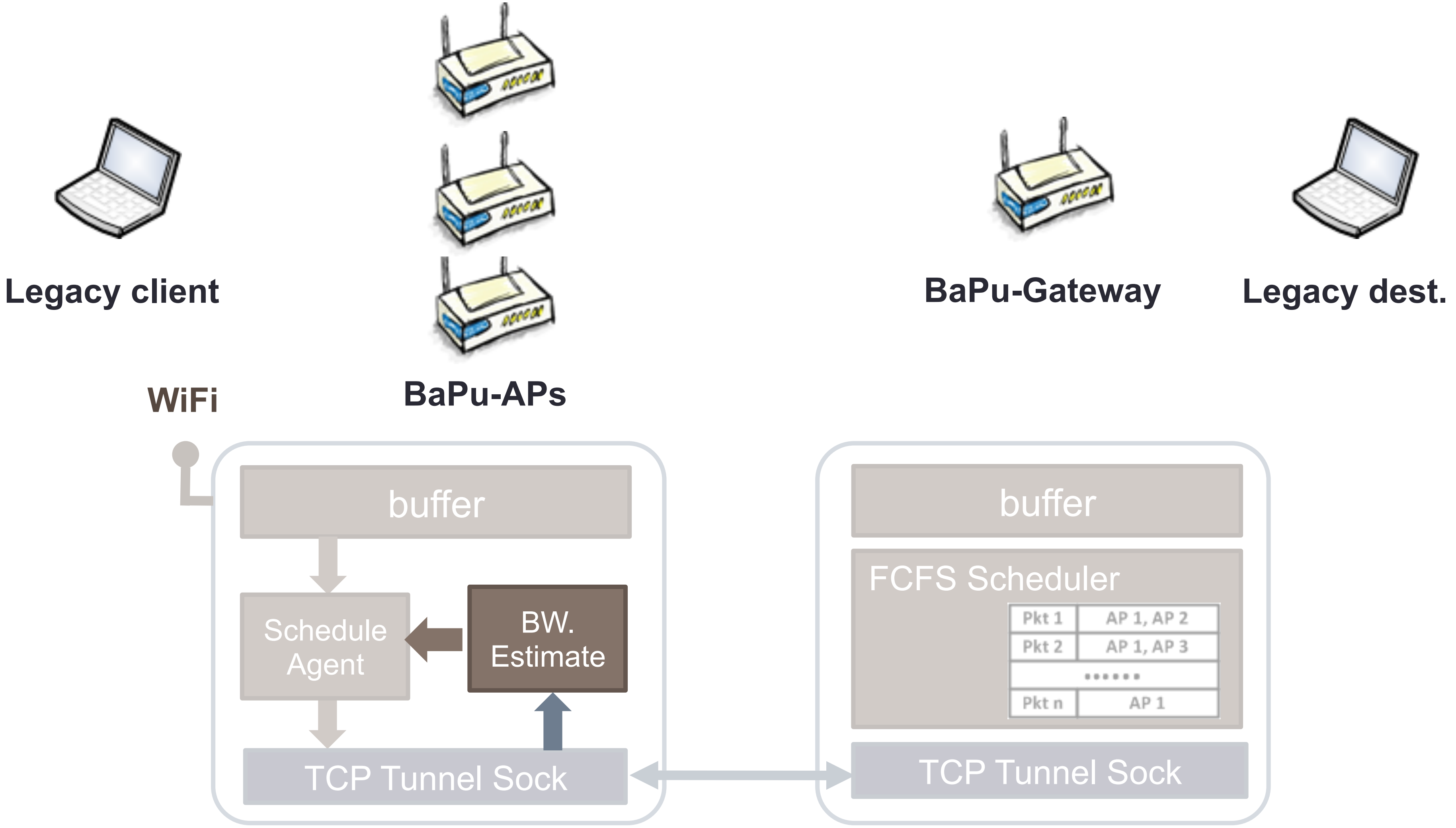
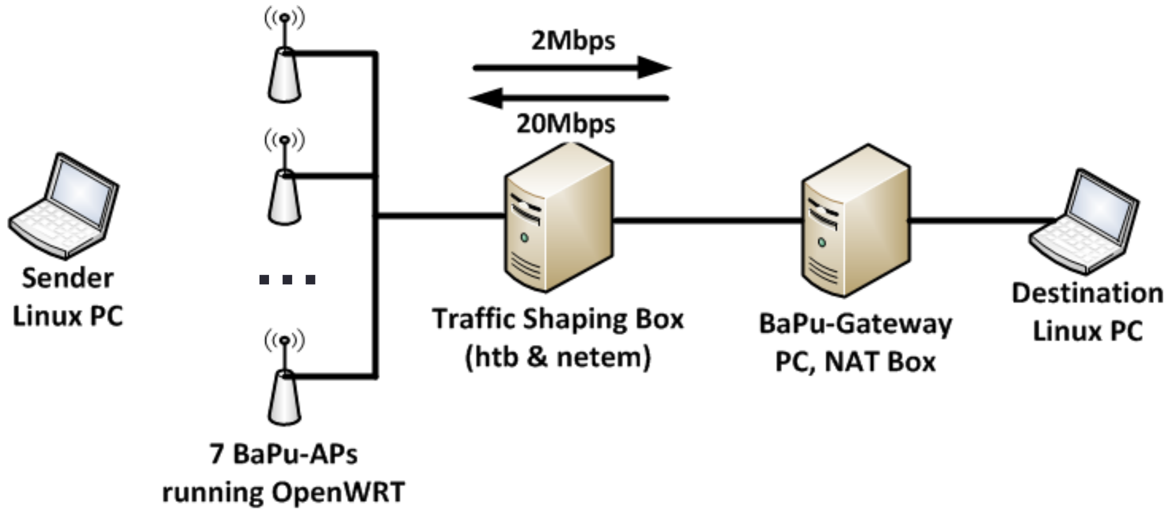


Load Balancing



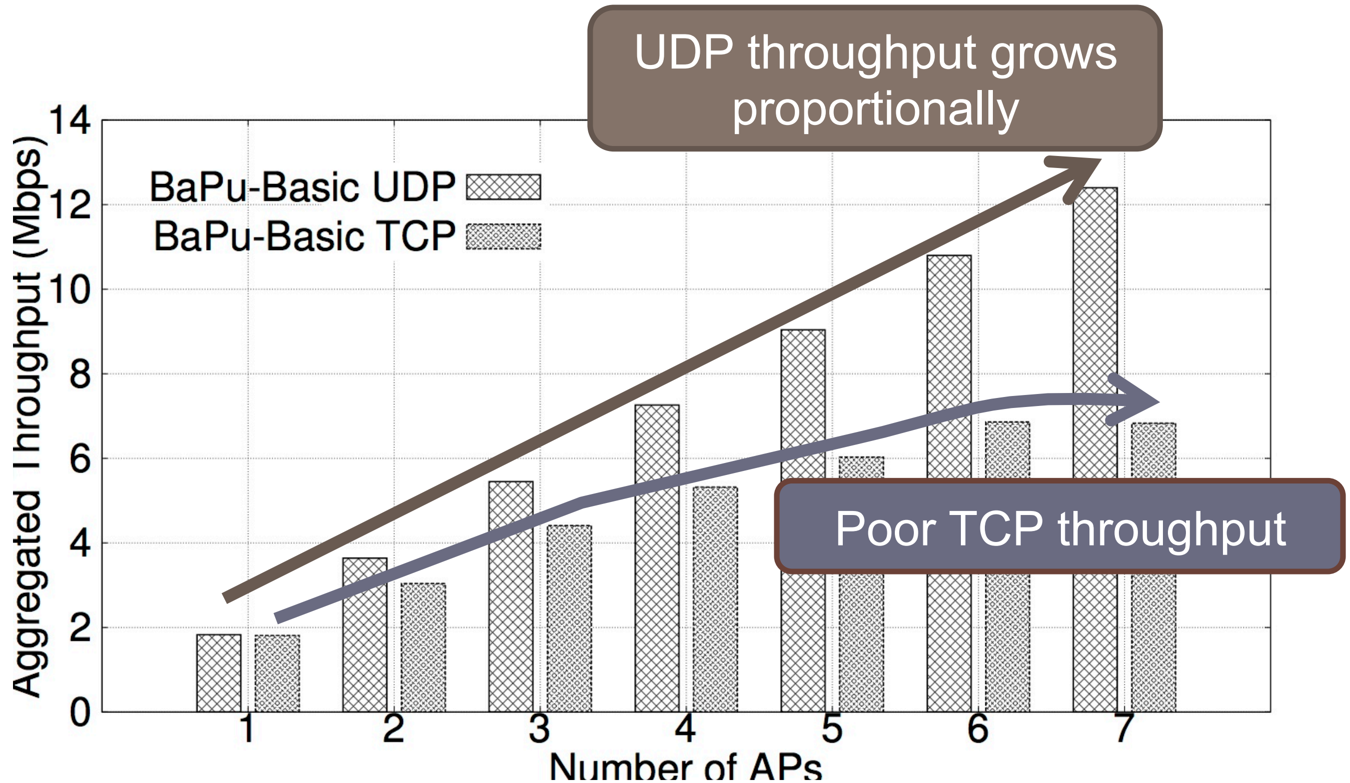
Experiment Setup



- Deploy up to 7 BaPu-APs, similar to our latest Wardriving measurement in Boston
- Emulate realistic network settings with Linux TC

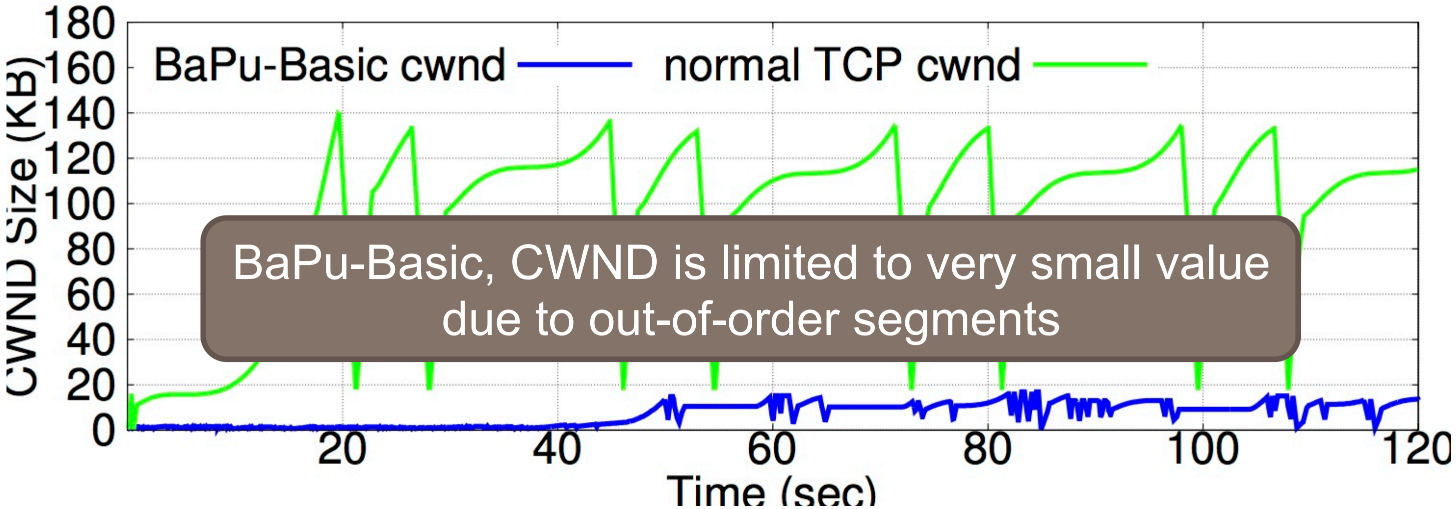
Preliminary Results

- Aggregated Throughput



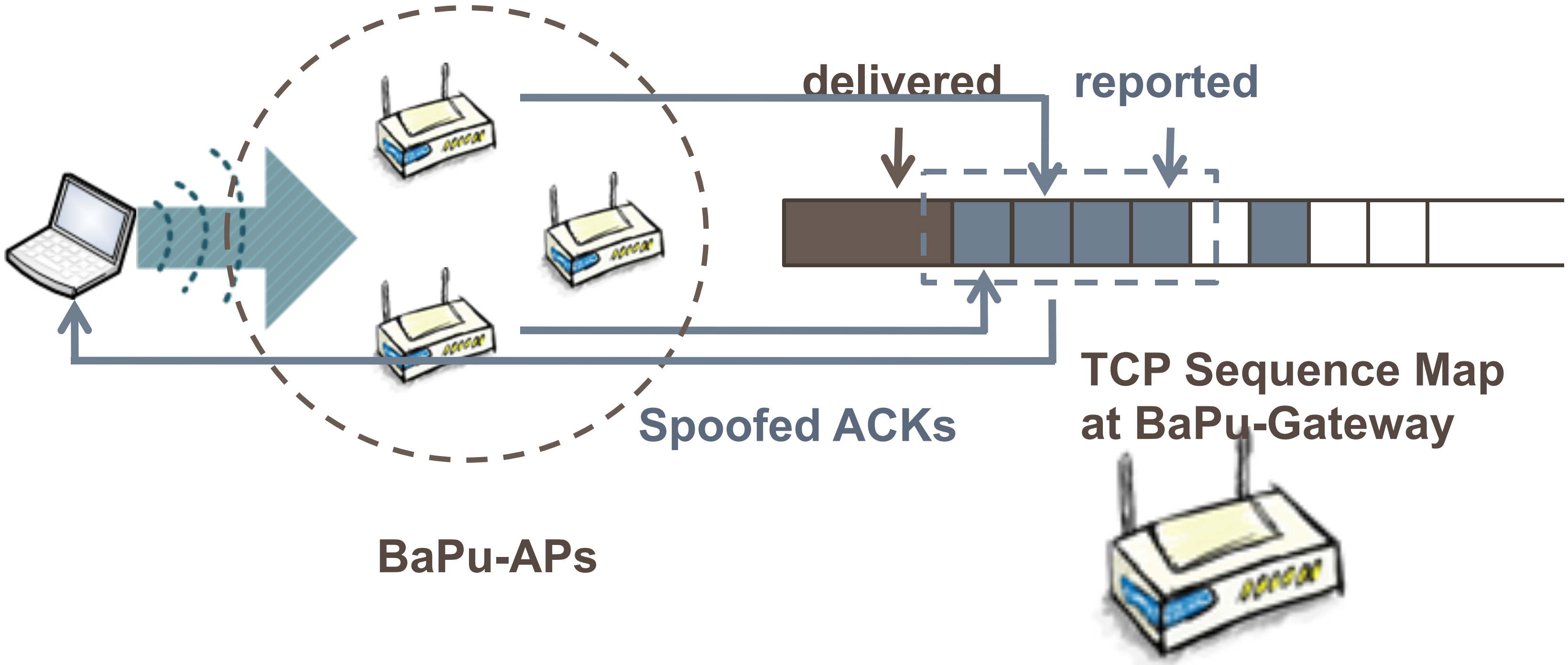
Look Into Poor TCP Throughput

- BaPu-APs forwards **Out-of-order** TCP segments due to diverse uplinks
- TCP **congestion control** mistakenly reduces Congestion Window Size



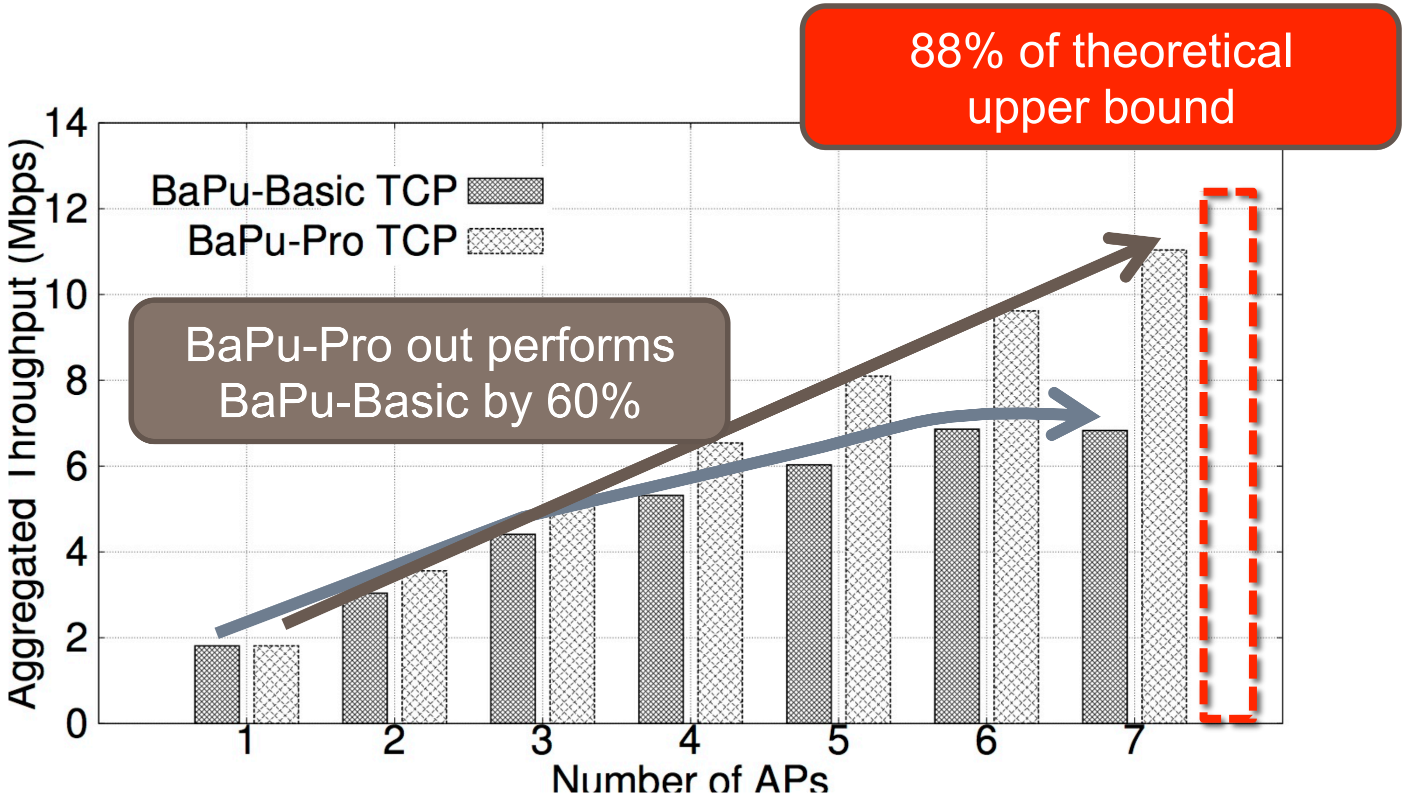
BaPu-Pro

- Proactive-ACK
  - Spoof TCP ACKs on receiving **reports** of continuous TCP sequence



BaPu-Pro Performance

- Aggregated Throughput



Discussion and Future Work

- Thorough evaluation in various network settings
  - network latency
  - AP traffic load
  - wireless diversity
  - …
- Feasibility study in residential area
  - WiFi reception from neighboring APs
  - Performance limit in residential broadband

Outline

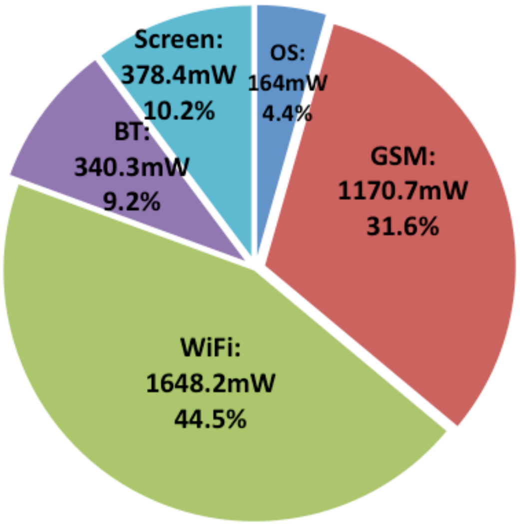
- Introduction
- Open Infrastructure Testbed
- BaPu
- WiZi-Cloud
  Application Transparent Dual ZigBee-WiFi Radios for Low Power Internet Access
- Task Schedule

Introduction

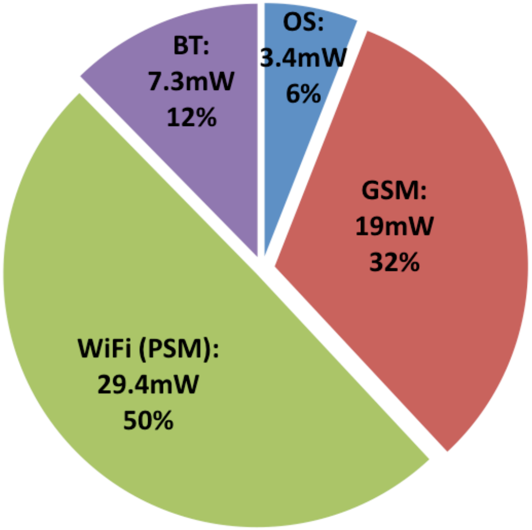
- Mobile technology outpacing battery technology
  - No battery tech. improvement since 2005
- Mobile apps are much reliant on battery

Energy Usage Breakdown on Android G1: Active vs. Idle

Setup



Radios active, screen on



Radios idle, screen off

Network interfaces are major energy consumer

Related Work

Reduce Energy Usage of Mobile Comm.

Optimize existing network interfaces, WiFi, GSM, BT

- Power saving protocols design
- Energy efficient HW design

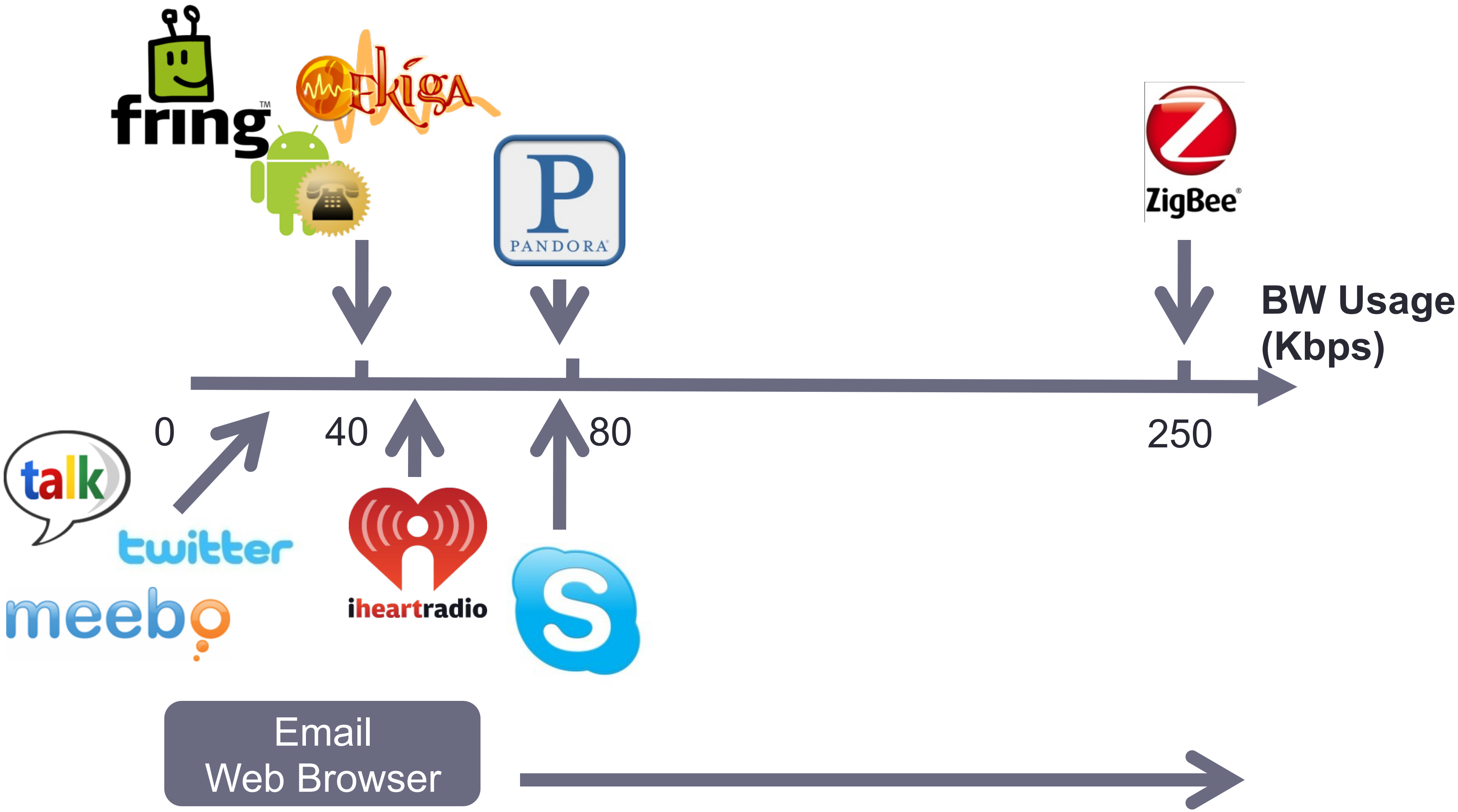
Use alternative low power radio to offload work from energy consuming interfaces

- "Wake-on-Wireless" uses a low power paging radio to wake up PDA [Shih et.al. MobiCom '02]
- Cell2Notify uses cellular radio to wake up WiFi on incoming VoIP call [Agarwal et.al. MobiSys '07]
- CoolSpot uses BT to offload traffic from WiFi [Pering et.al MobiSys '06]

Our Solution

- **Dual ZigBee-WiFi radios**
- Seamless dual-radio solution to OS, applications, etc.
- Feasibility: low power, but **low data rate (250Kbps)**
- Characteristics of energy consumption
- Complete design and prototype
  - Sufficient throughput to sustain main stream apps
  - 300% more energy efficient
  - Good coverage

What can 250Kbps do?



What can 250Kbps do?

ZigBee is capable of carrying traffic for many popular mobile network applications

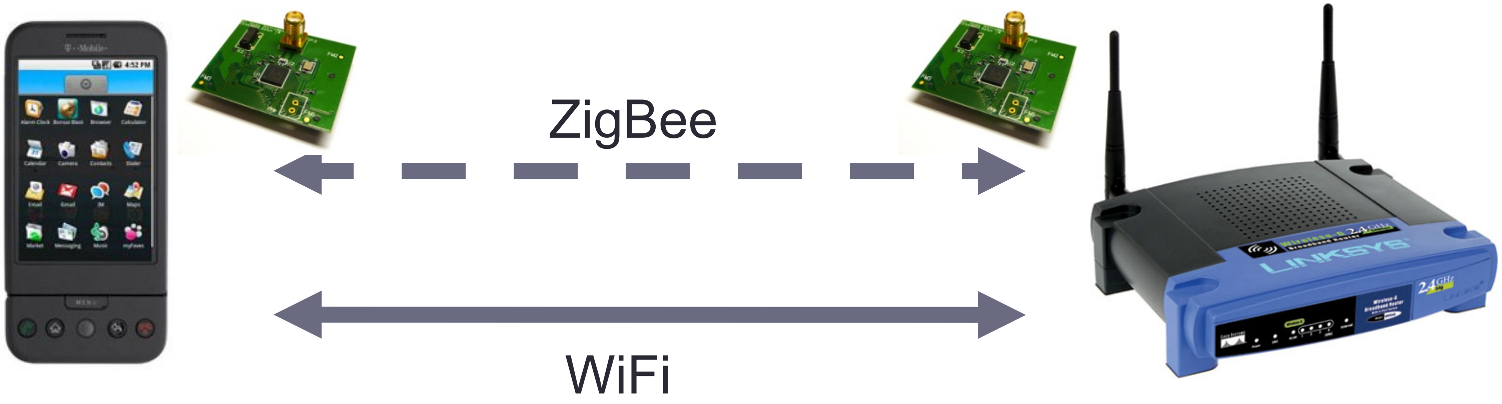
BW Usage (Kbps)

0

Email
Web Browser

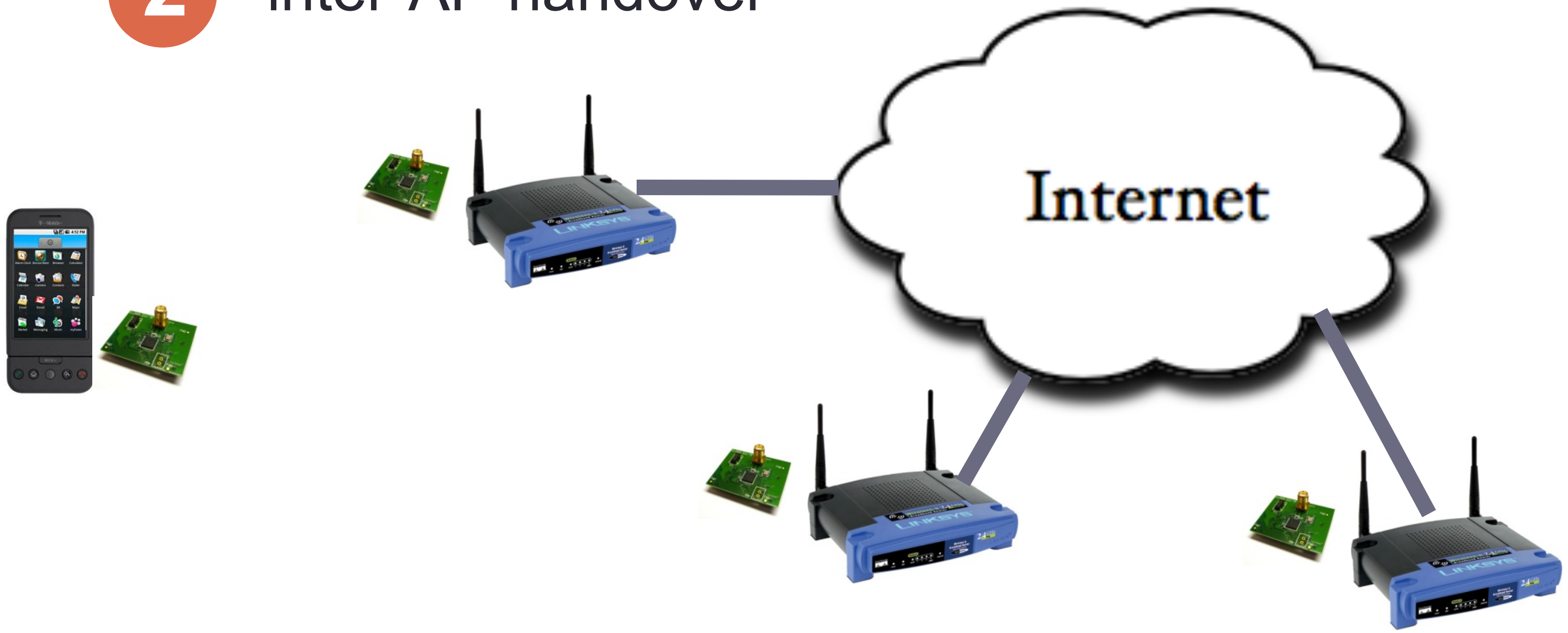
WiZi-Cloud System Design

1 Intra-device interface handover



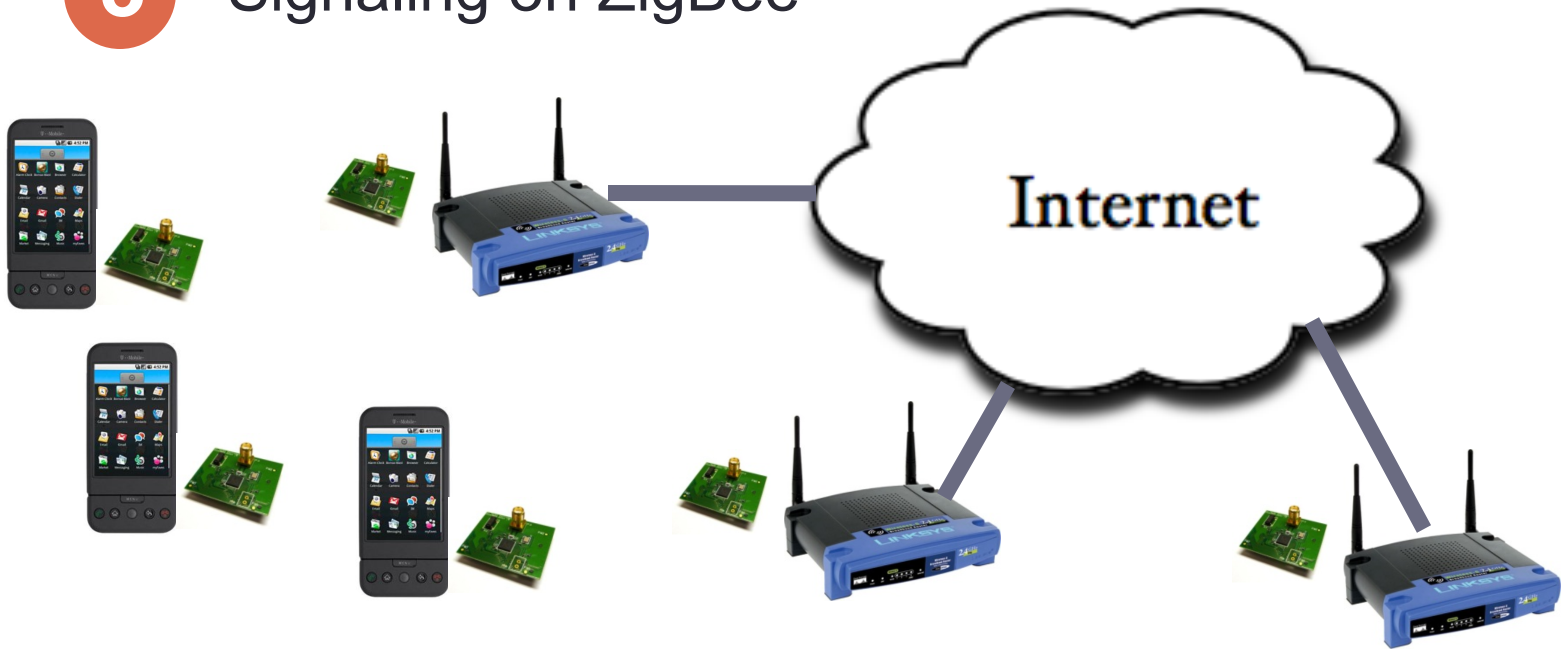
WiZi-Cloud System Design

2 inter-AP handover

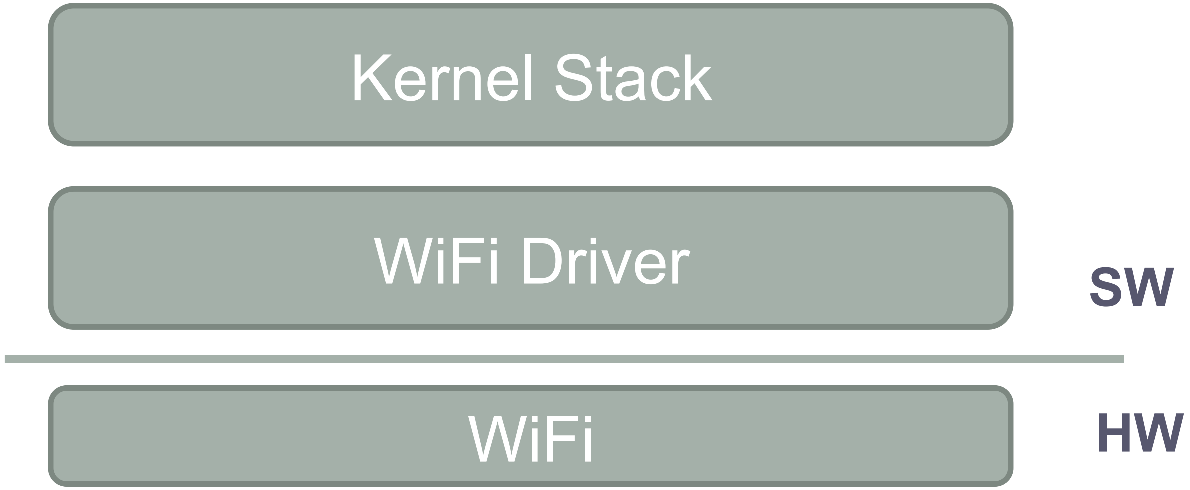


WiZi-Cloud System Design

3 Signaling on ZigBee



Software Architecture



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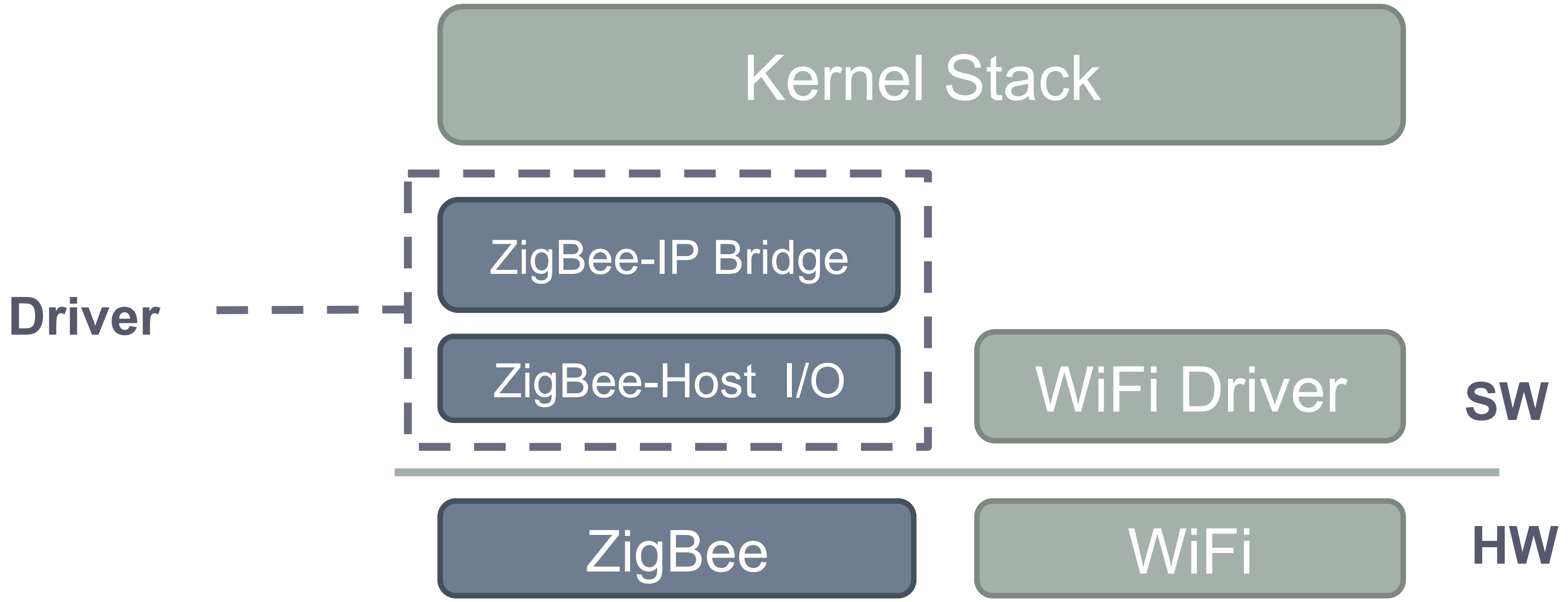

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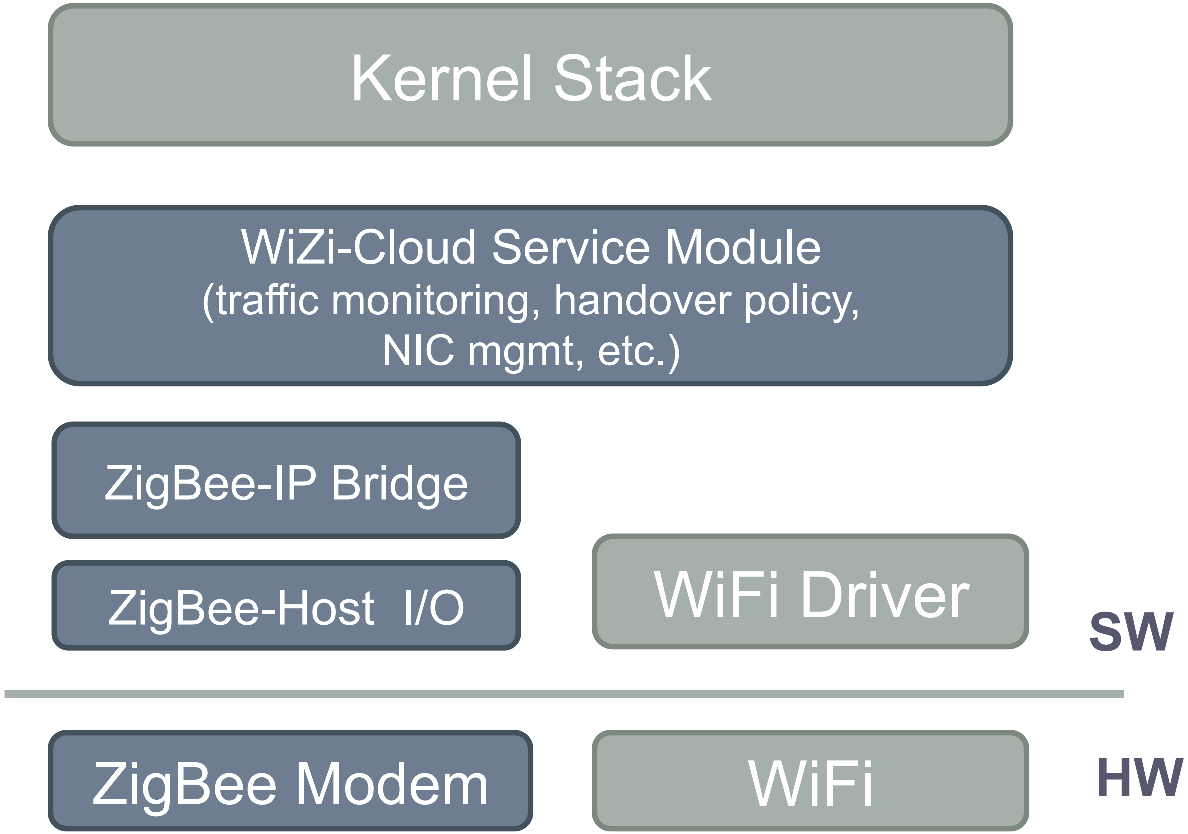

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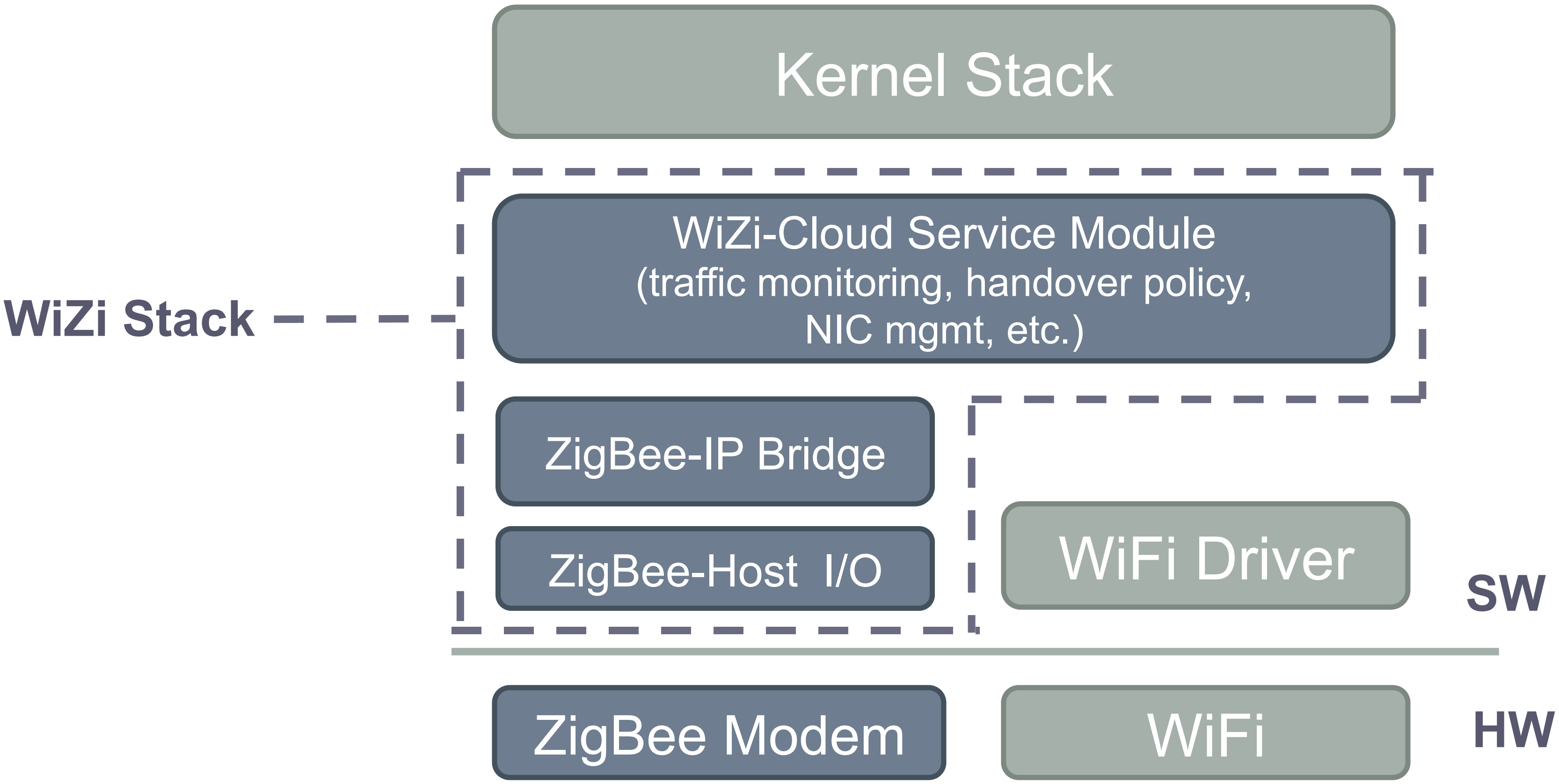
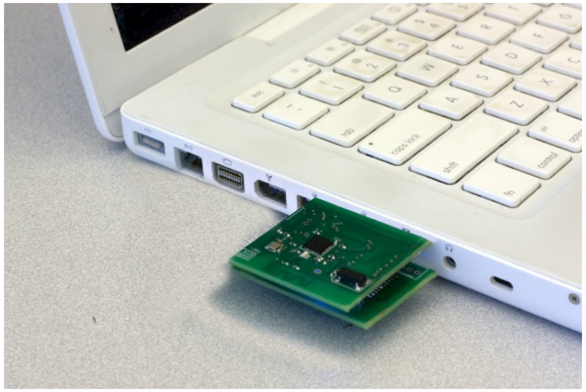
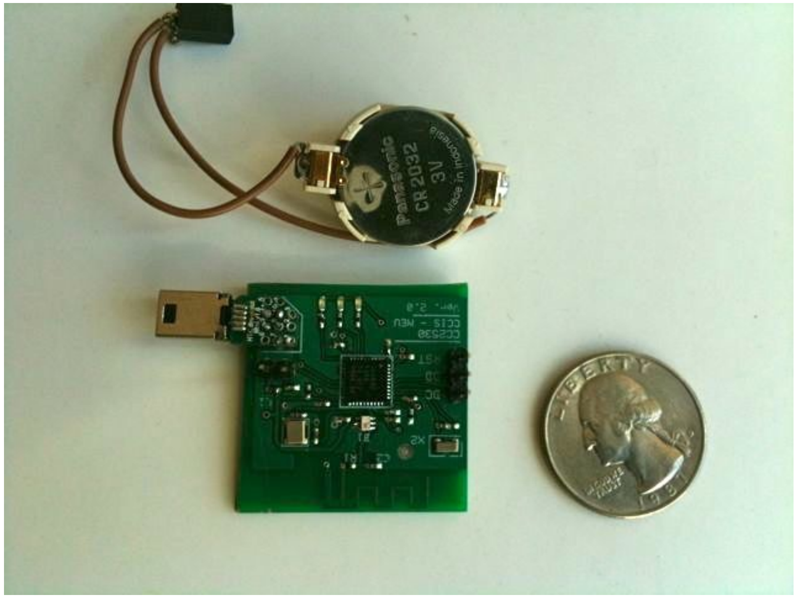


Client Prototype

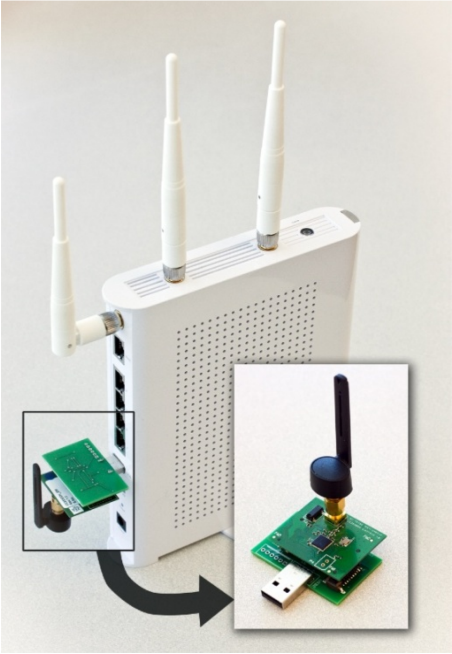
- Android G1, with modified Linux kernel, UART support
- User space WiZi stack
- ZigBee USB dongle



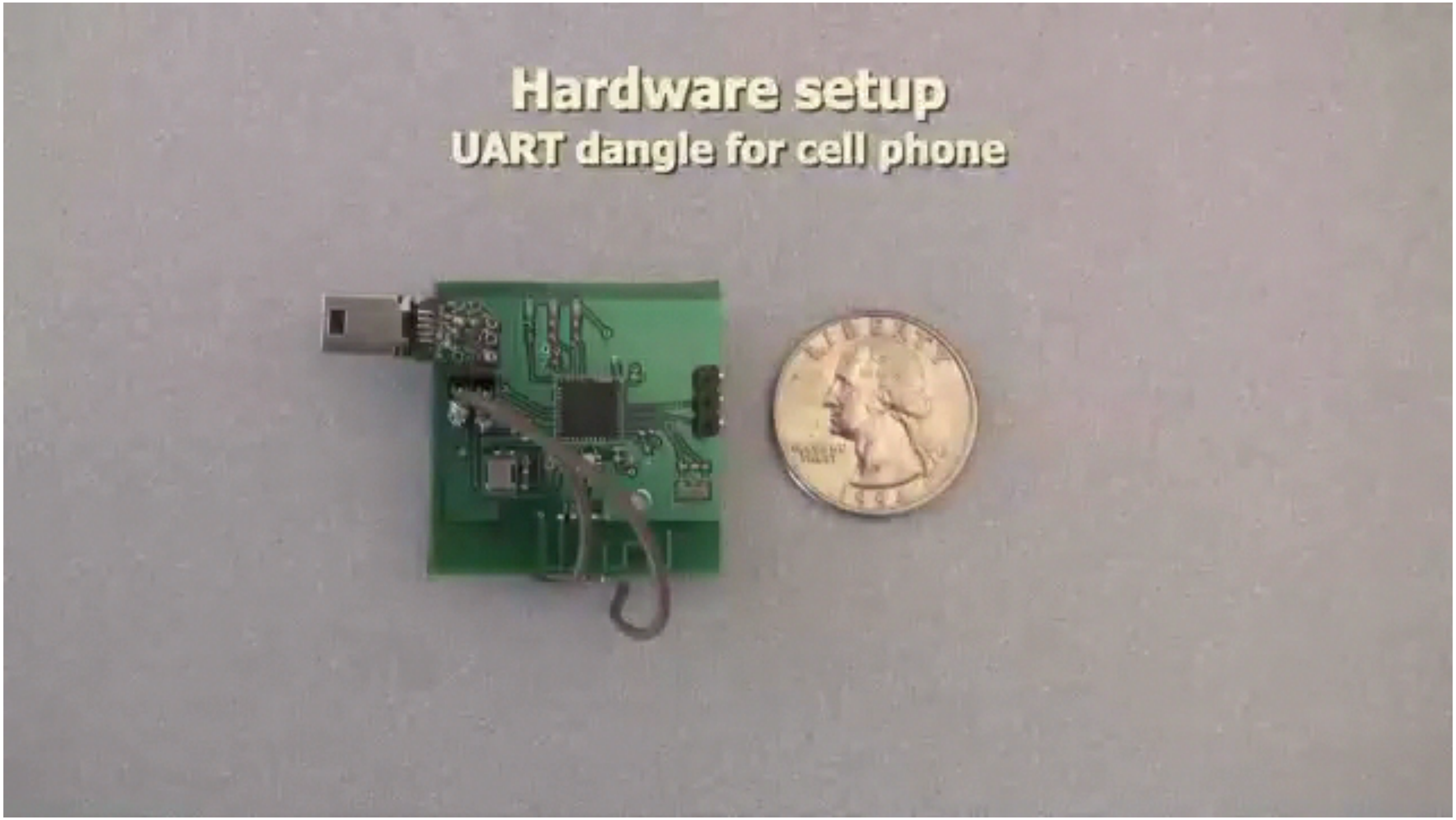


AP Prototype

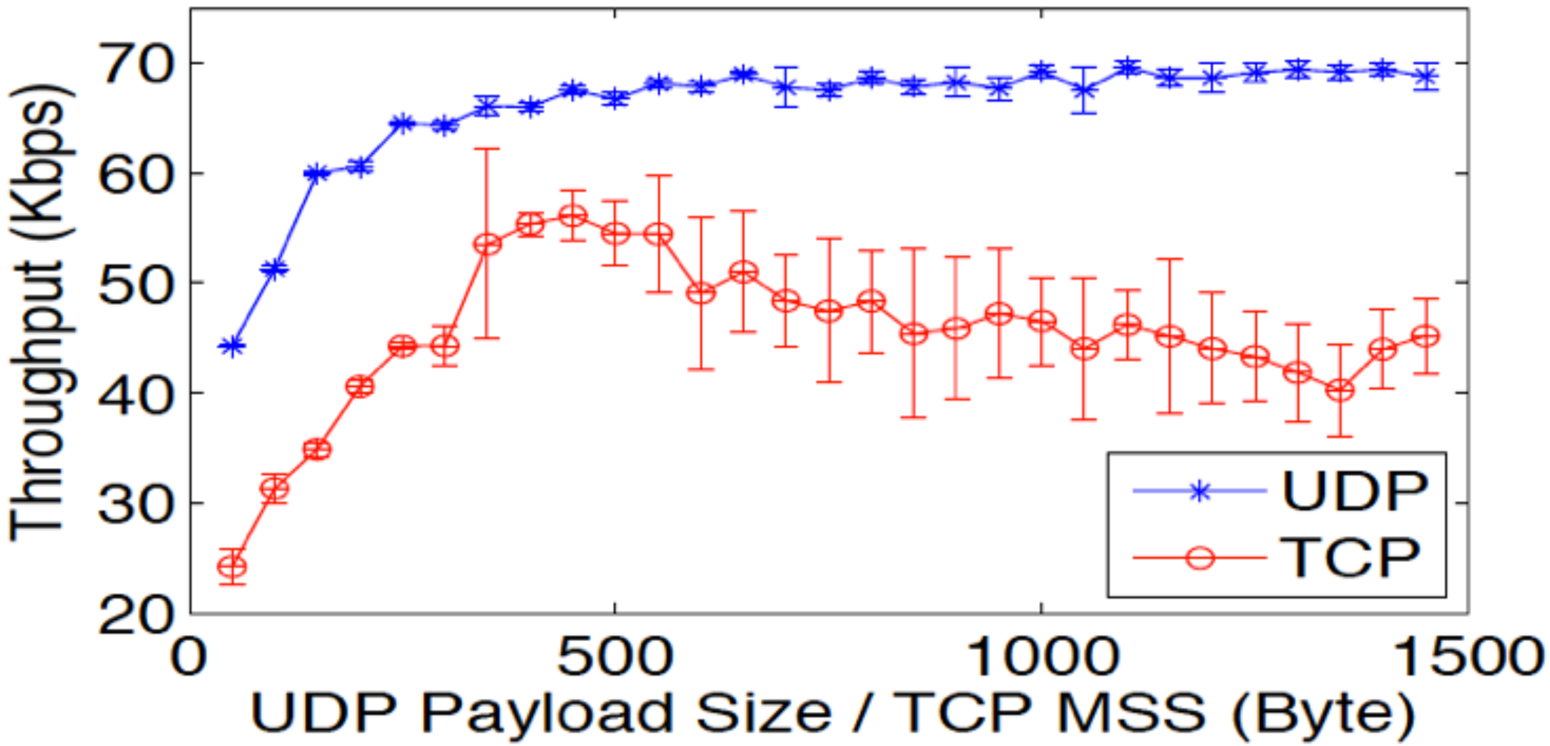
- OpenWrt based (Linux) AP firmware
- On-board serial port, USB port



Demo: Audio Streaming over ZigBee



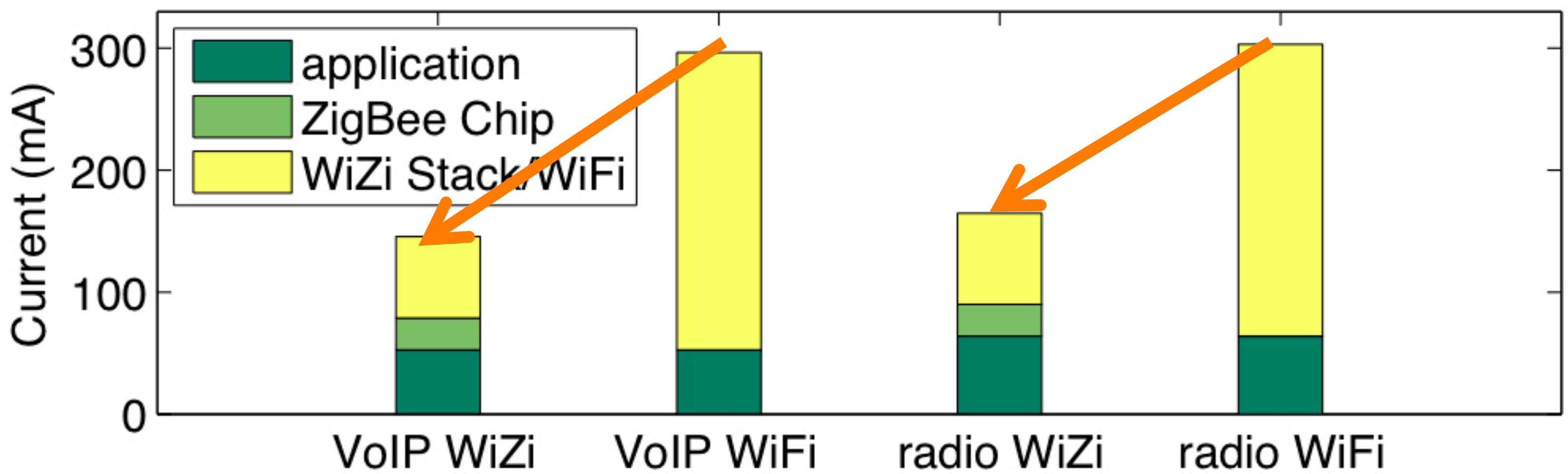
Evaluation 1. iperf Throughput



iperf goodput is close to the hardware limit of our prototype. G1 UART port supports 115Kbps.

Evaluation 2. Energy Efficiency

- VoIP & Stream Radio
  - High delay sensitivity
  - Moderate traffic load



In active mode, total energy cost reduced by 50%

Discussion and Future Work

- How WiZi-Cloud performs with other mobile apps?
  - Mobile apps have various characteristics
  - Trade-off: energy cost, throughput, user experience
- ZigBee coverage
  - Low power, but high **Energy Per Bit**
  - Comparable to WiFi
  - mechanisms to mitigate packet loss
    - Coding mechanism
    - Multiple antenna

Thanks!
Q & A?