

WiMAX in the Classroom: Teaching Cellular Networking with Hands-on Labs

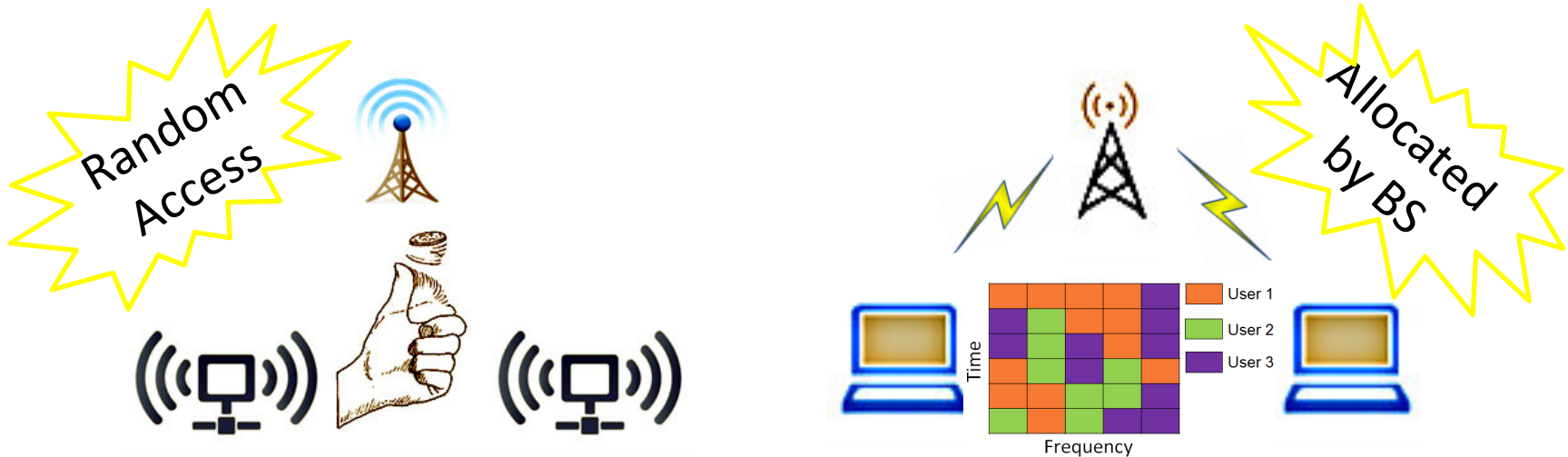
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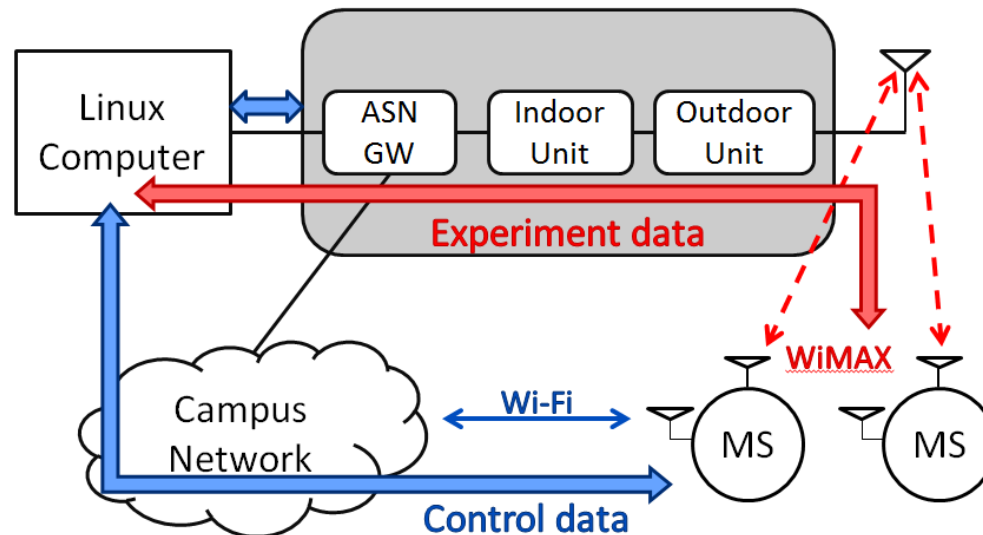
About the WiMAX Lab

- The goal: teach main cellular networking concepts
 1. Compare cellular (WiMAX) to WLAN (Wi-Fi)
 2. Understand the effect of the channel state on performance (throughput)
 3. Understand the QoS mechanisms



In the past...

- Setup: WiMAX BS and two laptops as mobile stations
- Two locations with different channel quality
- Graduate-level wireless & mobile networking class
- Had both on-campus and remote students

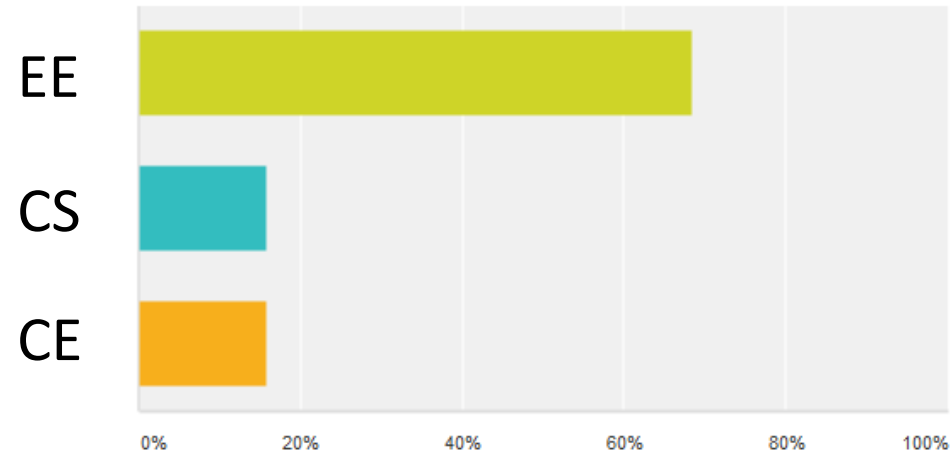
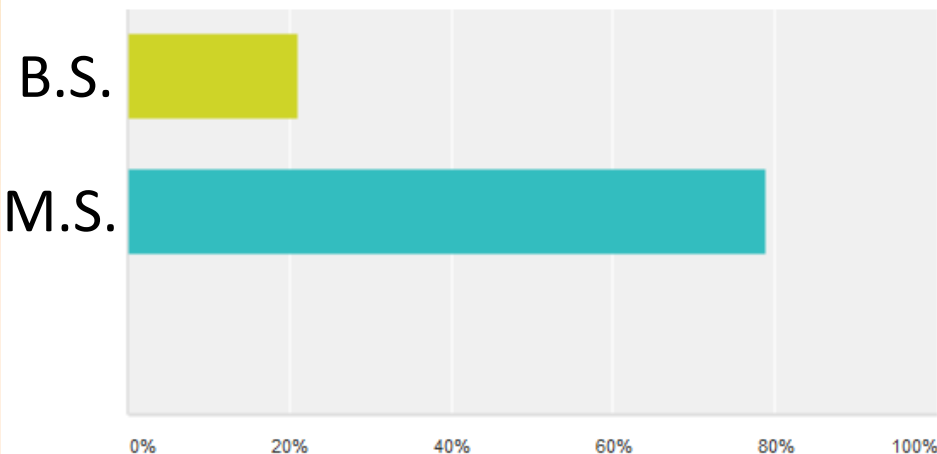


In Fall 2013

- Wanted to address issues from previous labs:
 - Unstable Wi-Fi connection
 - Unstable modulation
 - Changing locations
 - Remote students couldn't conduct the entire lab
 - Forgotten Wi-Fi round trip times
- Decided to build a more reliable setup
- Decided to make the lab completely remote

Class Overview

- This time, a different class—Networking Lab, taught by Prof. Gil Zussman
- Upper undergraduate/lower graduate
- The class does not cover wireless networking; mostly hands-on labs on Internet protocols
- 21 students in class



WiMAX Setup

- 4 ORBIT nodes, having LoS to the base station
- 2 nodes have attenuators to emulate “bad” channel

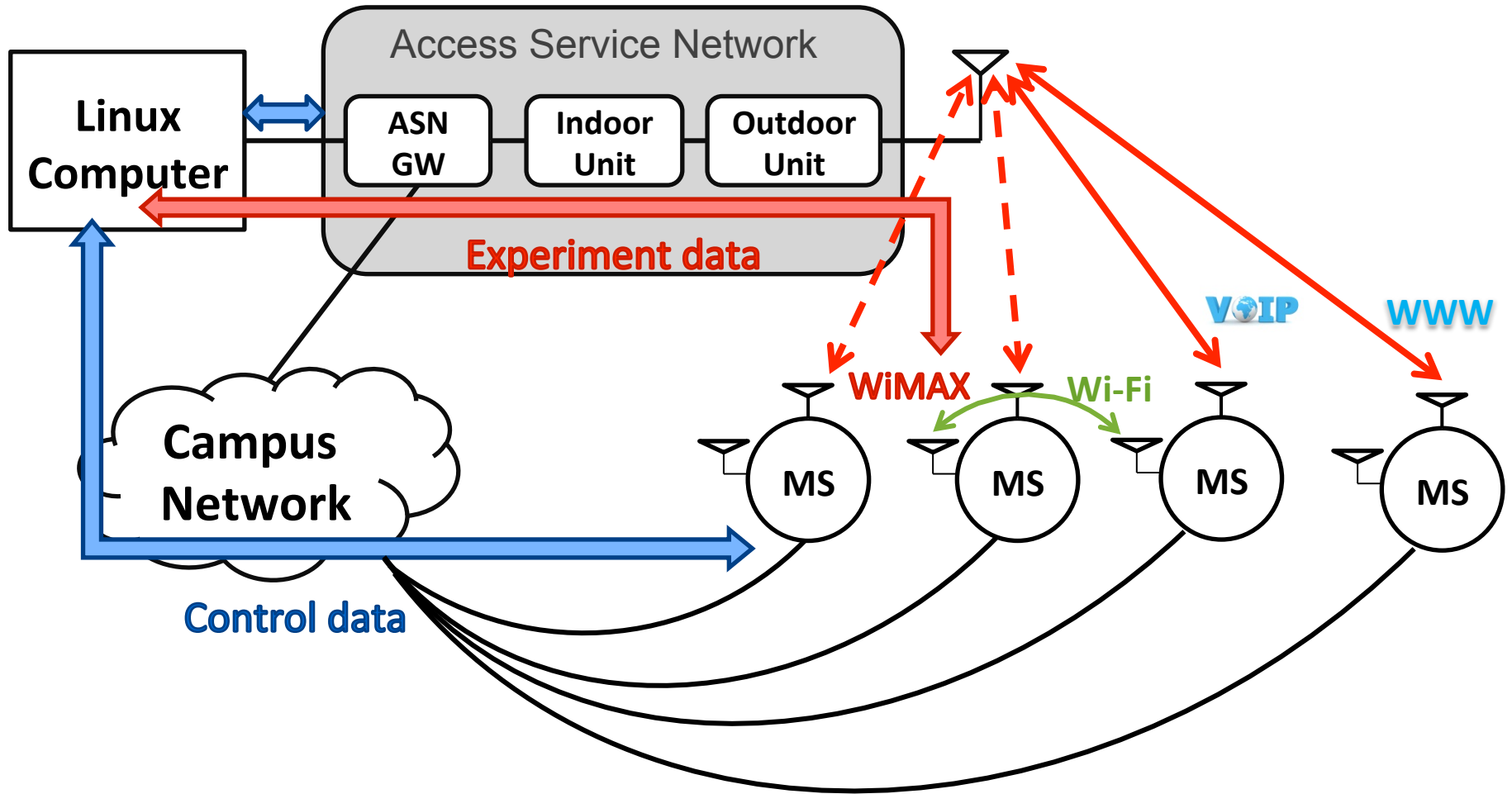


Base Station



ORBIT nodes

Hands-on Lab Network Configuration



The Hands-on Lab

- Preparing for the lab:

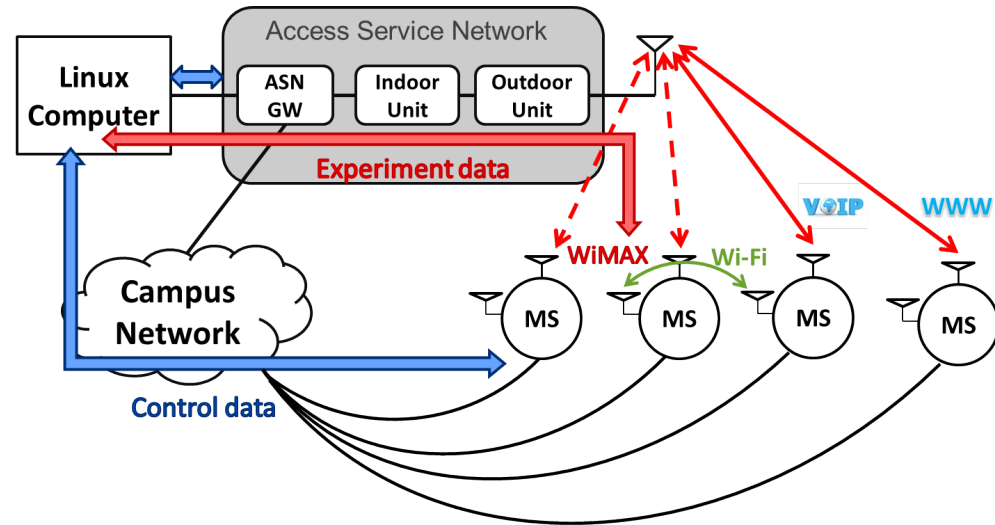
- Lecture & readings
- Pre-lab
- Lab instructions

- Experiments (3h):

1. System setup & ping tests
2. Maximum throughput measurements
3. QoS measurements

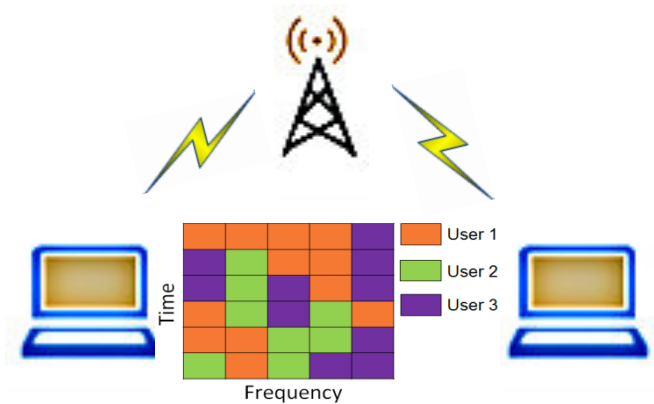
- Lab Report

- Survey



System Setup & Ping Tests

- Objective: configure & compare the round trip time (RTT) between WiMAX and Wi-Fi
- Steps:
 - Bring WiMAX interfaces up
 - Setup IP addresses
 - Ping the Linux computer over WiMAX and Wi-Fi
- Questions for the lab report:
 - Which technology has shorter RTT and why?

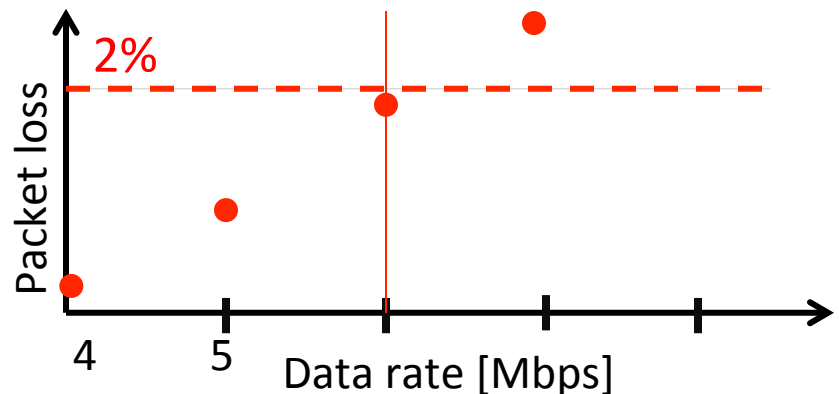


Maximum Throughput Measurements

- Objective: understand channel state impact on throughput
- Steps:
 - Observe modulation and link status
 - Send data: Linux computer → MS
 - Increase data rate until packet loss reaches 2%
- Questions:
 - Relate the channel state to the throughput

```
-----  
2 MS [0x001DE136FF28] monitor info  
-----  
UL modulation          16-QAM (CTC) 3/4  
UL RSSI                -74.75 dBm  
UL Physical CINR      18.75 dB  
  
DL modulation          64-QAM (CTC) 5/6  
DL Zone Specific Physical CINR 28 dB
```

```
$ sudo wimaxcu status link  
Link Status:  
    Frequency : 2590000 KHz  
    Signal    : Excellent  
    RSSI     : -61 dBm  
    CINR     : 29 dB  
    Avg TX PWR: -50 dBm  
    BS ID    : 44:51:DB:00:06:01
```

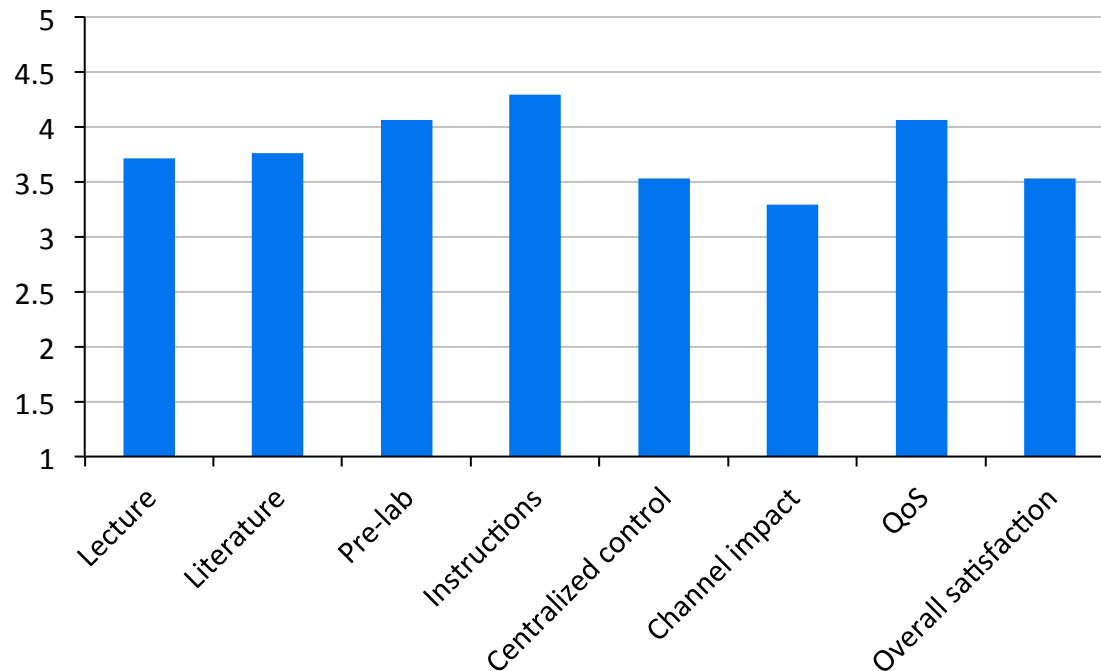


WiMAX QoS Measurements

- Objective: understand QoS mechanisms
- Setup: each pair of stations has one real-time (UGS) and one best effort (BE) MS
- Steps:
 - Ping flood the Linux computer from one MS at a time
(UGS gets lower average RTT)
 - Ping flood the Linux comp. from both MSs with the same channel quality simultaneously
 - Ping flood from all 4 stations simultaneously
(UGS gets lower deviance from average RTT)
- Questions:
 - Determine the MS-QoS class assignment

Lab Assessment

- Technical part:
 - The setup was more reliable than before—no interventions
 - Phantom MSs connecting to the BSs
 - Strange behavior at high modulation and coding scheme—very high packet loss (~70%)
- Student ratings of the lab (1-poor, 5-excellent):



Students' Impressions

What did you like most about the lab?

- “I could see UGS vs Best Effort in action”
- “Connecting remotely, and the pre-lab reading preparation.”
- “We were exposed to one of the latest technologies in the field of communication.”
- “Have access to the real base stations”

What was your least favorite thing about the lab?

- “Results were very inconsistent with what was supposed to happen, i.e., we saw no benefit of link adaptation for higher CINR. Also, we did not see the effect of simultaneous pings.”
- “Maybe the equipment was not well configured. The lab result was somehow different from what we expected”

Summary

- ✓ Overall, students liked the lab, apart from the technical difficulties
- ✓ Students find it interesting and important to learn about cellular networking
- ✓ Pre-lab and instructions were clear and helpful
- ✗ There are still issues that need to be resolved
 - We are interested in running the lab again this Spring
 - We could also implement similar LTE lab, if an LTE BS is obtained

(Thanks) Questions?

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Paper:

www.ee.columbia.edu/~jelena/wmx.pdf