

# WiMAX in the Classroom: Designing a Cellular Networking Hands-on Lab

Jelena Marašević<sup>1</sup>, Jan Janak<sup>2</sup>, Henning Schulzrinne<sup>2</sup>, Gil Zussman<sup>1</sup>

<sup>1</sup>Department of Electrical Engineering, <sup>2</sup>Department of Computer Science  
Columbia University, New York, NY

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# WiMAX Hands-on Lab Objectives

- Teach cellular networking concepts
- Compare to WLAN (Wi-Fi), highlight differences
- Use real hardware--GENI WiMAX Base Station (BS)



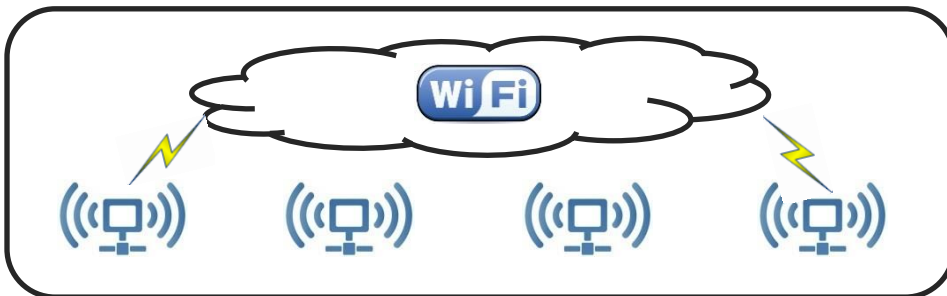
Base Station



Line of Sight

# Course Overview

- Graduate course in wireless and mobile networking, taught by Prof. Gil Zussman
- Various topics, focusing on layers above physical layer
- Students:
  - ~20 M.S.(majority) and Ph.D. students
  - 1-5 remote students
  - EE and CS background
- Hands-on labs:
  - Two Wi-Fi and one WiMAX lab



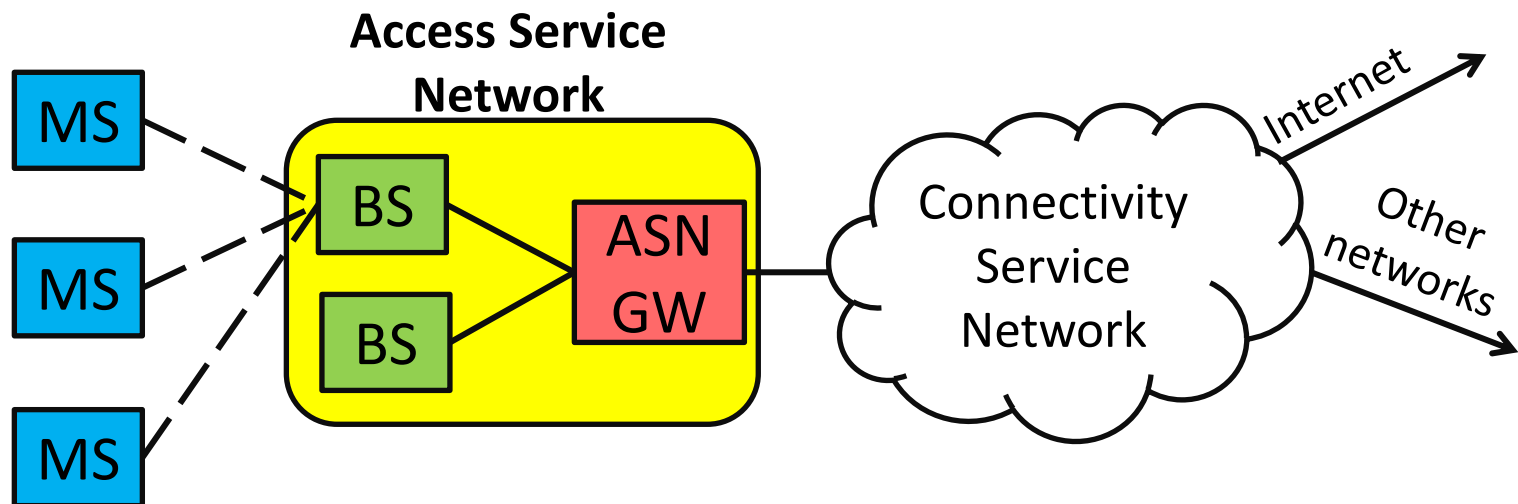
# WiMAX Overview

- “Last mile” broadband wireless access
- Mobile WiMAX: IEEE 802.16e standard
- Centralized control
- All IP wireless network
- 4G, similar to LTE



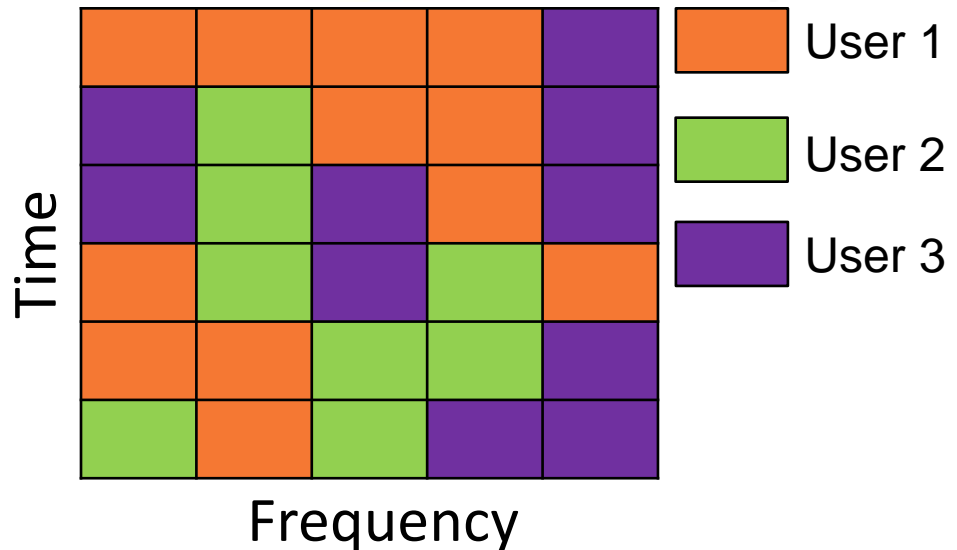
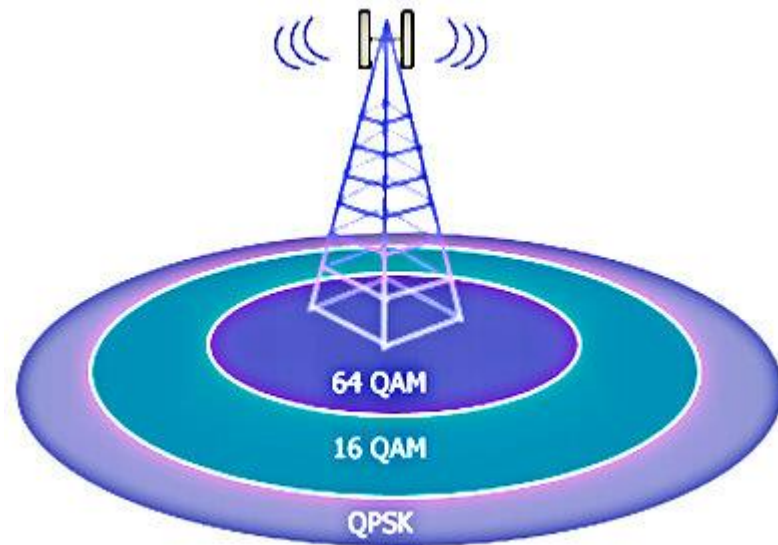
# WiMAX Network Model

- Mobile Station (MS): laptop or smartphone equipped with a WiMAX card
- Access Service Network (ASN):
  - Base Station (BS)
  - ASN Gateway (ASN GW)
- Connectivity Service Network (CSN)



# WiMAX Physical Layer—Highlights

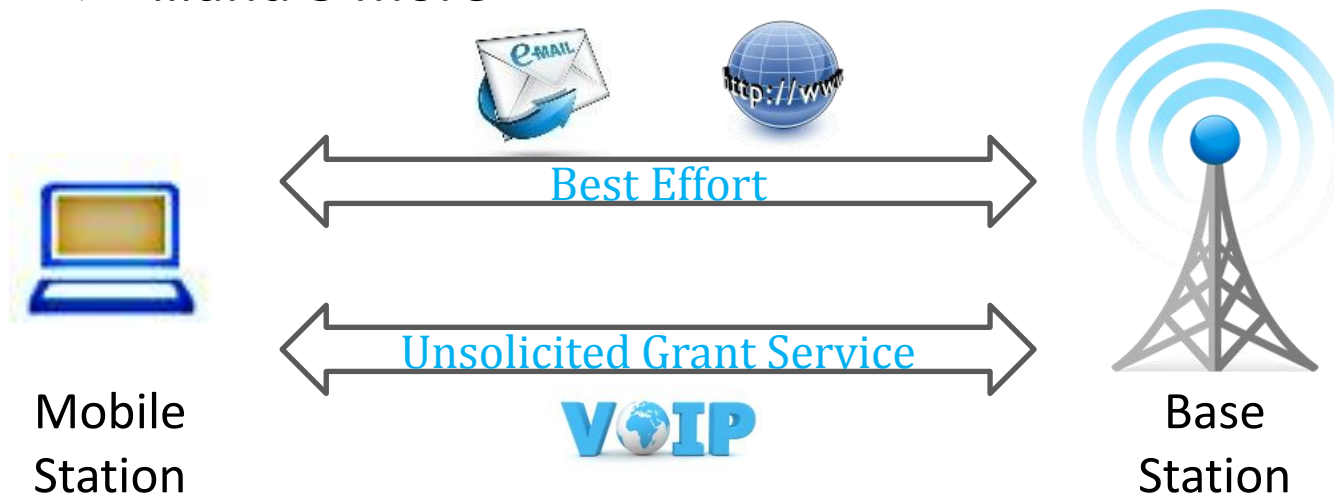
- Adaptive Modulation and Coding (AMC)
- Orthogonal Frequency Division Multiple Access (OFDMA)





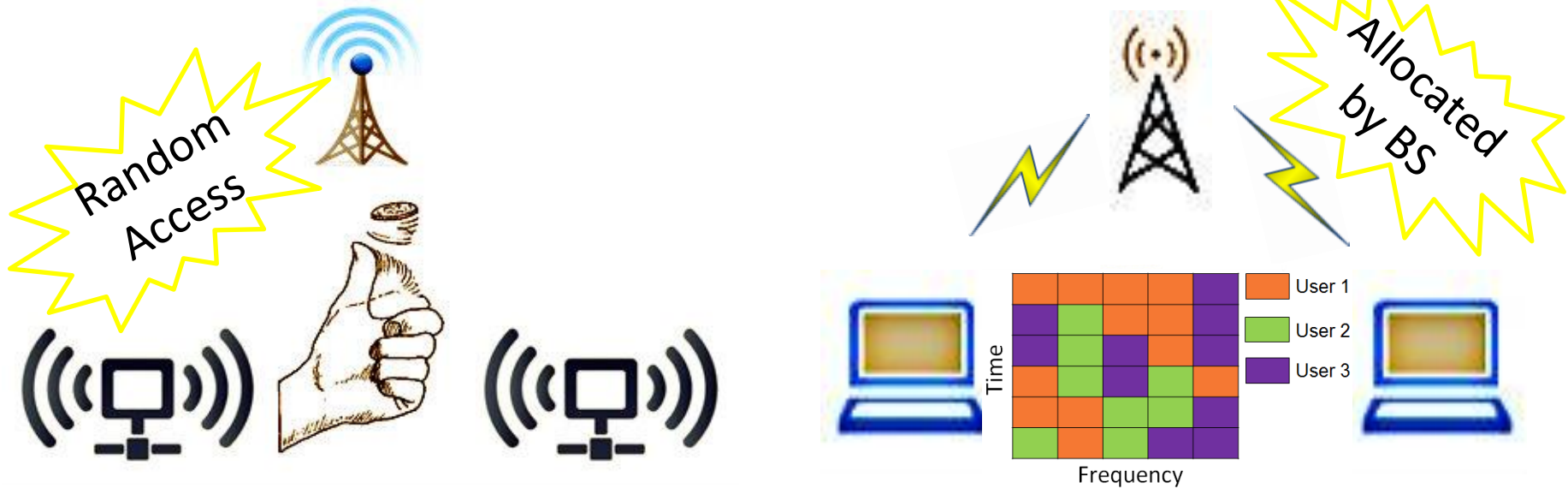
# WiMAX MAC Layer—Highlights

- Connection-oriented: Request/Grant
- Guaranteed QoS:
  - Service Flows
  - Classes:
    - Unsolicited Grant Service (UGS)
    - Best Effort (BE)
    - ...and 3 more



# Learning Objectives

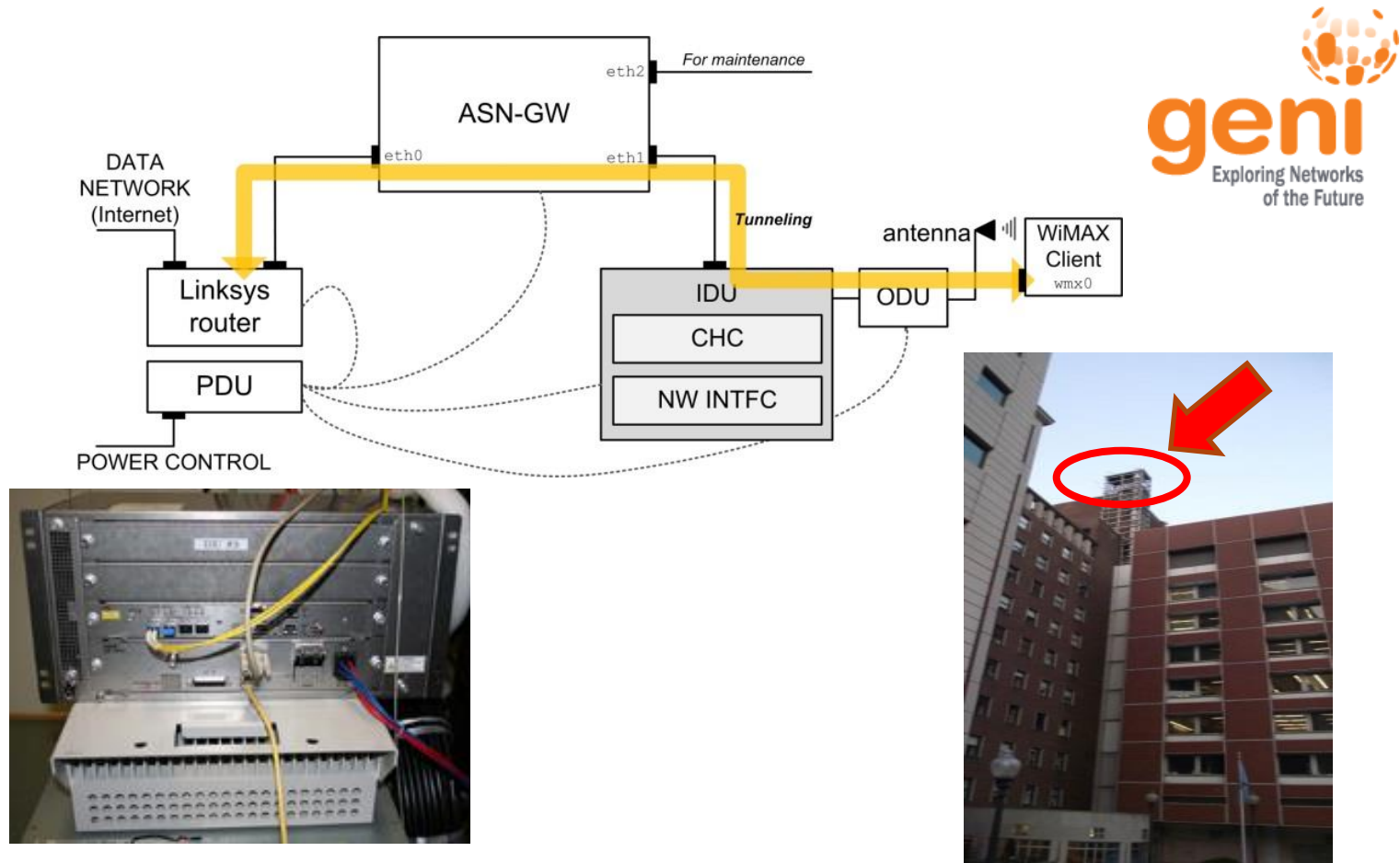
1. Compare cellular (WiMAX) to WLAN (Wi-Fi)  
(Most existing labs focus on Wi-Fi)
2. Understand the effect of the channel state on performance
3. Understand the QoS mechanisms





# Existing Setup

- Columbia University GENI WiMAX network, deployed by the group of Prof. Henning Schulzrinne



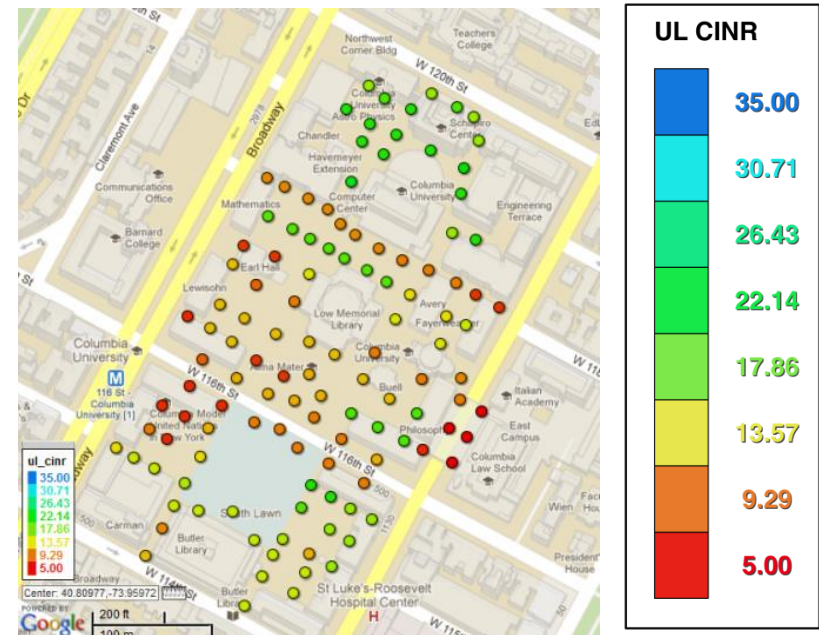
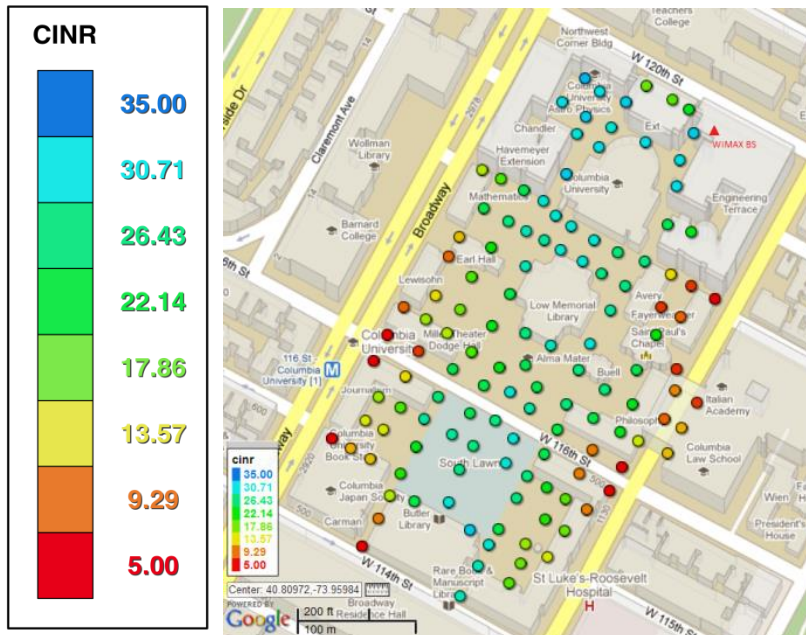
# Columbia Campus Coverage Maps

CINR = Carrier to  
Interference-plus-  
Noise Ratio

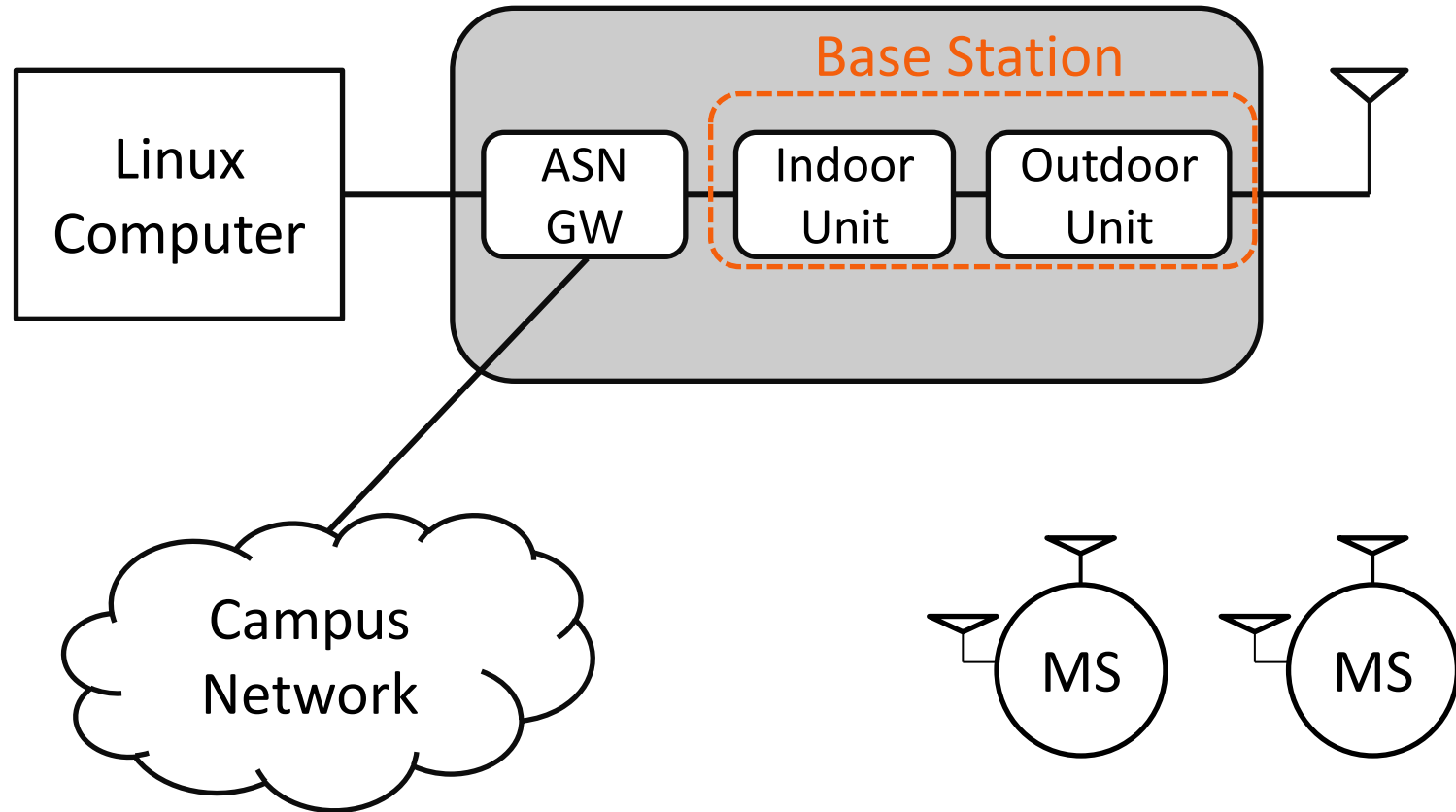
Downlink CINR



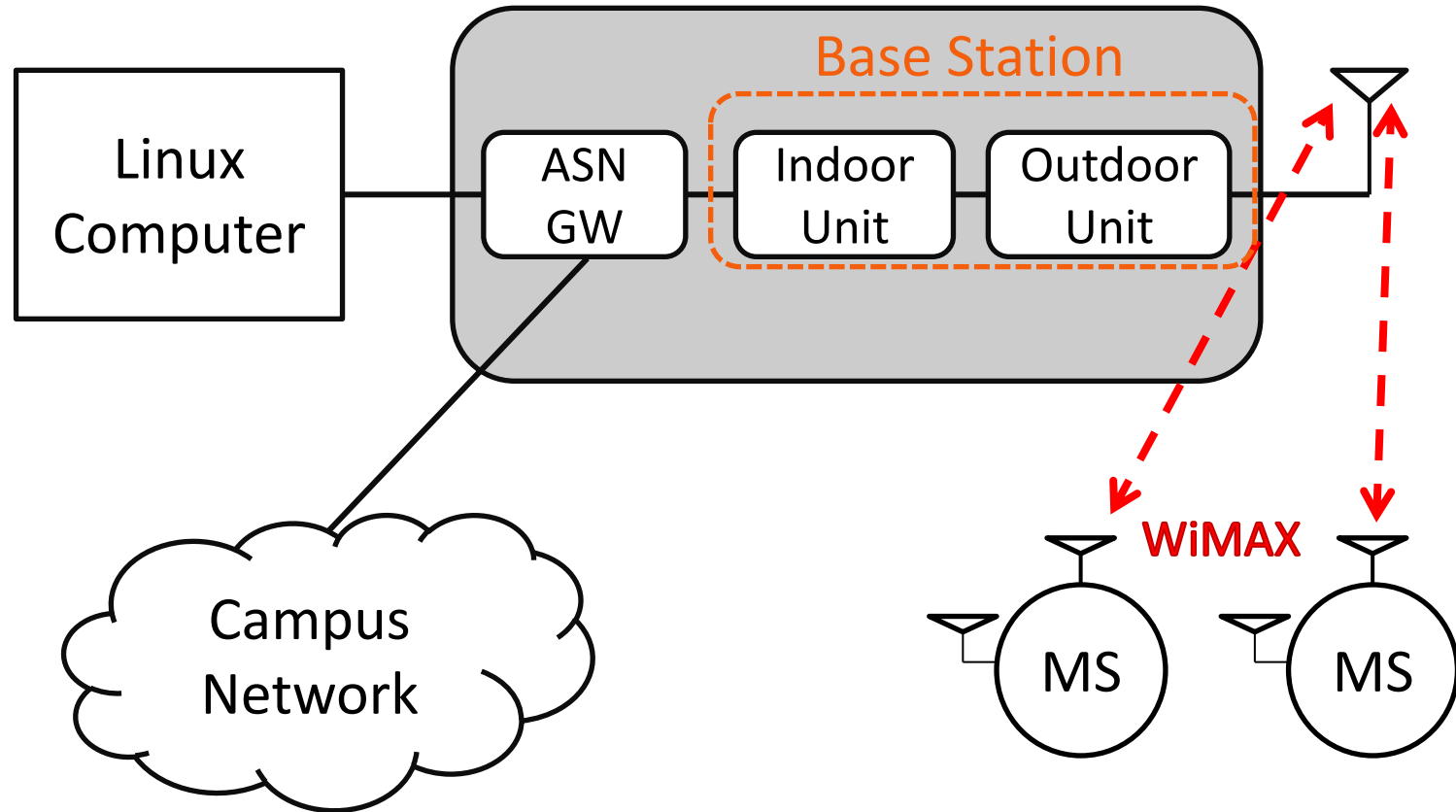
Uplink CINR



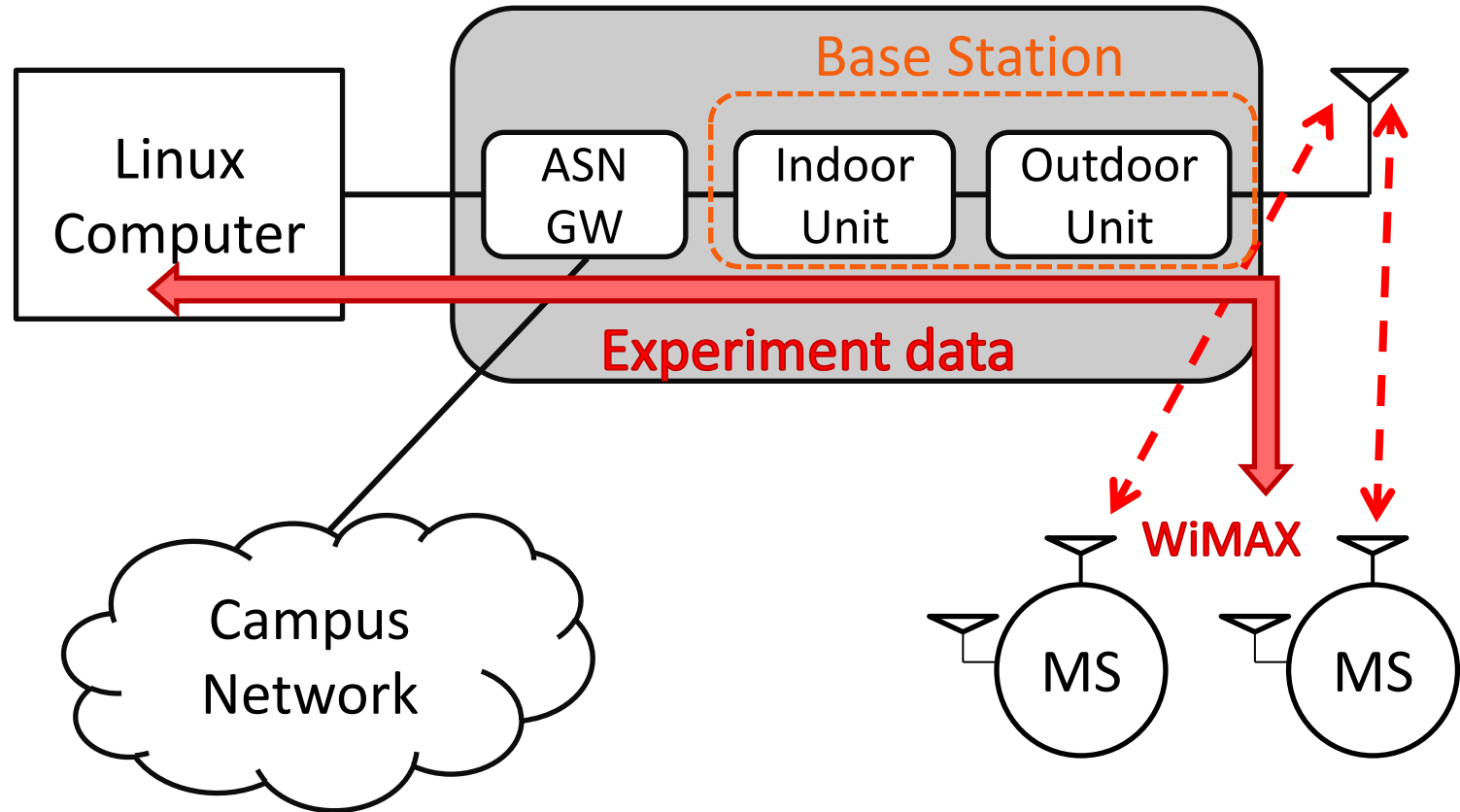
# Hands-on Lab Network Configuration



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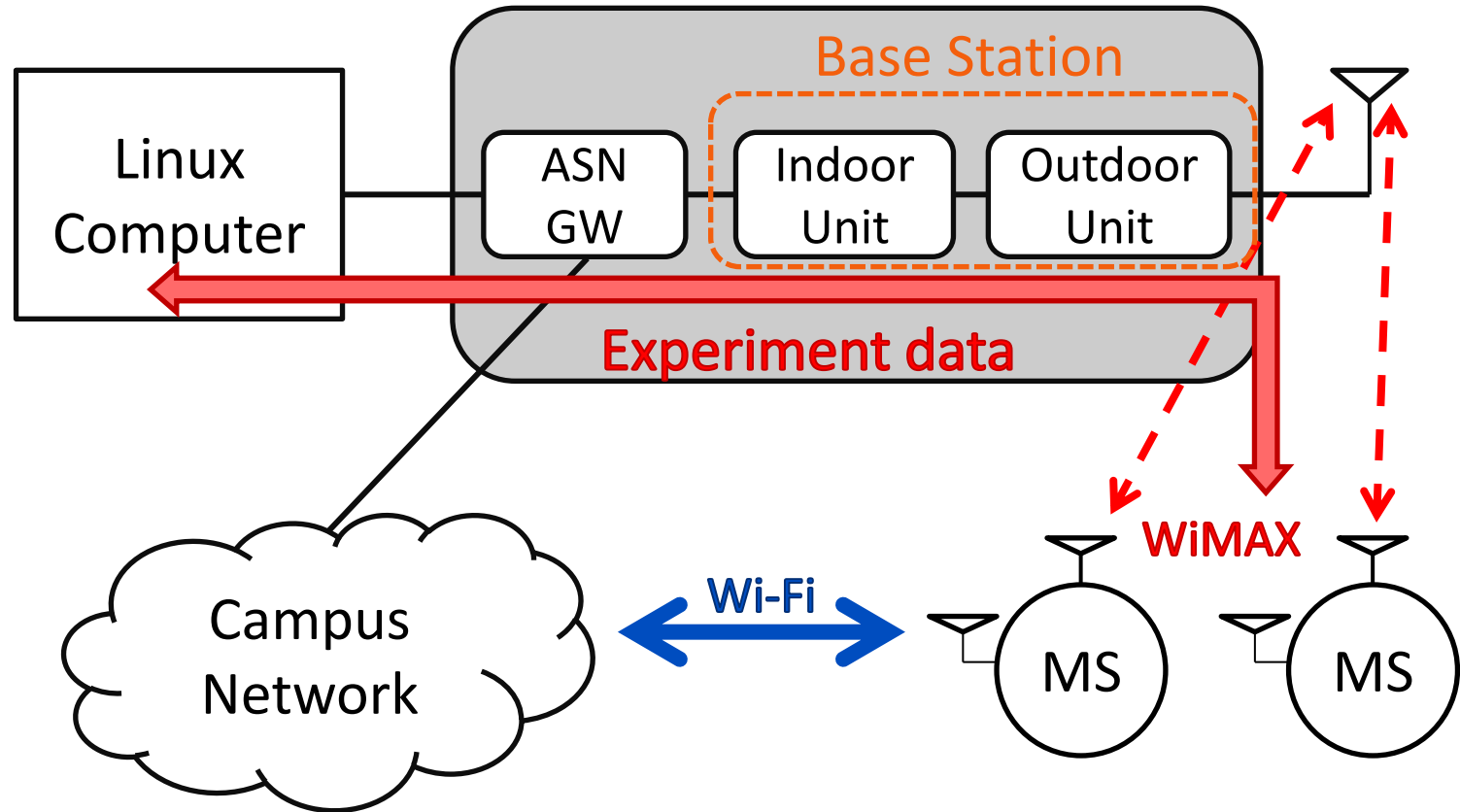


# Hands-on Lab Network Configuration



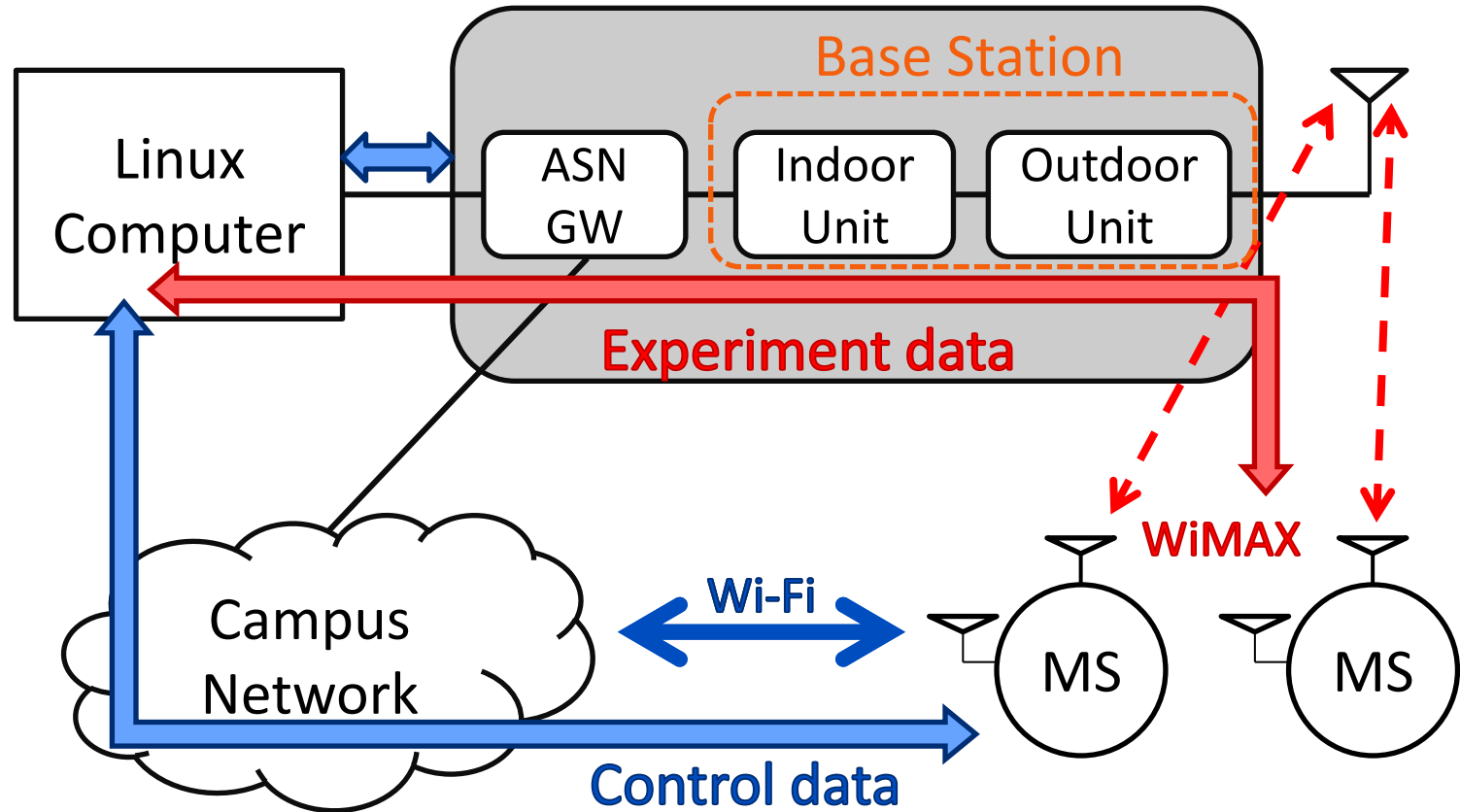


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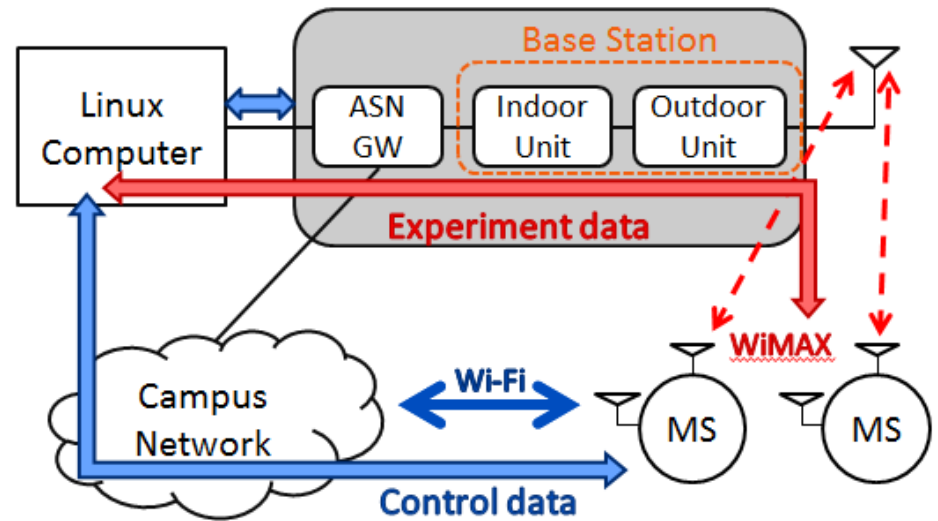


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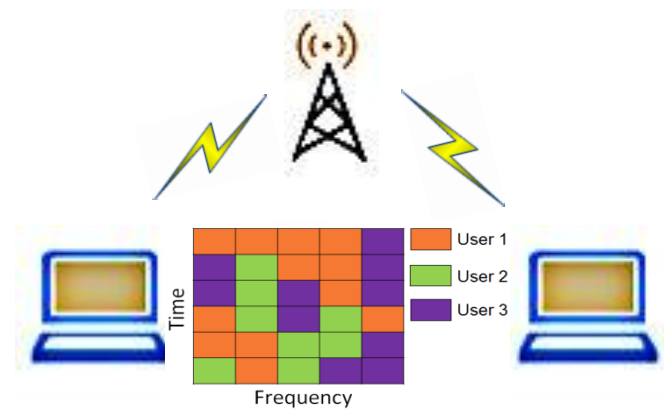
# The Hands-on Lab

- Preparing for the lab:
  - Lecture & readings
  - Pre-lab
  - Lab instructions
- Experiments:
  1. System setup & ping tests
  2. Maximum throughput measurements
  3. QoS measurements
- Lab Report
- Two locations for on-campus students, one for remote



# System Setup & Ping Tests

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



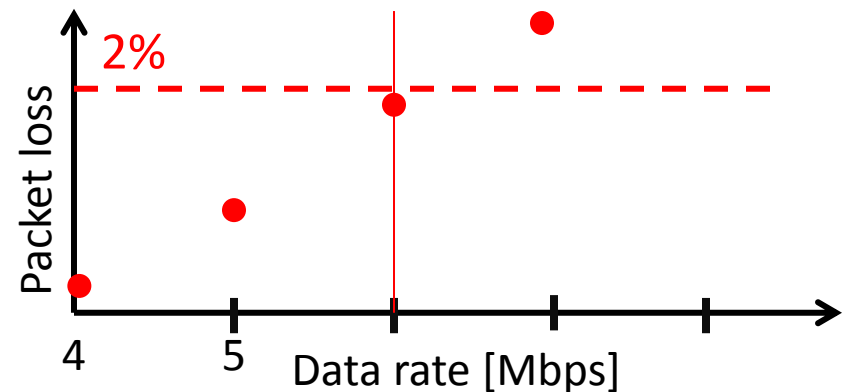
# Maximum Throughput Measurements

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

```
-----  
2 MS [0x001DE136FF28] monitor info  
-----
```

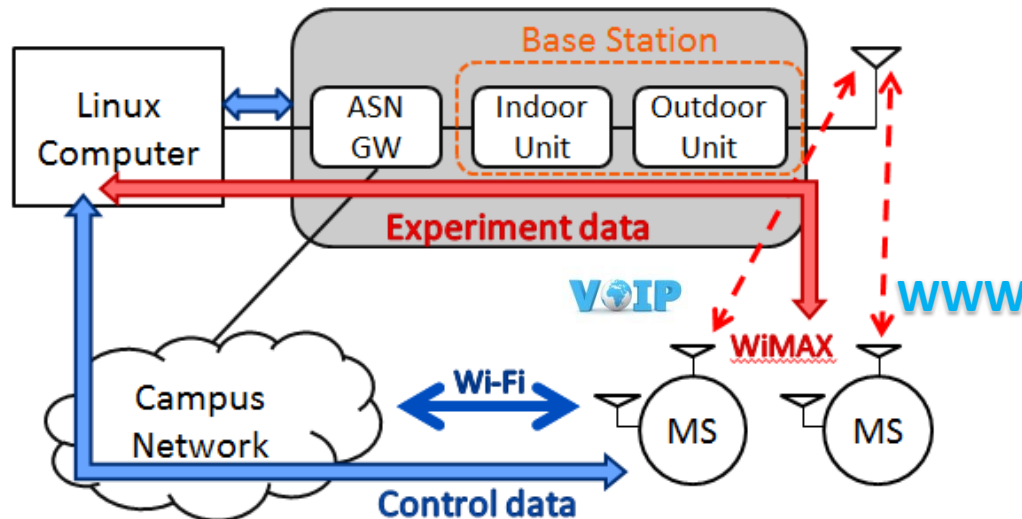
```
UL modulation          16-QAM (CTC) 3/4  
UL RSSI                -74.75 dBm  
UL Physical CINR       18.75 dB  
  
DL modulation          64-QAM (CTC) 5/6  
DL Zone Specific Physical CINR 28 dB
```

```
$ 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
```



# QoS Measurements

- Objective: understand QoS mechanisms
- 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 simultaneously  
(UGS gets lower deviance from average RTT)
- Questions:
  - Determine the MS-QoS class assignment



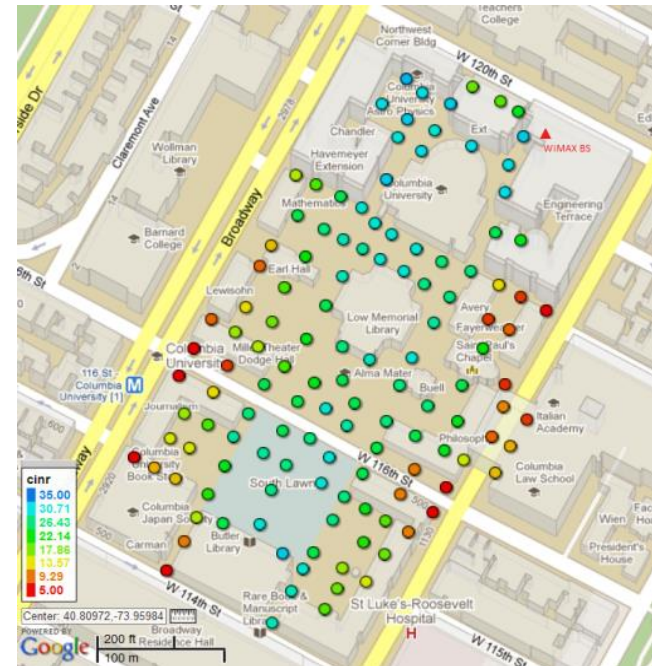
# Lab Effectiveness Evaluation

- Based on students' lab reports
- Overall, good understanding:
  - Resource allocation Wi-Fi vs WiMAX
  - Channel state impact on throughput
  - QoS classes
- Problems with controlling the environment
- In general, no major difference between on-campus & remote students



# Lessons Learned

- Controlling the environment
  - Modulation schemes not always the same
- Selecting the locations
  - Wi-Fi connectivity at “bad signal” location
- Selecting the MS equipment
  - Obtaining low-level data
- Configuring the BS
  - Bandwidth reservation



# Conclusions & Future Work

- First in-class cellular networking lab
- The lab demonstrates the main physical and MAC layer concepts of WiMAX that we wanted to teach
- Students have shown good understanding of the taught concepts
- Pre-lab and instructions available online
- Possible future work:
  - Smartphones or different WiMAX cards
  - Statically installed MSs—completely remote lab
  - Better QoS measurement experiment
  - More experiments

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**(Thanks) Questions?**

Email: [jelena@ee.columbia.edu](mailto:jelena@ee.columbia.edu)

Paper: [www.ee.columbia.edu/~jelena/wmx.pdf](http://www.ee.columbia.edu/~jelena/wmx.pdf)

