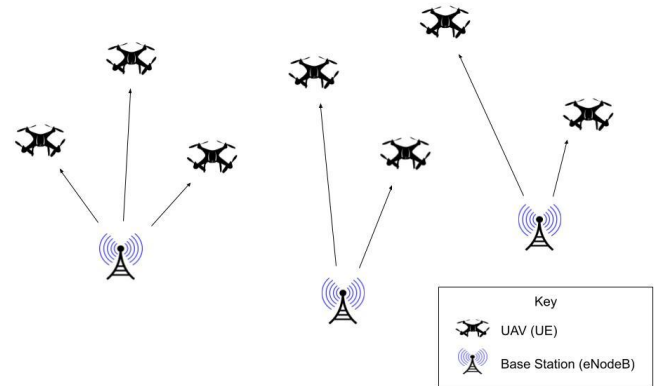


# Team sdmay21-13 · Open-source Prototyping of 5G Wireless Systems for Unmanned Aerial Vehicles

**Students:** Daniel Shaw, Ryan Ingram, Suraj Karn, Tyler Hutchinson  
**Faculty Adviser:** Dr. Hongwei Zhang

# Introduction and Project Topic

- Modeling 5G connected drones for reliable connection beyond the line of sight
  - Applications: drone delivery and safety inspections
- Open-source software:
  - OpenAirInterface5G (OAI)
  - Paparazzi UAV

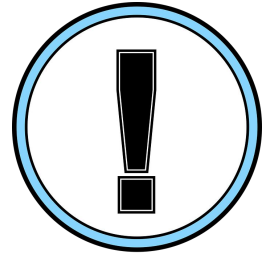




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## Target Audience

- 5G academic and industry research
- Meant to expand research in 5G devices
- Pass information along to perspective group



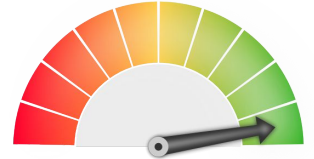
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## Requirements - Functional

- Simulation connection of eNB and UE
- Multi-cell environment of eNB's and UE's
- Location coordinates for network simulation



## Requirements - Non-Functional



- Build time
  - Powerful computer allows faster simulation build
- Timing
  - Physical computers with ethernet connection
  - Use of low-latency kernel



# Standards

- 3rd Generation Partnership Project (3GPP)
  - Release 10, 12, and 14
- nFAPI Specifications
  - Network Functional Platform Interface (nFAPI)
  - Functional split between MAC and PHY layers
  - P5 and P7 interfaces

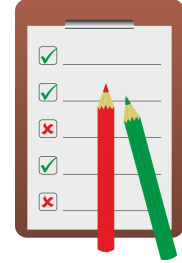




# Task Decomposition

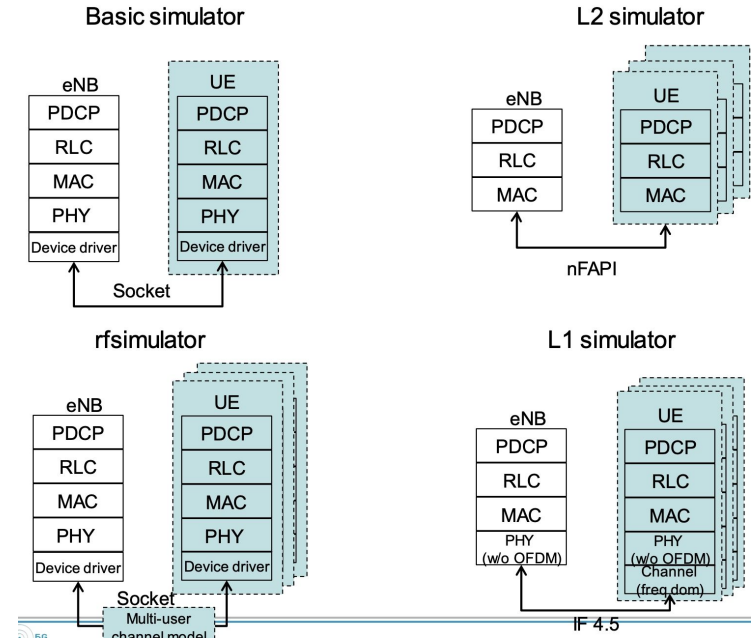
Split sections of project:

- Network Simulator (OAI) - Daniel, Suraj
- UAV Simulator (Paparazzi) - Ryan
- Networking Algorithms - Tyler



# OpenAirInterface

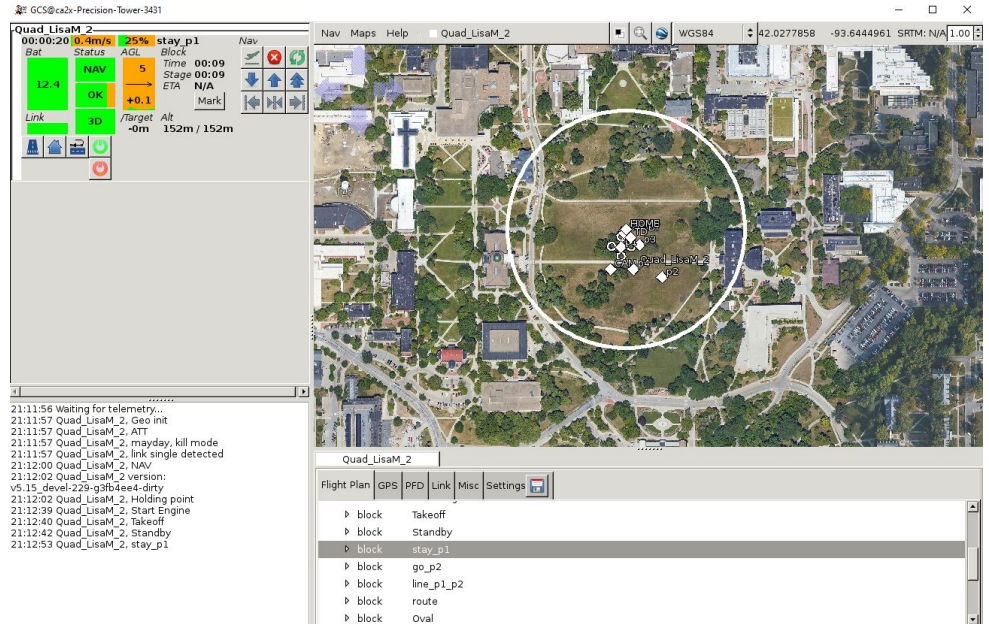
- Operating Environment: Ubuntu 16.04 with low-latency kernel
- Different simulators
- Using the L2 nFAPI simulator with no S1
  - Supports multiple UE device connections
  - Uses Cisco's Open-nFAPI project





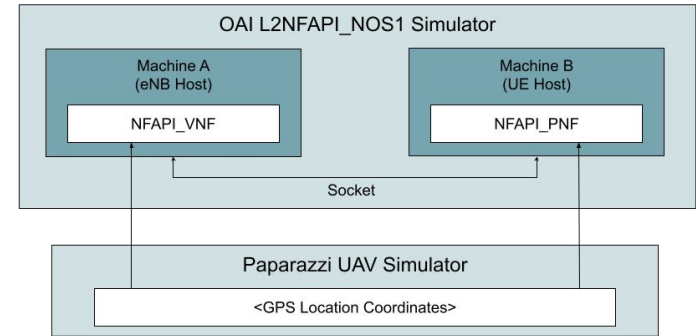
# Paparazzi

- Paparazzi Center
  - Main Interface
  - Three major components
- Configuration
  - Airframe
  - Flight Plan
- Ground Control Station
  - Customizable GUI
  - Monitor and control the aircraft



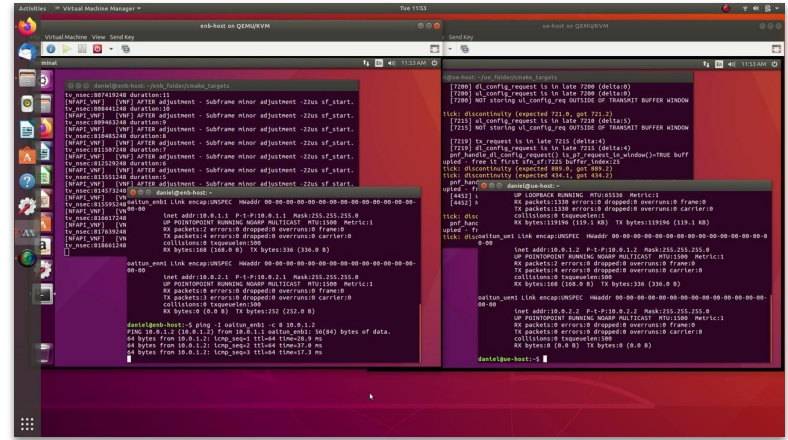
# Design Plan

- Location stored in the VNF and PNF code
- New functions to interface with OAI
- Cellular connection of drones through OAI and Paparazzi sync



# Results - OpenAirInterface

- Successfully ran the L2NFAPI\_NOS1 simulator on virtual machines (KVM/QEMU)
  - Passing ping tests
  - Supports multiple UEs

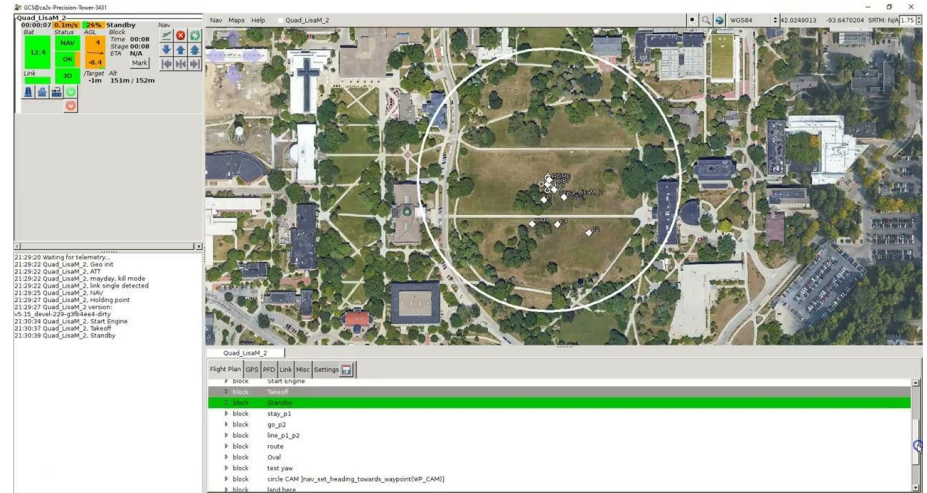


```
oaitun_ue1 Link encap:UNSPEC HWaddr 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00
0-00
    inet addr:10.0.1.2 P-t-P:10.0.1.2 Mask:255.255.255.0
    UP POINTOPOINT RUNNING NOARP MULTICAST MTU:1500 Metric:1
    RX packets:1 errors:0 dropped:0 overruns:0 frame:0
    TX packets:3 errors:0 dropped:0 overruns:0 carrier:0
    collisions:0 txqueuelen:500
    RX bytes:84 (84.0 B) TX bytes:252 (252.0 B)

oaitun_ue2 Link encap:UNSPEC HWaddr 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00
0-00
    inet addr:10.0.1.3 P-t-P:10.0.1.3 Mask:255.255.255.0
    UP POINTOPOINT RUNNING NOARP MULTICAST MTU:1500 Metric:1
    RX packets:0 errors:0 dropped:0 overruns:0 frame:0
    TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
    collisions:0 txqueuelen:500
    RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)
```

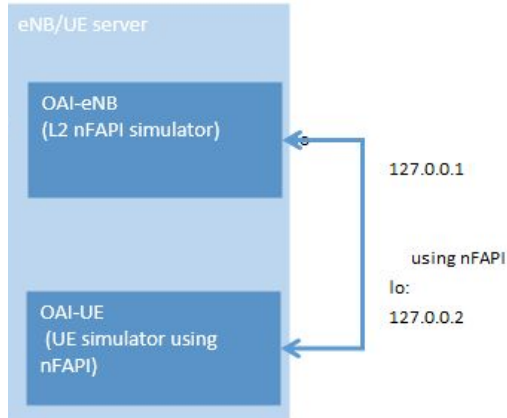
# Results - Paparazzi

- Create customized flight plans
- Simulate multiple aircrafts
- Access location points during flight



# Challenges and Shortcomings

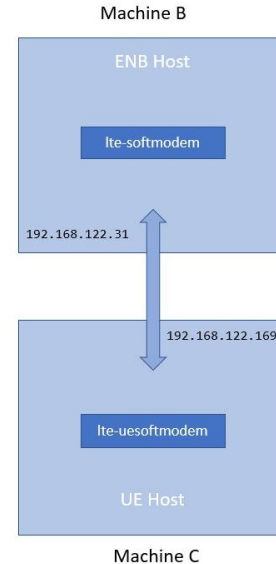
- Issues with single-host deployment
- Linux kernel drops packets with locally sourced addresses



```
1881 /*
1882  * NOTE. We drop all the packets that has local source
1883  * addresses, because every properly looped back packet
1884  * must have correct destination already attached by output routine.
1885  *
1886  * Such approach solves two big problems:
1887  * 1. Not simplex devices are handled properly.
1888  * 2. IP spoofing attempts are filtered with 100% of guarantee.
1889  * called with rcu_read_lock()
1890  */
```

## Challenges and Shortcomings Continued

- Problems with using virtual machines:
  - Network configuration
  - Meeting software/hardware requirements for OAI
  - Timing issues
- Weren't able to simulate multiple eNB
- Weren't able to work on integration



# Milestones and Project Status

- Stayed on track for most of the project
- Began running into difficulties once attempting to run OAI
- Shifted focus to creating a solid structure for the next team
- Did not hit as many milestones as we initially planned

Color Key: ■ Completed, ■ In-progress, ■ Incomplete

Task Name	8/17-8/30	8/31-9/13	9/14-9/27	9/28-10/11	10/12-10/18	10/19-11/1	11/2-11/15	11/25-12/7	12/8-12/21	12/22-1/3/7	1/8-1/21	1/22-1/4/4	1/5-1/18
Read 4G/5G Textbook (All)													
Install OAI (All)													
Install Paparazzi UAV (All)													
Get familiar with OAI (Daniel, Suraj)													
Setup Remote-Access Computer (Ryan, Tyler)													
Run OAI Simulator (Daniel, Suraj)													
Configure Remote-Access Computer (All)													







## Conclusion

- Learned structure of cellular networks
- Importance of software/hardware requirements
- Documentation of project for future teams



# References

- “5G Network FAPI Specifications.” Small Cell Forum, [www.smallcellforum.org/5g-network-fapi-specifications/#:~:text=The%205G%20network%20of%20functional%20application,is%20already%20enabled%20for%204G](http://www.smallcellforum.org/5g-network-fapi-specifications/#:~:text=The%205G%20network%20of%20functional%20application,is%20already%20enabled%20for%204G).
- Kaltenberger, Florian. “OpenAirInterface 5G Overview, Installation, Usage” 2019. PDF File, [https://www.openairinterface.org/docs/workshop/8\\_Fall2019Workshop-Beijing/Training/2019-12-03-KALTENBERGER-1.pdf](https://www.openairinterface.org/docs/workshop/8_Fall2019Workshop-Beijing/Training/2019-12-03-KALTENBERGER-1.pdf).

**Questions?**