Open-Source Prototyping of 5G Wireless Systems for UGV/UAV

Team: SDMAY20-36

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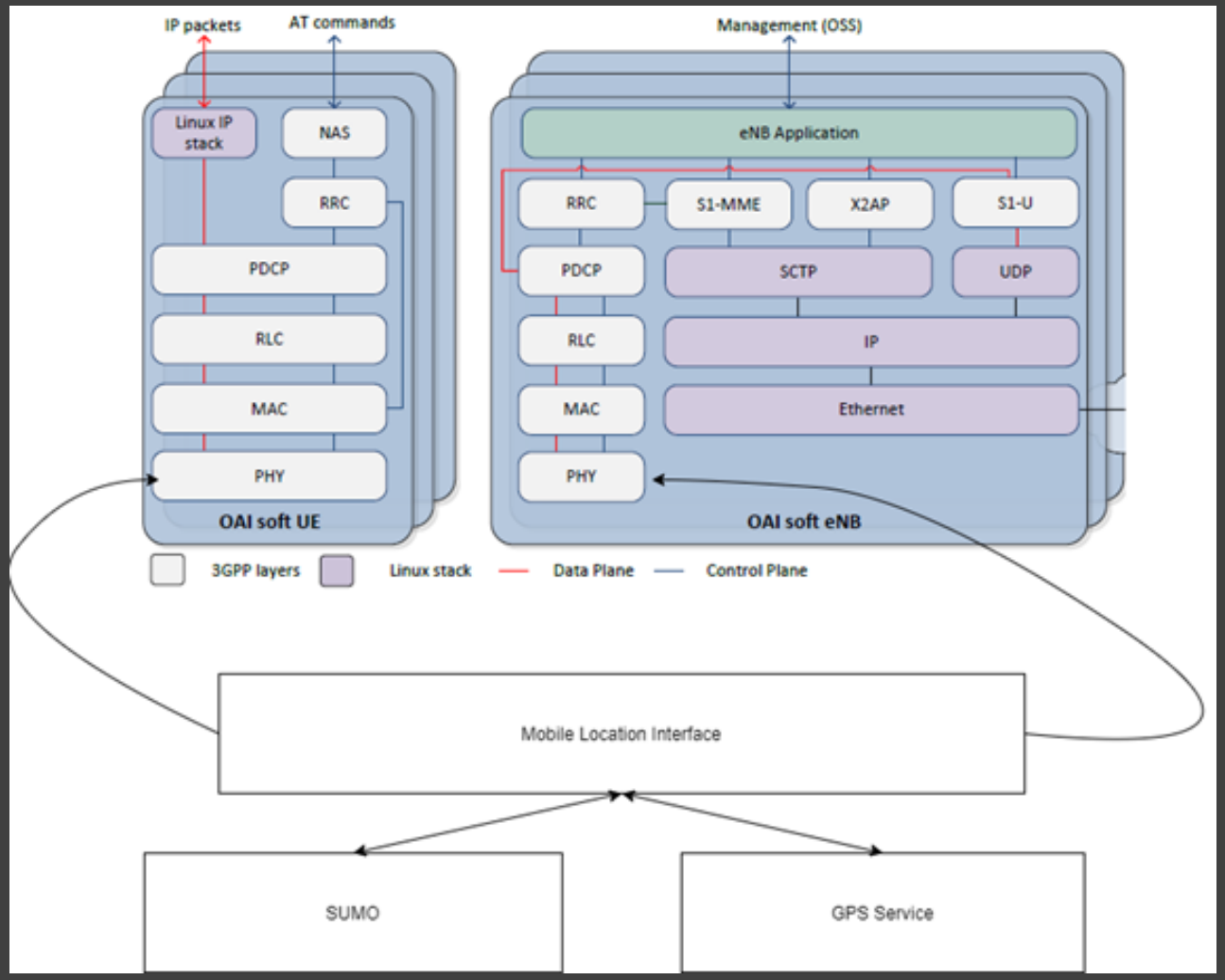
High Level Overview

- Create a 5G wireless solution that allows for large scale simulation of wireless networks
  - Low latency
  - High throughput
  - Extremely reliable network
- Tools
  - Open Air Interface (OAI)
  - Simulation of Urban Mobility (SUMO)
- Future uses
  - Connected autonomous transport
  - Smart agriculture

Problem Statement

- Need to modify OAI to simulate 5G networks in various traffic conditions
  - Need to simulate 100s of nodes
  - Ensure simulation output matches theory (no bugs)
- Utilize open source tools to solve the above problem

Conceptual Sketch



Functional Requirements

- Design a scalable system to test 5G scheduling algorithms
- Ensure the solution is:
  - Reliable
  - Has low latency
  - Has high throughput
- Utilize open source tools and follow good software practices
  - CI/CD
    - Jenkins
  - Cloud Deployments
  - OAI
  - SUMO

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Technical/Other Constraints

- Limited in terms of hardware
  - Current server specs:
    - Intel Xeon 8 core processor (2.4 Ghz)
    - 8 GB of RAM
    - 120 GB disk
- Simulator is difficult to use
  - Requires multiple computers for various components
  - Very specific hardware requirements
    - Linux Low Latency Kernel
    - AVX512 Instruction Support
    - Turbo Decoding
    - Disable Processor Power Saving Features

Potential Risks & Mitigation

- Lack of knowledge of complex network simulations
  - LTE and 5G network architecture
  - Mitigated by learning as much as possible about how these systems work within reason
- Bugs in our code
  - Learn how to properly debug these kinds of systems
  - Ask for assistance from people who worked on the development team for the simulator
- Specific hardware requirements and vague default test case results
  - Mitigated by creating a build system to make it easier to track errors

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Potential Risks & Mitigation

Risks

- Difficulty scaling networks to many UEs and eNBs
- New scheduling algorithm integration
- Difficulty recreating system configurations
  - Similar issues with cloud deployments
- Unknown simulator bugs
  - Large software project
  - Lots of legacy code

Mitigation

- Potentially deploy to cloud services
  - Cloudlab, ExoGENI
- Use CI/CD to verify old functionality isn't broken
- Use scripts where possible to create network layouts
  - Cloud formation templates
- Verify experiments match theory

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Resource Cost/Estimate

- Hardware capable of running OAI and SUMO
  - A test bed specifically for OAI
  - Linux
- No financial requirement
  - OAI and SUMO are open source

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Project Milestones

- Get OAI working
  - UE (like a cell phone)
  - ENB (a radio tower)
  - EPC (evolved packet core)
- Integrate OAI and SUMO
  - Get SUMO positional data
  - Find where in OAI to insert SUMO data
- Implement algorithm and check its validity
- Test system with network simulator and SUMO
  - Low Latency
  - High Throughput
  - High Reliability
  - Interoperability with current solutions

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Project Schedule

Assignment/Task	9/9-9/23	9/23-10/7	10/7-10/21	10/21-11/4	11/4-11/18	11/18-12/2	12/2-12/16	Winter Break	1/13-1/27	1/27-2/10	2/10-2/24	2/24-3/9	3/9-2/25	3/25-5/1
Read 4G/LTE Book														
Research PRKS Paper														
Research CPS Paper														
Research SUMO														
Research OAI and specific Install Steps														
Set Up Hardware/Operating Environment														
Install OAI														
Install SUMO														
Verify/Run OAI on Server														
OAI/SUMO Integration														
Algorithm Development														
Verify and Test Simulation														
Writing Report														
Compare Simulation Results to Control														
Hardware Deployment														
Finalize Report and Project														

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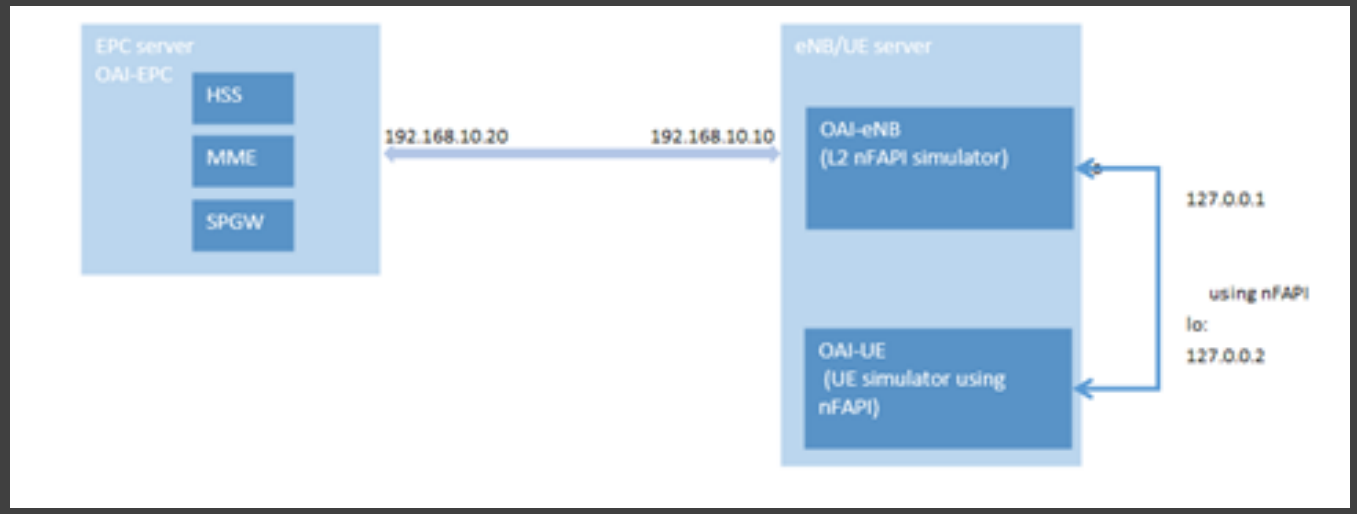
Functional Decomposition

- SUMO Traffic Generation
  - SUMO Server to create traffic simulations
  - Update positions of nodes in OAI using SUMO data
  - Interface between OAI and SUMO
- Network Emulation
  - Various eNB and UE in configurations
    - 1 eNB, 1 UE
    - 1 eNB, Many UEs
    - Many eNBs, Many UEs
- Scheduling Algorithm (CPS-V2X)
  - Based on PKRS, CPS, and UCS
  - Adjusted for dynamic node configurations

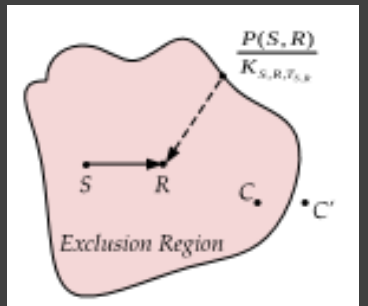
Detailed Design – OAI Simulation

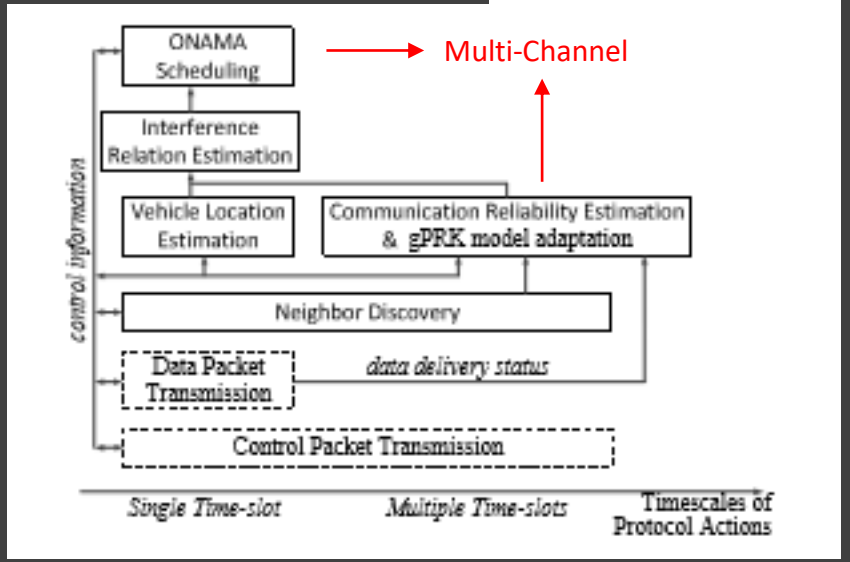
- Configure and run UE and eNB on one server
  - UE – mobile phone, tablet, modem
  - eNB - Base stations connected to the network that communicate wirelessly with mobile handsets
- Configure and run EPC on another server
    - Network Access Controls, Packet Routing, Mobility Management, Security



Detailed Design – CPS-V2X Algorithm

- Incorporates characteristics of three existing algorithms:
  - PRKS (Physical-Ratio-K Scheduling)
    - Interference control, High Reliability
  - CPS-V2V (Cyber-Physical Scheduling Vehicle to Vehicle)
    - Vehicle Mobility, Uses PRKS
  - UCS (Unified Cellular Scheduling)
    - Multi-Channel
- Will be implemented in MAC layer of OAI
  - Collision Detection, uses data from PHY layer





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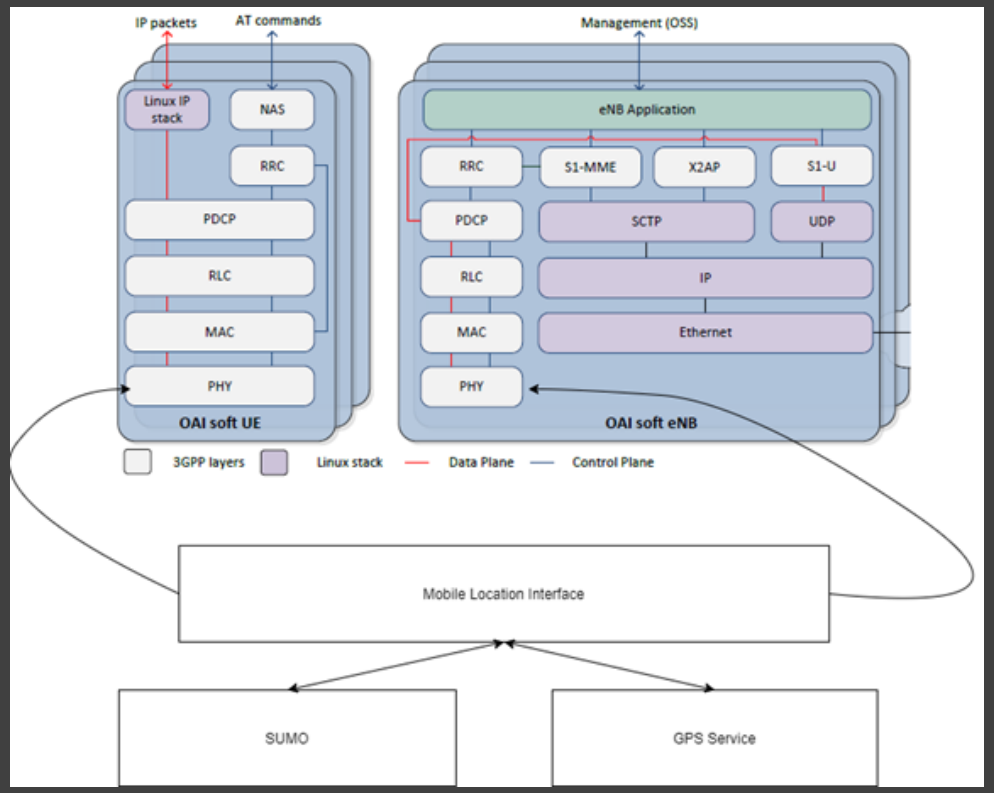
Detailed Design – OAI/SUMO Integration

- SUMO integrated with OAI at PHYS layer
- Mobile Location Interface between SUMO and OAI
  - Allows future integration of hardware-based GPS system instead of OAI
- PHYS layer returns location data to MAC layer through control plane



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Detailed Design – Jenkins

HW/SW/Technology Platforms Used

- OAI
  - Open Air Interface
  - Open source 5g network simulator/emulator/test bench
  - Highly optimized, written in C
- SUMO
  - Simulation of Urban Mobility
  - Open source, highly customizable traffic simulator
  - Include an API to get vehicle positioning data
- Jenkins
  - CI/CD
  - Pipelined build jobs for regression testing

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Test Plan

- Configure simulation test bed
  - 1 UE, 1 eNB to start with
  - Use nFAPI to facilitate communication
    - Network functional API
    - Connects Physical Network to Virtual Network (Layer 1 to Layer 2)
  - Modify number of eNBs/UEs
  - Incorporate SUMO traffic data
- Implement new scheduling algorithm
  - Does the simulation test bed break?
  - Unit tests using simple UE/eNB sets
  - Reliability, throughput, and latency measurements

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Prototype Implementations

- Currently running 1 UE and 1 eNB with an EPC
  - Have configuration files for multiple UE/eNBs created
- Built a C client to support SUMO API
  - Used for traffic data
- Newest version of OAI running on server
  - Updated from v.5.2 -> 1.2.0 -> 1.2.1

Engineering Standards and Design Practices

- 3GPP
- E-UTRAN
- EURECOM
- IEEE
- Continuous Integration, Continuous Development (CI/CD)
- Coding Best-Practices

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Conclusion

- Progress was slower than expected
  - Difficult learning curve with OAI
  - Switched to a newer version of OAI part of the way through
  - Able to run with one eNB and one UE

- Was able to get SUMO working
  - Created a program to grab information from SUMO and send it to a C program using sockets
  - Meant to be integrated with OAI to send data straight from SUMO to OAI

Conclusion

- The new scheduling algorithm has gotten to the point of carrying out the preliminary design
  - Not yet integrated into OAI
  - Have begun writing pseudocode and verifying functions
- Configured network simulation with one eNB/UE and EPC
  - eNB/UE run on the same server
  - EPC runs on separate server on same local network
  - Wrote documentation on how to recreate our configuration