Prototyping and Emulation Studies of Large-Scale 5G Wireless Systems

DESIGN DOCUMENT

Team Number-35

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Executive Summary

Development Standards & Practices Used

List all standard circuits, hardware, software practices used in this project. List all the Engineering standards that apply to this project that were considered.

- OpenAirInterface software:

A flexible platform towards an open LTE ecosystem

Used to build LTE base stations, user equipment, and a core network
The base stations can be connected to commercial or OAI UEs in order to test configurations and network setups and monitor the network and mobile devices in real-time

OAI is based on a PC hosted software radio frontend architecture

OAI objectives:

- Open and integrated development environment under the control of the experimenters;
- On the network side: Fully software-based network functions offering flexibility to architect, instantiate, and reconfigure the network components (at the edge, core, or cloud using the same or different addressing space);
- On UE side : Fully software-based UE functions which can be used by modem designers with upgrading and/or developing LTE and 5G advanced features
- Playground for commercial handsets as well as application, service, and content providers;
- Rapid prototyping of 3GPP compliant and non-compliant use-cases as well as new concepts towards 5G systems ranging from M2M/IoT and software-defined networking to cloud-RAN and massive MIMO

Software Platform currently 4th generation mobile cellular systems compliant with 3GPP LTE standards in C under real-time Linux optimized for x86

Hardware Platform can be interfaced with 3rd party SDR RF platforms. OAI supports these hardware platforms:

EURECOM EXMIMO2

USRP X-series/B-Series

Summary of Requirements

List all requirements as bullet points in brief.

- Running simulation of the PHY abstraction layer on two different versions of the code
- Management of interference and latency between cell base-station
- Enhancement of the automatic device to device wireless communication (D2D communication)

Applicable Courses from Iowa State University Curriculum

List all Iowa State University courses whose contents were applicable to your project.

- Signal and systems 1 and 2 (EE224 and EE324)
- Embedded Systems 1 (CprE 288)
- Linux (Com S 252)

New Skills/Knowledge acquired that was not taught in courses

List all new skills/knowledge that your team acquired which was not part of your Iowa State curriculum in order to complete this project.

- navigate throughout OAI(openairinterface)
- different layer structure of 5g technology
- installed VM and ubuntu 14.04
- Emulation/Simulation command using ubuntu
- explore different branch of the main repository in OAI

Table of Contents

List of figures/tables/symbols/definitions (This should be the similar to the project plan)

5G technology

5G NR(New Radio) Protocol Stack:

Latency- The time taken for devices to respond to each other over the wireless network

See Frequency Range chart here: https://www.rfwireless-world.com/Terminology/what-is-rf.html

Layer 1(Physical Layer):

Functions:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels
- Frequency and time synchronisation
- Radio characteristics measurements and indication to higher layers
- Multiple Input Multiple Output (MIMO) antenna processing
- Transmit Diversity (TX diversity)
- Digital and Analog Beamforming
- RF(Radio Frequency) processing

Physical Layer Processing Layout

Transport block -> CRC (Cycle Redundancy Check) Attachment -> LDPC (Low-density parity-check) Base Graph Selection -> Code block segmentation and CRC attachment -> LDPC encoding -> Rate matching -> Code block concatenation -> Scrambling -> Modulation -> Layer mapping -> Antenna port mapping -> Mapping to RBs (Resource Block)

Layer 2:

Made up of different sublayers:

- MAC (Medium Access Control)
- RLC (Radio Link Control)
- PDCP (Packet Data Convergence Protocol)

MAC and PDCP are the layers that mainly focus on data transfer and handling between logical channels of one UE and between UEs through dynamic scheduling

Functions of MAC sublayer:

- Beam management
- Random access procedure
- Mapping between logical channels and transport channels
- Concatenation of multiple MAC SDUs belonging to one logical channel into transport block (TB)
- Multiplexing/demultiplexing of 5G-MAC SDUs belonging to one or different logical channels into/from transport blocks (TB) delivered to/from the physical layer on transport channels
- Scheduling information reporting
- Error correction through HARQ
- Priority handling between logical channels of one UE
- Priority handling between UEs by means of dynamic scheduling
- Transport format selection
- Padding

Functions of RLC sublayer:

- Transfer of upper layer PDUs
- Error Correction through ARQ (only for AM data transfer)
- Reordering of 5G-RLC data PDUs (only for UM and AM data transfer)

- Duplicate detection (only for UM and AM data transfer)
- Protocol error detection (only for AM data transfer)
- 5G-RLC SDU discard (only for UM and AM data transfer)
- Segmentation (only for UM and AM data transfer)
- Resegmentation (only for AM data transfer)
- 5G-RLC re-establishment

Functions of PDCP sublayer:

- Transfer of user data
- In-sequence delivery of upper layer PDUs at 5G-PDCP re-establishment procedure for 5G-RLC AM

- Duplicate detection of lower layer SDUs at 5G-PDCP re-establishment procedure for 5G-RLC AM

- Retransmission of 5G-PDCP SDUs at mobility in connected mode for 5G-RLC AM

- Ciphering and deciphering (Note: Only AES shall be mandatory)

- Timer-based SDU discard in uplink

- Ciphering and Integrity Protection (Note: Only AES shall be mandatory)

- Transfer of control plane data

1 Introduction

1.1 Acknowledgement

We would like to acknowledge our faculty advisor Professor Hongwei Zhang and Grad Student Advisor Matthias Sander - Frigau for the guidance and assistance on our project.

1.2 Problem and Project Statement

The problem that we are faced with in this project is improving code from OpenAirInterface5g(OAI) to be able to stimulate and emulate the PHY abstraction layer of , then using that to connect from device to device with 5g. The one problem is with the physical abstraction layer of their code. The problem that we will face is trying to figure out why this layer is lagging. We will have to gain knowledge about 5g and how they implemented their code. Use that knowledge to make the needed changes, then test to verify that it emulates the right speed. The next problem that we will have is getting this to work for device to device connections. One issue we will face is making sure that we can hold the right frequency. We will have to use frequency modulation help us hold the correct frequency to emulate the 5g. Some of the things we hope to accomplish are learning how 5g works, why it can be beneficial in everyday use and also learn about frequency modulation. The outputs of this project will be being able to emulate 5g and use that to connect the device to device.

1.3 Operational Environment

The operational environment will be the Gitlab from the openairinterface and the end product will be able to stimulate and emulate the 5g physical abstraction layer of a cell. Besides we should be able to increase the wireless communication speed between UE. It will also be able to have the capability of having a device to device connection.

1.4 Requirements

The requirements for this project will be putting a virtual machine, we will need Ubuntu 14.03 64-bit architecture, we will need to clone the version of the OAI Gitlab repository.

1.5 Intended Users and Uses

The intended users and uses for this will be anybody wanting to test out 5g or use 5g speed on their device.

1.6 Assumptions and Limitations

Limitations

-Must utilize the most recent version of the 5G code as a base and make revisions to the code.

-Implementation of Device to Device communication as well as having the ability for channel modeling, interference modeling, and radio modeling

Assumptions

-The Physical Abstraction layers will need to allow for simultaneous modeling to provide an accurate test of the connection between towers and devices

-Minimal code will be added to the existing code revision

1.7 Expected End Product and Deliverables

- November - December 2019: Demonstration and performance evaluation of existing OpenAirInterface simulation/emulation systems, detailed design and (preliminary) implementation of the "Physical Layer Abstraction" extension of OpenAirInterface simulation/emulation
- January - March 2020: Spiral evaluation and refinement of the aforementioned enhanced OpenAirInterface simulation/emulation system, as well as the use of the enhanced system for studying 5G wireless solutions
- April 2020: demonstration and report

2. Specifications and Analysis

2.1 Proposed Design

As our timeline indicated, we are still in the learning phase, which included gathering information, installing the necessary software (VM, Gitlab..) and cloning the source codes for inspection. Later weeks we should discuss about the focus points on each code.

2.2 Design Analysis

So far we have started looking over the OAI code and learning about 5g and how it works. We have learned that, each cell is composed of different layer and the most relevant to us, as of right now, is the physical abstraction layer.

2.3 Development Process

The development process that we will use for this project will be a Spiral development process.

2.4 Design Plan

Our design plan will focus mainly on the physical layer of abstraction. We will modify the OAI source code in order to improve the tour to tour and the device to device wireless communication,while minimizing interferences and latency during signal transmission.

3. Statement of Work

3.1 Previous Work And Literature

Include relevant background/literature review for the project

5th generation wireless systems, or 5G, are the next generation mobile wireless telecommunications beyond the current 4G/International Mobile Telecommunications (IMT)-Advanced Systems. 5G wireless system is not only an evolution of the legacy 4G cellular networks but also a system with many new service capabilities. 5G research and development aim at various advanced characteristics, such as higher capacity than current 4G, a higher density of mobile broadband users, and supporting device-to-device (D2D) communications and massive machine-type communications. 5G planning also aims at lower latency and lower energy consumption, for better implementation of Internet of Things (IoT)

– If similar products exist in the market, describe what has already been done

– If you are following previous work, cite that and discuss the **advantages/shortcomings**

– Note that while you are not expected to “compete” with other existing products / research groups, you should be able to differentiate your project from what is available

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

3.2 Technology Considerations

Highlight the strengths, weakness, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

3.3 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and to understand interdependence among tasks.

3.4 Possible Risks And Risk Management

Include any concerns or details that may slow or hinder your plan as it is now. These may include anything to do with costs, materials, equipment, knowledge of area, accuracy issues, etc.

3.5 Project Proposed Milestones and Evaluation Criteria

What are some key milestones in your proposed project? Consider developing task-wise milestones. What tests will your group perform to confirm it works?

3.6 Project Tracking Procedures

What will your group use to track progress throughout the course of this and next semester?

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3.7 Expected Results and Validation

The desired outcome is to find the problems that openairinterface5g had with an older branch in the physical abstraction layer. make the needed improvements to emulate 5g speed. Then take code and implement device to device connectivity. The way to confirm that our solution will work at a high level by running a simple test on our code. The test will give us the results of the speed of the connection.

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

• A realistic, well-planned schedule is an essential component of every well-planned project

• Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity

• A detailed schedule is needed as a part of the plan:

– Start with a Gantt chart showing the tasks (that you developed in 3.3) and associated subtasks versus the proposed project calendar. The Gantt chart shall be referenced and summarized in the text.

– Annotate the Gantt chart with when each project deliverable will be delivered

• Completely compatible with an Agile development cycle if that's your thing

How would you plan for the project to be completed in two semesters? Represent with appropriate charts and tables or other means.

Make sure to include at least a couple paragraphs discussing the timeline and why it is being proposed. Include details that distinguish between design details for the present project version and later stages of the project.

4.2 Feasibility Assessment

Some of the challenges of the project is understanding all the code and what it does. The have a lot of code and most of the code is poorly documented so it can be hard to know what the code is doing. Also, trying to fully understand how 5g works in a short time and understand what improvements we can make that will work and improve the speed.

4.3 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be based on the projected effort required to perform the task correctly and not just "X" hours per week for the number of weeks that the task is active

4.4 Other Resource Requirements

Identify the other resources aside from financial, such as parts and materials that are required to conduct the project.

4.5 Financial Requirements

If relevant, include the total financial resources required to conduct the project.

5. Testing and Implementation

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, or a software library

Although the tooling is usually significantly different, the testing process is typically quite similar regardless of CprE, EE, or SE themed project:

1. Define the needed types of tests (unit testing for modules, integrity testing for interfaces, user-study for functional and non-functional requirements)
2. Define the individual items to be tested
3. Define, design, and develop the actual test cases
4. Determine the anticipated test results for each test case 5. Perform the actual tests
6. Evaluate the actual test results
7. Make the necessary changes to the product being tested 8. Perform any necessary retesting
9. Document the entire testing process and its results

Include Functional and Non-Functional Testing, Modeling and Simulations, challenges you've determined.

5.1 Interface Specifications

– Discuss any hardware/software interfacing that you are working on for testing your project

5.2 Hardware and software

– Indicate any hardware and/or software used in the testing phase

– Provide brief, simple introductions for each to explain the usefulness of each

5.3 Functional Testing

Examples include unit, integration, system, acceptance testing

5.4 Non-Functional Testing

Testing for performance, security, usability, compatibility

5.5 Process

– Explain how each method indicated in Section 2 was tested

– Flow diagram of the process if applicable (should be for most projects)

5.6 Results

– List and explain any and all results obtained so far during the testing phase

- – Include failures and successes
- – Explain what you learned and how you are planning to change it as you progress with your project
- – If you are including figures, please include captions and cite it in the text

  • This part will likely need to be refined in your 492 semester where the majority of the implementation and testing work will take place

-**Modeling and Simulation**: This could be logic analyzation, waveform outputs, block testing. 3D model renders, modeling graphs.

-List the **implementation Issues and Challenges**.

6. Closing Material

6.1 Conclusion

Summarize the work you have done so far. Briefly re-iterate your goals. Then, re-iterate the best plan of action (or solution) to achieving your goals and indicate why this surpasses all other possible solutions tested.

6.2 References

This will likely be different than in project plan, since these will be technical references versus related work / market survey references. Do professional citation style(ex. IEEE).

6.3 Appendices

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc. PCB testing issues etc. Software bugs etc.