Open-Source Prototyping of 5G-and-Beyond Wireless Systems

DESIGN DOCUMENT

Team Number: 15

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Executive Summary

Development Standards & Practices Used

- IEEE and SESC software development standards
- We will constantly communicate for trouble shootings/clarifications
- Show up on time for group meetings and advisor meetings
- We strive to be open about using the open-source platform srsLTE
- Continuous Integration/ Continuous Development
- As we continue development, we may revise important concepts

Summary of Requirements

We need to research concepts of 5G and wireless networks. Specifically, how the srsLTE platform implements their 5G network. We also need to learn how POWDER works and how it uses srsLTE to simulate a 5G network.

Our advisors gave us four resource documents with different scheduling algorithms that we needed to understand to pick the one that we wanted to implement. We have decided to implement the USC algorithm.

Another requirement then is to change the srsLTE source code to implement our picked algorithm and to pick an experiment template on POWDER to run our srsLTE network.

The main goal is for us to learn more about 5G and the software needed to implement it as well as see if implementing the algorithm would improve the scheduling speed of srsLTE.

Applicable Courses from Iowa State University Curriculum

- SE 329
- CPRE/EE 185

New Skills/Knowledge acquired that was not taught in courses

- 5g infrastructure
- Scheduling algorithms
- srsLTE
- POWDER

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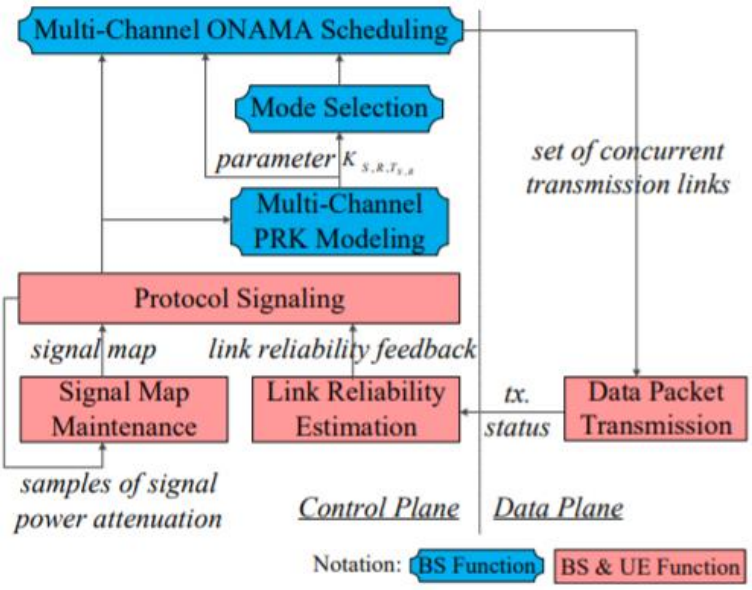


Fig. 1. UCS architecture

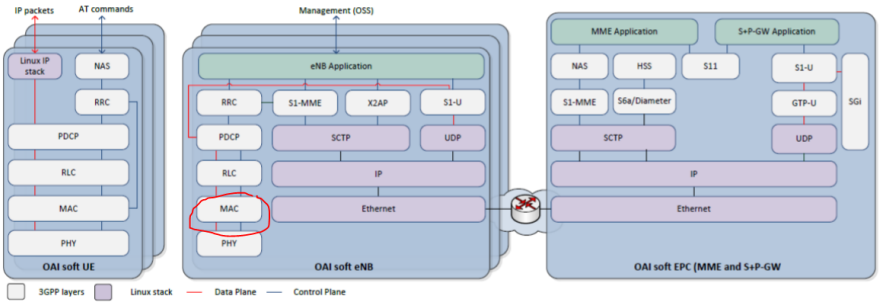


Fig. 2. UCS implementation in MAC layer

1 Introduction

1.1 Acknowledgement

We would like to acknowledge Professor Zhang for the research resources he has provided us with as well as the advice he will be providing us with for the remainder of the project.

1.2 Problem and Project Statement

Problem statement: Advancements in 5G technology have led to an increase in demand for qualified engineers with the ability to develop and prototype advanced

wireless solutions. 5G wireless networks are expected to enable not only Gbps mobile connectivity but also machine-type communications for smart agriculture, connected and automated vehicles, smart grid, Industry 4.0, and AR/VR. 5G wireless is projected to reach a market size of $250 billion by 2025, and it has been attracting significant investment from industry and government worldwide. Our project is in a research capacity, so while we will not be solving any specific problem, we will be looking into ways to improve the scheduling algorithm for 5G Systems.

Solution approach: Through this project, team members will get hands on experience with the development and implementation of advanced wireless 5G algorithms. As a part of the project, members will get to use platform technologies such as srsLTE, USRP software defined radios, and at scale wireless testbeds. Our main work will be done in adjusting and rewriting the Scheduler algorithm in order to improve its functionality.

Project outputs: Experience with platform technologies and testbeds. Knowledge of advanced wireless 5G algorithms, and implementation of these algorithms through at scale wireless testbeds.

1.3 Operational Environment

Our project will operate in a software environment. We will have an open-source software platform (srsLTE) and a testbed (powder) in which it will exist. Due to COVID-19 and lack of resources we will likely not be able to implement our system in a physical environment until the fall semester if at all. If able to implement in a physical environment we will have to consider environmental factors that could affect signal strength and propagation.

1.4 Requirements

Functionality

- Ensures schedule efficiency and must utilize an efficient time allocation process.
- RAN and Mobile core unity ensures communication between base stations and the mobile core.

User Interface: Users of our product must be able to access and use the modified algorithm for academic purposes. For example, future students should be able to understand our code through clear and concise comments.

Non-functional requirements

- Research done on 5G wireless Systems.
- Research done into srsLTE base code.

1.5 Intended Users and Uses

The product will be used for research purposes and other areas of academia. Therefore, the users will be primarily researchers, educators, and students.

1.6 Assumptions and Limitations

- Assumptions:
    - Our research will be used by other researchers in the 5G systems field.
    - Our test environment will apply to real life situations.
    - As a team we have the required skills or the ability to obtain the required skills to complete the project.
- Limitations:
    - Lack of time (need to be done by December)
    - Lack of access to physical RAN
    - Lack of knowledge in the field of advanced wireless algorithms and technologies.
    - This technology is very new so there is not much information or infrastructure for it.

1.7 Expected End Product and Deliverables

Deliverables: Wireless testbed setup, at scale testbed implementation of an advanced 5G wireless algorithm.

- The team will be implementing a simple wireless algorithm on an at scale wireless testbed to gain understanding of algorithm testing using at scale wireless testbeds. This will set the foundation for further analysis and testing of advanced wireless algorithms. To be implemented April 30, 2021
- With the testbed setup complete, the team will refine and test advanced dynamic algorithms. Expected implementation date, Nov 1, 2021.

2 Project Plan

2.1 Task Decomposition

- Complete Research
  - Cover given reference materials on 5G
- Tools Setup
  - Set up GitLab
    - CI/CD setup
  - Website setup
  - Testbed setup
- Implement/refine algorithm using srsLTE
  - Begin with simple implementation of wireless algorithm.
  - Begin implementation of advanced wireless algorithms.
  - Analyze testbed results.
  - Refine the algorithm.
  - Retest
- Refine algorithm using Powder

2.2 Risks And Risk Management/Mitigation

The nature of the project is purely/mostly software based as we are going to be developing algorithms. Therefore, our primary risk is code that does not work 100% of the time for all usage. This is most applicable to our dynamic design since not all UEs will behave as we expect them to. Some of the errors that can cause code to not function as expected are anomalies of the algorithm or user input.

The probability of our code not fitting all scenarios is 1.00 as it is almost impossible for our algorithm to cover everything that 5g can be provided. An obvious mitigation of this is to include as much code testing as possible or at least till we deem it satisfactory.

Cybersecurity is another factor involved in many software-based projects, however, since all code we will be using, and writing is open source and for academic purposes we will be sharing information freely with the public and have no need to worry about cybersecurity.

2.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

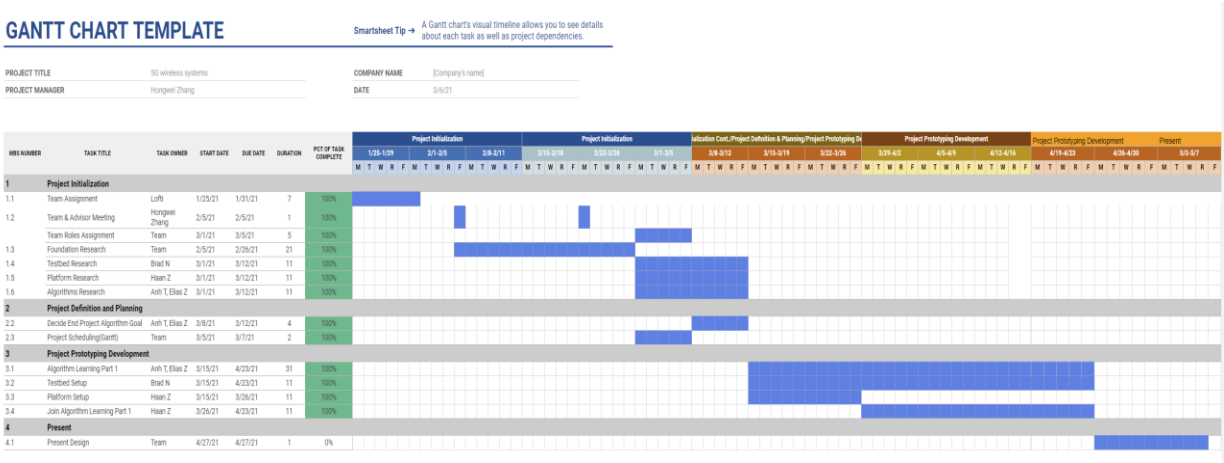
Milestones:

1. Complete research
2. Finish tools setup

3. Implement simple code on platform
4. Prototype of algorithm
5. Finished algorithm

Progress metric will be time spent on the given task.

2.4 Project Timeline/Schedule



2.5 Project Tracking Procedures

GitHub, MS Team, Gantt Chart (Google Excel)

2.6 Personnel Effort Requirements

Members	Anh To	Brad Norman	Haan Zilmer	Elias Zougmore
Time (Coding/Testing) Hours/Week	5hr	5hr	5hr	5hr

2.7 Other Resource Requirements

- Internet access
- Personal computers

- srsLTE
- Reference Materials
- At scale wireless testbeds
- Powder

2.8 Financial Requirements

We have no hardware involved in our project that the university does not already own. The only hardware needed will be provided by our professor and is already a part of his research.

3 Design

3.1 Previous Work And Literature

There are similar products everywhere in 5G wireless systems as each system needs a scheduler in order to function. For example, IEEE put out an article about a scheduler used with time reversal theory and downlink user selection algorithm. We will also be following a paper on scheduling written in part by our professor for base theory for our scheduler.

Our project will differ from each individual theory proposed in the literature by combining ideas from each source. If done correctly this can lead to the reduction of negatives from each strategy while keeping the positives.

3.2 Design Thinking

Through this project, team members will get hands on experience with the implementation of advanced 5G algorithms. We decided to work on srsLTE source code through powder technologies. This decision came up with implementing the static part first. We also thought about working on the mobile aspect of the transmission, which will bring more interference between base stations. We have planned out what we will do throughout the semester, and we have a Gantt chart that helps us follow up on what to do or when they are due.

3.3 Proposed Design

In order to approach this problem, we are thinking about working on the static part first and then we will work on a mobile one. We are trying to implement the source code for the srsLTE mac so we can know what to modify or not. The source code only works with Linux, so we are using a virtual machine to run the code. We are also using Powder to test the code and see how fast the signal can travel with all the interferences that might occur.

3.4 Technology Considerations

We will be using Powder as our testbed for this project and while it gives us the ability to edit the source code directly in the testbed it does remove some of the flexibility that comes with editing the source code in our own environment. Overall, the benefits outweigh the consequences as we will not have to worry about the implementation of the source code into the testbed being an issue. The alternative would be working on the source code in an environment outside of the testbed and as discussed before that solution would bring more negatives than positives. Another limitation of technology we have is a lack of radio to use in testing. Our solution to this problem is to simulate the radios in the testbed as well. With this comes the positive of the ability to run a full test and simulation, however, we will not have the ability to test and adjust our system for real life signal propagation. For this problem there are no existing solutions outside of obtaining radio to use.

3.5 Design Analysis

In 3.3 we proposed to work on the static part and then work on a mobile one. It did not work because we were not able to connect the user equipment to the router. We did not have enough permissions to use the commands. The first thing we should do is get more permissions on powder, then connect the devices and test our implemented code.

3.6 Development Process

We will be using an Agile development process. For our project we will need to have the ability to adapt our planning and code to the results of our tests. The waterfall method would not work for us as it does not allow us to adjust our algorithm to meet the test requirements, and the TDD method does not apply as our testing outcomes will be an analysis of the system functionality.

3.7 Design Plan

Our design will be different than most projects, as our project is solely research based. Therefore, our design will be focused on learning how our algorithm will function when compared to other algorithms. With that in mind the design plan for our scheduler algorithm will be testing and researching how the theory of unified scheduling and downlink scheduling work in a simulated environment.

4 Testing

The algorithm we write will be tested for compilations and goes through our own test cases to ensure that it works for values within our chosen domain. As of right now, our focus is purely on functionality. Quality testing against previous iterations of srsLTE will be done next semester.

Our algorithm design with srsLTE will be tested using POWDER's test suites.

4.1 Unit Testing

Our algorithm will be tested using srsLTE on the powder testbed. Powder offers experiment profiles which contain both fixed and mobile user equipment and base station resources. These recourses allow us to have complete administrative control over the equipment used in the experiment, thus allows us to modify the srsLTE source code within the equipment.

4.2 Interface Testing

Interfacing with srsLTE is done through Linux's command lines in both the user equipment and base station equipment shells. In order to test the functionality of our algorithm we will require interface between at least one base station and one or more static or mobile user equipment. Since our algorithm will be implemented in the scheduler of the mac layer of the base station, we will utilize the tools offered by powder to verify the proper frequency division multiplexing being performed by the base station scheduler.

4.3 Acceptance Testing

The algorithm's functional requirement is that it performs the frequency division multiplexing for the User Equipment's within the experiment's domain. A failure of the algorithm will result in interference between communication channels, the inability for the base station to interface with the User Equipment, slow data rates, mis allocation of resources between User Equipment and base station under test.

4.4 Results

We implemented some of POWDER's experiment files and were able to verify that UEs and base stations were able to communicate with each other.

There was also a separate test done on a virtual machine to see if srsLTE could handle simple uplink and downlink pinging, which it was able to do so.

5 Implementation

For the next semester, we are planning on using the implemented code of srsLTE (the well commented code) to continue implementation of the code and testing. We need to understand the code better to some extend that make changing the code easier. We need to keep testing so we can have the result we are looking for or even get a better result.

6 Closing Material

6.1 Conclusion

Our main goal is adjusting and rewriting the Scheduler algorithm in order to improve its functionality. In order to do this, we implemented the source code of srsLTE and are now working on the testing part of the code implemented. We are using Powder and testbed for the testing. We tried connecting the user equipment to the base station to test the connectivity between them. From there, we will have the adjustment of the source code left to be done, we need to make it so it meets our requirements.

6.2 References

Z. Wu, B. Wang, C. Jiang and K. J. R. Liu, "Downlink MAC Scheduler for 5G Communications With Spatial Focusing Effects," in *IEEE Transactions on Wireless Communications*, vol. 16, no. 6, pp. 3968-3980, June 2017, doi: 10.1109/TWC.2017.2690432.

Yuwei Xie, Hongwei Zhang, Pengfei Ren, "Unified Scheduling for Predictable Communication Reliability in Cellular Networks with D2D Links," https://www.ece.iastate.edu/~hongwei/group/publications/UCS.pdf

6.3 Appendices