4 Design

4.1 Design Content

Our project design revolves around developing a comprehensive learning tool for undergraduate students, utilize key resources of the ARA wireless living lab project, setup at Iowa State University and neighboring areas. This tool is centered around the exploration and application of Software Defined Radios (SDR), specifically using Universal Software Radio Peripherals (USRPs) and an open-source platform OpenAirInterface (OAI). The design content encompasses:

1. Integration of ARA Resources: Harnessing ARA's capabilities, including SDRs, and the OAI platform, to create an immersive learning environment. The integration will allow future undergraduate teams to delve into the practical aspects of wireless communication using state-of-the-art technology, and use this tool and ARA's resources to design a Senior Design Project of their choice.

2. Simulated Learning Environment: Leveraging ARA's sandboxed environment, that represents various elements of wireless networks such as Base Stations (BS) and User Equipment (UE), to deliver hands-on labs and experiments teaching students about the capabilities of SDRs in a risk-free environment.

3. Transition to Real-World Applications: Designing a pathway for students to transition from what was taught in the sandboxed environment, to real-world experiments that involve utilizing the capabilities of OpenAirInterface (OAI) platform to facilitate field experiments, establishing actual BS and UE links.

4. Culmination with a Scheduling Algorithm Lab: The learning tool will conclude with an advanced final lab, that serves as a capstone experience, demonstrating the effectiveness of ARA resources in combination with our learning tool, to implement a practical application. The final lab will involve the modification of the scheduling algorithm implemented in OAI, to enhance cellular network reliability in scenarios involving device-to-device(D2D) links, as outlined by the research paper on the Unified Cellular Scheduling (UCS) algorithm authored by our client, Dr. Hongwei Zhang.

4.2 Design Complexity

The design of our project integrates multiple components and subsystems, each grounded in distinct scientific, mathematical, or engineering principles, demonstrating its technical complexity. Firstly, the Software Defined Radios (SDR) aspect incorporates digital signal processing, modulation techniques, and error correction methods, all of which require a solid understanding of mathematical concepts like Fourier transforms and signal theory. The Universal Software Radio Peripherals (USRPs), serving as the hardware interface, involve principles of radio frequency engineering, signal integrity, and hardware-software integration, requiring knowledge in electrical engineering and computer science. Furthermore, the OpenAirInterface (OAI) platform brings in elements of network architecture and real-time software development, based on principles of computer networking and software engineering.

Our project scope includes multiple challenging requirements that match or exceed current solutions or industry standards, adding to its complexity. This is evident in the implementation of the Unified Cellular Scheduling (UCS) algorithm within the OAI framework, that mirrors complex, real-world problems in cellular network optimization. Our project also demands a sophisticated understanding of Software Defined Radios (SDR) specifically Universal Software Radio Peripherals (USRPs), and the OAI platform integrating these technologies in practical applications that exceed the typical scope of academic projects. The design and development of a comprehensive learning tool by leveraging ARAs resources further align with professional software development standards, emphasizing our project's alignment with the cutting edge of wireless communications technology and education.

4.3 Modern Engineering Tools

We are using many tools for this project, such as:

- **GitLab: for team editing so that everyone has the ability to edit**
- **GitHub: the 5G Site stores its source code here; the GitLab will be synced with this GitHub so that changes to the GitLab persist onto the GitHub**
- **ReadTheDocs: the 5G Site presents its compiled source code from ReadTheDocs**
- **Sphinx & HTML: the 5G Site is written in Sphinx and compiled into HTML**
- **GNU Radio: GNU Radios, provide a framework for simulating radio systems, crucial for our work with Software Defined Radios**
- **Linux Tools (e.g., Bash, SSH, Netplan): Using fundamental linux environment tools for scripting, remote access, network configuration – all essential for managing the ARA resources and SDR/USRP functionality**
- **Network Simulation Tools (e.g., NS3, GNS3): These are employed for creating detailed network simulations, which are vital for testing and validating network protocols and configurations in a controlled, risk-free environment.**
- **Performance Monitoring Tools (e.g., Wireshark, perf, GDB): These tools are essential for analyzing network traffic, monitoring performance, and debugging, helping to optimize our applications and troubleshoot issues.**

4.4 Design Context

For our project, we are making a website that don't really affect a lot of these area's. So, we will be answering a lot of these questions about the generalities of improving the accessibility of 5G as we learn and implement the website.

The main community will be students in the future that will be taking 491 as well as assigned this project for their senior project. This can community can also be anyone that is also interested in understanding how 5G works, but the main focus will be in class 491 senior design.

By the end of the project, we hope that we can make a difference with rural areas and possibly urban areas with 5G. Society, especially rural and urban areas have problems with 5G accessibility whether it is some kind of interference with transmission or lack of signal overall. We strive to understand 5G more and why these problems are still existing in today's society.

Area	Description	Examples
Public health, safety, and welfare	How does your project affect the general well-being of various stakeholder groups? These groups may be direct users or may be indirectly affected (e.g., solution is implemented in their communities)	**With 5G accessibility available in rural areas, safety can be improved by increasing automation of technology unmanned. Decreases accidents.**
Global, cultural, and social	How well does your project reflect the values, practices, and aims of the cultural groups it affects? Groups may include but are not limited to specific communities, nations, professions, workplaces, and ethnic cultures.	**Improving 5G will overall affect the world. Simply because the work done in rural area's help feed a large percentage of the world. With 5G access, they are able to check the quality of crops and livestock's and gather data. If this can help solve problems for people that live in rural areas then this perhaps aligns with their values. Although implementation of more technology in rural areas can be counterintuitive to some people in rural area's that perhaps want to get away from technology.**
Environmental	What environmental impact might your project have? This can include indirect effects, such as deforestation or unsustainable practices related to materials manufacture or procurement.	**To increase accessibility, this might require more technology to be implemented, which can increase costs, and energy. We could use solar power, but this adds another problem of energy effiency and how much is required to power such technology in rural area's.**
Economic	What economic impact might your project have? This can include the financial viability of your product within your team or company, cost to consumers, or broader economic effects on communities, markets, nations, and other groups.	**With the website, it is simply free and accessible. But on the accessibility of 5G we realized that it takes a lot of money to implement RAN's and UE's**

4.5 Prior Work/Solutions

Include relevant background/literature review for the project

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

5G open-source platforms provided by the client:

- srsRAN
- OpenAirInterface (OAI)
- O-RAN software community

ARA software was provided as well which allows us access to Sandbox

Additional open-source platforms in relation to 5G:

- Open Compute Project
- Aether
- Open5GCore
- Introduction to open source private LTE and 5G networks

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

- The site linked here is the closest representation to the product being made here and previous work that provides the biggest influence on the product being developed by our team.
- Advantages here are that the previously existing site provides a general outline of the necessary learning components of understanding and applying 5G. It shows us what information is already included which always us to build on the information and generate detailed labs using ARA sandbox.
- Shortcomings here are that the site already includes highly in-depth information and learning tasks that require us to think of higher-level concepts and, in addition, we have to think of ways to differentiate our product from this already existing product.

– 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. Thus, provide a list of pros and cons of your target solution compared to all other related products/systems.

- Pros:
  - Higher level learning modules
  - Labs
  - More in-depth information
- Cons:
  - Lots of overlapping information
  - Learning material with be updated by similar

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.

(what other websites/resources online already exist?)

Mentioned above.

4.6 Design Decisions

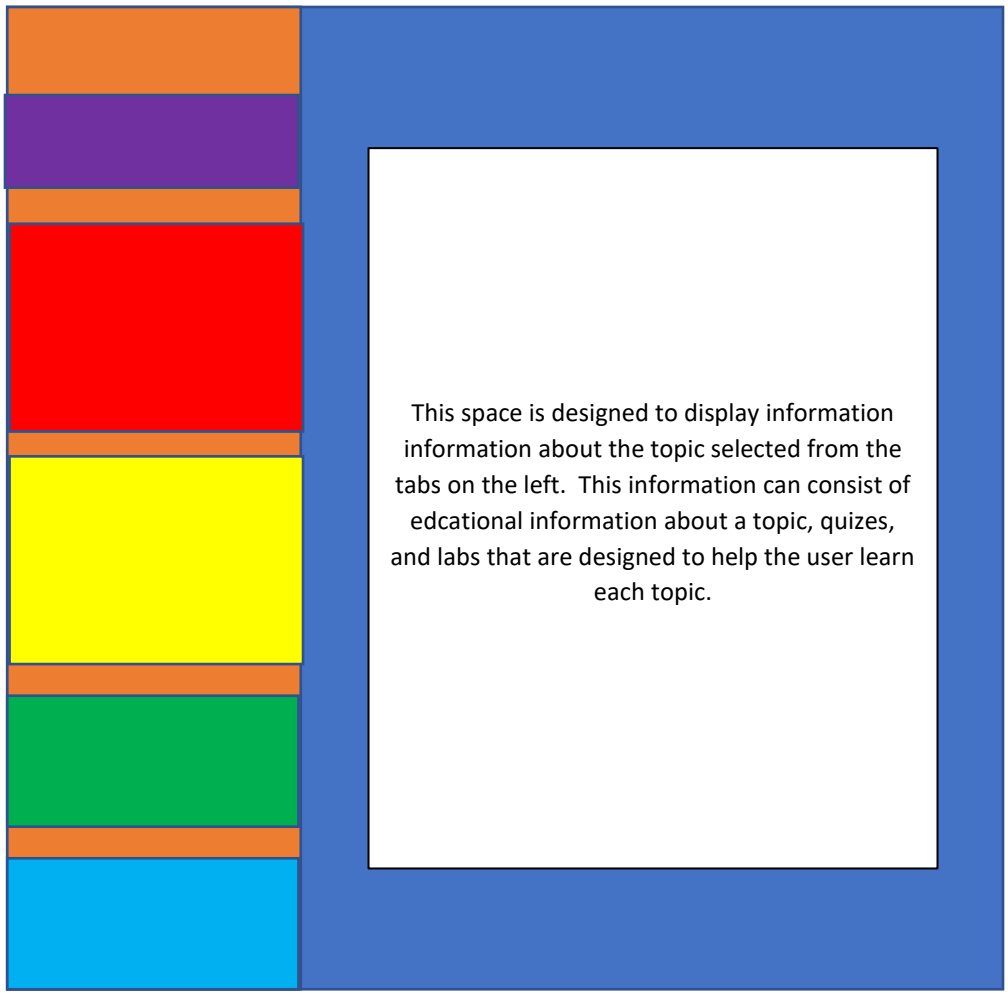
1) **Incorporating the use of interactive, hands-on labs**
    a. **Taking advantage of ARA Tools such as Sandbox in a manner to help convey information concerning 5G networks. These labs with help users gather an understanding on SDRs, OAIs, USRPs, etc. By teaching users this information, it will force them to gather a grasp on how 5G networks operate.**
    b. **The final lab we create will be a scheduling algorithm implemented in OAI, to enhance cellular network reliability in scenarios involving device-to-device(D2D) links. Therefore, the user will need to have completed previous labs to have a complete understanding which is why this lab will be listed last.**
2) **Connecting our private GitLab with a public GitHub and ReadTheDocs**
    a. **We were given a private GitLab from our client that was designed to contain the program for our website. The website is hosted using ReadTheDocs which contains the labs that are created and information. Due to ReadTheDocs needing a public Git in order to host the website we decided we would clone the private GitLab to a public GitHub in order to connect to the host.**
3) **Using simple English and easy-to-understand language**
    a. **A big part of our project is appealing to an audience that has basic knowledge of 5G and is seeking to learn. Because of this, we will be avoiding the overuse of complex technical jargon. Although some technical words will be needed, we will thoroughly describe and define them to ensure our materials make sense.**

4.7 Proposed Design

4.7.1 Design 0 (Initial Design)

Design Visual and Description

Diagram for the Website:



Key:

Orange: represents the five main topics that are represented on the website

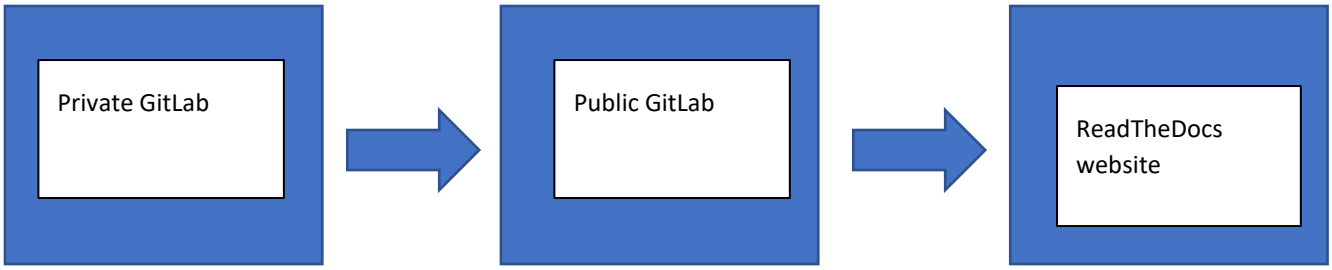
Purple: represents the getting started topic on the website. This contains brief information that the user should know before diving deeper into the material.

Red: represents the learning modules that are available on the website. Some of these modules consist of user equipment, Radio access networks, 5G physical layer, ect. Each one of these sub topics will have several tabs as well to help with assist with the learning and a quiz at the end to ensure the user understood the material.

Yellow: represents multiple experiments that are accessible for the user to help further insight on material. These will be very hands on and will assist the user through difficult labs to help gain experience with information from the modules.

Green: represents ARA technical overview. This goes into detail about how ARA operates and helps gain a further understanding. This tab will go into detail about ARA infrastructure, backhaul networks, and wireless access networks.

Blue: represents the about us tab which is a brief description of each team member. This is used so the user can gain a quick understanding of who created the website and the background experience of each member.



The diagram above demonstrates how the gitlab is linked to readthedocs. We have all our code stored in a private gitlab that allows us to make modifications locally. From there we then clone the gitlab to a public github in order to establish a connection to the host for the website readthedocs. Readthedocs is able to read our files from a public github to generate the website.

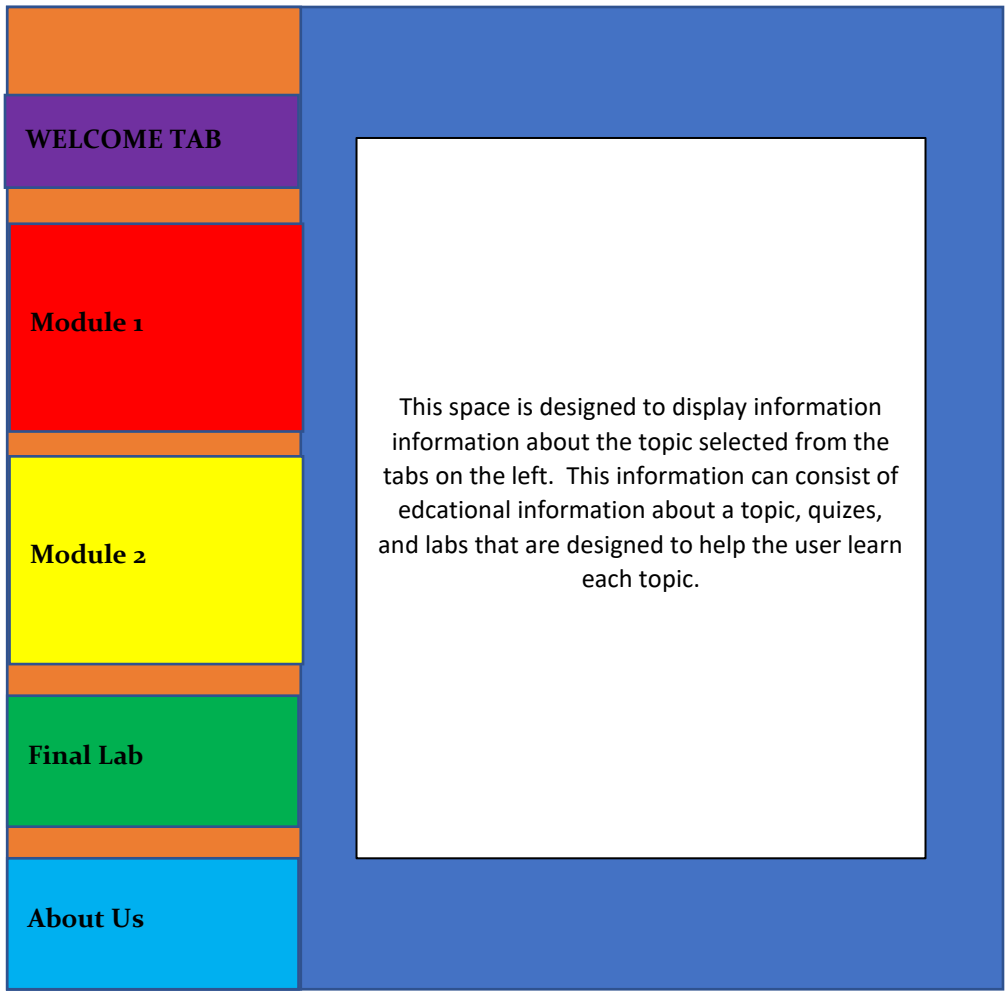
Functionality

The current design satisfies the functional requirements due to it providing a visual representation of how the website works. Our functional requirements are adding open-source material and improving the preexisting websites material to make it easy for users to learn material. These designs provide our group with a smooth way to execute our functional requirements.

-- OPTIONAL FROM HERE ON --

4.7.2 Design 1 (Design Iteration)

Include another most matured design iteration details. Describe what led to this iteration and what are the major changes that were needed in Design 0.



NOTE: There are more that 2 modules and was displayed this way due to lack of space on the image.

On the new design we have decided to design the website to separate our learning material into modules. These modules will be based around a topic which will contain educational information, a quiz, and a lab that the user will be able to complete. The information will be displayed first, then a quiz to ensure they comprehended the material, and then followed by a hands-on lab. The welcome tab will be a brief description of the content that will be provided. Finally, the About us will just be a quick description of our team.

Design Visual and Description

The biggest changes that occurred our we are going to structure around labs that are about each module. We will continue to have information about the topic but the main objective is to complete hands-on labs.

We will also be creating a lab on a scheduling algorithm implemented in OAI, to enhance cellular network reliability in scenarios involving device-to-device(D2D) links. These changes allowed us to fulfill requirements for the project. When generating these labs, we will not only need to have a great understanding but will also need to engineer labs that contain a lot of information but are able to be completed.

NOTE: The following sections will be included in your final design document but do not need to be completed for the current assignment. They are included for your reference. If you have ideas for these sections, they can also be discussed with your TA and/or faculty adviser.

4.8 Technology Considerations

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

Discuss possible solutions and design alternatives

4.9 Design Analysis

- Did your proposed design from 4.7 work? Why or why not?
- What are your observations, thoughts, and ideas to modify or iterate further over the design?