Design

3.1 Design Context

3.1.1 Broader Context

Describe the broader context in which your design problem is situated. What communities are you designing for? What communities are affected by your design? What societal needs does your project address?

List relevant considerations related to your project in each of the following areas:

Area	**Description**	**Examples**
Public health, safety, and welfare	Our project will potentially help increase the yield and health of crops or livestock. This will mean that society will have more food to consume, leading to lower prices over time and less health concerns.	Decrease bad product, meaning more food can be produced in meaningful amounts.
Global, cultural, and social	Farmers are hardworking, thus always looking for better ways to do their job. Our project will reflect this desire to use their time more effectively.	Automation in feeding will allow farmers to prioritize the health of their animals in other areas like living conditions, and also reduce work on their end.
Environmental	Our project can make farming more sustainable and less demanding for the farmer. This will lead to higher yields, quality of product, and increased time utilization where not applied.	Higher quality crops can be produced because of automation, especially if that means picking them as soon as they are of the highest quality.
Economic	Our Project will do one of two things: Automation or video-based livestock farming. Automation would allow farmers to run tasks without having to work on it themselves- allowing them to better use their time on what matters more. Livestock farming could also allow farmers to understand how much their livestock eats, drinks, and when and by what it may have gotten sick by.	Automation: analyze how much food is left in each area, and automatically use a robot or another device to deliver the precise amount that is needed. Livestock: Analyze how much each animal eats, leading to a higher understanding of dietary items. If they eat higher quality food, the animal could be sold for more.

3.1.2 User Needs

List each of your user groups. For each user group, list a needs statement in the form of:

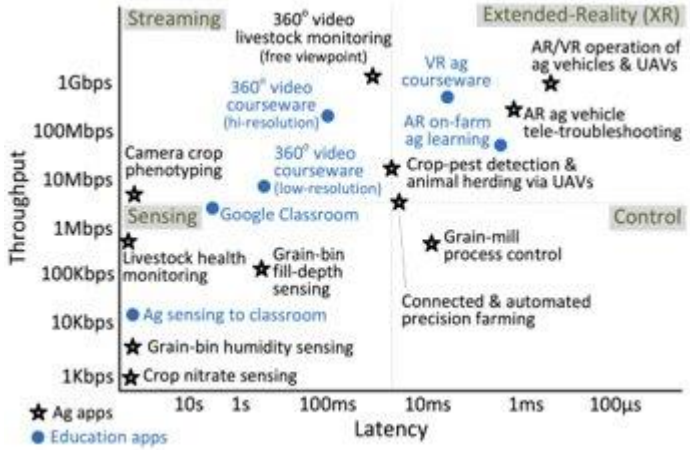
User group needs (a way to) do something (i.e., a task to accomplish, a practice to implement, a way to be) because some insight or detail about the user group.

- Commerical Farmer

A commercial farmer needs to be able to run his farm in an efficient manner and because of this he wants to utilize new technology as it becomes available.

- Dr Hongwei's requirements

Dr. Hongwei needs our solution to use a data rate and latency in our design that would require a 5g network to accomplish, so that our project can be of value to his 5g research.



3.1.3 Prior Work/Solutions

Include relevant background/literature review for the project

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

There exists current ways to connect video feed and other data wirelessly such that it can be viewed and processed remotely.

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

Previous solutions are not designed or optimized for the new 5g ARA network and similar networks that will become increasingly available to farmers and rural communities.

– 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.

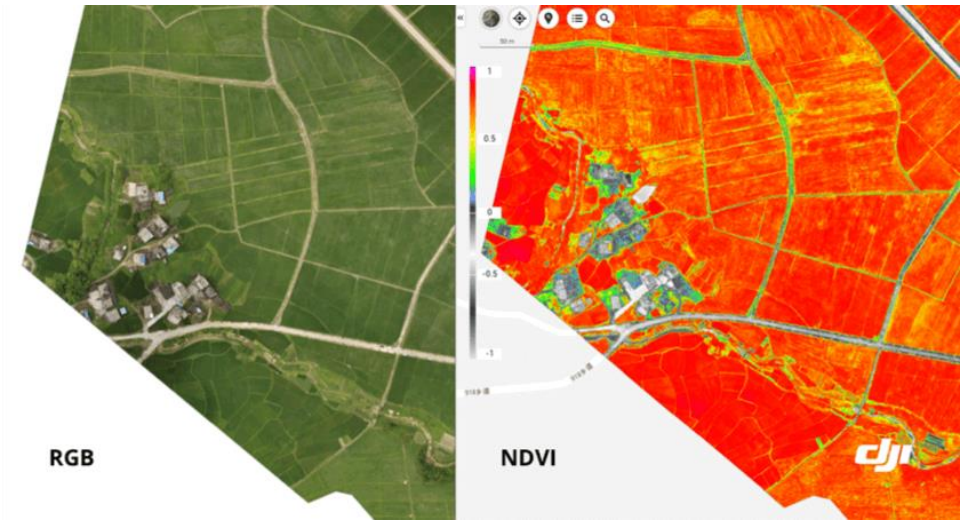
Our system will be designed to use the ARA network and potentially future 5g networks.

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.

- research on drone usage (sam)

There is research being done on how to use drones to image farmland to create images of farmland to track soil moisture and other research on using the cameras to automate targeted pesticide spraying. Below is an example of using infrared light to identify locations in the field that are in need of moisture.

https://enterprise-insights.dji.com/blog/drones-in-agriculture,



- IoT soil sensing (cristofer)

Some companies are currently using wireless infrastructure for soil sensing. Soil can be tested for pH levels, mineral content, soil moisture, and salinity among a plethora of other factors to plant health. Testing is performed to improve nutrition in soil, protect the environment from contamination by runoff and leaching of excessing fertilizers, and aid in the diagnosis of plant culture problems. This allows for optimized and efficient crop production. Farmers save money from reduced yield loss and applying only the amount of fertilizer needed.

One company that is currently doing this is Farm21, based in Amsterdam. They provide in-field soil probes to capture agri-data. Their technology utilizes previous wireless technology (2G/LTE-M/NB-IoT).

- phenotype bot

Current research is being done through ARA in collaboration with Iowa State looking at using robots to help with phenotyping crops and eventually will involve sending that data through the wireless network.

https://arawireless.org/research/agriculture-use-case/,

- insta360 pro john deere video feed

John Deere is working on automating seeders, sprayers, and combines with the use of sensors and cameras which requires high-speed and high-data-rate connections between the sensors and the tractors.

https://arawireless.org/research/agriculture-use-case/,

- microsoft smart farming

Microsoft is conducting research on how to minimize the costs of collecting and transmitting data for smaller farm settings. For example, using balloons instead of drones and using TV whitespace to transmitt data instead of the frequency bands that make up wifi.

https://www.microsoft.com/en-us/research/uploads/prod/2022/09/Democratizing_Data-Driven_Agriculture_Using_Affordable_Hardware.pdf,

https://www.microsoft.com/en-us/research/uploads/prod/2020/04/SIGCOMM_Editorial.pdf,

3.1.4 Technical Complexity

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

1. The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles –AND–
2. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

In order to be successful in our design we need to have an understanding of a variety of complex topics such as the ones listed below

- understanding of communication system modulation techniques
- understanding of developing technology such as massive MIMO, beamforming, network splicing
- understanding of computer/mobile network architecture
- embedded system C programming for 5G RAN solution

Additionally, we will be transmitting our data of the ARA wireless network which is something other projects, such as the phenotyping bot, have not yet implemented into their design.

3.2 Design Exploration

3.2.1 Design Decisions

List key design decisions (at least three) that you have made or will need to make in relation to your proposed solution. These can include, but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc.

- Current ARA projects' progress -> video feed

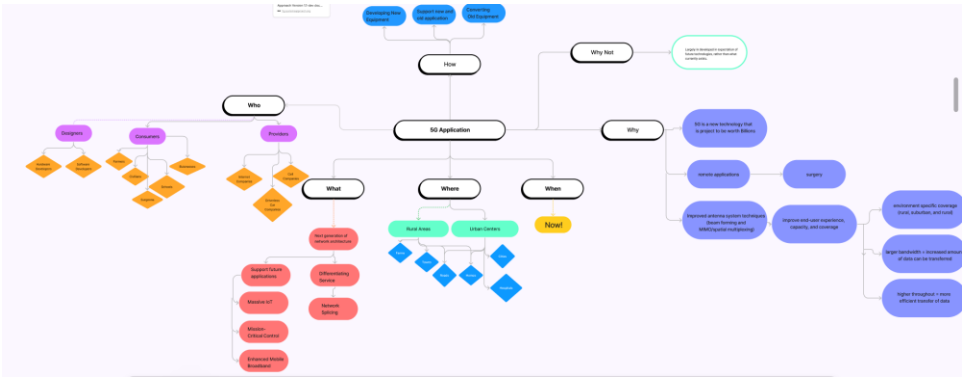
- Dr Hongwei's requirements -> XR, video feed, automation OVER IoT Sensing

-Interacting with the network ->srsRAN_Project open-source code (C)

-User experience-> Monitor displays, VR equipment, displayed information, etc.

3.2.2 Ideation

For one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). List at least five options that you considered.



The project proposal given to us was very open-ended. Our advisor prompted us to develop an application to run on the newly created ARA 5G network that either focused on agriculture or educational purposes. Once we decided on following through with the agricultural application, we went through many different design application ideas for different use-cases. We wanted to find an application we thought would meaningfully impact the agricultural community and utilize the full power of the new 5G technology.

To figure out our options, we first looked at the current issues within agriculture and potential applications we could create to solve these problems. Some of these issues were as follows:

- Soil contamination
    - Use soil sensors and IoT devices to monitor soil quality
- Livestock monitoring
    - Use biometric sensors and video feed to give real-time updates to farmers
- Crop Growth
    - Pheno-bots and drones give collect data for real-time and high throughput phenotyping and precision farming
- Agricultural Automation
    - Use drone to autonomously spread pesticides on crops
- XR Farming
    - Use VR equipment to remotely control farming equipment or to improve the user farming experience

3.2.3 Decision-Making and Trade-Off

Demonstrate the process you used to identify the pros and cons or trade-offs between each of your ideated options. You may wish you include a weighted decision matrix or other relevant tool. Describe the option you chose and why you chose it.

After brainstorming our potential applications, we assessed the feasibility of each project and if the project would benefit by using the new 5G network. Because our client's main concern is applications that utilize the high data transmission and low-latency aspects of the 5G network, we decided to choose an application that inhibits video data. This data can be crucial for making real-time decisions while farming and the private network allows for data speeds that are not common in other rural areas. This limited our choices to

both livestock monitoring and using VR/XR to improve upon current farming methods. Since our advisor is eager to begin both these applications, he has directed us to start looking into both and begin the groundwork for future improvements.

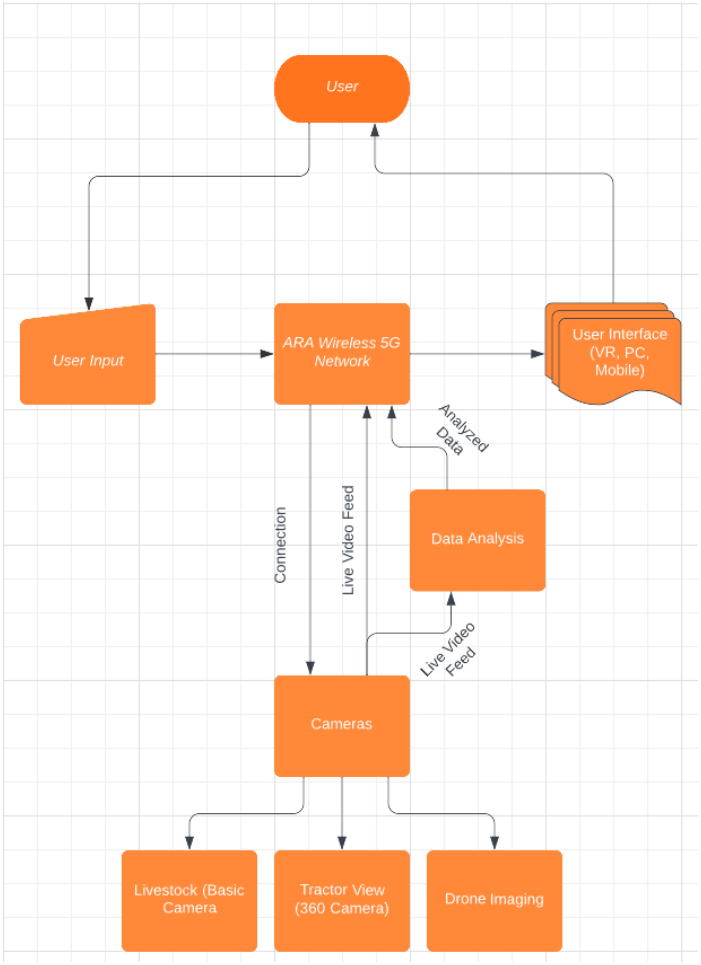
3.3 Proposed Design

Discuss what you have done so far – what have you tried/implemented/tested?

- - Proposed IoT soil sensing
    - Look at what composes the soil (minerals, etc) and deliver data to farmer
- - Looking into 5G srsRAN solution (open-source code for UE-BS connection)
- - Live video feed applications and data analysis
    - Possibly investigate OpenVR (open-source VR code) and ways to implement them into agricultural applications
- Automation in farms
    - Automate feeding
- 5G Security analysis
    - Look for exploits, issues that can be either patched or used later

3.3.1 Design Visual and Description

Include a visual depiction of your current design. Different visual types may be relevant to different types of projects. You may include: a block diagram of individual components or subsystems and their interconnections, a circuit diagram, a sketch of physical components and their operation, etc.



Describe your current design, referencing the visual. This design description should be in sufficient detail that another team of engineers can look through it and implement it.

A user should be able to access the ARA wireless network, from there, the user will have access to a few different cameras. With the combination of 5G and the connection to the cameras, the user will have a live video feed and be able to see what the camera(s) see in real time. The user should be able to view analyzed data that comes from the video feed. The data should be analyzed in real time, which would allow the user to see everything needed from the cameras.

3.3.2 Functionality

Describe how your design is intended to operate in its user and/or real-world context. This description can be supplemented by a visual, such as a timeline, storyboard, or sketch.

The functionality of our design is quite simple on a top-level, generic look:

- Users will have access to the ARA network. User interface can range from mobile devices to desktop computers, to even virtual reality devices
- Through 5G technology and the ARA wireless network, connections will be available to many different cameras (IR cameras, 360 cameras, basic security cameras, etc.)

- From this connection, data from cameras will be seen in real time by the user. The cameras can be used for many different applications such as livestock farming, autonomous vehicle control, and real time data collection

How well does the current design satisfy functional and non-functional requirements?

- The current design is experimental and a top-level look into many possible applications. We are looking at live video feed applications, so now, we are working on developing the connections and 5G code related to live video feed. From there, we plan on looking into ways of collecting and analyzing data from that connection, and creating a process where there is very little to no latency between the user and the application.

3.3.3 Areas of Concern and Development

Based on your current design, what are your primary concerns for delivering a product/system that addresses requirements and meets user and client needs?

An immediate concern of ours is testing our code and solutions for the live video feed. We need to look at many performance characteristics, such as throughput, delay, delay jitter, reliability, quality of experience, etc. We need to be able to properly determine these performance characteristics to create the best solution possible for our design.

Developing a connection with the network is also a small concern of ours. We are all quite new to networking, however, we have many people in this project that can help with this.

What are your immediate plans for developing the solution to address those concerns? What questions do you have for clients, TAs, and faculty advisers?

We plan on sitting into some of the tests currently being worked on and developed with the ARA network. We've contacted many different researchers in this field and are setting up times to come and observe experiments and performance characterization.

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.

3.4 Technology Considerations

Strengths	Weaknesses
- better coverage due to beamforming techniques - higher system spectral efficiency	- obsolescence of previous generation devices that are not 5G capable

- broadband cable internet-like experience (10Gbps peak data rate, less than 1ms latency) - higher throughput	- new infrastructure required, not necessarily a cheap transition

3.5 Design Analysis

Our group has discussed at length what projects we want to focus on, and of all the projects none of them have stuck as long as the projects in development on the ARA wireless website.

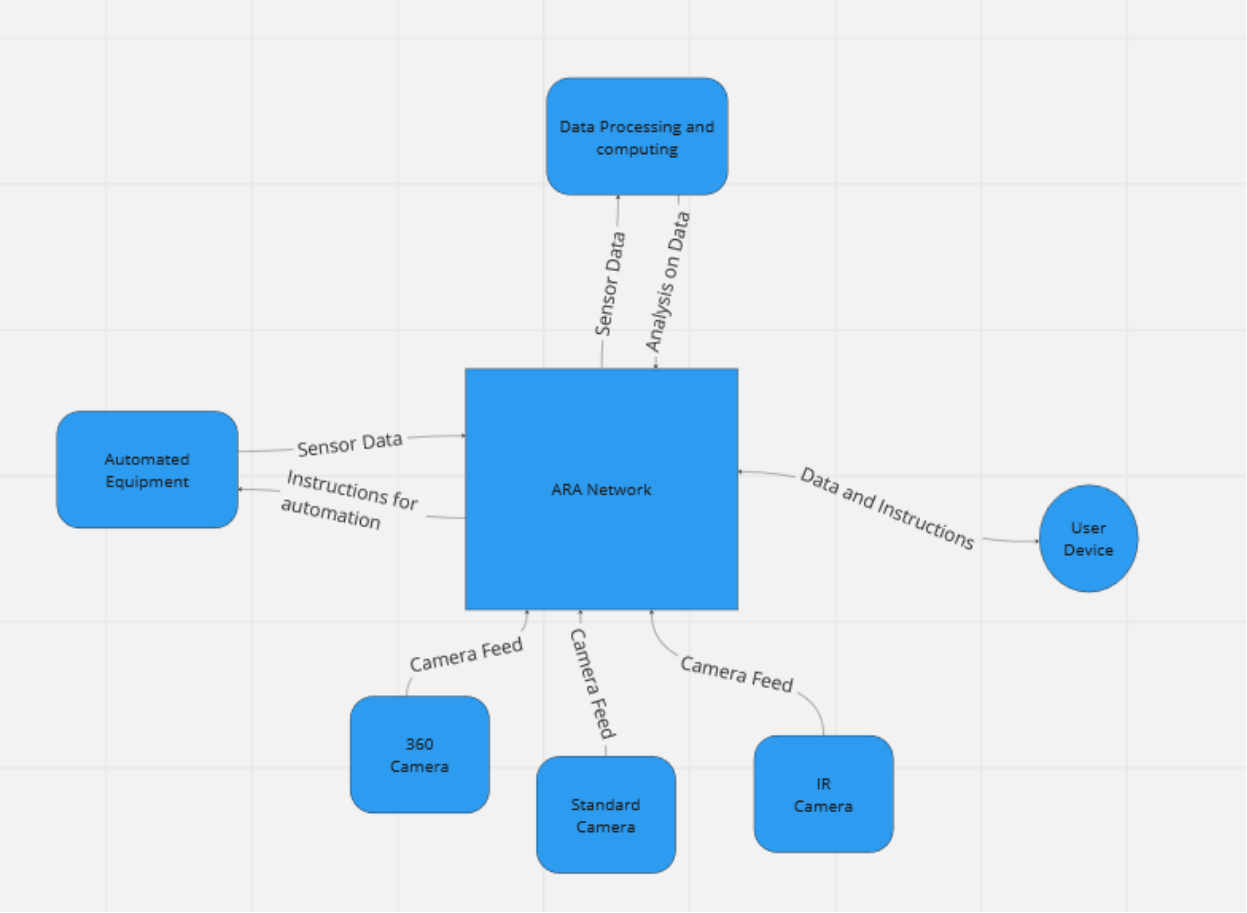
Projects like IoT soil testing are useful, but ultimately would fail to effectively use the full range of 5G capabilities. Thus, the current idea with the most traction is the Live video feed application and data analysis. This project has several advantages that do not exist in other areas:

1. The hardware (for the most part) exists and is easy to install and use.
2. The live analysis can be delivered instantaneously, allowing for up-to-date data at all times.
3. 5G by its nature is not tied to wires, thus allows for interconnectivity over vast areas.
    a. This allows for different key factors to be analyzed all at once, and as the data begins to come in consistently, allows for trends to be created.
4. Implementations of similar projects are in active development, or otherwise have resources for us to utilize.

For these reasons and many more, live video analysis is only one of the two strongest designs for us to look at. This further extends to Automation, which makes life easier as a baseline for farmers.

3.6 Design Plan

Because of the open-ended nature of our project our design plan had to be adaptable to the various projects we wanted to look into. A lot of the modules already exist separately for the most part so our design had to incorporate these existing modules together. All of our modules are dependent on the ARA Network which is how we establish the 5G connection between devices.


Data Processing and computing
Sensor Data
Analysis on Data
Automated Equipment
Sensor Data
Instructions for automation
ARA Network
Data and Instructions
User Device
Camera Feed
Camera Feed
Camera Feed
360 Camera
Standard Camera
IR Camera