3 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	Quantum computers have the possibility to affect every aspect of modern life. Conversely, quantum networks will enable these computers to coordinate and share information.	Increasing human understanding of virtually every field of science and thereby improving the quality of human life.
Global, cultural, and social	The project we are working on has the long term potential to affect virtually every human being on the planet. For our purposes, we intend to integrate a humanistic approach to our work. This means that as we design and realize our work, we are always considering the impact to humanity and its best interests.	As a potentially powerful tool, it will be possible to enable great harm to society and also great benefit as well.
Environmental	Immediately this project has no environmental impact. However it does have the potential to drastically impact the environment.	Will likely aid in the developing of renewable materials and battery solutions etc etc , will likely have a dramatically positive impact but may also have a profoundly negative one as well
Economic	Immediately this project poses little impact on the local or global economy. This project is serving as a prototype for a later physical implementation. Long term this project may have some significant impact on economic activity.	Product will be a simulation of a network. This will be free. Our client does not need to pay us for this either.

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

Dr. Durga needs us to design a system that can take a list of quantum computing tasks, and split them into nodes and determine which nodes need what information. Our quantum router needs to be able to send quantum information to the correct node and the correct timing so that there are no errors or mistakes.

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

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

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.

Quantum routers exist and have been used in a closed setting, but they have never been used as a quantum cluster to split quantum tasks into smaller tasks. Classical clusters are used extensively in computing but they have never implemented any quantum elements. Our project is going to combine both of these to create the first ever quantum computing cluster. *ex)IBM Quantum router : https://arxiv.org/abs/1803.06530*

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.**

Our project fulfills these needs. We are going to have two iterative designs: a cluster computer that starts with each node and has tasks that have no dependencies on each node. That should be easier because the router just has to juggle errors from each node. These "errors" should have no correlation between each node. The next step is to have the tasks are what we call "later dependencies." For example, if our cluster has 2 nodes, A and B, and task 30 of B requires an answer from task 3 of node A. If everything moves smoothly there should be no issues. However, if A gets stalled there should be a functionality that alerts the primary computer that node B might need to stall. That is where an interrupt handler will come in. We will create an interrupt handler that will handle all the errors that we find. For example but not limited to, if entanglement has an issue the classical portion will fire an interrupt to let the primary router know what to initiate to fix the issue.

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.

1. Deciding how much information should the quantum nodes have, should they know that there are other nodes, this would generate problems with node configuration but would help with routing. We have decided to make our quantum nodes as simple as possible to help the system be as scalable as possible and easy to implement more nodes.
2. Task Distribution and Scheduling we have decided to first implement a system with no dependencies and implement this into our switch later in development.
3. How quantum information will be exchanged. We decided to use one of the basics of quantum computing, Bell states or EPR pairs, which are used to exchange quantum information over a short distance with reliability. On top of this, our router will use quantum swapping to exchange information between nodes.

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.

For deciding on the quantum nodes, we considers a

- Quantum nodes have an entire operating system and route themselves.
- Quantum nodes know only their closest neighbors
- Quantum nodes route through the router but create the destination themselves
- Quantum nodes have no knowledge other than what their task is
- Quantum nodes know how to send it back to the router when they are done

3.2.3 Decision-Making and Trade-Off

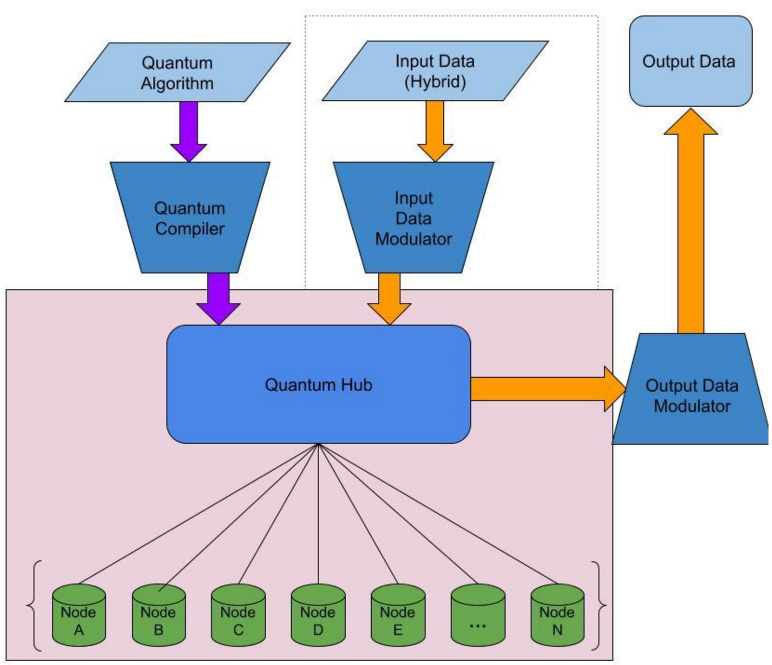
Demonstrate the process you used to identify the pros and cons or trade-offs between each of your ideated options. You may wish to include a weighted decision matrix or other relevant tool. Describe the option you chose and why you chose it.

		63	90	112
Options		No depende	Later depen	Immediate c
Decision making factors	Weighting	Your Score	Your Score	Your Score
Complexity	1	1	5	10
Scalability	5	4	8	10
Speed	3	10	7	4
Usefulness	4	3	6	10

It is preferable to pick an immediate dependency. We want to choose this because it is easy to scale and it has uses that far outway the other two options. It also gives the user the most options for jobs that they can give to the cluster.

3.3 Proposed Design

3.3.1 Design Visual and Description



This diagram shows our quantum network for cluster computing very conceptually. For cluster computing, we should first take care of distributing one big job to several tasks which also requires very profound algorithms. Since it is not what our advisors and customers expected of us, we assume that one job is already distributed efficiently. What we are trying to achieve is to make a quantum router which is almost the same as a scheduler in a classical cluster computing or in an operating system. What differentiates between classical cluster computing router and our quantum cluster computing router is that our quantum router includes quantum gates which enable us to share data the same as the speed of light. To do this, We're planning to take care about error correction of quantum nodes, dependency of distributed tasks etc. But we're planning to make a very rudimentary quantum network router and move to take care of real problems such as error correction and task distribution.

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.

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

As we highlighted several times, this topic is state of the art of technology and still needs intensive research concerning building practical quantum networks. For example, we need to take care more seriously about the difference between quantum and classical when we distribute a single job to multiple tasks for the quantum router scheduling process. But since that is not our goals and needs for our advisors and customers, we're not caring about practical difficulties when we're simulating at the first time. We're planning to take care of practical difficulties after we successfully get a rudimentary version of quantum networks. However, our simulated version of the network will be used for the basic structure of Dr Durga's future research. And our simulated version of the network also works well if we have the same environment as our simulation's assumption. For example, our work can be used to compute complex quantum operations which would take too long to compile on one quantum machine when the ideal state is assumed. It will need to do this quickly and reliably as well as not lose any information along the way. This design works because it will be scalable, as once the switch is working, we can implement as many nodes as we want which will all increase how fast our system can compute complex algorithms.

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?

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

Our main concerns are about scheduling and dependencies on our tasks which are essential parts of what our advisors and customers need. Our immediate plan for our project is, thus, to make a rudimentary quantum network for quantum cluster computing to meet basic requirements for our advisors and users. We assumed ideal states for some points to meet our primary goal for this, such as, we're assuming that quantum information that we used for our simulations are entangled and very stable. After we handle the primary problem, we're planning to consider other practical considerations such as error correction, entanglement time.