Research Plan for CSE3000 Research Project

Noisy Byzantine agreement protocol in a small quantum network

Kimon Kyparos

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Background of the research

This research project tackles the problem of applying a Byzantine agreement protocol on a quantum network. It involves implementing a Byzantine agreement protocol on a four-qubit network and assessing its potential performance on real hardware. This is done by simulating the network and using a noise model to mimic errors caused by imperfect hardware, specifically measurement errors. The quantum variant of this protocol is worth exploring, as it allows reaching consensus with a maximum number of faulty components $t < n/2$, where n is the number of components. This is a significant improvement over the $t < n/3$ achieved by the classical variant.[1].

Research Question

Main Question
"How is the failure probability of the quantum Byzantine agreement protocol influenced by measurement errors?"

Sub-Questions

- What is the failure probability of the protocol when running on perfect hardware?
- Why do measurement errors affect the failure probability?
- What is the failure probability of the protocol after introducing simulated measurement errors?
- Is this quantum variant a feasible improvement over the classical implementation?

Method

The main tool used in this project is SquidASM, a Python SDK used to simulate quantum networks. Collaboration with the peer group will include deciding on a general implementation of the protocol, although each student will write their own code. Additionally, each student will use a different noise model, which they will also have to implement.

Planning of the research project

Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Start reading related papers (e.g. [1], [2])	Start implementing basic noiseless protocol	ACS Assignment 2: Author Feedback and Midterm poster	Rework poster	Midterm presentation
Follow SquidASM tutorial	Recreate graphs from Figure 4 of [1] (with lower samples)	Improve graphs (DelftBlue?)	Group meeting: Set date for final presentation	ACS Assignment 3: Improve first 300 words and add section
Meeting with supervisor - divide research questions	ACS Assignment 1: First 300 words	Group meeting: Compare code progress	Start working on adding "measurement error" noise	Group meeting: Receive midterm feedback

Week 6	**Week 7**	**Week 8**	**Week 9**	**Week 10**
Complete protocol implementation including noise model	Paper Draft v1	Implement Paper Draft v1 Feedback	Finalize paper	Finalize poster
Expand paper: Definition and implementation of model	Peer Review Draft v1	Expand data and graphs	Group meeting: Feedback on final state of paper	Final presentation
Group meeting: Assess progress, Decide if expansion of RQ is possible	Group meeting: Receive feedback on Paper Draft v1	Start working on missing paper sections	Submit final paper	
Produce initial failure probability graphs	Start working on Results section	Paper Draft v2		

References

[1] Guba et al. "Resource Analysis for Quantum-aided Byzantine agreement with the four-qubit singlet state". In: *Quantum* 8 (Apr. 2024), p. 1324. DOI: 10.22331/q-2024-04-30-1324.

[2] Tao Shang et al. "Multi-party Quantum Byzantine consensus based on full quantum one-way function". In: *Quantum Information Processing* 24.1 (Jan. 2025). DOI: 10.1007/s11128-024-04621-5.