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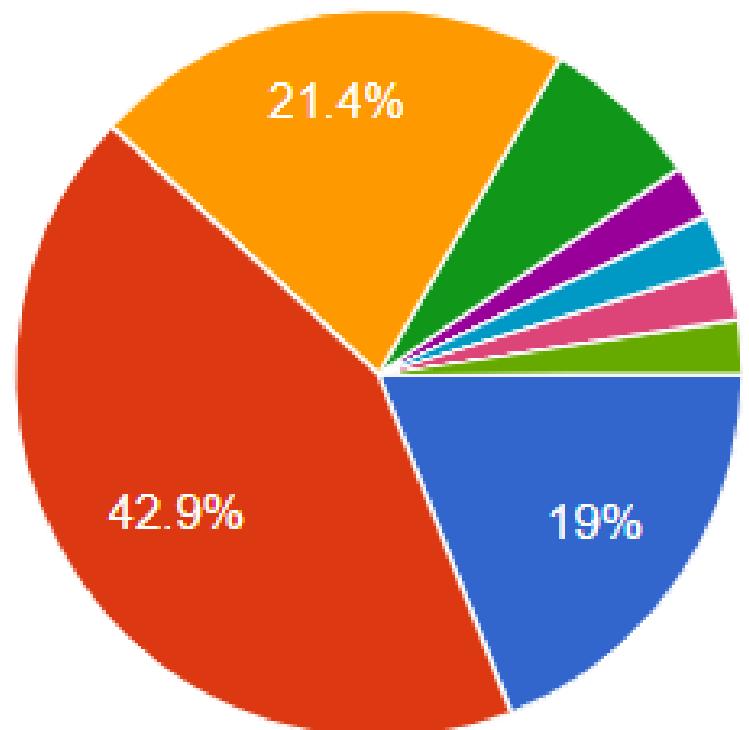
SEPT 2024

# Stakeholders

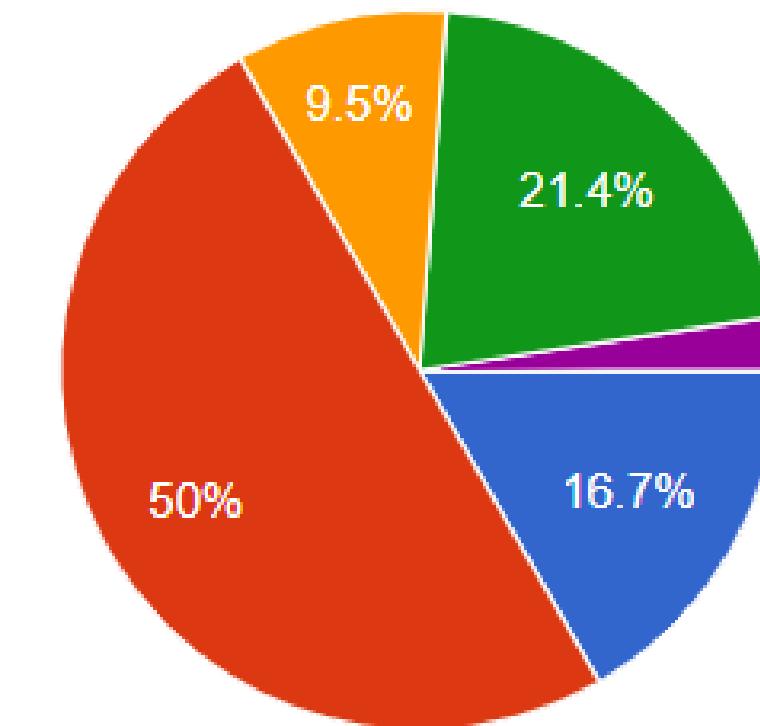


- Our stakeholders consisted of :
  1. Students
  2. Professors
  3. Daily commuters
  4. Researchers (From research based companies)
- Our largest stakeholders were students and daily commuters.

# ALL-inclusive educational background



- Physics
- Computer Science
- Engineering
- Mathematics
- Chemistry
- Quantum Computing
- Design
- Quantum Machine Learning



- High school
- Bachelor's degree
- Master's degree
- PhD
- Research scholar



# Educational background IN stem field



# Empathy map

Says

Traffic, logistics definitely need much better optimization.

Many factory automation processes are often far too slow for any feasible outcome.

Failure in current classical algorithms in traffic signals causes unjustifiable fees.

Satellites are failing to convey over enough range and the speed of information transmission is too slow.

Thinks

Quantum computing is definitely plausible in the future.

Quantum annealing can solve optimization problems 10x as fast as the classical ones.

Quantum computing is tough with its scalability.

The current RSA, A symmetrical, etc... encryption methods are slowly phasing out.

Does

I'm constantly tweaking my model to fit the constraints

Fellow peers interested in seeing advancements in automations and mundane tasks

Collaborate with others to improve my approach and make sure I'm considering all the trade-offs

Researches methods to optimize daily problems

Feels

I feel proud about my existing work, but I'm struggling to find effective solutions and often face burnout due to stress. It's challenging to improve performance.

I feel helpless sitting in traffic in Bangalore, wishing they'd optimize the signal or routes so I could just get home to my family instead of wasting my life stuck here!

Honestly things could be better if we can fix this power grid problem in bangalore.

I feel overwhelmed by all the variables and methods, but it's exciting when I finally find a solution that works.

# Questions asked in the survey

- Problems faced daily that could need automation?
- Knowledge about few solutions offered
- Bottlenecks in existing technology for these problems
- In your opinion, how significant is the potential impact of quantum annealing on industry and research?
- Do you think quantum annealing will become a mainstream technology and if so, where would its potential applications be?
- What do you see as some of the main challenges facing quantum computing

# Questions asked in interviews

- Problems faced daily that could need automation?
- Knowledge about few solutions offered
- In your opinion, how significant is the potential impact of quantum annealing on industry and research?
- Do you think quantum annealing will become a mainstream technology and if so, where would its potential applications be?
- What do you see as some of the main challenges facing quantum computing

# Questions asked in the INTERVIEWS

- What are the best practices for integrating quantum annealing into hybrid classical-quantum algorithms, especially when using hybrid solvers? How should one handle cases where classical optimization algorithms dominate, and the quantum contribution appears minimal?
- How do we optimally map combinatorial optimization problems onto a quantum annealer for complex real-world applications? For instance, in cases where the problem graph topology doesn't match the hardware (Chimera or Pegasus graph)

# Insights gained from the survey

- Accessibility and understanding for a wider audience
- Use with other quantum computing techniques
- Large scale
- Use alongside AI and cryptography
- Specialized qubits
- Applications in drug discovery and logistics
- Determination of error rates
- Ability to represent larger problems
- Rigorous benchmarking
- Finding a class of problems suitable for applying quantum annealing

# Insights gained from the survey

- We asked respondents about various daily issues, ranging from the traffic they face daily to the manufacturing industry in India and much more.
- Several interviews suggested that many simple daily problems - delivery, traffic, mobile network, etc.. seemed to hamper their enjoyability in life.

# Insights gained from the survey

- Upon asking about current areas where optimization could become a huge improvement or necessity we received these were the top 3 results :
  - Traffic jams
  - Drug discovery
  - Improving satellite placements to maximize coverage

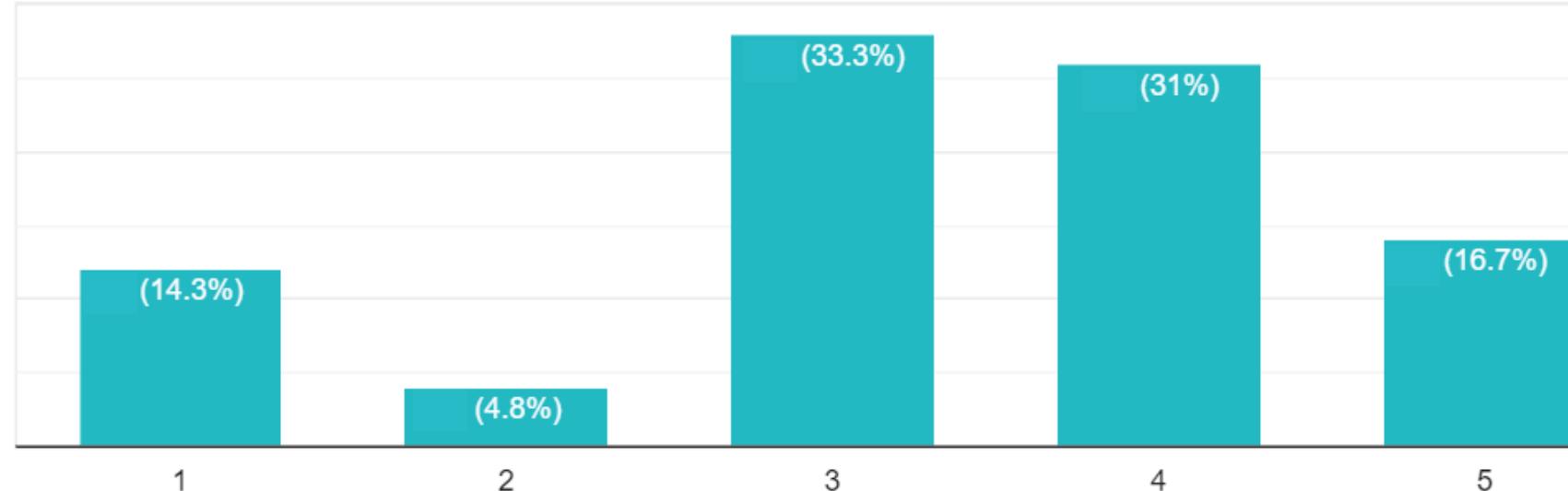
# Insights gained from the survey

- To tackle a few of these issues such as traffic, mobile networks, drug discovery - we suggested different methods of optimization which included:
  - Classical Machine Learning
  - Quantum Computing (Specifically quantum annealing)
  - A hybrid mix of both

# Insights from professionals

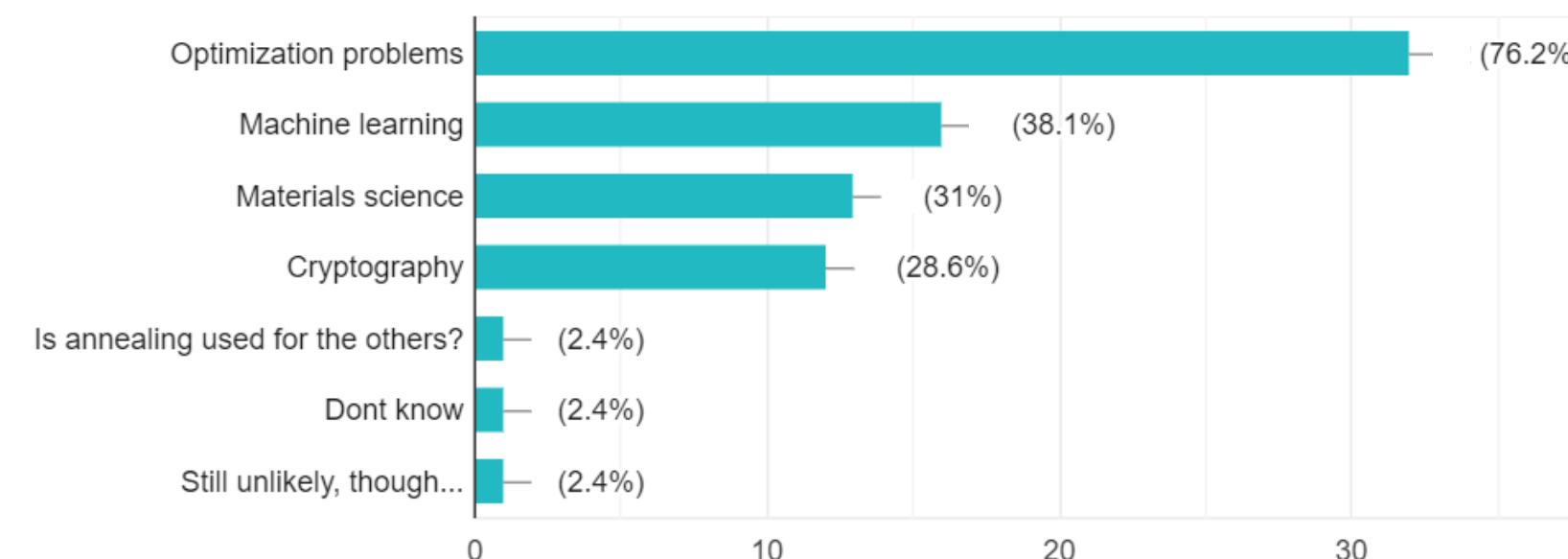
## IMPACT ON INDUSTRY & RESEARCH

In your opinion, how significant is the potential impact of quantum annealing on industry and research?



## POSSIBLE APPLICATIONS

What applications of quantum annealing do you find most promising? (Select all that apply)



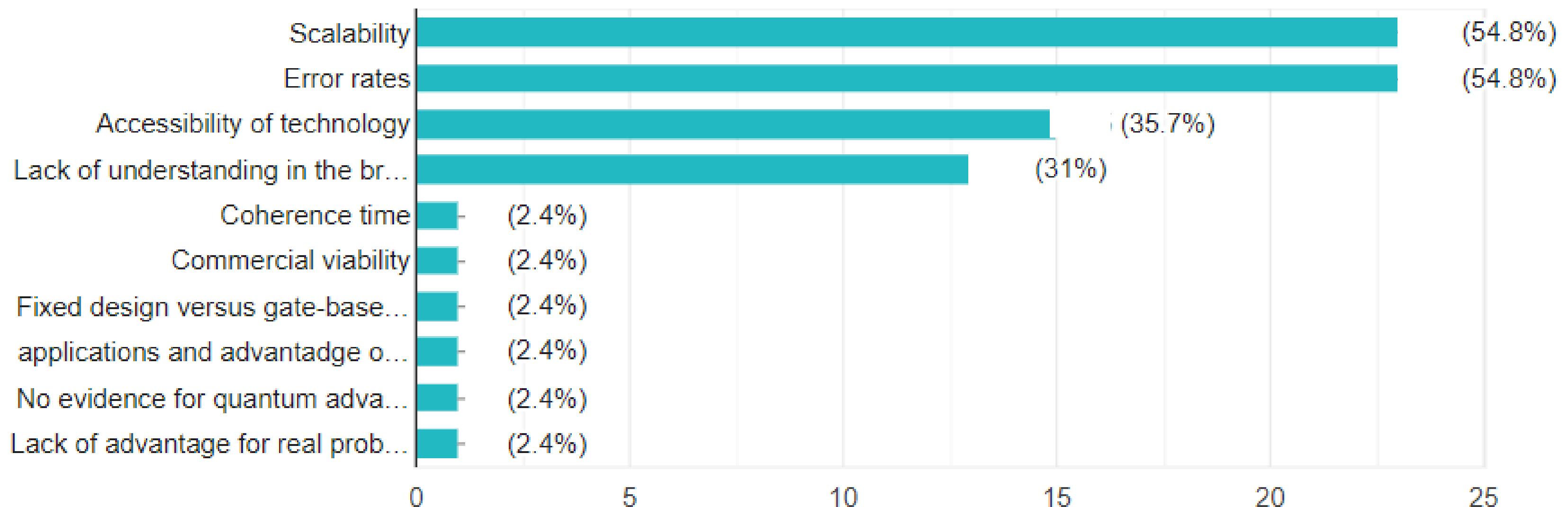
# Insights gained from a company

- "Initially, we were uncertain about the best direction to take in quantum computing, especially when it came to choosing the right approach. However, insights gained from the company helped us clarify our path. They highlighted that quantum annealing hardware is not only more widespread but likely to be well-developed far sooner than quantum gate hardware. Their guidance also helped us identify key applications and areas for improvement, shaping our understanding and supporting us throughout this journey in quantum computing."

# Insights gained from a Professional

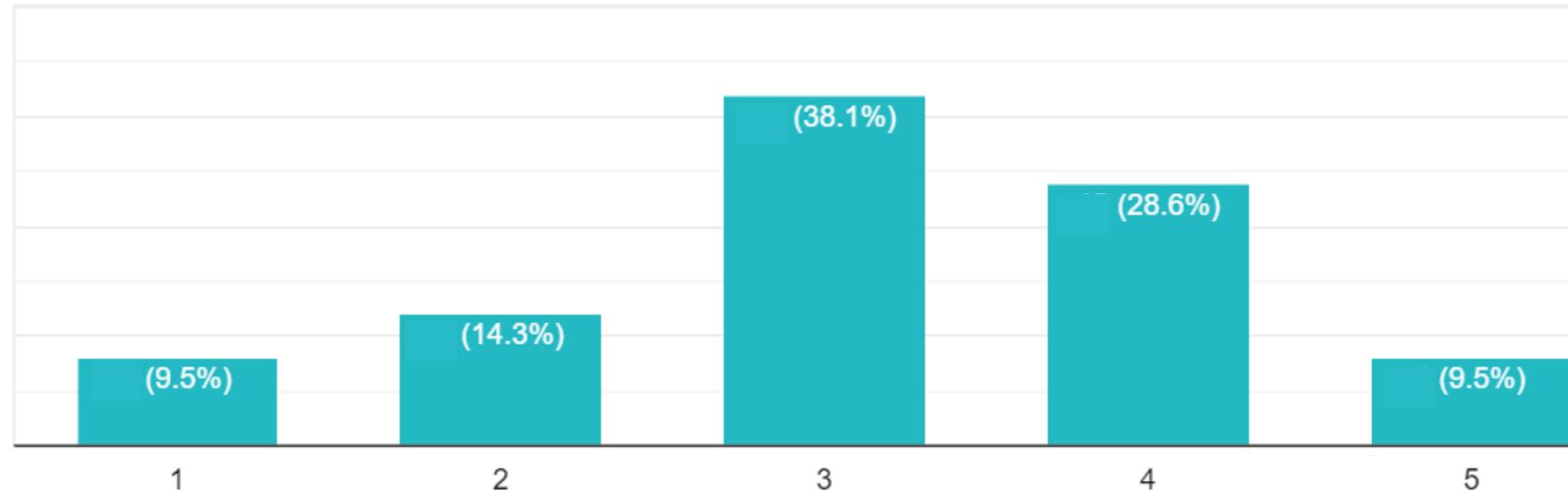
- Treat quantum annealing as an exploratory tool. While classical solvers might dominate now, quantum annealing can reveal insights into alternative solution pathways that classical algorithms might miss. These insights might not be substantial today but could become critical as quantum hardware improves.
- Hybrid solvers often switch between classical and quantum optimization cycles. You should iteratively refine your solution by leveraging quantum annealing for certain optimization steps, such as local search or heuristic improvement, while relying on classical solvers for larger, deterministic portions.

# Insights gained from the survey



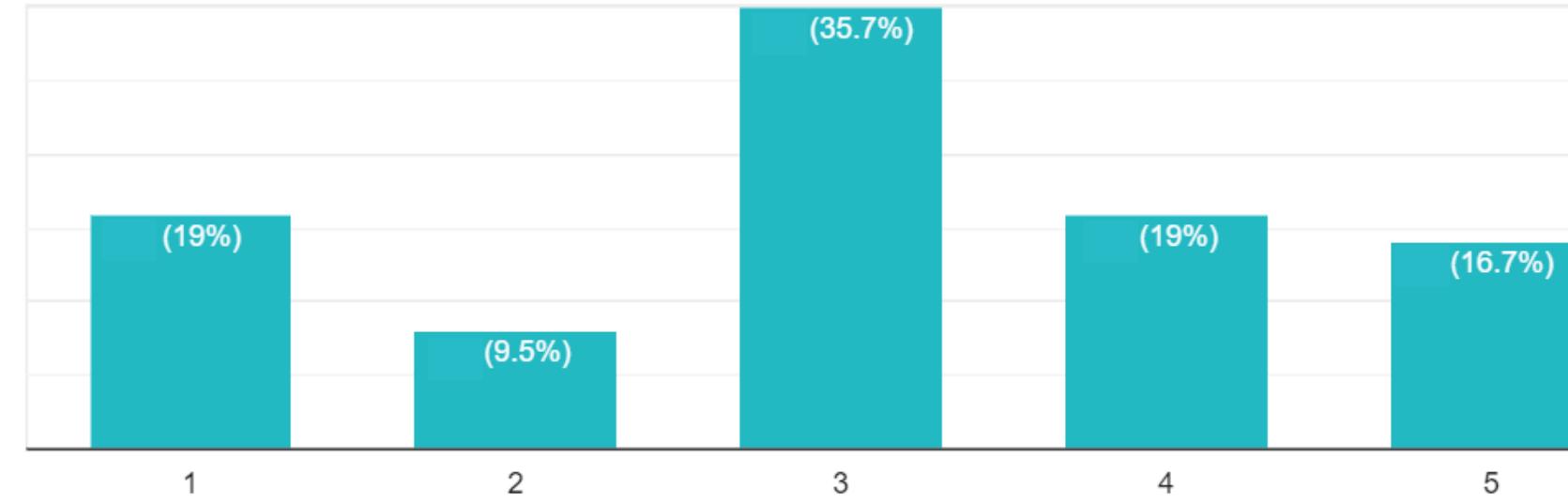
# Insights from professionals

How do you think quantum annealing compares to classical optimization techniques?



## COMPARISON TO CLASSICAL COMPUTING

How likely are you to engage with quantum annealing technologies in your work or studies in the future?



## INTEREST IN ANNEALING

# Insights from professionals

Classical optimizers already do a fantastic job. if you look at the industry relevant problems in the field it's not worth it to "maybe" get a moderate improvement from an expensive quantum annealer using heuristics. Extremely skeptical of DWave's business and anyone else that claims they get advantage from their machine

We use quantum annealing to sample large combinatorial optimization problems. It very effectively returns solutions that meet our constraints and maximize the objective. The ability to represent 10x larger problems would make it a solid alternative to classical sampling...

Simulating QA on conventional hardware does yield better solutions than conventional SA in some cases but takes too much time to be practical. Need a working, scalable, accessible, affordable quantum computer for industrial applications.

## OPINIONS AND FEEDBACK ON QUANTUM ANNEALING

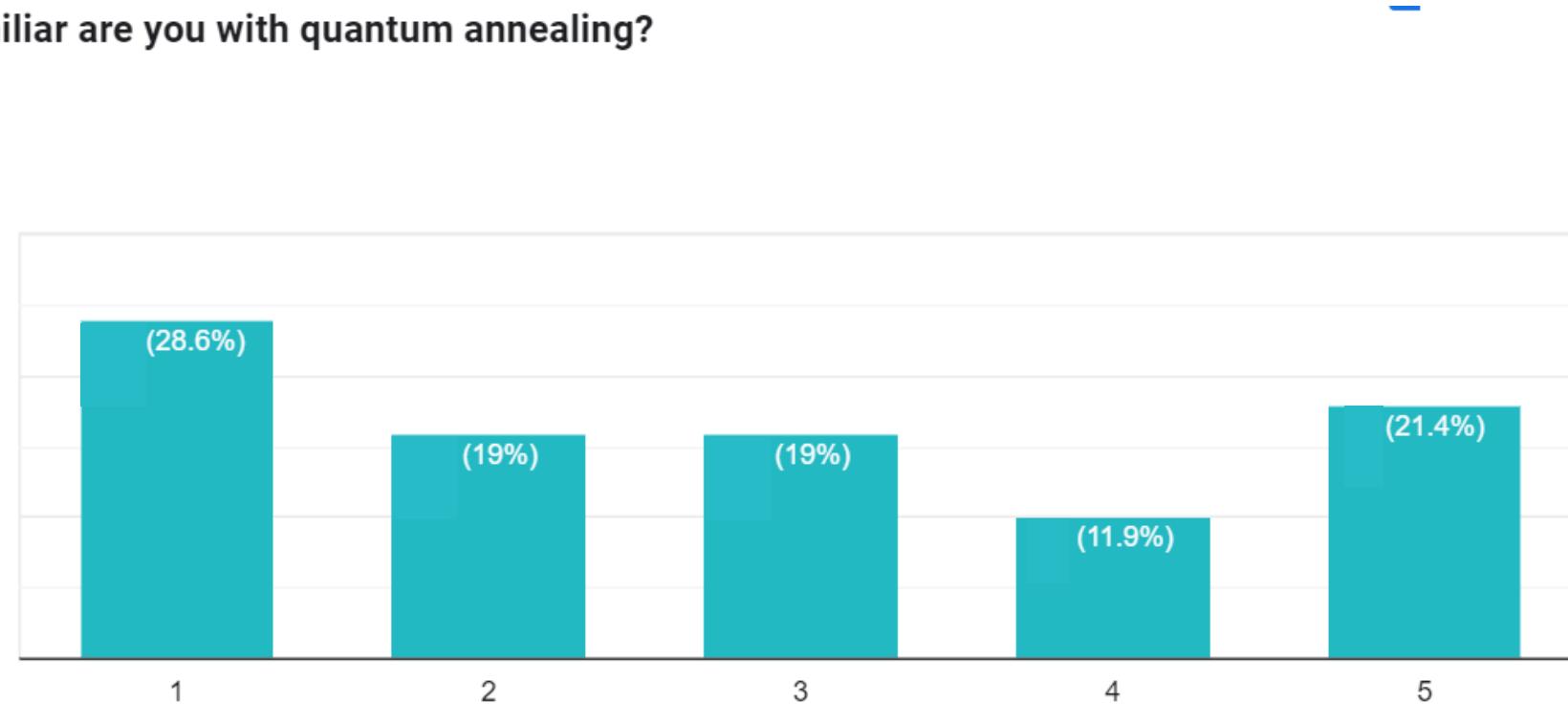
# Insights gained from the survey

- We received an overwhelming majority suggesting classical optimization methods for the given solutions, often stating that, quantum-based solutions had scalability issues.
- But, we received many responses stating that the classical methods are often erroneous and do not work as intended accurately.

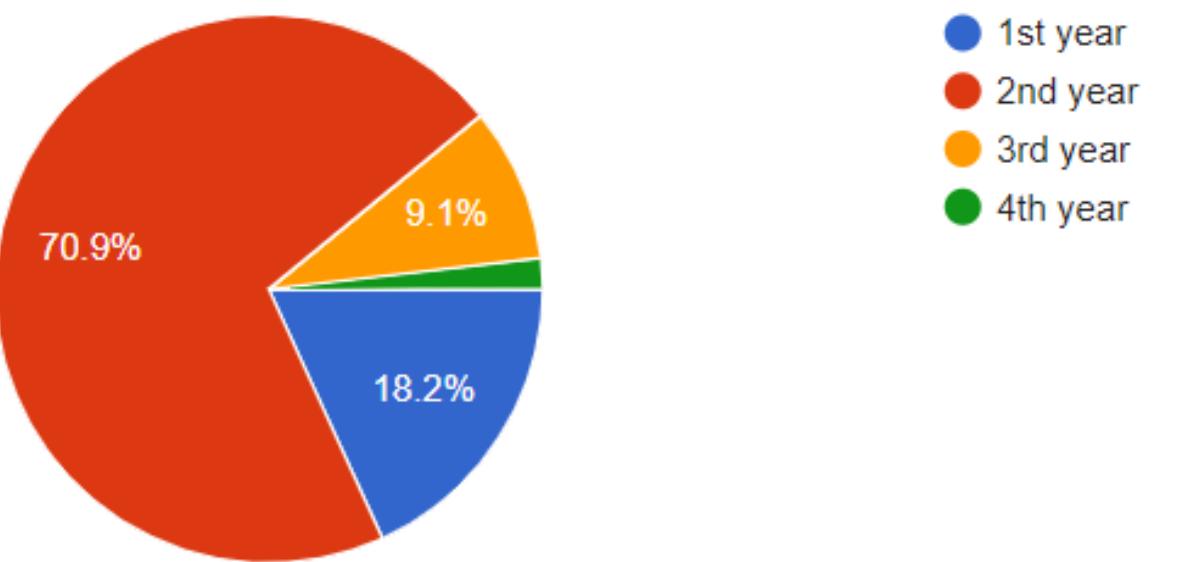
# Knowledge about quantum computing (RVCE)

## Familiarity

How familiar are you with quantum annealing?

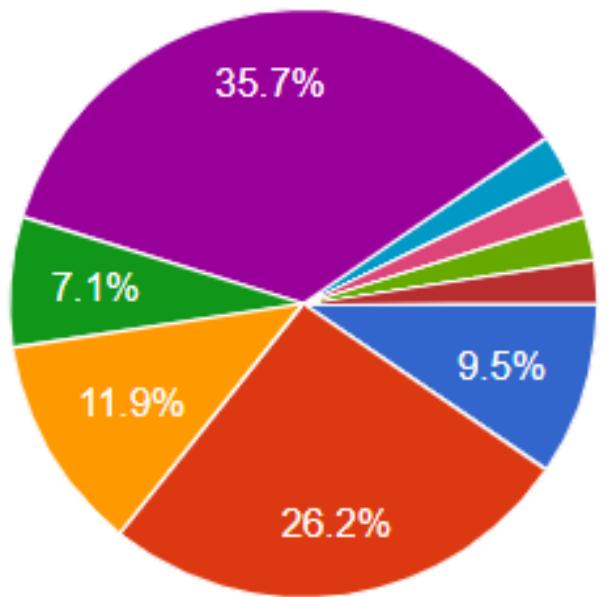


## YEAR OF STUDY



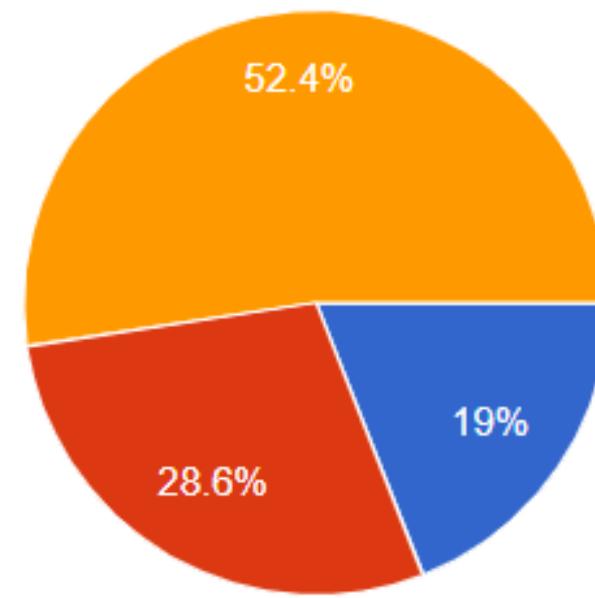
# Knowledge about quantum computing (STEM)

## Familiarity



- Academic courses
- Online articles/blogs
- Conferences/workshops
- Social media
- Haven't heard of it
- Work
- From colleagues
- My friends dad who works in oracle
- friend told me about it

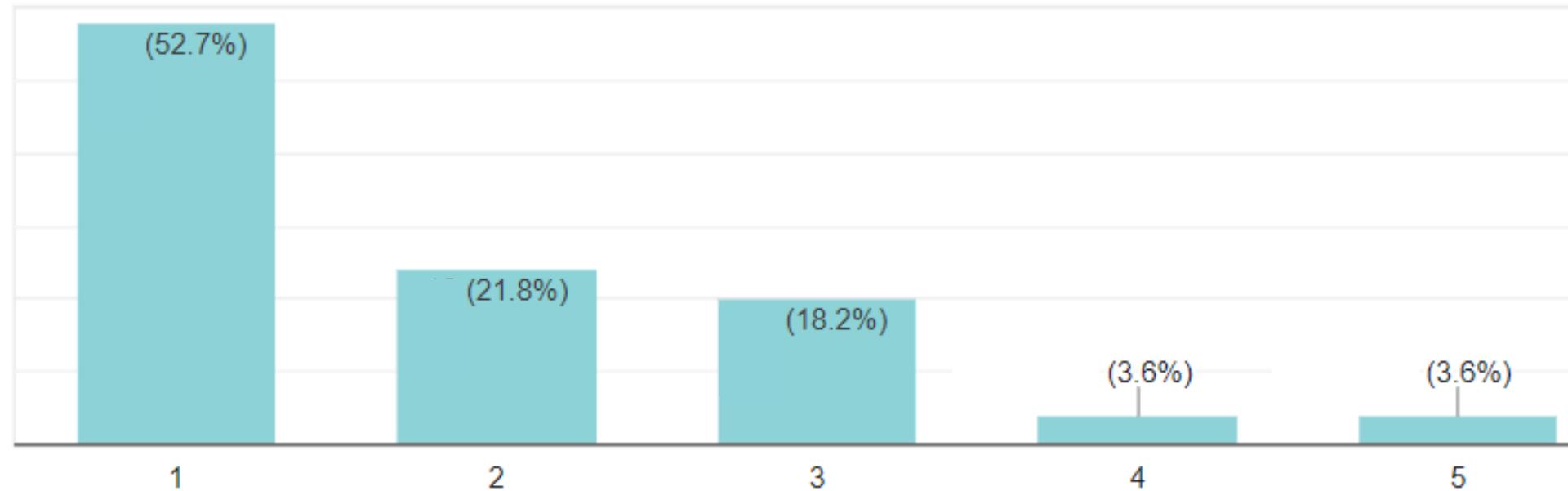
## USER BELIEF SCORES



- Yes
- No
- Maybe

# Researchers SURVEY RESULTS

## Familiarity of quantum annealing



- 21.4% of the respondents say they are familiar with quantum annealing.
- 54.8% of them voice out the issue of scalability with quantum computers being expensive.
- They suggest that in the current world optimization problems are facing a large bottleneck and quantum annealing can reduce time by 10x- via solving gradient loss issues in classical methods, etc..

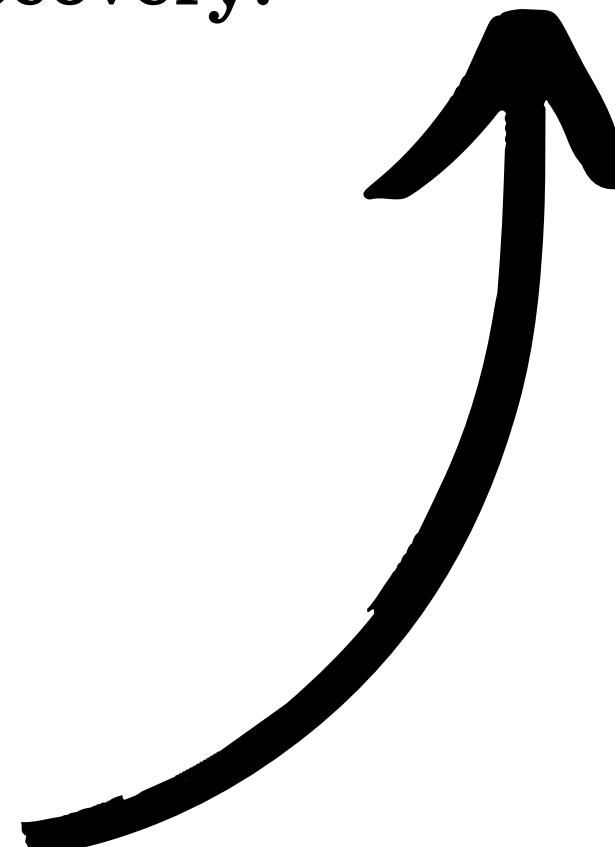
# Target Audience

- Large scale businesses
- government agencies
- researchers

- Used by Volkswagen for Logistics and traffic optimization.
- Monte Carlo Problem.
- Siemens and GE to optimize power grids
- Biogen and D-wave for drug discovery.



**CURRENT OPTIMIZATION  
APPLICATIONS**



# User persona



## ABOUT

Janet Snyder, 35, is a marketing manager in San Francisco who relies on messaging apps for work and personal use. After experiencing a privacy breach that leaked sensitive business information, Janet has become cautious about data security. While not tech-savvy, she values apps that provide strong privacy protections with easy-to-use interfaces.

## MOTIVATION

- Trust in apps with proven security (e.g., Quantum Key Distribution).
- Effortless communication without compromising privacy.
- Clear, accessible information about data protection.

## END GOALS

- Privacy breaches and vague security claims.
- Overcomplicated or poorly integrated security features.

End goals aligned to work with these pain points:

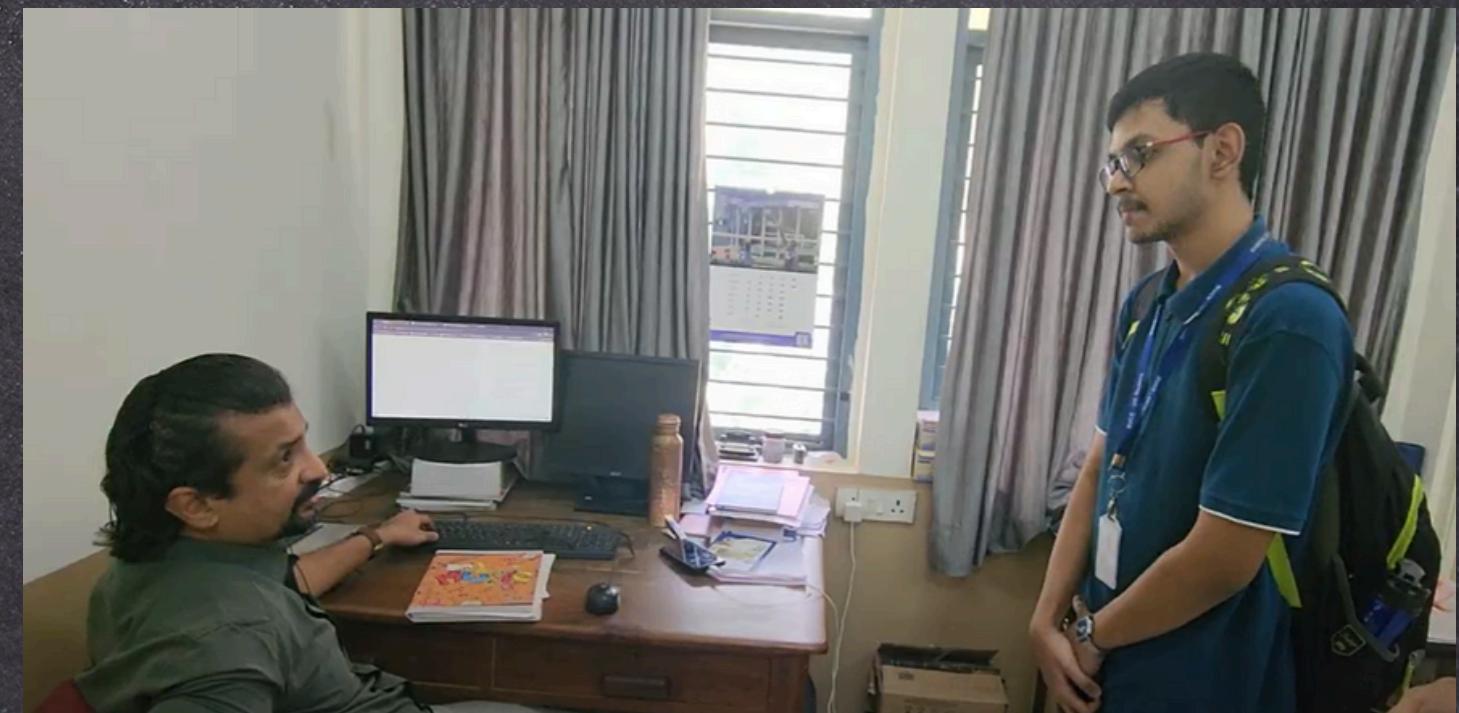
- Use secure messaging apps to protect sensitive data.
- Balance privacy with efficiency in daily communication.

# User Journey map

	Morning	Journey Phase	Afternoon	Evening
User Actions (Activities)	Person wakes up and starts their day by checking work emails and notifications.	Person tries to send confidential work documents while commuting.	Person encounters delays in file transfers or receives notifications about potential data breaches.	Person uses a messaging app to send personal messages but remains worried about privacy risks.
Sentiments (Thought Bubbles)	"Today's the day to get things done securely!"	"Why is the file transfer taking so long? Is it even safe?"	"I hope my client's sensitive data doesn't get intercepted... but who knows?"	"Why can't messaging apps guarantee my data stays private?"
Emotions (Mood Meter)	<p>The mood meter is a vertical scale divided into four horizontal bands. The top band is light blue and labeled "DELIGHTED". The middle band is teal and labeled "NEUTRAL". The bottom band is light green and labeled "FRUSTRATED". A black bell-shaped curve starts at the bottom left (FRUSTRATED), rises to a peak at the top center (DELIGHTED), and ends at the bottom right (FRUSTRATED). Small black dots mark the peak, the midpoint, and the end points of the curve.</p>			
Possible Solutions (Opportunities to improve the experience)	Ensure seamless integration of QKD-enabled secure communication tools in messaging apps.	Develop real-time quantum-encrypted file-sharing systems with instant verification of data safety.	Use quantum gates for faster data processing, ensuring reliability even under weak signals or high traffic.	Introduce end-to-end encrypted messaging platforms powered by QKD, giving users peace of mind for both work and personal communication.

# Journey

- We developed the surveys to find out where optimization can be applied on real world problems (such as traffic, manufacturing)
- We e-mailed various Indian quantum computing start-ups to request interviews.
- Conducted interviews with students to gather insights.
- Reviewed a few research papers
- Analyzed survey responses to identify key themes.



# Pain points

- Seeking more professional responses for insights.
- Need to streamline problem statement decisions.
- Finding research papers can be challenging.
- On a positive note, we received encouraging feedback from our professor

# Conclusions from the survey

- Traffic, drug discovery and many more daily problems require automation and optimization.
- Classical optimization is good but needs practical rescaling.
- Annealing may not become a mainstream technology but is beneficial when used in combination with classic methods

# Ideation Phase

- Dynamic traffic signal control
- Optimal satellite positioning to maximize signal coverage
- Optimize traffic flow to ease congestion
- Predictive maintenance scheduling for traffic infrastructure
- Optimized city planning based on traffic and population data
- Optimizing investment portfolios
- Fraud detection
- Optimizing risk assessment models for better financial forecasting
- Accelerating the discovery of new materials with specific properties
- Supply chain optimization
- Optimizing treatment plans
- Speeding up drug discovery
- Optimizing the dosage distribution in cancer therapy
- Optimizing distribution of electricity in smart grids

# Ideation Phase

- Optimizing extraction efficiency of oil to reduce environmental impact
- Optimizing battery charging and discharging cycles for efficient usage\
- Optimizing cargo loading and unloading
- Optimizing air traffic flow and schedules
- Optimizing placement of sensors to monitor endangered species
- Optimizing pollution control
- Dynamic Pricing for businesses
- Hyperparameter tuning in Machine Learning
- Optimization of Cryptographic algorithms
- Enhancing network intrusion detection systems
- Waste management cycle optimization
- Optimizing water distribution networks.

# Best idea

## Data Compression and Transmission: Optimizing data compression algorithms and transmission schedules

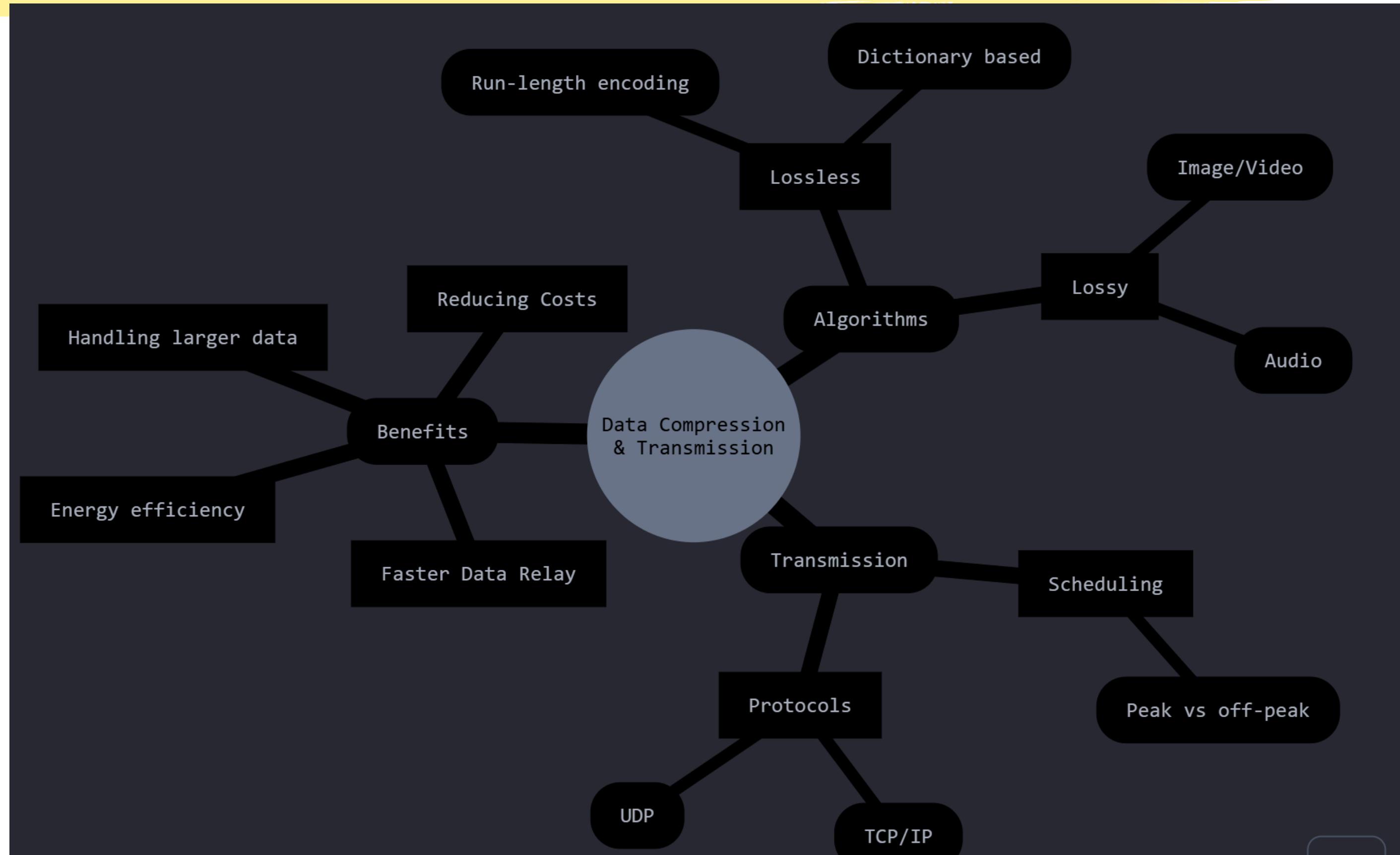
- Energy efficiency
- Handling larger data
- Reducing Costs
- Faster Data Relay

# Worst Idea

**Wildlife Tracking: Optimizing the placement of tracking devices and sensors in conservation areas to monitor wildlife movements and protect endangered species.**

- Simplicity of the Problem
- Availability of Classical Solutions
- Cost and Infrastructure
- Unpredictable Variables

# Mind map



# Potential prototypes

- Quantum ANNEALER USING D-WAVE API
- Quantum gate based compRession and Quantum key DISTRIBUTION (QKD)
- Quantum-Assisted Sorting Algorithm for Secure Packet Prioritization

# Quantum ANNEALER USING D-WAVE API

**Why did we NOT IMPLEMENT this one?**

- Quantum annealing although supported by multiple libraries, is hard to implement due to API reliance constraints.
- Quantum annealing is often slower than Quantum gate based operations.
- Flexibility in Algorithm Design
- Security Applications

# Quantum-Assisted Sorting Algorithm for Secure Packet Prioritization

**Why did we NOT IMPLEMENT this one?**

- No Compression
- It lacks a robust security mechanism like QKD or entanglement-based protection.
- Focused only on sorting and prioritization, with no broader implications for overall data transmission efficiency or cryptographic security.

# Quantum-gate based compression & Quantum Key Distribution (QKD)

## Justification

- Quantum gates are the basis of the new and upcoming quantum computers.
- Quantum Key Decryption allows us to ensure a strong encryption for the data, ensuring no-one may be able to snag the data from us.
- It is faster than quantum annealing where we must optimize the energy states by minimizing the energy at all levels.
- It is more easily compatible with binary numbers.

## Most important advantages

- Classical encryption cannot protect data from damage, as eventually a bigger number can be broken as always.
- Data transmission usually done in chunks can now be sent at multiple chunks at the same time in parallel.
- If the KEY is measured, it implies eavesdropping which means very strong security.

# Implementation Details

## LIBRARIES USED:

- json
- heapq
- defaultdict
- flask
- pennylane
- numpy

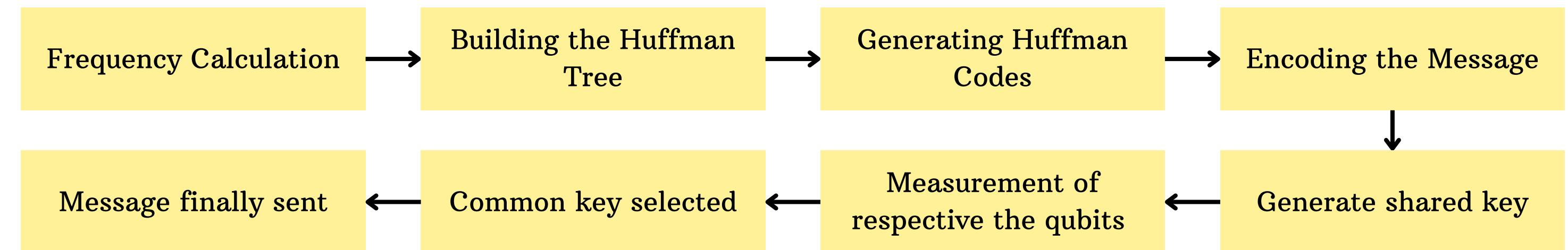
# Implementation Details

## HUFFMAN ENCODING:

- Each bit of the Huffman-encoded stream is mapped to a quantum state: 0 →  $|0\rangle$  and 1 →  $|1\rangle$
- This stream of qubits is initialized in a quantum register.
- Pairs of qubits are entangled using the CNOT gate. This ensures that interception of qubits is detectable.
- The encoded qubits are passed through a Hadamard gate, creating superpositions  $|0\rangle + |1\rangle$ . This enhances the transmission by allowing multiple bits of information to be represented simultaneously.
- Quantum gates for error correction protect against noise during transmission.

# Implementation Details

## FLOW OF ENCRYPTION:



## FLOW OF deCRYPTION:



# Implementation Details

## QUANTUM KEY DISTRIBUTION:

- It uses the BB84 protocol to securely share a key. Qubits are encoded in random bases via Hadamard gates. The receiver measures qubits in random bases and publicly compares results to verify matching bases. A shared secret key is established without direct transmission.
- Huffman data and the QKD key are sent over a secure quantum channel. The receiver decodes the data using the reverse Huffman table. Any eavesdropping is detected by measuring fidelity with expected entangled states.

# Applications

- Secure Satellite Communication: Compressing and securely transmitting massive data streams between Earth stations and satellites.
- Quantum Internet: Building a scalable and efficient quantum communication framework for real-time data exchange.
- Healthcare Data Transmission: Securing sensitive medical data like DNA sequences or MRI images using quantum-enhanced Huffman encoding.

# Working of the prototype

**Quantum Chat Simulator**

**Alice's Chat**

Alice: Hello Bob!

Alice (Response): Hey Alice how's it going?  
Shared Key: 0000000000000000

Type a message for Alice...

Send

**Bob's Chat**

Bob (Response): Hello Bob!  
Shared Key: 0000

Bob: Hey Alice how's it going?

Type a message for Bob...

Send

Encoded: 11100000101110111101110100001

Encoded: 01001111100100111011011001101011110011010101110010111100110001110000100  
0101001110010100011011

# Validation and Testing

- Friend Network Testing: Invited friends to interact with the system, providing feedback on message clarity, response accuracy, and functionality in various scenarios.
- Community Platforms: Shared a test version on platforms like Discord and Reddit, collecting diverse user feedback and suggestions for improvement.

# Teamwork and Participation

- Quantum Annealing Research & Design: One team member spearheaded the research on quantum annealing techniques, focusing on optimizing message transmission for speed and security. Their work involved designing a theoretical framework that applied quantum principles to reduce transmission time and address security vulnerabilities, forming the core foundation of the project.

# Teamwork and Participation

**QKAD Development & Algorithm Optimization:** Another team member took the theoretical research and translated it into a functional system. They implemented the QKAD algorithms, ensuring the message encoding and decoding processes were optimized for both efficiency and security. Additionally, they integrated quantum error correction techniques to enhance the system's reliability and robustness, ensuring that the system could withstand the inherent noise in quantum systems.

# Teamwork and Participation

**User Testing & Feedback Integration:** One member led the testing phase, managing user interactions on platforms like Discord, Reddit, and through direct feedback channels. The testing assessed the system's performance in real-world scenarios, with users offering insights into the user interface, system responsiveness, and functionality. This phase was essential for identifying usability issues and technical flaws. He analysed the feedback to guide improvements, refine performance, and ensure QKAD was user-friendly and met practical needs. I also monitored performance metrics to ensure the system could handle various use cases and network conditions, enhancing its versatility and reliability.