High-Dimensional Semi-Quantum Cryptography

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Objectives

Can we have unconditional communication security with limited quantum resources?

- Bridge the gap between classical and quantum realm.
- Use less expensive quantum hardwares.
- Fallback option for fully-fledged quantum key distribution.

Motivation

- Unconditional security is impossible with all-classical capabilities but possible with quantum resources.
- High-dimensional QKD offers better protection.
- Using HD-resources in SQKD provides advantages.

What is Quantum Key Distribution

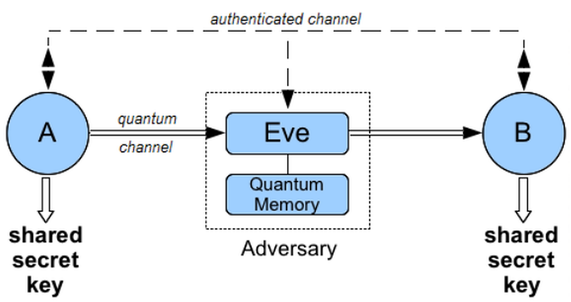

Figure: Quantum Key Distribution

- Alice sends her friend Bob information via qubit through quantum channel.
- Adversary Eve can attack the channel in various ways.
- Alice and Bob communicates classically to produce a shared key.
- The key is secure as long as Eve does not know 'too much' about it compared to Bob.

What is High-Dimensional SQKD

- High-Dimensional qudits instead of traditional qubits.
- More information transmitted in each iteration.
- Robust against quantum cloning.
- Better noise resistance.

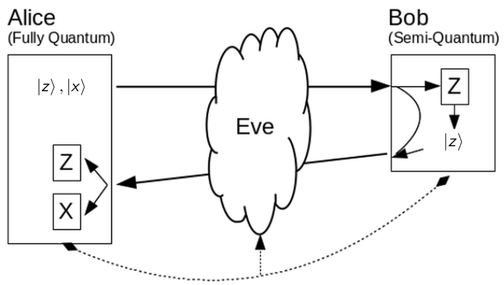

Figure: High-dimensional SQKD

Important Result

High-dimensional SQKD offers the best key-rate so far. Proof simplification technique developed here is applicable to other quantum key distribution protocols.

Simplified Protocol

HD-SQKD	OW-SQKD
1. Alice prepares $\|z\rangle$ or $\|x\rangle$, sends to Bob.	1. Bob prepares and sends two different states based on measure-resend or reflect.
2. Eve attacks the forward channel.	2. Eve attacks only once.
3. Bob measure-resends or reflects.	3. Alice measures in two basis.
4. Eve attacks the reverse channel.	
5. Alice measures the returning qubits.	

Reduction Process

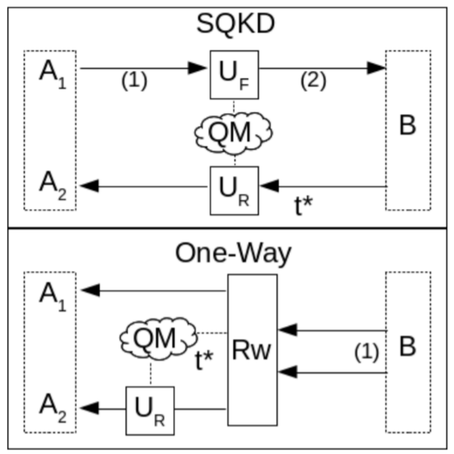

Figure: Convert two-way attack to one-way using a special attack operator R_w

Evaluation

- Noise tolerance: How much disturbance in the channel can the protocol withstand.
- How does it compare to a famous fully quantum HD-QKD protocol.

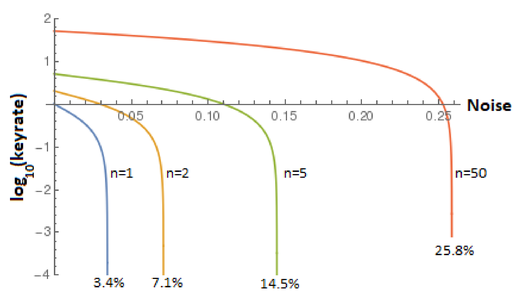

Figure: Noise Tolerance in different dimensions

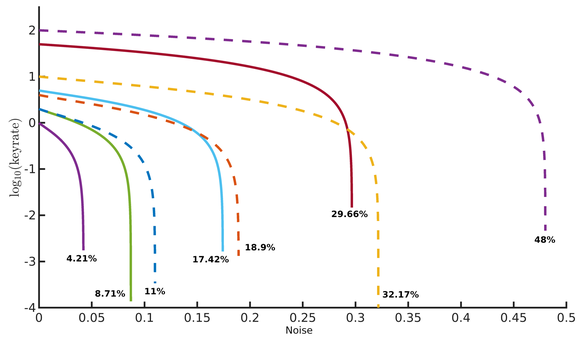

Figure: Noise vs Key rate: HD-SQKD vs HD-BB84

Conclusion

- We have proposed a new HD-SQKD protocol.
- Performed an information-theoretic security analysis.
- Showed how to reduce a two-way protocol to one way.
- Proved that qudits can indeed benefit SQKD model.
- Applying this proof technique to other protocols would be quite interesting.

References

[1] Michel Boyer, Dan Kenigsberg, and Tal Mor. Quantum key distribution with classical bob. In *2007 First International Conference on Quantum, Nano, and Micro Technologies (ICQNM'07)*, pages 10–10. IEEE, 2007.

[2] Charles H Bennett and Gilles Brassard. Quantum cryptography: public key distribution and coin tossing. *Theor. Comput. Sci.*, 560(12):7–11, 2014.

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