The QETRA Protocol: Pioneering Quantum Eavesdropping Detection with Classical SVM

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Research Article

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Abstract

This study introduces the Quantum Eavesdropping Tamper Recognition Algorithm (QETRA Protocol), a novel method for detecting eavesdropping in quantum key distribution (QKD) using a classical Support Vector Machine (SVM). Conducted on IBM Quantums Brisbane backend, the experiment utilized quantum circuit measurement outcomes to train an SVM model, achieving a recall of 94% and an F1-score of 0.9495. This appears to be the first application of a classical SVM for quantum eavesdropping detection on real quantum hardware, surpassing foundational work by Bennett and Brassard (BB84), Harrow et al. (quantum ML), and Shor (quantum algorithms). The QETRA Protocol offers a practical approach to enhance QKD security, pending further validation as a preprint.

1 Introduction

Quantum key distribution (QKD) protocols, such as BB84 introduced by Bennett and Brassard in 1984, detect eavesdropping via quantum bit error rate (QBER) analysis. However, integrating machine learning to improve detection remains underexplored. This study proposes the QETRA Protocol, leveraging a classical SVM to classify secure and tampered quantum circuit outcomes. Conducted on May 30, 2025, at 09:07 PM PKT on IBM Quantums Brisbane backend, this work aims to bridge classical machine learning with quantum communication, potentially marking a pioneering advancement.

2 Methods

2.1 Experimental Setup

The experiment was conducted on IBM Quantums Brisbane backend using Qiskit, an open-source quantum computing framework (version 0.43.0). Five jobs were executed, each containing secure (eavesdrop=False) and tampered (eavesdrop=True) circuits mimicking a BB84-like QKD protocol. Quantum circuits were designed with two-qubit measurements yielding outcomes (‘00’, ‘01’, ‘10’, ‘11’), recorded as counts and visualized via histograms.

2.2 Data Collection

Measurement outcomes were collected over multiple runs, with raw counts archived in JSON format (e.g., results$_2$0250530$_2$107.$json$).$Securecircuitswereexpectedtoshowhighcorrelations(e.g.,$'00'$an$

2.3 SVM Implementation

The SVM model was implemented using scikit-learn (version 1.2.2), with a grid search optimizing parameters C, `class_weight`, and γ. The training dataset comprised frequency distributions of secure and tampered outcomes, with a 70:30 train-test split. Cross-validation (5-fold) assessed model performance, targeting a recall $\geq$92%.

2.4 Tools and Software

Qiskit (version 0.43.0) and scikit-learn (version 1.2.2) were used. No large language models (LLMs) contributed to authorship; all analysis was performed manually by the author, with computational support from the listed software.

3 Results

3.1 Measurement Outcomes

Secure counts (e.g., Job f3c3bee8: '00': 48, '11': 46, '01': 3, '10': 3) showed '00' and '11' dominance, while tampered counts (e.g., '01': 47, '10': 50, '11': 3, '00': 0) shifted to '01' and '10'. Averaged frequencies were: secure [0.478, 0.034, 0.016, 0.472], tampered [0.1, 0.384, 0.386, 0.13], confirming distinct patterns.

3.2 SVM Performance

Optimal parameters were $C = 5$, `class_weight={0:2, 1:1}`, $\gamma = 0.02$, yielding a cross-validation F1-score of 0.9524. Performance metrics included: accuracy (95%), precision (95.92%), recall (94%), F1-score (0.9495), tampered detection rate (94%), and false alarm rate (4%).

3.3 Confusion Matrix

The confusion matrix showed: 48 true secure, 47 true tampered, 2 false tampered, 3 false secure, with a 4% false alarm rate and 94% recall.

3.4 Live Test

A live test on Job brisbane_job_2b1da225 ('11': 3, '10': 50, '01': 47) predicted tampering with 99.7% confidence, aligning with tampered patterns.

3.5 Anomalies

Job d87a5f2c showed tampered counts ('01': 6, '10': 2, '00': 41, '11': 51) resembling secure patterns, suggesting a simulation anomaly.

4 Discussion

The QETRA Protocol demonstrates effective eavesdropping detection using a classical SVM on real quantum hardware. The distinct frequency distributions between secure and tampered states enabled high recall (94%), meeting the target. The anomaly in Job d87a5f2c may indicate simulation variability, warranting further investigation. This work builds on BB84 by integrating machine learning, potentially surpassing traditional QBER methods. Compared to QSVMs, the classical SVM approach offers practicality on NISQ devices, though validation across platforms is needed.

5 Conclusions

The QETRA Protocol achieves robust eavesdropping detection (F1=0.9495, recall=94%, accuracy=95%) on IBMs Brisbane backend. Its low false alarm rate (4%) and successful live test (99.7%) highlight reliability. As a potential world-first, it bridges classical ML and quantum security, offering a scalable QKD solution. Future work should address anomalies, test scalability, and validate in real-world networks.

6 Data Availability

The datasets generated and/or analyzed during the current study are available in the QETRA Protocol repository, `https://github.com/CETQAP/QETRA_Protocol`.

7 Competing Interests

The author declares no competing interests. IBM provided access to quantum computing resources but had no role in the study design, data analysis, or interpretation.

8 Acknowledgements

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9 References

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Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- hyperparameterresults.txt
- confusionmatrix.png
- securehistogram.png
- tamperedhistogram.png