
A NOVEL APPROACH OF SECURE AUDIO TRANSMISSION IN POST-QUANTUM ERA.

RESEARCH ARTICLE

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ABSTRACT

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Keywords Lorem ipsum, Placeholder text, Text generation, Typography, LaTeX formatting, Document design, Content management, Semantic analysis, Latin text, Formatting templates, Filler content, Automated writing, Document structure

1 Introduction

The most simplest, as well as the most important, form of exchange for human beings is verbal communications. The invention of the Telephone by Alexander Graham Bell in 1876 transformed the verbal communication demography - making the transmission of human voice, which are essentially audio signals, over long distances possible. In the subsequent centuries, technological improvements has broadened the scope of audio transmission. With the rise of the Internet, the amount of information exchanged through audio signals increased rapidly. This increase number audio transmission resulted in the development of different encryption techniques and cryptographic algorithms. The most popular among these algorithms are the symmetric AES and the asymmetric RSA encryption schemes. AES [1] is a block cipher scheme that utilizes multiple matrix operation to encrypt and decrypt data using the same key. Without any knowledge of the cipher key, it is computationally infeasible to reverse the operations performed during encryption. RSA [2], on the other hand, utilizes prime number factorization to generate public-private key-pairs for each user that are used to encrypt and decrypt data. The security of the RSA scheme relies on the insane amount of computational power required to obtain the private key from a public through prime number factoring.

However, with the advent of Quantum Computers with increasing number of functional qubits, these classical cryptography and encryption schemes face an imposing threat [3]. In 1996, Lov K. Grover proposed an algorithm to search an unordered database of size N using \sqrt{N} quantum queries [4]. Using Grover's algorithm, the number of trials required to brute-force a key of length k reduces from 2^k to $2^{k/2}$. This reduction in number of brute-force

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trials effectively reduces the security level of symmetric encryption schemes such as AES [5]. For example, the AES-128 encryption scheme with a pre-quantum security level of 128 reduces to a post-quantum security level of 64, which is much easier to brute-force. In 1994, P.W. Shor presented a quantum algorithm that can quickly find the prime factorization of any positive integer N [6]. As the security of the RSA algorithm relies on the arduousness of prime number factorization to derive private key from public key, it is currently facing an existential threat due to the exponential speed of Shor's algorithm. It is estimated that the time complexity for Shor's algorithm is $\mathcal{O}(72(\log(N))^3)$, as opposed to $\mathcal{O}(N^3)$ for classical computers.

To address these arising challenges, new research is being done on the field of quantum augmented communication systems. These systems exploits the principles of quantum mechanics to attain secure data transmission. One of the most promising area of research in the field of quantum communications is Quantum Key Distribution (QKD). QKD protocols works by establishing a secure cryptographic key between two users over an insecure channel [7]. QKD employ properties unique to quantum mechanics, such as the no-cloning theorem [8] and the uncertainty principle [9], that ensures the detection of any eavesdropping attempts and thereby guarantees the security of the key. However, QKD itself does not provide security on its own, rather it facilitates the establishment and secure exchange of secret keys that are subsequently used by other cryptographic algorithms and encryption techniques to secure the transmitted information. In resemblance, the research being done on the field of steganography heralds the emergence of an effective information concealing technique to obscure sensitive information within seemingly harmless transmission. Steganography is the technique of hiding secret message within another message in such a manner that it is not discernible that a secret message is embedded [10]. However, the security of any steganographic technique is heavily dependent on the strength of cryptographic technique employed to encrypt the data [11].

This paper introduces a novel approach to reinforce the security of digital audio communication by combining the competency of QKD, classical encryption schemes and steganography. Our system utilizes the E91 QKD protocol proposed by Artur K. Ekert in 1991 [12] to generate a shared key with increased security, which is then hashed to produce a fixed-length (256 bits), high-entropy key that is suitable for symmetric encryption by employing the Secure Hashing Algorithm-3 (SHA3-256) [13]. We inspect the use of ChaCha20-Poly1305 authenticated encryption with associated data (AEAD) algorithm [14] - which combines the stream cipher scheme, ChaCha20 [15] with the message authentication code, Poly1305 [16] - to encrypt the steganographic audio. We performed least significant bit (LSB) substitution steganography to hide an audio signal inside another audio signal [17]. The incorporation of QKD with classical symmetric encryption addresses various security concernment, providing protection against both classical and quantum threats.

The new vulnerabilities in secure data transmission due to quantum computer and the need to oppose them have been the motivation for our research. With the advancement in quantum computing technology, it is imperative to devise innovative cryptographic techniques that can keep the data secure in the prospect of an attack from these powerful computers. It is our aim to develop a vigorous solution for secure data communication by combining the strength of quantum communication with hash function, classical encryption and steganography. Hence, the objective our experimental work is to investigate the viability and credibility of integrating encrypted steganographic techniques with quantum protocols, specifically QKD, to strengthen the security and resilience of audio communication. This innovative amalgamation of steganography and quantum communication embodies a significant furtherance in the field, providing an exceptional and optimistic approach to secure data transmission. Our main contribution can be summarized as follows -

- Proposed an original architecture that successfully combines E91 QKD protocol, ChaCha20-Poly1305 AEAD and audio steganography using LSB.
- Utilized E91 as the key distribution protocol which employs principles of quantum mechanics for secure key exchange.
- Assimilated audio steganography using LSB substitution into the architecture to augment the security and robustness of the overall system.
- Assessed the performance and reliability of the proposed scheme by measuring the security through end-to-end encryption.

Our paper is organized as follows - Section 2 demonstrates the present state of the field through the review of existing research and their development, laying the foundation for our proposed scheme. Section 3 describes the proposed methodology, presenting a detailed piecemeal explanation of our proposed architecture. In section 4, we present the experimental methods as well as the findings. Section 5 explore deeper into an extensive analysis of the results, construing the findings and excerpting key insights. Finally, section 6 concludes the paper by indicating the direction of future work, highlighting the potential application and extension of our research.

2 Related Works

3 Methodology

The architecture that we proposed is a system that integrates E91 QKD protocol with classical cryptographic schemes and lsb steganography to ensure a heavily secure audio data encryption system. The system utilizes the E91 for QKD to generate and exchange the cryptographic keys called the Ekert key, SHA3 to derive a high-entropy 256 bit key from the Ekert key for ChaCha20-Poly1305 encryption and LSB substitution for steganography. The architecture ensures augmented data security through the combination of classical and quantum techniques. Figure 1 provides a high level overview of our proposed system.

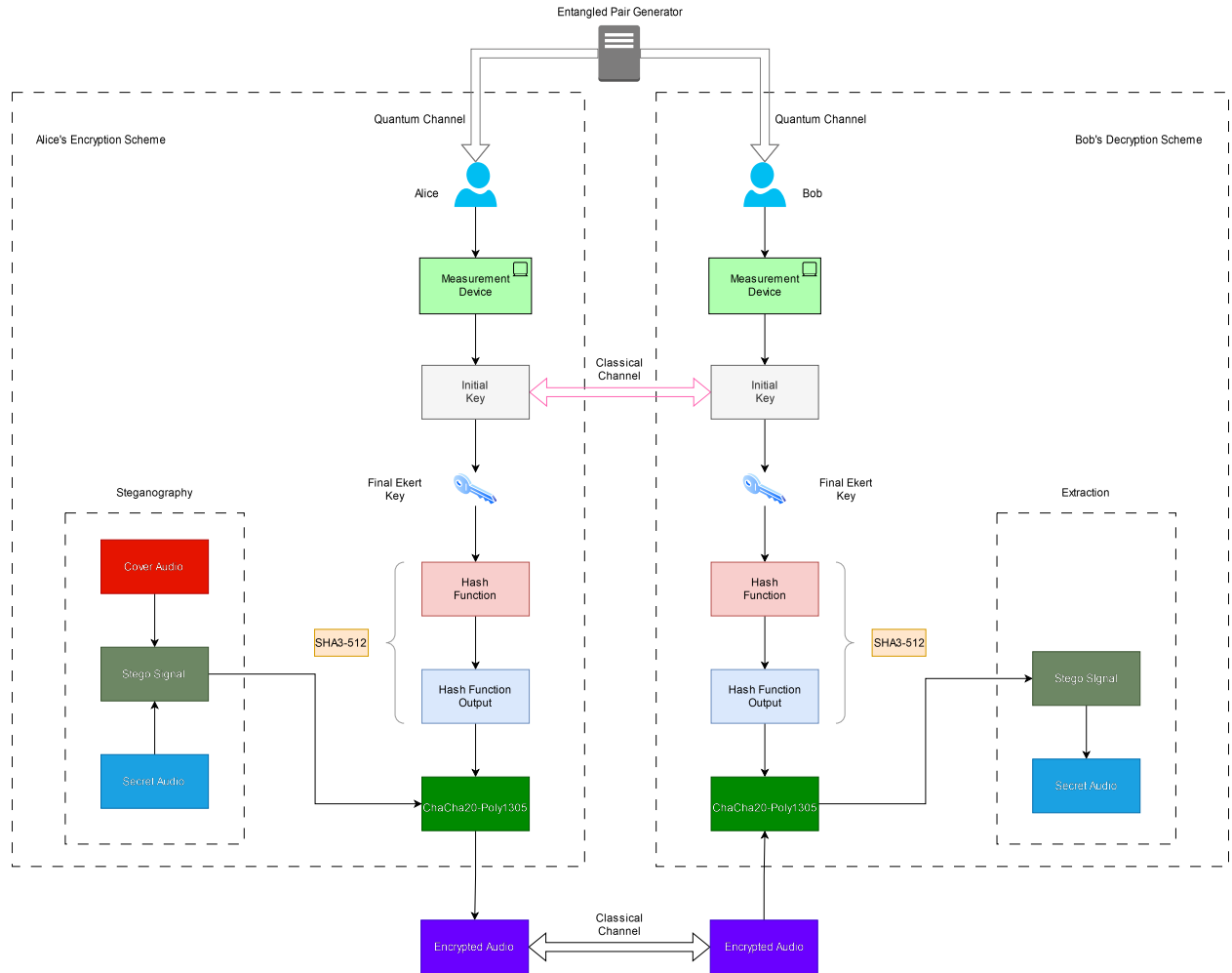


Figure 1: Methodology

4 Experiments and Results

5 Findings and Discussion

6 Conclusion and Future Work

References

- [1] V. Rijmen and J. Daemen, “Advanced encryption standard,” *Proceedings of federal information processing standards publications, national institute of standards and technology*, vol. 19, p. 22, 2001.
- [2] R. L. Rivest, A. Shamir, and L. Adleman, “A method for obtaining digital signatures and public-key cryptosystems,” *Communications of the ACM*, vol. 21, no. 2, pp. 120–126, 1978.
- [3] D. J. Bernstein and T. Lange, “Post-quantum cryptography,” *Nature*, vol. 549, no. 7671, pp. 188–194, 2017.
- [4] L. K. Grover, “A fast quantum mechanical algorithm for database search,” in *Proceedings of the twenty-eighth annual ACM symposium on Theory of computing*, pp. 212–219, 1996.
- [5] J. Daemen and V. Rijmen, *The Design of Rijndael*. Springer Berlin Heidelberg, 2002.
- [6] P. W. Shor, “Polynomial-time algorithms for prime factorization and discrete logarithms on a quantum computer,” *SIAM Journal on Computing*, vol. 26, p. 14841509, Oct. 1997.
- [7] R. Alléaume, C. Branciard, J. Bouda, T. Debuisschert, M. Dianati, N. Gisin, M. Godfrey, P. Grangier, T. Länger, N. Lütkenhaus, *et al.*, “Using quantum key distribution for cryptographic purposes: a survey,” *Theoretical Computer Science*, vol. 560, pp. 62–81, 2014.
- [8] V. Bužek and M. Hillery, “Quantum copying: Beyond the no-cloning theorem,” *Physical Review A*, vol. 54, no. 3, p. 1844, 1996.
- [9] D. Sen, “The uncertainty relations in quantum mechanics,” *Current Science*, pp. 203–218, 2014.
- [10] D. Kahn, *The history of steganography*, p. 15. Springer Berlin Heidelberg, 1996.
- [11] R. J. Anderson and F. A. Petitcolas, “On the limits of steganography,” *IEEE Journal on selected areas in communications*, vol. 16, no. 4, pp. 474–481, 1998.
- [12] A. K. Ekert, “Quantum cryptography based on bells theorem,” *Physical Review Letters*, vol. 67, p. 661663, Aug. 1991.
- [13] M. J. Dworkin, “Sha-3 standard: Permutation-based hash and extendable-output functions,” 2015.
- [14] Y. Nir and A. Langley, “Chacha20 and poly1305 for ietf protocols,” tech. rep., 2015.
- [15] D. J. Bernstein *et al.*, “Chacha, a variant of salsa20,” in *Workshop record of SASC*, vol. 8, pp. 3–5, Citeseer, 2008.
- [16] D. J. Bernstein, “The poly1305-aes message-authentication code,” in *International workshop on fast software encryption*, pp. 32–49, Springer, 2005.
- [17] N. Cvejic and T. Seppanen, “Increasing the capacity of lsb-based audio steganography,” in *2002 IEEE Workshop on Multimedia Signal Processing*, pp. 336–338, IEEE, 2002.