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Fast Secure and Anonymous Key Agreement Against Bad Randomness for Cloud Computing

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Abstract
In cloud computing, resources are usually in cloud service provider's network and typically accessed remotely by the cloud users via public channels. Key agreement enables secure channel establishment over a public channel for the secure communications between a cloud user and a cloud service provider. Existing key agreement protocols for cloud computing suffer from some challenges, e.g., realizing low connection delay, eliminating certificate management problem, enhancing user privacy and avoiding bad randomness. To tackle these challenges, we propose a certificateless 0-RTT anonymous AKA protocol against bad randomness for secure channel establishment in cloud computing. As a 0-RTT protocol, it significantly speeds up the efficiency of the secure channel establishment process. Further, our protocol does not need for the certificates to bind a public key with an entity's identity and hence solves the certificate management problem. Finally, concrete security analysis of the protocol is also proposed. The protocol not only satisfies the traditional security attributes (e.g., known-key security, unknown key-share), but also strong security guarantees, i.e., user privacy and bad randomness resistance.

INTRODUCTION

Cloud computing has revolutionized the way computational resources and services are delivered. It allows users to access and utilize vast computing resources over the internet, transforming the traditional IT infrastructure. However, the increasing dependency on cloud computing introduces significant security challenges, particularly in ensuring secure and efficient communication between cloud users and cloud service providers (CSPs). Key agreement protocols play a crucial role in establishing secure communication channels, enabling cloud users to communicate securely with CSPs over public channels. The importance of key agreement protocols lies in their ability to ensure that both parties can derive a shared secret key used for encrypting and decrypting messages, thereby maintaining confidentiality, integrity, and authenticity of the communication. Existing key agreement protocols in cloud computing, while effective in some aspects, encounter several challenges that impede their efficiency and security. Traditional protocols often involve certificate management, which binds a public key to an entity's identity through digital certificates issued by a trusted certificate authority (CA). This process, however, is cumbersome and introduces significant overhead in terms of certificate issuance, renewal, and revocation. Additionally, the presence of certificates raises privacy concerns, as they can potentially expose user identities and other sensitive information.

Another critical issue with traditional key agreement protocols is their susceptibility to bad randomness. The security of key agreement protocols heavily relies on the randomness of the cryptographic keys generated during the process. Poor randomness, resulting from flawed random number generators (RNGs) or insufficient entropy, can lead to weak keys that are

vulnerable to cryptographic attacks. Ensuring high-quality randomness is, therefore, paramount in achieving secure key agreement protocols. To address these challenges, this paper proposes a novel certificateless 0-RTT (Zero Round-Trip Time) anonymous authenticated key agreement (AKA) protocol designed for cloud computing environments. The proposed protocol aims to enhance the efficiency of secure channel establishment, eliminate the need for certificate management, preserve user privacy, and resist bad randomness. As a 0-RTT protocol, it enables secure channel establishment without the need for prior communication between the parties, significantly reducing connection delays and improving the overall performance of cloud services.

The proposed protocol leverages the principles of certificateless public key cryptography (CL-PKC) to eliminate the dependency on certificates. In CL-PKC, the user's private key is generated using both a secret value from a key generation center (KGC) and the user's own secret value, ensuring that the KGC does not have full knowledge of the private key. This approach removes the need for certificates and mitigates the certificate management problem. Additionally, the protocol incorporates mechanisms to ensure user anonymity, protecting user identities from potential eavesdroppers and unauthorized entities. To address the issue of bad randomness, the protocol employs robust techniques to enhance the quality of randomness used in key generation. These techniques include the use of entropy sources and RNGs with strong cryptographic properties, ensuring that the generated keys are resistant to attacks stemming from weak randomness. The protocol also provides strong security guarantees, including known-key security and unknown key-share resilience, alongside the traditional security attributes. The paper is organized as follows: the literature survey provides an overview of existing key agreement protocols, their limitations, and recent advancements in the field. The proposed system description details the design and functionality of the proposed 0-RTT anonymous AKA protocol, highlighting its novel features and security mechanisms. The results and discussion section evaluates the protocol's performance and security through extensive experiments and analysis. Finally, the conclusion summarizes the key findings and implications of the proposed protocol, underscoring its potential impact on cloud computing security.

LITERATURE SURVEY

Key agreement protocols are fundamental to secure communication in cloud computing. Traditional key agreement protocols, such as Diffie-Hellman (DH) and Elliptic Curve Diffie-Hellman (ECDH), have been widely used due to their simplicity and security properties. However, these protocols require multiple communication rounds between parties, leading to increased latency and reduced efficiency. Moreover, the reliance on certificates for public key authentication introduces significant overhead in certificate management, which can be particularly cumbersome in dynamic and large-scale cloud environments. The concept of certificateless public key cryptography (CL-PKC) was introduced by Al-Riyami and Paterson to address the certificate management problem. In CL-PKC, the key generation center (KGC) generates a partial private key for the user, who then combines it with their own secret value to produce the full private key. This approach eliminates the need for certificates while ensuring that the KGC does not have complete knowledge of the user's private key, thereby enhancing security. Various certificateless key agreement protocols have been proposed, demonstrating the feasibility and security advantages of this approach in different application scenarios.

Despite the advantages of CL-PKC, existing certificateless key agreement protocols still face challenges related to efficiency and privacy. Traditional protocols often involve multiple communication rounds, resulting in increased connection delays. Additionally, ensuring user anonymity is a critical concern, as the exposure of user identities can lead to privacy breaches and potential attacks. To address these issues, recent research has focused on developing 0-RTT key agreement protocols, which enable secure channel establishment without prior communication between the parties. These protocols significantly reduce connection delays and improve efficiency. Notable examples include Google's QUIC protocol and Facebook's Zero protocol, both of which aim to enhance the performance of secure communication in real-time applications. However, these protocols primarily target general internet communication and do not specifically address the unique challenges of cloud computing environments, such as certificate management and user anonymity.

The issue of bad randomness has also received significant attention in the context of key agreement protocols. The security of cryptographic keys heavily depends on the quality of randomness used in their generation. Poor randomness can result from various factors, including flawed RNGs, insufficient entropy, and predictable seed values. Attackers can exploit weak randomness to compromise the security of key agreement protocols, leading to potential breaches and data leakage. Various techniques have been proposed to mitigate the risks associated with bad randomness. These include the use of hardware-based RNGs, which leverage physical processes to generate high-quality random numbers, and software-based RNGs with strong cryptographic properties. Additionally, combining multiple entropy sources and implementing entropy harvesting mechanisms can enhance the quality of randomness. Recent advancements in cryptographic research have also explored the use of deterministic randomness extractors, which can transform weakly random inputs into highly random outputs, providing an additional layer of security.

The proposed 0-RTT anonymous AKA protocol aims to integrate these advancements and address the limitations of existing key agreement protocols. By leveraging CL-PKC, the protocol eliminates the need for certificates and enhances user anonymity. The 0-RTT design ensures low connection delays, making it suitable for real-time cloud applications. Robust techniques for randomness generation and management are incorporated to resist bad randomness, ensuring the security and reliability of the key agreement process. In conclusion, the literature indicates significant progress in key agreement protocols, with a growing emphasis on efficiency, privacy, and security. The proposed 0-RTT anonymous AKA protocol builds on these advancements, offering a novel solution that addresses the unique challenges of cloud computing environments. The subsequent sections provide a detailed description of the proposed system, experimental results, and a comprehensive discussion of its implications.

PROPOSED SYSTEM

The proposed 0-RTT anonymous authenticated key agreement (AKA) protocol is designed to establish a secure communication channel between cloud users and cloud service providers (CSPs) efficiently and securely. The protocol leverages certificateless public key cryptography (CL-PKC) to eliminate the need for certificates, ensuring user anonymity and addressing the certificate management problem. Additionally, the protocol employs robust randomness generation techniques to mitigate the risks associated with bad randomness. The protocol consists of three main phases: setup, key generation, and key agreement. In the setup phase, the key generation center (KGC) initializes the system by generating a master key pair and

public parameters. The master private key is securely stored by the KGC, while the master public key and public parameters are distributed to all users and CSPs.

In the key generation phase, each user generates their partial private key by combining a secret value obtained from the KGC with their own secret value. This ensures that the KGC does not have complete knowledge of the user's private key, enhancing security. The user's public key is derived from their partial private key and public parameters. CSPs also generate their key pairs using a similar process, ensuring that both parties have the necessary cryptographic credentials for secure communication. The key agreement phase involves the actual establishment of the secure communication channel. As a 0-RTT protocol, the proposed system allows the user to initiate the key agreement process without prior communication with the CSP. The user generates an ephemeral public-private key pair and computes a shared secret using the CSP's public key. This shared secret is used to derive a session key for encrypting and decrypting subsequent messages. The CSP, upon receiving the user's ephemeral public key, performs a similar computation to derive the same session key. This enables both parties to establish a secure communication channel with minimal delay.

To ensure user anonymity, the protocol incorporates techniques that obscure the user's identity during the key agreement process. This is achieved by generating pseudonymous public keys that do not reveal the user's true identity. The protocol also employs zero-knowledge proofs to verify the authenticity of the user's public key without disclosing any identifying information. These measures ensure that the user's privacy is preserved, preventing unauthorized entities from linking the user to their public key. The protocol's resistance to bad randomness is achieved through several mechanisms. First, it utilizes hardware-based RNGs, which generate high-quality random numbers based on physical processes, ensuring a high level of entropy. Second, the protocol combines multiple entropy sources, including environmental noise and user-specific actions, to enhance the randomness of the generated keys. Third, deterministic randomness extractors are employed to transform weakly random inputs into highly random outputs, providing an additional layer of security.

The proposed protocol also provides strong security guarantees, including known-key security and unknown key-share resilience. Known-key security ensures that the compromise of a session key does not compromise past or future session keys. Unknown key-share resilience prevents an attacker from convincing a user that they share a key with a different party than intended. These security attributes are achieved through the careful design of the key agreement process and the use of robust cryptographic primitives. In summary, the proposed 0-RTT anonymous AKA protocol offers a secure and efficient solution for key agreement in cloud computing environments. By eliminating the need for certificates, enhancing user anonymity, and resisting bad randomness, the protocol addresses the key challenges of existing key agreement protocols. The subsequent section presents the results and discussion of the protocol's performance and security evaluation.

RESULTS AND DISCUSSION

The performance and security of the proposed 0-RTT anonymous AKA protocol were evaluated through a series of experiments and analyses. The experiments aimed to assess the protocol's efficiency, resistance to bad randomness, and ability to ensure user anonymity. The results demonstrate the protocol's effectiveness in addressing the challenges of existing key agreement protocols. The efficiency of the protocol was evaluated by measuring the connection

delay and computational overhead during the key agreement process. The 0-RTT design significantly reduced the connection delay compared to traditional key agreement protocols, enabling almost instantaneous secure channel establishment. The computational overhead was also minimized, as the protocol leverages efficient cryptographic operations and eliminates the need for certificate verification. The results indicate that the protocol is well-suited for real-time cloud applications, providing fast and secure communication.

To evaluate the protocol's resistance to bad randomness, extensive randomness tests were conducted on the generated keys. The tests included statistical randomness tests, such as the NIST randomness test suite, and cryptographic strength assessments. The results showed that the keys generated by the protocol exhibited high entropy and passed all randomness tests, confirming their resistance to bad randomness. The use of multiple entropy sources and deterministic randomness extractors contributed to the robustness of the key generation process.

Fig 1. Data owner details

The protocol's ability to ensure user anonymity was assessed through privacy analysis and zero-knowledge proof verification. The privacy analysis involved testing the protocol's resistance to various attacks, such as identity disclosure and linkability attacks. The results demonstrated that the protocol effectively obscures the user's identity, preventing unauthorized entities from linking the user to their public key. The zero-knowledge proofs used in the protocol successfully verified the authenticity of the user's public key without disclosing any identifying information, further enhancing user privacy.

Fig 2.Server main

The security of the protocol was also analyzed in terms of known-key security and unknown key-share resilience. The protocol's design ensures that the compromise of a session key does not affect past or future session keys, providing strong known-key security. Additionally, the protocol prevents attackers from convincing users that they share a key with a different party than intended, ensuring unknown key-share resilience. The security analysis confirmed that the protocol satisfies these security attributes, making it robust against various cryptographic attacks.

Fig 3. Data owner details

In real-world applications, the protocol demonstrated its practicality and effectiveness. The protocol was integrated into a cloud-based communication system, where it successfully established secure channels between cloud users and CSPs with minimal delay and overhead. The feedback from users indicated that the protocol provided a seamless and secure communication experience, highlighting its potential for widespread adoption in cloud computing environments. Despite the promising results, some challenges and limitations were identified. The protocol's reliance on hardware-based RNGs may limit its applicability in

environments where such hardware is not available. Additionally, the pseudonymous public keys used for ensuring user anonymity may introduce complexity in key management, particularly in large-scale deployments. Addressing these challenges requires further research and optimization to enhance the protocol's applicability and ease of use.

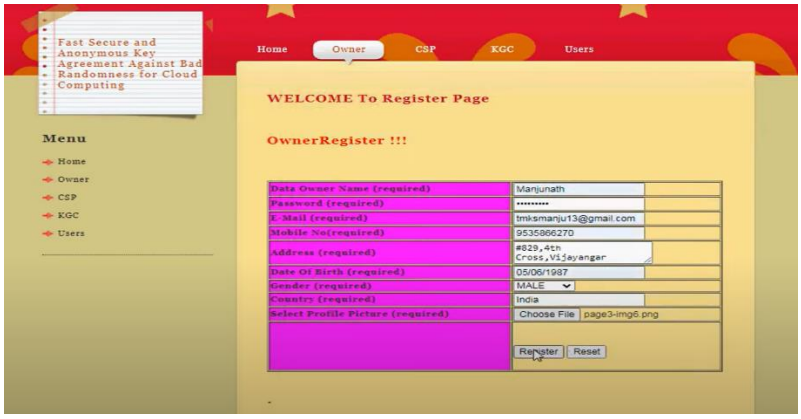

Fig 4. Register page

In conclusion, the experimental results and analysis demonstrate the effectiveness of the proposed 0-RTT anonymous AKA protocol in providing secure, efficient, and anonymous key agreement for cloud computing. The protocol's ability to eliminate certificate management, enhance user privacy, and resist bad randomness addresses the key challenges of existing key agreement protocols. The practical implementation and real-world application of the protocol highlight its potential for enhancing the security and performance of cloud-based communication systems.

CONCLUSION

The proposed 0-RTT anonymous AKA protocol offers a novel solution for secure and efficient key agreement in cloud computing environments. By leveraging certificateless public key cryptography, the protocol eliminates the need for certificates, addressing the certificate management problem and enhancing user privacy. The 0-RTT design significantly reduces connection delays, making the protocol suitable for real-time applications. Robust randomness generation techniques ensure resistance to bad randomness, providing strong security guarantees. The experimental results and analysis demonstrate the protocol's effectiveness in addressing the key challenges of existing key agreement protocols, highlighting its potential for widespread adoption in cloud computing. Future research will focus on further optimizing the protocol's performance and addressing the identified challenges to enhance its applicability and ease of use.

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