CAPSTONE PROJECT

Elliptic Curve Integrated Encryption Scheme Implementation for Android Platforms

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ABSTRACT:

Elliptic curve cryptography (ECC) is considered one of the strongest cryptographic methods in terms of security level. According to the National Institute of Standards and Technology (NIST), a 160-bit ECC key is roughly equivalent to a 1024-bit RSA key, making ECC a highly efficient choice for secure communications. The Elliptic Curve Integrated Encryption Scheme (ECIES) is a robust hybrid encryption scheme that operates similarly to a static Diffie-Hellman key exchange, followed by symmetric encryption for enhanced security. In the realm of Java and C# Cryptography Extension and Java Cryptography Architecture, Bouncy Castle is a well-known provider, while its Android counterpart is known as Spongy Castle. In this paper, we present a comprehensive implementation of the Elliptic Curve Integrated Encryption Scheme (ECIES) using Spongy Castle on Android platforms. The implementation process encompasses several critical aspects, including elliptic curve key generation, message encryption, and decryption. We conducted extensive testing of our application on three different platforms to evaluate its performance and compatibility.

The first platform utilized was an Android virtual device simulating a Samsung Nexus S, providing a controlled environment for initial testing. The second platform involved a physical Samsung Nexus S device, equipped with an ARM Cortex-A8 CPU running at 1GHz and 512MB of RAM, offering a more realistic user scenario. Finally, we tested the application on an Android Mini TV featuring a Dual-Core A9 Processor, which operates at 1GHz and is equipped with 1GB of RAM, to assess the performance on a higher-end device. Through these tests, we were able to demonstrate the viability and efficiency of implementing ECIES on Android platforms using Spongy Castle. This work not only highlights the practical aspects of ECC-based encryption on mobile devices but also underscores the importance of choosing the right cryptographic tools and libraries to ensure robust security in mobile applications.

INTRODUCTION:

Elliptic Curve Cryptography (ECC) is renowned for its high security level and efficiency, making it a preferred choice in modern cryptographic applications. ECC provides equivalent security to traditional public-key cryptosystems like RSA but with significantly smaller key sizes, leading to faster computations and reduced storage requirements. For instance, a 160-bit ECC key offers a security level comparable to a 1024-bit RSA key, as outlined by the National Institute of Standards and Technology (NIST).

One of the prominent applications of ECC is the Elliptic Curve Integrated Encryption Scheme (ECIES). ECIES is a hybrid encryption scheme that combines the Diffie-Hellman key exchange mechanism with symmetric encryption for robust data security. It provides both confidentiality and data integrity, making it suitable for secure communications over untrusted networks.

In this project, we present the implementation of ECIES on Android platforms using the Spongy Castle library, a widely used cryptographic library tailored for Android. The project aims to demonstrate the practical application of ECIES, showcasing key generation, encryption, and decryption processes within an Android environment. We use JAVA SE 6 JDK 1.6 and the Eclipse SDK V4.2.2 as our development tools, leveraging the Spongy Castle package for the cryptographic operations.

The implementation is tested on various Android platforms, including both virtual and physical devices, to ensure compatibility and performance efficiency. Through this project, we aim to highlight the benefits and feasibility of using elliptic curve cryptography for securing mobile communications, providing insights into the integration of advanced cryptographic techniques in mobile applications.

Elliptic Curve Integrated Encryption Scheme

I. ECIES

ECC operates based on a chosen elliptic curve and a base point \( P \) on it. We use the Weierstrass form for our elliptic curve, defined by parameters \( a \) and \( b \). The curve is over a prime field \( p \) and has an order \( n \). A point \( P \) on the curve is chosen as the base point.

The ECIES scheme consists of three main algorithms: key generation, encryption, and decryption.

A. Key Generation

1. Choose a shared secret \( d \) as the private key.

2. Generate the public key \( Q \) using \( Q = [d]P \).

3. The key generator returns a key pair \((Q, d)\).

B. ECIES Encryption

To encrypt a message:

1. Generate a random number \( k \in [1,p] \).

2. Calculate \( U = [k]P \).

3. Calculate \( T = [k]Q \).

4. Use a key derivation function (KDF) to compute two keys \( k1 \) and \( k2 \) from \( T \). Since \( T \) is a 192-bit key, a hash function is used to hash it into 256 bits.

5. Use the 128-bit AES encryption algorithm to encrypt the message with key \( k1 \), obtaining ciphertext \( c \).

6. Use HMAC-SHA256 to calculate a message authentication code (MAC) \( r \) with \( k2 \).

7. Send the pair \((U, c, r)\) as the encrypted message.

C. ECIES Decryption

To decrypt a message:

1. Parse the encrypted message into \((U, c, r)\).

2. Use the secret private key \( d \) to compute \( T = [d]U \).

3. Use the same KDF to obtain \( k1 \) and \( k2 \).

4. Compute the MAC using \( k2 \) and compare it with \( r \). If they match, proceed; otherwise, discard the message as invalid.

5. Use the 128-bit AES decryption algorithm to decrypt \( c \) and obtain the original message \( m \).

If any of the checks fail, reject the message as forged.

Implementation

This ECIES implementation is developed using JAVA SE 6 JDK 1.6 and the Spongy Castle package, within the Eclipse SDK V4.2.2 development environment. Spongy Castle artifacts, which are available on Maven Central, provide essential cryptographic libraries needed for the implementation.

Required Libraries:

The following libraries must be downloaded and added to the Java build path:

- sc-light-jdk15on (jar): Core lightweight API

- scprov-jdk15on (jar): JCE provider (requires sc-light-jdk15on)

- scpkix-jdk15on (jar): PKIX, CMS, EAC, TSP, PKCS, OCSP, CMP, and CRMF APIs (requires scprov-jdk15on)

The Java `BigInteger` library is crucial for handling large numbers of arbitrary length. Our implementation utilizes `BigInteger` for both the private key and the public key. The public key, represented as point \( Q \), consists of two `BigInteger` variables.

Java Class Structure:

A. `ECIESEngine` Class

The `ECIESEngine` class is defined as the core of our ECIES implementation. We utilize the NIST 192-bit curve for elliptic curve operations. The class handles key generation, encryption, and decryption processes.

-Key Generation: This involves generating elliptic curve key pairs using the NIST 192-bit curve.

- Encryption: This process includes generating a random number, calculating points on the curve, and using AES for encrypting the message.

- Decryption: This involves parsing the encrypted message, computing the necessary keys, and using AES for decrypting the message.

B. `ECIESDemoActivity` Class

The `ECIESDemoActivity` class builds an application on top of the `ECIESEngine` class. This class functions as an Android activity, providing a user interface for demonstrating the ECIES encryption and decryption processes.

Development Environment:

The development environment setup involves configuring Eclipse SDK V4.2.2 with the necessary libraries and packages.

Spongy Castle libraries are added to the build path to provide the cryptographic functionality required for ECIES.

Practical Application;

The `ECIESDemoActivity` class showcases the practical application of ECIES in an Android environment. The user interface allows users to input messages, encrypt them using ECIES, and then decrypt them to retrieve the original message.

In summary, this implementation demonstrates how to effectively utilize Spongy Castle for ECIES in Java and Android environments, leveraging the power of elliptic curve cryptography for secure communication.

My original implementation of AES can only deal with a message that is a multiple of 16 characters. With the Cipher Block Chaining (CBC) technique, we can encrypt arbitrary long messages, such as the message the demo shows.For future work, we need to take care of side channel attacks.

For example, when calculating point multiplication, an aggressive attacker could leverage the timing information to launch timing attacks. Encryption process could also be attacked by some malicious process which fills cache beforehand and computes cache usage on Android device to do cache timing attack. Point multiplication is also vulnerable to the simple power analysis or differential power analysis when the device is obtained by a malicious person.

**CONCLUSION:**

The implementation of the Elliptic Curve Integrated Encryption Scheme (ECIES) on Android platforms using the Spongy Castle library has demonstrated the viability and efficiency of elliptic curve cryptography (ECC) for secure mobile communications. Our comprehensive approach encompassed key generation, encryption, and decryption processes, ensuring robust data security. Testing on various platforms, including virtual and physical devices, affirmed the compatibility and performance of the implementation across different hardware configurations.

The results highlight the practical benefits of ECC, offering strong security with smaller key sizes and faster computations compared to traditional cryptographic methods. The use of Spongy Castle facilitated seamless integration of ECC-based encryption in an Android environment, underscoring its potential for enhancing security in mobile applications.

Future work should address potential side-channel attacks, such as timing and power analysis attacks, to further bolster the security of the implementation. Techniques like constant-time algorithms and additional countermeasures can mitigate these risks, ensuring even higher levels of security.

In conclusion, this work showcases the effectiveness of implementing ECIES on Android platforms, providing a solid foundation for secure mobile communication and paving the way for future advancements in mobile cryptography.

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