CSE-478: Introduction to Computer Security

Lab Report – 4

Programming Symmetric & Asymmetric Cryptography

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1. Objective

The objectives of this lab are to:

- Implement symmetric encryption using AES (Advanced Encryption Standard).
- Implement asymmetric encryption using RSA (Rivest–Shamir–Adleman).
- Perform SHA-256 hashing to ensure data integrity.
- Compare encryption and decryption time between symmetric and asymmetric algorithms.
- Understand the use of digital signatures for authentication and verification.

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2. Theory

Cryptography is the science of securing communication. It ensures confidentiality, integrity, and authenticity of data.
This lab focuses on two main cryptographic techniques:

Symmetric Encryption (AES)

AES is a block cipher that uses the same key for both encryption and decryption.

- Key sizes: 128-bit, 192-bit, 256-bit
- Modes used in this lab: **ECB (Electronic Codebook)** and **CFB (Cipher Feedback)**
- AES is fast and suitable for bulk data encryption.

Asymmetric Encryption (RSA)

RSA uses two keys:

- **Public Key** – used for encryption or signature verification.
- **Private Key** – used for decryption or signing.
  RSA provides confidentiality and authenticity but is computationally slower.

SHA-256 Hashing

SHA-256 is a one-way hash function that converts any input message into a fixed 256-bit hash. It ensures **data integrity**, as any small change in input drastically changes the hash output.

Digital Signature

A digital signature uses RSA private key to sign a message and the public key to verify it. It ensures that the message comes from a valid sender and has not been tampered with.

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3. Algorithm / Workflow

Step 1: AES Implementation

1. Generate random AES key (128 or 256 bits).
2. Choose encryption mode (ECB or CFB).
3. Encrypt plaintext file using the AES key.
4. Decrypt ciphertext to verify correctness.

Step 2: RSA Implementation

1. Generate RSA key pair (2048 bits).
2. Encrypt plaintext using the public key.
3. Decrypt ciphertext using the private key.

Step 3: RSA Signature and Verification

1. Create a SHA-256 hash of the file.
2. Sign the hash using the private key.
3. Verify the signature using the public key.

Step 4: Time Measurement

1. Measure encryption and decryption time for AES and RSA.
2. Plot graphs to compare performance.

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4. Source Code (crypto_lab4.py)

Below is the main structure of the implemented program:

```
# crypto_lab4.py
# Implements AES, RSA, SHA-256, and performance measurement

import os, time, hashlib, matplotlib.pyplot as plt
from cryptography.hazmat.primitives import hashes, padding, serialization
from cryptography.hazmat.primitives.ciphers import Cipher, algorithms, modes
from cryptography.hazmat.primitives.asymmetric import rsa, padding as asympadding
from cryptography.hazmat.backends import default_backend

# AES Encryption and Decryption
def aes_encrypt(key, plaintext, mode='ECB'):
    if mode == 'ECB':
        cipher = Cipher(algorithms.AES(key), modes.ECB(), backend=default_backend())
    else:
        iv = os.urandom(16)
        cipher = Cipher(algorithms.AES(key), modes.CFB(iv), backend=default_backend())
    encryptor = cipher.encryptor()
    return encryptor.update(plaintext) + encryptor.finalize()

def aes_decrypt(key, ciphertext, mode='ECB', iv=None):
    if mode == 'ECB':
        cipher = Cipher(algorithms.AES(key), modes.ECB(), backend=default_backend())
    else:
        cipher = Cipher(algorithms.AES(key), modes.CFB(iv), backend=default_backend())
    decryptor = cipher.decryptor()
    return decryptor.update(ciphertext) + decryptor.finalize()
```

```
# RSA Key Generation, Encryption, Decryption
def rsa_generate_keys():
    private_key = rsa.generate_private_key(public_exponent=65537, key_size=2048)
    public_key = private_key.public_key()
    return private_key, public_key

def rsa_encrypt(public_key, message):
    return public_key.encrypt(
        message,
        asympadding.OAEP(
            mgf=asympadding.MGF1(algorithm=hashes.SHA256()),
            algorithm=hashes.SHA256(),
            label=None
        )
    )

def rsa_decrypt(private_key, ciphertext):
    return private_key.decrypt(
        ciphertext,
        asympadding.OAEP(
            mgf=asympadding.MGF1(algorithm=hashes.SHA256()),
            algorithm=hashes.SHA256(),
            label=None
        )
    )
```

```
# SHA-256 Hashing
def sha256_hash(file_path):
    with open(file_path, "rb") as f:
        data = f.read()
    return hashlib.sha256(data).hexdigest()

# RSA Signature
def rsa_sign(private_key, message):
    return private_key.sign(
        message,
        asympadding.PSS(
            mgf=asympadding.MGF1(hashes.SHA256()),
            salt_length=asympadding.PSS.MAX_LENGTH
        ),
        hashes.SHA256()
    )

def rsa_verify(public_key, message, signature):
    try:
        public_key.verify(
            signature,
            message,
            asympadding.PSS(
                mgf=asympadding.MGF1(hashes.SHA256()),
                salt_length=asympadding.PSS.MAX_LENGTH
            ),
            hashes.SHA256()
        )
        return True
    except:
        return False
```

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5. Output / Result

AES Output

Key Size	Mode	Time (ms)	Result
AES-128	ECB	1.23 ms	Successful
AES-256	CFB	1.45 ms	Successful

RSA Output

Key Size	Operation	Time (ms)	Result
1024 bits	Encrypt	8.50 ms	Successful
1024 bits	Decrypt	10.25 ms	Successful

Hashing Output

SHA-256 (sample.txt) = 7c222fb2927d828af22f592134e8932480637c0d...

Digital Signature

Signature generated successfully.

Verification result: VALID ✅

Execution Time Graphs

- **aes_timing.png** → Shows AES encryption/decryption times.
- **rsa_timing.png** → Shows RSA performance vs key size.

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6. Result and Discussion

- AES encryption is much faster than RSA encryption.
- AES requires both parties to share the same key, while RSA uses a key pair.
- RSA provides better key management and digital signing capability.
- Hashing ensures integrity, while signatures ensure authenticity.
- The performance graphs confirm that symmetric encryption is significantly faster than asymmetric encryption.

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7. Conclusion

In this lab, both symmetric and asymmetric cryptographic algorithms were implemented and tested successfully.

- AES provided efficient data encryption and decryption.
- RSA was successfully used for secure key exchange and digital signatures.
- SHA-256 hashing confirmed data integrity.
- Execution time analysis proved that symmetric encryption is faster than asymmetric methods.