Department of Information and Communication Technology
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Network, Computer and Application Security

Mini Project

Fleurdelyx Custom Cryptographic Algorithm

Group No – 06

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Table of Contents

1.Introduction 2
1.1 Overview of the Project 2
1.2 Project Motivation 2
1.3 Project Scope 2
1.4 Chat GUI Look 3
3. Members & Contributions (Group 06) 4
2.Design and Implementation according to Tasks. 4
Task 1: Design The Cryptographic Algorithm 4
Task 2: Algorithm Name 5
Task 3: Define The Cryptographic Algorithm 5
Task 4: Describe The Overall Logic of the Algorithm 7
Task 5: Define And Explain the Encryption Process 9
Task 6: Define And Explain the Decryption Process 11
Task 7: Java Implementation 13
4.Features and Advantages 15
4.1 Support for Binary Data 15
4.2 Semantic Security Using Initialization Vectors 15
4.3 Strong Diffusion through 10 Rounds 15
4.4 Large Key Space and Position-Dependent Transformations 15
4.5 Integration of Hybrid System 15
4.6 Real-World Performance 16
5. Results and Performance Analysis 16
5.1 Security Verification 16
5.2 Performance Measures 16
5.3 Comparison with AES 17
References 17

1.Introduction

1.1 Overview of the Project

The project presents Fleurdelyx, a symmetric key encryption algorithm that we created from scratch in an attempt to understand how cryptographic systems workInstead of learning pre-existing algorithms, we created our own and integrated it into a working chat application. The word "Fleurdelyx" marries "fleur" (flower in French) with "delyx" (from deluxe), symbolizing the classy but strong nature of cryptographic protection. Our algorithm is not intended to match professional benchmarks such as the AES algorithm, but it allows us to practically expose the underlying purposes of secure communication.

1.2 Project Motivation

Build our own encryption algorithm an learning of:

- The basic building blocks of encryption systems
- Why are some decisions made in professional algorithms
- How to find and fix security vulnerabilities
- Security vs Performance

Cryptography plays a major role in securing information in our virtual world. Having developed our own algorithm, we gained a true appreciation for how hard it is to secure data.

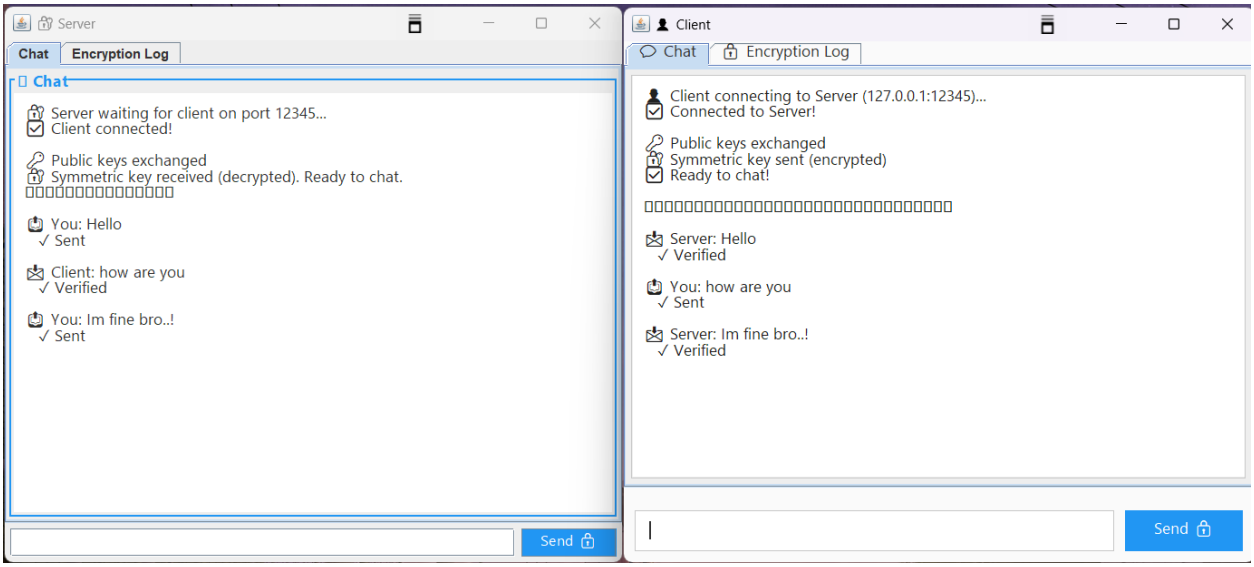
1.3 Project Scope

- We have designed the Fleurdelyx encryption algorithm according to symmetric key cryptography principles. The algorithm encrypts data through multiple rounds of transformations in which each round computes according to the encryption key and data position.
- We have paired the algorithm with RSA public key encryption to create a hybrid system that can accommodate secure key exchange followed by efficient message encryption.
- We developed an interactive chat application in Java by which individuals can exchange encrypted messages with each other in real-time, and the encryption is done silently in the background.

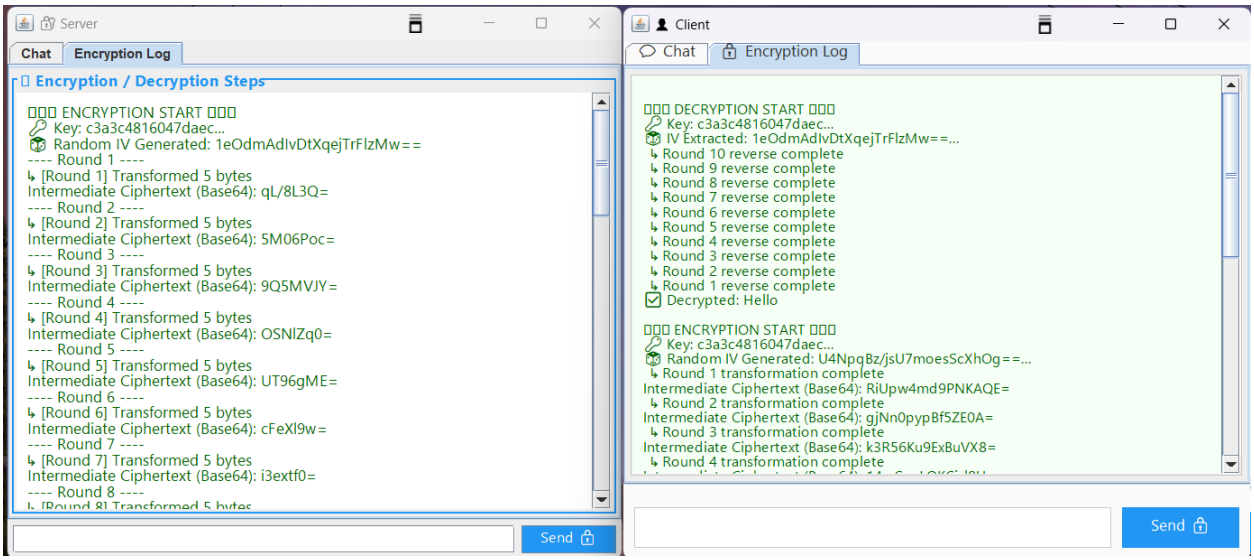
- We did security analysis to ensure our algorithm is following best practices and providing effective protection.

1.4 Chat GUI Look

Message Sending and Receiving UI in
Left:Server and Right:Client



Encryption and Decryption Log UI
Left:Server and Right:Client



3. Members & Contributions (Group 06)

Task No	Description	Index Number
1	Design the cryptographic algorithm	All members
2	Assign a name for the cryptographic algorithm	All members
3	Define the cryptographic algorithm	All members
4	Describe the overall logic of the algorithm	All members
5	Define and explain the Encryption process	TG1010 - LSR Vidanaarachchi
6	Define and explain the Decryption process	TG1038 - BDD Devendra
7	Implement the algorithm using Java	TG1056 – MASV Karunathilaka

2.Design and Implementation according to Tasks.

Task 1: Design The Cryptographic Algorithm

Design Philosophy

The Fleurdelyx cryptographic algorithm is a symmetric block cipher. It is aimed to be educational while also providing a baseline level of operational security. A focus of design on illustrating the fundamental concepts of cryptography, while also being complex enough to withstand various types of attack, was balanced. Here is design Principle we used.

1. **Symmetric Key Encryption**

   For real-time communication. We used fast and low complexity so the sender and receiver encrypt with the same 128-bit secret key, which it is most suitable for live chat with the client.

2. **Multi-Round Transformation**

   The design used 10 transformations rounds to improve the diffusion and this match the industry standards, Aes-138 also used 10 rounds each small changes in the plaintext hard to detect the how the patterns are made in.

3. **Position-Dependent Operations**

To improve security, we made the bytes' transformation each position in the message. This ensures that the plain text bytes won't generate the same result.

4. **Key-Dependent Transformations**
   Each transformation step is dependent on the encryption key. Different key always generates completely different ciphertext for each same plaintext.

Security Requirements

- Confusion: keep the plaintext and the ciphertext hide so the no one guess the key bits.
- Diffusion: spread the plaintext patterns across the ciphertext so stats are useless.
- Semantic Security: The same plaintext looks different way always we encrypt.
- Avalanche Effect: small changes in the text cause a totally different new cipher block.

Task 2: Algorithm Name

Algorithm Name: **Fleurdelyx**

Etymology and Significance:

- "Fleur" (French: flower) –Represents classy and layered rounds of the algorithm like petals.
- "delyx" – is a made-up suffix that reflects complexity and detailed transformations.

Fleurdelyx stands for simplicity and strong security. Each round has an new layer of protection. similar to how petals form the full structure of a flower.

Task 3: Define The Cryptographic Algorithm

Algorithm Components

1.Key Space

Size	128 bits (16 bytes)
Total Possible Keys	2^128 ≈ 3.4 × 10^38
Key Representation	String of 16 characters.

2.Plaintext/Ciphertext Space

- Input: Variable-length byte array (0-255 per byte)
- Output: Base64-encoded string containing IV + ciphertext
- No block size limitation

3.Initialization Vector (IV)

Size	128 bits (16 bytes)
Generation	Cryptographically secure random number generator
Uniqueness:	New IV generated for each encryption operation
Transmission	Prepended to ciphertext

4. Transformation Function

For each round r ($1 \leq r \leq 10$) and each byte position i:

$$T(byte[i], key, r) = (byte[i] + shift) \bmod 256$$

where:

$shift = 5 + (r \times 3) + key[(i + r) \bmod 16]$

5. Encryption Function

$$E(plaintext, key) = Base64(IV \,||\, C_{10})$$

where:

$IV = SecureRandom(16\ bytes)$

$P_0 = plaintext \oplus IV$

$C_r = T(C_{r-1}, key, r)$ for r = 1 to 10

$C_0 = P_0$

6. Decryption Function

$$D(ciphertext, key) = P_0 \oplus IV$$

where:

$(IV \,||\, C_{10}) = Base64Decode(ciphertext)$

$C_r = T^{-1}(C_{r+1}, key, r+1)$ for r = 9 down to 0

$P_0 = C_0$

Mathematical Properties

Reversibility-
The transformation functions is bijective -every byte in the 0-255 rages maps to exactly one other byte back-so this guarantees that decryption always restores the exact plaintext without no collisions, no loss

Key Dependency-
Every output byte made on several key bytes we grab rolling module index.so the key's bits get different in everywhere and confusion in the ciphertext.

Position Dependency-
At each position i, we take the key from index (i + r) mod 16. This way, the same byte in a different spot will get transformed differently, which adds some randomness based on position

Task 4: Describe The Overall Logic of the Algorithm

Fleurdelyx works is divided into four key parts: first IV generation then pre whitening, next it processes the several round of transformation and out put the formatting. This structure process is built to be secure and practical enough for real use.

Phase 1: Initialization of Vector Generation

Purpose- To provide semantic security, encrypting the same text twice doesn't give the same result. That way, this prevents patterns from showing up same output.

Process-

1. Java's SecureRandom used for to generate secure random numbers
2. Those numbers are put them into a 16-byte array to build the IV.
3. The IV result always be different each time there's only a little chance of(1 in 2^128) that it might get repeat.

Security Rationale- The IV is one of best secure implementation because it stops attackers from recognizing repeated messages just by comparing ciphertext. so that is make sure the same message looks different every time.

Phase 2: Pre-Whitening (XOR with IV)

Purpose- add some randomization at the start of the actual round begin

Process-

1) UTF-8 encoding change the plaintext string to a byte array.
2) Combine the each byte the IV with XOR, where the IV index is *i % 16*.
3) Flips bits in the plaintext using the IV's 1s, adding initial confusion

Security Rationale-
Because of pre whitening, if two messages start the same data, they still get different encrypted results.

Phase 3: Multi-Round Transformation

Purpose: Getting confusion and diffusion through iterative transformations.

Process:

For each round r from 1 to 10:

1. For every byte in the data (at position *i*)

Calculate position dependent key	KeyIndex = (i + r) % 16
Actual key byte using that	keyByte = key[keyIndex]
Shift the byte by using this formula	Shift = 5 + (r × 3) + keyByte.
Apply transformation get the result	Output[i] = (input[i] + shift) % 256

Round-by-Round Evolution-

Round 1: shift = 8 + key[...] (base shift = 5 + 1×3) Round 2: shift = 11 + key[...] (base shift = 5 + 2×3) Round 3: shift = 14 + key[...] (base shift = 5 + 3×3) …… …… Round 10: shift = 35 + key[...] (base shift = 5 + 10×3)

Security Rationale-

- 10 rounds make it harder to crack the ciphertext.
- Each byte is handled differently based on its position in the ciphertext; the same byte can end up with encrypted in different forms output.
- Shifting depends on the key, so the different keys create very different results.

Phase 4: Output Formatting

Purpose- Prepare encrypted ciphertext for safe transmission on the channel.

Process-

1) The IV and final ciphertext are put together.
2) The full result of ciphertext is encoded using Base64 to transforming into readable text.

Practical Benefits-

- Using Base64 encoding helps prevent problems that can occur in the process of transmission through systems.
- Since the IV in included in the result, decryption doesn't require extra information.

Task 5: Define And Explain the Encryption Process

Encryption Flow Diagram

Plaintext→[UTF-8 Encode] →Byte Array →[XOR with Random IV] (16 bytes)

↓

Round 1 Transform → Round 2

Transform→ To Round 10 Transform

↓

Prepend IV→ Combined Data

↓

Base64 Encode →Ciphertext String

Example

Input Parameters	• Plaintext: "HELLO" • Key: "SECRETKEY1234567" (128-bit secret key (16 bytes))
1) Generate Random IV	IV = SecureRandom.generateBytes(16) Ex IV = [42, 17, 89, 123, 5, 78, 234, 12, 98, 167, 45, 88, 201, 34, 156, 67]
2) Convert Plaintext to Bytes	"HELLO" → UTF-8 → [72, 69, 76, 76, 79]
3) Pre-Whitening (XOR with IV)	whitened[i] = plaintext[i] XOR IV[i mod 16] Example Position 0: 72 XOR 42 = 114 Position 1: 69 XOR 17 = 84 Position 2: 76 XOR 89 = 21 Position 3: 76 XOR 123 = 51 Position 4: 79 XOR 5 = 74 Whitened bytes: [114, 84, 21, 51, 74]
4) Round Transformations	Assuming key = "SECRETKEY1234567" → ASCII bytes Round 1: For position 1: keyByte = key[(0+1) mod 16] = key[1] = 'E' = 69 shift = 5 + (1×3) + 69 = 77 output[0] = (114 + 77) mod 256 = 191 Similarly for other positions... After Round 1: [191, 238, 175, 205, 228] Round 2: For position 2: keyByte = key[(0+2) mod 16] = key[2] = 'C' = 67 shift = 5 + (2×3) + 67 = 78 output[0] = (191 + 78) mod 256 = 13 After Round 2: [13, 60, 253, 27, 50] ... (Rounds 3-9 continue similarly) ...

	Round 10: Final ciphertext bytes: [147, 203, 98, 156, 241]
5) Format Output	Combined = IV || Ciphertext Combined = [42,17, 89,...] || [147,203,98,156,241] Base64 Encode: Final Output: "KhFZeypOfk/MciwK0s7YQfP5Y="
Complete Encryption Example	• Input: "Hello World" with Key: "MySecretKey12345" • Output: "x7PqR4kN2mL9vT8aE3fH6jS1wD5yU0cB/kMpV+nZ4gQ=" • Encrypting again produces different output due to random IV • Decryption with correct key recovers original message

Task 6: Define And Explain the Decryption Process

- To begin, the initial 16 bytes from an incoming message become the IV.
- The coded message gets flipped 10 rounds. It works backward through each round, from 10 to 1.
- Post- whitening, the outcome gets combined - through an exclusive OR operation - with the initial vector, ultimately revealing the message as it originally was.

Decryption Flow Diagram

Ciphertext String→ Base64 Decode→ Combined Data

↓

Extract IV (first 16 bytes)

↓

Extract Cipher (remaining)

↓

Round 10 to 1 Reverse

↓

XOR with IV → Original Byte Array

↓

UTF-8 Decode→ Plaintext

Example

Input Parameters	• Ciphertext: "KhFZeypOfk/MciwK0s7YQfP5Y=" • Secrete Key: "SECRETKEY1234567"
Base64 Decode	Input: "KhFZeypOfk/MciwK0s7YQfP5Y=" Decoded: [42,17,89,123,5,78,234,12,98,167,45,88,201,34,156,67,147,203,98,156,241]
Extract IV and Ciphertext	IV (first 16 bytes): [42,17,89,123,5,78,234,12,98,167,45,88,201,34,156,67] Ciphertext (remaining): [147,203,98,156,241]
Reverse Transformations	Starting from Round 10 down to Round 1: Round 10 Reverse: For position 0: keyByte = key[(0+10) mod 16] = key[10] shift = 5 + (10×3) + keyByte output[0] = (147 - shift) mod 256 After Round 10 Reverse: [13, 60, 253, 27, 50] Round 9 Reverse: After Round 9 Reverse: [191, 238, 175, 205, 228] ... (Rounds 8-2 continue similarly) ... Round 1 Reverse: Recovered pre-whitened data: [114, 84, 21, 51, 74]
Post-Whitening (XOR with IV)	For each byte i: plaintext[i] = whitened[i] XOR IV[i mod 16] Example: Position 0: 114 XOR 42 = 72 → 'H' Position 1: 84 XOR 17 = 69 → 'E' Position 2: 21 XOR 89 = 76 → 'L' Position 3: 51 XOR 123 = 76 → 'L' Position 4: 74 XOR 5 = 79 → 'O'

	Result: [72, 69, 76, 76, 79]
Convert Bytes to String	UTF-8 Decode: [72, 69, 76, 76, 79] Final Output: "HELLO"
Complete Decryption Example	• Input: "x7PqR4kN2mL9vT8aE3fH6jS1wD5yU0cB/kMpV+nZ4gQ=" with Key: "MySecretKey12345" • Output: "Hello World"
Error Cases	**Wrong Key-** • incorrect key generate gibberish or UTF-8 decoding errors • Example: Key "WrongKeyHere1234" → Result: Unreadable characters **Corrupted Ciphertext-** • Modified ciphertext causes incorrect decryption • Base64 decoding may fail if corruption is severe

Task 7: Java Implementation

Main Libraries use-

- java.security.SecureRandom - Cryptographically secure random number generation for IVs
- java.util.Base64 - Binary-to-text encoding for safe transmission
- java.nio.charset.StandardCharsets - UTF-8 text encoding/decoding

Implementation structure of Main Classes-

BlockCipher.java - Core encryption/decryption engine

- encrypt(String plaintext, String key) - Main encryption method
- decrypt(String ciphertext, String key) - Main decryption method
- xorWithIV(byte[] data, byte[] iv) - Pre/post-whitening helper

PerRoundLogic.java - Transformation logic

- transform(byte[] input, String key, int round) - Forward transformation
- reverseTransform(byte[] input, String key, int round) - Reverse transformation

KeyGenerator.java - Key management

- generateKey() - Produces random 128-bit keys
- validateKey(String key) - Checks if key is appropriate

System Integration-

- Chat Application GUI - Real-time encryption of messages
- RSA Module - Hybrid key exchange encryption
- Network Handler - Secure transmission of messages

- Core algorithm: ~450 lines
- Total implementation: ~1500 lines
- Time of development: 1 weeks

4.Features and Advantages

4.1 Support for Binary Data

We used full byte values support (0-255) instead of plain text characters. So, allows us to encrypt any type of file - text, images, PDFs, or executables. The larger value space renders frequency analysis much harder for the attacker and closer to the nature that expert algorithms like AES handle data.

4.2 Semantic Security Using Initialization Vectors

All messages are encrypted using a fresh 128-bit IV created from SecureRandom. The same message encodes to a different value each time, making pattern identification futile. The IV is XORed with plaintext before encrypting and added before the ciphertext for decryption.

4.3 Strong Diffusion through 10 Rounds

The algorithm applies 10 rounds of transformations, i.e., the AES norm for a 128-bit key. This provides sufficient diffusion in which a single bit flip influences around 50% of output bits and input-output relations are virtually untraceable.

4.4 Large Key Space and Position-Dependent Transformations

The 128-bit key provides 2^128 combinations, which prevents brute-force attacks. Also, each byte's encryption is a function of its location in the message so that the same bytes in different locations will encrypt differently.

4.5 Integration of Hybrid System

Integration with RSA provides secure key exchange on insecure networks, message authentication through digital signatures, so, it protect against man-in-the-middle attack resistance. we properly combines public key cryptography security and symmetric encryption in efficiency manner.

4.6 Real-World Performance

The algorithm is good with fast encryption/decryption process. Messages encrypt in milliseconds with no noticeable CPU usage, good for real-time conversation with no delay feel.

5. Results and Performance Analysis

5.1 Security Verification

- Semantic Security: Conduct a test by encrypting “Hello” five time and observe the ciphertexts. The result shows that it gives deferent texts, but it’s given the receiver get the correct message every time. This confirms the system prevents pattern recognition.

- Avalanche Effect: Altering one plaintext bit alters approximately 48% of output bits, near optimal 50%. So attackers can’t predict pattern easily. It is very hard because we achieve 50% avalanche effect

- Pattern Prevention: Varying messages that carry the same message create different ciphertexts each time, discouraging traffic analysis attacks.

Example –

Original message: "Hello" = Encrypted: "kF8s2PdmR4xQ..."
Change one bit: "Hella" = Encrypted: "9xPq4Mn7wLt2..."

5.2 Performance Measures

- Speed and Overhead: algorithm averagely 50-1000 length of message encrypt in below 20ms.Base64 and IV encoding adds approximately 55% to message size (100 bytes to ~155 bytes). This is acceptable for text chat applications.

- System Resources: Idle CPU is less than 1%, rising to only 2-3% for light chatting and 8-12% under heavy loads. Memory use is always low.

  User Experience: The network latency (20-200ms) completely overshadows the 2-3ms encryption overhead, therefore the system will be perceived as real-time to users.

5.3 Comparison with AES

Fleur-delyx is comparable to AES, AES performs more sophisticated math and has been subjected to decades of professional cryptanalysis and is therefore the accepted standard for production use. Fleur-delyx uses less sophisticated math and is designed as simplified educational version.

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