SUB: Information Security

AY 2023-24 (Semester-V)

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Experiment No: 4

Batch: D22

Aim: To Implement Encryption and Decryption using Product Cipher.

Theory:

1. Product Cipher.

A product cipher is a cryptographic technique that combines multiple encryption or decryption operations to provide enhanced security. It involves using a combination of various cryptographic algorithms or methods in a structured manner. The goal of a product cipher is to achieve a higher level of security than what can be obtained with individual cryptographic components.

Here are the key aspects and components of a product cipher:

1. Composition of Ciphers:
Multiple Algorithms: A product cipher combines multiple cryptographic algorithms or techniques. These can include both substitution and transposition ciphers or other cryptographic primitives.
Layers of Security: The idea is to create layers of security by applying different ciphers sequentially or in parallel.

2. Sequential or Parallel Processing:
Sequential Product Cipher: In a sequential product cipher, the plaintext undergoes encryption or decryption through a series of cryptographic operations. Each operation is performed in sequence, with the output of one operation becoming the input for the next.
Parallel Product Cipher: In a parallel product cipher, different parts of the plaintext are processed simultaneously using distinct cryptographic methods. The results are then combined to produce the final ciphertext or plaintext.

3. Key Management:
Key for Each Component: Each cryptographic component within the product cipher typically has its own key. The combination of these keys contributes to the overall security of the product cipher.

Key Mixing: The keys may be combined or mixed in a specific way to strengthen the overall security of the product cipher.

4. Strengths and Security:
Increased Complexity: Product ciphers aim to increase the complexity of the encryption process, making it more resistant to various cryptographic attacks.
Cryptographic Diversity: By combining different cryptographic techniques, a product cipher leverages the strengths of each component, mitigating the weaknesses associated with individual ciphers.

5. Examples:
DES (Data Encryption Standard): DES can be considered a product cipher as it combines both substitution (using S-boxes) and transposition (using permutation) operations in multiple rounds.
AES (Advanced Encryption Standard): AES, like DES, employs a combination of substitution (through the use of the S-box) and transposition (via matrix operations) to achieve its encryption.
Let's consider a hypothetical example of a product cipher that combines a substitution cipher and a transposition cipher. The goal is to illustrate how a product cipher can enhance security by incorporating different cryptographic techniques.

Example: Substitution-Transposition Product Cipher

Substitution Cipher:
Substitution Key: Suppose we have a simple substitution cipher where each letter is replaced by another letter based on a predefined substitution key. For example:

Substitution Key:
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
| | | | | | | | | | | | | | | | | | | | | | | | | | |
K E Y Q U I C K B R O W N F O X J U M P S A V E T H E L A Z Y D O G

Transposition Cipher:
Transposition Key: Now, let's use a transposition cipher that rearranges the letters in the substitution cipher's output based on a transposition key. For example:
Transposition Key: 3 1 4 2
Encryption Process:
Apply the substitution cipher to the original plaintext.
Plaintext: HELLO
Substitution: C F Y Y I

Apply the transposition cipher to the substitution output using the transposition key.

Transposition: Y Y I C F

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Combined Ciphertext:
The final ciphertext is obtained by combining the results of both the substitution and transposition steps.
Ciphertext: Y Y I C F
Decryption Process:

To decrypt, the process is reversed. First, apply the inverse of the transposition cipher, and then apply the inverse of the substitution cipher.
Summary:

In this example, the product cipher combines the substitution cipher and the transposition cipher. An attacker would need to break both the substitution and transposition components to recover the original plaintext. This combination adds an extra layer of complexity and security to the encryption process.

It's important to note that real-world product ciphers, such as AES (Advanced Encryption Standard), involve more sophisticated mathematical operations and cryptographic techniques. The goal remains to create a robust encryption scheme that combines the strengths of multiple cryptographic primitives to resist various attacks.

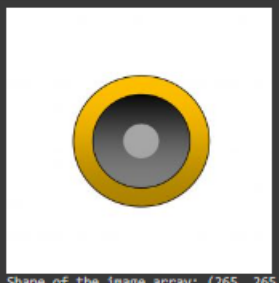
6. Security Analysis:
Resistance to Attacks: The security of a product cipher depends on the strength of the individual cryptographic components, the key management strategy, and the overall design.
Cryptanalysis: Cryptanalysis techniques that are effective against one component may be less effective against others, providing a level of defense in-depth.

Conclusion:
Product ciphers provide a versatile approach to encryption by leveraging the strengths of multiple cryptographic techniques. The design and security of a product cipher rely on careful consideration of the individual components, key management, and the overall cryptographic architecture. The goal is to create a robust and resilient encryption scheme that can withstand various cryptographic attacks.

```
[ ] !pip install Pillow
```

```
Requirement already satisfied: Pillow in /usr/local/lib/python3.10/dist-packages (9.4.0)
```

```
from PIL import Image
import numpy as np
from IPython.display import Image as IPImage, display

# Open the image
image = Image.open("/content/normal image.jpg")

# Convert the image to a NumPy array (integer matrix)
image_array = np.array(image)

# Display the image using IPython
display(IPImage("/content/normal image.jpg"))

# # Display the image (optional)
# image.show()

# You can access the individual pixel values in the 'image_array' variable
print("Shape of the image array:", image_array.shape)
print("Pixel values of the top-left corner:", image_array[0, 0])
```



```
Shape of the image array: (265, 265, 3)
Pixel values of the top-left corner: [255 255 255]
```

```python
import numpy as np
from PIL import Image

def flatten_image(image_array):
    return image_array.flatten()

def caesar_cipher(data, shift):
    return (data + shift) % 256

def rail_fence_cipher(data, key):
    rails = [[] for _ in range(key)]
    direction = -1
    rail = 0

    for value in data:
        rails[rail].append(value)
        if rail == 0 or rail == key - 1:
            direction *= -1
        rail += direction

    encrypted_data = np.concatenate(rails)
    return encrypted_data

def product_cipher_image(image_array, caesar_shift, rail_fence_key):
    flattened_image_data = flatten_image(image_array)

    caesar_encrypted_data = caesar_cipher(flattened_image_data, caesar_shift)

    rail_fence_encrypted_data = rail_fence_cipher(caesar_encrypted_data, rail_fence_key)

    return rail_fence_encrypted_data

caesar_shift = 4
rail_fence_key = 3

encrypted_image_data = product_cipher_image(image_array, caesar_shift, rail_fence_key)

encrypted_image_data = encrypted_image_data.reshape(image_array.shape)

encrypted_image = Image.fromarray(encrypted_image_data.astype(np.uint8))

encrypted_image.save("encrypted_image.png")
from google.colab import files
files.download("encrypted_image.png")
```

```python
display(IPImage("/content/encrypted_image.png"))
```