MES Wadia College of Engineering Pune-01

Department of Computer Engineering

Name of Student:	**Class: TE Comp**
Semester/Year: 6th	**Roll No:**
Date of Performance:	**Date of Submission:**
Examined By: Prof(Dr.)S.K.Wagh	**Experiment No: Part 2-IS-03**

PART 2- LPII-ELII-IS-ASSIGNMENT NO: 03

AIM:
Write a Java/C/C++/Python program to implement AES Algorithm

OBJECTIVE:

1. Understand Cryptographic Principles

Implementing AES from scratch requires a deep understanding of its underlying principles, including symmetric key cryptography, block cipher modes of operation, and the specifics of the AES algorithm itself (such as the substitution-permutation network). It's an excellent way to learn about cryptography by doing.

2. Apply Theory to Practice

Programming an AES algorithm allows you to apply theoretical knowledge in a practical context. It involves translating the mathematical and procedural aspects of the algorithm into executable code, thereby solidifying your understanding of both the theory and its application.

3. Develop Programming Skills

The process of implementing a complex algorithm like AES tests and improves your programming skills, including problem-solving, designing algorithms, debugging, and optimizing code for performance and security.

4. Gain Insights into Security Mechanisms

By building an encryption tool yourself, you gain insights into how data can be protected, how keys are managed, and the importance of cryptographic security in protecting information against unauthorized access.

5. Understand the Importance of Standards in Cryptography

Implementing a standardized algorithm like AES, which is widely used in various security protocols and systems, highlights the importance of standards in ensuring interoperability, reliability, and vetted security across different platforms and applications.

APPRATUS:

- Operating System recommended: 64-bit Open source Linux or its derivative.
- Java, C, C++, or Python

THEORY:

Advanced Encryption Standard (AES) is a specification for the encryption of electronic data established by the U.S National Institute of Standards and Technology (NIST) in 2001. AES is widely used today as it is a much stronger than DES and triple DES despite being harder to implement.

- AES is a block cipher.
- The key size can be 128/192/256 bits.
- Encrypts data in blocks of 128 bits each.

That means it takes 128 bits as input and outputs 128 bits of encrypted cipher text as output. AES relies on substitution-permutation network principle which means it is performed using a series of linked operations which involves replacing and shuffling of the input data.

Working of the cipher:
AES performs operations on bytes of data rather than in bits. Since the block size is 128 bits, the cipher processes 128 bits (or 16 bytes) of the input data at a time.

The number of rounds depends on the key length as follows:

- 128 bit key – 10 rounds
- 192 bit key – 12 rounds
- 256 bit key – 14 rounds

Creation of Round keys:
A Key Schedule algorithm is used to calculate all the round keys from the key. So the initial key is used to create many different round keys which will be used in the corresponding round of the encryption.

Encryption :
AES considers each block as a 16 byte (4 byte x 4 byte = 128) grid in a column major arrangement.

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[b0 | b4 | b8 | b12 |

| b1 | b5 | b9 | b13 |

| b2 | b6 | b10| b14 |

| b3 | b7 | b11| b15]

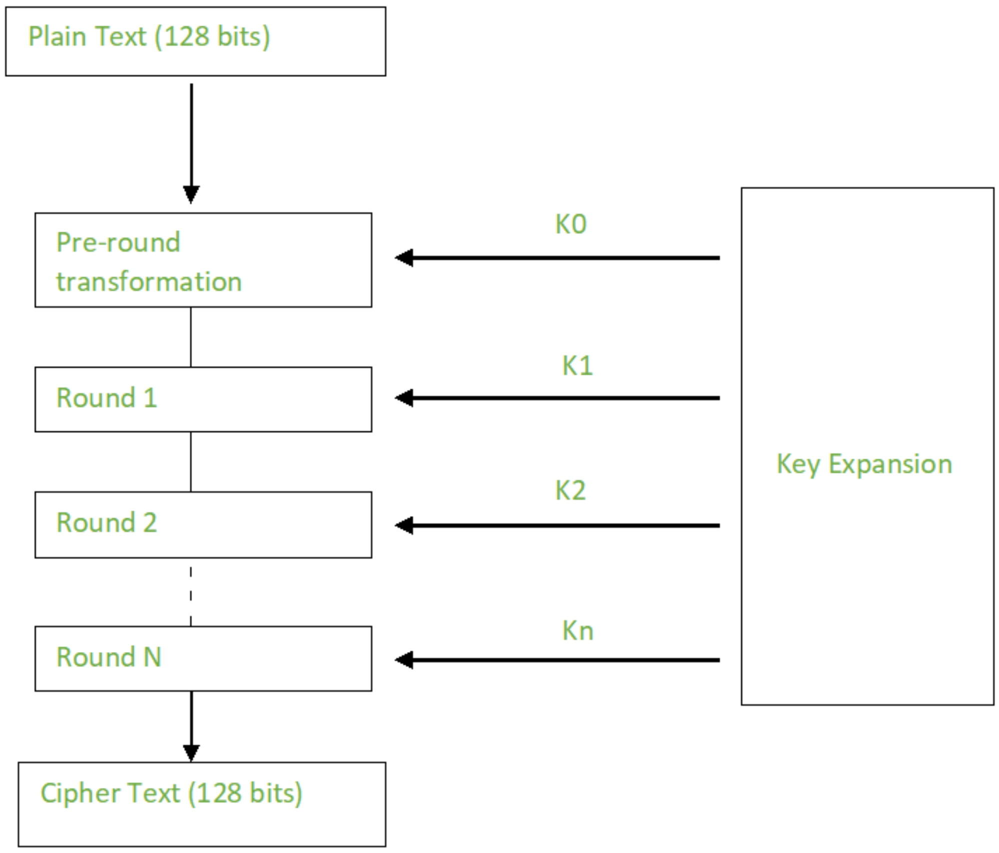
Each round comprises of 4 steps :

- SubBytes

- ShiftRows
- MixColumns
- Add Round Key

The last round doesn't have the MixColumns round.

The SubBytes does the substitution and ShiftRows and MixColumns performs the permutation in the algorithm.



SubBytes :
This step implements the substitution.

In this step each byte is substituted by another byte. Its performed using a lookup table also called the S-box. This substitution is done in a way that a byte is never substituted by itself and also not substituted by another byte which is a compliment of the current byte. The result of this step is a 16 byte (4 x 4) matrix like before.

The next two steps implement the permutation.

ShiftRows :
This step is just as it sounds. Each row is shifted a particular number of times.

- The first row is not shifted
- The second row is shifted once to the left.

- The third row is shifted twice to the left.
- The fourth row is shifted thrice to the left.

(A left circular shift is performed.)

```
[ b0  | b1  | b2  | b3  ]        [ b0  | b1  | b2  | b3  ]
| b4  | b5  | b6  | b7  |   ->   | b5  | b6  | b7  | b4  |
| b8  | b9  | b10 | b11 |        | b10 | b11 | b8  | b9  |
[ b12 | b13 | b14 | b15 ]        [ b15 | b12 | b13 | b14 ]
```

MixColumns :
This step is basically a matrix multiplication. Each column is multiplied with a specific matrix and thus the position of each byte in the column is changed as a result.

This step is skipped in the last round.

```
[ c0 ]       [ 2  3  1  1 ]  [ b0 ]
| c1 |  =    | 1  2  3  1 |  | b1 |
| c2 |       | 1  1  2  3 |  | b2 |
[ c3 ]       [ 3  1  1  2 ]  [ b3 ]
```

Add Round Keys :
Now the resultant output of the previous stage is XOR-ed with the corresponding round key. Here, the 16 bytes is not considered as a grid but just as 128 bits of data.

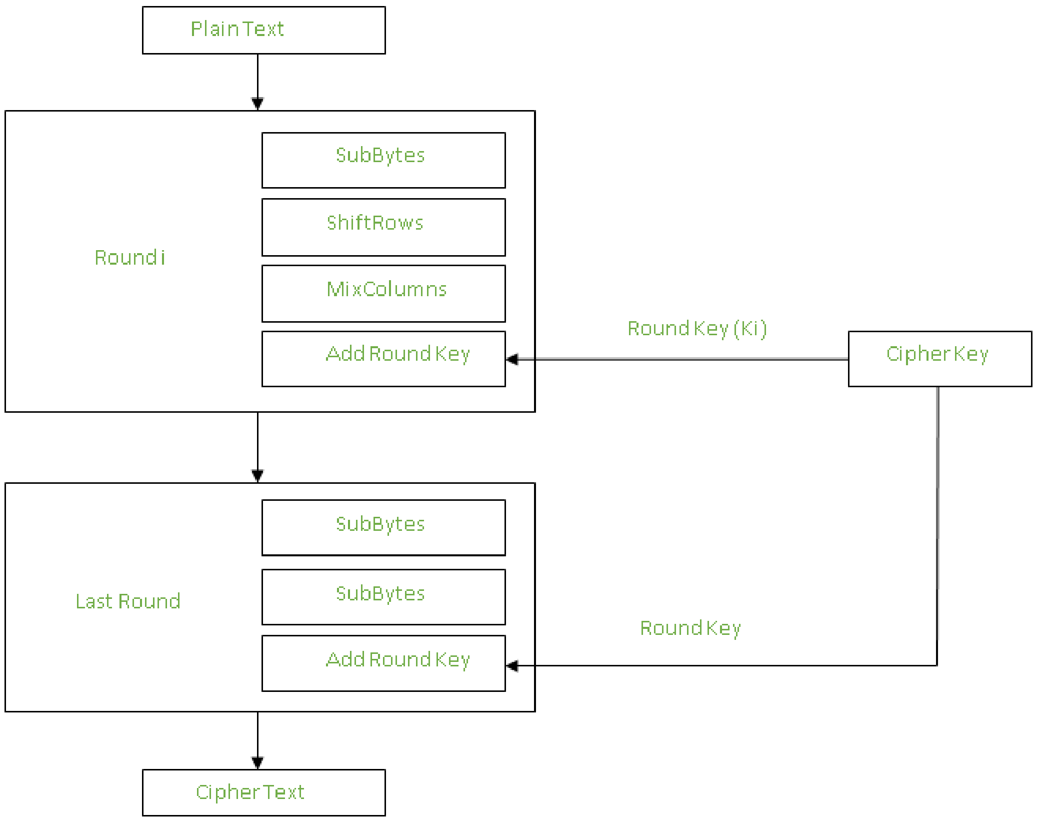
After all these rounds 128 bits of encrypted data is given back as output. This process is repeated until all the data to be encrypted undergoes this process.

Decryption :
The stages in the rounds can be easily undone as these stages have an opposite to it which when performed reverts the changes.Each 128 blocks goes through the 10,12 or 14 rounds depending on the key size.

The stages of each round in decryption is as follows :

- Add round key
- Inverse MixColumns
- ShiftRows
- Inverse SubByte

The decryption process is the encryption process done in reverse so i will explain the steps with notable differences.



Inverse MixColumns :

This step is similar to the MixColumns step in encryption, but differs in the matrix used to carry out the operation.

[b0]   [14 11 13 9] [c0]

| b1 | = | 9   14 11 13 | | c1 |

| b2 | | 13 9   14 11 | | c2 |

[b3]   [11 13 9   14]   [c3]

Inverse SubBytes :

Inverse S-box is used as a lookup table and using which the bytes are substituted during decryption.

Applications:

AES is widely used in many applications which require secure data storage and transmission. Some common use cases include:

- **Wireless security:** AES is used in securing wireless networks, such as Wi-Fi networks, to ensure data confidentiality and prevent unauthorized access.
- **Database Encryption:** AES can be applied to encrypt sensitive data stored in databases. This helps protect personal information, financial records, and other confidential data from unauthorized access in case of a data breach.

- **Secure communications:** AES is widely used in protocols like such as internet communications, email, instant messaging, and voice/video calls.It ensures that the data remains confidential.
- **Data storage:** AES is used to encrypt sensitive data stored on hard drives, USB drives, and other storage media, protecting it from unauthorized access in case of loss or theft.
- **Virtual Private Networks (VPNs):** AES is commonly used in VPN protocols to secure the communication between a user's device and a remote server. It ensures that data sent and received through the VPN remains private and cannot be deciphered by eavesdroppers.
- **Secure Storage of Passwords:** AES encryption is commonly employed to store passwords securely. Instead of storing plaintext passwords, the encrypted version is stored. This adds an extra layer of security and protects user credentials in case of unauthorized access to the storage.
- **File and Disk Encryption:** AES is used to encrypt files and folders on computers, external storage devices, and cloud storage. It protects sensitive data stored on devices or during data transfer to prevent unauthorized access.

CONCLUSION:

QUESTIONS:

1. What are possible attacks on AES algorithm? Explain
2. What is SAES algorithm input and key size?