Session: 16

# Encrypting and Decrypting Data

# Objectives

- Explain symmetric encryption.
- Explain asymmetric encryption.
- List the various types in the `System.Security.Cryptography` namespace that supports symmetric and asymmetric encryptions.

# Introducing Cryptography and Encryption 1-2

- All organizations need to handle sensitive data.
- This data can be either present in storage or may be exchanged between different entities within and outside the organization over a network.

**Example**

- Steve is the CEO of a company.
- Steve while travelling needs to access performance appraisal reports of the top management of the company.
- These reports contain data that are confidential and are stored in the company's server.
- Such data is often prone to misuse either intentionally with malicious intent or unintentionally.
- To avoid such misuse, there should be some security mechanism that can ensure confidentiality and integrity of data.

# Introducing Cryptography and Encryption 2-2

- Cryptography is a security mechanism to ensure data confidentiality and integrity.
- The commonly used ways to secure sensitive data is through encryption.

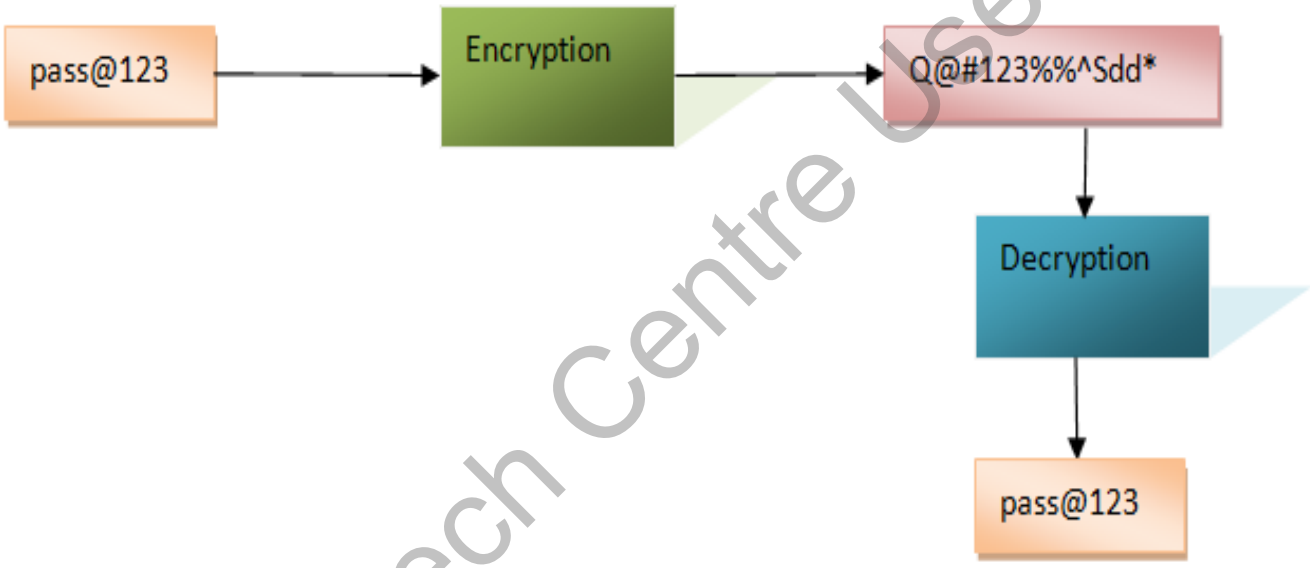
- The primary objective of cryptography is to secure data exchanged between entities, each of which can be a person or an application.

Example

- Consider a scenario:
  - User A transmits sensitive data to User B.
  - The transmission needs to be confidential to ensure that even if a third party obtains the data, the data is incomprehensible.
  - User B before using the data must be sure about the integrity of the data, which means that User B must be sure that the data has not been modified in transit.
  - User B must be able to authenticate that the data is actually been sent by User A.
  - After sending the data, User A must not be able to deny sending the data to User B.

- **Encryption:**
  - Is a cryptographic technique that ensures data confidentiality.
  - Converts data in plain text to cipher (secretly coded) text.
- The opposite process of encryption is called decryption, which is a process that converts the encrypted cipher text back to the original plain text.

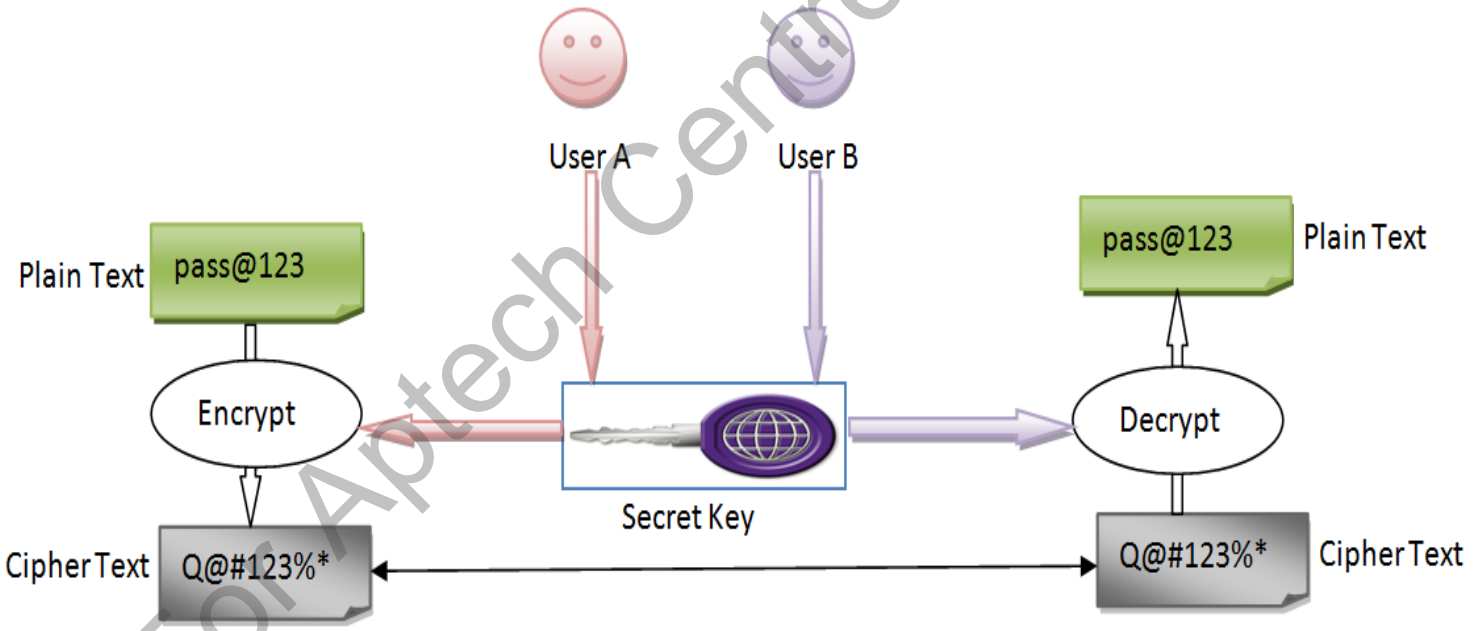
- The following figure shows the process of encryption and decryption of a password as an example.




- In the figure:
  - The plain text,pass@123 is encrypted to a cipher text.
  - The cipher text is decrypted back to the original plain text.

- Symmetric encryption, or secret key encryption, uses a single key, known as the secret key both to encrypt and decrypt data.

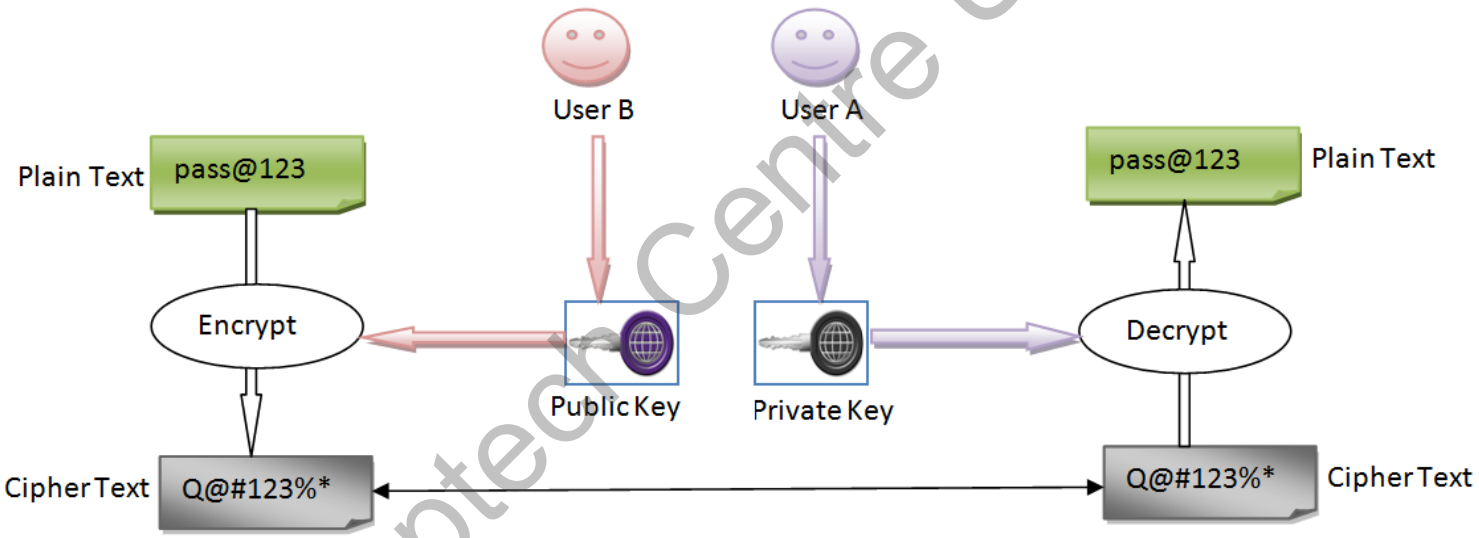
- The following figure shows the symmetric encryption and decryption process.



- The following steps outline an example usage of symmetric encryption:
  - User A uses a secret key to encrypt a plain text to cipher text.
  - User A shares the cipher text and the secret key with User B.
  - User B uses the secret key to decrypt the cipher text back to the original plain text.

# Asymmetric Encryption 1-2

- Asymmetric encryption uses a pair of public and private key to encrypt and decrypt data.
- The following figure shows the symmetric encryption and decryption process.

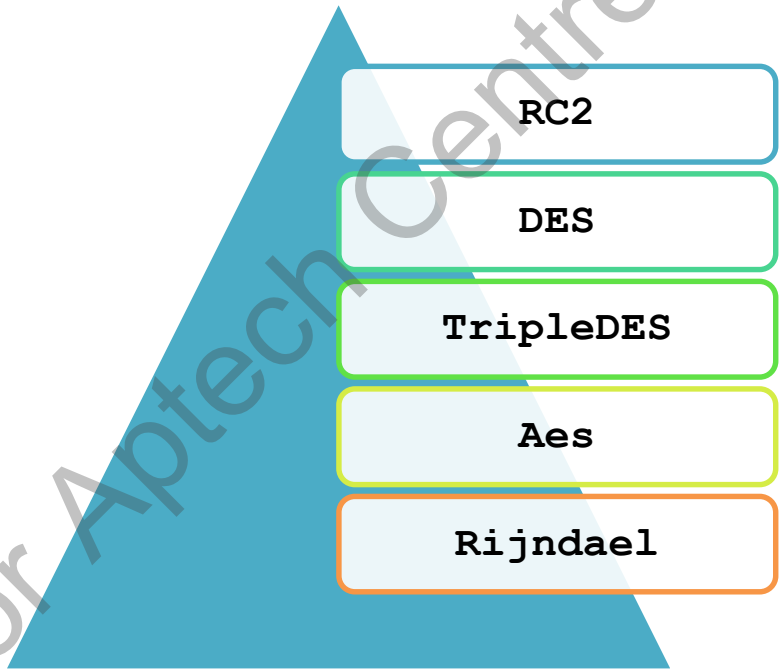


- The following steps outline an example usage of asymmetric encryption:
  - User A generates a public and private key pair.
  - User A shares the public key with User B.
  - User B uses the public key to encrypt a plain text to cipher text.
  - User A uses the private key to decrypt the cipher text back to the original plain text.

# Symmetric Encryption Algorithms 1-6

- The `System.Security.Cryptography` namespace provides the `SymmetricAlgorithm` base class for all symmetric algorithm classes.

- The derived classes of the `SymmetricAlgorithm` base class are as follows:



## RC2

- Is an abstract base class for all classes that implement the RC2 algorithm.
- Is a proprietary algorithm developed by RSA Data Security, Inc in 1987.
- Supports key sizes ranging from 40 bits to 128 bits in 8-bit increments for encryption.
- Was designed for the old generation processors and currently have been replaced by more faster and secure algorithms.
- Derives the `RC2CryptoServiceProvider` class to provide an implementation of the RC2 algorithm.

## DES

- Is an abstract base class for all classes that implement the Data Encryption Standard (DES) algorithm.
- Developed by IBM but as of today available as a U.S. Government Federal Information Processing Standard (FIPS 46-3).
- Works on the data to encrypt as blocks where each block is of 64 bits.
- Uses a key of 64 bits to perform the encryption. On account of its small key size DES encrypts data faster as compared to other asymmetric algorithms.
- Is prone to brute force security attacks because of its smaller key size.
- Derives the `DESCryptoServicerProvider` class to provide an implementation of the DES algorithm.

## TripleDES

- Is an abstract base class for all the classes that implement the TripleDES algorithm.
- Is an enhancement to the DES algorithm for the purpose of making the DES algorithm more secured against security threats.
- Works on 64 bit blocks that is similar to the DES algorithm.
- Supports key sizes of 128 bits to 192 bits.
- Derives the `TripleDESCryptoServiceProvider` class to provide an implementation of the TripleDES algorithm.

## Aes

- Is an abstract base class for all classes that implement the Advanced Encryption Standard (AES) algorithm.
- Is a successor of DES and is currently considered as one of the most secure algorithm.
- Is more efficient in encrypting large volume of data in the size of several gigabytes.
- Works on 128-bits blocks of data and key sizes of 128, 192, or 256 bits for encryption.
- Derives the `AesCryptoServiceProvider` and `AesManaged` classes to provide an implementation of the AES algorithm.

## Rijndael

- Is an abstract base class for all the classes that implement the `Rijndael` algorithm.
- Is a superset of the `Aes` algorithm.
- Supports key sizes of 128, 192, or 256 bits similar to the `Aes` algorithm.
- Can have block sizes of 128, 192, or 256 bits, unlike `Aes`, which has a fixed block size of 128 bits.
- Provides the flexibility to select an appropriate block size based on the volume of data to encrypt by supporting different block sizes.
- Derives the `RijndealManaged` class to provide an implementation of the `Rijndeal` algorithm.

# Asymmetric Encryption Algorithm 1-2

- The `System.Security.Cryptography` namespace provides the `AsymmetricAlgorithm` base class for all asymmetric algorithm classes.
- `RSA` is an abstract class that derives from the `AsymmetricAlgorithm` class.
- The `RSA` class is the base class for all the classes that implement the RSA algorithm.
- The RSA algorithm was designed in 1977 by Ron Rivest, Adi Shamir, and Leonard Adleman and till now is the most widely adopted algorithm to perform asymmetric encryption and decryption.
- This algorithm functions in three steps: key generation, encryption, and decryption.

# Asymmetric Encryption Algorithm 2-2

- The RSA algorithm generates a public key as a product of two large prime numbers, along with a public (or encryption) value.
- The algorithm generates a private key as a product of the same two large prime numbers, along with a private (or decryption) value.
- The public key is used to perform encryption while the private key is used to perform decryption.
- In the .NET Framework, the `RSACryptoServiceProvider` class derives from the RSA class to provide an implementation of the RSA algorithm.

- You need to use one of the symmetric encryption implementation classes of the .NET Framework to perform symmetric encryption.

- The first step to perform symmetric encryption is to create the symmetric key.

# Generating Symmetric Keys 1-4

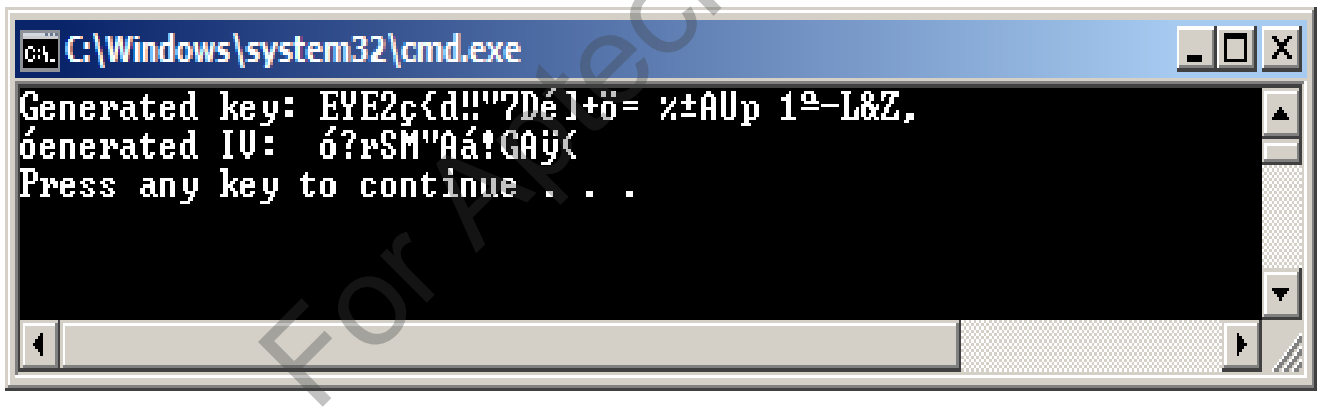
- When you use the default constructor of the symmetric encryption classes, such as `RijndaelManaged` and `AesManaged`, a key and IV are automatically generated.
- The generated key and the IV can be accessed as byte arrays using the `Key` and `IV` properties of the encryption class.
- The following code creates a symmetric key and IV using the `RijndaelManaged` class.

**Snippet**

```
using System;
using System.Security.Cryptography;
using System.Text;
. . .
. . .
RijndaelManagedsymAlgo = new RijndaelManaged();
Console.WriteLine("Generated key: {0}, \nGenerated IV:  {1}",
Encoding.Default.GetString(symAlgo.Key), Encoding.Default.GetString(symAlgo.IV));
```

- The code snippet uses the default constructor of the `RijndaelManaged` class to generate a symmetric key and IV.
- The `Key` and `IV` properties are accessed and printed as strings using the default encoding to the console.
- The following figure shows the output of the code.

Output



- The symmetric encryption classes, such as `RijndaelManaged` also provide the `GenerateKey()` and `GenerateIV()` methods that you can use to generate keys and IVs, as shown in the following code:

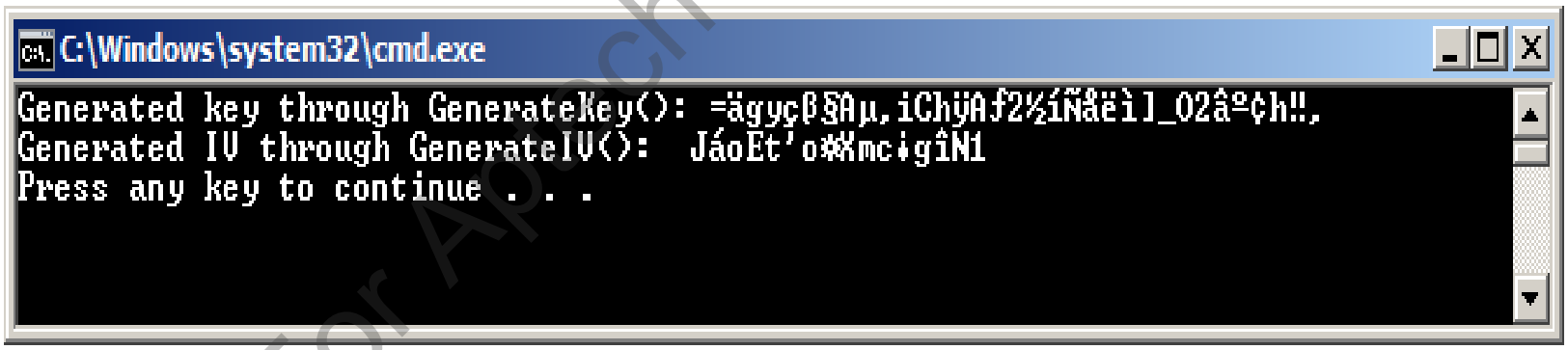
Snippet

```
using System;
using System.Security.Cryptography;
using System.Text;
. . .
. . .
RijndaelManagedsymAlgo = new RijndaelManaged();
symAlgo.GenerateKey();
symAlgo.GenerateIV();
byte[] generatedKey = symAlgo.Key;
byte[] generatedIV =symAlgo.IV;
Console.WriteLine("Generated key through GenerateKey(): {0}, \nGenerated IV through
            GenerateIV(): {1}", Encoding.Default.GetString(generatedKey),
            Encoding.Default.GetString(generatedIV));
```

- In the code:
  - An `RijndaelManaged` object is created and the `GenerateKey()` and `GenerateIV()` methods are called to generate a key and an IV.
  - The Key and the IV properties are then accessed and printed as strings using the default encoding to the console.

- The following figure shows the output of the code.

Output



- The symmetric encryption classes of the .NET Framework provides the `CreateEncryptor()` method that returns an object of the `ICryptoTransform` interface.
- The `ICryptoTransform` object is responsible for transforming the data based on the algorithm of the encryption class.
- Once you have obtained an `ICryptoTransform` object, you can use the `CryptoStream` class to perform encryption.
- The `CryptoStream` class acts as a wrapper of a stream-derived class, such as `FileStream`, `MemoryStream`, and `NetworkStream`.

- The `CryptoStream` class acts as a wrapper of a stream-derived class, such as `FileStream`, `MemoryStream`, and `NetworkStream`.

- A `CryptoStream` object operates in one of the following two modes defined by the `CryptoStreamMode` enumeration:
  - **`Write`**:
    - This mode allows write operation on the underlying stream.
    - Use this mode to perform encryption.
  - **`Read`**:
    - This mode allows read operation on the underlying stream.
    - Use this mode to perform decryption.

- You can create a `CryptoStream` object by calling the constructor that accepts the following three parameters:
  - The underlying stream object
  - The `ICryptoTransform` object
  - The mode defined by the `CryptoStreamMode` enumeration
- After creating the `CryptoStreamobject` you can call the `Write()` method to write the encrypted data to the underlying stream.
- The following code encrypts data using the `RijndaelManaged` class and writes the encrypted data to a file.

Snippet

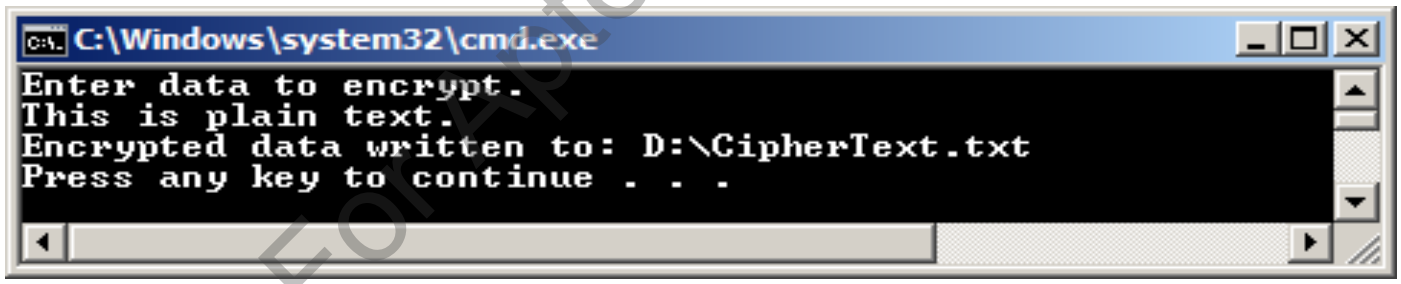
```
using System;
using System.IO;
using System.Security.Cryptography;
using System.Text;
class SymmetricEncryptionDemo
{
        static void EncryptData(String plainText, RijndaelManaged algo)
        {
           byte[] plainDataArray = ASCIIEncoding.ASCII.GetBytes(plainText);
```

```
        ICryptoTransform transform=algo.CreateEncryptor();
          using (var fileStream = new FileStream("D:\\CipherText.txt",
                      FileMode.OpenOrCreate, FileAccess.Write))
          {
              using (var cryptoStream = new CryptoStream(fileStream, transform,
                     CryptoStreamMode.Write))
              {
                  cryptoStream.Write(plainDataArray, 0,
                                plainDataArray.GetLength(0));
                  Console.WriteLine("Encrypted data written to:
                                                  D:\\CipherText.txt");
              }
          }
       }
      static void Main()
        {
          RijndaelManaged symAlgo = new RijndaelManaged();
          Console.WriteLine("Enter data to encrypt.");
          string dataToEncrypt = Console.ReadLine();
          EncryptData(dataToEncrypt, symAlgo);
        }
}
```

- In the code:
  - The `Main()` method creates a `RijndaelManaged` object and passes it along with the data to encrypt to the `EncryptData()` method.
  - The call to the `CreateEncryptor()` method creates the `ICryptoTransform` object in the `EncryptData()` method.
  - Then, a `FileStream` object is created to write the encrypted text to the `CipherText.txt` file.
  - The `CryptoStream` object is created and its `Write()` method is called.

- The following figure shows the output of the code.

Output



# Decrypting Data 1-4

- To decrypt data, you need to:

**Step 1**
- Use the same symmetric encryption class, key, and IV used for encrypting the data.

**Step 2**
- Call the `CreateDecryptor()` method to obtain a `ICryptoTransform` object that will perform the transformation.

**Step 3**
- Create the `CryptoStream` object in Read mode and initialize a `StreamReader` object with the `CryptoStream` object.

**Step 4**
- Call the `ReadToEnd()` method of the `StreamReader` that returns the decrypted text as a string.

- The code creates a program that performs both encryption and decryption.

## Snippet

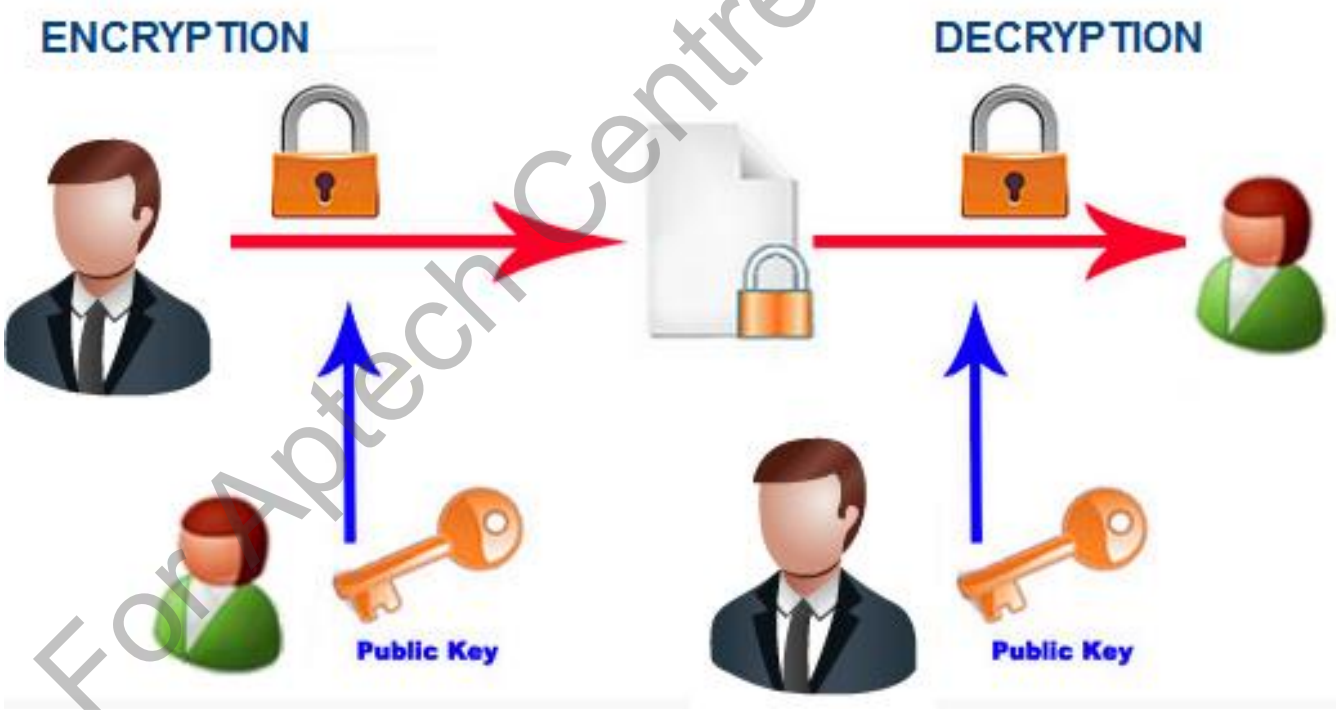
```
using System;
using System.IO;
using System.Security.Cryptography;
using System.Text;
class SymmetricEncryptionDemo
{
    static void EncryptData(String plainText, RijndaelManaged algo)
    {
        byte[] plainDataArray = ASCIIEncoding.ASCII.GetBytes(plainText);

        ICryptoTransform transform = algo.CreateEncryptor();
        using (var fileStream = new FileStream("D:\\CipherText.txt",
FileMode.OpenOrCreate, FileAccess.Write))
        {
            using (var cryptoStream = new CryptoStream(fileStream, transform,
CryptoStreamMode.Write))
            {
                cryptoStream.Write(plainDataArray, 0, plainDataArray.GetLength(0));
                Console.WriteLine("Encrypted data written to: D:\\CipherText.txt");
            }
        }
    }
    static void DecryptData(RijndaelManaged algo)
    {
```

```
ICryptoTransform transform = algo.CreateDecryptor();
        using (var fileStream = new FileStream("D:\\CipherText.txt", FileMode.Open,
FileAccess.Read))
        {
            using (CryptoStream cryptoStream = new CryptoStream(fileStream,
transform, CryptoStreamMode.Read))
            {

                using (var streamReader = new StreamReader(cryptoStream))
                {
                    string decryptedData = streamReader.ReadToEnd();
                    Console.WriteLine("Decrypted data: \n{0}", decryptedData);

                }
            }
        }
    }
    static void Main()
    {
        RijndaelManaged symAlgo = new RijndaelManaged();
        Console.WriteLine("Enter data to encrypt.");
        string dataToEncrypt = Console.ReadLine();
        EncryptData(dataToEncrypt, symAlgo);
        DecryptData(symAlgo);
    }
}
```

- In the code:
  - The `Main()` method creates a `RijndaelManaged` object and passes it along with the data to encrypt the `EncryptData()` method.
  - The encrypted data is saved to the `CipherText.txt` file.
  - The `Main()` method calls the `DecryptData()` method passing the same `RijndaelManaged` object created for encryption.
  - The `DecryptData()` method creates the `ICryptoTransformobject` and uses a `FileStream` object to read the encrypted data from the file.
  - The `CryptoStream` object is created in the Read mode initialized with the `FileStream` and `ICryptoTransformobjects`.
  - A `StreamReader` object is created by passing the `CryptoStream` object to the constructor.
  - The `ReadToEnd()` method of the `StreamReader` object is called.
- The decrypted text returned by the `ReadToEnd()` method is printed to the console, as shown in the following figure:

Output

- You can use the `RSACryptoServiceProvider` class of the `System.Security.Cryptography` namespace to perform asymmetric encryption.



# Generating Asymmetric Keys 1-2

- When you call the default constructor of the `RSACryptoServiceProvider` class, a new public/private key pair is automatically generated.
- After you create a new instance of the class, you can export the key information by using one of the following methods:
  - `ToXMLString()`
    - Returns an XML representation of the key information.
  - `ExportParameters()`
    - Returns an `RSAParameters` structure that holds the key information.
    - Accept a `Boolean` value by both the `ToXMLString()` and `ExportParameters()` methods.
    - A `false` value indicates that the method should return only the public key information while a `true` value indicates that the method should return information of both the public and private keys.

# Generating Asymmetric Keys 2-2

- The following code shows how to create and initialize an `RSACryptoServiceProvider` object and then export the public key in XML format:

**Snippet**

```
using System;
using System.Security.Cryptography;
using System.Text;
. . .
RSACryptoServiceProviderrSAKeyGenerator = new RSACryptoServiceProvider();
string publicKey = rSAKeyGenerator.ToXmlString(false);
}
```

- The following code shows how to create and initialize an `RSACryptoServiceProvider` object and then export both the public and private keys as an `RSAParameters` structure:

**Snippet**

```
using System;
using System.Security.Cryptography;
using System.Text;
. . .
RSACryptoServiceProviderrSAKeyGenerator = new RSACryptoServiceProvider();
RSAParametersrSAKeyInfo = rSAKeyGenerator.ExportParameters(true);
```

# Key Containers 1-3

- Private keys used to decrypt data in asymmetric encryption should be stored using a secured mechanism.
- To achieve this, you can use a key container that is a logical structure to securely store asymmetric keys.
- The .NET Framework provides the `CspParameters` class to create a key container and to add and remove keys to and from the container.
- To create a key container for an `RSACryptoServiceProvider` object:
  - Use the default constructor of the `CspParameters` class to create a key container instance.
  - Set the container name using the `KeyContainerName` property of the `CspParameters` class.
  - Pass the `CspParameters` object to the constructor while creating the `RSACryptoServiceProvider` object to store the key pair in the key container.

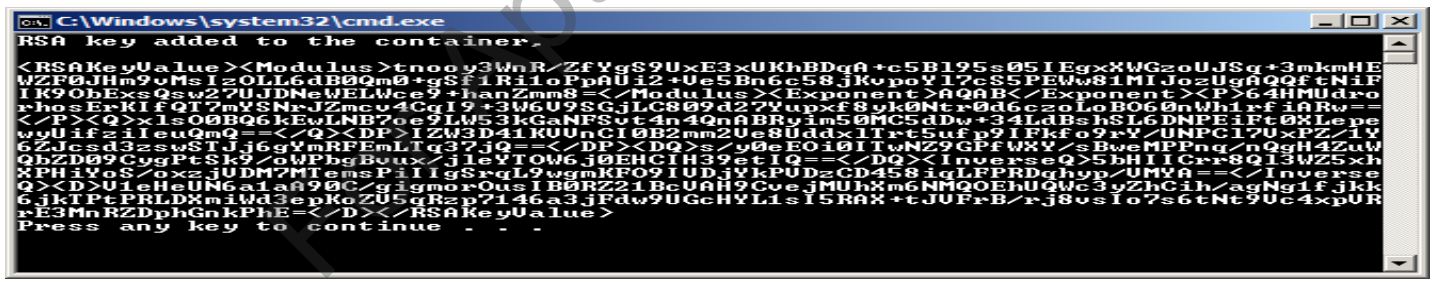
- The following code uses a key container to store a key pair:

**Snippet**

```
using System;
using System.Security.Cryptography;
using System.Text;
...
CspParameterscspParams = new CspParameters();cspParams.KeyContainerName =
"RSA_CONTAINER";RSACryptoServiceProviderrSAKeyGenerator =
newRSACryptoServiceProvider(cspParams);Console.WriteLine("RSA key added to the
container,\n\n{0}",   rSAKeyGenerator.ToXmlString(true));
```

- The following figure shows the output of the code:

**Output**



# Key Containers 3-3

- To retrieve a key pair from the container:
  - Create a new object of the `CspParameters` class and initialize it with the name of the key container that contains the key pair.
  - Create a new object of the `RSACryptoServiceProvider` initialized with the `CspParameters` object.
- The `RSACryptoServiceProvider` object will now contain the keys stored in the key container.
- The following code retrieves keys from the key container, named `RSA_CONTAINER`:

**Snippet**

```
using System;
using System.Security.Cryptography;
using System.Text;
. . .
CspParameterscp = new CspParameters();
cp.KeyContainerName = "RSA_CONTAINER";
RSACryptoServiceProviderrsaEncryptor = new RSACryptoServiceProvider(cp);
```

# Encrypting Data 1-3

- To encrypt data, you need to:
  - Create a new instance of the `RSACryptoServiceProvider` class
  - Call the `ImportParameters()` method to initialize the instance with the public key information exported to an `RSAParameters` structure.

- The following code shows how to initialize an `RSACryptoServiceProvider` object with the public key exported to an `RSAParameters` structure:

**Snippet**

```
using System;
using System.Security.Cryptography;
using System.Text;
. . .
. . .
RSACryptoServiceProviderrSAKeyGenerator = new
RSACryptoServiceProvider();
RSAParametersrSAKeyInfo = rSAKeyGenerator.ExportParameters(false);
RSACryptoServiceProviderrsaEncryptor= new
RSACryptoServiceProvider();
rsaEncryptor.ImportParameters(rSAKeyInfo);
```

- If the public key information is exported to XML format, you need to call the `FromXmlString()` method to initialize the `RSACryptoServiceProvider` object with the public key, as shown in the following code:

Snippet

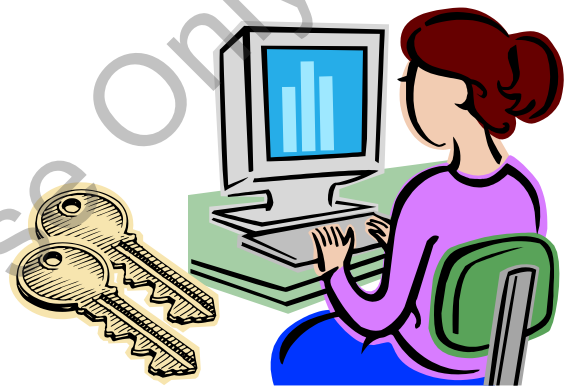
```
using System;
using System.Security.Cryptography;
using System.Text;
. . .
RSACryptoServiceProviderrSAKeyGenerator = new
RSACryptoServiceProvider();
string publicKey = rSAKeyGenerator.ToXmlString(false);
RSACryptoServiceProviderrsaEncryptor= new RSACryptoServiceProvider();
rsaEncryptor.FromXmlString(publicKey);
```

- After the `RSACryptoServiceProvider` object is initialized with the public key, you can encrypt data by calling the `Encrypt()` method of the `RSACryptoServiceProvider` class.
- The `Encrypt()` method accepts the following two parameters:
  - `byte` array of the data to encrypt
  - A `Boolean` value (It indicates whether or not to perform encryption using Optimal Asymmetric Encryption Padding (OAEP) padding. A true value uses OAEP padding while a false value uses PKCS#1 v1.5 padding.)
- The `Encrypt()` method after performing encryption returns a byte array of the encrypted text, as shown in the code:

**Snippet**

```
byte[] plainbytes = new UnicodeEncoding().GetBytes("Plain text to encrypt.");
byte[] cipherbytes = rsaEncryptor.Encrypt(plainbytes, true);
```

- To decrypt data, you need to initialize an `RSACryptoServiceProvider` object using the private key of the key pair whose public key was used for encryption.



- The following code shows how to initialize an `RSACryptoServiceProvider` object with the private key exported to an `RSAParameters` structure:

**Snippet**

```
RSACryptoServiceProviderrSAKeyGenerator = new
RSACryptoServiceProvider();
RSAParametersrSAKeyInfo = rSAKeyGenerator.ExportParameters(true);
RSACryptoServiceProviderrsaDecryptor= new RSACryptoServiceProvider();
rsaDecryptor.ImportParameters(rSAKeyInfo);
```

- The following code shows how to initialize an `RSACryptoServiceProvider` object with the private key exported to XML format:

Snippet

```
RSACryptoServiceProviderrSAKeyGenerator = new
RSACryptoServiceProvider();
string keyPair = rSAKeyGenerator.ToXmlString(true);
RSACryptoServiceProviderrsaDecryptor = new
RSACryptoServiceProvider();
rsaDecryptor.FromXmlString(keyPair);
```

- When the `RSACryptoServiceProvider` object is initialized with the private key, you can decrypt data by calling the `Decrypt()` method of the `RSACryptoServiceProvider` class.

- The `Decrypt()` method accepts the following two parameters:
  - `byte` array of the encrypted data
  - A `Boolean` value (It indicates whether or not to perform encryption using OAEP padding. A true value uses OAEP padding while a false value uses PKCS#1 v1.5 padding.)

- The `Decrypt()` method returns a byte array of the original data, as shown in the following code:

Snippet

```
byte[] plainbytes = rsaDecryptor.Decrypt(cipherbytes, false);
```

- The following code shows a program that performs asymmetric encryption and decryption:

Snippet

```
using System;
using System.IO;
usingSystem.Security.Cryptography;
usingSystem.Text;
classAsymmetricEncryptionDemo
 {
```

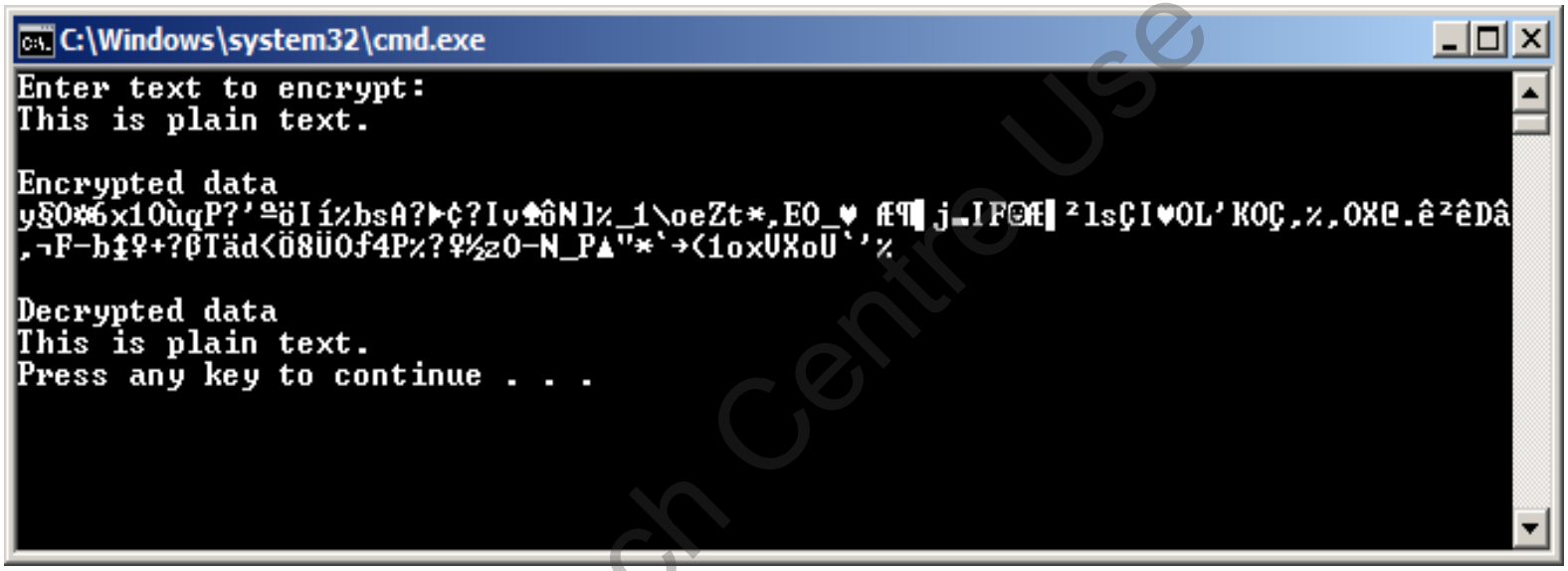
```
static byte[] EncryptData(string plainText, RSAParameters
rsaParameters)
   {
byte[] plainTextArray = new
UnicodeEncoding().GetBytes(plainText);
RSACryptoServiceProvider RSA = new RSACryptoServiceProvider();
RSA.ImportParameters(rsaParameters);
byte[] encryptedData = RSA.Encrypt(plainTextArray,true);
                return encryptedData;

   }
static byte[] DecryptData(byte[] encryptedData, RSAParameters
rsaParameters)
 {
RSACryptoServiceProvider RSA = new
RSACryptoServiceProvider();
RSA.ImportParameters(rsaParameters);
byte[] decryptedData = RSA.Decrypt(encryptedData,true);
returndecryptedData;
```

```
}
    static void Main(string[] args)
    {
        Console.WriteLine("Enter text to encrypt:");
        String inputText = Console.ReadLine();
        RSACryptoServiceProvider RSA = new RSACryptoServiceProvider();
        RSAParametersRSAParam=RSA.ExportParameters(false);
        byte[] encryptedData = EncryptData(inputText, RSAParam);
        stringencryptedString =
        Encoding.Default.GetString(encryptedData);
        Console.WriteLine("\nEncrypted data \n{0}",encryptedString);
        byte[] decryptedData = DecryptData(encryptedData,
                                           RSA.ExportParameters(true));
        StringdecryptedString = new

        UnicodeEncoding().GetString(decryptedData);
        Console.WriteLine("\nDecrypted data \n{0}", decryptedString);
    }
}
```

- In the code:
  - The `Main()` method creates a `RSACryptoServiceProvider` object and exports the public key as a `RSAParameters` structure.
  - The `EncryptData()` method is then called passing the user entered plain text and the `RSAParameters` object.
  - The `EncryptData()` method uses the exported public key to encrypt the data and returns the encrypted data as a byte array.
  - The `Main()` method then exports both the public and private key of the `RSACryptoServiceProvider` object into a second `RSAParameters` object.
  - The `DecryptData()` method is called passing the encrypted byte array and the `RSAParameters` object.
  - The `DecryptData()` method performs the decryption and returns the original plain text as a string.

- The following figure shows the output of the code.

Output



# Summary

- Encryption is a security mechanism that converts data in plain text to cipher text.
- An encryption key is a piece of information or parameter that determines how a particular encryption mechanism works.
- The .NET Framework provides various types in the `System.Security.Cryptography` namespace to support symmetric and asymmetric encryptions.
- When you use the default constructor to create an object of the symmetric encryption classes, a key and IV are automatically generated.
- The `ICryptoTransform` object is responsible for transforming the data based on the algorithm of the encryption class.
- The `CryptoStream` class acts as a wrapper of a stream-derived class, such as `FileStream`, `MemoryStream`, and `NetworkStream`.
- When you call the default constructor of the `RSACryptoServiceProvider` and `DSACryptoServiceProvider` classes, a new public/private key pair is automatically generated.