RSA Algorithm

RSA algorithm is a public key encryption technique and is considered as the most secure way of encryption. It was invented by Rivest, Shamir and Adleman in year 1978 and hence name RSA algorithm.

The RSA algorithm holds the following features −

- RSA algorithm is a popular exponentiation in a finite field over integers including prime numbers.
- The integers used by this method are sufficiently large making it difficult to solve.
- There are two sets of keys in this algorithm: private key and public key.

You will have to go through the following steps to work on RSA algorithm −

Step 1: Generate the RSA modulus

The initial procedure begins with selection of two prime numbers namely p and q, and then calculating their product N, as shown −

N=p*q

Here, let N be the specified large number.

Step 2: Derived Number (e)

Consider number e as a derived number which should be greater than 1 and less than (p-1) and (q-1). The primary condition will be that there should be no common factor of (p-1) and (q-1) except 1

Step 3: Public key

The specified pair of numbers n and e forms the RSA public key and it is made public.

Step 4: Private Key

Private Key d is calculated from the numbers p, q and e. The mathematical relationship between the numbers is as follows −

ed = 1 mod (p-1) (q-1)

The above formula is the basic formula for Extended Euclidean Algorithm, which takes p and q as the input parameters.

Encryption Formula

Consider a sender who sends the plain text message to someone whose public key is (n,e). To encrypt the plain text message in the given scenario, use the following syntax −

C = Pe mod n

Decryption Formula

The decryption process is very straightforward and includes analytics for calculation in a systematic approach. Considering receiver C has the private key d, the result modulus will be calculated as −

Plaintext = Cd mod n

Creating RSA Keys

Step wise implementation of RSA algorithm using Python.

Generating RSA keys

The following steps are involved in generating RSA keys −

- Create two large prime numbers namely p and q. The product of these numbers will be called n, where n= p*q
- Generate a random number which is relatively prime with (p-1) and (q-1). Let the number be called as e.
- Calculate the modular inverse of e. The calculated inverse will be called as d.

Algorithms for generating RSA keys

We need two primary algorithms for generating RSA keys using Python − Cryptomath module and Rabin Miller module.

Cryptomath Module

The source code of cryptomath module which follows all the basic implementation of RSA algorithm is as follows

```
def gcd(a, b):
  while a != 0:
    a, b = b % a, a
  return b
def findModInverse(a, m):
  if gcd(a, m) != 1:
    return None
  u1, u2, u3 = 1, 0, a
  v1, v2, v3 = 0, 1, m
    while v3 != 0:
    q = u3 // v3
      v1, v2, v3, u1, u2, u3 = (u1 - q * v1), (u2 - q * v2), (u3 - q * v3), v1, v2, v3
  return u1 % m
```

RabinMiller Module

The source code of RabinMiller module which follows all the basic implementation of RSA algorithm is as follows

```
import random
def rabinMiller(num):
   s = num - 1
   t = 0

   while s % 2 == 0:
      s = s // 2
      t += 1
   for trials in range(5):
      a = random.randrange(2, num - 1)
      v = pow(a, s, num)
      if v != 1:
         i = 0
         while v != (num - 1):
            if i == t - 1:
               return False
            else:
               i = i + 1
               v = (v ** 2) % num
      return True
def isPrime(num):
   if (num 7< 2):
      return False
   lowPrimes = [2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61,
   67, 71, 73, 79, 83, 89, 97, 101, 103, 107, 109, 113, 127, 131, 137, 139, 149, 151,
   157, 163, 167, 173, 179, 181, 191, 193, 197, 199, 211, 223, 227, 229, 233, 239, 241,
   251, 257, 263, 269, 271, 277, 281, 283, 293, 307, 311, 313,317, 331, 337, 347, 349,
   353, 359, 367, 373, 379, 383, 389, 397, 401, 409, 419, 421, 431, 433, 439, 443, 449,
```

```
    457, 461, 463, 467, 479, 487, 491, 499, 503, 509, 521, 523, 541, 547, 557, 563, 569,
    571, 577, 587, 593, 599, 601, 607, 613, 617, 619, 631, 641, 643, 647, 653, 659, 661,
    673, 677, 683, 691, 701, 709, 719, 727, 733, 739, 743, 751, 757, 761, 769, 773, 787,
    797, 809, 811, 821, 823, 827, 829, 839, 853, 857, 859, 863, 877, 881, 883, 887, 907,
    911, 919, 929, 937, 941, 947, 953, 967, 971, 977, 983, 991, 997]
    if num in lowPrimes:
        return True
    for prime in lowPrimes:
        if (num % prime == 0):
            return False
    return rabinMiller(num)
def generateLargePrime(keysize = 1024):
    while True:
        num = random.randrange(2**(keysize-1), 2**(keysize))
        if isPrime(num):
            return num
```

The complete code for generating RSA keys is as follows:

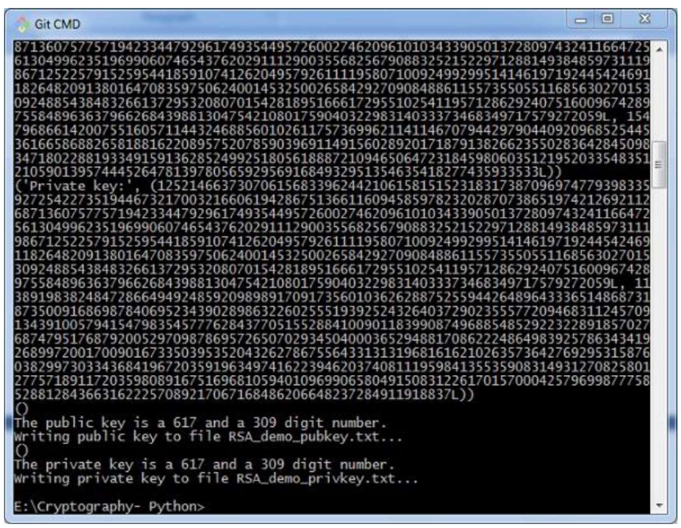
```
import random, sys, os, rabinMiller, cryptomath


def main():
    makeKeyFiles('RSA_demo', 1024)


def generateKey(keySize):
    # Step 1: Create two prime numbers, p and q. Calculate n = p * q.
    print('Generating p prime...')
    p = rabinMiller.generateLargePrime(keySize)
    print('Generating q prime...')
    q = rabinMiller.generateLargePrime(keySize)
    n = p * q
```

```
    # Step 2: Create a number e that is relatively prime to (p-1)*(q-1).
    print('Generating e that is relatively prime to (p-1)*(q-1)...')
    while True:
        e = random.randrange(2 ** (keySize - 1), 2 ** (keySize))
        if cryptomath.gcd(e, (p - 1) * (q - 1)) == 1:
            break

    # Step 3: Calculate d, the mod inverse of e.
    print('Calculating d that is mod inverse of e...')
    d = cryptomath.findModInverse(e, (p - 1) * (q - 1))
    publicKey = (n, e)
    privateKey = (n, d)
    print('Public key:', publicKey)
    print('Private key:', privateKey)
    return (publicKey, privateKey)


def makeKeyFiles(name, keySize):
    # Creates two files 'x_pubkey.txt' and 'x_privkey.txt'
        (where x is the value in name) with the the n,e and d,e integers written in them,
    # delimited by a comma.
    if os.path.exists('%s_pubkey.txt' % (name)) or os.path.exists('%s_privkey.txt' % (name)):
        sys.exit('WARNING: The file %s_pubkey.txt or %s_privkey.txt already exists! Use a different name
or delete these files and re-run this program.' % (name, name))
    publicKey, privateKey = generateKey(keySize)
    print()
    print('The public key is a %s and a %s digit number.' % (len(str(publicKey[0])), len(str(publicKey[1]))))
    print('Writing public key to file %s_pubkey.txt...' % (name))
        fo = open('%s_pubkey.txt' % (name), 'w')
            fo.write('%s,%s,%s' % (keySize, publicKey[0], publicKey[1]))
    fo.close()
```

```
  print()

  print('The private key is a %s and a %s digit number.' % (len(str(publicKey[0])),
len(str(publicKey[1]))))

  print('Writing private key to file %s_privkey.txt...' % (name))

    fo = open('%s_privkey.txt' % (name), 'w')

  fo.write('%s,%s,%s' % (keySize, privateKey[0], privateKey[1]))

  fo.close()

# If makeRsaKeys.py is run (instead of imported as a module) call

# the main() function.

if __name__ == '__main__':

  main()
```

Output

The public key and private keys are generated and saved in the respective files as shown in the following output.



RSA Cipher Encryption

Python file for implementing RSA cipher algorithm implementation.

The modules included for the encryption algorithm are as follows –

```
from Crypto.PublicKey import RSA

from Crypto.Cipher import PKCS1_OAEP

from Crypto.Signature import PKCS1_v1_5

from Crypto.Hash import SHA512, SHA384, SHA256, SHA, MD5

from Crypto import Random

from base64 import b64encode, b64decode

hash = "SHA-256"
```

We have initialized the hash value as SHA-256 for better security purpose. We will use a function to generate new keys or a pair of public and private key using the following code.

```
def newkeys(keysize):

   random_generator = Random.new().read

   key = RSA.generate(keysize, random_generator)

   private, public = key, key.publickey()

   return public, private

def importKey(externKey):

   return RSA.importKey(externKey)
```

For encryption, the following function is used which follows the RSA algorithm –

```
def encrypt(message, pub_key):
   cipher = PKCS1_OAEP.new(pub_key)
   return cipher.encrypt(message)
```

Two parameters are mandatory: message and pub_key which refers to Public key. A public key is used for encryption and private key is used for decryption.

The complete program for encryption procedure is mentioned below –

```
from Crypto.PublicKey import RSA

from Crypto.Cipher import PKCS1_OAEP

from Crypto.Signature import PKCS1_v1_5

from Crypto.Hash import SHA512, SHA384, SHA256, SHA, MD5

from Crypto import Random
```

```
from base64 import b64encode, b64decode

hash = "SHA-256"

def newkeys(keysize):
   random_generator = Random.new().read
   key = RSA.generate(keysize, random_generator)
   private, public = key, key.publickey()
   return public, private

def importKey(externKey):
   return RSA.importKey(externKey)

def getpublickey(priv_key):
   return priv_key.publickey()

def encrypt(message, pub_key):
   cipher = PKCS1_OAEP.new(pub_key)
   return cipher.encrypt(message)
```

RSA Cipher Decryption

The function used to decrypt cipher text is as follows −

```
def decrypt(ciphertext, priv_key):
   cipher = PKCS1_OAEP.new(priv_key)
   return cipher.decrypt(ciphertext)
```

For public key cryptography or asymmetric key cryptography, it is important to maintain two important features namely Authentication and Authorization.

Authorization

Authorization is the process to confirm that the sender is the only one who have transmitted the message. The following code explains this −

```
def sign(message, priv_key, hashAlg="SHA-256"):
   global hash
   hash = hashAlg
   signer = PKCS1_v1_5.new(priv_key)


   if (hash == "SHA-512"):
```

```
    digest = SHA512.new()
  elif (hash == "SHA-384"):
    digest = SHA384.new()
  elif (hash == "SHA-256"):
    digest = SHA256.new()
  elif (hash == "SHA-1"):
    digest = SHA.new()
  else:
    digest = MD5.new()
  digest.update(message)
  return signer.sign(digest)
```

Authentication

Authentication is possible by verification method which is explained as below –

```
def verify(message, signature, pub_key):
  signer = PKCS1_v1_5.new(pub_key)
  if (hash == "SHA-512"):
    digest = SHA512.new()
  elif (hash == "SHA-384"):
    digest = SHA384.new()
  elif (hash == "SHA-256"):
    digest = SHA256.new()
  elif (hash == "SHA-1"):
    digest = SHA.new()
  else:
    digest = MD5.new()
  digest.update(message)
  return signer.verify(digest, signature)
```

The digital signature is verified along with the details of sender and recipient. This adds more weight age for security purposes.

RSA Cipher Decryption

You can use the following code for RSA cipher decryption –

```
from Crypto.PublicKey import RSA
from Crypto.Cipher import PKCS1_OAEP
from Crypto.Signature import PKCS1_v1_5
from Crypto.Hash import SHA512, SHA384, SHA256, SHA, MD5
from Crypto import Random
from base64 import b64encode, b64decode
hash = "SHA-256"

def newkeys(keysize):
   random_generator = Random.new().read
   key = RSA.generate(keysize, random_generator)
   private, public = key, key.publickey()
   return public, private

def importKey(externKey):
   return RSA.importKey(externKey)

def getpublickey(priv_key):
   return priv_key.publickey()

def encrypt(message, pub_key):
   cipher = PKCS1_OAEP.new(pub_key)
   return cipher.encrypt(message)

def decrypt(ciphertext, priv_key):
   cipher = PKCS1_OAEP.new(priv_key)
   return cipher.decrypt(ciphertext)
```

```
def sign(message, priv_key, hashAlg = "SHA-256"):
  global hash
  hash = hashAlg
  signer = PKCS1_v1_5.new(priv_key)

  if (hash == "SHA-512"):
    digest = SHA512.new()
  elif (hash == "SHA-384"):
    digest = SHA384.new()
  elif (hash == "SHA-256"):
    digest = SHA256.new()
  elif (hash == "SHA-1"):
    digest = SHA.new()
  else:
    digest = MD5.new()
  digest.update(message)
  return signer.sign(digest)

def verify(message, signature, pub_key):
  signer = PKCS1_v1_5.new(pub_key)
  if (hash == "SHA-512"):
    digest = SHA512.new()
  elif (hash == "SHA-384"):
    digest = SHA384.new()
  elif (hash == "SHA-256"):
    digest = SHA256.new()
  elif (hash == "SHA-1"):
    digest = SHA.new()
  else:
    digest = MD5.new()
```

```
digest.update(message)
return signer.verify(digest, signature)
```