Final Year B. Tech., Sem VII 2022-23

Cryptography And Network Security

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Assignment No. 10

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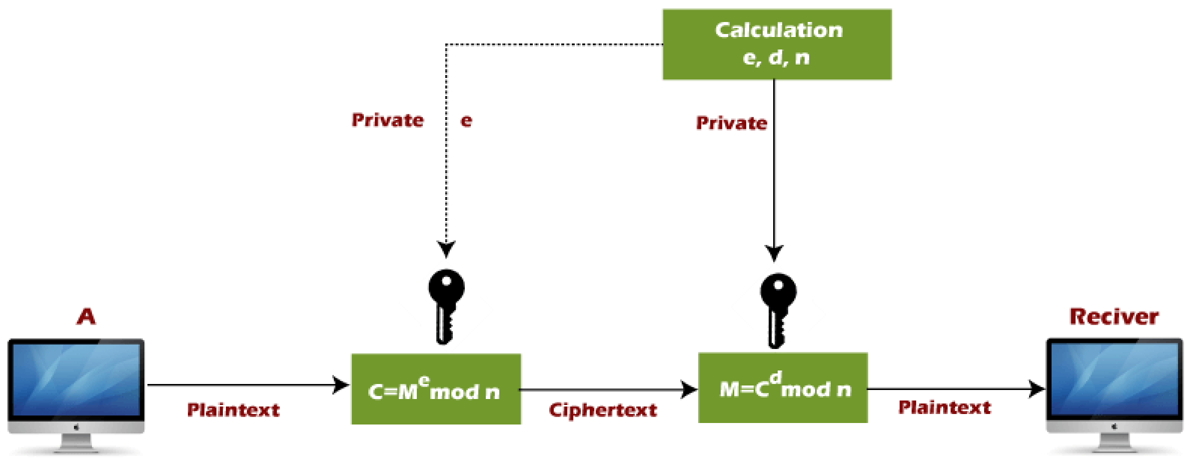
1. **Aim:**
   Implementation of RSA Algorithm

2. **Theory:**

RSA encryption algorithm is a type of public-key encryption algorithm.

RSA encryption algorithm:

RSA is the most common public-key algorithm, named after its inventors Rivest, Shamir, and Adelman (RSA).



RSA

RSA algorithm uses the following procedure to generate public and private keys:

- Select two large prime numbers, p and q.
- Multiply these numbers to find n = p x q, where n is called the modulus for encryption and decryption.

- Choose a number e less than n, such that n is relatively prime to (p - 1) x (q -1). It means that e and (p - 1) x (q - 1) have no common factor except 1. Choose "e" such that 1<e < φ (n), e is prime to φ (n),
  gcd (e,d(n)) =1
- If n = p x q, then the public key is <e, n>. A plaintext message m is encrypted using public key <e, n>. To find ciphertext from the plain text following formula is used to get ciphertext C.
  $C = m^e \bmod n$
  Here, m must be less than n. A larger message (>n) is treated as a concatenation of messages, each of which is encrypted separately.
- To determine the private key, we use the following formula to calculate the d such that:
  $D_e \bmod \{(p - 1) \times (q - 1)\} = 1$
  Or
  $D_e \bmod \varphi (n) = 1$
- The private key is <d, n>. A ciphertext message c is decrypted using private key <d, n>. To calculate plain text m from the ciphertext c following formula is used to get plain text m.
  $m = c^d \bmod n$

Let's take some example of RSA encryption algorithm:

This example shows how we can encrypt plaintext 9 using the RSA public-key encryption algorithm. This example uses prime numbers 7 and 11 to generate the public and private keys.

Explanation:

Step 1: Select two large prime numbers, p, and q.

p = 7

q = 11

Step 2: Multiply these numbers to find n = p x q, where n is called the modulus for encryption and decryption.

First, we calculate

n = p x q

n = 7 x 11

n = 77

Step 3: Choose a number e less that n, such that n is relatively prime to (p - 1) x (q -1). It means that e and (p - 1) x (q - 1) have no common factor except 1. Choose "e" such that $1<e < \varphi$ (n), e is prime to φ (n), gcd (e, d (n)) =1.

Second, we calculate

φ (n) = (p - 1) x (q-1)

φ (n) = (7 - 1) x (11 - 1)

φ (n) = 6 x 10

φ (n) = 60

Let us now choose relative prime e of 60 as 7.

Thus, the public key is <e, n> = (7, 77)

Step 4: A plaintext message m is encrypted using public key <e, n>. To find ciphertext from the plain text following formula is used to get ciphertext C.

To find ciphertext from the plain text following formula is used to get ciphertext C.

$C = m^e \bmod n$

$C = 9^7 \bmod 77$

C = 37

Step 5: The private key is <d, n>. To determine the private key, we use the following formula d such that:

D_e mod {(p - 1) x (q - 1)} = 1

7d mod 60 = 1, which gives d = 43

The private key is <d, n> = (43, 77)

Step 6: A ciphertext message c is decrypted using private key <d, n>. To calculate plain text m from the ciphertext c following formula is used to get plain text m.

$m = c^d \bmod n$

$m = 37^{43} \bmod 77$

m = 9

In this example, Plain text = 9 and the ciphertext = 37

3. Code:

```
#include <bits/stdc++.h>

using namespace std;

void file()

{

#ifndef ONLINE_JUDGE

freopen("input.txt", "r", stdin);

freopen("output.txt", "w", stdout);

#endif

}


// Function for extended Euclidean Algorithm

int ansS, ansT;

int findGcdExtended(int r1, int r2, int s1, int s2, int t1, int t2)

{

// Base Case

if (r2 == 0)

{

ansS = s1;

ansT = t1;

return r1;

}


int q = r1 / r2;

int r = r1 % r2;

int s = s1 - q * s2;

int t = t1 - q * t2;
```

```
cout << q << " " << r1 << " " << r2 << " " << r << " " << s1 << " " << s2 << " " << s << " "
<< t1 << " " << t2 << " " << t << endl;

return findGcdExtended(r2, r, s2, s, t2, t);

}


int modInverse(int A, int M)

{

int x, y;

int g = findGcdExtended(A, M, 1, 0, 0, 1);

if (g != 1) {

cout << "Inverse doesn't exist";

return 0;

}

else {

// m is added to handle negative x

int res = (ansS % M + M) % M;

cout << "Inverse is: " << res << endl;

return res;

}

}


long long powM(long long a, long long b, long long n)

{

if (b == 1)

return a % n;

long long x = powM(a, b / 2, n);

x = (x * x) % n;
```

```
if (b % 2)
x = (x * a) % n;
return x;
}
int findGCD(int num1, int num2)
{
if (num1 == 0)
return num2;
return findGCD(num2 % num1, num1);
}

// Code to demonstrate RSA algorithm
int main()
{
file();
// Two random prime numbers
long long p, q, e, msg;
//17 31 7 2
cin >> p >> q >> e >> msg;
cout<<"Two prime Numbers are: "<<p<<" "<<q<<endl;
// First part of public key:
long long n = p * q;
cout << "Product of two prime number n is " << n << endl;
// Finding other part of public key.
// e stands for encrypt
cout << "Taken e is " << e << endl;
long long phi = (p - 1) * (q - 1);
```

```
cout << "phi is " << phi << endl;
while (e < phi) {
// e must be co-prime to phi and
// smaller than phi.
if (findGCD(e, phi) == 1)
break;
else
e++;
}

cout << "Final e value is " << e << endl;
// Private key (d stands for decrypt)
long long d = modInverse(e, phi);
cout << "d is " << d << endl;
cout << "\nSo now our public key is " << "<" << e << "," << n << ">" << endl;
cout << "\nSo now our private key is " << "<" << d << "," << n << ">" << endl << endl;
// Message to be encrypted
cout << "Message data is " << msg << endl;
// Encryption c = (msg ^ e) % n
long long c = powM(msg, e, n);
cout << "Encripted Message is " << c << endl;
// Decryption m = (c ^ d) % n
long long m = powM(c, d, n);
cout << "Original Message is " << m << endl;
return 0;
}
```

4. Output:

input.txt

```
17 31 7 2
```

output.txt

```
Two prime Numbers are: 17 31
Product of two prime number n is 527
Taken e is 7
phi is 480
Final e value is 7
0 7 480 7 1 0 1 0 1 0
68 480 7 4 0 1 -68 1 0 1
1 7 4 3 1 -68 69 0 1 -1
1 4 3 1 -68 69 -137 1 -1 2
3 3 1 0 69 -137 480 -1 2 -7
Inverse is: 343
d is 343

So now our public key is <7,527>

So now our private key is <343,527>

Message data is 2
Encripted Message is 128
Original Message is 2

```

5. Conclusion:

Successfully implemented RSA Algorithm.