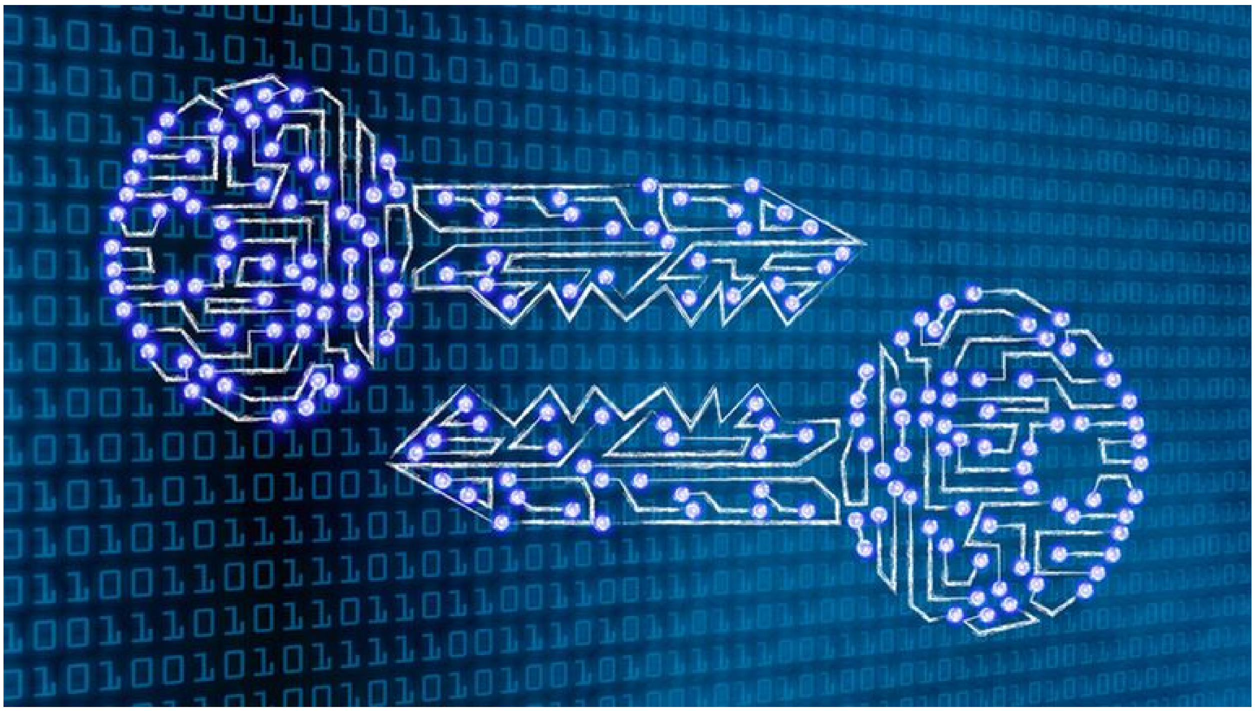
Hardware Security

Side-channel attack

Assignment #2



Introduction

Modification of the RSA implementation to use Montgomery modular multiplication and measuring the performance speed up with this modification . and implementing a side channel attack to this implementation.

Source Code : *https://github.com/khadijaAssem/Montgomery-modular-multiplication*

Part 1: Montgomery modular multiplication

Observation

Using Montgomery multiplication improved the time of execution since the normal multiplication implementation takes O(n^2)

Sample Runs

Time taken by unmodified RSA implementation 111

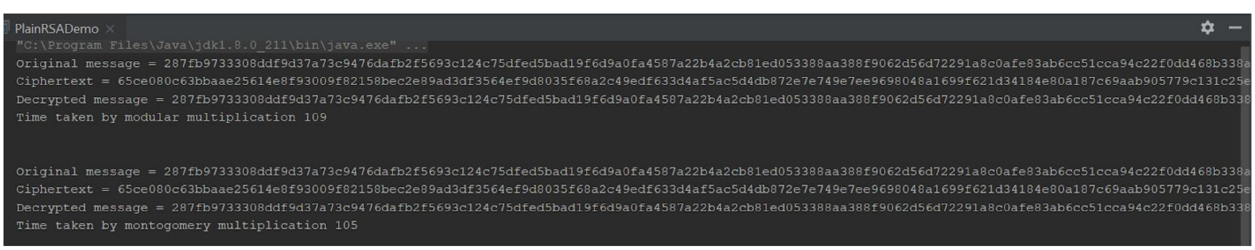
Time taken by montgomery modified RSA implementation 93

Time taken by unmodified RSA implementation 101

Time taken by montgomery modified RSA implementation 98

Time taken by unmodified RSA implementation 109

Time taken by montgomery modified RSA implementation 105



Time taken by unmodified RSA implementation 114

Time taken by montgomery modified RSA implementation 93

```
Original message = 57aa4a7b2fffcb19b7aa446fe08c0702116a04987df7c8a74c92413c4b853b78b189ab8e0902f0e
Ciphertext = 802dff4150f0aa5959c5831d720f61715b39dbe87855cdef31359ce3a8ba70c82d277d8b503f31cc3ff6c
Decrypted message = 57aa4a7b2fffcb19b7aa446fe08c0702116a04987df7c8a74c92413c4b853b78b189ab8e0902f0
Time taken by modular multiplication 114


Original message = 57aa4a7b2fffcb19b7aa446fe08c0702116a04987df7c8a74c92413c4b853b78b189ab8e0902f0e
Ciphertext = 802dff4150f0aa5959c5831d720f61715b39dbe87855cdef31359ce3a8ba70c82d277d8b503f31cc3ff6c
Decrypted message = 57aa4a7b2fffcb19b7aa446fe08c0702116a04987df7c8a74c92413c4b853b78b189ab8e0902f0
Time taken by montogomery multiplication 93
```

Time taken by unmodified RSA implementation 106

Time taken by montgomery modified RSA implementation 93

```
PlainRSADemo
"C:\Program Files\Java\jdk1.8.0_211\bin\java.exe" ...
Original message = 2a08295b377d68dd2549a1af5ca251393c5dfb9e64029c5095b76582513af5f7b7f76dfab0ffbad6bb4a280fc6feddbf3e0fbe6f51be080fcfb
Ciphertext = 969a3c248938467da9927d50684210c51e4eec1ae74ba8b0bf868316c338e1c631afc35d48849657d419b8fcf85b3ce5306e1a9ae14004a2807467091
Decrypted message = 2a08295b377d68dd2549a1af5ca251393c5dfb9e64029c5095b76582513af5f7b7f76dfab0ffbad6bb4a280fc6feddbf3e0fbe6f51be080fcf
Time taken by modular multiplication 106


Original message = 2a08295b377d68dd2549a1af5ca251393c5dfb9e64029c5095b76582513af5f7b7f76dfab0ffbad6bb4a280fc6feddbf3e0fbe6f51be080fcfb
Ciphertext = 969a3c248938467da9927d50684210c51e4eec1ae74ba8b0bf868316c338e1c631afc35d48849657d419b8fcf85b3ce5306e1a9ae14004a2807467091
Decrypted message = 2a08295b377d68dd2549a1af5ca251393c5dfb9e64029c5095b76582513af5f7b7f76dfab0ffbad6bb4a280fc6feddbf3e0fbe6f51be080fcf
Time taken by montogomery multiplication 93

Process finished with exit code 0
```

Part 2: Side-channel timing attack

Observation

This attack gives satisfying results as it succeeds to recognize the 2nd most significant bit many times with a good confidence ratio.

1st I tried implement the attack taking the advantage of the fact that the first MSB is one :

```
/* simulating bit two = 0 */
if (!One) {
    result = mont.multiply(result, result);// step 1 (2bd MSB)
    start = System.nanoTime();
    result = mont.multiply(result, result);// step 2 (3rd MSB)
    end = System.nanoTime();
    time = end-start;
    bool0 = mont.getBool();
      System.out.println(bool0);
}

/* simulating bit two = 1 */
else {
    result = mont.multiply(result, result);// step 1 (2bd MSB)
    result = mont.multiply(result, aBar);// step 1 (2bd MSB)
    start = System.nanoTime();
    result = mont.multiply(result, result);// step 3 (3rd MSB)
    end = System.nanoTime();
    time = end-start;
    bool1 = mont.getBool();
      System.out.println(bool1);
}
```

By doing so I got the results where no test failed and the program succeeded to recognize the 2nd MSB successfully for 20 times:

```
bit is one !!
Of 20 iterations 0 faild
```

2nd I did what was mentioned in the requirements and assumed that the private exponent used by the target implementation is only the three most significant bits.and then the five MSB and then 20, 50,100

```
start = System.nanoTime();
/* simulating bit two = 0 */
if (!One) {
    result = mont.multiply(result, result);// step 1 (2bd MSB)
    result = mont.multiply(result, result);// step 2 (3rd MSB)
    bool0 = mont.getBool();
      System.out.println(bool0);
}

/* simulating bit two = 1 */
else {
    result = mont.multiply(result, result);// step 1 (2bd MSB)
    result = mont.multiply(result, aBar);// step 1 (2bd MSB)
    start = System.nanoTime();
    result = mont.multiply(result, result);// step 3 (3rd MSB)
    bool1 = mont.getBool();
      System.out.println(bool1);
}

int expBitlength = exponent.bitLength();
/* Starts from expBitlength - 3 since the 1st bit is known to be
                 1 and 2nd bit is already assumed before */
for (int i = expBitlength - 3; i >= expBitlength - 100; i--) {
    result = mont.multiply(result,result);
    if (exponent.testBit(i)) {
        result = mont.multiply(result,aBar);
    }
}
end = System.nanoTime();
time = end-start;
return mont.fromMSpace(result);
```

And the output was as follows:

Where :

- **avgBitOneNRed :** is the average of times taken when the bit is assumed to be **one** and it **didn't require** montgomery additional reduction
- **avgBitOneRed :** is the average of times taken when the bit is assumed to be **one** and it **required** montgomery additional reduction
- **avgBitZeroNRed :** is the average of times taken when the bit is assumed to be **Zero** and it **didn't require** montgomery additional reduction
- **avgBitZeroRed :** is the average of times taken when the bit is assumed to be **Zero** and it **required** montgomery additional reduction

Using 3 bits

```
Of 20 iterations 1 faild
```

```
In iteration 19 :
avgBitOneNRed 41928
avgBitOneRed 62607
avgBitZeroNRed 67230
avgBitZeroRed 89028
bit is zero !!
```

Using 5 bits

```
In iteration 20 :
avgBitOneNRed 61617
avgBitOneRed 80757
avgBitZeroNRed 81232
avgBitZeroRed 91925
bit is one !!
Of 20 iterations 1 faild
```

Using 10 bits

```
bit is one !!
Of 20 iterations 5 faild
```

```
In iteration 16 :
avgBitOneNRed 187712
avgBitOneRed 201721
avgBitZeroNRed 211155
avgBitZeroRed 225216
bit is zero !!

In iteration 17 :
avgBitOneNRed 133498
avgBitOneRed 143525
avgBitZeroNRed 146744
avgBitZeroRed 159198
bit is zero !!
```

Using 20 bits

```
In iteration 20 :
avgBitOneNRed 168283
avgBitOneRed 174909
avgBitZeroNRed 174152
avgBitZeroRed 178463
bit is one !!
Of 20 iterations 5 faild
```

```
In iteration 2 :
avgBitOneNRed 338988
avgBitOneRed 351511
avgBitZeroNRed 348223
avgBitZeroRed 372834
bit is zero !!

In iteration 3 :
avgBitOneNRed 384394
avgBitOneRed 391714
avgBitZeroNRed 404976
avgBitZeroRed 408027
bit is one !!

In iteration 4 :
avgBitOneNRed 352118
avgBitOneRed 367412
avgBitZeroNRed 367147
avgBitZeroRed 383067
bit is zero !!
```

Using 50 bits

```
Of 20 iterations 6 faild
```

```
In iteration 1 :
avgBitOneNRed 603848
avgBitOneRed 582648
avgBitZeroNRed 607138
avgBitZeroRed 614863
bit is zero !!

In iteration 2 :
avgBitOneNRed 568440
avgBitOneRed 573246
avgBitZeroNRed 582213
avgBitZeroRed 591788
bit is zero !!

In iteration 3 :
avgBitOneNRed 561375
avgBitOneRed 552376
avgBitZeroNRed 572014
avgBitZeroRed 567425
bit is zero !!
```

Using 100 bits

```
Of 20 iterations 10 faild
```

```
In iteration 2 :
avgBitOneNRed 1258011
avgBitOneRed 1250115
avgBitZeroNRed 1262817
avgBitZeroRed 1283709
bit is zero !!

In iteration 3 :
avgBitOneNRed 1237389
avgBitOneRed 1254014
avgBitZeroNRed 1244790
avgBitZeroRed 1270670
bit is zero !!

In iteration 4 :
avgBitOneNRed 1270836
avgBitOneRed 1254932
avgBitZeroNRed 1268572
avgBitZeroRed 1286181
bit is zero !!
```

Summary

Conclusion

In part 1 : Using Montgomery multiplication made it faster to encrypt and decrypt the message.

In part 2 : As we increase the number of private exponent used by the target implementation bits the attack precision decreases.