ECE/CS 5560

Lab 4: Public Key Encryption and Signature

Covered Topic

- Public-key cryptography
- The RSA algorithm and key generation
- Big number calculation
- Encryption and Decryption using RSA
- Digital signatures
- X.509 certificates

This lab is part of Assignment 4

Task 1

- Goal: Deriving the Private Key

```
p:
877120207828103588060123669605304803636762908805750
39025592945358193408249897

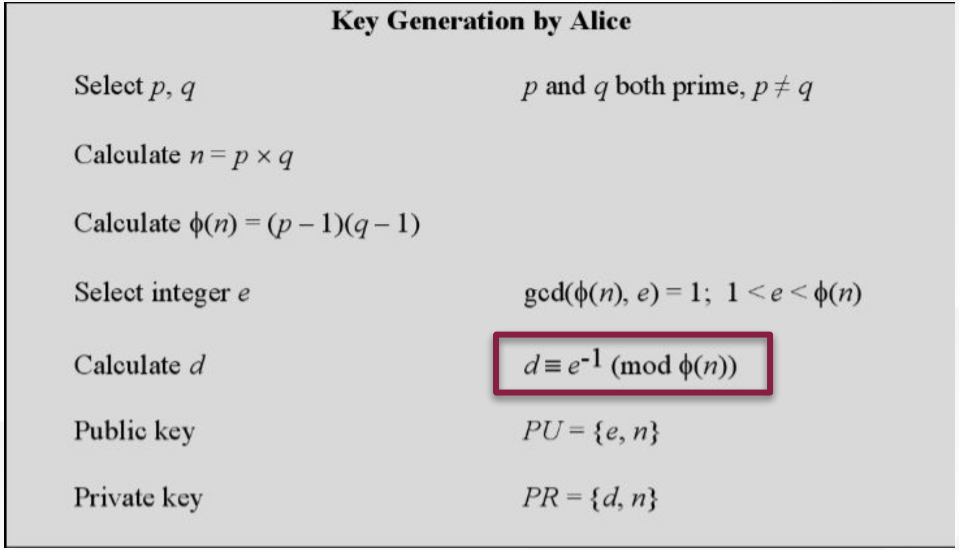
q:
102835471351264451708400576484301274347085188629221
996951152314010256656047547

e:
65537

N:
901990700037220684000499639846381245527509884514014
708960288439420664527461699910675170666871590973556
373453958389578171059667963876154490777546489852659
```

Task 1

- Python code for calculate d:
  pow(number**(e)**, power**(-1)**, modulus**(phi)**)



Key Generation by Alice

Select p, q	p and q both prime, $p \neq q$
Calculate $n = p \times q$	
Calculate $\phi(n) = (p - 1)(q - 1)$	
Select integer e	$\gcd(\phi(n), e) = 1;\ 1 < e < \phi(n)$
Calculate d	$\boxed{d \equiv e^{-1} \pmod{\phi(n)}}$
Public key	$PU = \{e, n\}$
Private key	$PR = \{d, n\}$

Task 1

- Randomly generate p and q
  number.getPrime(size)
- Run the above code, measure execution time
- Report observation

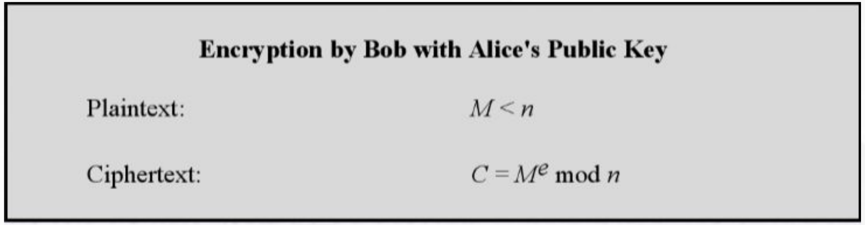
```
import time

start = time.time()
…
end = time.time()

execution = end - start
```

Task 2

- Goal: Encrypting a Message using public key
- Message: **Hello, this is my first RSA message!**
- Known parameters: **N, e, d, msg (all numbers in HEX)**

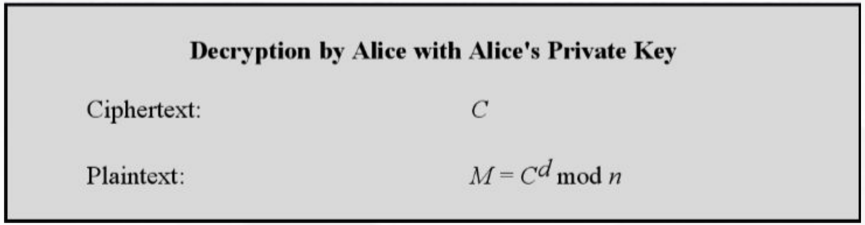


Encryption by Bob with Alice's Public Key

Plaintext:	$M < n$
Ciphertext:	$C = M^e \bmod n$

Task 3

- Goal: Decrypting a Message
- Known parameters: **N, e, d, ciphertext (all numbers in HEX)**

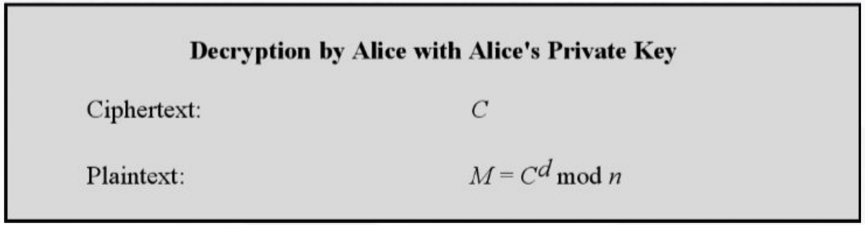


Decryption by Alice with Alice's Private Key

Ciphertext:	C
Plaintext:	$M = C^d \bmod n$

Task 4

- Goal: Signing a Message using private key
- Message: **This is a contact for $20,000**
- Same algorithm as Task 3



Decryption by Alice with Alice's Private Key

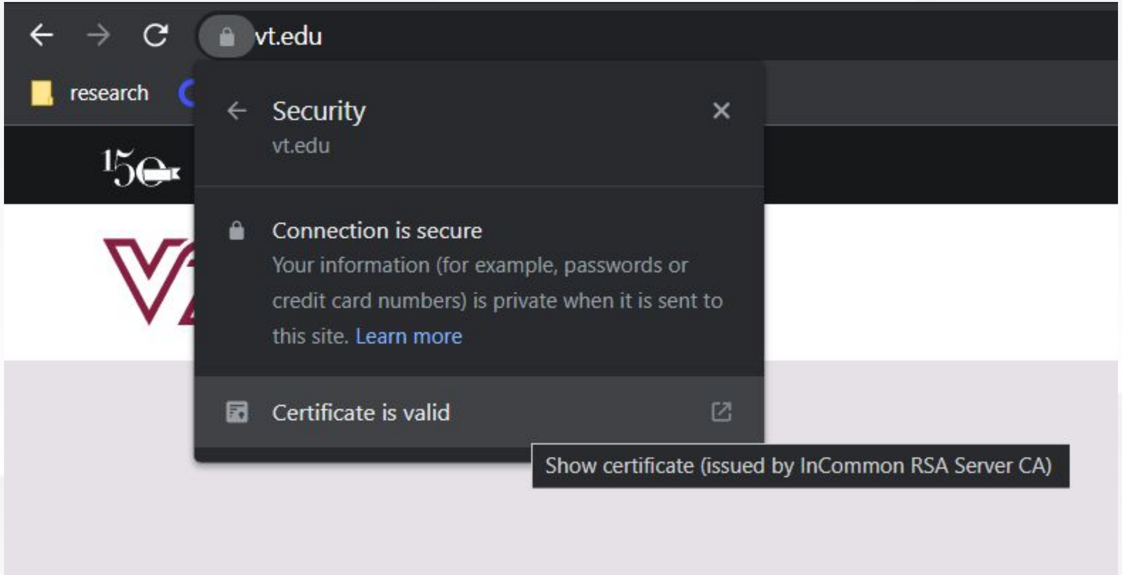
Ciphertext:	C
Plaintext:	$M = C^d \bmod n$

Task 5

- Goal: Verifying a Message
- Sign a message using private key, decrypt it using public key
- Generate files with size from 1KB, 100KB, 1MB, to 10MB
- Measure the execution time

Task 6 (Extra Credit)

- Using our code to Verify an Web (X.509) Certificate



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research

Security

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Connection is secure

Your information (for example, passwords or credit card numbers) is private when it is sent to this site. Learn more

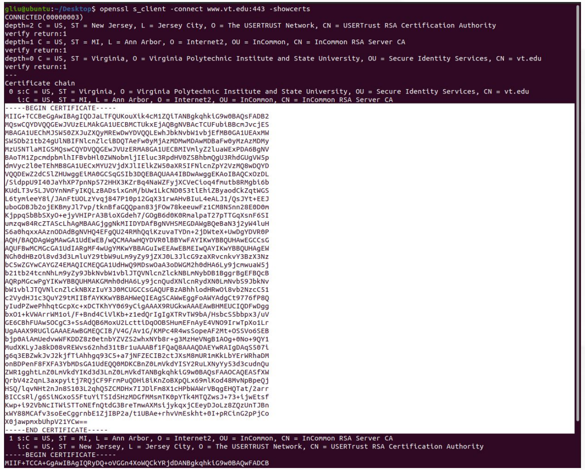
Certificate is valid

Show certificate (issued by InCommon RSA Server CA)

Task 6 (Extra Credit)

- Choose a domain name with multiple certificates: **vt.edu**
- Use openssl to obtain certificates:

```
$ openssl s_client -connect www.vt.edu:443
-showcerts > openssl_out.txt
```



```
gliu@ubuntu:~/Desktop$ openssl s_client -connect www.vt.edu:443 -showcerts
CONNECTED(00000003)
depth=2 C = US, ST = New Jersey, L = Jersey City, O = The USERTRUST Network, CN = USERTrust RSA Certification Authority
verify return:1
depth=1 C = US, ST = MI, L = Ann Arbor, O = Internet2, OU = InCommon, CN = InCommon RSA Server CA
verify return:1
depth=0 C = US, ST = Virginia, O = Virginia Polytechnic Institute and State University, OU = Secure Identity Services, CN = vt.edu
verify return:1
---
Certificate chain
 0 s:C = US, ST = Virginia, O = Virginia Polytechnic Institute and State University, OU = Secure Identity Services, CN = vt.edu
   i:C = US, ST = MI, L = Ann Arbor, O = Internet2, OU = InCommon, CN = InCommon RSA Server CA
-----BEGIN CERTIFICATE-----
MIIG+TCCBeGgAwIBAgIQDJaLTFQUKouXik4cM1ZQiTANBgkqhkiG9w0BAQsFADB2
MQswCQYDVQQGEwJVUzELMAkGA1UECBMCTUkxEjAQBgNVBAcTCUFubiBBcmJvcjES
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X0jawpmxbUhpV21YCw==
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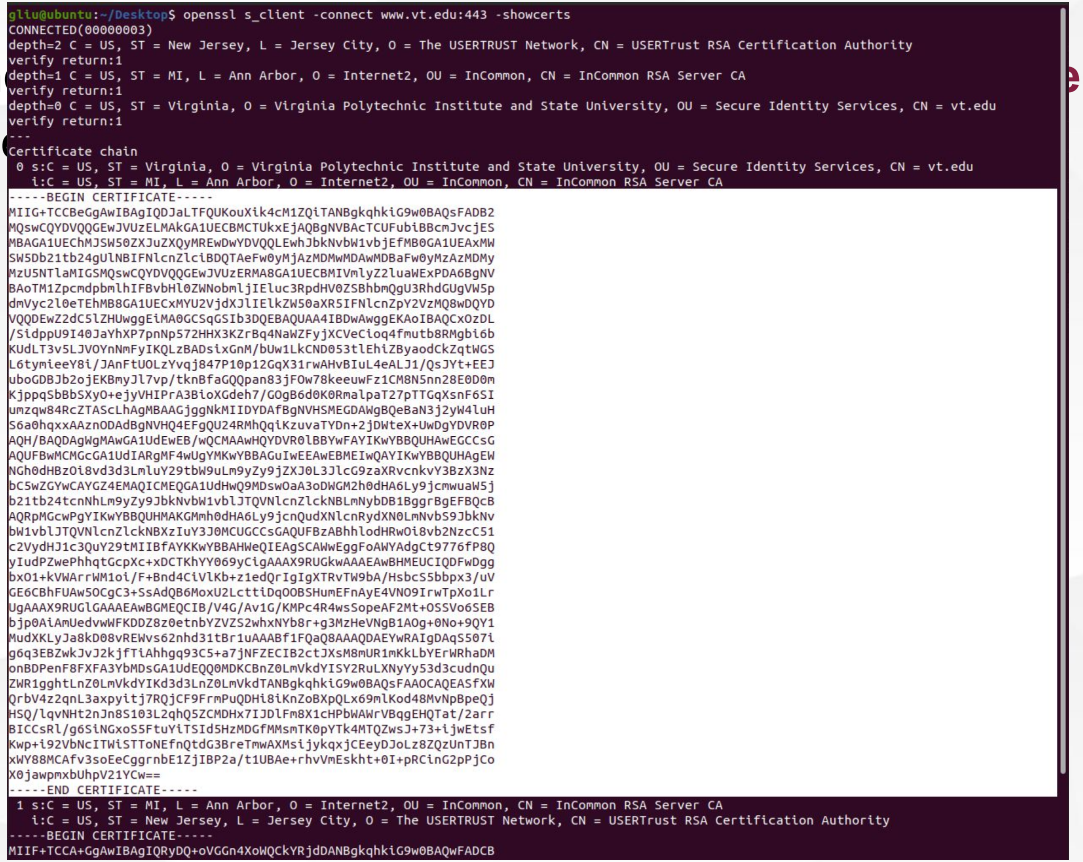
```

Task 6 (Extra Credit)

- Ch edu
- Us



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MQswCQYDVQQGEwJVUzELMAkGA1UECBMCTUkxEjAQBgNVBAcTCUFubiBBcmJvcjES
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X0jawpmxbUhpV21YCw==
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-----BEGIN CERTIFICATE-----
MIIF+TCCA+GgAwIBAgIQRyDQ+oVGGn4XoWQCkYRjdDANBgkqhkiG9w0BAQwFADCB
```

Task 6 (Extra Credit)

- Extract public key (**issuer: c1**):

For modulus (n):

```
$ openssl x509 -in c1.pem -noout -modulus
```

Print out all the fields, find the exponent (e):

```
$ openssl x509 -in c1.pem -text -noout
```

- Extract signature (**server: c0**):

```
$ openssl x509 -in c0.pem -text -noout
```

(look for Signature Algorithm)

```
$ cat signature | tr -d ’[:space:]:’
```

Task 6 (Extra Credit)

- Extract the body of the certificate

```
$ openssl asn1parse -i -in c0.pem -strparse 4 -out c0_body.bin  -noout
$ sha256sum c0_body.bin
```

- Verify the signature
  - Decrypt signature using public key (e,n), **code in previous tasks**
  - Check if the decrypted value is partially the same as sha256sum of the certificate body

Questions?

Yousef Akbar

akbary@vt.edu

Office Hours: Mon. 1:30 - 3:30pm, Thu. 1:30 - 3:30pm

Zoom: https://virginiatech.zoom.us/j/6931202457