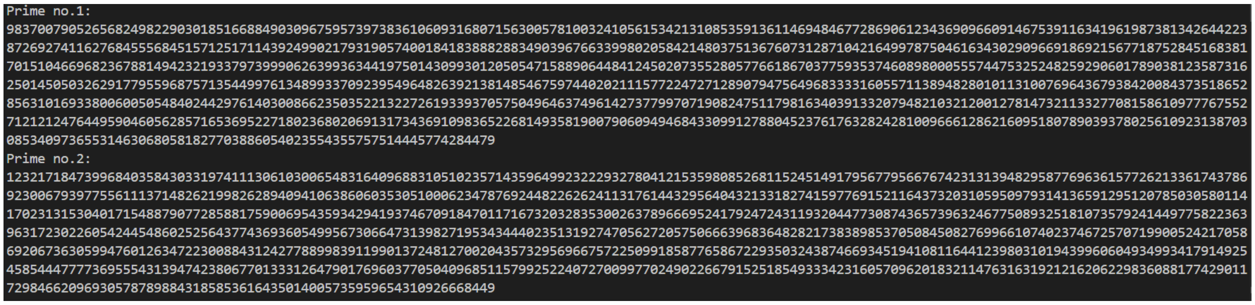
Question-1

Overview

This code is giving a cryptographic system that combine RSA(asymmetric encryption) and Salsa20 (symmetric encryption) to ensure secure communication between two persons, Alice and Bob. RSA algorithm securely exchanges a symmetric key, this key is then used with salsa20 for encryption and decryption of the message.

Take two large prime numbers as input
These below are the two prime numbers I used:



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Prime no.1:
9837007905265682498229030185166884903096759573973836106093168071563005781003241056153421310853591361146948467728690612343690966091467539116341961987381342644223
8726927411627684555684515712517114392499021793190574001841838882883490396766339980205842148037513676073128710421649978750461634302909669186921567718752845168381
7015104669682367881494232193379739990626399363441975014309930120505471588906448412450207355280577661867037759353746089800055574475325248259290601789038123587316
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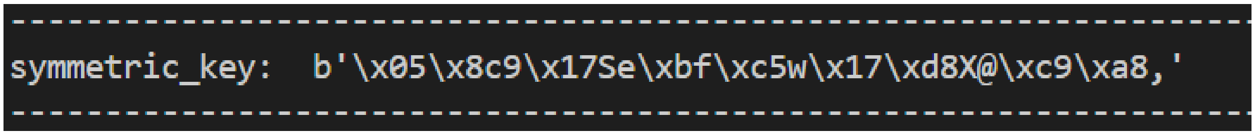
8563101693380060050548402442976140300866235035221322726193393705750496463749614273779970719082475117981634039133207948210321200127814732113327708158610977767552
7121212476449590460562857165369522718023680206913173436910983652268149358190079060949468433099127880452376176328242810096661286216095180789039378025610923138703
085340973655314630680581827703886054023554355757514445774284479
Prime no.2:
1232171847399684035843033197411130610300654831640968831051023571435964992322293278041215359808526811524514917956779566767423131394829587769636157726213361743786
9230067939775561113714826219982628940941063860603530510006234787692448226262411317614432956404321331827415977691521164373203105950979314136591295120785030580114
1702313153040171548879077285881759006954359342941937467091847011716732032835300263789666952417924724311932044773087436573963246775089325181073579241449775822363
9631723022605424454860252564377436936054995673066473139827195343444023513192747056272057506663968364828217383898537050845082769966107402374672570719900524217058
6920673630599476012634722300884312427788998391199013724812700204357329569667572250991858776586722935032438746693451941081164412398031019439960604934993417914925
4585444777736955543139474238067701333126479017696037705040968511579925224072700997702490226679152518549333423160570962018321147631631921216206229836088177429011
729846620969305787898843185853616435014005735959654310926668449
```

Alice generates a 16-byte random symmetric key using the Random.get_random_bytes(16) function. This key will later be encrypted using RSA and securely transmitted to Bob. This key later used to encrypt and decrypt the data.



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-----------------------------------------------------------------------
symmetric_key:  b'\x05\x8c9\x17Se\xbf\xc5w\x17\xd8X@\xc9\xa8,'
-----------------------------------------------------------------------
```
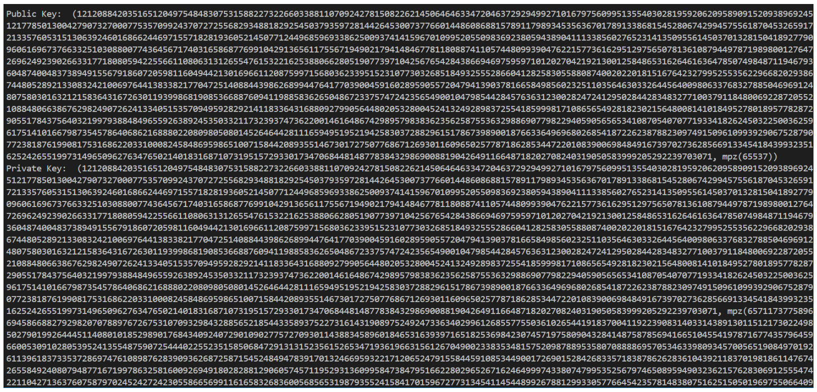

Now Bob generates the RSA key pair using the given prime numbers.

- Compute n = p * q
- Compute Euler’s totient function: z = (p-1) * (q-1)
- Choose a public exponent e = 65537
- Compute the private exponent d, the modular inverse of e mod z

Public key and Private key



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Public Key:  (1212088420351651204975484830753158822732266033881107092427815082262145064646334720463729294992710167975609951355403028159206209589091520938969245
1217785013004279073270007753570992437072725568293488182925450379359728144264530073776601448608688157891179893453563670178913386815452806742994575561870453265917
2133576053151306392460168662446971557182819360521450771244968596933862500937414159670109952055098369238059438904111338560276523141350955614503701328150418927790
9606169673766332510308800774364567174031658687769910429136561175567194902179414846778118088741105744809939047622157736162951297565078136108794497871989800127647
2696249239026633177180805942255661108063131265547615322162538806628051907739710425676542843866946975959710120270421921300125848653162646163647850749848711946793
6048740048373894915567918607205981160494421301696611208759971568036233951523107730326851849325552866041282583055880874002022018151676423279952553562296682029386
7448052892133083242100697644138338217704725140884439862689944764177039004591602895905572047941390378166584985602325110356463033264456400980633768327885046969124
8075803016321215836431672630119399868190853668876094119885836265048672337574724235654900104798544284576363123002824724129502844283483277100379118480069228720552
1088480663867629824907262413340515357094959282921411833643168809279905644802053280045241324928983725541859998171086565492818230215648008141018495278018957782872
9055178437564032199793884849655926389245350332117323937473622001461648674298957983836235625875536329886907798229405905656534108705407077193341826245032250036259
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7723818761990817531686220331000824584869598651007158442089355146730172750776867126930116096502577871862853447220108390069848491673970273628566913345418439932351
6252426551997314965096276347650214018316871073195157293301734706844814877838432986900881904264911664871820270824031905058399920529223970 3071, mpz(65537))
Private Key:  (121208842035165120497548483075315882273226603388110709242781508226214506464633472046372929499271016797560995135540302815920620958909152093896924
5121778501300427907327000775357099243707272556829348818292545037935972814426453007377660144860868815789117989345356367017891338681545280674299457556187045326591
7213357605315130639246016866244697155718281936052145077124496859693386250093741415967010995205509836923805943890411133856027652314135095561450370132815041892779
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1625242655199731496509627634765021401831687107319515729330173470684481487783843298690088190426491166487182027082403190505839992052922397 03071, mpz(6571173775896
6945866882792982070788976726753107093298432885652185443358937522731614319089752492473363402996126855775503610265441918370041192239083140331438913011512173022498
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2655849240807948771671997863258160092694918028288129060574571195293136099584738479516622802965267162464999743380747995352567974650895949032362157628306912555474
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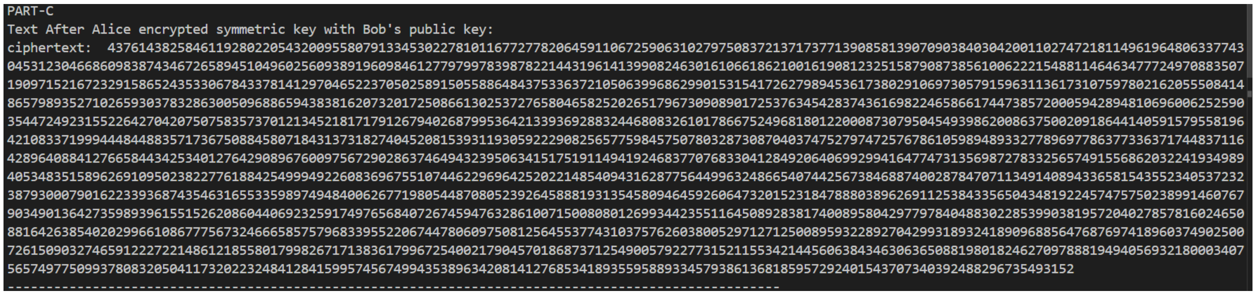
Now Alice encrypts the symmetric key using Bob’s public key (n, e). The symmetric key (a byte string) is converted to an integer before encryption

Encryption Formula:

- C=M^e(modn)



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PART-C
Text After Alice encrypted symmetric key with Bob's public key:
ciphertext:  437614382584611928022054320095580791334530227810116772778206459110672590631027975083721371737713908581390709038403042001102747218114961964806337743
0453123046686098387434672658945104960256093891960984612779799783987822144319614139908246301610661862100161908123251587908738561006222154881146463477724970883507
1909715216723291586524353306784337814129704652237050258915055886484375336372105063996862990153154172627989453617380291069730579159631136173107597802162055508414
8657989352710265930378328630050968865943838162073201725086613025372765804658252026517967309089017253763454283743616982246586617447385720005942894810696006252590
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4289640884127665844342534012764290896760097567290286374649432395063415175191149419246837707683304128492064069929941647747313569872783325657491556862032241934989
4053483515896269109502382277618842549994922608369675510744622969642520221485409431628775644996324866540744256738468874002878470711349140894336581543552340537232
3879300079016223393687435463165533598974948400626771980544870805239264588819313545809464592606473201523184788803896269112538433565043481922457475750238991460767
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5657497750993780832050411732022324841284159957456749943538963420814127685341893559588933457938613681859572924015437073403924882967354931 52
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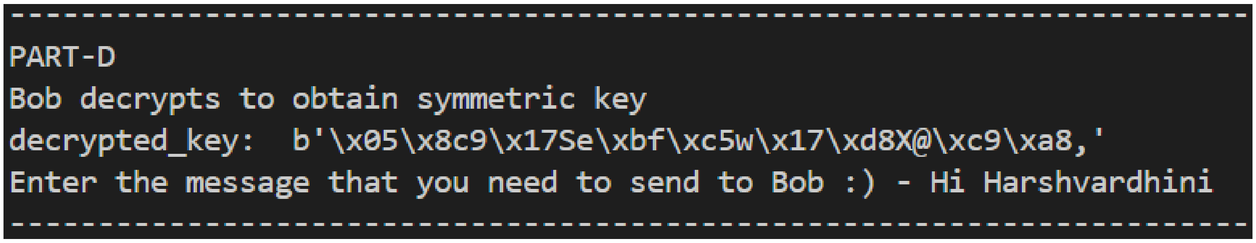
After Bob receives the ciphertext he decrypts the ciphertext using his private key (n, d).

Decryption Formula:

- M = C^d mod n



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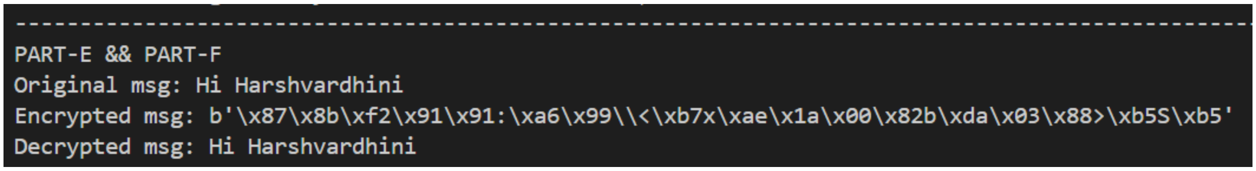
-------------------------------------------------------------------------
PART-D
Bob decrypts to obtain symmetric key
decrypted_key:  b'\x05\x8c9\x17Se\xbf\xc5w\x17\xd8X@\xc9\xa8,'
Enter the message that you need to send to Bob :) - Hi Harshvardhini
-------------------------------------------------------------------------
```

Now Bob encrypts the message using Salsa20 with the decrypted symmetric key. AAs you can see in above image it is asking for the text that needs to be encrypted and send to Alice. Salsa20 generates a nonce and encrypts the message.



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---------------------------------------------------------------------------------------------
PART-E && PART-F
Original msg: Hi Harshvardhini
Encrypted msg: b'\x87\x8b\xf2\x91\x91:\xa6\x99\\<\xb7x\xae\x1a\x00\x82b\xda\x03\x88>\xb5S\xb5'
Decrypted msg: Hi Harshvardhini
```

Finally Alice decrypts the received ciphertext using the same symmetric key which has been shared to bob previously. In above picture as you can see the original message and decrypted message are same which means securely shared the correct information maintaining the integrity.

This approach ensures confidentiality, integrity, and authenticity in communication.