Instituto Politécnico Nacional
Escuela Superior de Cómputo

Ingeniería en Sistemas Computacionales

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Practica 5.

(Diffie-Hellman con Curvas Elípticas)

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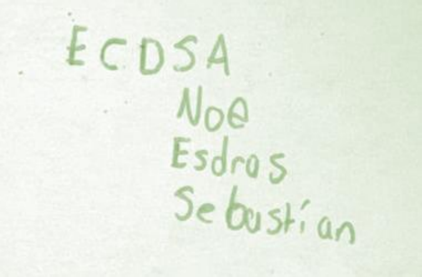

ECDSA
Noe
Esdras
Sebastían

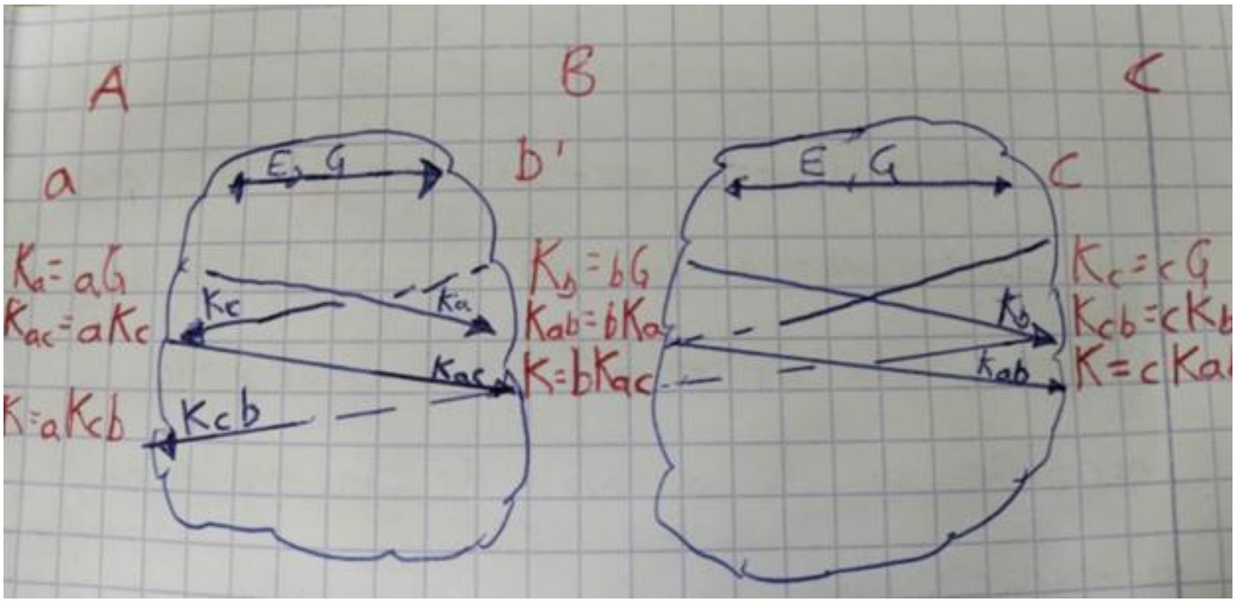
Grupo: 7CM1
Selected Topics in Cryptography
14 de mayo del 2024

Práctica 5

DESCRIPCION DEL ALGORITMO

ECDH es un protocolo de acuerdo de claves que permite a dos partes, cada una con un par de claves pública-privada de curva elíptica, establecer un secreto compartido a través de un canal inseguro. Este secreto compartido se utiliza para derivar otra clave simétrica. El protocolo ECDH es una variante del protocolo Diffie-Hellman que utiliza criptografía de curva elíptica. ECDH deriva un valor secreto compartido a partir de una clave secreta poseída por una Entidad A y una clave pública poseída por una Entidad B, cuando las claves comparten los mismos parámetros de dominio de la curva elíptica. La Entidad A puede ser el iniciador de una transacción de acuerdo de claves, o el respondedor en un esquema. Si dos entidades realizan correctamente las mismas operaciones con claves correspondientes como entradas, se produce el mismo valor secreto compartido.

DIAGRAMA ECDH



CARACTERISTICAS DE LOS DISPOSITIVOS

PC	RAM	S.O.	PROCESADOR
A (Noé)	**16 GB**	**W 11**	**RYZEN 7 (4800U)**
B (Esdras)	**4 GB**	**W 10**	**INTEL PENTIUM R**
C (Israel)	**8 GB**	**W 11**	**INTEL CORE I5 (10 GEN)**

LENGUAJE, BIBLIOTECA Y CURVA

Lenguaje: PYTHON ver 3.11

Biblioteca: TYNYEC import EC

Curva: curve = registry.get_curve('brainpoolP512r1')

PROBLEMAS DURANTE EL DESARROLLO

Inicialmente usábamos una librería de criptografía que no nos permitía generar los puntos y por ende las llaves no se generaban bien.

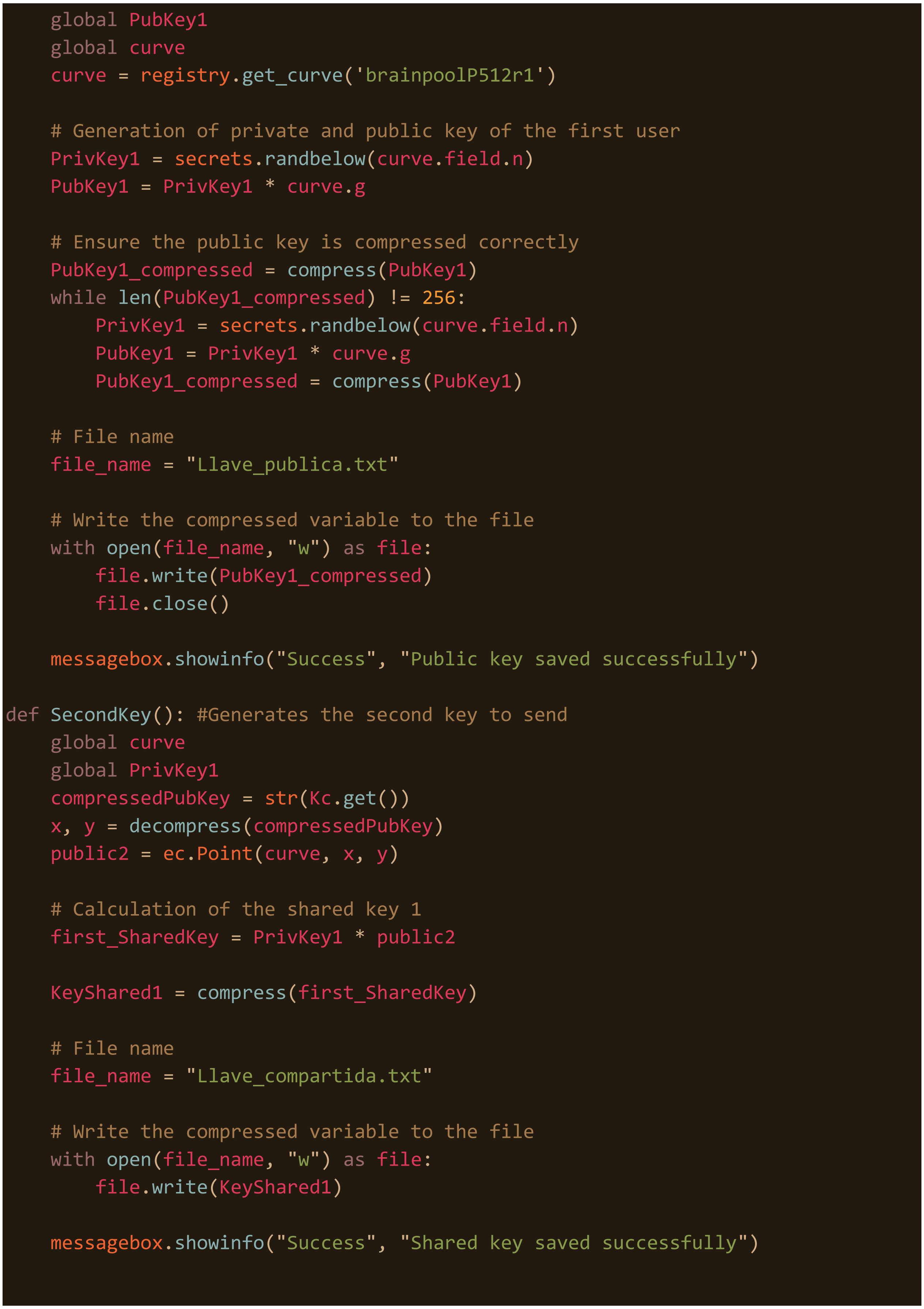
También que no nos permitía manejar los archivos por que al guardar se usaba utf-8 y eso manipulaba la información final al momento de leerla.

PRUEBAS DE IMPLEMENTACION

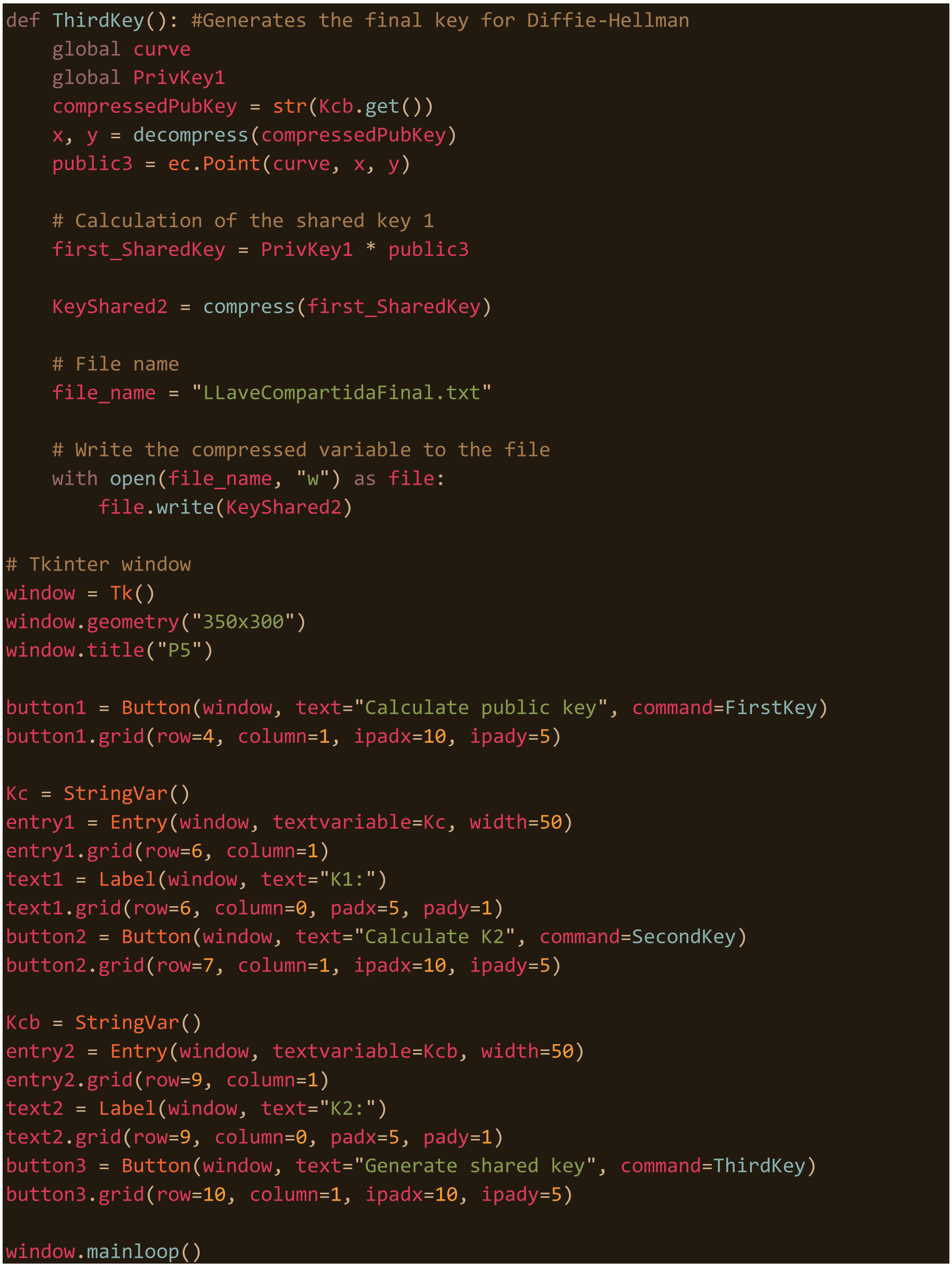
Para solucionar el problema de la curva, cambiamos de librería, en vez de usar *cryptodome* empezamos a usar *tynyec* que permite manipular los puntos de la curva de manera mas eficaz al realizar las operaciones.

CODIGO

```
from tkinter import *
from tkinter import filedialog
from tkinter import messagebox
from tinyec import registry
import secrets
from tinyec import ec

global PrivKey1
global PubKey1
global curve

def compress(pubKey):
    x_hex = hex(pubKey.x)[2:]
    y_hex = hex(pubKey.y)[2:]
    compressed = x_hex + y_hex
    return compressed

def decompress(compressedPubKey):
    x = int(compressedPubKey[:128], 16)
    y = int(compressedPubKey[128:], 16)
    return x, y

def FirstKey(): #Generates public and private keys
    global PrivKey1
```



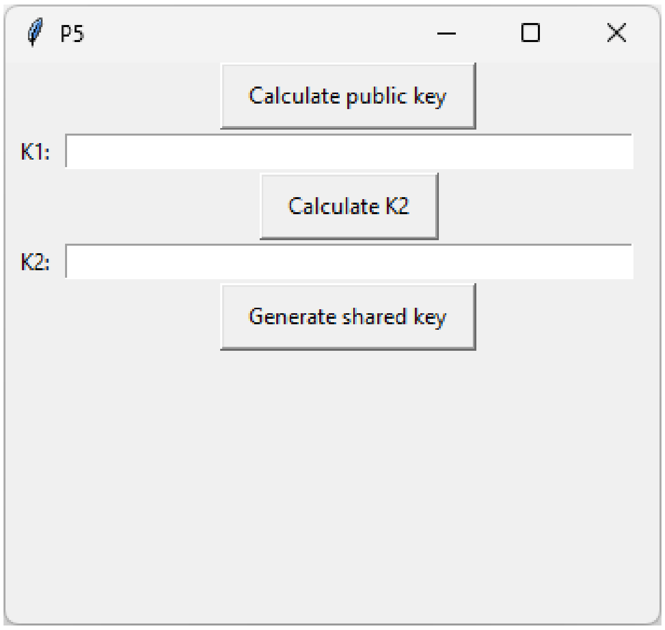
```python
    global PubKey1
    global curve
    curve = registry.get_curve('brainpoolP512r1')

    # Generation of private and public key of the first user
    PrivKey1 = secrets.randbelow(curve.field.n)
    PubKey1 = PrivKey1 * curve.g

    # Ensure the public key is compressed correctly
    PubKey1_compressed = compress(PubKey1)
    while len(PubKey1_compressed) != 256:
        PrivKey1 = secrets.randbelow(curve.field.n)
        PubKey1 = PrivKey1 * curve.g
        PubKey1_compressed = compress(PubKey1)

    # File name
    file_name = "Llave_publica.txt"

    # Write the compressed variable to the file
    with open(file_name, "w") as file:
        file.write(PubKey1_compressed)
        file.close()

    messagebox.showinfo("Success", "Public key saved successfully")

def SecondKey(): #Generates the second key to send
    global curve
    global PrivKey1
    compressedPubKey = str(Kc.get())
    x, y = decompress(compressedPubKey)
    public2 = ec.Point(curve, x, y)

    # Calculation of the shared key 1
    first_SharedKey = PrivKey1 * public2

    KeyShared1 = compress(first_SharedKey)

    # File name
    file_name = "Llave_compartida.txt"

    # Write the compressed variable to the file
    with open(file_name, "w") as file:
        file.write(KeyShared1)

    messagebox.showinfo("Success", "Shared key saved successfully")
```



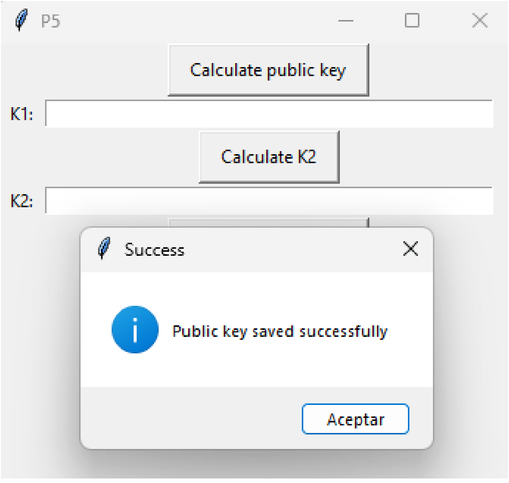
```
def ThirdKey(): #Generates the final key for Diffie-Hellman
    global curve
    global PrivKey1
    compressedPubKey = str(Kcb.get())
    x, y = decompress(compressedPubKey)
    public3 = ec.Point(curve, x, y)

    # Calculation of the shared key 1
    first_SharedKey = PrivKey1 * public3

    KeyShared2 = compress(first_SharedKey)

    # File name
    file_name = "LLaveCompartidaFinal.txt"

    # Write the compressed variable to the file
    with open(file_name, "w") as file:
        file.write(KeyShared2)

# Tkinter window
window = Tk()
window.geometry("350x300")
window.title("P5")

button1 = Button(window, text="Calculate public key", command=FirstKey)
button1.grid(row=4, column=1, ipadx=10, ipady=5)

Kc = StringVar()
entry1 = Entry(window, textvariable=Kc, width=50)
entry1.grid(row=6, column=1)
text1 = Label(window, text="K1:")
text1.grid(row=6, column=0, padx=5, pady=1)
button2 = Button(window, text="Calculate K2", command=SecondKey)
button2.grid(row=7, column=1, ipadx=10, ipady=5)

Kcb = StringVar()
entry2 = Entry(window, textvariable=Kcb, width=50)
entry2.grid(row=9, column=1)
text2 = Label(window, text="K2:")
text2.grid(row=9, column=0, padx=5, pady=1)
button3 = Button(window, text="Generate shared key", command=ThirdKey)
button3.grid(row=10, column=1, ipadx=10, ipady=5)

window.mainloop()
```

CAPTURAS

INTERFAZ



Prueba 1



Public key saved successfully

Llave publica A:
1b80dc5875b60aa042fea9ce26c2499fd2122
cb901ef15c5e545f59b9d3c311dd68e01c590
2e92ef40c96f6a7519e9c17401ffb49c6ca016
dcc0b7da5ed963fd6bf738ffc17d32c3cfdd46
b2c228f3465f2bef459eeab98113d259f64975
14d804a276ced9a4fc6ad56b415510313d85
76d61e33bc9dc081d57faa3a24f99cb9

Llave publica B:

9aea7583e8566eb1b6d690f84953b7c7c62b
7f841cb8c8591913aacfebd59e995300a1b3e24b22b9e59d7f8cd2301a2633cf4
c0a1475eda99467d19b6bde7cf9254669bd4eebedfadd3451a1e28b05a7fb2e1
9da4c948cc43e682cfb8bfcd7e099b09615199273d02ab73a04ecb7f9db02ca47
f5a3f114e87cd4344fb0ab4af4

Llave publica C:

9817ef9cd1bdf45d7e34ca7284b64115c5fdbb87978201cbed9ddaf47bb627e97
7e155194ba7464ae1e98646a8dc749d21d59b8b4e6dfd0471831d177e56c917
928c644e36382f635426e901befb0182a81ae30400397fe5c0b49cb9aa7f78c07
63002548821d14b0bf3144164896c702f36c58406f6791e251a85aacea8e20f

Llave AB:

6fbed505c14dbe4426b3423057ffc76cfa0048a0ea697bbdebb0c5c4a75ad6ea5
2de4484905ba6f12668e43d566ca941e601894ebf2f89397962f364adc16cb099
82840c6d3df3dc900fa5b762d326192ffe8b5bbfaabb2f88489307be1bc979011b
fdb6c16f75c24d3129c34df96b4cf0132b861c95f80e9de70d665ac6e690

Llave BC:

95741d7aba7766e8217320923db626a05259e9a6b66076caad459050c54c26d
13ddbb723765383ac8a023cc638b550ac700100891065e450174ea8acdbff0ee
95047721f19dc9c2c4f196b42395df5c5a848326b291b9e861c9c4ee88d0a0ca9
4284a7353b3776c64ce10ee49dbe530b4a330bfd1695b651484d48df45c59a0e

Llave CA:

2dcef5f96aa50785ca32be9836dda6076f180d26d74be1bc4302c0d6e589406ff
5e5edb9cc49fd030265836cf40e14c0e3dee61db908c5f7f74bb431bd4f79c2a1
ae3fc5ac9c26c41e1c0c929dd82a3b67ab7a644e8c316c21744c98c535e61bce
b83325079d869f84daebe991381e5cbfba7c68e3de295e5f3ba3953f4ef7e6

Secreto compartido:

b07a741128f0ea8c884bd78aff99a471edf32cf82974215db56dacb012422ff4d4
a042bdc2173f0aaafd4aef3cd18d63cf0f3597cb45ee8ade381fc6c542cfc11f5d9
4188a9f43078f59d0396c5df29156f59863556478d39dffa9daf5112604cbcbe05
7e32c176becfe9d5f4565a623c11f9b6afaeb1f937edfbd055bfeb70

Prueba 2

Llave A:

557d8f8c00456b47d9db3494b2effea542c96ea3ec5d9467e0f7a31307064b9c4
f518e4251b7b781fda01576682111406da4c159b150cdeea9f9fac2d97f94f76aa
580e4aa6ab4946ddae6d92578c853101ca5e7261831ab768b3aa356d79576f0
cbc46790d6e89ac83a829f4696324658790a0623f2a92740ffc9a1a5ebfd94

Llave B:

13f798fad7779459efd94f6e2c7c4c29f8cab928249d9383cbbf14e4c41172e910
c16979c4c92a55d6f5553d260a94a81850fe62a8e503eb9af51e643b9fad847f5
2fd0113b8f877dd96ab478442f26d9e6a01a2af124c582d60b85f684b1f0beddb
cff4e3fa9f3df9b27787468ed33514400fb11320ff6bba37fb3e06c610ba

Llave C:

737bbf31946cc3235c8a94b8795538afe29f425a3d881b179c0b5df7dd181edd0
3f9a1dc1850376b240d7d86afec446854dab6ca43ca85df48b1e020aa2bf75a4b
346d6c71104d3a5e072d554a874c4b7463fa360a9b4127f167afcd635c36ae95f
c97ef232173907b28070f189a5954e904ea79a539f711e8c6b9e6f5df0d9b

Llave AB:

```
212ee08ea812aa15fd3a5a7ea5a968929e4ddfa2667923574e9abc04bcff9b52a
476f1ed95ad61ce97dbb48b441f8fe50626338d18a396d82487d0b87244a7c3a
144b4eaa0d34dc37a9f401446b3de614018b8c920f05eac6ff65fa2cce4d6aa19
a65d72853db24ba66b2e240213b28efda7a5ed290cf3c44b2e183118ca63a1
```

Llave BC:

```
404165af186c55b1952ce9db7a9f1899729063fa0c9519db87da016e58b9ea59
9993eff30b7aa7538ed49baf919e2bc676421812a7a18ec9e8fd489584e6c56c8
c82d902c28de375c704bcc886c08a66c659beead3231e3b7200162688a8ba77f
240be0ad803ebcef6ad4beca4a0f8140f871a628d1bc80eaa89a53e307f89ea
```

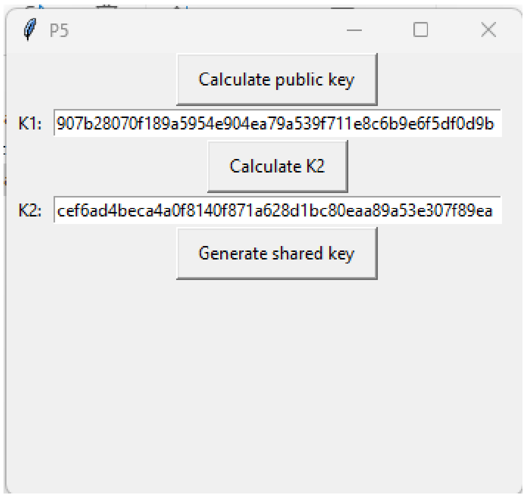
Llave CA:

```
29f9f6339bf9bf35a5e89f6c52072857a87381813d67a5cf206d9b00628e9b589
0dae201ad36628b34d0723c98e97f64c1ccc5fe52d1ad1a7598b007b34e0fd49
e63b279dd59c13ec0a25d54af7de5f6a927d9fea610ee1ed99957ecf04ea94700
349a73b10071416672e4c0ad51985de29ae6d08b7b2e67e823c7bac89c2564
```

Secreto Compartido:

```
89c822b06ccbe0f4345ee08f5144633a499ba50e799cb1a99878f3cf3f8383b73
13e2579c5951346682b5b657c9e93c7b25266edd713c95c97a40f1041f5d5074
b160447c487d326b967f725c851b0ffb76b83dbb66057cbe8ef046e2d274aacd4
db5324d2b4f5c7478aa15b589dc37e6ec22c30e15b7d16c55e1a27f4571944
```

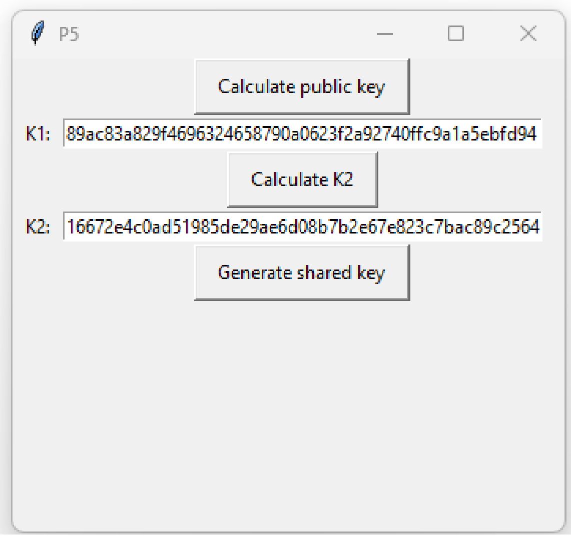
A:



K1: 907b28070f189a5954e904ea79a539f711e8c6b9e6f5df0d9b

K2: cef6ad4beca4a0f8140f871a628d1bc80eaa89a53e307f89ea

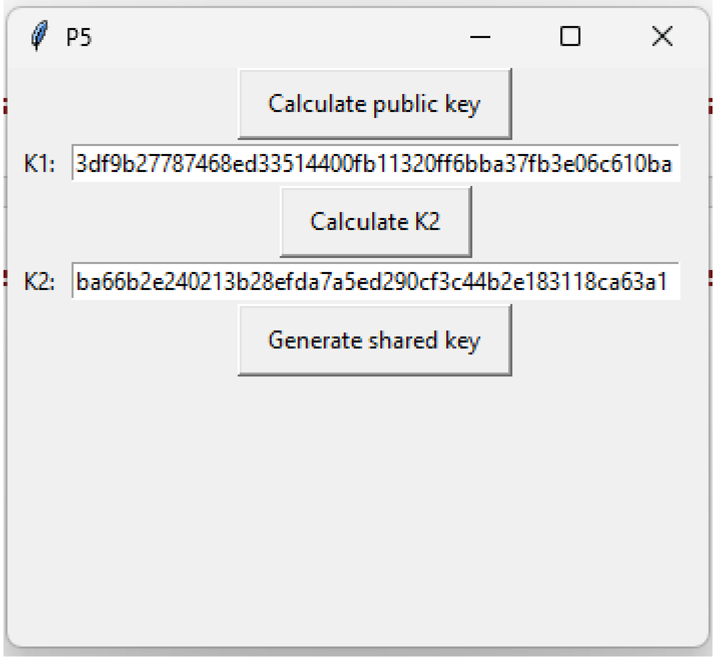
B:



K1: 89ac83a829f4696324658790a0623f2a92740ffc9a1a5ebfd94

K2: 16672e4c0ad51985de29ae6d08b7b2e67e823c7bac89c2564

C:



K1: 3df9b27787468ed33514400fb11320ff6bba37fb3e06c610ba

K2: ba66b2e240213b28efda7a5ed290cf3c44b2e183118ca63a1

Prueba 3

Llave A:

1dd354b62fe5c2623f406b88a0c54f277f07356d586f3a4c4c00c8acfb6c266721
e90a10677bec6cac75d79d8fb2da60a1ceda392a097a7e729fbc16508da5e437
034393fc83f92bbb1fdae168d14e7b3af8000cffc4a75eb2b5883d6aa0ca64688b
da010234f47d1557e2c826365d17916db6d20dc69de154743b77fb59b2c7

Llave B:

634e9df4cc30d6bce9db28d9097f4b1f4e6a146d769ef7f52f12dfd484e3d364c1
6d03269fc070ceffcf06851fd86eeb93bc579c07f0867258e255b2ffc8b6d87b1c3
662e4c28838e292242cb4ebf1b18aa983fa5211b1d9ecd3a368447a294cb3d23
bd297c1d9edffd0194d06a04f1b35afa38b5229a45a35b5cfcb67f3d710

Llave C:

8d698fd1c24fa154e647eb7fb008fa0e54c7ea84edb26dbef81d7119e36da6222
ecc385c6173c345fdd1dae738537570cd0fe7b01a0b38f9bfad60dad2f2d64d48
e728c5ee02fa1947ced052cae55c761335efa7daa73aacb61f7bb6121af9ebe4a
5f49f9c97ddc976467674072b82ba219dd7748db6c7f5ba27549e87c8d821

Llave AB:

1dd4040a8382d109c6d97e6ef2e08c71c9410c0f9006ae92aa19b0a0747bf56c
62b7f44fb62a7b1d4ee3e0bc62eefd87106f30b1795ba3cdece85f295273cf3b60
98ef761c063f8190c01bcdfdd3aa8466c820d7e943c810a2fc9250340dc9ff4c92
a4f3f8f485b1b8b6dd75d0b04b070fa7e20e3d1ceb758d0a8903aa2baf9e

Llave BC:

46b8348485043d88ce6fd4f4491526279eee0da91b899edcaca47fcc0f726e4d8
4d8ad97c63a8cd561dabf78eaa151466197bc4ea096d9b7601754a40f9132b05
2c46f2f975f8b98d9a01c6df9f0655da38e8396d5955c0d19857b4b497d9ff2db5
2d314baa6be5928f113f9a4069e58d5ef9a9d19baf5e56c406c5b95136277

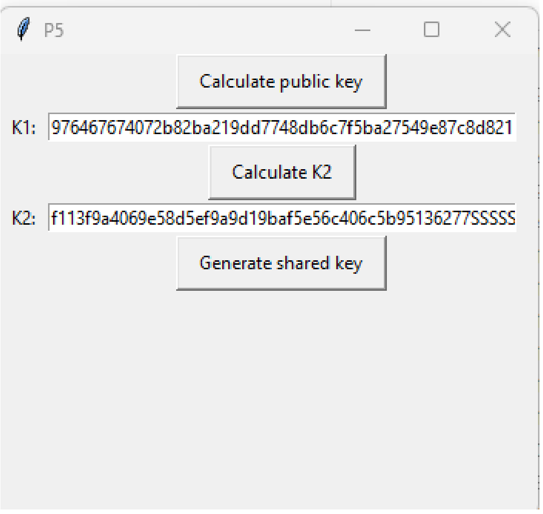
Llave CA:

9242a2a740644d37bc2c341a0b68a95ae7fda88b97e71e5750d7f72786b1f3b9
495a251cb7bd5e23bd9da9293b3e83103bb3627baae61d31693b7a809ad8093
e5f3f686d71b0f0af95eaa97761a0af973b9e6de60bfa84615dd0eb3d8f01ce14e
0fcc7650d10285ac32cbf658152e55c29c8c817053c5e70e8cc83d28ccf8761

Secreto compartido:

63b5a63c7450f225f4fd939f3b3dee66ab87266a61e3d74b56492952fa0d065b1
980179c7712bd4469140a8a5baaa2665705750c97cfeec5b19a8d15fecc51a55
80380ce40012b5568c63ceb9f0eeeaa161ff3121f38206d43495f76ac7ef07e200
88e56b038bd614cb2d9fa4969af1421e94325de78c3e261582940d73f7ba1

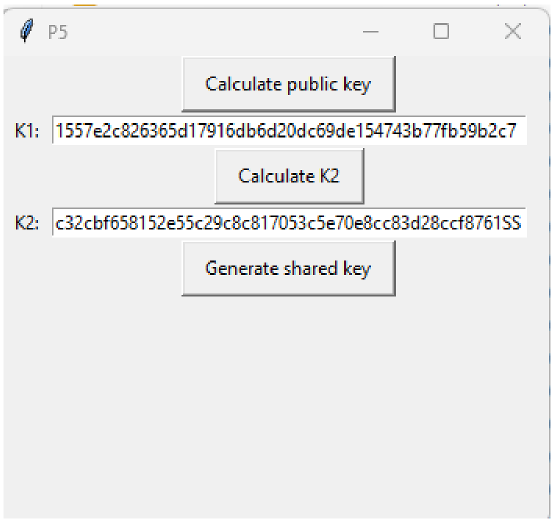
A:



K1: 976467674072b82ba219dd7748db6c7f5ba27549e87c8d821

K2: f113f9a4069e58d5ef9a9d19baf5e56c406c5b95136277SSSSS

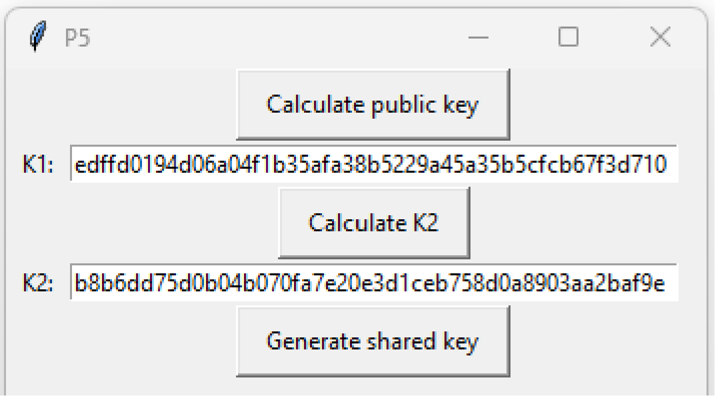
B:



K1: 1557e2c826365d17916db6d20dc69de154743b77fb59b2c7

K2: c32cbf658152e55c29c8c817053c5e70e8cc83d28ccf8761SS

C:

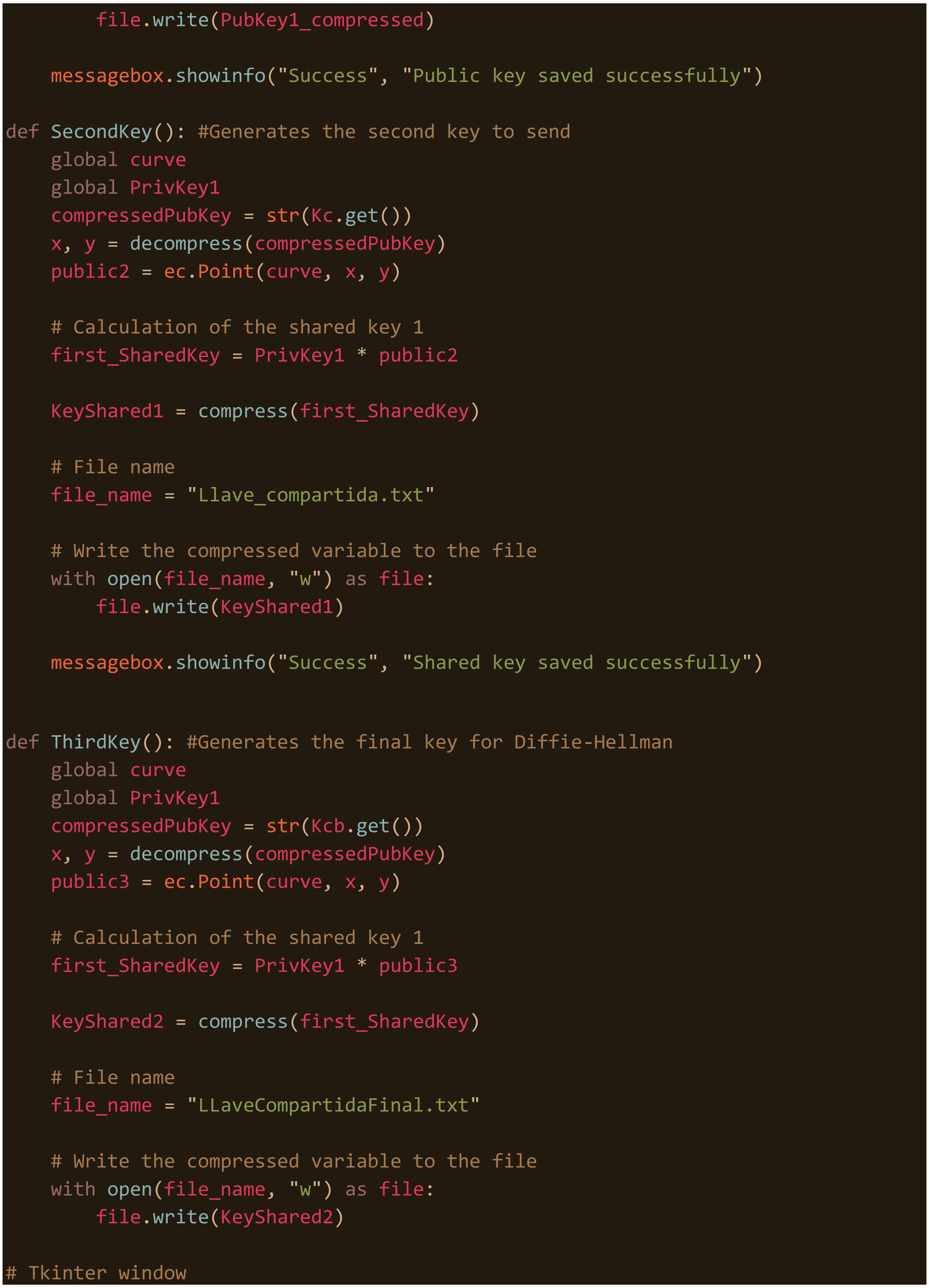


K1: edffd0194d06a04f1b35afa38b5229a45a35b5cfcb67f3d710

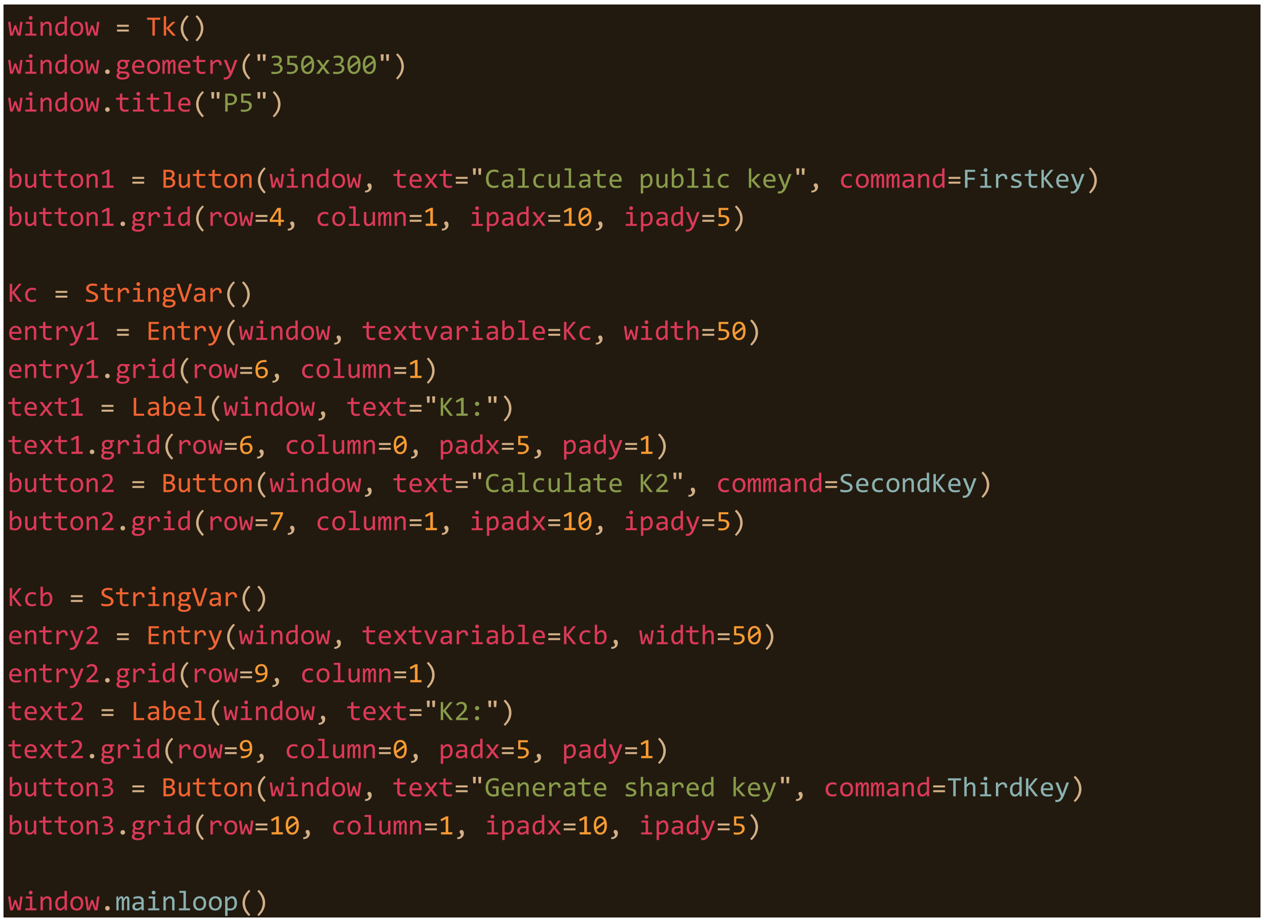
K2: b8b6dd75d0b04b070fa7e20e3d1ceb758d0a8903aa2baf9e

Codigo fuente

```python
from tkinter import *
from tkinter import filedialog
from tkinter import messagebox
from tinyec import registry
import secrets
from tinyec import ec

global PrivKey1
global PubKey1
global curve

def compress(pubKey):
    x_hex = hex(pubKey.x)[2:]
    y_hex = hex(pubKey.y)[2:]
    compressed = x_hex + y_hex
    return compressed

def decompress(compressedPubKey):
    x = int(compressedPubKey[:128], 16)
    y = int(compressedPubKey[128:], 16)
    return x, y

def FirstKey(): #Generates public and private keys
    global PrivKey1
    global PubKey1
    global curve
    curve = registry.get_curve('brainpoolP512r1')

    # Generation of private and public key of the first user
    PrivKey1 = secrets.randbelow(curve.field.n)
    PubKey1 = PrivKey1 * curve.g

    # Ensure the public key is compressed correctly
    PubKey1_compressed = compress(PubKey1)
    while len(PubKey1_compressed) != 256:
        PrivKey1 = secrets.randbelow(curve.field.n)
        PubKey1 = PrivKey1 * curve.g
        PubKey1_compressed = compress(PubKey1)

    # File name
    file_name = "Llave_publica.txt"

    # Write the compressed variable to the file
    with open(file_name, "w") as file:
```



```python
        file.write(PubKey1_compressed)

    messagebox.showinfo("Success", "Public key saved successfully")

def SecondKey(): #Generates the second key to send
    global curve
    global PrivKey1
    compressedPubKey = str(Kc.get())
    x, y = decompress(compressedPubKey)
    public2 = ec.Point(curve, x, y)

    # Calculation of the shared key 1
    first_SharedKey = PrivKey1 * public2

    KeyShared1 = compress(first_SharedKey)

    # File name
    file_name = "Llave_compartida.txt"

    # Write the compressed variable to the file
    with open(file_name, "w") as file:
        file.write(KeyShared1)

    messagebox.showinfo("Success", "Shared key saved successfully")


def ThirdKey(): #Generates the final key for Diffie-Hellman
    global curve
    global PrivKey1
    compressedPubKey = str(Kcb.get())
    x, y = decompress(compressedPubKey)
    public3 = ec.Point(curve, x, y)

    # Calculation of the shared key 1
    first_SharedKey = PrivKey1 * public3

    KeyShared2 = compress(first_SharedKey)

    # File name
    file_name = "LLaveCompartidaFinal.txt"

    # Write the compressed variable to the file
    with open(file_name, "w") as file:
        file.write(KeyShared2)

# Tkinter window
```



```
window = Tk()
window.geometry("350x300")
window.title("P5")

button1 = Button(window, text="Calculate public key", command=FirstKey)
button1.grid(row=4, column=1, ipadx=10, ipady=5)

Kc = StringVar()
entry1 = Entry(window, textvariable=Kc, width=50)
entry1.grid(row=6, column=1)
text1 = Label(window, text="K1:")
text1.grid(row=6, column=0, padx=5, pady=1)
button2 = Button(window, text="Calculate K2", command=SecondKey)
button2.grid(row=7, column=1, ipadx=10, ipady=5)

Kcb = StringVar()
entry2 = Entry(window, textvariable=Kcb, width=50)
entry2.grid(row=9, column=1)
text2 = Label(window, text="K2:")
text2.grid(row=9, column=0, padx=5, pady=1)
button3 = Button(window, text="Generate shared key", command=ThirdKey)
button3.grid(row=10, column=1, ipadx=10, ipady=5)

window.mainloop()
```

Conclusión

En conclusión, esta implementación de intercambio de claves Diffie-Hellman mediante criptografía de curva elíptica ofrece una forma segura y eficiente de establecer una clave compartida entre dos partes sin necesidad de intercambiar la clave directamente. La utilización de curvas elípticas proporciona una mayor seguridad y eficiencia en comparación con otros métodos de intercambio de claves. Además, la retroalimentación al usuario a través de mensajes informativos contribuye a una experiencia de usuario más satisfactoria. En resumen, esta implementación brinda una solución versátil y sólida para el intercambio seguro de claves en aplicaciones que requieren comunicaciones seguras y confiables.