НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ УКРАЇНИ
“КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ” ФІЗИКО-ТЕХНІЧНИЙ ІНСТИТУТ

Лабораторна робота 1

«Методи реалізації криптографічних механізмів»

Виконали

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Тема: “Вибір та реалізація базових фреймворків та бібліотек”.
Мета роботи: «Вибір базових бібліотек/сервісів для подальшої реалізації криптосистеми».

Завдання на лабораторну роботу
Для другого типу лабораторних робіт – вибір бібліотеки реалізації основних криптографічних примітивів з точки зору їх ефективності за часом та пам’яттю для різних програмних платформ.
Підгрупа 2А. Порівняння бібліотек OpenSSL, crypto++, CryptoLib, PyCrypto для розробки гібрідної криптосистеми під Windows платформу.

Оформлення результатів роботи. Опис функції бібліотеки реалізації основних криптографічних примітивів обраної бібліотеки, з описом алгоритму, вхідних та вихідних даних, кодів повернення. Контрольний приклад роботи з функціями. Обґрунтування вибору бібліотеки.

Ми обрали OpenSSL та PyCrypto бібліотеки для виконання криптографічних операцій і порівняння швидкості та виділеної пам’яті.

OpenSSL — це бібліотека програмного забезпечення для програм, які забезпечують безпечний зв’язок через комп’ютерні мережі від прослуховування або потребують ідентифікації сторони на іншому кінці. Основна бібліотека, написана на мові програмування C, реалізує основні криптографічні функції та надає різноманітні службові функції. Доступні обгортки, які дозволяють використовувати бібліотеку OpenSSL різними комп’ютерними мовами.

Код програми:
```
import os
import cpuinfo

def main():
    print ("Used libs: os, cpuinfo")
    print ("CPU where tests will be performed: " +
cpuinfo.get_cpu_info()['brand_raw'] + "\n")

    for i in range(1000, 10500, 500):
        print ("Testing rsa2048, sha256 and aes-256-cbc with random " + str(i) + "
bytes.")
        os.system("openssl speed -bytes " + str(i) + " rsa2048 sha256 aes-256-cbc")
        print ("\n")


if __name__ == '__main__':
    main()
```

Результати:

```
Testing rsa2048, sha256 and aes-256-cbc with random 1000 bytes.
Doing sha256 for 3s on 1000 size blocks: 5776546 sha256's in 2.99s
Doing aes-256-cbc for 3s on 1000 size blocks: 3281483 aes-256-cbc's in 2.92s
Doing 2048 bits private rsa's for 10s: 18071 2048 bits private RSA's in 9.98s
Doing 2048 bits public rsa's for 10s: 719713 2048 bits public RSA's in 9.97s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           1000 bytes
sha256         1931955.18k
aes-256-cbc    1123795.55k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000552s 0.000014s   1810.7  72187.9


Testing rsa2048, sha256 and aes-256-cbc with random 1500 bytes.
Doing sha256 for 3s on 1500 size blocks: 4158691 sha256's in 2.99s
Doing aes-256-cbc for 3s on 1500 size blocks: 2253375 aes-256-cbc's in 3.00s
Doing 2048 bits private rsa's for 10s: 17960 2048 bits private RSA's in 9.96s
Doing 2048 bits public rsa's for 10s: 712959 2048 bits public RSA's in 9.94s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           1500 bytes
sha256         2086299.83k
aes-256-cbc    1126687.50k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000555s 0.000014s   1803.2  71726.3

Testing rsa2048, sha256 and aes-256-cbc with random 2000 bytes.
Doing sha256 for 3s on 2000 size blocks: 3186608 sha256's in 2.98s
Doing aes-256-cbc for 3s on 2000 size blocks: 1684772 aes-256-cbc's in 2.99s
Doing 2048 bits private rsa's for 10s: 17994 2048 bits private RSA's in 9.96s
Doing 2048 bits public rsa's for 10s: 706545 2048 bits public RSA's in 9.91s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           2000 bytes
sha256         2138663.09k
aes-256-cbc    1126937.79k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000554s 0.000014s   1806.6  71296.2


Testing rsa2048, sha256 and aes-256-cbc with random 2500 bytes.
Doing sha256 for 3s on 2500 size blocks: 2631246 sha256's in 2.99s
Doing aes-256-cbc for 3s on 2500 size blocks: 1350889 aes-256-cbc's in 2.99s
Doing 2048 bits private rsa's for 10s: 18118 2048 bits private RSA's in 9.98s
Doing 2048 bits public rsa's for 10s: 723610 2048 bits public RSA's in 9.99s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           2500 bytes
sha256         2200038.46k
aes-256-cbc    1129505.85k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000551s 0.000014s   1815.4  72433.4
```

```
Testing rsa2048, sha256 and aes-256-cbc with random 3000 bytes.
Doing sha256 for 3s on 3000 size blocks: 2230436 sha256's in 2.99s
Doing aes-256-cbc for 3s on 3000 size blocks: 1121939 aes-256-cbc's in 2.99s
Doing 2048 bits private rsa's for 10s: 18051 2048 bits private RSA's in 9.96s
Doing 2048 bits public rsa's for 10s: 702778 2048 bits public RSA's in 9.81s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           3000 bytes
sha256         2237895.65k
aes-256-cbc    1125691.30k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000552s 0.000014s   1812.3  71638.9


Testing rsa2048, sha256 and aes-256-cbc with random 3500 bytes.
Doing sha256 for 3s on 3500 size blocks: 1918844 sha256's in 2.96s
Doing aes-256-cbc for 3s on 3500 size blocks: 958386 aes-256-cbc's in 2.98s
Doing 2048 bits private rsa's for 10s: 17949 2048 bits private RSA's in 9.94s
Doing 2048 bits public rsa's for 10s: 718300 2048 bits public RSA's in 9.96s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           3500 bytes
sha256         2268903.38k
aes-256-cbc    1125621.14k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000554s 0.000014s   1805.7  72118.5

Testing rsa2048, sha256 and aes-256-cbc with random 4000 bytes.
Doing sha256 for 3s on 4000 size blocks: 1713677 sha256's in 2.98s
Doing aes-256-cbc for 3s on 4000 size blocks: 813635 aes-256-cbc's in 2.93s
Doing 2048 bits private rsa's for 10s: 17441 2048 bits private RSA's in 9.80s
Doing 2048 bits public rsa's for 10s: 705996 2048 bits public RSA's in 9.87s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           4000 bytes
sha256         2300237.58k
aes-256-cbc    1110764.51k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000562s 0.000014s   1779.7  71529.5


Testing rsa2048, sha256 and aes-256-cbc with random 4500 bytes.
Doing sha256 for 3s on 4500 size blocks: 1530570 sha256's in 2.99s
Doing aes-256-cbc for 3s on 4500 size blocks: 741698 aes-256-cbc's in 2.98s
Doing 2048 bits private rsa's for 10s: 17591 2048 bits private RSA's in 9.86s
Doing 2048 bits public rsa's for 10s: 714533 2048 bits public RSA's in 9.94s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           4500 bytes
sha256         2303533.44k
aes-256-cbc    1120013.76k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000561s 0.000014s   1784.1  71884.6
```

```
Testing rsa2048, sha256 and aes-256-cbc with random 5000 bytes.
Doing sha256 for 3s on 5000 size blocks: 1379665 sha256's in 2.98s
Doing aes-256-cbc for 3s on 5000 size blocks: 663694 aes-256-cbc's in 2.98s
Doing 2048 bits private rsa's for 10s: 17650 2048 bits private RSA's in 9.90s
Doing 2048 bits public rsa's for 10s: 701461 2048 bits public RSA's in 9.87s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           5000 bytes
sha256         2314874.16k
aes-256-cbc    1113580.54k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000561s 0.000014s   1782.8  71070.0


Testing rsa2048, sha256 and aes-256-cbc with random 5500 bytes.
Doing sha256 for 3s on 5500 size blocks: 1239393 sha256's in 2.96s
Doing aes-256-cbc for 3s on 5500 size blocks: 601538 aes-256-cbc's in 2.97s
Doing 2048 bits private rsa's for 10s: 17735 2048 bits private RSA's in 9.90s
Doing 2048 bits public rsa's for 10s: 710983 2048 bits public RSA's in 9.91s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           5500 bytes
sha256         2302926.18k
aes-256-cbc    1113959.26k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000558s 0.000014s   1791.4  71744.0

Testing rsa2048, sha256 and aes-256-cbc with random 6000 bytes.
Doing sha256 for 3s on 6000 size blocks: 1157265 sha256's in 2.97s
Doing aes-256-cbc for 3s on 6000 size blocks: 559602 aes-256-cbc's in 2.99s
Doing 2048 bits private rsa's for 10s: 17718 2048 bits private RSA's in 9.89s
Doing 2048 bits public rsa's for 10s: 713568 2048 bits public RSA's in 9.95s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           6000 bytes
sha256         2337909.09k
aes-256-cbc    1122947.16k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000558s 0.000014s   1791.5  71715.4


Testing rsa2048, sha256 and aes-256-cbc with random 6500 bytes.
Doing sha256 for 3s on 6500 size blocks: 1082094 sha256's in 2.99s
Doing aes-256-cbc for 3s on 6500 size blocks: 516857 aes-256-cbc's in 2.99s
Doing 2048 bits private rsa's for 10s: 17911 2048 bits private RSA's in 9.94s
Doing 2048 bits public rsa's for 10s: 714193 2048 bits public RSA's in 9.93s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           6500 bytes
sha256         2352378.26k
aes-256-cbc    1123602.17k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000555s 0.000014s   1801.9  71922.8
```

```
Testing rsa2048, sha256 and aes-256-cbc with random 7000 bytes.
Doing sha256 for 3s on 7000 size blocks: 1007641 sha256's in 2.99s
Doing aes-256-cbc for 3s on 7000 size blocks: 477311 aes-256-cbc's in 2.97s
Doing 2048 bits private rsa's for 10s: 17867 2048 bits private RSA's in 9.93s
Doing 2048 bits public rsa's for 10s: 713239 2048 bits public RSA's in 9.94s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           7000 bytes
sha256         2359025.75k
aes-256-cbc    1124975.42k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000556s 0.000014s   1799.3  71754.4


Testing rsa2048, sha256 and aes-256-cbc with random 7500 bytes.
Doing sha256 for 3s on 7500 size blocks: 944375 sha256's in 2.99s
Doing aes-256-cbc for 3s on 7500 size blocks: 431173 aes-256-cbc's in 2.92s
Doing 2048 bits private rsa's for 10s: 17733 2048 bits private RSA's in 9.91s
Doing 2048 bits public rsa's for 10s: 720291 2048 bits public RSA's in 9.98s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           7500 bytes
sha256         2368833.61k
aes-256-cbc    1107464.90k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000559s 0.000014s   1789.4  72173.4
```

```
Testing rsa2048, sha256 and aes-256-cbc with random 8000 bytes.
Doing sha256 for 3s on 8000 size blocks: 888622 sha256's in 2.99s
Doing aes-256-cbc for 3s on 8000 size blocks: 422096 aes-256-cbc's in 2.99s
Doing 2048 bits private rsa's for 10s: 18035 2048 bits private RSA's in 9.98s
Doing 2048 bits public rsa's for 10s: 720502 2048 bits public RSA's in 9.97s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           8000 bytes
sha256         2377583.95k
aes-256-cbc    1129353.85k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000553s 0.000014s   1807.1  72267.0


Testing rsa2048, sha256 and aes-256-cbc with random 8500 bytes.
Doing sha256 for 3s on 8500 size blocks: 843694 sha256's in 2.99s
Doing aes-256-cbc for 3s on 8500 size blocks: 397522 aes-256-cbc's in 3.00s
Doing 2048 bits private rsa's for 10s: 18045 2048 bits private RSA's in 9.98s
Doing 2048 bits public rsa's for 10s: 718049 2048 bits public RSA's in 9.96s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           8500 bytes
sha256         2398461.20k
aes-256-cbc    1126312.33k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000553s 0.000014s   1808.1  72093.3

Testing rsa2048, sha256 and aes-256-cbc with random 9000 bytes.
Doing sha256 for 3s on 9000 size blocks: 796473 sha256's in 2.99s
Doing aes-256-cbc for 3s on 9000 size blocks: 377628 aes-256-cbc's in 2.99s
Doing 2048 bits private rsa's for 10s: 18072 2048 bits private RSA's in 9.98s
Doing 2048 bits public rsa's for 10s: 719743 2048 bits public RSA's in 9.98s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           9000 bytes
sha256         2397410.37k
aes-256-cbc    1136672.91k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000552s 0.000014s   1810.8  72118.5


Testing rsa2048, sha256 and aes-256-cbc with random 9500 bytes.
Doing sha256 for 3s on 9500 size blocks: 753287 sha256's in 2.99s
Doing aes-256-cbc for 3s on 9500 size blocks: 357226 aes-256-cbc's in 2.99s
Doing 2048 bits private rsa's for 10s: 18035 2048 bits private RSA's in 9.96s
Doing 2048 bits public rsa's for 10s: 717306 2048 bits public RSA's in 9.97s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type           9500 bytes
sha256         2393386.79k
aes-256-cbc    1134999.00k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000552s 0.000014s   1810.7  71946.4


Testing rsa2048, sha256 and aes-256-cbc with random 10000 bytes.
Doing sha256 for 3s on 10000 size blocks: 716574 sha256's in 2.99s
Doing aes-256-cbc for 3s on 10000 size blocks: 338570 aes-256-cbc's in 3.00s
Doing 2048 bits private rsa's for 10s: 18072 2048 bits private RSA's in 9.98s
Doing 2048 bits public rsa's for 10s: 720306 2048 bits public RSA's in 9.98s
version: 3.0.7
built on: Tue Nov  1 14:14:36 2022 UTC
options: bn(64,64)
compiler: clang -fPIC -arch arm64 -O3 -Wall -DL_ENDIAN -DOPENSSL_PIC -D_REENTRANT -DOPENSSL_BUILDING_OPENSSL -DNDEBUG
CPUINFO: OPENSSL_armcap=0x7d
The 'numbers' are in 1000s of bytes per second processed.
type          10000 bytes
sha256         2396568.56k
aes-256-cbc    1128566.67k
                  sign    verify    sign/s verify/s
rsa 2048 bits 0.000552s 0.000014s   1810.8  72174.9
```

Бачимо, що в середньому хешування за допомогою sha256 і шифрування за допомогою aes-256-cbc займає 3 секунди і не збільшується лінійно чи експоненційно в залежності від довжини вхідних даних. Підпис і верифікація за допомогою RSA 2048 займає 0.552

ms і 0.014 ms відповідно і не збільшується лінійно чи експоненційно в залежності від довжини вхідних даних.

PyCryptodome — це самодостатній пакет низькорівневих криптографічних примітивів на Python.
PyCryptodome не є оболонкою для окремої бібліотеки C, як OpenSSL. Максимально можливою мірою алгоритми реалізовані на чистому Python. Лише фрагменти, які надзвичайно критичні для продуктивності (наприклад, блокові шифри), реалізуються як розширення C.

Код програми:

```
import cpuinfo
import time
import random
import matplotlib.pyplot as plt
from memory_profiler import profile
from Crypto.Hash import SHA256
from Crypto.Cipher import AES, PKCS1_OAEP
from Crypto.PublicKey import RSA
from Crypto.Util.Padding import pad, unpad
from Crypto.Signature import pkcs1_15

@profile
def perform_sha256_tests():
    print ("Performing SHA-256 tests:")

    data = []
    hash_time = []

    sha256_instance = SHA256.new(b"CopyRights Measures")

    for i in range(1000, 10500, 500):
        data_to_hash = random.randbytes(i)

        start_time = time.time()
        sha256_hash = sha256_instance.update(data_to_hash)
        end_time = time.time()

        time_spent = (end_time - start_time) * 10**3

        data.append(i)
        hash_time.append(time_spent)

    print ("Array sizes of data tested (in bytes): " + str(data))
    print ("Hash times (ms): " + str(hash_time))

    print ("Drawing image...")
    plt.title("SHA-256 Hashing times compared to the Data Length")
    plt.xlabel("Data Length (bytes):")
    plt.ylabel("Time spent (ms):")
    plt.plot(data, hash_time)
```

```
    plt.show()

@profile
def perform_aes_256_cbc_tests():
    print ("Performing AES-256-CBC tests:")

    print ("Testing encryption...")

    key = random.randbytes(32)
    iv = random.randbytes(16)

    print ("Generated key: " + str(key))
    print ("Generated IV: " + str(iv))

    aes_instance = AES.new(key, AES.MODE_CBC, iv)
    aes_instance.encrypt(pad(b"CopyRight Measures", AES.block_size))

    data = []
    encrypted_data = []
    encryption_time = []

    for i in range(1000, 10500, 500):
        data_to_encrypt = random.randbytes(i)

        start_time = time.time()
        encrypted = aes_instance.encrypt(pad(data_to_encrypt, AES.block_size))
        end_time = time.time()

        time_spent = (end_time - start_time) * 10**3

        data.append(i)
        encrypted_data.append(encrypted)
        encryption_time.append(time_spent)

    print ("Array sizes of data tested (in bytes): " + str(data))
    print ("Encryption times (ms): " + str(encryption_time))

    print ("Drawing image...")
    plt.title("AES-256-CBC Encryption times compared to Data Length")
    plt.xlabel("Data Length (bytes):")
    plt.ylabel("Time spent (ms):")
    plt.plot(data, encryption_time)
    plt.show()

    print ("Testing decryption...")

    aes_instance = AES.new(key, AES.MODE_CBC, iv)
    aes_instance.decrypt(pad(b"CopyRight Measures", AES.block_size))

    decryption_time = []
```

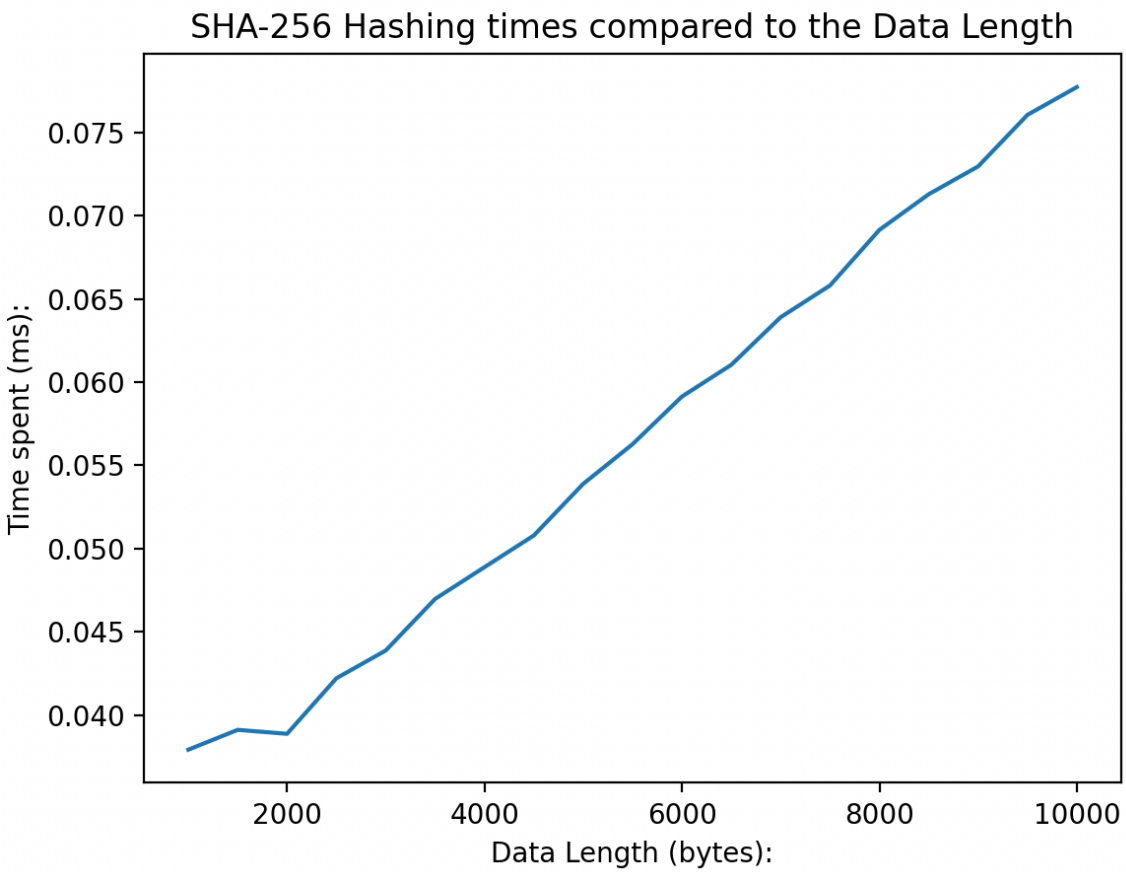
```
    for i in encrypted_data:
        start_time = time.time()
        decrypted_data = unpad(aes_instance.decrypt(i), AES.block_size)
        end_time = time.time()

        time_spent = (end_time - start_time)* 10**3

        decryption_time.append(time_spent)

    print ("Decryption times (ms): " + str(decryption_time))

    print ("Drawing image...")
    plt.title("AES-256-CBC Decryption times compared to Data Length")
    plt.xlabel("Data Length (bytes):")
    plt.ylabel("Time spent (ms):")
    plt.plot(data, decryption_time)
    plt.show()

@profile
def perform_rsa_2048_tests():
     print ("Performing RSA-2048 tests:")

     print ("Testing encryption...")

     rsa_keys = RSA.generate(2048)

     private_key = RSA.import_key(rsa_keys.export_key())
     public_key = RSA.import_key(rsa_keys.publickey().export_key())

     print ("Private Key: " + str(rsa_keys.export_key()))
     print ("Public Key: " + str(rsa_keys.publickey().export_key()))

     rsa_instance = PKCS1_OAEP.new(public_key)

     rsa_instance.encrypt(b"CopyRight Measures")

     data = []
     encrypted_data = []
     encryption_time = []

     for i in range(1, 191):
        data_to_encrypt = random.randbytes(i)

        start_time = time.time()
        encrypted = rsa_instance.encrypt(data_to_encrypt)
        end_time = time.time()

        time_spent = (end_time - start_time) * 10**3

        data.append(i)
        encrypted_data.append(encrypted)
```

```
    encryption_time.append(time_spent)

print ("Array sizes of data tested (in bytes): " + str(data))
print ("Encryption times (ms): " + str(encryption_time))

print ("Drawing image...")
plt.title("RSA-2048 Encryption times compared to Data Length")
plt.xlabel("Data Length (bytes):")
plt.ylabel("Time spent (ms):")
plt.plot(data, encryption_time)
plt.show()

print ("Testing decryption...")

rsa_instance = PKCS1_OAEP.new(private_key)

rsa_instance.decrypt(encrypted_data[0])

decryption_time = []

for i in encrypted_data:
    start_time = time.time()
    decrypted = rsa_instance.decrypt(i)
    end_time = time.time()

    time_spent = (end_time - start_time) * 10**3

    decryption_time.append(time_spent)

print ("Array sizes of data tested (in bytes): " + str(data))
print ("Decryption times (ms): " + str(decryption_time))

print ("Drawing image...")
plt.title("RSA-2048 Decryption times compared to Data Length")
plt.xlabel("Data Length (bytes):")
plt.ylabel("Time spent (ms):")
plt.plot(data, decryption_time)
plt.show()

print ("Testing signing...")

signature_instance = pkcs1_15.new(private_key)
sha256_instance = SHA256.new(b"CopyRight Measures")

signature_instance.sign(sha256_instance)

data = []
signed_messages = []
singing_time = []

for i in range(1000, 10500, 500):
```

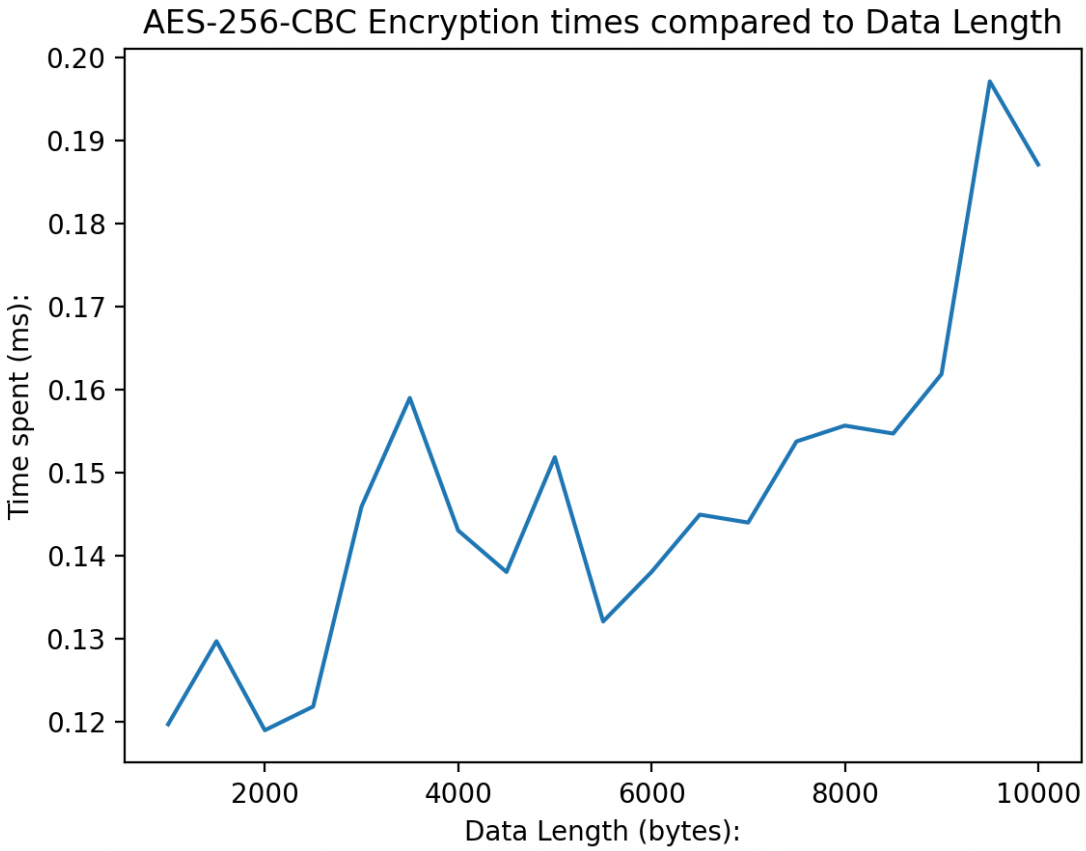
```
        message_to_sign = random.randbytes(i)

        start_time = time.time()
        sha256_instance.update(message_to_sign)
        signed_message = signature_instance.sign(sha256_instance)
        end_time = time.time()

        time_spent = (end_time - start_time) * 10**3

        data.append(i)
        signed_messages.append({ "message": message_to_sign, "signature":
signed_message })
        singing_time.append(time_spent)

    print ("Array sizes of data tested (in bytes): " + str(data))
    print ("Signing times (ms): " + str(singing_time))

    print ("Drawing image...")
    plt.title("RSA-2048 Signing times compared to Data Length")
    plt.xlabel("Data Length (bytes):")
    plt.ylabel("Time spent (ms):")
    plt.plot(data, singing_time)
    plt.show()

    print ("Testing verification...")

    signature_instance = pkcs1_15.new(public_key)
    sha256_instance = SHA256.new(b"CopyRight Measures")

    is_valid = []
    verification_time = []

    for i in signed_messages:
        message = i["message"]
        signature = i["signature"]

        start_time = time.time()
        sha256_instance.update(message)
        valid_signature = sha256_instance

        try:
            signature_instance.verify(valid_signature, signature)
            is_valid.append(True)
        except (ValueError, TypeError):
            is_valid.append(False)

        end_time = time.time()

        time_spent = (end_time - start_time) * 10**3

        verification_time.append(time_spent)
```

```
        print ("Array sizes of data tested (in bytes): " + str(data))
        print ("Is Valid signature (bool): " + str(is_valid))
        print ("Verification times (ms): " + str(verification_time))

        print ("Drawing image...")
        plt.title("RSA-2048 Verification times compared to Data Length")
        plt.xlabel("Data Length (bytes):")
        plt.ylabel("Time spent (ms):")
        plt.plot(data, verification_time)
        plt.show()

def main():
    print ("Used libs: cpuinfo, time, random, pyplot, memory_profiler,
PyCryptodome")
    print ("CPU where tests will be performed: " +
cpuinfo.get_cpu_info()['brand_raw'] + "\n")

    # sha-256
    perform_sha256_tests()
    #

    # aes-256-cbc
    perform_aes_256_cbc_tests()
    #

    # rsa-2048
    perform_rsa_2048_tests()
    #

if __name__ == '__main__':
    main()
```

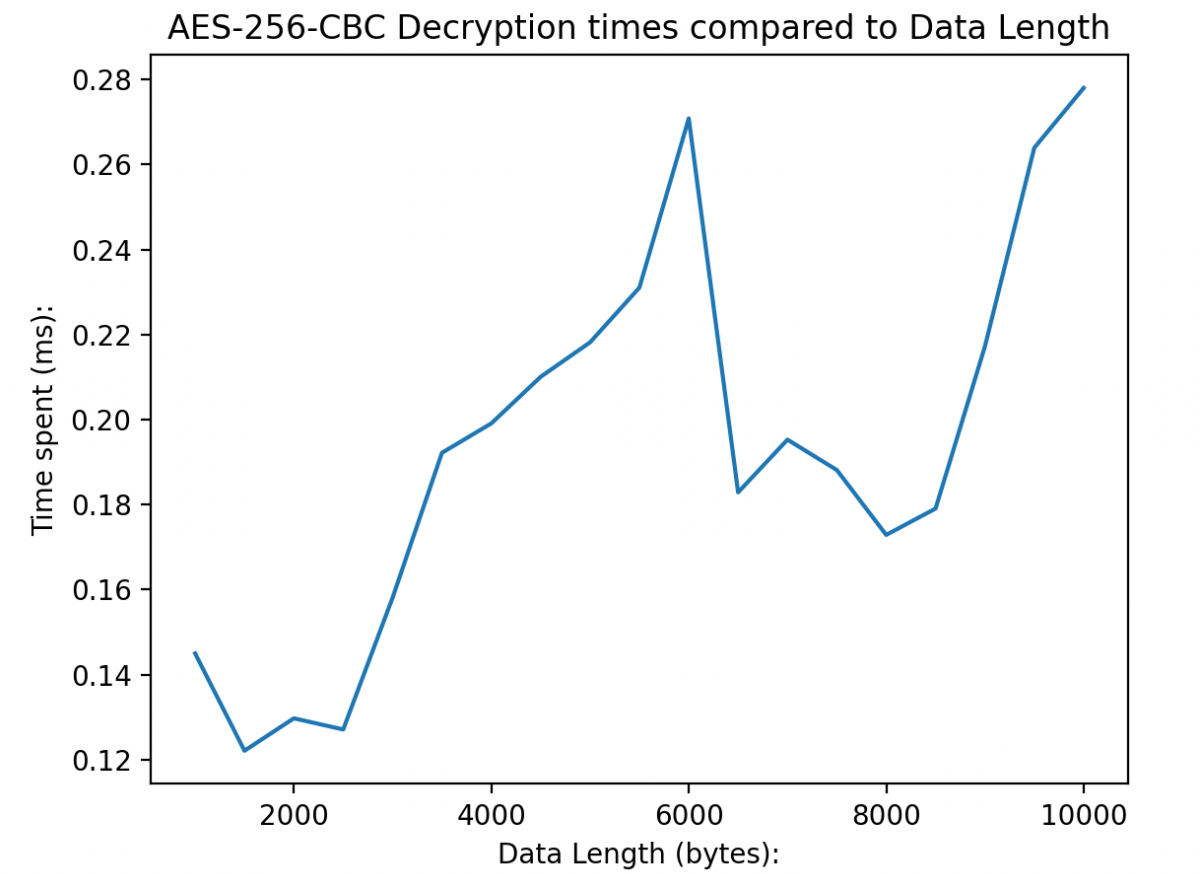
Резултати:



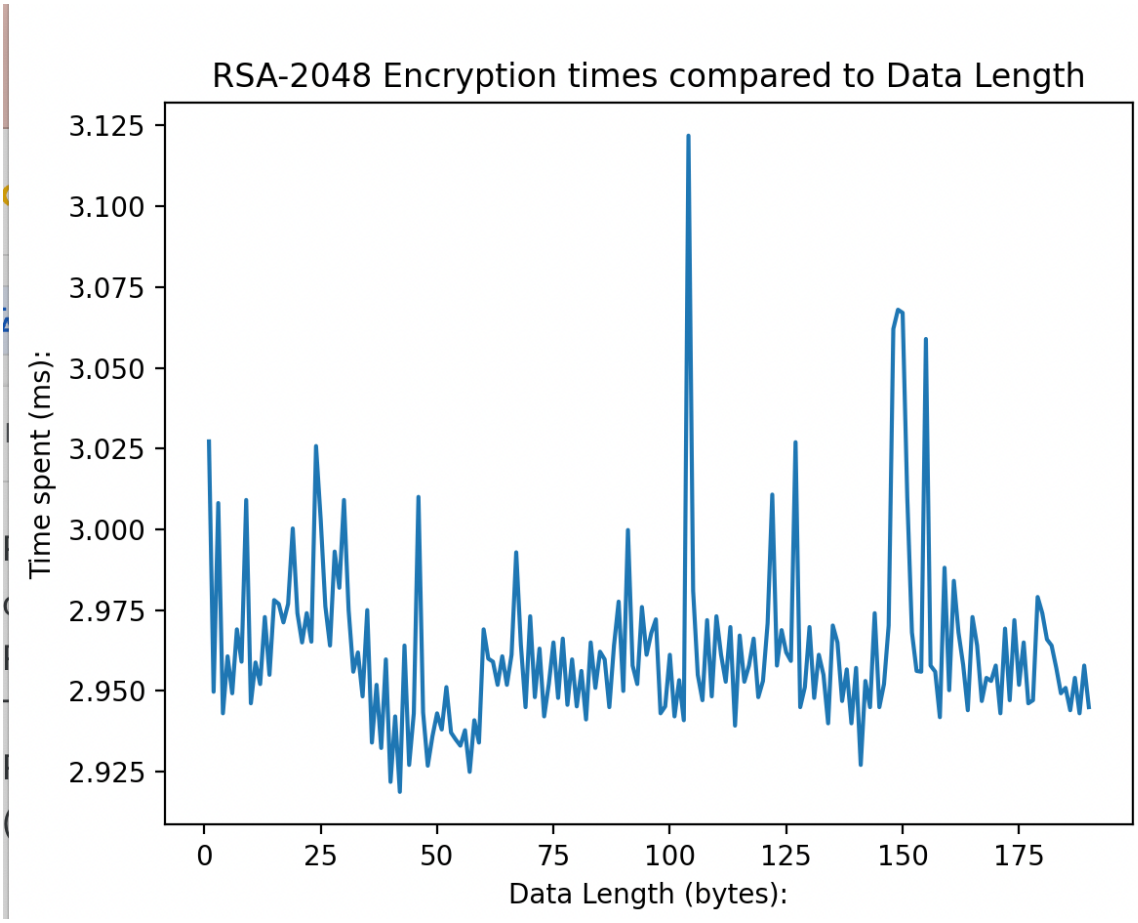
Хешування за допомогою sha256 займає від 0.040 ms до 0.075 ms для вхідних даних від 1000 до 1000 байтів. Час збільшується лінійно.



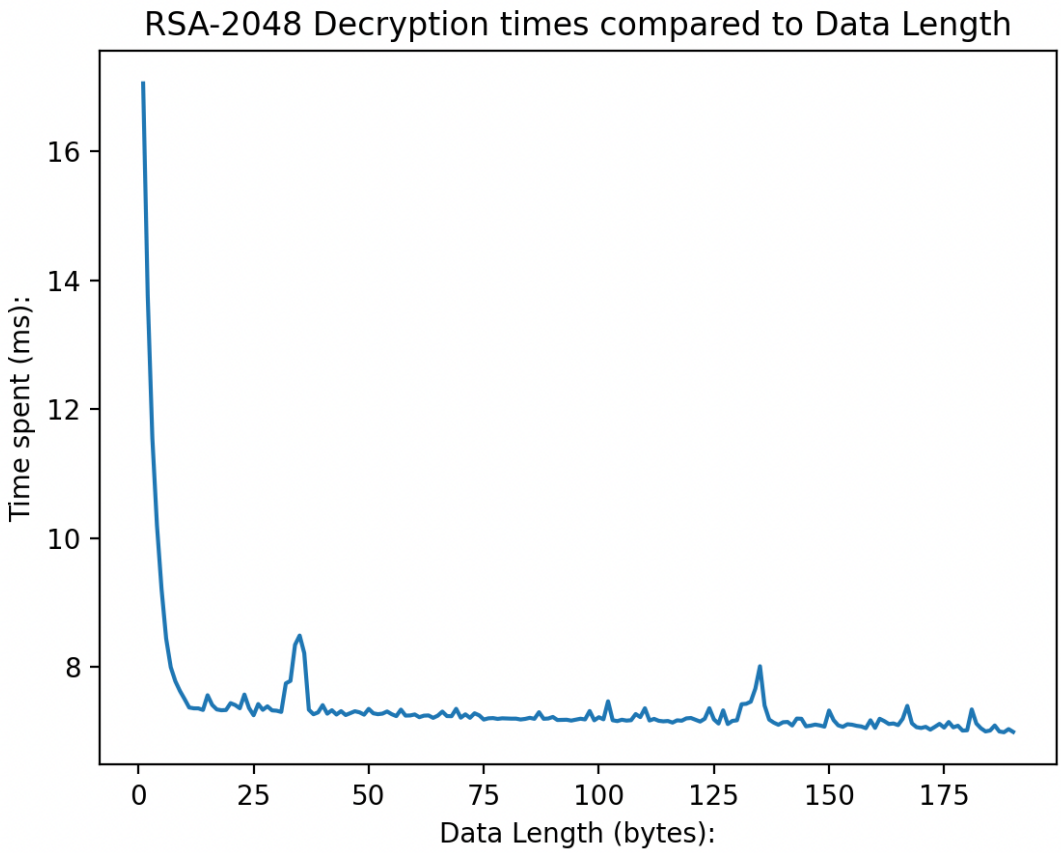
Шифрування за допомогою aes-256-cbc займає від 0.12 ms до 0.20 ms для вхідних даних від 1000 до 1000 байтів. Час збільшується нерівномірно, але можна вивести усереднену лінію.



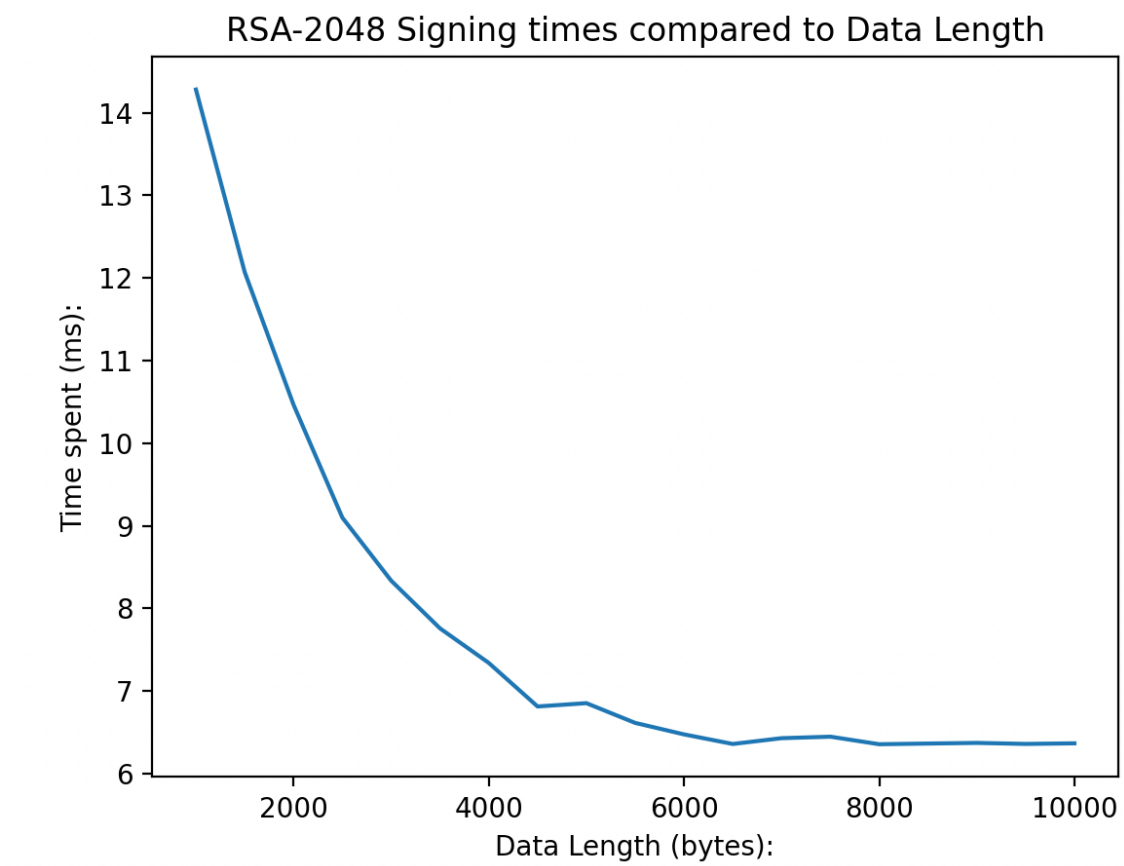
Дешифрування за допомогою aes-256-cbc займає від 0.12 ms до 0.28 ms для вхідних даних від 1000 до 1000 байтів. Час збільшується нерівномірно, але можна вивести усереднену лінію.



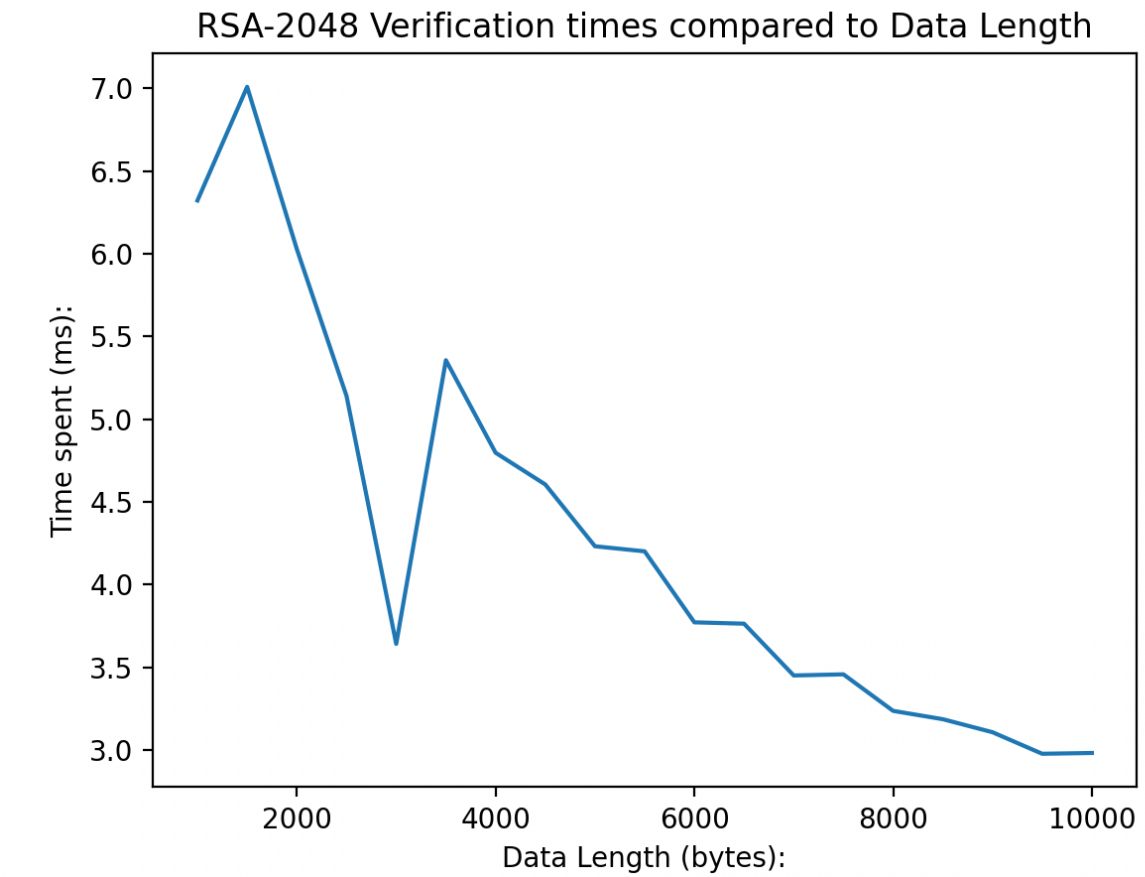
Шифрування за допомогою rsa-2048 займає від 2.925 ms до 3.125 ms для вхідних даних від 1 до 190 байтів. Графік нагадує синусоїду, але можна вивести усереднену лінію, яка вкаже, що час є однаковим і не залежить від розміру даних, скоріш від самих даних.



Дешифрування за допомогою rsa-2048 займає від 4 ms до 16 ms для вхідних даних від 1 до 190 байтів. Графік є спадаючим, спочатку він схожий на експоненту, а далі затихає лінійно.



Підпис за допомогою rsa-2048 займає від 6 ms до 14 ms для вхідних даних від 1000 до 10000 байтів. Графік є спадаючим і схожим на експоненту.



Верифікація підпису за допомогою rsa-2048 займає від 3 ms до 7 ms для вхідних даних від 1000 до 10000 байтів. Графік є спадаючим і можна провести усереднену лінію, яка вкаже на лінійність графіку.

Тестуючи виділення пам'яті, ми не помітили великих навантажень. Ми отримали 0.2 mb для шифрування aes та 0.1 mb для шифрування rsa. Ми вважаємо, що інші операції зайняли менше 0.1 mb пам'яті.

```
Performing SHA-256 tests:
Array sizes of data tested (in bytes): [1000, 1500, 2000, 2500, 3000, 3500, 4000,
4500, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000, 9500, 10000]
Hash times (ms): [0.03790855407714844, 0.03910064697265625, 0.03886222839355469,
0.04220008850097656, 0.0438690185546875, 0.04696846008300781, 0.04887580871582031,
0.05078315734863281, 0.053882598876953125, 0.05626678466796875, 0.0591278076171875,
0.06103515625, 0.06389617919921875, 0.06580352783203125, 0.06914138793945312,
0.07128715515136719, 0.07295608520507812, 0.07605552673339844, 0.07772445678710938]
Drawing image...
Filename: /Users/viktoriia/Downloads/mrkm_lab1.py

Line #    Mem usage    Increment  Occurrences   Line Contents
=============================================================
    12     83.8 MiB     83.8 MiB           1   @profile
    13                                         def perform_sha256_tests():
    14     83.8 MiB      0.0 MiB           1       print ("Performing SHA-256
tests:")
```

```
    15
    16     83.8 MiB      0.0 MiB           1       data = []
    17     83.8 MiB      0.0 MiB           1       hash_time = []
    18
    19     83.8 MiB      0.0 MiB           1       sha256_instance =
SHA256.new(b"CopyRights Measures")
    20
    21     83.9 MiB      0.0 MiB          20       for i in range(1000, 10500,
500):
    22     83.9 MiB      0.0 MiB          19           data_to_hash =
random.randbytes(i)
    23
    24     83.9 MiB      0.0 MiB          19           start_time = time.time()
    25     83.9 MiB      0.0 MiB          19           sha256_hash =
sha256_instance.update(data_to_hash)
    26     83.9 MiB      0.0 MiB          19           end_time = time.time()
    27
    28     83.9 MiB      0.0 MiB          19           time_spent = (end_time -
start_time) * 10**3
    29
    30     83.9 MiB      0.0 MiB          19           data.append(i)
    31     83.9 MiB      0.0 MiB          19           hash_time.append(time_spent)
    32
    33     83.9 MiB      0.0 MiB           1       print ("Array sizes of data
tested (in bytes): " + str(data))
    34     83.9 MiB      0.0 MiB           1       print ("Hash times (ms): " +
str(hash_time))
    35
    36     83.9 MiB      0.0 MiB           1       print ("Drawing image...")
    37    104.6 MiB     20.7 MiB           1       plt.title("SHA-256 Hashing times
compared to the Data Length")
    38    104.6 MiB      0.0 MiB           1       plt.xlabel("Data Length
(bytes):")
    39    104.6 MiB      0.0 MiB           1       plt.ylabel("Time spent (ms):")
    40    104.7 MiB      0.0 MiB           1       plt.plot(data, hash_time)
    41    142.1 MiB     37.5 MiB           1       plt.show()


Performing AES-256-CBC tests:
Testing encryption...
Generated key:
b'\x05`^\xa2}\xab\xd8}DJ>\x1e\xa9\xb0\x08\xe7\x927=\x87\x85l\xf9\xe5\xffa\x8d\xc9Q\
x8e\xdc\x9b'
Generated IV: b']\xf6/#\xb2R\x1cr\x99\x99\xe2\xdc\xc26\xccN'
Array sizes of data tested (in bytes): [1000, 1500, 2000, 2500, 3000, 3500, 4000,
4500, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000, 9500, 10000]
Encryption times (ms): [0.11968612670898438, 0.12969970703125, 0.11897087097167969,
0.12183189392089844, 0.14591217041015625, 0.1590251922607422, 0.1430511474609375,
0.1380443572998047, 0.1518726348876953, 0.13208389282226562, 0.1380443572998047,
0.14495849609375, 0.14400482177734375, 0.1537799835205078, 0.1556873321533203,
0.15473365783691406, 0.16188621520996094, 0.1971721649169922, 0.18715858459472656]
```

```
Drawing image...
Testing decryption...
Decryption times (ms): [0.14495849609375, 0.1220703125, 0.12969970703125,
0.1270771026611328, 0.15807151794433594, 0.19216537475585938, 0.1990795135498047,
0.21004676818847656, 0.2181529998779297, 0.23102760314941406, 0.270843505859375,
0.18286705017089844, 0.1952648162841797, 0.1881122589111328, 0.1728534698486328,
0.17905235290527344, 0.21719932556152344, 0.2639293670654297, 0.2779960632324219]
Drawing image...
Filename: /Users/viktoriia/Downloads/mrkm_lab1.py

Line #    Mem usage    Increment  Occurrences   Line Contents
=============================================================
    43    142.1 MiB    142.1 MiB           1   @profile
    44                                         def perform_aes_256_cbc_tests():
    45    142.1 MiB      0.0 MiB           1       print ("Performing AES-256-CBC
tests:")
    46
    47    142.1 MiB      0.0 MiB           1       print ("Testing encryption...")
    48
    49    142.1 MiB      0.0 MiB           1       key = random.randbytes(32)
    50    142.1 MiB      0.0 MiB           1       iv = random.randbytes(16)
    51
    52    142.1 MiB      0.0 MiB           1       print ("Generated key: " +
str(key))
    53    142.1 MiB      0.0 MiB           1       print ("Generated IV: " +
str(iv))
    54
    55    142.1 MiB      0.0 MiB           1       aes_instance = AES.new(key,
AES.MODE_CBC, iv)
    56    142.2 MiB      0.0 MiB           1
aes_instance.encrypt(pad(b"CopyRight Measures", AES.block_size))
    57
    58    142.2 MiB      0.0 MiB           1       data = []
    59    142.2 MiB      0.0 MiB           1       encrypted_data = []
    60    142.2 MiB      0.0 MiB           1       encryption_time = []
    61
    62    142.4 MiB      0.0 MiB          20       for i in range(1000, 10500,
500):
    63    142.3 MiB      0.0 MiB          19           data_to_encrypt =
random.randbytes(i)
    64
    65    142.3 MiB      0.0 MiB          19           start_time = time.time()
    66    142.4 MiB      0.2 MiB          19           encrypted =
aes_instance.encrypt(pad(data_to_encrypt, AES.block_size))
    67    142.4 MiB      0.0 MiB          19           end_time = time.time()
    68
    69    142.4 MiB      0.0 MiB          19           time_spent = (end_time -
start_time) * 10**3
    70
    71    142.4 MiB      0.0 MiB          19           data.append(i)
```

```
    72    142.4 MiB      0.0 MiB          19
encrypted_data.append(encrypted)
    73    142.4 MiB      0.0 MiB          19
encryption_time.append(time_spent)
    74
    75    142.4 MiB      0.0 MiB           1       print ("Array sizes of data
tested (in bytes): " + str(data))
    76    142.4 MiB      0.0 MiB           1       print ("Encryption times (ms): "
+ str(encryption_time))
    77
    78    142.4 MiB      0.0 MiB           1       print ("Drawing image...")
    79    143.5 MiB      1.1 MiB           1       plt.title("AES-256-CBC
Encryption times compared to Data Length")
    80    143.5 MiB      0.0 MiB           1       plt.xlabel("Data Length
(bytes):")
    81    143.5 MiB      0.0 MiB           1       plt.ylabel("Time spent (ms):")
    82    143.5 MiB      0.0 MiB           1       plt.plot(data, encryption_time)
    83    164.9 MiB     21.4 MiB           1       plt.show()
    84
    85    164.9 MiB      0.0 MiB           1       print ("Testing decryption...")
    86
    87    164.9 MiB      0.0 MiB           1       aes_instance = AES.new(key,
AES.MODE_CBC, iv)
    88    164.9 MiB      0.0 MiB           1
aes_instance.decrypt(pad(b"CopyRight Measures", AES.block_size))
    89
    90    164.9 MiB      0.0 MiB           1       decryption_time = []
    91
    92    164.9 MiB      0.0 MiB          20       for i in encrypted_data:
    93    164.9 MiB      0.0 MiB          19           start_time = time.time()
    94    164.9 MiB      0.0 MiB          19           decrypted_data =
unpad(aes_instance.decrypt(i), AES.block_size)
    95    164.9 MiB      0.0 MiB          19           end_time = time.time()
    96
    97    164.9 MiB      0.0 MiB          19           time_spent = (end_time -
start_time)* 10**3
    98
    99    164.9 MiB      0.0 MiB          19
decryption_time.append(time_spent)
   100
   101    164.9 MiB      0.0 MiB           1       print ("Decryption times (ms): "
+ str(decryption_time))
   102
   103    164.9 MiB      0.0 MiB           1       print ("Drawing image...")
   104    165.9 MiB      1.0 MiB           1       plt.title("AES-256-CBC
Decryption times compared to Data Length")
   105    165.9 MiB      0.0 MiB           1       plt.xlabel("Data Length
(bytes):")
   106    165.9 MiB      0.0 MiB           1       plt.ylabel("Time spent (ms):")
   107    165.9 MiB      0.0 MiB           1       plt.plot(data, decryption_time)
   108    185.7 MiB     19.8 MiB           1       plt.show()
```

```
Performing RSA-2048 tests:
Testing encryption...
Private Key: b'-----BEGIN RSA PRIVATE KEY-----
\nMIIEogIBAAKCAQEAlZIGkqE+C2Kl7udTGyByztu8OKlkHy/lfJW+frF/5loSW5L5\nRfTmfra8nZ+NtA1
F27XaamXfKl/l2cZBlm9gluPb4LAj3fd6jp77qAadOERcPj6P\nCwkYtA9lSuHklgzRRnTN5kI+l6AzH3ah
PiZyHqSuhdrd7vXEhn9UYWkwdyEBfWIN\n+L6ySKer9wwRXkScFuR3DfWiOLaMTZDVYNRi490TTjWtdrwbg
NE3F4JowE2DgCVZ\nGV45qaMZz5VDP8aL9Fs4yrEDh2vxgY4mWsYmVF6IPLWWxb05PFCUz6PlHBIYV8bE\n
/EzGsIGpJedig7T+HYbJU0mS12sao7S4qzSFbQIDAQABAoIBACAzMMEOf4n58dkt\n6eFUKgNIoQvdw9VG/
XPF1R33Xp6b04ntaUbbQ2gSNScF+37AwMJdMylmxxWbUaOB\noAsf7T5uzZ5grUgTCEp+BZWV3vEHHoiz9R
2eFrhk/ByT5x86oS825EDnEAyai4cB\nhhMYOcdJEt10UgUo2edOsD7MY4exud7jytMMj5vKjbOv6foX+aS
w0Q8PfWfBIpyv\nfsTkq0vUgUpOWSYJO8X3CW/T4IkCXbKrHHgFdrwlBO7s28gVyAjAoEZYNDvAgcXU\nno
/wYwNuShdnfQsqtIUp9DGiASmwcxTMuAz3WdoroaCXjIBxnPJLvNLX6bLFpu3T\n+wN9uU0CgYEAtXHnYQ/
/crGrAhEmrquGutyGPUzrRR6jf0chTSt0v6i66e1tI0Oe\nrJyQb10uXG8eq2+vX7bU3bvTmSyj/dSLZZrR
HqkwdNJ6IU6NRqnL5x3fyI7l6xwW\nlCIPt1BlzgcnRGv8Uw94cZV06+Ph9nKdTdnS+gBBSl8QGfF2QOCTu
/cCgYEA0wdB\n9gi/Mz7EBqFDN3ET7O/uY0VSWjZjWf9ERHfdcqGP/N+HZJ2UZEFfsOeTKoL0eodv\n++eS
p0o5hOIgDYj1p4dOUMz1YQm9AN/psjq2g7rH4Sk4HrkPZgRFmCyzKW5pqWLN\nyUvc3Ra9ohdzfBH/Z3h43
+Ey6acpa1vXgEZJiLsCgYBiITw17mUFLrmB4Ky/At1W\n6jVfqd4D/9IE3/9OsRXvId4U7ed8jvGeAP7Me+
S68Q3xQfHjHgp58T87ND1s5iqN\nxPEcV/xw8fRDVyxo7yPr1uhUm5QVV5eOfe1qAv1MM+o0wwIwGcnWBDK
78P8gPlR8\n6jWEJ+cnxcn7fe+qnsrHeQKBgD2pqz6HQ8dnmcQOLyPuKNJdMZ1UTkIKDnHnwzz2\ngYDTcM
2FS3y9BvVcnOeGY1xSs7lyBejnu9SiPbh0ksUhthZj1SCLI1BdlhrBUvo/\nacGIPIuwjbN8g+FdcjCLLzb
2Cm3ybwtY3YrE8FiC3b3tTGIhs8BHf6cCr3mtdoUH\nBMmtAoGAE1sxj8B4H/9tRI+WyIrAM2AnIeDGIK/d
Q6lOALyBpGM5t817ropSkko7\n3+SARz+eGCYPoJeFubq5+nPmRVI2zwesapDamM5tfns/dqmJIdyYu+gir
xC7v1/p\nLyXo4UBpBu42aOxZOi1ooS7E3aQa+lszKmeLv7uzdydzMinNRiE=\n-----END RSA PRIVATE
KEY-----'
Public Key: b'-----BEGIN PUBLIC KEY-----
\nMIIBIjANBgkqhkiG9w0BAQEFAAOCAQ8AMIIBCgKCAQEAlZIGkqE+C2Kl7udTGyBy\nztu8OKlkHy/lfJW
+frF/5loSW5L5RfTmfra8nZ+NtA1F27XaamXfKl/l2cZBlm9g\nluPb4LAj3fd6jp77qAadOERcPj6PCwkY
tA9lSuHklgzRRnTN5kI+l6AzH3ahPiZy\nHqSuhdrd7vXEhn9UYWkwdyEBfWIN+L6ySKer9wwRXkScFuR3D
fWiOLaMTZDVYNRi\n490TTjWtdrwbgNE3F4JowE2DgCVZGV45qaMZz5VDP8aL9Fs4yrEDh2vxgY4mWsYm\n
VF6IPLWWxb05PFCUz6PlHBIYV8bE/EzGsIGpJedig7T+HYbJU0mS12sao7S4qzSF\nbQIDAQAB\n-----
END PUBLIC KEY-----'
Array sizes of data tested (in bytes): [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,
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131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146,
147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162,
163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178,
179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190]
Encryption times (ms): [3.027200698852539, 2.9497146606445312, 3.008127212524414,
2.9430389404296875, 2.960681915283203, 2.949237823486328, 2.969026565551758,
2.959012985229492, 3.0090808868408203, 2.946138381958008, 2.9587745666503906,
2.952098846435547, 2.972841262817383, 2.9549598693847656, 2.978086471557617,
2.9768943786621094, 2.971172332763672, 2.9768943786621094, 3.0002593994140625,
2.9740333557128906, 2.9649734497070312, 2.9740333557128906, 2.965211868286133,
3.0257701873779297, 3.0031204223632812, 2.9761791229248047, 2.964019775390625,
```

2.9931068420410156, 2.981901168823242, 3.0090808868408203, 2.974987030029297,
2.955913543701172, 2.961874008178711, 2.948284149169922, 2.974987030029297,
2.933979034423828, 2.9518604278564453, 2.932310104370117, 2.959728240966797,
2.9218196868896484, 2.9420852661132812, 2.918720245361328, 2.964019775390625,
2.927064895629883, 2.9430389404296875, 3.0100345611572266, 2.943277359008789,
2.9268264770507812, 2.9358863830566406, 2.9430389404296875, 2.9380321502685547,
2.9511451721191406, 2.9370784759521484, 2.9349327087402344, 2.933025360107422,
2.937793731689453, 2.9249191284179688, 2.9408931732177734, 2.933979034423828,
2.969026565551758, 2.9599666595458984, 2.959012985229492, 2.9518604278564453,
2.960681915283203, 2.9518604278564453, 2.9611587524414062, 2.992868423461914,
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2.9478073120117188, 2.966165542602539, 2.9456615447998047, 2.959728240966797,
2.9451847076416016, 2.9561519622802734, 2.941131591796875, 2.9649734497070312,
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2.964019775390625, 2.977609634399414, 2.949953079223633, 2.9997825622558594,
2.9578208923339844, 2.952098846435547, 2.975940704345703, 2.9611587524414062,
2.96783447265625, 2.972126007080078, 2.9430389404296875, 2.9451847076416016,
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2.949237823486328, 2.950906753540039, 2.9439926147460938, 2.9540061950683594,
2.9430389404296875, 2.9578208923339844, 2.9449462890625]
Drawing image...
Testing decryption...
Array sizes of data tested (in bytes): [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,
14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34,
35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55,
56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76,
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115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130,
131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146,

```
147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162,
163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178,
179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190]
Decryption times (ms): [17.05312728881836, 13.747215270996094, 11.548995971679688,
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7.193088531494141, 7.20977783203125, 7.194280624389648, 7.297039031982422,
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7.177829742431641, 7.179975509643555, 7.166862487792969, 7.182121276855469,
7.195711135864258, 7.1849822998046875, 7.314920425415039, 7.171154022216797,
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7.158994674682617, 7.179975509643555, 7.166862487792969, 7.172822952270508,
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7.193088531494141, 7.163763046264648, 7.155179977416992, 7.160663604736328,
7.135868072509766, 7.170915603637695, 7.164955139160156, 7.200956344604492,
7.207155227661133, 7.179975509643555, 7.15184211730957, 7.195234298706055,
7.359027862548828, 7.1849822998046875, 7.121086120605469, 7.325172424316406,
7.112979888916016, 7.161855697631836, 7.171154022216797, 7.421016693115234,
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7.400989532470703, 7.182121276855469, 7.134914398193359, 7.102012634277344,
7.14111328125, 7.145881652832031, 7.091045379638672, 7.198095321655273,
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```

```
Drawing image...
Testing signing...
Array sizes of data tested (in bytes): [1000, 1500, 2000, 2500, 3000, 3500, 4000,
4500, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000, 9500, 10000]
Signing times (ms): [14.281034469604492, 12.070178985595703, 10.465860366821289,
9.099721908569336, 8.336782455444336, 7.759809494018555, 7.341146469116211,
6.814002990722656, 6.854057312011719, 6.615161895751953, 6.476163864135742,
6.360054016113281, 6.430149078369141, 6.448268890380859, 6.356954574584961,
6.365299224853516, 6.372928619384766, 6.360769271850586, 6.367921829223633]
Drawing image...
Testing verification...
Array sizes of data tested (in bytes): [1000, 1500, 2000, 2500, 3000, 3500, 4000,
4500, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000, 9500, 10000]
Is Valid signature (bool): [True, True, True, True, True, True, True, True, True,
True, True, True, True, True, True, True, True, True, True]
Verification times (ms): [6.321191787719727, 7.008075714111328, 6.0272216796875,
5.140066146850586, 3.6420822143554688, 5.356073379516602, 4.7969818115234375,
4.605293273925781, 4.231929779052734, 4.201173782348633, 3.772258758544922,
3.7641525268554688, 3.451108932495117, 3.4580230712890625, 3.2372474670410156,
3.186941146850586, 3.1082630157470703, 2.978086471557617, 2.9828548431396484]
Drawing image...
Filename: /Users/viktoriia/Downloads/mrkm_lab1.py

Line #    Mem usage    Increment  Occurrences   Line Contents
=============================================================
   110    185.7 MiB    185.7 MiB           1   @profile
   111                                         def perform_rsa_2048_tests():
   112    185.7 MiB      0.0 MiB           1       print ("Performing RSA-2048
tests:")
   113
   114    185.7 MiB      0.0 MiB           1       print ("Testing encryption...")
   115
   116    186.0 MiB      0.2 MiB           1       rsa_keys = RSA.generate(2048)
   117
   118    186.1 MiB      0.2 MiB           1       private_key =
RSA.import_key(rsa_keys.export_key())
   119    186.1 MiB      0.0 MiB           1       public_key =
RSA.import_key(rsa_keys.publickey().export_key())
   120
   121    186.1 MiB      0.0 MiB           1       print ("Private Key: " +
str(rsa_keys.export_key()))
   122    186.1 MiB      0.0 MiB           1       print ("Public Key: " +
str(rsa_keys.publickey().export_key()))
   123
   124    186.1 MiB      0.0 MiB           1       rsa_instance =
PKCS1_OAEP.new(public_key)
   125
   126    186.1 MiB      0.0 MiB           1
rsa_instance.encrypt(b"CopyRight Measures")
   127
   128    186.1 MiB      0.0 MiB           1       data = []
```

```
   129    186.1 MiB      0.0 MiB           1       encrypted_data = []
   130    186.1 MiB      0.0 MiB           1       encryption_time = []
   131
   132    186.2 MiB      0.0 MiB         191       for i in range(1, 191):
   133    186.2 MiB      0.0 MiB         190           data_to_encrypt =
random.randbytes(i)
   134
   135    186.2 MiB      0.0 MiB         190           start_time = time.time()
   136    186.2 MiB      0.1 MiB         190           encrypted =
rsa_instance.encrypt(data_to_encrypt)
   137    186.2 MiB      0.0 MiB         190           end_time = time.time()
   138
   139    186.2 MiB      0.0 MiB         190           time_spent = (end_time -
start_time) * 10**3
   140
   141    186.2 MiB      0.0 MiB         190           data.append(i)
   142    186.2 MiB      0.0 MiB         190
encrypted_data.append(encrypted)
   143    186.2 MiB      0.0 MiB         190
encryption_time.append(time_spent)
   144
   145    186.2 MiB      0.0 MiB           1       print ("Array sizes of data
tested (in bytes): " + str(data))
   146    186.2 MiB      0.0 MiB           1       print ("Encryption times (ms):
" + str(encryption_time))
   147
   148    186.2 MiB      0.0 MiB           1       print ("Drawing image...")
   149    187.2 MiB      1.0 MiB           1       plt.title("RSA-2048 Encryption
times compared to Data Length")
   150    187.2 MiB      0.0 MiB           1       plt.xlabel("Data Length
(bytes):")
   151    187.2 MiB      0.0 MiB           1       plt.ylabel("Time spent (ms):")
   152    187.2 MiB      0.0 MiB           1       plt.plot(data, encryption_time)
   153    202.2 MiB     15.0 MiB           1       plt.show()
   154
   155    202.2 MiB      0.0 MiB           1       print ("Testing decryption...")
   156
   157    202.2 MiB      0.0 MiB           1       rsa_instance =
PKCS1_OAEP.new(private_key)
   158
   159    202.2 MiB      0.0 MiB           1
rsa_instance.decrypt(encrypted_data[0])
   160
   161    202.2 MiB      0.0 MiB           1       decryption_time = []
   162
   163    202.2 MiB      0.0 MiB         191       for i in encrypted_data:
   164    202.2 MiB      0.0 MiB         190           start_time = time.time()
   165    202.2 MiB      0.0 MiB         190           decrypted =
rsa_instance.decrypt(i)
   166    202.2 MiB      0.0 MiB         190           end_time = time.time()
   167
```

```
   168    202.2 MiB      0.0 MiB         190           time_spent = (end_time -
start_time) * 10**3
   169
   170    202.2 MiB      0.0 MiB         190
decryption_time.append(time_spent)
   171
   172    202.2 MiB      0.0 MiB           1       print ("Array sizes of data
tested (in bytes): " + str(data))
   173    202.2 MiB      0.0 MiB           1       print ("Decryption times (ms):
" + str(decryption_time))
   174
   175    202.2 MiB      0.0 MiB           1       print ("Drawing image...")
   176    203.1 MiB      0.9 MiB           1       plt.title("RSA-2048 Decryption
times compared to Data Length")
   177    203.1 MiB      0.0 MiB           1       plt.xlabel("Data Length
(bytes):")
   178    203.1 MiB      0.0 MiB           1       plt.ylabel("Time spent (ms):")
   179    203.1 MiB      0.0 MiB           1       plt.plot(data, decryption_time)
   180    225.0 MiB     21.9 MiB           1       plt.show()
   181
   182    225.0 MiB      0.0 MiB           1       print ("Testing signing...")
   183
   184    225.0 MiB      0.0 MiB           1       signature_instance =
pkcs1_15.new(private_key)
   185    225.0 MiB      0.0 MiB           1       sha256_instance =
SHA256.new(b"CopyRight Measures")
   186
   187    225.0 MiB      0.0 MiB           1
signature_instance.sign(sha256_instance)
   188
   189    225.0 MiB      0.0 MiB           1       data = []
   190    225.0 MiB      0.0 MiB           1       signed_messages = []
   191    225.0 MiB      0.0 MiB           1       singing_time = []
   192
   193    225.1 MiB      0.0 MiB          20       for i in range(1000, 10500,
500):
   194    225.1 MiB      0.1 MiB          19           message_to_sign =
random.randbytes(i)
   195
   196    225.1 MiB      0.0 MiB          19           start_time = time.time()
   197    225.1 MiB      0.0 MiB          19
sha256_instance.update(message_to_sign)
   198    225.1 MiB      0.0 MiB          19           signed_message =
signature_instance.sign(sha256_instance)
   199    225.1 MiB      0.0 MiB          19           end_time = time.time()
   200
   201    225.1 MiB      0.0 MiB          19           time_spent = (end_time -
start_time) * 10**3
   202
   203    225.1 MiB      0.0 MiB          19           data.append(i)
```

```
   204    225.1 MiB      0.0 MiB          19           signed_messages.append({
"message": message_to_sign, "signature": signed_message })
   205    225.1 MiB      0.0 MiB          19
singing_time.append(time_spent)
   206
   207    225.1 MiB      0.0 MiB           1       print ("Array sizes of data
tested (in bytes): " + str(data))
   208    225.1 MiB      0.0 MiB           1       print ("Signing times (ms): " +
str(singing_time))
   209
   210    225.1 MiB      0.0 MiB           1       print ("Drawing image...")
   211    226.2 MiB      1.1 MiB           1       plt.title("RSA-2048 Signing
times compared to Data Length")
   212    226.2 MiB      0.0 MiB           1       plt.xlabel("Data Length
(bytes):")
   213    226.2 MiB      0.0 MiB           1       plt.ylabel("Time spent (ms):")
   214    226.2 MiB      0.0 MiB           1       plt.plot(data, singing_time)
   215    250.9 MiB     24.6 MiB           1       plt.show()
   216
   217    250.9 MiB      0.0 MiB           1       print ("Testing
verification...")
   218
   219    250.9 MiB      0.0 MiB           1       signature_instance =
pkcs1_15.new(public_key)
   220    250.9 MiB      0.0 MiB           1       sha256_instance =
SHA256.new(b"CopyRight Measures")
   221
   222    250.9 MiB      0.0 MiB           1       is_valid = []
   223    250.9 MiB      0.0 MiB           1       verification_time = []
   224
   225    250.9 MiB      0.0 MiB          20       for i in signed_messages:
   226    250.9 MiB      0.0 MiB          19           message = i["message"]
   227    250.9 MiB      0.0 MiB          19           signature = i["signature"]
   228
   229    250.9 MiB      0.0 MiB          19           start_time = time.time()
   230    250.9 MiB      0.0 MiB          19
sha256_instance.update(message)
   231    250.9 MiB      0.0 MiB          19           valid_signature =
sha256_instance
   232
   233    250.9 MiB      0.0 MiB          19           try:
   234    250.9 MiB      0.0 MiB          19
signature_instance.verify(valid_signature, signature)
   235    250.9 MiB      0.0 MiB          19               is_valid.append(True)
   236                                                  except (ValueError,
TypeError):
   237                                                      is_valid.append(False)
   238
   239    250.9 MiB      0.0 MiB          19           end_time = time.time()
   240
```

```
   241    250.9 MiB      0.0 MiB          19           time_spent = (end_time -
start_time) * 10**3
   242
   243    250.9 MiB      0.0 MiB          19
verification_time.append(time_spent)
   244
   245    250.9 MiB      0.0 MiB           1       print ("Array sizes of data
tested (in bytes): " + str(data))
   246    250.9 MiB      0.0 MiB           1       print ("Is Valid signature
(bool): " + str(is_valid))
   247    250.9 MiB      0.0 MiB           1       print ("Verification times
(ms): " + str(verification_time))
   248
   249    250.9 MiB      0.0 MiB           1       print ("Drawing image...")
   250    251.7 MiB      0.9 MiB           1       plt.title("RSA-2048
Verification times compared to Data Length")
   251    251.7 MiB      0.0 MiB           1       plt.xlabel("Data Length
(bytes):")
   252    251.7 MiB      0.0 MiB           1       plt.ylabel("Time spent (ms):")
   253    251.8 MiB      0.0 MiB           1       plt.plot(data,
verification_time)
   254    266.8 MiB     15.1 MiB           1       plt.show()
```

Висновок:
Ми протестували OpenSSL і PyCrypto. За нашими тестами PyCrypto показує кращий час для основних крипто примитивів.