Final assignment of "Management and Analysis of Physics Datasets"- Module B

June 18, 2021

Gerardo Carmona

Saverio Monaco You might have seen this kind of puzzles on social media. It should be straightforward for you to understand which operations connect the two numbers before the '=' sign. What is the result of the **?** field? Show proof for each line!

$$1 + 2 = 3$$
$$2 + 5 = 7$$
$$3 + 7 = 4$$
$$4 + 5 = \textbf{?}$$
$$5 + 9 = 12$$

SOLUTION If we rewrite the digits as binary, we can easily guess the actual operation:

$$\begin{array}{llll} 1+2=3 & : & f(01,10) & = 11 \\ 2+5=7 & : & f(010,101) & = 111 \\ 3+7=4 & : & f(011,111) & = 100 \\ 4+5=? & : & f(100,101) & = ? \\ 5+9=12 & : & f(0101,1001) & = 1100 \end{array}$$

For all expression, we can replace $f(a,b)$ with $a \oplus b$, thus obtaining $100 \oplus 101 = 001 = 1$ for "$4+5$".

1 Redundancy

We are programming a file based RAID-4 software algorithm. For this purpose we are converting a single input (**raid4.input**) file into four data files `raid4.0`,`raid4.1`,`raid4.2`,`raid4.3` and one parity file `raid4.4` - the four data and one parity file we call 'stripe files'.

The input file can be downloaded from: http://apeters.web.cern.ch/apeters/pd2021/raid4.input

To do this we are reading in a loop sequentially blocks of four bytes from the input file until the whole file is read: * in each loop we write one of the four read bytes round-robin to each data file, compute the parity of the four input bytes and write the result into the fifth parity file. (see the drawing for better understanding)

- we continue until all input data has been read. If the last bytes read from the input file are not filling four bytes, we consider the missing bytes as zero for the parity computation.

Input File (horizontal) **raid4.input - total size 170619 bytes** (number in cell = byte offset in file)

0	1	2	3	4	5	6	7	8	9	10	11	12	...	...	170618

Output File (vertical) (number in cell = byte offset in file, p0,1,2... are the row-wise parities)

raid4.0	raid4.1	raid4.2	raid4.3	raid4.4
0	1	2	3	p0
4	5	6	7	p1
8	9	10	11	p2
12	13	14	15	p3
...	...	...	...	...

Stripe parity (column wise parity)

q0=0^{4}8^12	q1	q2	q3	q4

[1]:
```python
import numpy as np

def get_arr(path):
    '''Reads a file as bytes'''
    with open(path,'r+b') as file:
        v = np.frombuffer(file.read(),dtype = np.uint8)
    return v


def post_arr(arr, path):
    '''Writes an array to a file, converting it to bytes'''
    with open(path,'w+b') as file:
        file.write(arr.tobytes())
    return


def xor_arr(matrix):
    '''Applies the bitwise xor function to a collection of arrays, given as rows in a matrix.'''
    # Neutral xor array
    v = np.zeros(len(matrix[0]),dtype = np.uint8)
    # Applying bitwise_xor between the matrix rows
    for arr in matrix:
```

```
        v = np.bitwise_xor(v,arr)
    return v
```

1.1 Write a program (C,C++, R or Python), which produces four striped data and one parity file as described above using the given input file.

hint: if you have a problem programming this yourself, you can download the core program in C++ from http://apeters.web.cern.ch/apeters/pd2021/raid4.cSee the explanations in the beginning how to compile and run it. You have to add the parity computations at the IMPLEMENT THIS sections! If you can't compile or run it, you can still fill in the missing implementation!

[2]:
```python
n = 4
src_file = 'raid4.input'
all_bytes = get_arr(src_file)
all_bytes

# We calculate how many zeros have to be added in the end
extra = n - len(all_bytes)%n
bytes_arr = np.hstack([all_bytes,np.zeros(extra, dtype = np.uint8)])

# Reshaping array
nrows = len(bytes_arr)//n
ncols = n
bytes_arr = bytes_arr.reshape((nrows,ncols))
## Rendered as unsigned integers of 8 bits.
bytes_arr
```

[2]:
```
array([[ 37,  80,  68,  70],
       [ 45,  49,  46,  51],
       [ 10,  37, 196, 229],
       ...,
       [ 55,  55,  51,  55],
       [ 10,  37,  37,  69],
       [ 79,  70,  10,   0]], dtype=uint8)
```

[3]:
```python
# Iterate over the columns and generate the files
for i, v in enumerate(bytes_arr.T):
    post_arr(v, f'raid{n}.{i}')

# Evaluating parity between stripes
row_p = xor_arr(bytes_arr.T)

#Store the row parity
post_arr(row_p,f'raid{n}.{n}')
```

[4]:
```python
## Unsigned 8bit integer representation of the parity stripe
row_p.T
```

[4]: array([119,   1, 14, ...,   4, 79,   3], dtype=uint8)

1.2 Extend the program to compute additionally the parity of all bytes within one stripe file.

You can say, that the computed column-wise parity acts as a *corruption check* for each stripe file. Compute the size overhead by comparing the size of all 5 stripe files with the original file.

[5]:
```
# We end up with five files with the same number of bytes, which is simply the␣
↪length of the arrays.
overhead = len(row_p)*5/len(all_bytes)-1
overhead *= 100
print(f'The size overhead is {round(overhead,2)}%')
```

```
The size overhead is 25.0%
```

[6]:
```
# We now wish to generate an extra file with the parity of each column
ext_bytes = np.vstack((bytes_arr.T, row_p)).T

# Evaluating parity for each stripe
col_p = xor_arr(ext_bytes)

# Store the resulting parity
post_arr(col_p,f'raid{n}.col')
```

1.3 What is the 5-byte parity value if you write it it in hexadecimal format like P^5 =0x[q0][q1][q2][q3][q4], where the [qx] are the hexadecimal parity bytes computed by xor-ing all bytes in each stripe file.

A byte in hexadecimal has two digits and you should add leading 0 if necessary. Examples: * a byte with contents 1 in hexadecimal is 0x01. A byte with contents 255in hexadecimal is 0xff. * a possible 5-byte parity would be P5 = 0 x 01 0c 1a 2f 3e

[7]:
```
# Casting as strings the hexadecimal representation of each byte and setting to␣
↪a convenient format.
p_5 = [str(i.tobytes()).split('x')[1][:-1] for i in col_p]
p_5 = '0x'+'_'.join(p_5)
print(f'The 5-parity in hex format is {p_5}')
```

```
The 5-parity in hex format is 0xa5_07_a0_9c_9e
```

1.4 If you create a sixth stripe file, which contains the row-wise parities of the five stripe files, what would be the contents of this file?

Write down the equation for R, which is the XOR between all data stripes D0,D1,D2,D3 and the parity P. Remember P was the parity of D0,D1,D2,D3! Reduce the equation removing P from it to get the answer about the contents!

SOLUTION

$$
\begin{aligned}
R &= D_0 \oplus D_1 \oplus D_2 \oplus D_3 \oplus P \\
&= P \oplus P \\
&= \mathbf{0}
\end{aligned}
$$

since $a \oplus b$ evaluates to 0 when a and b have the same value, which is of course the case for every row in the expression above.

1.5 After some time you recompute the 5-byte parity value as in 1.3. Now the result is P^5 = 0x a5 07 a0 01 9e. Something has been corrupted. You want to reconstruct the original file raid4.input using the 5 stripe files.

Describe how you can recreate the original data file. Which stripe files do you use and how do you recreate the original data file with the correct size?

[8]:
```
def correct(col_parity, new_col_parity, file_key):
    # Both col_p and new_col_p are expected as bytes objects
    col_p = np.frombuffer(bytes(col_parity),dtype = np.uint8)
    new_p = np.frombuffer(new_col_parity,dtype = np.uint8)
    mask = col_p != new_p

    # How many parity values have changed?
    wrong = np.arange(len(col_p))[mask]
    right = np.arange(len(col_p))[~mask]

    # We cannot correct if more than one stripe is damaged or no stripe damage␣
↪was detected.
    if len(wrong) != 1:
        message = 'More than one stripe has corrupted elements. Nothing can be␣
↪done.'\
            if wrong else 'Nothing to correct.'
        print(message)
        return None

    # If only one stripe is damaged then we can proceed to bit correction.
    # Retrieve as an array of row vectors those stripes to be evaluated
    w = np.vstack([get_arr(f'{file_key}.{i}') for i in right])
    v = xor_arr(w)

    # Time to correct
    [j] = wrong
    path = f'{file_key}.{j}'
    post_arr(v,path)
    print(f'Successfully rewrote {path}')

    return v
```

[9]:
```
p_5 = 0xa5_07_a0_01_9e.to_bytes(5,'big')
p_5
```

[9]:
```
b'\xa5\x07\xa0\x01\x9e'
```

[10]:
```
correct(bytes(col_p),p_5,'raid4')
```

```
Successfully rewrote raid4.3
```

[10]:
```
array([ 70,  51, 229, ...,  55,  69,   0], dtype=uint8)
```

[ ]:
```

```

2 Cryptography

The Caesar cipher is named for Julius Caesar, who used an alphabet where decrypting would shift three letters to the left. A friend has emailed you the following text: K]amua!trgpy. She told you that her encryption algorithm works similar to the Caesar cipher: * to each ASCI value of each letter I add a secret keyvalue. (note that ASCII values range from 0 to 255) * additionally to make it more secure I add a variable (so called) noncevalue to each ASCII number.

The nonce start value is 5 for the first character of the message. For each following character add 1 to the nonce of the previous character, e.g. for the second letter the nonce added is 6, for the third letter it is 7 aso.

2.1 Is this symmetric or asymmetric encryption and explain why?

SOLUTION Ceasar cipher is a symmetric encryption: the sender and the receiver only need the public key just containing the information about the shifts of the characters.

2.2 Write a small brute force program which tests keys from 0..255 and use a dictionary approach to figure out the original message.

In Python you can use the ord() function to get an integer representation of a character and the chr() to retrieve a character string from an integer!

[11]:
```
#!pip install pyenchant
import re, string, enchant
d = enchant.Dict("en_US")
```

[12]:
```
'''This function will be used in the decrypt method'''
# If the ASCII character is over 255, it will bring it back between 0 and 255␣
 ↪cycling it
# for example if ord(letter) = 260 it will be transformed to 4
# (assuming the range being from 0 to 255)
def reshift(letter,ascimin,ascimax):
    if ord(letter) < ascimin:
```

```
        return chr(ord(letter) - ascimin + ascimax + 1)
    elif ord(letter) > ascimax:
        return chr(-ascimax + ord(letter) + ascimin - 1)
    else:
        return letter

'''Decryption function'''
def decrypt(mex,nonce0,shift,ascimin,ascimax):
    word = []
    nonce = nonce0 # the starting value of the nonce value

    for letter in mex:
        # Since we are decrypting and not encrypting, nonce must be negative
        shiftedchr = chr(ord(letter) - nonce + shift)

        # Here we are eventually correcting the ASCII number if it is higher␣
 ↪ascimax or lower than ascimin
        # because of the shifting
        correctedshiftedchr =␣
 ↪reshift(reshift(shiftedchr,ascimin,ascimax),ascimin,ascimax)
        word.append(correctedshiftedchr)
        nonce = nonce + 1 #  for each letter nonce grows by 1

    return word

'''Setting the descypted proposals'''
# Sicne we need to check if the words belong to an English dictionary, we need␣
 ↪to preprocess
# the result of decrypt function, we make everything lowercase, split the words␣
 ↪whenever we find a space
# character and removing every puntuation character
def stringtowords(phrase):
    clear_word = ''
    for char in phrase:
        if char not in string.punctuation:
            clear_word += char
    return clear_word.lower().split()
```

[13]:
```
ascimax = 255
ascimin = 0
mex = 'K]amua!trgpy'
nonce0 = 5

for i in range(ascimin,ascimax):
    decrypted = decrypt(mex,nonce0,i,ascimin,ascimax)
    words = stringtowords(decrypted)
```

```python
    for word in words:
        # In the dictionary valid words are single digits numbers and letters, this avoids getting those
        # samples
        if len(word) != 1:
            # Some special non-printable characters break the function d.check()
            try:
                d.check(word)
                if d.check(word) == True:
                    print(i,':',' '.join(words))
            except:
                pass
```

```
10 : padova rocks
25 : ps p^rz
246 : mpbm ow
```

The used key is 10, the original message text is Padova rocks!

3 Object Storage

In an object storage system we are mapping objects by name to locations using a hash table. Imagine we have a system with ten hard disks (10 locations). We enumerate the location of a file using an index of the hard disk [0..9].

Our hash algorithm for placement produces hashes, which are distributed uniform over the value space for a flat input key distribution.

We want now to simulate the behaviour of our hash algorithmwithout the need to actually compute any hash value.

Instead of using real filenames, which we would hash and map using a hash table to a location (as we did in the exercise), we are 'computing' a location for 'any' file by generating a random number for the location in the range [0..9] to assign a file location. To place a file in the storage system we use this random location where the file will be stored and consumes space.

Assume each disk has 1TB of space, we have 10TB in total.

Place as many files of 10GB size as possible to hard disks choosing random locations until one hard disk is full. **Hint:** a hard disk is full once you have stored hundred 10GB files.

3.1 Write a program in Python, R or using ROOT, which simulates the placement of 10GB files to random locations and account the used space on each hard disk. Once the first hard disk is full, you stop to place files.

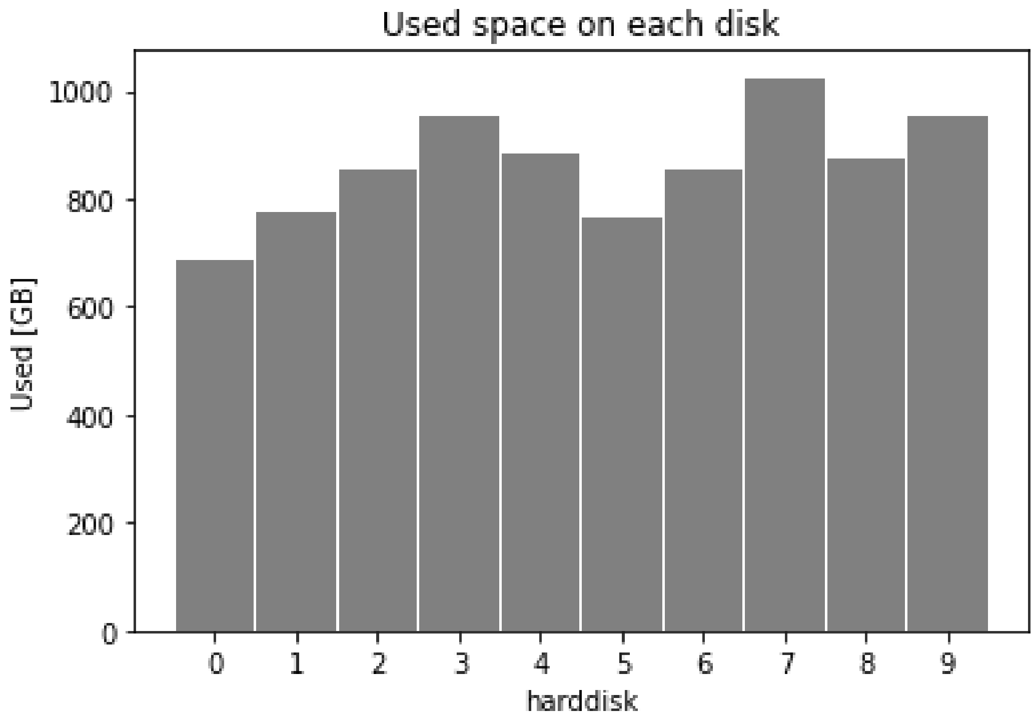
Remark: the distribution changes every time if the random generator is not seeded always with the same start value. Nevertheless both ways are accepted!

Possibly visualise the distribution similar to the histogram above.

[1]:
```
#!pip install psutil
import psutil
import matplotlib.pyplot as plt
import numpy as np
from numba import njit
np.random.seed(1234)
choice = np.random.choice

# Assuming np.int64 arrays,
# this is the maximum array size allowed for the system
n_available = psutil.virtual_memory().available//8

# The simulation function is a bit more elaborate than a file-by-file while loop␣
↪approach.
# Although the latter is more straightforward, it proved to be too slow for the␣
↪calculations performed in 3.4.
# This approach exploits numpy and numba for speed purposes.
@njit(fastmath = True)
def place_files(N_disks, disk_size, file_size, cores_running = 1):
    # Initially available space (translated to files)
    eff_size = disk_size//file_size
    max_new_files = np.repeat(eff_size,N_disks)

    while np.all(max_new_files > 0):
        # At least how many more files have to be placed to fill one of the hard␣
↪disks?
        min_max_files = max_new_files.min()

        # On average, how many placements would have to be made for this to be␣
↪reached?
        avg_new_files = (3*N_disks//4)*min_max_files

        # Generate an array for random placement of that many files
        placings = choice(np.arange(N_disks),min(n_available//
↪cores_running,avg_new_files))# For memory reasons, there's an upper bound to␣
↪the number of new files.

        ## Count how many files will be added to each disk
        new_files, _ = np.histogram(placings,bins = np.arange(N_disks+1))

        # did we miss?
        excess = new_files - max_new_files
        # is more than one disk full? Stepping back element by element.
        while np.any(excess > 0) or (excess==0).sum() > 1:
            rem_in = placings[-1]
```

```
            placings = placings[:-1]
            new_files[rem_in] -= 1
            excess = new_files - max_new_files


        # How much space is left now?
        max_new_files -= new_files

    free_space = max_new_files*file_size
    return free_space


def plot_usage(disk_size,free_space):
    N_disks = len(free_space)
    used = [(disk_size - f)/1024 for f in free_space]
    plt.bar(range(N_disks),used, width = 0.98, tick_label = range(N_disks),␣
 ↪color = 'gray')
    plt.title('Used space on each disk')
    plt.xlabel('harddisk')
    plt.ylabel('Used [GB]')
    plt.show()
```

[3]:
```
N_disks = 10; disk_size = 1024*1024 # ten 1TB = 1048576MB disks
file_size = 10*1024 # 10GB files

free_space = place_files(N_disks,disk_size,file_size)
free_space
placed_files = (N_disks*disk_size-free_space.sum())//file_size

plot_usage(disk_size,free_space)
```



3.1.1 How many files did you manage to place?

```
[4]: print(f'{placed_files} files were successfully placed.')
```

```
862 files were successfully placed.
```

3.1.2 What is the percentage of total used space on all hard disks in the moment the first disk is full?

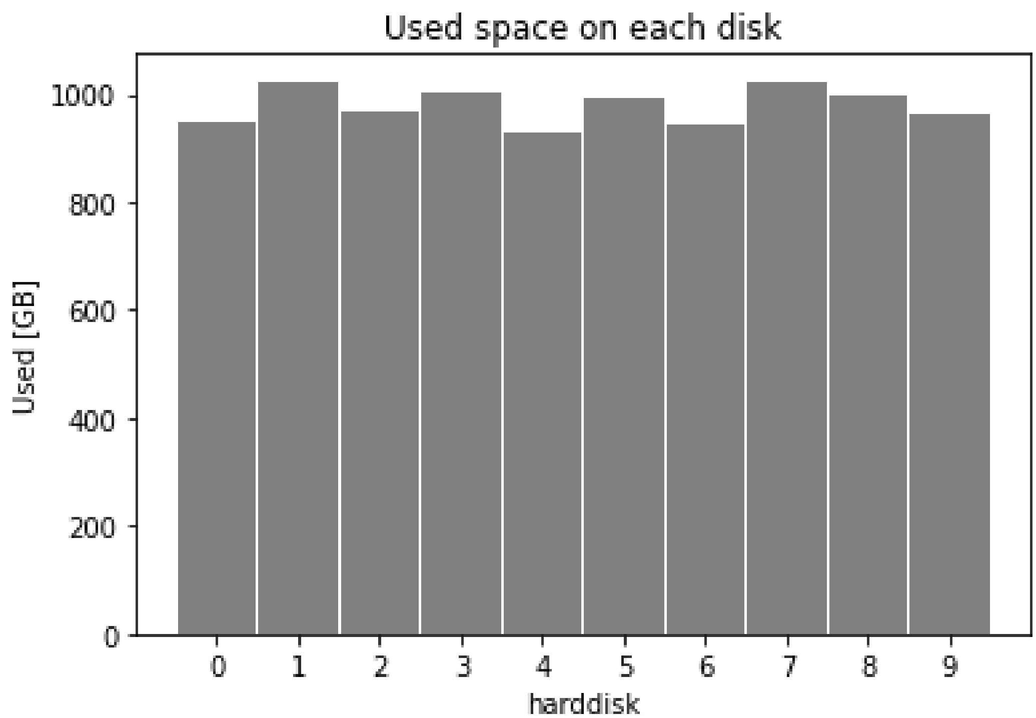
```
[5]: total_space = N_disks*disk_size
     used_percentage = 100*(total_space-sum(free_space))/total_space
     print(f'{round(used_percentage,2)}% of the total available space was used.')
```

```
84.18% of the total available space was used.
```

3.2 Repeat the same task placing 1GB files until the first hard disk is full.

```
[6]: file_size = 1024 # 1GB files

     free_space = place_files(N_disks,disk_size,file_size)

     placed_files = (N_disks*disk_size-free_space.sum())//file_size
```

```
plot_usage(disk_size,free_space)
```



3.2.1 How many files did you manage to place?

[7]:
```
print(f'{placed_files} files were successfully placed.')
```

```
9786 files were successfully placed.
```

3.2.2 What is the percentage of total used space on all hard disks in the moment the first disk is full?

[8]:
```
total_space = N_disks*disk_size
used_percentage = 100*(total_space-sum(free_space))/total_space
print(f'{round(used_percentage,2)}% of the total available space was used.')
```

```
95.57% of the total available space was used.
```

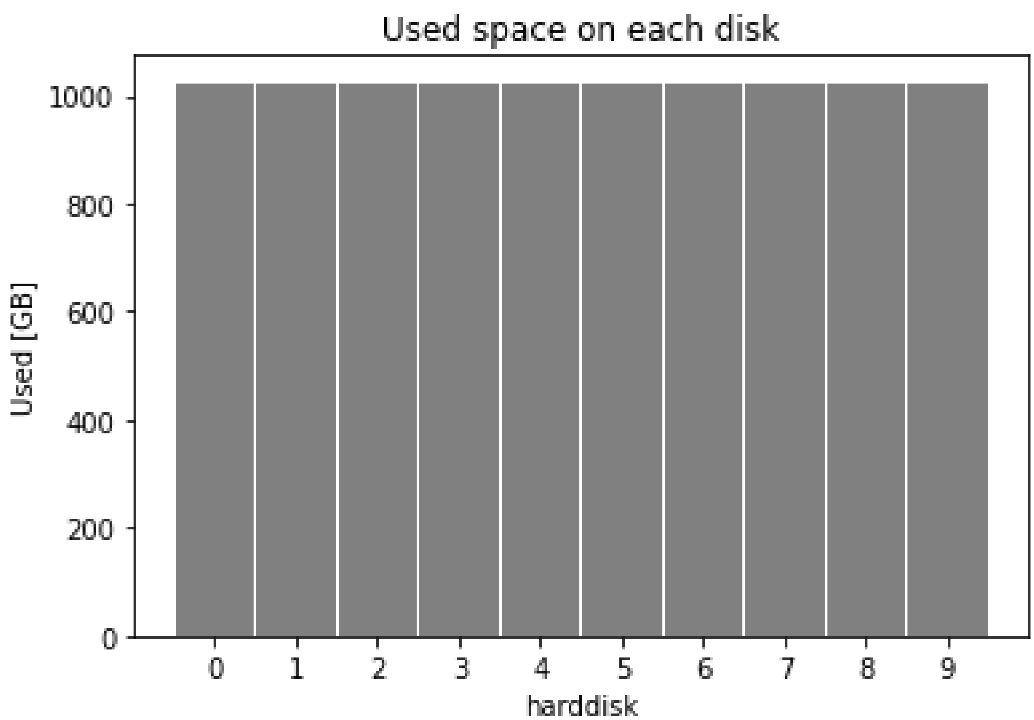
3.3 Based on this observation: why do you think object storage typically stores fixed size blocks of 4M and not files of GBs size as a whole? (so called block storage approach)

Run the same program for 4M block sizes and demonstrate the benefits

SOLUTION To begin with, as the file size is smaller, a bigger fraction of the fullest disk can be used before stopping. Let each disk have the same probability of being selected for storage. Since, when using smaller blocks, the number N of files is greater for a given size. As N increases, a more evenly distributed placement of files is expected, therefore being able to use a larger fraction of the total space before having to stop.

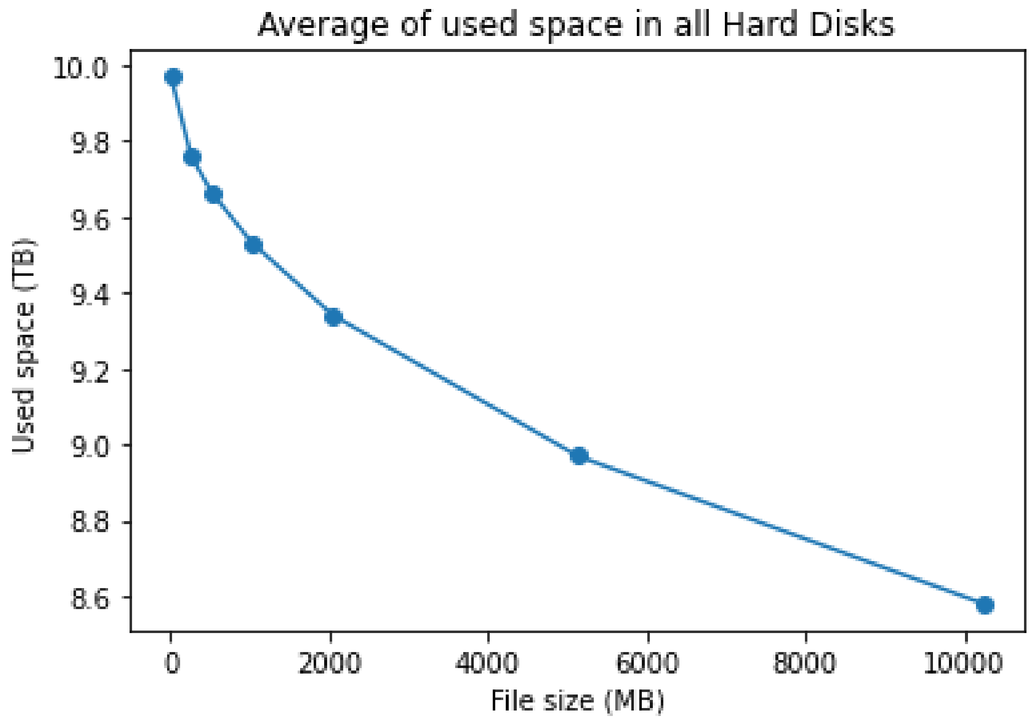
[9]:
```python
file_size = 4 # 4MB files

free_space = place_files(N_disks,disk_size,file_size)

placed_files = (N_disks*disk_size-free_space.sum())//file_size

print(f'{placed_files} files were successfully placed.')
total_space = N_disks*disk_size
used_percentage = 100*(total_space-sum(free_space))/total_space
print(f'{round(used_percentage,2)}% of the total available space was used.')
plot_usage(disk_size,free_space)
```

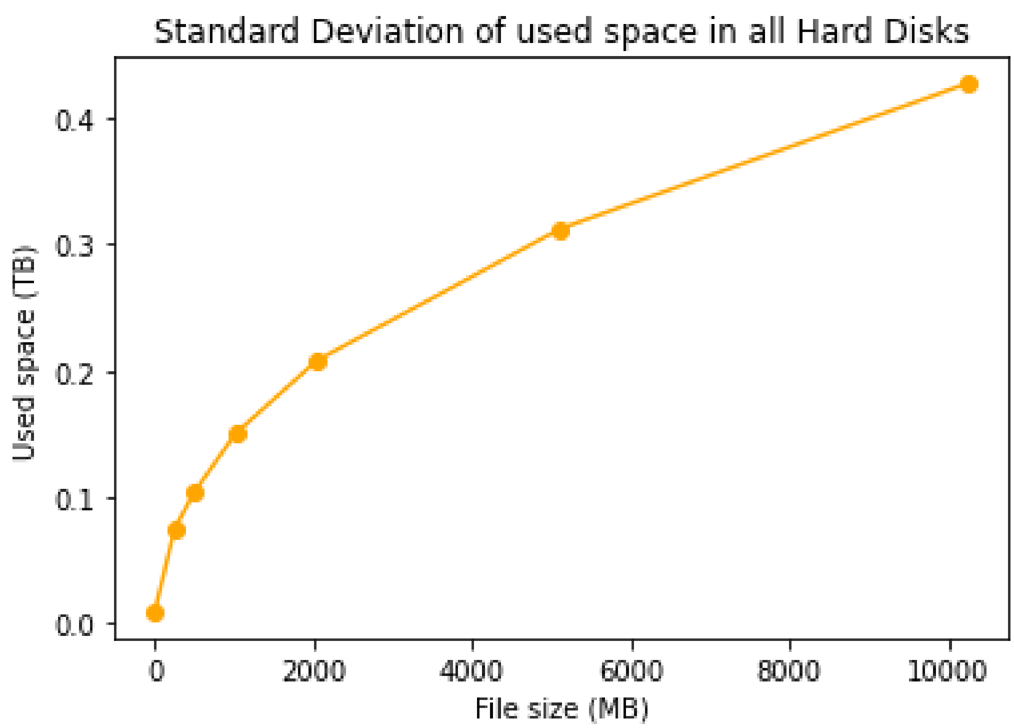
```
2617552 files were successfully placed.
99.85% of the total available space was used.
```



3.4 Compute the average used space on all hard disks and the standard deviation for the average used space for 10 GB and 1GB and 4M files. How is the standard deviation correlated to the block size and why? If we now repeat such an experiment for many more (thousands) of hard disks, which kind of distribution do you get when you do a histogram of the used space of all hard disks?

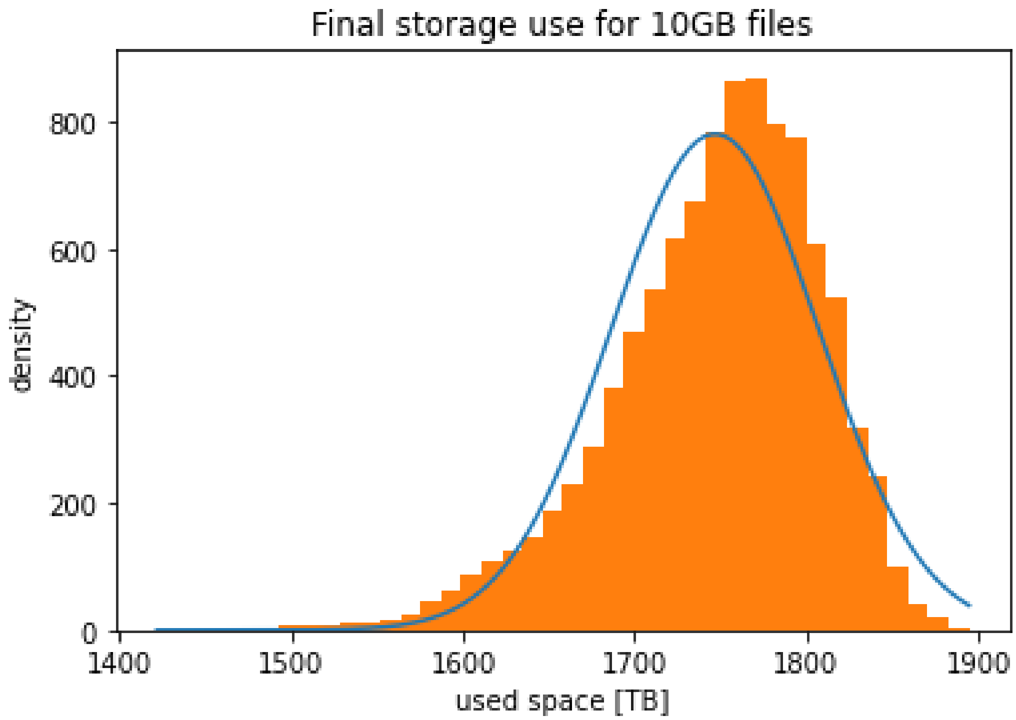
[10]:
```
# Using dask for simulation time purposes
import dask as dk

avgs = []
stds = []
sizes = [4,256,512,1024,2*1024,5*1024,10*1024]
N_disks = 10
cores_running = psutil.cpu_count()

for file_size in sizes:
    simulate = lambda N: dk.delayed()(
        [
            dk.delayed(place_files)(N_disks,disk_size,file_size, cores_running =␣
 ↪cores_running).sum()\
            for _ in range(N)
        ]
        ).compute()
    sims = np.array(simulate(2500))
    used = (N_disks*disk_size - sims)/1024/1024

    avg = np.average(used)
    std = np.std(used)

    avgs.append(avg)
    stds.append(std)

plt.title('Average of used space in all Hard Disks')
plt.xlabel('File size (MB)')
plt.ylabel('Used space (TB)')
plt.plot(sizes,avgs,'o-')
plt.show()

plt.title('Standard Deviation of used space in all Hard Disks')
plt.xlabel('File size (MB)')
plt.ylabel('Used space (TB)')
plt.plot(sizes,stds,'o-',color ="orange")
plt.show()
```


Average of used space in all Hard Disks
Used space (TB)
10.0
9.8
9.6
9.4
9.2
9.0
8.8
8.6
0
2000
4000
6000
8000
10000
File size (MB)


Standard Deviation of used space in all Hard Disks
Used space (TB)
0.4
0.3
0.2
0.1
0.0
0
2000
4000
6000
8000
10000
File size (MB)

[11]:
```
## Repeating experiment but with thousands of disks. Only performed for file␣
↪size 10 GB because of computation time.

file_size = 10*1024
N_disks = 2500
simulate = lambda N: dk.delayed()(
    [
        dk.delayed(place_files)(N_disks,disk_size,file_size, cores_running =␣
↪cores_running).sum()\
        for _ in range(N)
    ]
    ).compute()
sims = np.array(simulate(10000))
used = (N_disks*disk_size - sims)/1024/1024
```

[20]:
```
from scipy.stats import norm as scnorm

avg = np.average(used)
std = np.std(used)
rv = scnorm(avg,std)
x = np.linspace(used.min(),used.max(),1000)
p = rv.pdf(x)
a, beans = np.histogram(used, bins = 40)
A = (a*(beans[1:]-beans[:-1])).sum()
plt.plot(x,A*p)
plt.hist(used, bins = 40)
unit = 'GB'
norm = 1024
plt.title(f'Final storage use for {int(file_size/norm)}{unit} files')
plt.xlabel('used space [TB]')
plt.ylabel('density')
plt.show()
```



SOLUTION The Pascal (Negative Binomial) distribution gives the probability of amounting to K failures before achieving N successes.
Let B be the first hard disk to be filled. We consider placing a file in B to be a successful trial. The procedure stops as $N =$ `int(disk_size/file_size)` trials are successful.
The histogram represents the frequency of a given `(K+N)*file_size` final storage use. This is equivalent to the frequency of a given range of $K + N$ total trials.
When `N_disks` is large enough, $K + N \approx K$, in which case this would be approximately the frequency of a given range of K total failures before achieving N successes.
Therefore, with good approximation, the distribution of used space follows a Pascal distribution, which can in turn be fitted with a normal distribution.

4 Rest APIs & Block Chain Technology

Under https://pansophy.app:8443 you find a Crypto Coin Server exporting a simple Block Chain.

You can open this URL in any web browser to see the current Block Chain status and the account information. At the time of writing the initial birth account of the Block Chain contained 1M coins ("genesis" : 1000000) :

The REST responses are given in JSON format. Our REST API uses secure HTTP protocol and it is based on two HTTP methods:

GET

POST

GET requests are used, to retrieve any kind of information, POST requests are used to change state in the server.

The task is to implement a client and use a simple REST API to submit transactions to the Block Chain. Your goal is to book coins from other people's accounts to your own account. The server implements a Proof Of Time algorithm. To add a transaction to move coins to your account, you have to submit a merit request and you have to let time pass before you can send a claim request to execute your transaction on the Block Chain. If you claim your transaction too fast after a merit request, your request is discarded. The server enforces a Proof Of Time of a minimum of 10 seconds!

[27]:
```
import os
import json
import time
import numpy as np
import multiprocessing
```

[28]:
```
url     = 'https://pansophy.app:8443/'
ourteam = 'GitPush'
```

[29]:
```
# If the site does not temporarely work, I saved in this file an example of the␣
↪json code:
exfile = 'jsonex'

with open(exfile, 'r') as file:
    src = file.read().replace('\n', '')
data = json.loads(src)
```

[30]:
```
'''This function is just auxiliary for other functions. It returns the json of␣
↪the page'''
# url: the page: https://pansophy.app:8443/
# sec: for how long do you want to read it
# debug: prints the json string
def rest_curl(url,sec = 5, verbose = False, debug = False):
    cmd =  'curl -k ' + url + ' & sleep ' + str(sec) + ' ; kill $!'

    if verbose:
        print('Executing:\n  ',cmd)
    scr = os.popen(cmd).read()

    if debug:
        print(scr)

    if len(scr) == 0:
        print('ERROR: The site is currently NOT working')
        return 0
    else:
        return json.loads(scr)
```

[31]:

```python
'''Returns the current situation regarding teams and their coins'''
# offline: if the site does not work set offline=True to load a json example
def rest_teamsandcoins(url, offline = False):
    if offline:
        jsn = data
    else:
        jsn = rest_curl(url, sec = 1, verbose = False)

    return(jsn['accounts'])

teams = rest_teamsandcoins(url)

#print(teams.keys())   # Prints the teams
#print(teams.values()) # Prints the values

# To convert to an array you can do:
## names = list(teams.keys())
## coins = list(teams.values())

## print(names[0], coins[0])
```

[32]:

```python
def rest_initiatetransation(url, team, stealfrom, howmuch = 100):
    cmd = 'curl -k -X POST -H "Content-Type: application/json" -d \'{"operation":
 ↪ "merit","team": "'+ team +'", "coin": '+str(howmuch)+', "stealfrom": "' +␣
 ↪stealfrom +'"}\' ' + url
    #print(cmd)
    os.system(cmd)
    return

def rest_claimtransation(url, team):
    cmd = 'curl -k -X POST -H "Content-Type: application/json" -d \'{"operation":
 ↪ "claim","team": "'+team+'"}\' ' + url
    #print(cmd)
    os.system(cmd)

def rest_initiateandclaim(url, ourteam, enemyteam, howmuch = 100):
    rest_initiatetransation(url, ourteam, enemyteam, howmuch)
    time.sleep(10)

    rest_claimtransation(url,ourteam)
    rest_claimtransation(url,enemyteam)
```

4.1 Rest API transactions

4.1.1 Use the REST API and the curl command to transfer coins of the genesis or any other account on your own team account.

You can use the -d option to POST a document. You have to indicate in your request, that the content type of the document is JSON. To do this you can add an HTTP header for this command `curl ... -H''Content-Type: application/json'' ...`

If you prefer, you can use a Python program, doing the same HTTPS requests respecting Proof of Time.If you want to have some more fun, you can also load the current state into your Python script using GET requests and programatically steal from accounts which are reported. Be aware, that you can never steal the last coin of an account and if at the time of a claim there are not enough coins left on an account, your transaction is discarded.

To you will have to add at least one successful transaction to the Block Chain.

[39]:
```python
teams = rest_teamsandcoins(url)
names = list(teams.keys())
coins = list(teams.values())

print('Balance before transfer:')
print('  ',names[names.index(ourteam)],': ',coins[names.index(ourteam)])

rest_initiatetransation(url, ourteam, 'CANE', 100)
time.sleep(10)
rest_claimtransation(url,ourteam)

teams = rest_teamsandcoins(url)
names = list(teams.keys())
coins = list(teams.values())

print('\nBalance after tansaction')
print('  ',names[names.index(ourteam)],': ',coins[names.index(ourteam)])
```

```
Balance before transfer:
   GitPush :  1

Balance after tansaction
   GitPush :  101
```

4.1.2 What is the maximum number of transactions one given team can add to the Block Chain in one day?

SOLUTION To find the maximum number of transaction we tried different methods:

[34]:
```python
'''BRUTEFORCE'''
# this method just makes a transaction every 10 seconds and updates a counter
bruteforce = False
i = 0
```

```python
while(bruteforce):
    rest_initiatetransation(url, ourteam, 'genesis')
    time.sleep(10)
    rest_claimtransation(url,ourteam)

    teams = rest_teamsandcoins(url)
    names = list(teams.keys())
    coins = list(teams.values())

    print(i,':',names[names.index(ourteam)],': ',coins[names.index(ourteam)])
    i = i + 1
```

The bruteforce method is that straightforward, eventually we would expect some error to show up but until now it didn't, the amount of transactions appears to be only limited by the **Proof Of Time** rule:Maximum number of transactions $= \frac{\text{\# seconds in a day}}{10} = \frac{24*3600}{10} = 8640$

Two methods were tried in order to bypass this limit, however they ended up being unsuccessful. (See Appendix)

4.2 The server has a function to compute a hash of a block in the Block Chain:

[35]:
```python
import hashlib

def calculate_hash(index,team,prev_hash,coins,timestamp):
    block_of_string = "{}{}{}{}{}".format(index,
                                          team,
                                          prev_hash,
                                          coins,
                                          timestamp)

    return hashlib.sha256(block_of_string.encode()).hexdigest()

calculate_hash(2250,'GitPush',"d30ac7cf770b3db510ae388fc84160534c805d93c681c5dcbb8b1c8933e87525
```

[35]:
```
'bbed9bfd59dbb2bd92c5d82797c827dd6a646bf0a69795eddc76bc0796958c04'
```

4.2.1 Explain what this function does and why is this 'the key' for Block Chain technology?

SOLUTION Given an instance, the function `calculate_hash` creates the next hash in the chain. Each block of the blockchain contains the hashstring for the previous block and for itself. This will let us navigate in the blockchain through this reference method.

Most importantly the hash is used for decorruption and security purposes (as explained later)

4.2.2 If you have the knowledge of the hash function, how can you validate the contents of the Block Chain you received using a GET request to make sure, nobody has tampered with it? You don't need to implement it! Explain the algorithm to validate a Block Chain!

SOLUTION Being the hash generated using the contents as an input, we can generate the hash from the block and see if it maches the hash we already have.

4.2.3 Why might the GET REST API run into scalability problems?

Express the scalability behaviour of execution times of GET and POST requests in Big O notation in relation to the number of transactions recorded in the Block Chain! Draw execution time vs transactions for GET and POST requests.

SOLUTION POST just appends text in json format in the document, it does not depend on how many transactions were made, it scales as O(1)
GET reads the whole document, the bigger the file is the longer it will take, it scales as O(n)

4.2.4 If the Crypto server goes down, the way it is implemented it loses the current account balances. How can the server recompute the account balances after a restart from the saved Block Chain?

SOLUTION It should compute the balances starting again from the Genesis block and updating them after any transaction made, possibly checking if the hashes are correct (Integrity check).
Of course, this is not optimal if the number of all transactions is very high.

4.2.5 What are the advantages of using a REST API and JSON in a client-server architecture? What are possible disadvantages?

SOLUTION A client-server architecture is relatively easy to implement and often has a fast performance. However, it lacks proper security protocols. A more common choice is a peer-to-peer architecture, which is more secure given it is decentalized, however it faces some complexity of syncronization between all nodes (solved by sophisticated algorithms).

5 Appendix

5.1 4

The following two methods are attemps to by-pass the **Proof Of Time** 10-seconds block: * Using multiprocess it was tested if was possible to claim different transactions from different teams to ours, however the error: `{"msg": "accepted"}{"msg": "claim too early - deleted your request"}` appeared anyway.

```
[ ]: '''TRYING TO PARALLELIZE IT USING MULTIPROCESSING'''
# this method finds the available accounts we can steal from an use the␣
 ↪multiprocess library to
# steal from them in parallel
multi = False
i = 0
```

```
while (multi):
    teams = rest_teamsandcoins(url)
    names = np.array(list(teams.keys()))
    coins = np.array(list(teams.values()))
    print(i,':',names[np.where(names == ourteam)],': ',coins[np.where(names ==␣
 ↪ourteam)])
    availableteams = np.delete(names[coins > 100],np.where(names[coins > 100] ==␣
 ↪ourteam))
    for enemy in availableteams:
        p1 = multiprocessing.
 ↪Process(target=rest_initiatetransation,args=(url,ourteam,enemy))
        p1.start()

    time.sleep(10)
    p1.join()
    p1.terminate()
    p1.close()
    rest_claimtransation(url,ourteam)
    i = i + 1
```

- The **Proof Of Time** block must then be linked to the accounts who steals, then a way to bypass the Proof of Time blok would consist in making parallelized instances stealing from our team, to the others, but using a negative value as quantity of coins stealed. This way each parallelized instance is made from a different account. Sadly the error `{"msg": "negative or zero values are forbidden"}` showed up, telling us we can make a transacion of negative or zero values

[36]:
```
'''NEGATIVE THEFT IDEA'''
# this method instead of stealing a certain amount from accounts, makes in␣
 ↪parallel instances from all the
# available accounts to ours of a negative amount
negamulti = False
i = 0

while(negamulti):
    teams = rest_teamsandcoins(url)
    names = np.array(list(teams.keys()))
    coins = np.array(list(teams.values()))
    print(i,':',names[np.where(names == ourteam)],': ',coins[np.where(names ==␣
 ↪ourteam)])
    availableteams = np.delete(names[coins > 100],np.where(names[coins > 100] ==␣
 ↪ourteam))
    for enemy in availableteams:
        p1 = multiprocessing.
 ↪Process(target=rest_initiatetransation,args=(url,enemy,ourteam,-100,))
        p1.start()
```

```
    p1.join()
    p1.terminate()
    p1.close()
    i = i + 1
    for enemy in availableteams:
        rest_claimtransation(url,enemy)
        rest_claimtransation(url,ourteam)
```