cw2

October 27, 2023

1 Experimental Evaluation

MIFE scheme, we used ElGamal as the public-key encryption scheme

This notebook was runned with a HP Laptop 14s-dq1xxx with a 1GHz Intel Core i5 and 8GB RAM running Windows 10, 64 bit and Python 3.10 using `PyCryptoDome` and `numpy`

We first begin by generating some 1024 bit G, P parameters that will be recycled for the whole experiment, since it is the most time consuming operation

[1]:
```
from util import generate_gp

LOAD_GP = True

if LOAD_GP:
    # loading the generated values
    with open('gp.txt', 'r') as f:
        G = int(f.readline().split('=')[1])
        P = int(f.readline().split('=')[1])
else:
    G, P = generate_gp(nbits=1024, num_processes=8)
    print("G =", G)
    print("P =", P)
    # saving the generated values
    with open('gp.txt', 'w') as f:
        f.write("G = " + str(G) + "\n")
        f.write("P = " + str(P) + "\n")
```

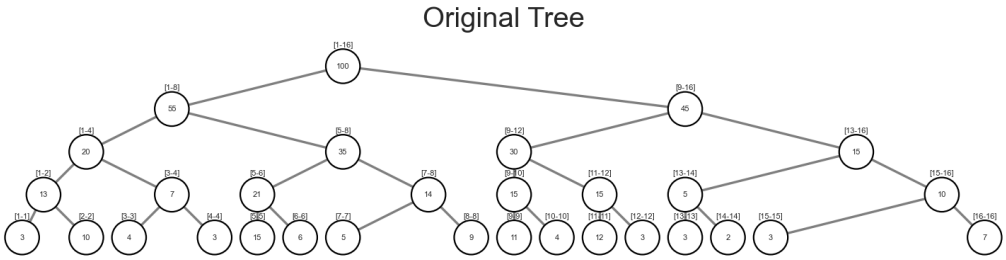
After this we proceed to show an initial representation of the tree, and the following operations

1. **Tree generation and population**: The tree nodes are initialized depending on the N value and a dataset is added
2. **Noise addition**: Noise is added to each node
3. **Encryption**: Each node is encypted. Note that the result of *ElGamal* encryption gives two large values of which only the first two digits are represented in the tree

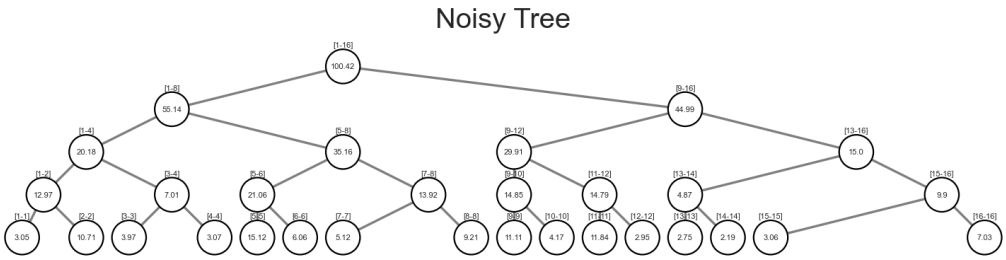
[15]:
```
import random
import math
import numpy as np
from mife import MIFE, ElGamal
```

```
from util import *
from plm import PLM_H
from entities import BinaryRangeTree, Curator
import matplotlib as mpl

mpl.rcParams['figure.dpi'] = 200
mpl.rcParams['figure.dpi'] = 200


N = 4
DATASET_SIZE = 100

print(f"Num_leaves: {2**N}, Num_nodes: {2**(N+1)-1}")

x = np.random.randint(1, 2**N+1, DATASET_SIZE)
C = Curator(N, x, G=G, P=P)
plot_tree(C.T, "Original Tree")
print(f"Query [1 - 5]: {C.T.query_interval([1, 5])}")
C.add_noise(10)
plot_tree(C.T, "Noisy Tree")
print(f"Query [1 - 5]: {C.T.query_interval([1, 5])}")
C.encrypt()
plot_tree(C.T, "Encrypted Tree")
print(f"Query [1 - 5]: {C.T.query_interval([1, 5])}")
print(C.times)
```

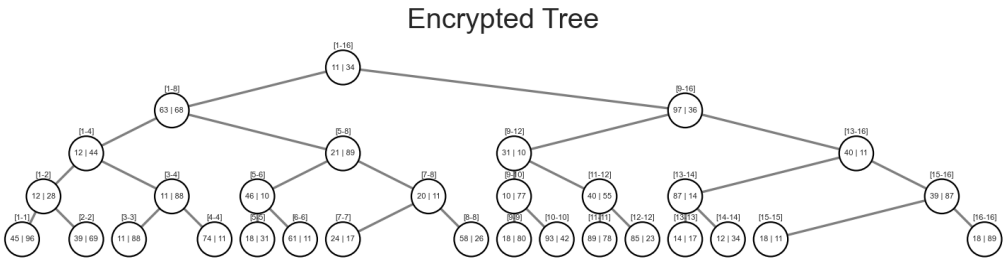
```
Num_leaves: 16, Num_nodes: 31
```




```
Query [1 - 5]: 35
```




```
Query [1 - 5]: 35.30046355645504
```




```
Query [1 - 5]: 35
{'generateAndPopulate': 0.000611600000411272, 'generateKeys':
0.6069549999956507, 'addNoise': 8.81000014487654e-05, 'encrypt':
0.3701751232147217}
```

[ ]:
```
import pandas as pd
import openpyxl

N_values = range(5, 11)
Dataset_Sizes = [10**i for i in range(2, 5)]

df1 = pd.DataFrame(columns=['Dataset Size', 'Number of Leaves', 'Time (ms)'])
df2 = pd.DataFrame(columns=['Total Number of Tree Nodes', 'Laplacian Noise',␣
 ↪'Key Generation', 'Encryption', 'Tree Generation(Dataset size = 10000)',␣
 ↪'Total Time'])

for dataset_size in Dataset_Sizes:
    for N in N_values:
        x = np.random.randint(1, 2**N, dataset_size)
        C = Curator(N, x, G=G, P=P)
        C.add_noise(10)
        C.encrypt()
```

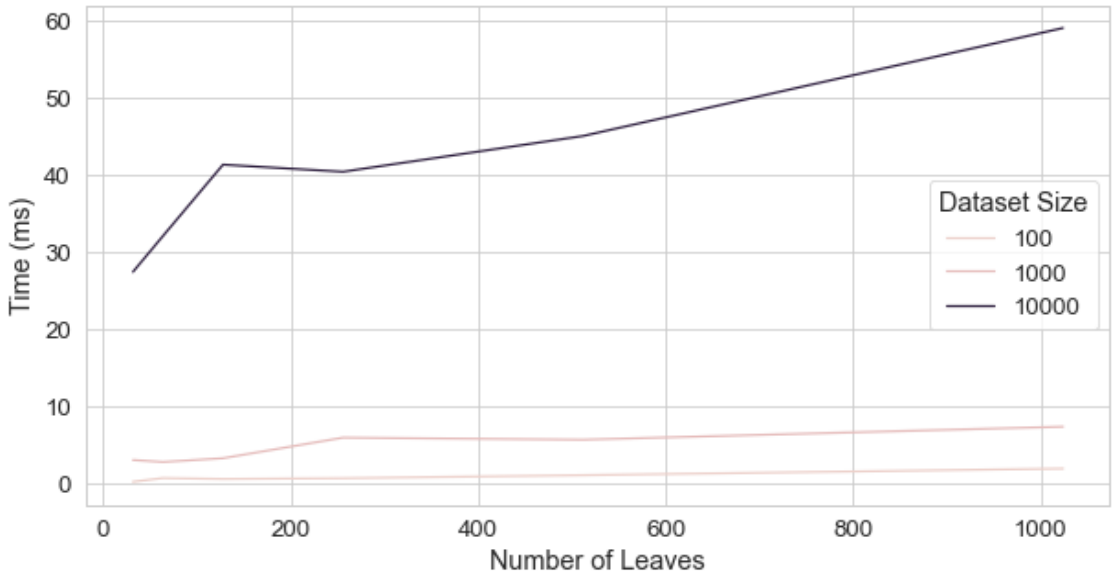
```
        df1 = pd.concat([df1, pd.DataFrame({'Dataset Size': [dataset_size],␣
 ↪'Number of Leaves': [2**N], 'Time (ms)': [C.
 ↪times["generateAndPopulate"]*1000]})], ignore_index=True)
        if dataset_size == 10000:
            df2 = pd.concat([df2, pd.DataFrame({'Total Number of Tree Nodes':␣
 ↪[2**(N+1)-1], 'Laplacian Noise': [C.times["addNoise"]], 'Key Generation': [C.
 ↪times["generateKeys"]], 'Encryption': [C.times["encrypt"]],'Tree␣
 ↪Generation(Dataset size = 10000)': [C.times["generateAndPopulate"]], 'Total␣
 ↪Time': [sum(C.times.values())]})], ignore_index=True)
        print(N, dataset_size, C.times)

# save to excel
df1.to_excel("cw2_1.xlsx")
df2.to_excel("cw2_2.xlsx")
```

[4]:
```
# show the table
df1
```

[4]:

	Dataset Size	Number of Leaves	Time (ms)
0	100	32	0.3063
1	100	64	0.7791
2	100	128	0.6616
3	100	256	0.7620
4	100	512	1.1578
5	100	1024	2.0108
6	1000	32	3.1234
7	1000	64	2.8639
8	1000	128	3.3490
9	1000	256	6.0163
10	1000	512	5.7509
11	1000	1024	7.4345
12	10000	32	27.4762
13	10000	64	32.1238
14	10000	128	41.3532
15	10000	256	40.4388
16	10000	512	45.0662
17	10000	1024	59.0453

[13]:
```
# draw the graph number of leaves vs time as a graph and points
import matplotlib.pyplot as plt
import seaborn as sns
sns.set_theme(style="whitegrid")
sns.set_context("paper", font_scale=1.5)
plt.figure(figsize=(10, 5))
ax = sns.lineplot(x="Number of Leaves", y="Time (ms)", hue="Dataset Size",␣
 ↪data=df1)
```



[6]:
```
df2
```

[6]:

	Total Number of Tree Nodes	Laplacian Noise	Key Generation	Encryption	Tree Generation(Dataset size = 10000)	Total Time
0	63	0.000142	0.883105	0.602663	0.027476	1.513387
1	127	0.000210	1.765950	1.221347	0.032124	3.019631
2	255	0.000530	3.640154	2.495387	0.041353	6.177423
3	511	0.001102	7.236615	4.866972	0.040439	12.145129
4	1023	0.001436	15.082199	10.468735	0.045066	25.597437
5	2047	0.003723	31.189803	21.395037	0.059045	52.647607

Finally we capture a, fully unrealistic/worst-case scenario, retrieve the values from all the leaves of a 1024 leaves tree

[14]:
```
import time

N = 10

x = np.random.randint(1, 2**N, 10000)
C = Curator(N, x, G=G, P=P)
C.encrypt()
```

```
t0 = time.perf_counter()
checksum = sum([C.T.query_interval([i, i]) for i in range(1, 2**N+1)])
if checksum == 10000:
    print("Time to retrieve leaves: ", round(time.perf_counter() - t0, 5), "s",␣
 ↪sep="")
else:
    print("Error", time.time() - t0)
```

```
Time to retrieve leaves: 0.16545s
```