DCS PROGRAMMING PROJECT REPORT

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Experiment Part 1

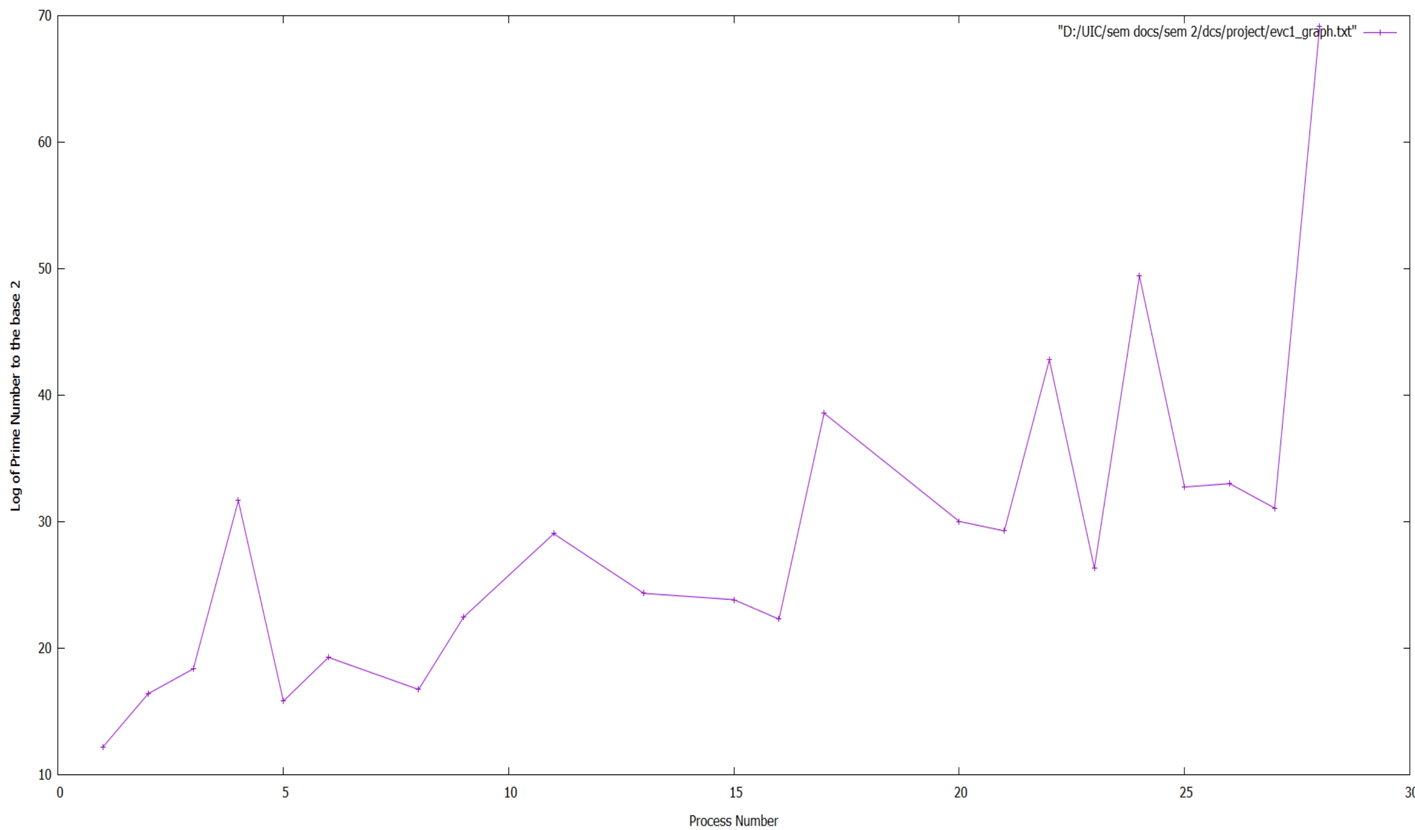
A goal of the project is to identify how fast the EVC grows, as a function of the number of events executed by a process, and the number of events executed by all the processes collectively. n is an input parameter. With n processes and assuming 32-bit integer, how many events it takes for the size of the EVC to occupy a number equal to 32n bits long. Once it equals 32n bits long, we can do a system-wide EVC reset. (Repeat the experiment assuming 64-bit integer instead of 32-bit.)

The below table helps in plotting the size of EVC in bits as a function of the number of events executed in the system. ‘n’ is an input parameter. With n = 30 processes, the below table shows the ‘Process Number’ (N) in the first column, the ‘Prime Number’ associated with the corresponding process number in the second column and the ‘Log of the prime number to the base 2’ of the corresponding process number in the third column.

Process Number	Prime number	Log base 2
1	4761	12.21704891355634
2	87025	16.40914228849841
3	337561	18.36478870680906
4	3390125123	31.65869137543058
5	57967	15.822944202454996
6	634933	19.276244836923958
8	109503	16.740610869613352
9	5768419	22.4597445305859
11	555497761	29.0492058557705
13	21169201	24.335463482206492
15	14969161	23.835490026886436
16	5134475	22.29178533786025
17	407821454881	38.569146719155256
20	1092748753	30.02531458576645
21	647959343	29.27132805138712
22	7597270400643	42.78861830894097
23	84033889	26.324467916299234
24	750562130239321	49.41496482902072
25	7191388769	32.743623258402785
26	8655490567	33.010968443482454
27	2265104507	31.07693046860764
28	650972292864256214473	69.1411580374546

By plotting a line graph of the above tabulated data, we can identify how fast the EVC grows, as a function of the number of events executed by a process, and the number of events executed by all the processes collectively.

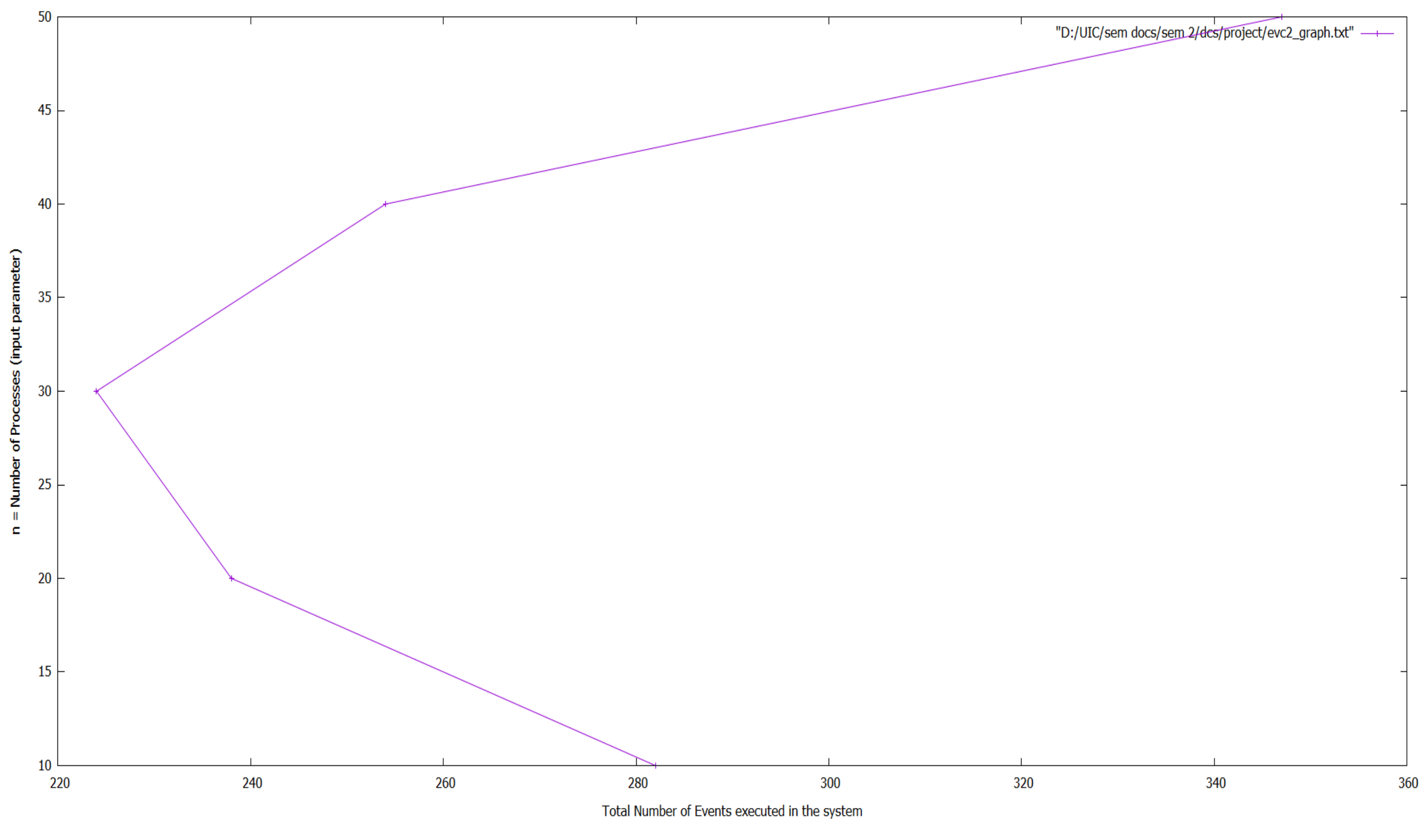
This graph is as shown below:



ANALYSIS: As seen from above graph, as the number of processes in the system increases, the logarithmic value (Y-axis) also increases. Thus, we can infer that the increase of number of processes also increases the EVC size

Now, we tabulate and then plot the (minimum) number of events executed per process, and the total number of events executed in the system, until the EVC size reaches 32n bits long, as a function of n = number of processes in the system. Again, ‘n’ is input parameter.

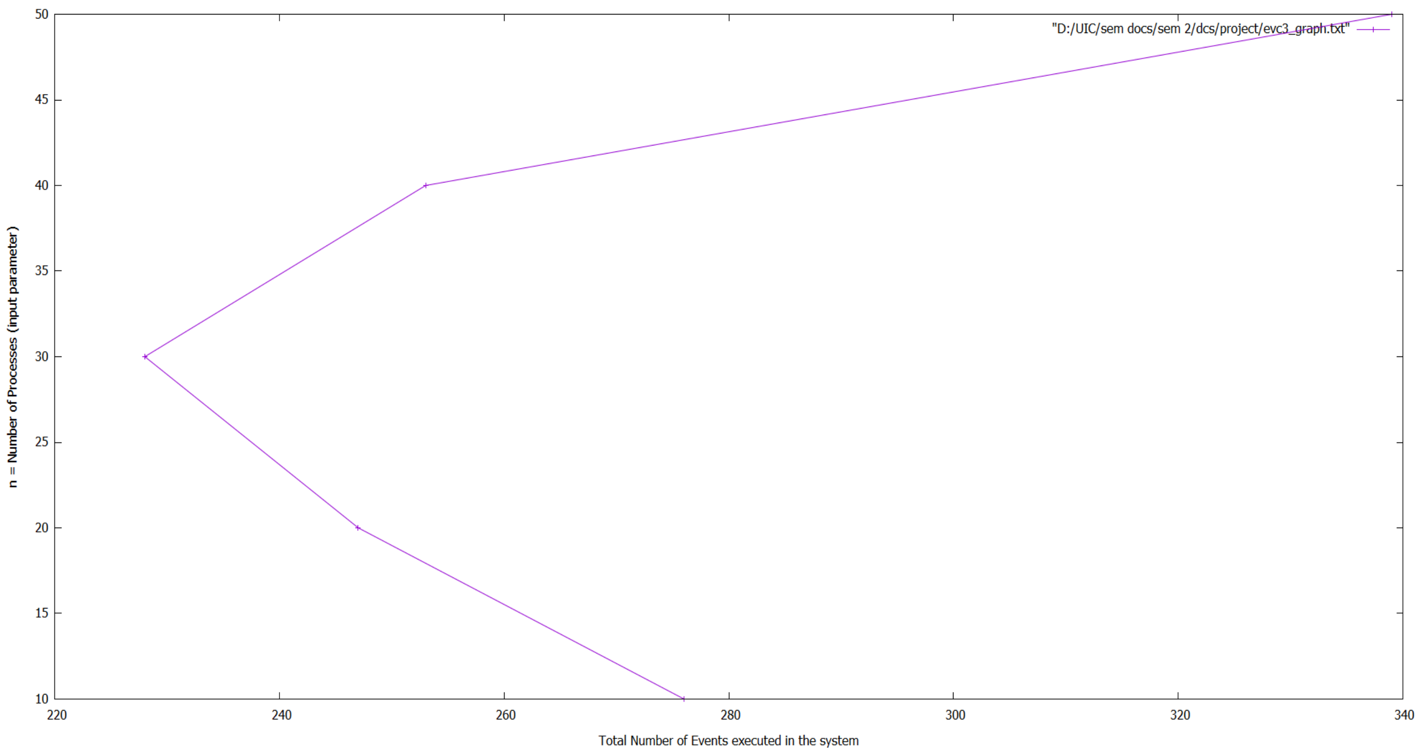
(min) number of events	Total number of events	n
9	282	10
18	238	20
13	224	30
14	254	40
47	347	50



Repeat the above experiment assuming size is 64n bits long.

Thus, we tabulate and then plot the (minimum) number of events executed per process, and the total number of events executed in the system, until the EVC size reaches 64n bits long, as a function of n = number of processes in the system. Again, ‘n’ is input parameter.

(min) number of events	Total number of events	n
11	256	10
7	237	20
15	268	30
18	243	40
21	339	50



ANALYSIS: By observing the above 2 graphs for 32-bit and 64-bit, we can conclude that as the number of processes (n) increases, the total number of events decreases at first and then increases again at approximately the same rate.

Operation of EVC ti at process Pi

- Initialize ti =1
- Before an internal event happens at process Pi, ti = ti ∗ pi (local tick).
- Before process Pi sends a message, it first executes ti = ti ∗ pi (local tick), then it sends the message piggybacked with ti .
- When process Pi receives a message piggybacked with timestamp s, it executes ti = LCM(s,ti) (merge); ti = ti ∗ pi (local tick) before delivering the message

Internal v/s Communication events

Internal v/s Communication events are represented by local ticks and shared ticks.

Local Tick: Whenever the logical time advances locally at Pi, the local component of the vector clock needs to tick. This increases the local component in the vector by 1: V [i] = V [i] + 1 While using EVC, this operation is equivalent to multiplying the EVC timestamp by the local prime number pi , Enc(V) = Enc(V) ∗ pi

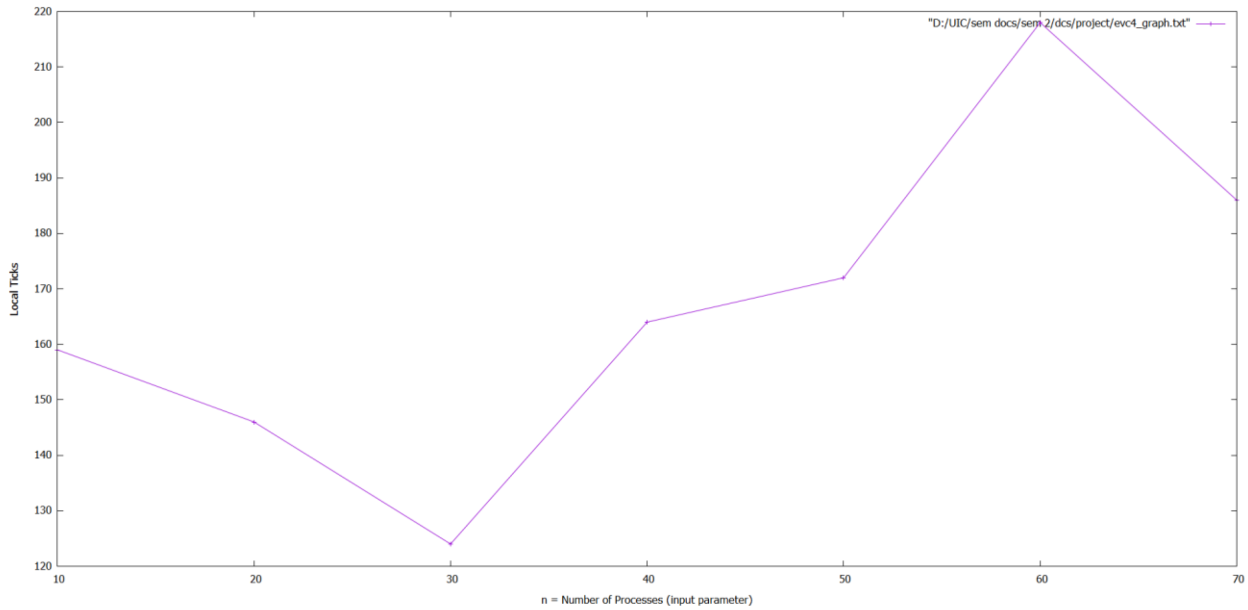
<u>Now, we vary the above graphs by varying the mix percentage of internal events (baseline case is with no internal events) and communication events.</u>

The data observed is tabulated below. ‘n’ is taken as input and it is the number of processes to be executed by the system.

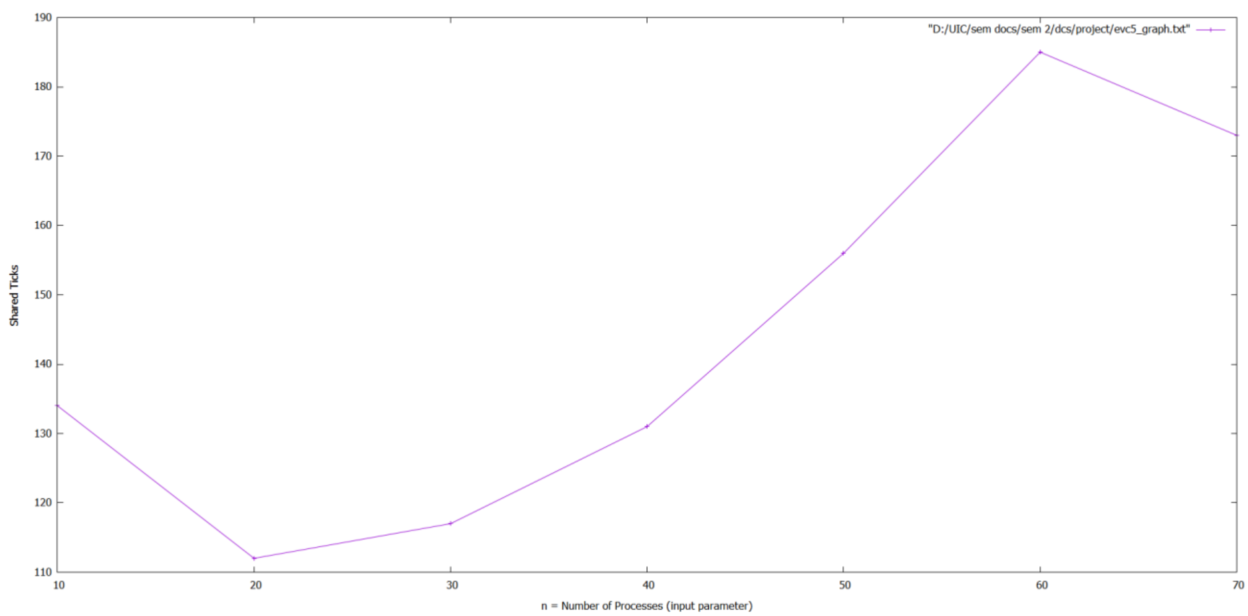
N	Local Tick	Shared Tick
10	159	134
20	146	112
30	124	117
40	164	131
50	172	156
60	218	185
70	186	173

Thus, we plot and get 2 graphs

1. The ‘n = number of processes’ v/s ‘Local Ticks’ graph



2. The ‘n = number of processes’ v/s ‘Shared Ticks’ graph



ANALYSIS: The above two graphs show similar trends. As the ‘number of processes (n)’ increases, the number of shared and local ticks decrease at first and then increase again at approximately the same rate. This decrease and then increase in number of shared and local ticks seems to be a continuing pattern as the ‘number of processes (n)’ keeps increases.

Experiment Part 2

To understand the benefits and limitations of storing and transmitting the logarithms of the EVCs (instead of the EVCs themselves). Due to finite-precision arithmetic, round-off errors may get introduced. Such errors may cause inaccuracies in the comparison test between the EVCs of two events. (Recall the comparison test, for events e and f, e ◊ f if essentially EVC(f) mod EVC(e) = 0; now implement this using logarithms as shown in the paper, Section 4.4.) An important part of understanding the limitations is being able to quantify the level of accuracy (or its complement, the error rate introduced) in the use of logarithms and anti-logarithms.

We need to quantify the errors introduced by the rounding-offs in using finite-precision mantissas in the logarithms of the EVCs.

Below, the tables present data about the number and percentages of false positives and false negatives

Distributed executions for n = 10, 20, 30, 40, 50 have been generated.

v=50, base value (b) = 2, m = 32, 64, 128, 512, 1024 are set.

The percentage rate of errors (false positives and false negatives), for various n and m is calculated.

Error Rate of FP : FP / (FP + TN)

Error Rate of FN : FN / (FN + TP)

M= 32

N	10	20	30	40	50
FP	1549	7048	19352	35391	74764
FP Error Rate	1.3519174	1.5776161	1.9029845	1.9803394	2.696253
FN	1715	13503	21932	33266	56412
FN Error Rate	22.310394	32.291466	29.833773	23.07863	22.492374

M= 64

N	10	20	30	40	50
FP	1215	4725	9329	30053	45637
FP Error Rate	1.070796	1.041033	0.92599857	1.7103361	1.6418189
FN	1896	7371	17184	19334	40952
FN Error Rate	24.27346	21.871105	22.208149	10.580059	16.648983

M= 128

N	10	20	30	40	50
FP	1410	5885	9221	19930	31327
FP Error Rate	1.2315809	1.2930144	0.9104535	1.1211324	1.146076
FN	1410	7285	10873	26272	27577
FN Error Rate	17.045454	23.911118	13.5592165	18.57755	9.452627

M= 512

N	10	20	30	40	50
FP	2004	6583	8172	10870	15396
FP Error Rate	1.7326796	1.4346018	0.8064437	0.6146417	0.555635
FN	2638	7312	8172	13477	20544
FN Error Rate	34.825085	24.625332	10.454807	8.119995	7.934528

M= 1024

N	10	20	30	40	50
FP	1564	4475	7538	7416	6.911157
FP Error Rate	1.3505461	0.98548305	0.75096285	0.41448507	0.5380928
FN	1390	4868	10005	18007	21606
FN Error Rate	20.182953	13.726982	11.215991	11.893188	6.9111557

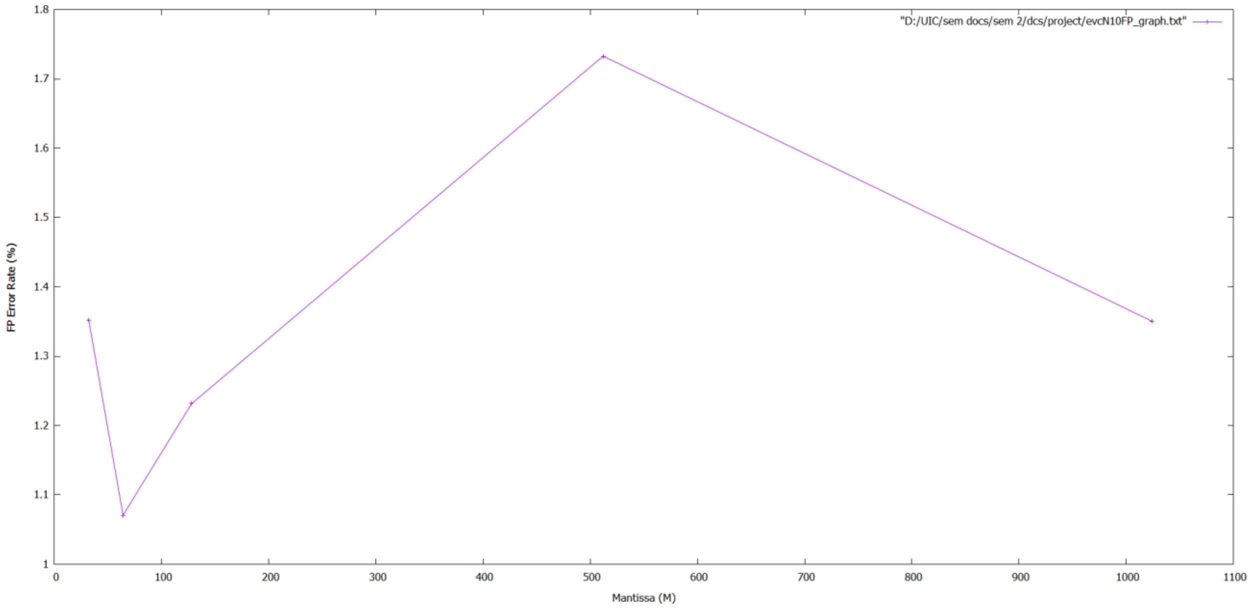
An important part of understanding the limitations is being able to quantify the level of accuracy (or its complement, the error rate introduced) in the use of logarithms and anti-logarithms.

Now we need to plot the percentage error rate (or degree of accuracy) of false negatives and false positives of the causality relation, for various n and m

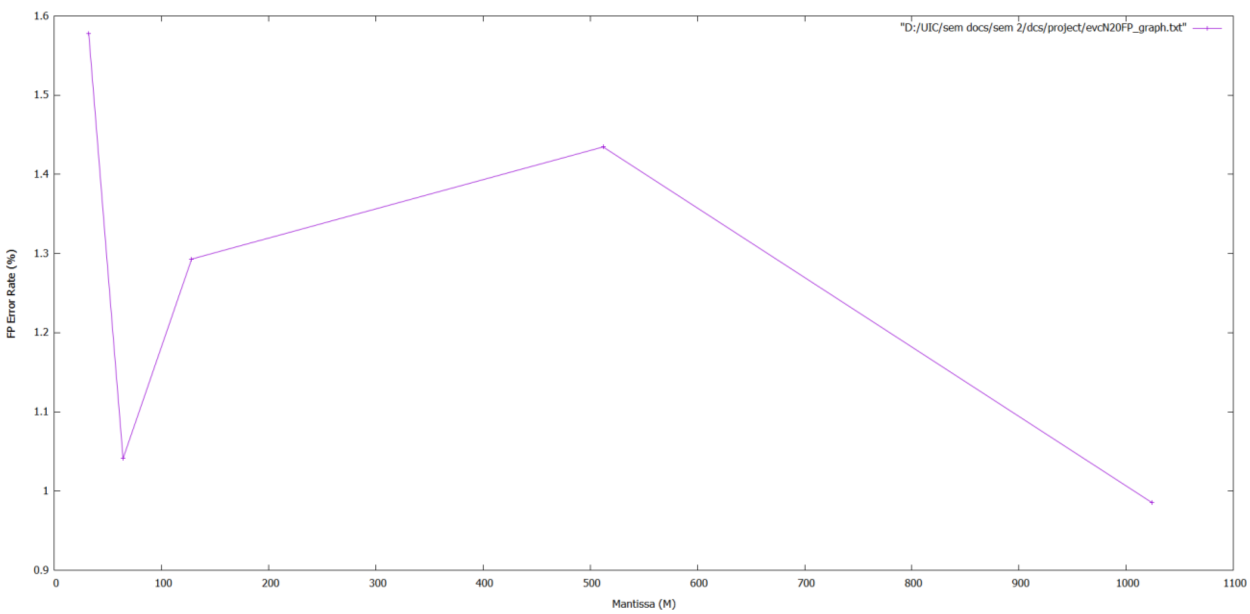
Using the above tables, we get generate the following table and plot its line graphs:

Mantissa (M) v/s FP%

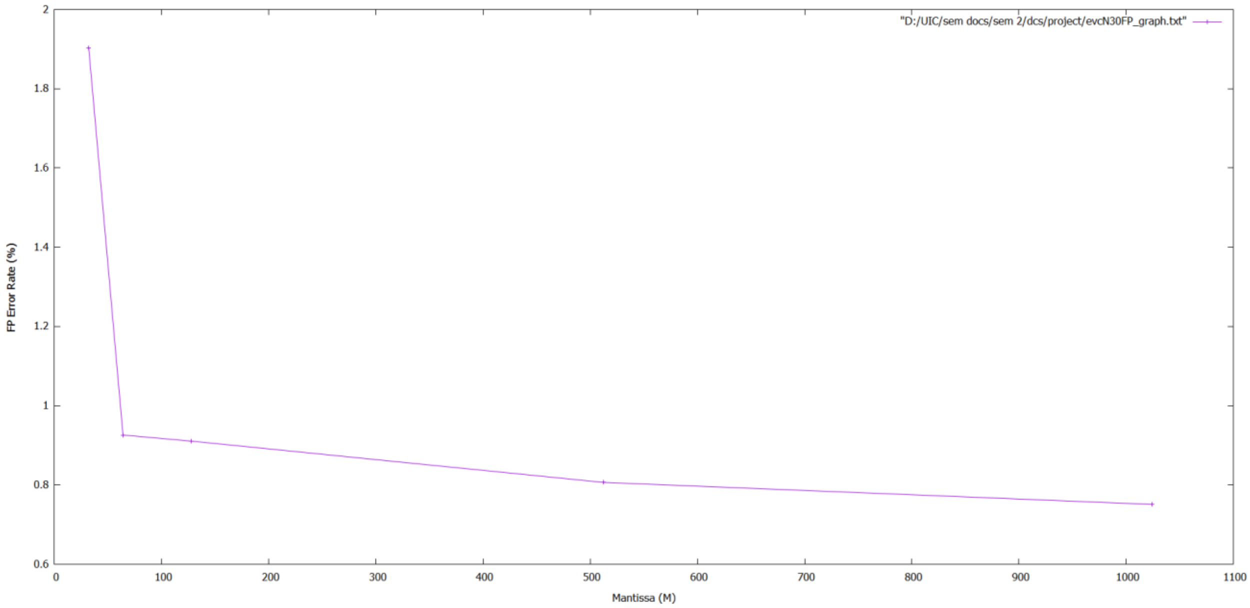
For N = 10



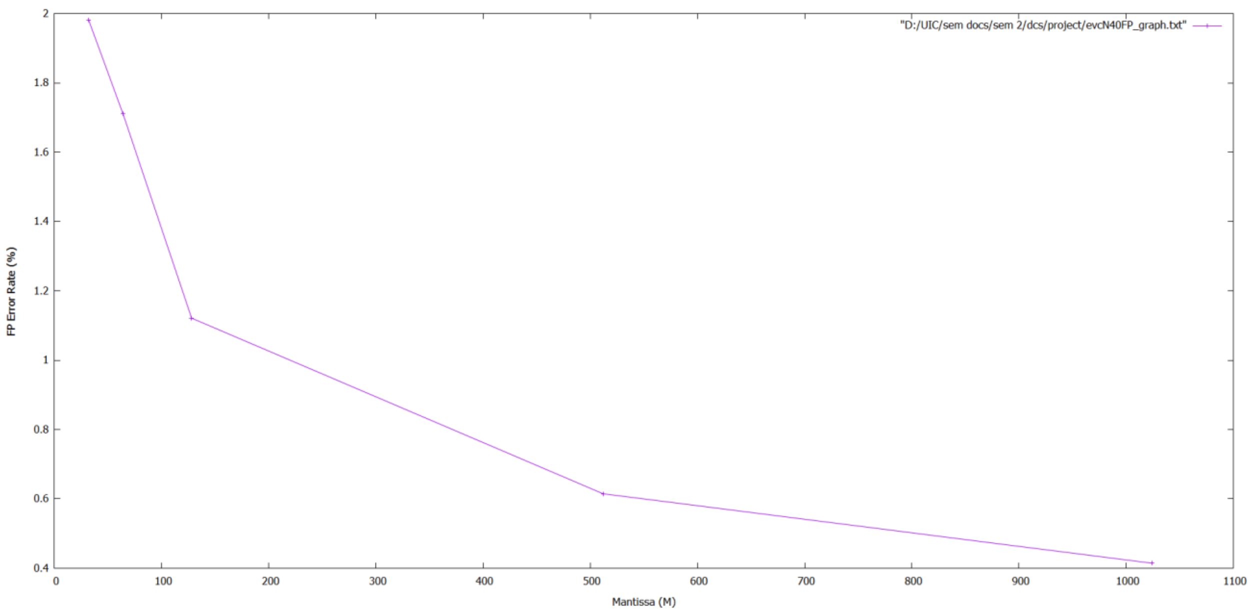
For N = 20



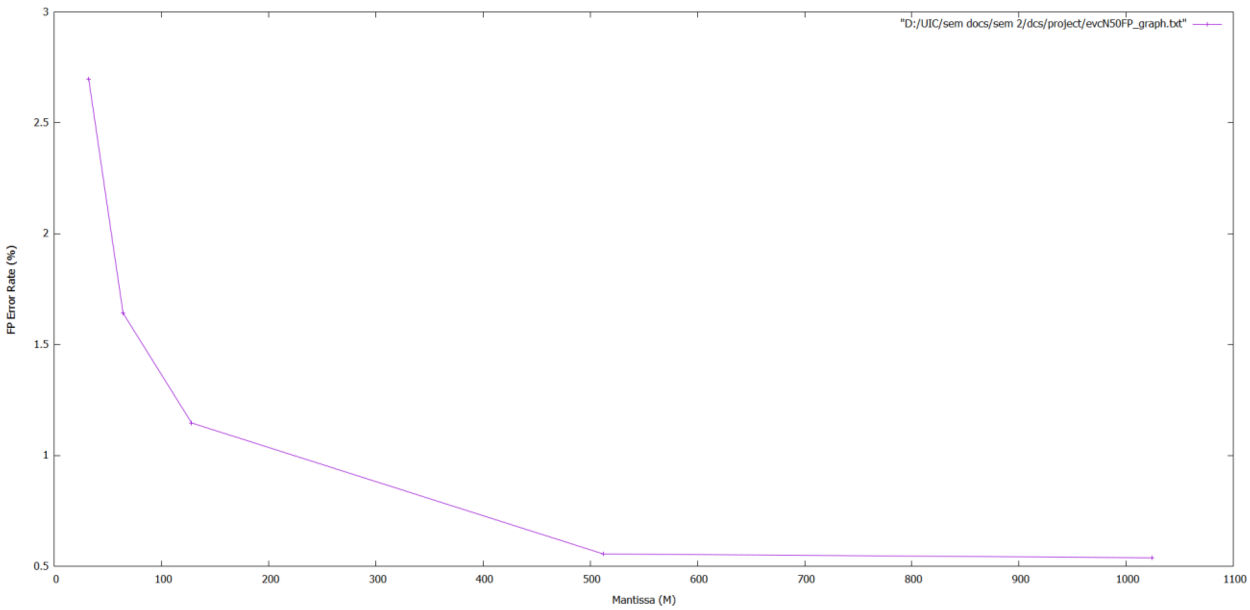
For N = 30



For N = 40



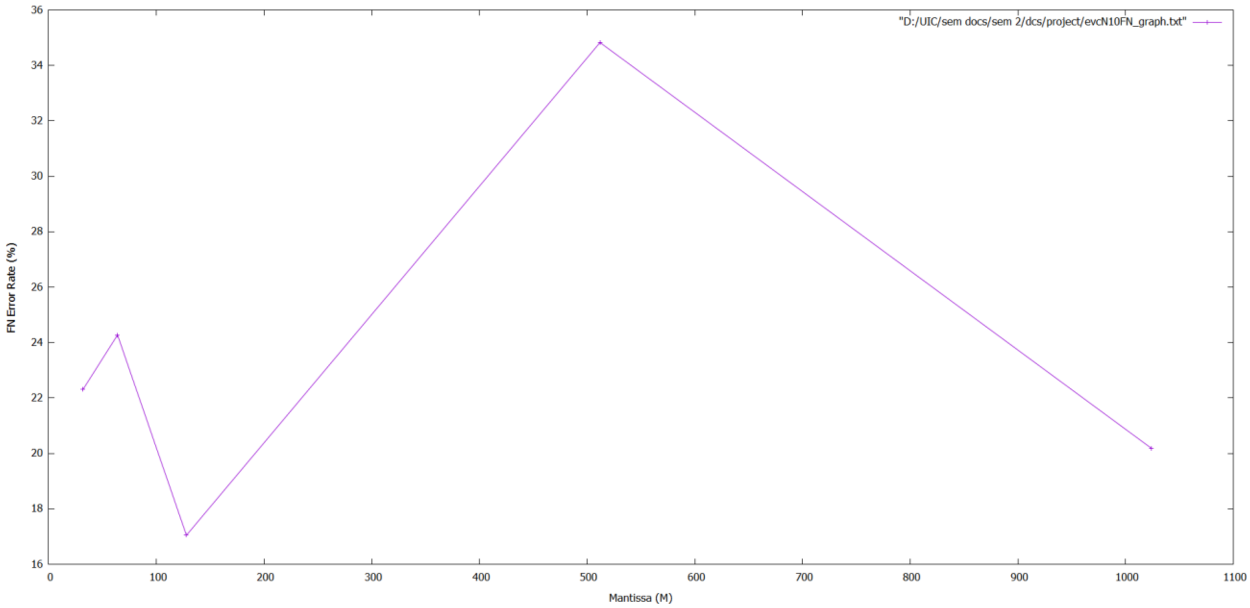
For N = 50



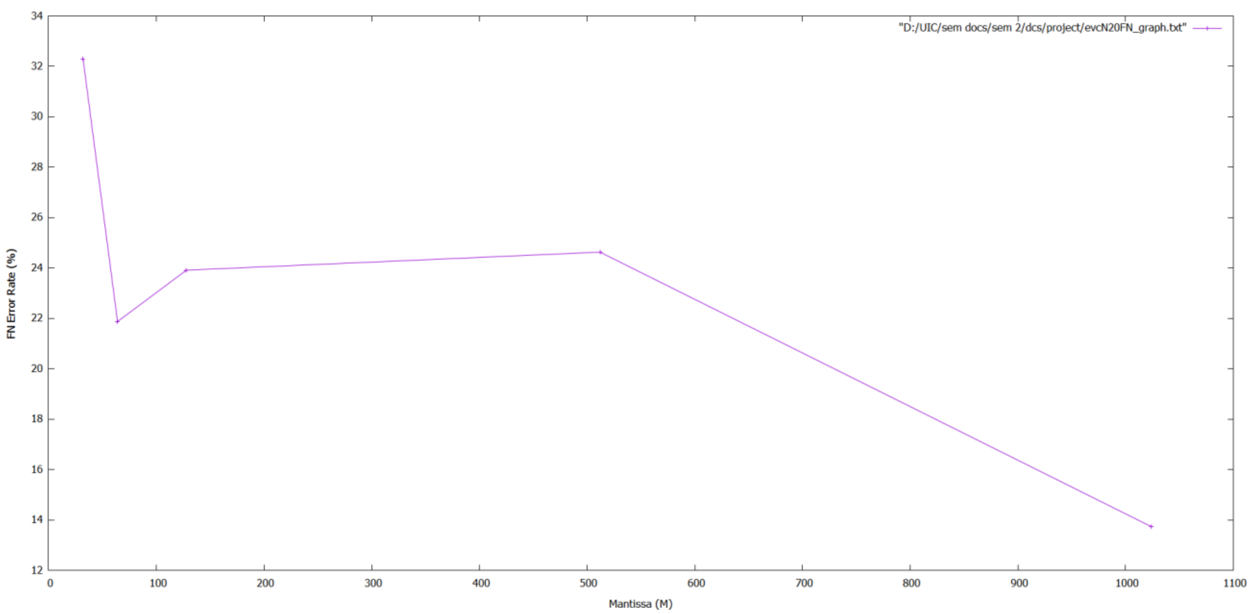
ANALYSIS: We observe the above 5 graphs and can conclude that as the mantissa (m) increases, the False Positive Error Rate (%) decreases. This is the case in all the graphs above for n = 10, 20, 30, 40, 50

Mantissa (M) v/s FN%

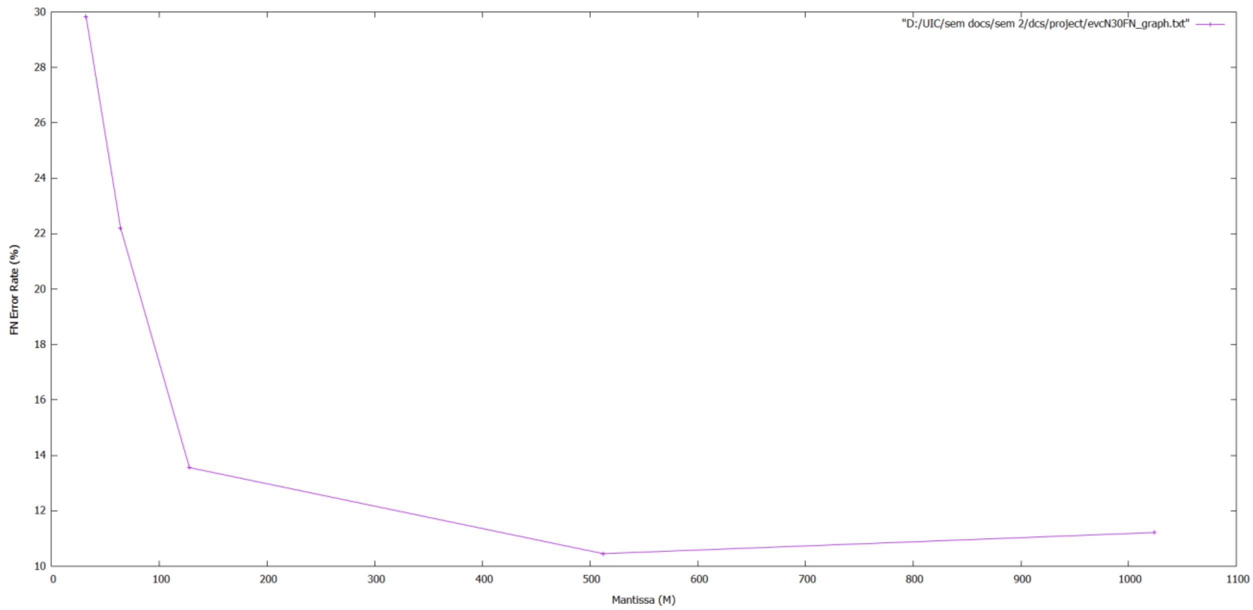
For N = 10



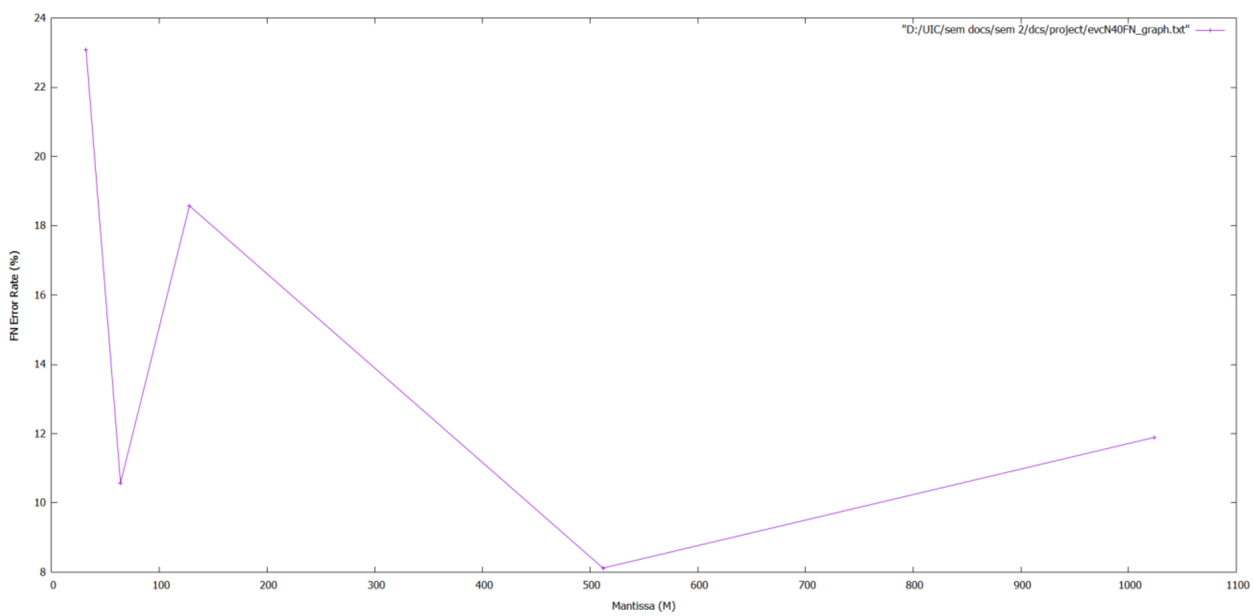
For N = 20



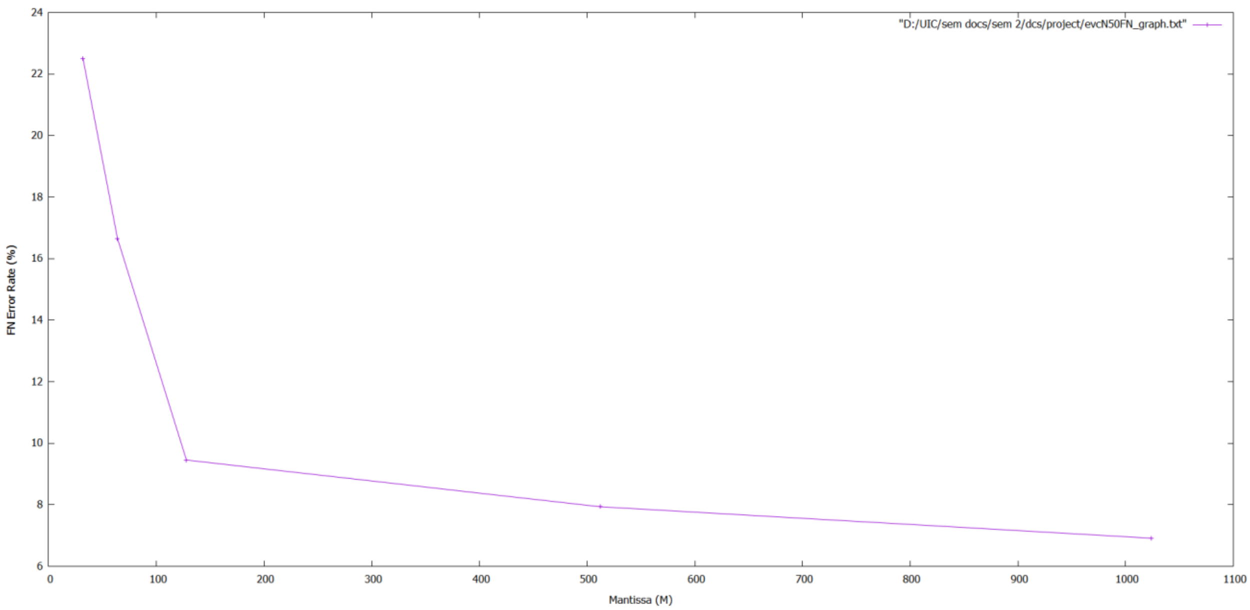
For N = 30



For N = 40



For N = 50



ANALYSIS: We observe the above 5 graphs and can conclude that as the mantissa (m) increases, the False Negative Error Rate (%) decreases. This is the case in all the graphs above for n = 10, 20, 30, 40, 50