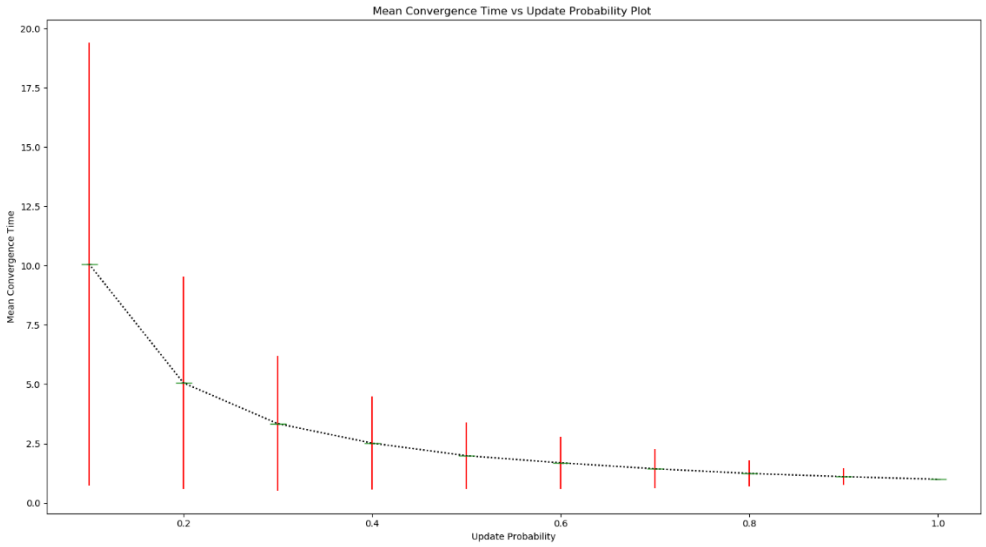
IISC Summer Report

Arth Banka

1. Probabilistic Toggle Switch

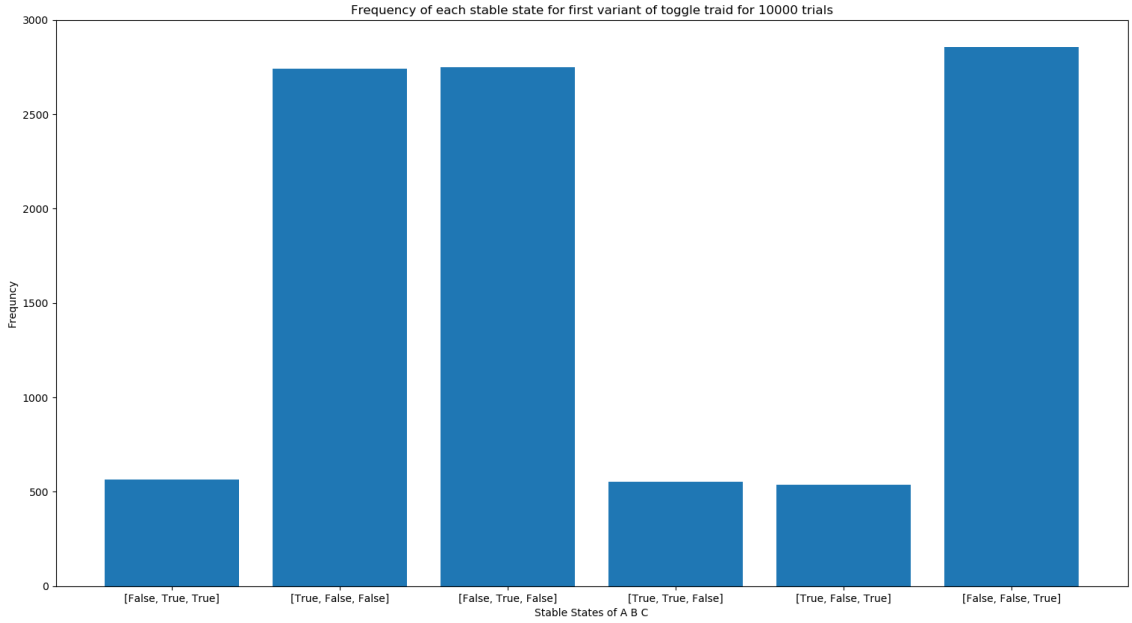


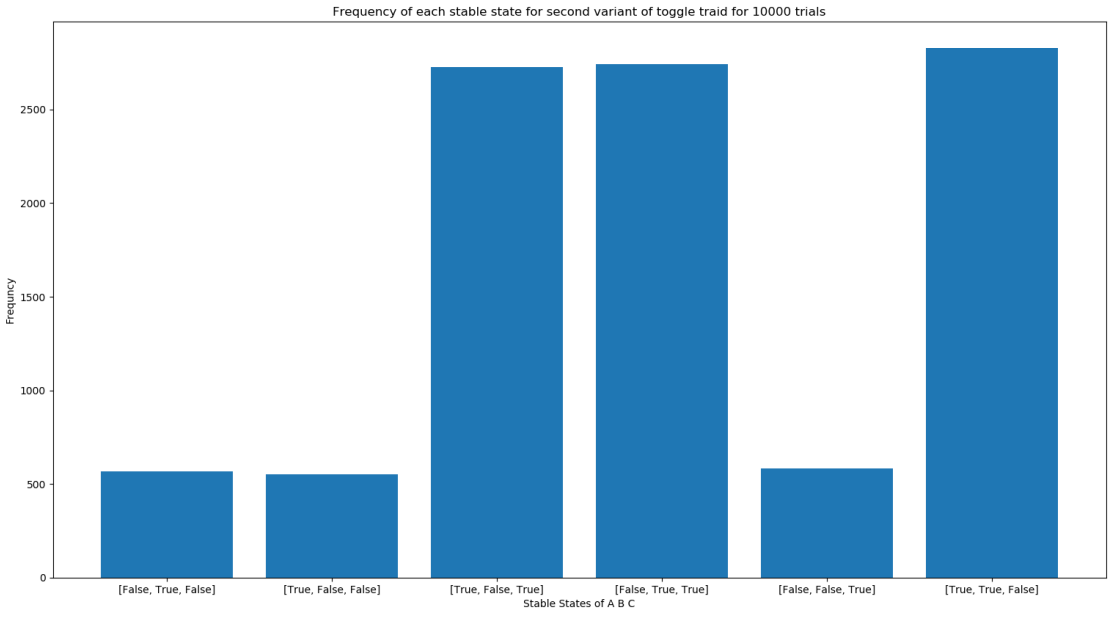
The Probabilistic Toggle Switch randomly chooses one of the nodes and updates. The probability of update was varied from 0.1 to 1 in steps of 0.1 and the result showed that the time of convergence to a one high – one low state was directly proportional to the update probability. The error bars here were calculated for sample standard deviation and actual error bars would be smaller than the ones shown in the figure above.

2. Toggle Triad

There are two forms of toggle triad that we will consider
Form 1:
A = !B & !C ; B = !C & !A ; C = !A & !B
Form 2:
A = !B | !C ; B = !C | !A ; C = !A | !B

The frequency distribution of the various stable states in both the forms of toggle triads per 10,000 simulations has been shown below.

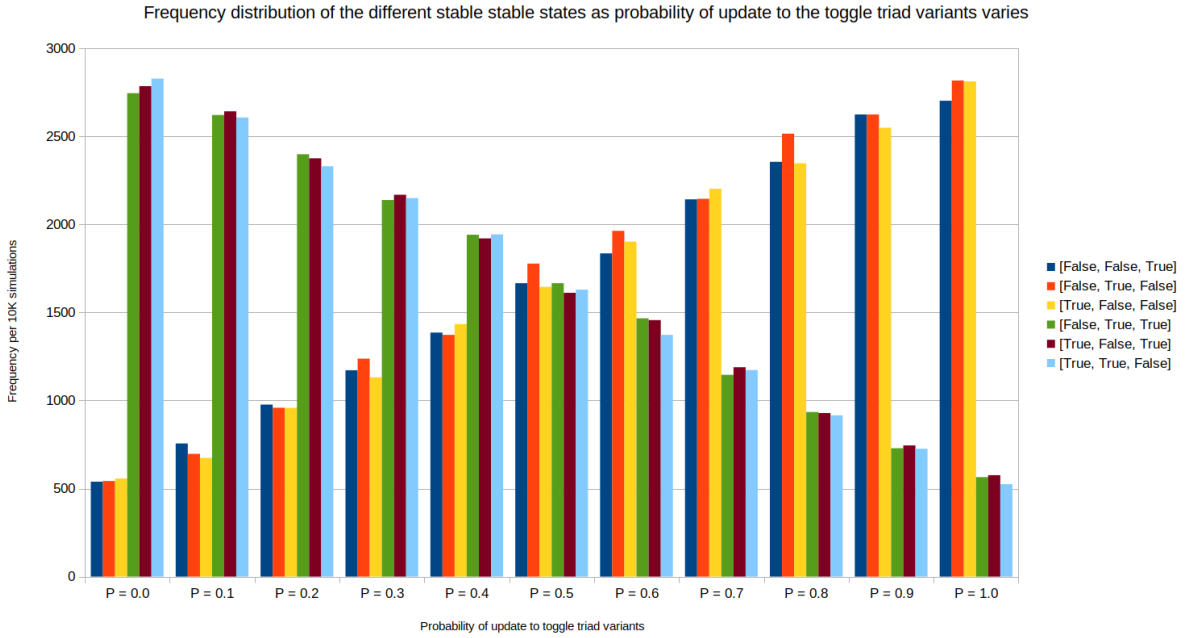




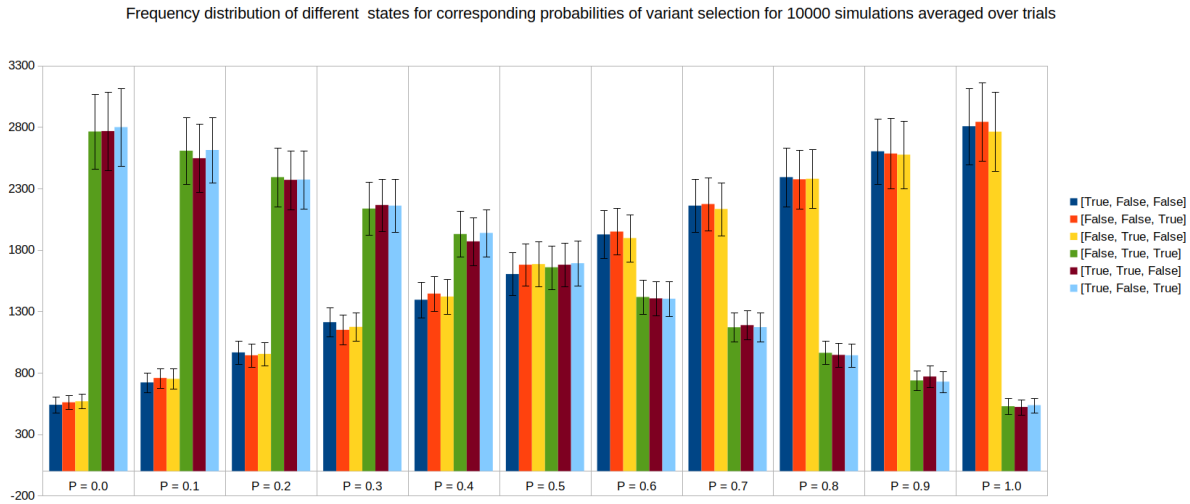
3. Probabilistic Toggle Triad

The Toggle Triad (TT) was randomly updated after selecting one of the three nodes either through the state transition rules of TT form 1 or form 2. The probability of using transition rules of TT form 1 is denoted

by P in the graphs below. P was varied from 0.1 to 1 in time steps of 0.1 and the frequency distribution obtained has been plotted below.



The graph follows an expected trend (from TT simulations).

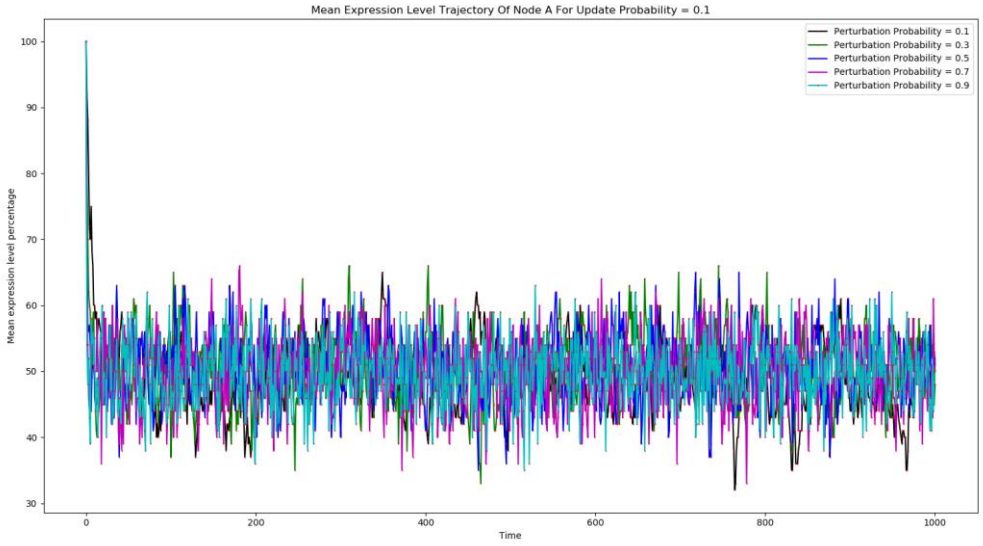


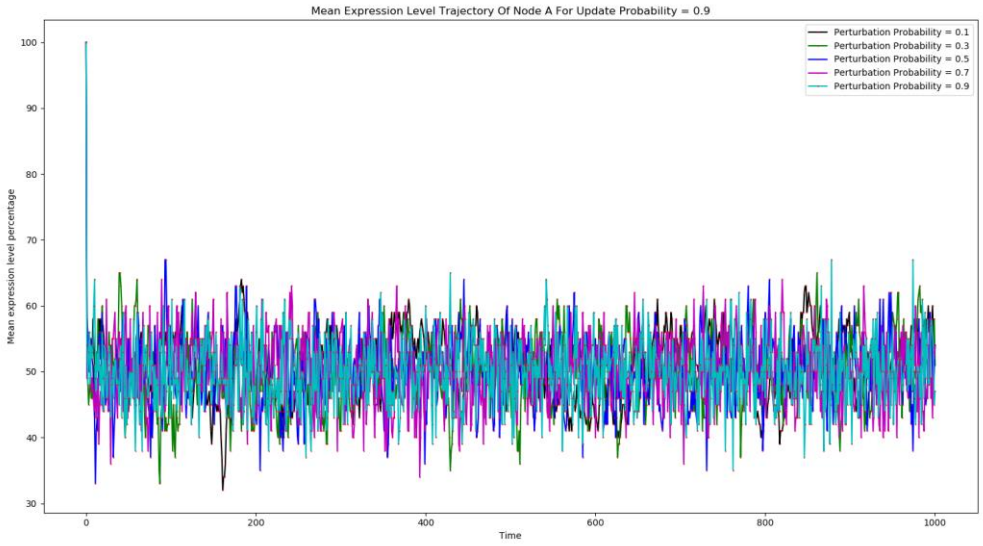
The error bars for the simulations were small and insignificant.

4. Perturbed Probabilistic Toggle Switch

Perturbation probability was added to the probabilistic toggle switch system and the perturbation probability was varied from 0.1 to 0.9 in

steps of 0.2. The two scenarios of update probability 0.1 and 0.9 have been plotted in the graphs below.





The system was tested for all different initial states as well as a random selection of initial states and it was inferred that the initial state of the nodes didn't affect the node state trajectory.

The mean residence time for different states were also calculated.

```
STATE   MRT     STD. DEV

P_update=0.1    P_perturb = 0.1
00      159.34  31.586459124124694
01      343.45  56.564896358077064
10      333.82  52.413047993796354
11      164.39  32.809113063293864

P_update=0.1    P_perturb = 0.3
00      205.89  21.352702405082127
01      290.75  29.30951210784649
10      289.88  30.901223276757182
11      214.48  20.056161148136002

P_update=0.1    P_perturb = 0.5
00      223.14  18.74034151236311
01      273.49  21.8766976484112
10      276.84  22.22328508569334
11      227.53  18.214529914329383

P_update=0.1    P_perturb = 0.7
00      230.21  15.087276096101641
01      268.64  15.9025281009027
10      268.68  17.615833786681797
11      233.47  14.452304314537527

P_update=0.1    P_perturb = 0.9
00      234.4   11.656757696718243
01      265.96  12.479519221508495
10      263.46  12.6161959401398
11      237.18  11.239555151339399
```

```
STATE    MRT      STD. DEV

P_update=0.9     P_perturb = 0.1
00       5.25     2.299456457513384
01       488.06   66.1686965263787
10       501.35   65.94033287753406
11       6.34     2.1317598363793233

P_update=0.9     P_perturb = 0.3
00       15.13    4.021579291770833
01       489.39   38.87155643912397
10       480.2    39.11035668464301
11       16.28    3.9826624260662618

P_update=0.9     P_perturb = 0.5
00       24.6     5.524490926773253
01       472.49   26.080833959058904
10       477.72   25.834504059493767
11       26.19    5.319201067829641

P_update=0.9     P_perturb = 0.7
00       32.33    5.52096911782705
01       466.62   19.115846829267074
10       467.25   19.798674198036593
11       34.8     5.280151512977634

P_update=0.9     P_perturb = 0.9
00       42.47    6.378800827741841
01       458.94   13.45794932372685
10       457.14   14.643783664067152
11       42.45    5.286539510870982
```

5. Toggle Triad + Self Activation

The equations for the AND and OR variants of the toggle triad along with self-activations respectively have been shown below. The node trajectories have been plotted as well.

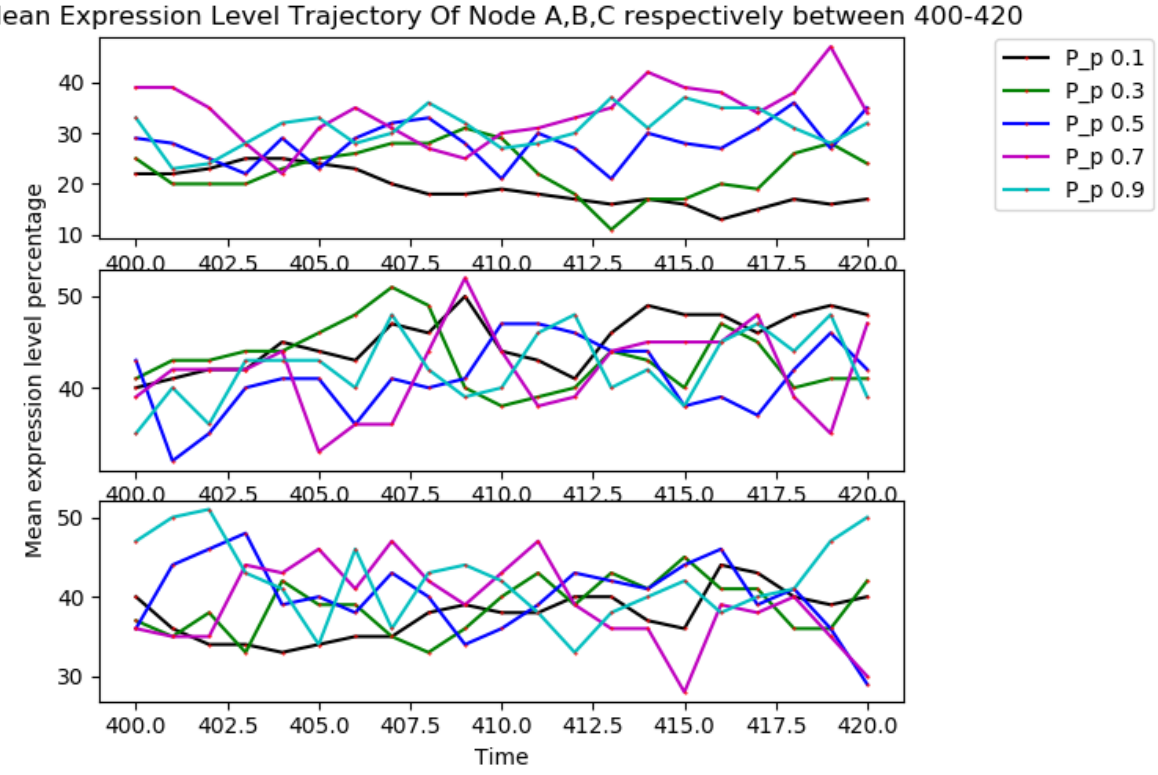
TT + 1 SA: A = !B & !C & A, B = !A & !C, C = !A & !B //

A = !B | !C | A, B = !A | !C, C = !A | !B

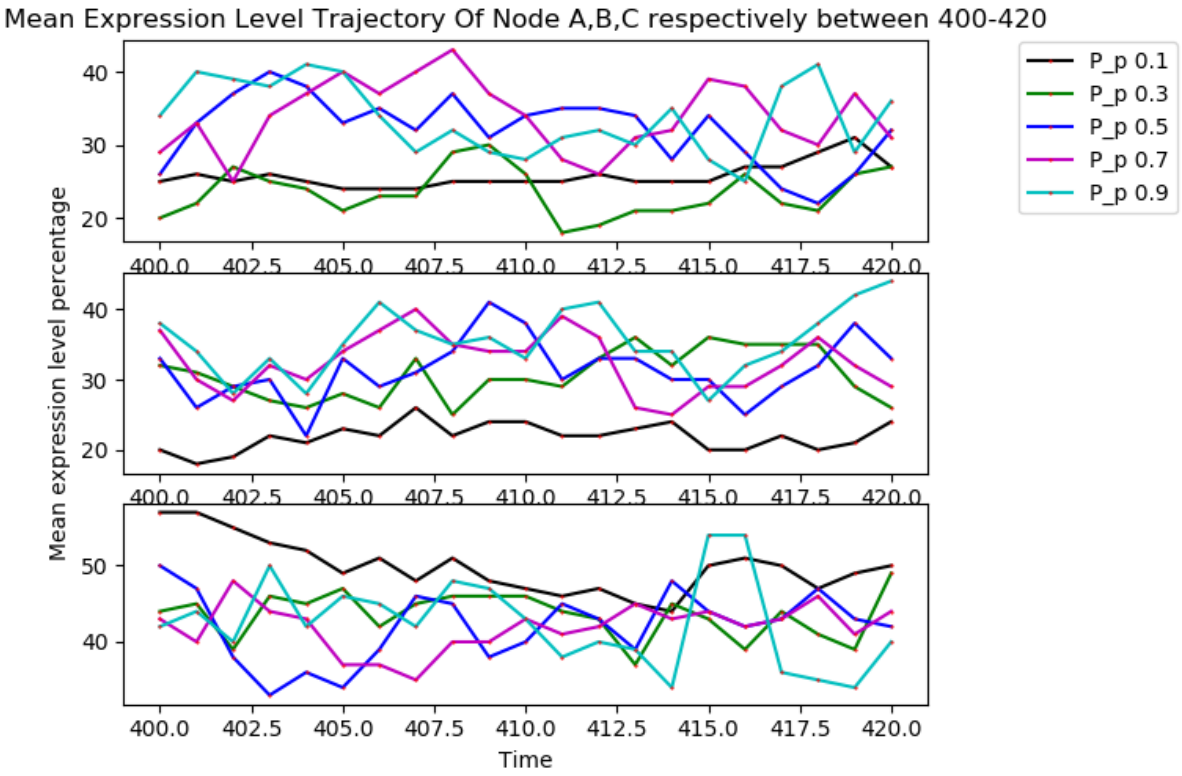
TT + 2 SA: A = !B & !C & A, B = !A & !C &B, C = !A & !B //
A = !B | !C | A, B = !A | !C | B, C = !A | !B

TT + 3 SA: A = !B & !C & A, B = !A & !C &B, C = !A & !B & C //
A = !B | !C | A, B = !A | !C | B, C = !A | !B | C

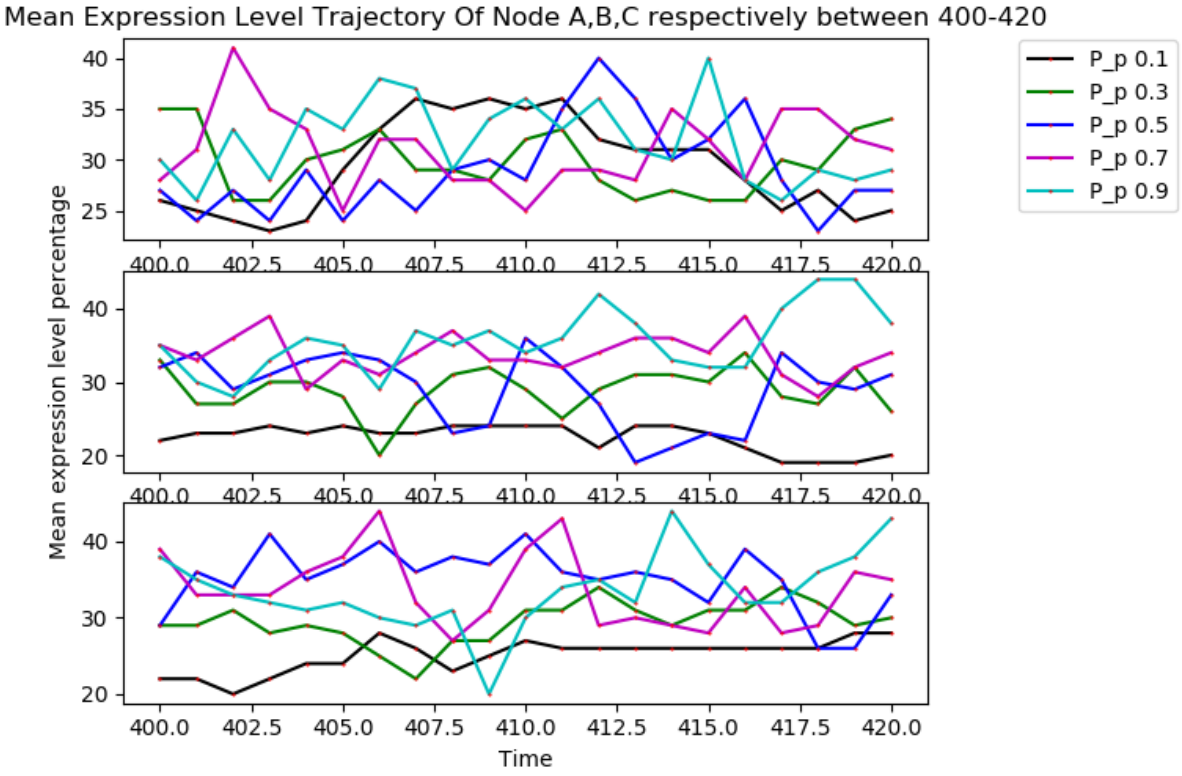
For TT + 1 SA (AND) at 0.9 Update Probability



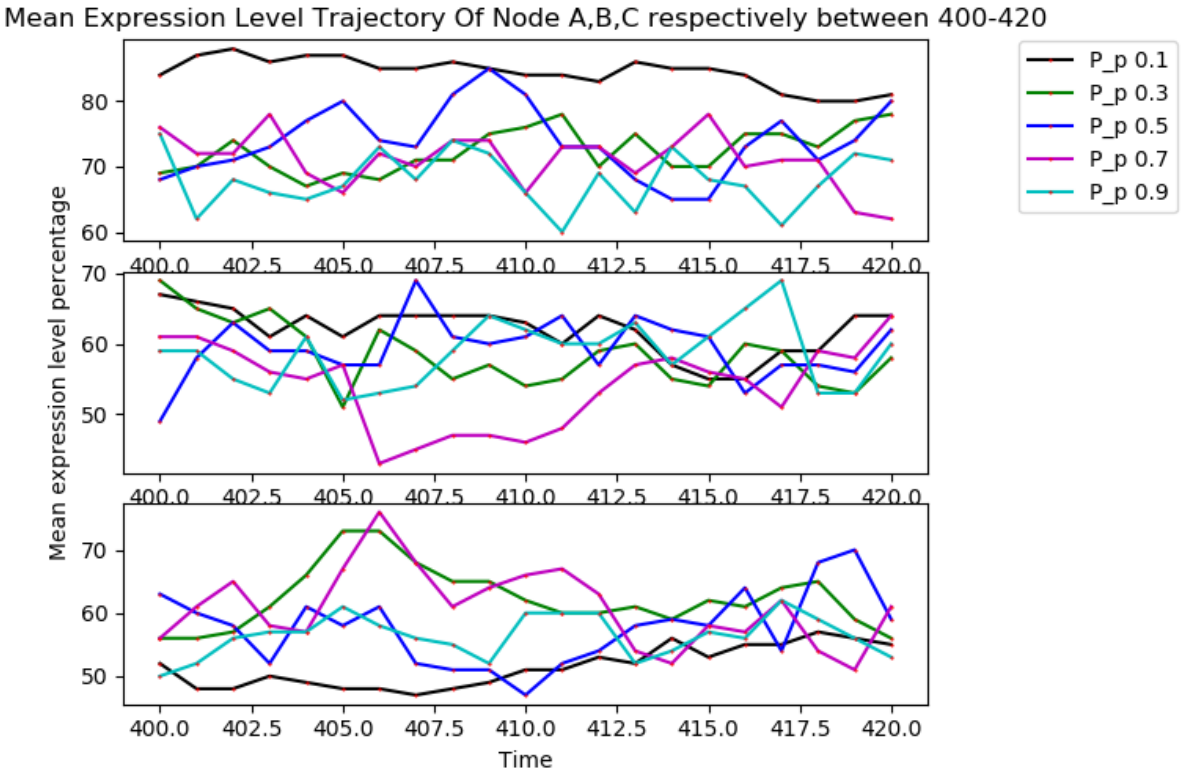
For TT + 2 SA (AND) at 0.9 Update Probability



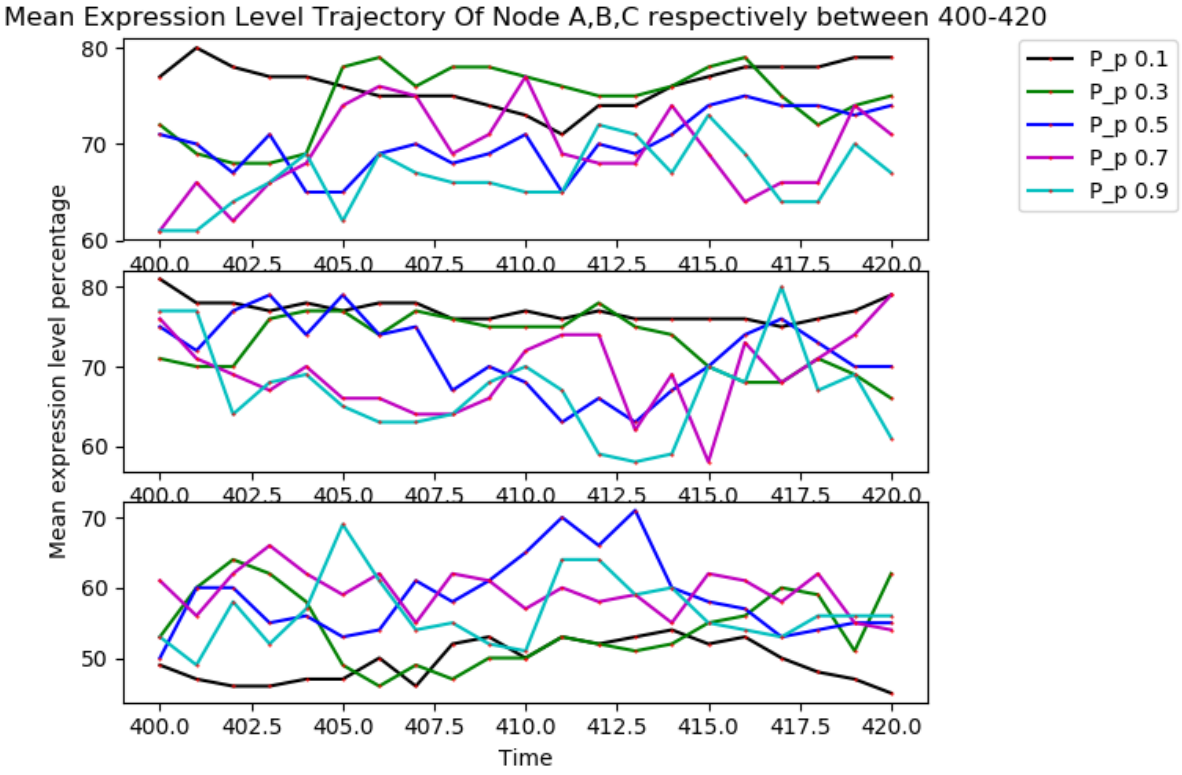
For TT + 3 SA (AND) at 0.9 Update Probability



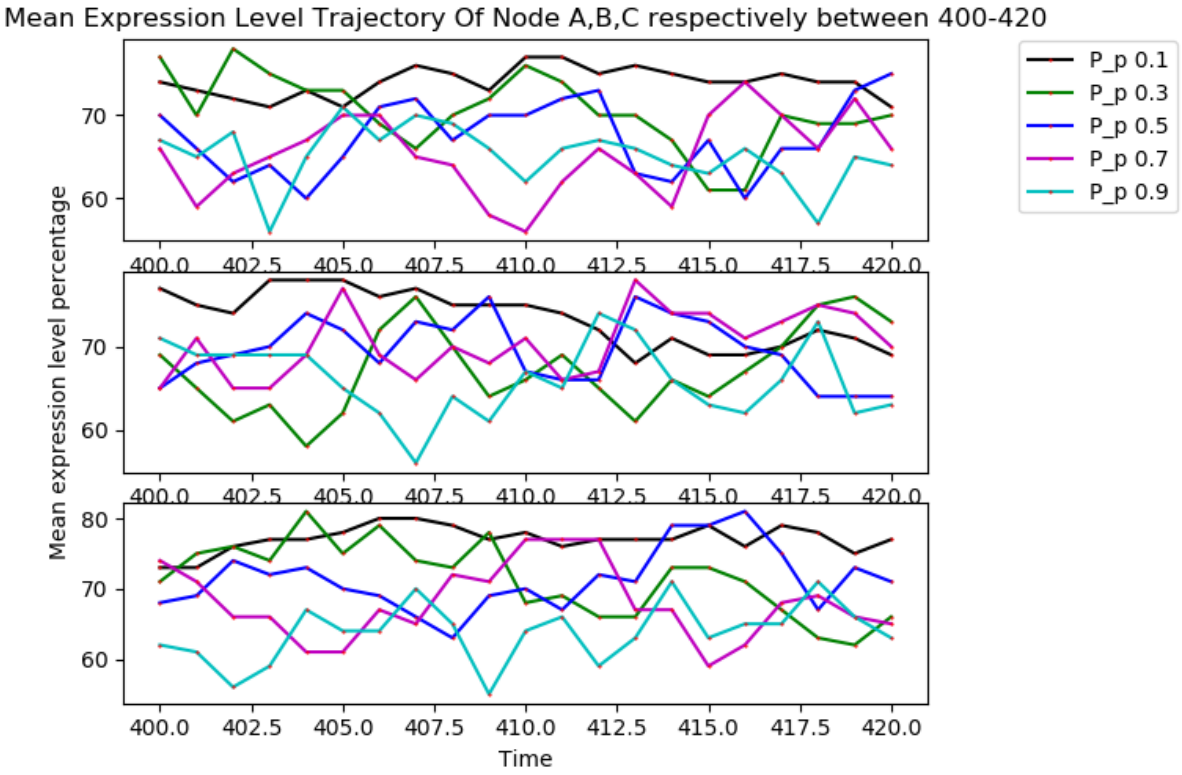
For TT + 1 SA (OR) at 0.9 Update Probability



For TT + 2 SA (OR) at 0.9 Update Probability



For TT + 3 SA (OR) at 0.9 Update Probability



6. Asymmetric Networks with Two Nodes

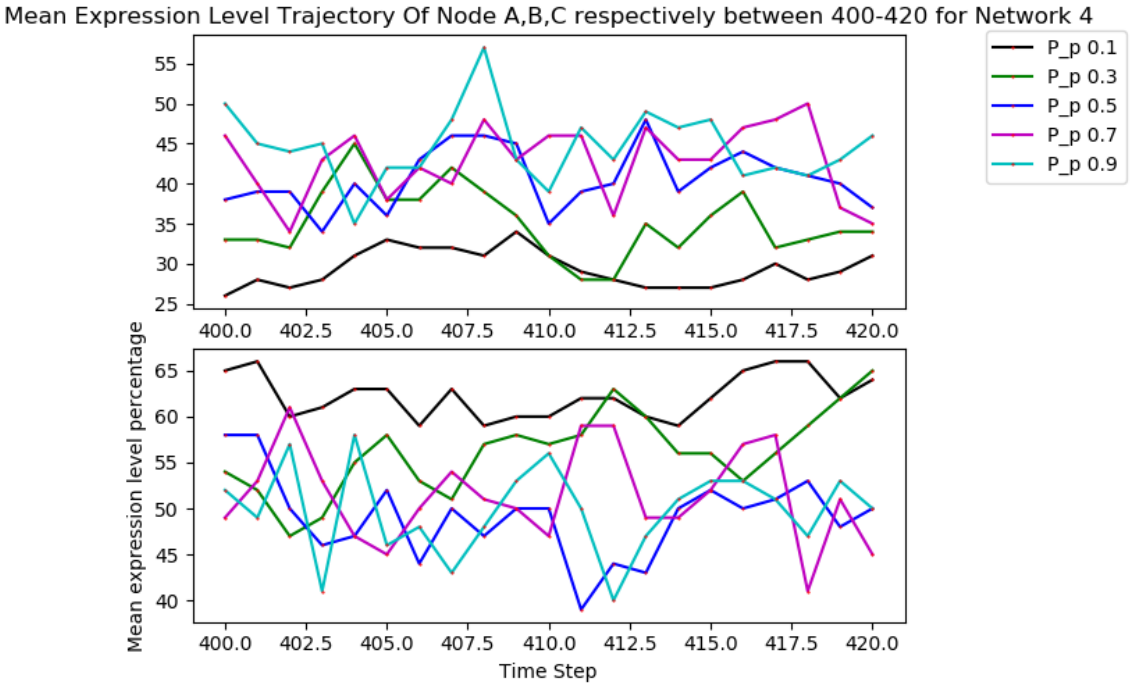
Network 4:

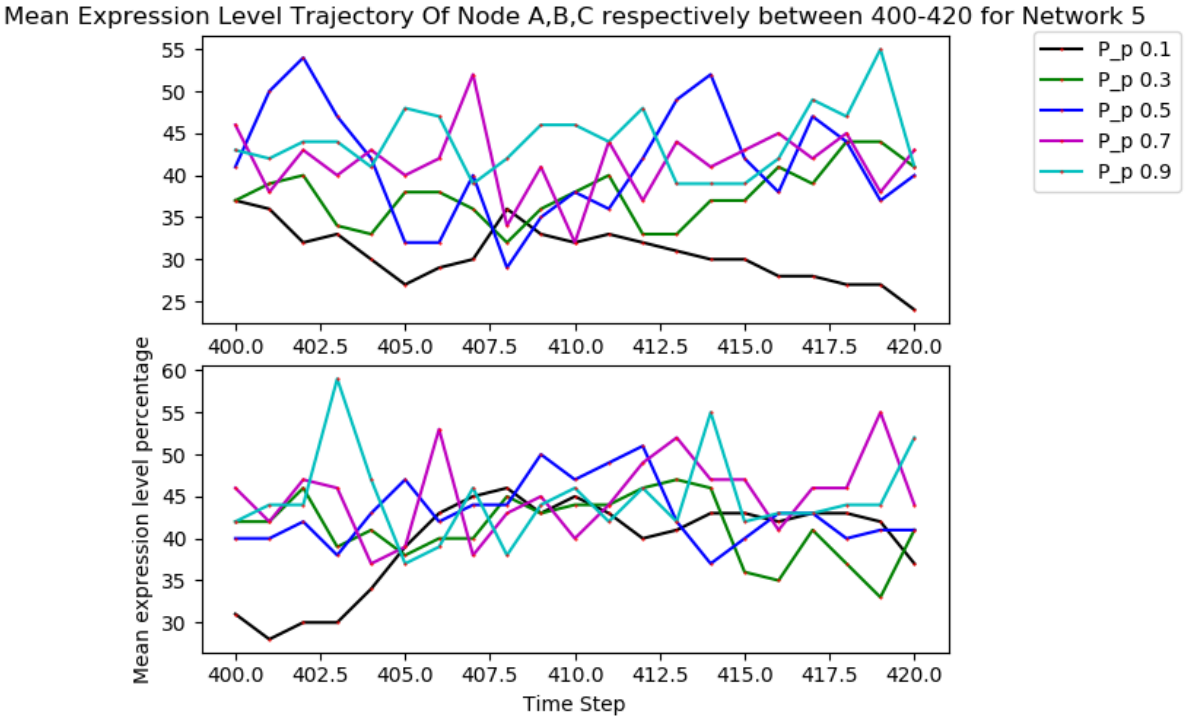
A = !B & A ; B = !A

Network 5:

A = !B & A ; B = !A & B

The mean node expression for the networks above have been plotted. The update probability has been set to 0.9 and perturbations have been varied from 0.1 to 0.9 in steps of 0.2, the trajectory has been zoomed in as well. The update probability follows a normal distribution with mean = 0.4 and standard deviation = 0.1





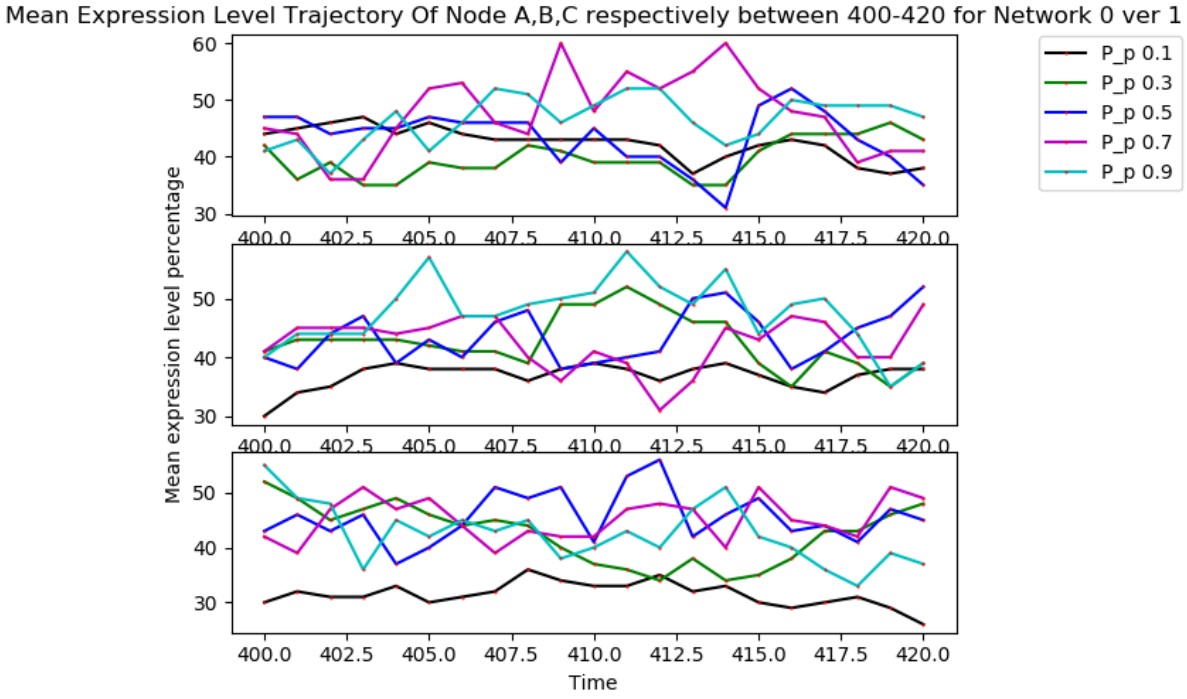
7. **Three Node Networks with Normal Distribution of Update Probability**
   Network 0 version 1 and version 2 refer to toggle triads AND & OR variants.

Network 1
A = !B & !C ; B = C & !A ; C = !A & B

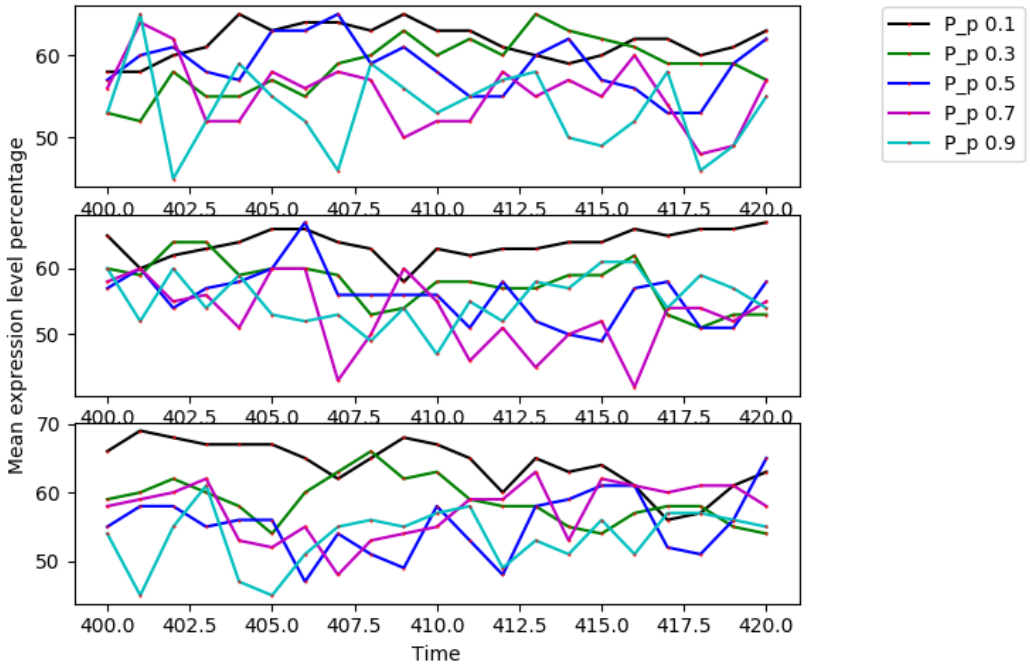
Network 2
A = !B & !C ; B = C & !A ; C = !A

Network 3
A = !B & !C ; B = !C & !A ; C = !A

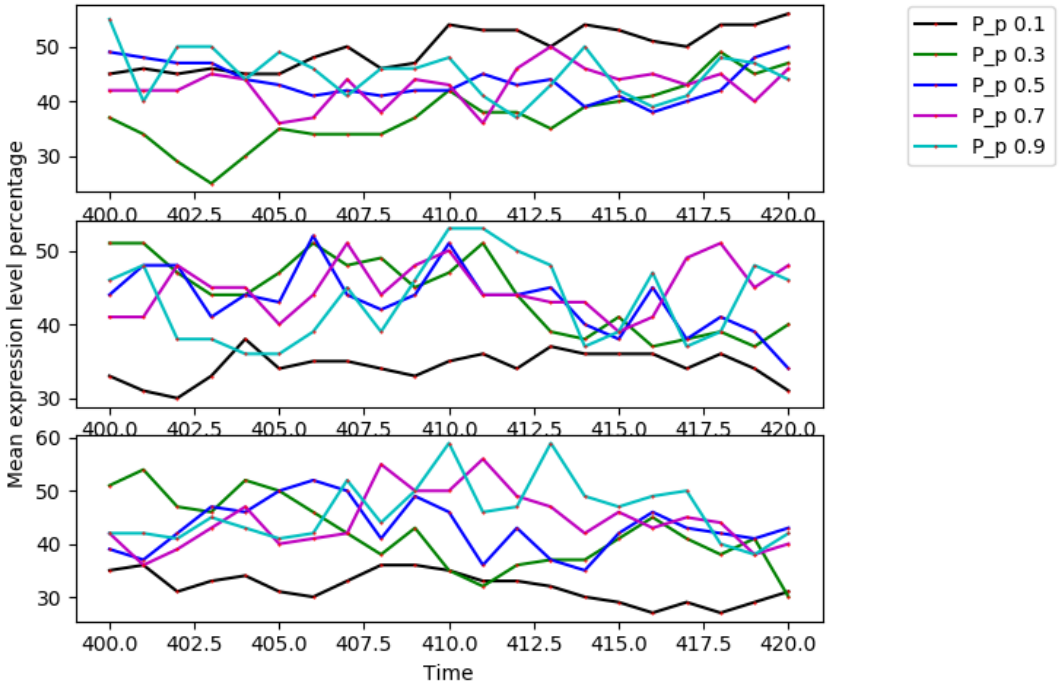
The mean node expression for the networks above have been plotted. The update probability has been set to 0.9 and perturbations have been varied from 0.1 to 0.9 in steps of 0.2, the trajectory has been zoomed in as well. The update probability follows a normal distribution with mean = 0.4 and standard deviation = 0.1

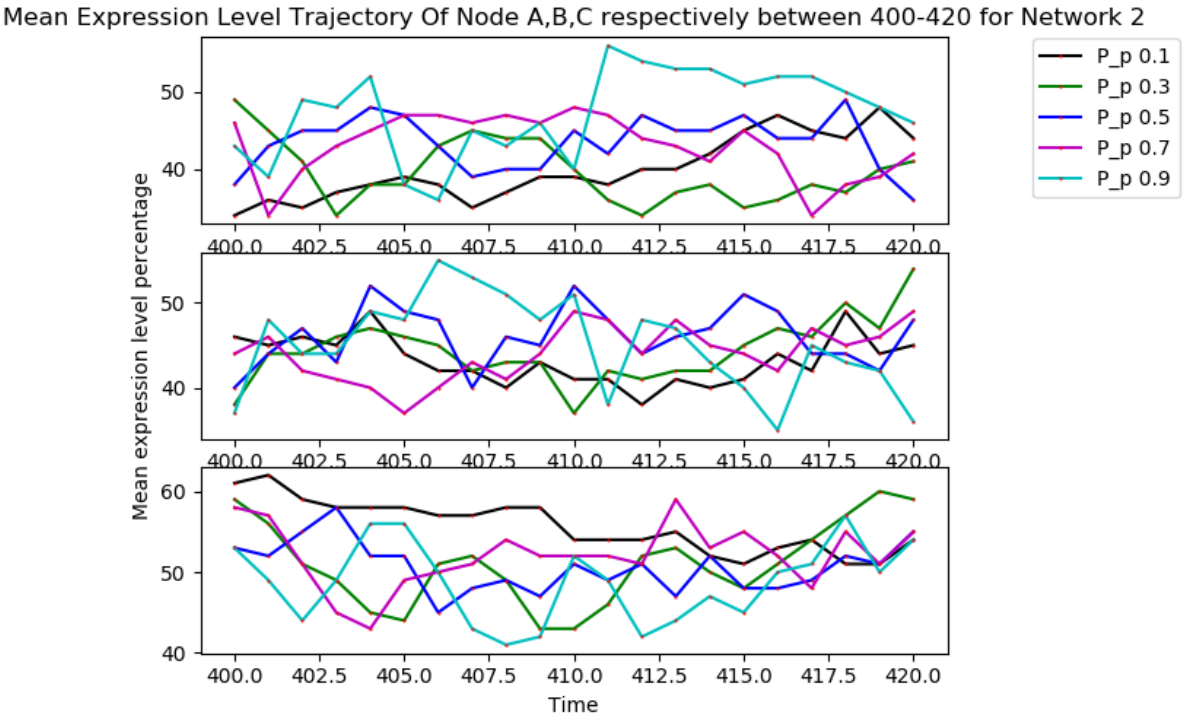


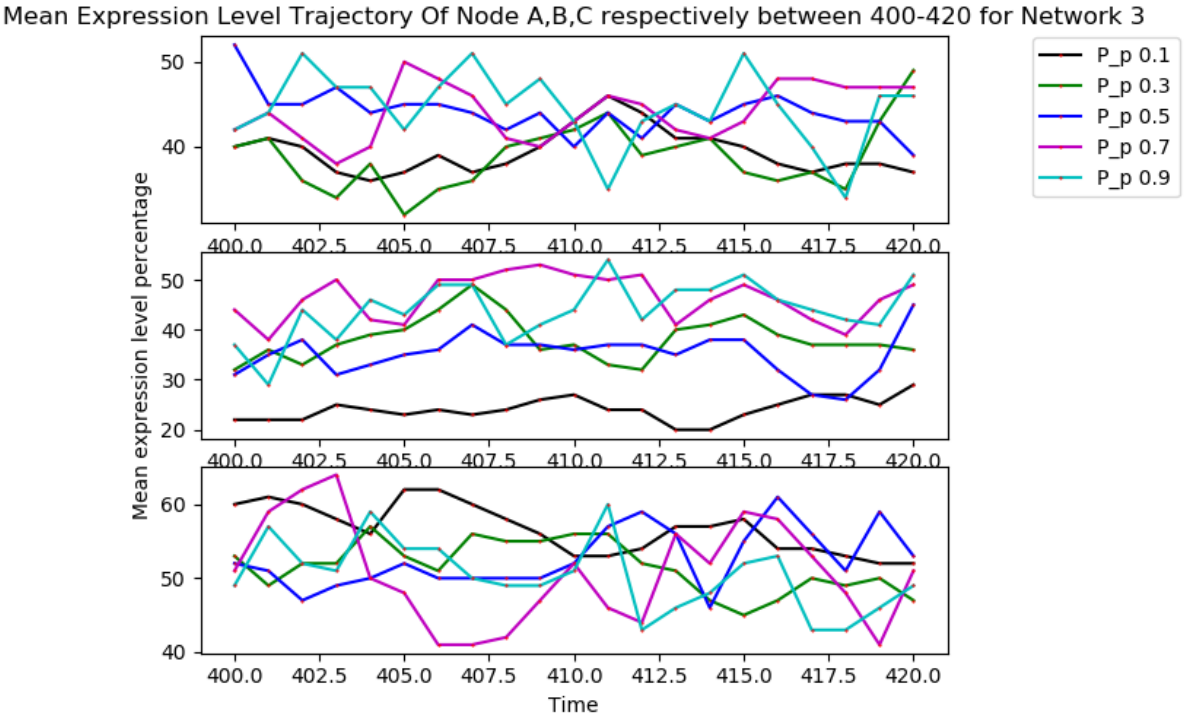
Mean Expression Level Trajectory Of Node A,B,C respectively between 400-420 for Network 0 ver 2



Mean Expression Level Trajectory Of Node A,B,C respectively between 400-420 for Network 1



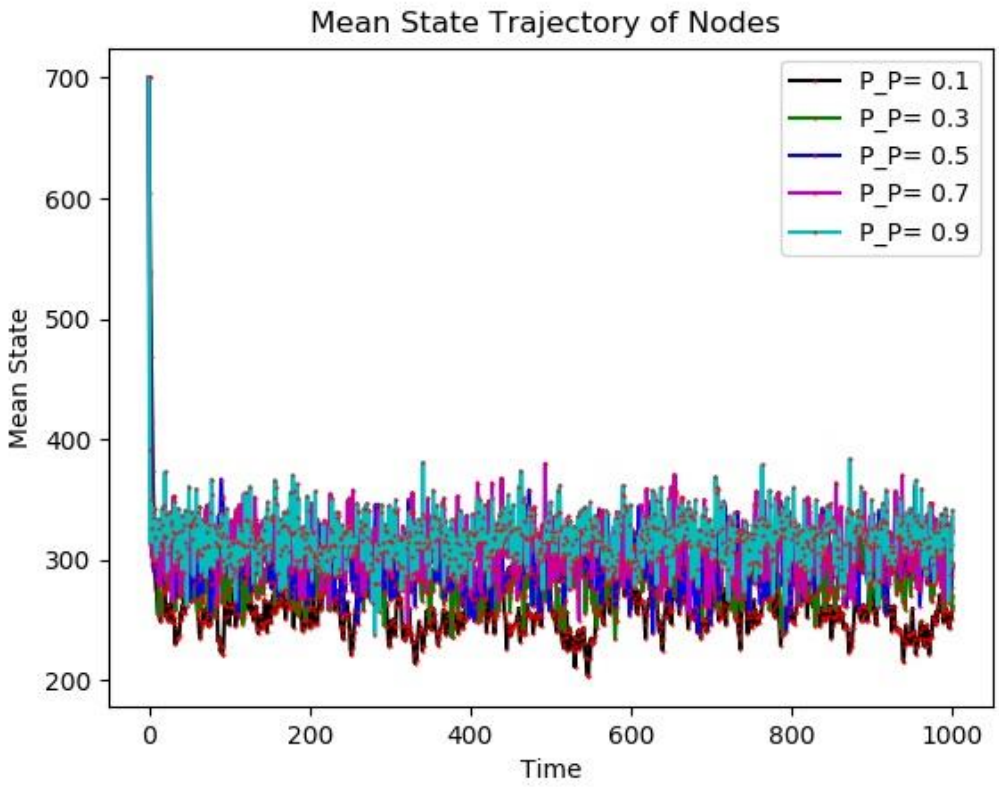




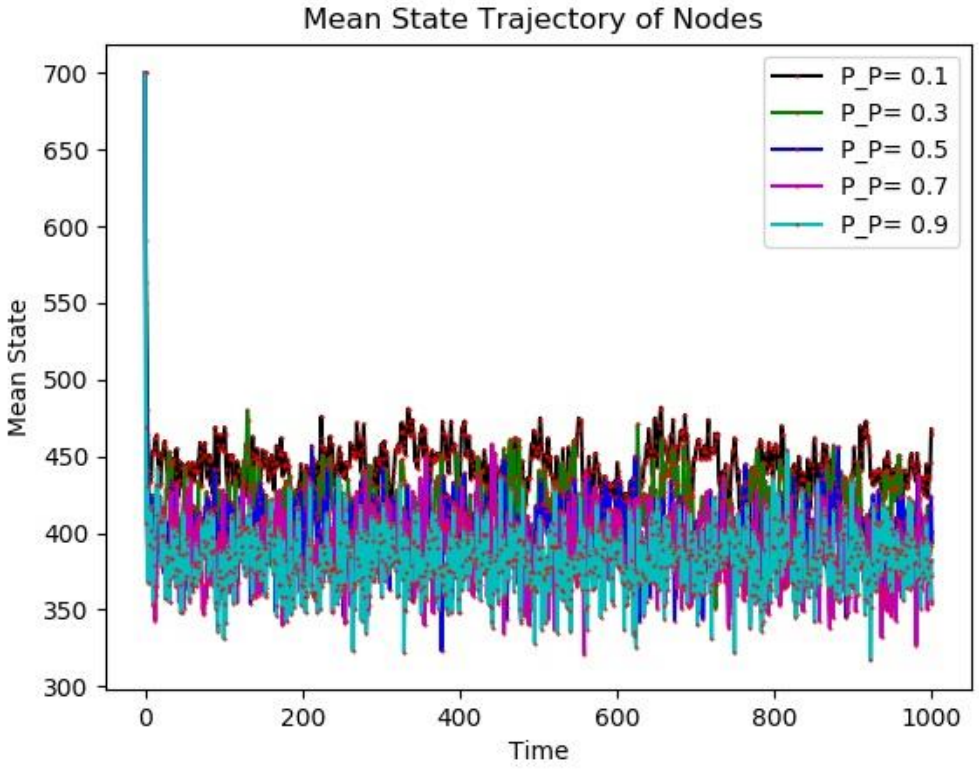
8. Mean State Trajectory for Three Node Networks

700 refers to a 111 state, the Y-axis represents the state in binary converted to decimal times 100. This is just a convenient notation to represent the state of the network. The probability is a normal distribution with mean 0.4 and std deviation = 0.1

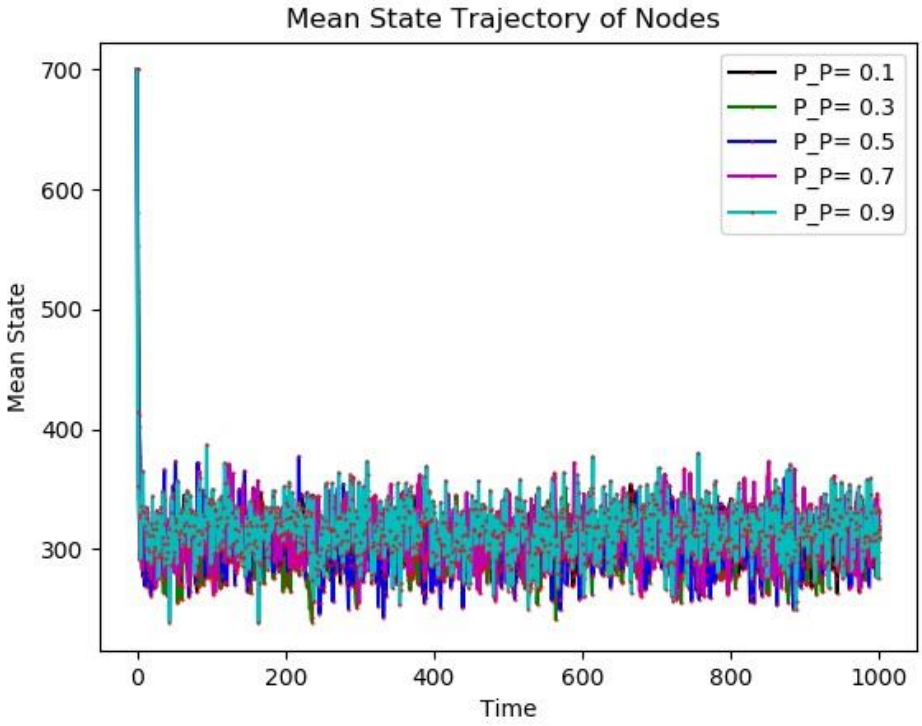
Network 0 ver 1



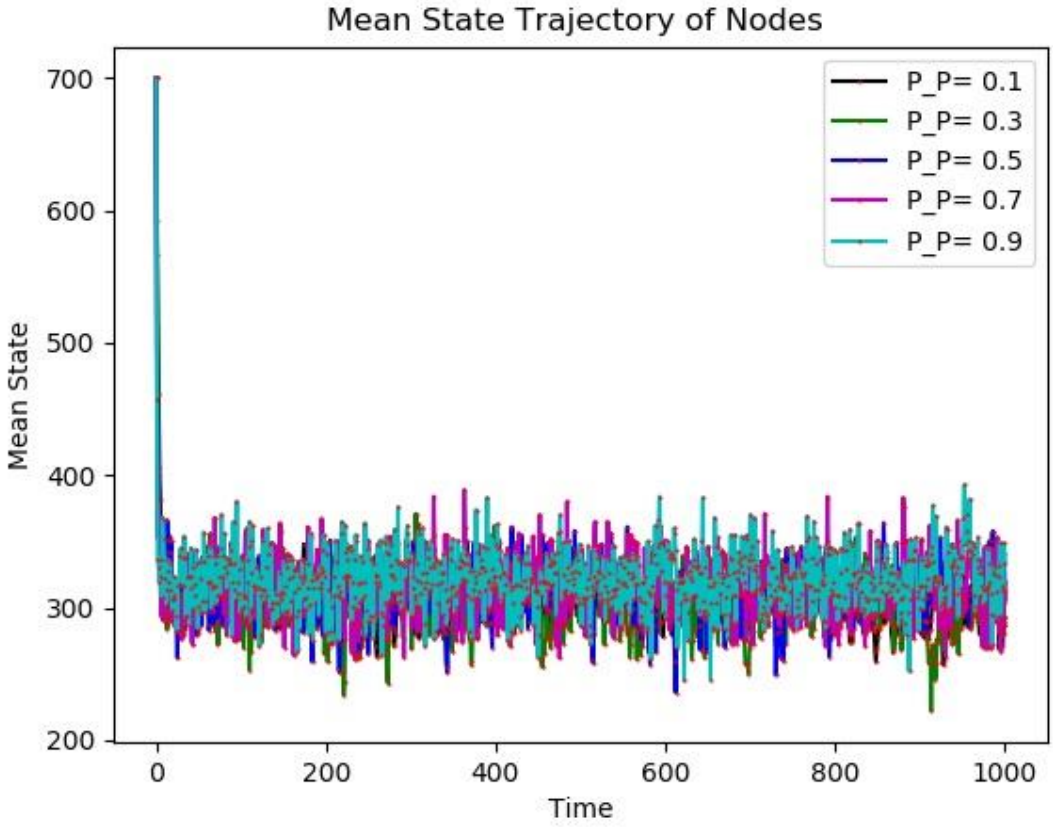
Network 0 ver 2



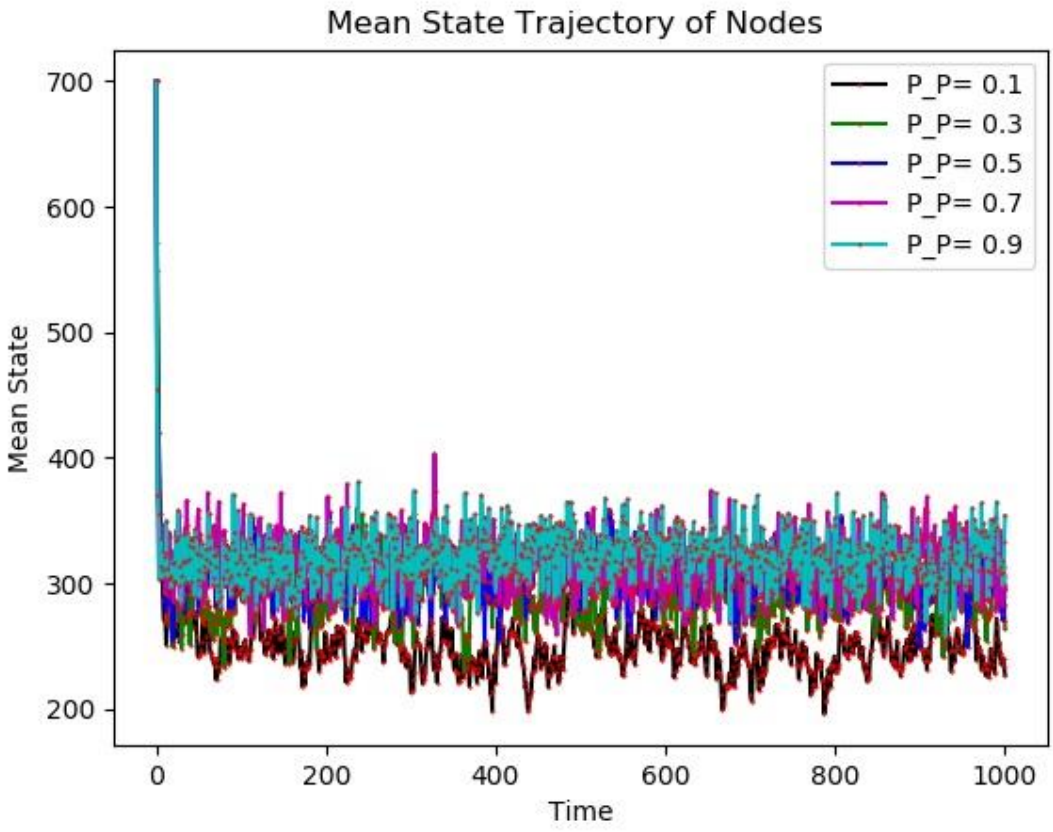
Network 1



Network 2



Network 3


Mean State Trajectory of Nodes
P_P= 0.1
P_P= 0.3
P_P= 0.5
P_P= 0.7
P_P= 0.9
Mean State
Time
700
600
500
400
300
200
0
200
400
600
800
1000