Model of Energy Consumption Ratio Achievable in MANET Using Location-Aware Transmission in Ubicomp.

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Abstract – **Efficient Location tracking is still subject to research and new functionalities/applications depending on it are continuing to appear on the market [37-52]. An area where improvements will be very desirable is MANET communication over which ubicomp will rely. A big section missing in MAUC remains the software engineering approaches into metrics development and gathering appropriate models which can be used for prediction and better gearing of future investments and research [2]. A particular sub-section of concern here is energy considerations in MANETs. Quite some results of prior research has been put forward [14-17] which are more directly concerned with energy. The subsequent level is "metrics indirectly concerned with energy for transmission". One such topic of research is: "What is the ratio of energy consumption for each node over the energy consumed by the sender? What are the corresponding patterns of trend observable for different sets of node densities? How to predict the trend equations and using them for predictive probability calculations.**

The area of modelling in ubicomp involves much work and this paper adds to this area. Designers will use it to formulate better ubicomp architectures and components. This paper follows from previous work [1-17].

Key terms: Ubicomp- Ubiquitous Computing, MAUC-Mobile and Ubiquitous Computing, ECR- Energy Consumption Ratio, MANET- Mobile Adhoc Network, CBR- Constant Bit Rate. PCN_ECR_NN- % communicating nodes for ECR node_number.

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1. Introduction

Many factors affect energy consumption in MAUC [2]. One pertinent factor is type of transmission; the type of concern here is MANET transmission, probing into which, a consequent factor is node density. Researchers claim that MANET transmission helps to contain or even save energy required for transmission [53]. When using MANETs, sender nodes together with those nodes forming part of MANET routes, are spending energy. These relay nodes could also be other user nodes instead of infrastructure nodes. Sender nodes transmit to closest neighbouring node which subsequently transmits to next nearest neighbour. In effect, cooperation from MANET nodes is being expected. It is legitimate in cooperation to determine how much assistance, in this case energy requirements, it is being required to give compared to the sending node's effort itself together with corresponding trends for varying nodes densities.

This may be considered for a whole CBR transmission instead of per packet transmission, in which case, an added complication will be changes in MANET routes during CBR transmission as follows:

i. The sequence of nodes in the MANET route till the destination has remained the same but the nodes locations have varied significantly.
ii. Certain nodes have been removed from the route and the number of nodes in the MANET path has reduced (reduced hop count).
iii. New nodes have been integrated into the route and hop count increases.
iv. A combination of part (ii) and (iii) giving a totally different MANET paths.

The key contributions of this paper is firstly, the development of a new metric ECR (though an empirical simulation-based experiment as in previous paper [14]), including its definition and rationale, and secondly, the model of trend put forward for the metric ECR with results for varying node densities from 7 until 56. The model suggested here is split into 2:

➢ A straight line F(x) from left of the graph towards right until a peak value (at around ECR value 0.3)
$$F(x) = d*x + f$$

➢ As from the peak value, the trend is smoothly exponentially decreasing and asymptotic to the x-axis
$$G(x) = a * \exp (b * (x - c))$$

The rest of this paper is organised as follows: section 2- New Derived Metric- Energy Consumption Ratio, section 3- ECR Trend Assessment over Varying Node Numbers, 4- Conclusion and References.

2. New Derived Metric: Energy Consumption Ratio.

ECR is "the ratio of energy consumption for each node over the energy consumed by the sender node".

The ratios obtained in the experiment [14] are positive values (rounded to 1 d.p) subdivided into 3 categories:
 i. ECR values less than 1: indicating that the corresponding MANET node has spent less energy than the sender for a CBR.
 ii. ECR values equal to 1: indicating that the corresponding MANET node has spent just as much energy as the sender node.
iii. ECR values greater than 1: indicating that the corresponding MANET node has spent more energy than the sender node.

It is expected to have some significantly very high values of ratios. This metric and its trend model, if accurately gauged and tracked, can serve several purposes including:
 i. Decision formulation if a particular sub area of the topography is not having enough MANET nodes and need of deploying some support infrastructure nodes.
 ii. Decision formulation for sender nodes whether to continue transmission or to delay/reschedule a transmission in case excessively high ratios are encountered for long durations.
iii. Decision formulation for a MANET node with battery power limitations to accept being part of the MANET route or not, i.e. to forward or not forward packets.
iv. History tracking in each node about past ratios reached for each sender encountered before and formulate trust levels for each such node over suitable durations. This can also help in calibrating appropriate QoS in the MANET.
 v. Better understanding the trends of battery power durations and "lesser expected" sudden battery unavailability.
vi. Traceability of nodes behaviour, whether user nodes in MANETs or Infrastructure nodes, of the reasons of certain odd behaviours like "refusal to forward".

3. ECR Trend Assessment over Varying Node Numbers.

3.0 Major Observations.

In all plots for node numbers 7 until 56, the leftmost plot at x-coordinate 0.0 has been very outlying with very high value of y-coordinate, though it decreases with increasing node numbers. Hence, this point has been ignored in trend analyses.

The rightmost plot was also very outlying with very low y-coordinate value. The x-range of plot was therefore set from 0.1 to a particular value covering more than 90 % of CBRs concerned. A peak value is observed in each plot at about ECR value of 0.3

3.1 Tabular Summary of Results.

A tabular summary for results of equations of curves, F(x) and G(x), observed here is shown below. Column headings are: A→node number, B→Value of parameter d, C→Value of parameter f, D→ reduced Chi-square value of plot F(x), E→ ECR value of peak value, F→ Value of parameter a, G→ Value of parameter b, H→ Value of parameter c, I→ reduced chi-sq value of plot G(x), J→ Corresponding figure number.

A	B	C	D	E
7	5.940 69	3.362 2	0.000 511 145	0.3
8	4.507 8	3.077 6	0.001 021 47	0.3
9	4.034 64	3.054 23	0.005 758 42	0.3
10	2.096 76	3.783 69	0.001 765 82	0.3
11	4.322 69	3.248 31	0.018 839 5	0.3
12	1.952	3.690 14	0.003 899 15	0.4
13	2.279 62	3.759 85	0.010 879	0.3
14	4.352 02	3.236 65	0.101 868	0.3
15	3.710 093 8	3.332 448 6	0.053 823 3	0.3
16	4.738 8	3.081 72	0.068 762 8	0.3
17	2.15	3.632 83	0.012 575 1	0.4
18	3.132 81	3.504 61	0.003 774 68	0.3
19	4.263 51	3.268 85	0.050 117 3	0.3
20	3.847 17	3.409 16	0.019 158 3	0.3
21	3.321 9	3.503 77	0.023 901 9	0.3
22	2.163 09	3.649 73	0.007 697 94	0.4
23	2.779 89	3.470 53	0.006 103 93	0.4
24	2.497 33	3.561 69	0.002 819 74	0.4
25	2.710 02	3.491 18	0.022 097	0.4
26	3.245 37	3.313 86	0.012 074 3	0.4
27	4.478 49	2.982 81	0.024 073 5	0.4
28	7.307 01	2.464 72	0.003 274 5	0.3
29	5.731 8	2.630 28	0.107 78	0.4
30	5.401 64	2.688 92	0.094 788 6	0.4
31	5.110 26	2.824 05	0.064 038 2	0.4
32	5.271 74	2.751 43	0.074 203 2	0.4
33	5.002 11	2.784 87	0.042 379 9	0.4
34	3.955 88	2.925 82	0.057 008 1	0.5
35	4.659 23	2.750 58	0.042 745 6	0.5
36	4.507 02	2.786 1	0.048 802 2	0.5
37	4.152 49	2.821 42	0.085 102 5	0.5
38	3.324 88	2.957 5	0.131 676	0.6
39	3.234 01	2.978 33	0.114 479	0.6
40	4.023 93	2.818 01	0.083 081 7	0.5
41	4.405 28	2.694 86	0.065 973 4	0.5
42	4.483 4	2.629 14	0.035 289 9	0.5
43	4.204 27	2.696 03	0.137 071	0.5
44	3.505 71	2.800 79	0.170 698	0.6
45	4.589 95	2.561 91	0.182 989	0.5
46	4.450 92	2.593 55	0.210 606	0.3
47	4.793 34	2.513 28	0.200 68	0.5
48	5.190 37	2.371 41	0.191 954	0.5
49	4.961 26	2.471 99	0.216 034	0.5
50	6.961 42	2.147 83	0.116 048	0.4
51	3.584 41	2.832 94	0.266 299	0.6
52	6.856 32	2.118 69	0.106 486	0.4
53	6.840 83	2.156 76	0.080 302 2	0.4
54	6.823 93	2.166 98	0.113 065	0.4
55	6.370 4	2.300 29	0.108 518	0.4
56	4.662 87	2.629 45	0.168 434	0.5

Table 1(a):results for ECR equations of curves node num 7-56

A	F	G	H	I	J
7	6.494 98	-0.897 104	0.074 740 6	0.008 832 209	1
8	6.465 16	0.887 697	-0.080 717 5	0.006 152 9	2
9	6.472 65	-0.869 674	-0.042 113 9	0.008 469 15	3
10	6.452 58	-0.771 351	-0.145 444	0.004 669 44	4
11	6.452 99	-0.760 194	-0.142 774	0.003 863 23	5
12	6.463 41	-0.774 59	-0.089 579 3	0.003 057 61	6
13	6.453 15	-0.730 374	-0.140 17	0.003 671 51	7
14	6.453 88	-0.725 497	-0.136 093	0.004 483 37	8
15	6.450 42	-0.713 278	-0.152 728	0.004 274 22	9
16	6.456 52	-0.719 173	-0.122 255	0.004 056 04	10
17	6.465 78	-0.736 201	-0.075 892 7	0.002 638 1	11
18	6.458 1	-0.718 19	-0.114 144	0.003 022 96	12
19	6.456 72	-0.711 977	-0.120 715	0.002 805 84	13
20	6.459 39	-0.716 251	-0.107 495	0.003 022 07	14
21	6.461 12	-0.712 402	-0.098 488 4	0.002 968 7	15
22	6.472 06	-0.734 641	-0.043 702 7	0.002 126 66	16
23	6.474 51	-0.736 56	-0.031 214 4	0.002 404 01	17
24	6.474 78	-0.735 873	-0.029 792 2	0.001 993 5	18
25	6.469 25	-0.719 463	-0.057 522 9	0.002 274 41	19
26	6.482 78	-0.737 63	0.011 160 2	0.002 268 78	20
27	6.484 07	-0.738 088	0.017 744 6	0.001 824 01	21
28	6.472 43	-0.711 885	-0.041 291 5	0.003 400 45	22
29	6.486 3	-0.741 487	0.029 263 1	0.001 860 17	23
30	6.487 7	-0.742 825	0.036 474 7	0.001 974 35	24
31	6.490 97	-0.748 52	0.053 2368	0.002 081 22	25
32	6.490 57	-0.747 702	0.051 166 3	0.002 027 93	26
33	6.490 03	-0.744 915	0.048 383 2	0.002 216 67	27
34	6.500 72	-0.768 757	0.103 764	0.001 368 95	28
35	6.504 38	-0.776 808	0.122 783	0.001 308 63	29
36	6.507 36	-0.785 491	0.138 256	0.001 389 13	30
37	6.506 71	-0.772 15	0.134 883	0.001 380 15	31
38	6.512 4	-0.782 744	0.164 503	0.001 268 81	32
39	6.513 76	-0.787 241	0.171 573	0.001 325 23	33
40	6.504 86	-0.762 179	0.125 181	0.002 187 49	34
41	6.505 39	-0.759 946	0.127 924	0.001 697 37	35
42	6.505 04	-0.757 196	0.126 064	0.001 583 03	36
43	6.507 52	-0.760 027	0.138 928	0.002 264 06	37
44	6.514 38	-0.776 703	0.174 761	0.001 629 64	38
45	6.504 88	-0.752 886	0.125 121	0.001 979 86	39
46	6.503 04	-0.747 093	0.115 494	0.002 291 63	40
47	6.504 76	-0.751 279	0.124 464	0.002 197 38	41
48	6.504 24	-0.749 598	0.121 831	0.001 908 6	42
49	6.504 38	-0.750 678	0.122 555	0.001 837 16	43
50	6.490 99	-0.723 657	0.053 143 6	0.002 185 11	44
51	6.507 76	-0.761 24	0.140 307	0.001 499 76	45
52	6.492 39	-0.725 181	0.060 291 2	0.002 622 43	46
53	6.492 76	-0.726 893	0.062 226 6	0.002 518 55	47
54	6.491 92	-0.724 438	0.057 869 9	0.002 717 98	48
55	6.489 76	-0.720 2	0.046 799	0.002 548 64	49
56	6.499 96	-0.743 561	0.099 677	0.001 707 75	50

Table 1(b):results for ECR equations of curves node num 7-56

3.2 Graphical Plots for Results Obtained.

This analysis is performed in gnuplot in Linux.

1. Node Number 7
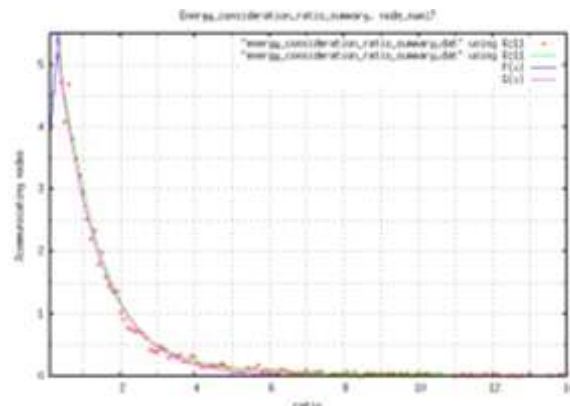
Figure 1: PCN_ECR_NN 7

2. Node Number 8
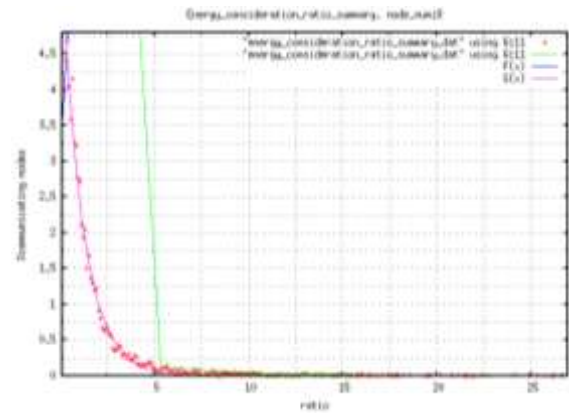
Figure 2: PCN_ECR_NN 8

3. Node Number 9
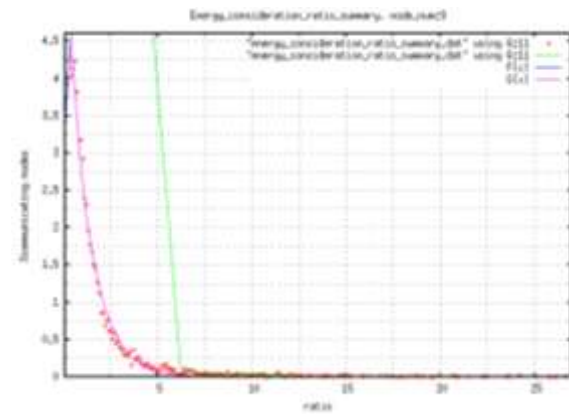
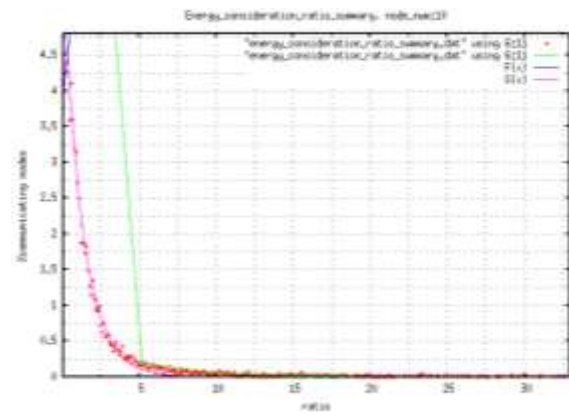**Figure 3: PCN_ECR_NN 9**

4. Node Number 10
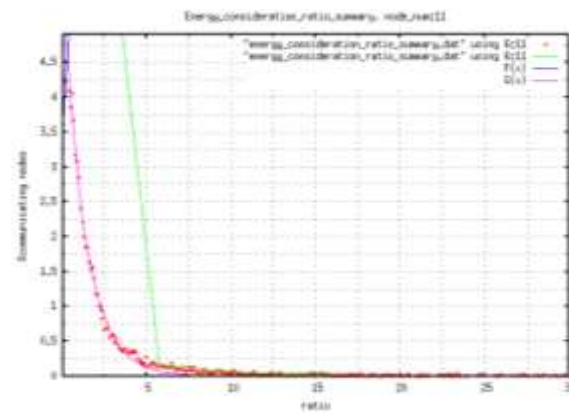

Figure 4: PCN_ECR_NN 10
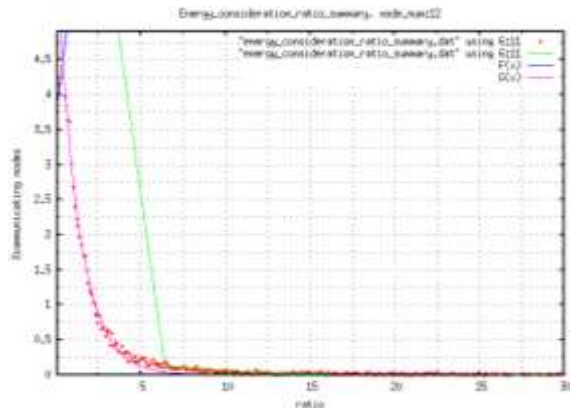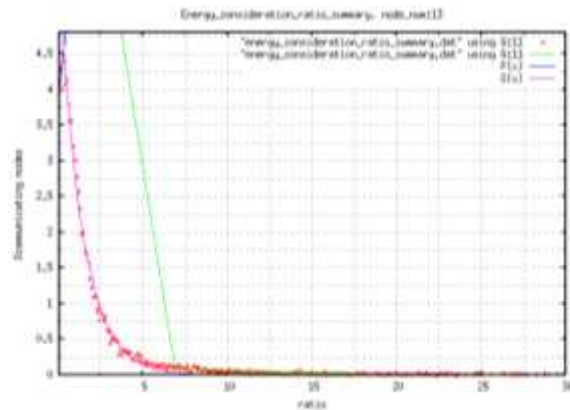
5. Node Number 11

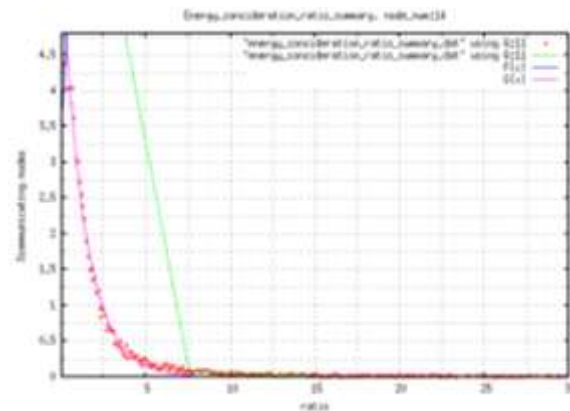**Figure 5: PCN_ECR_NN 11**

6. Node Number 12

78

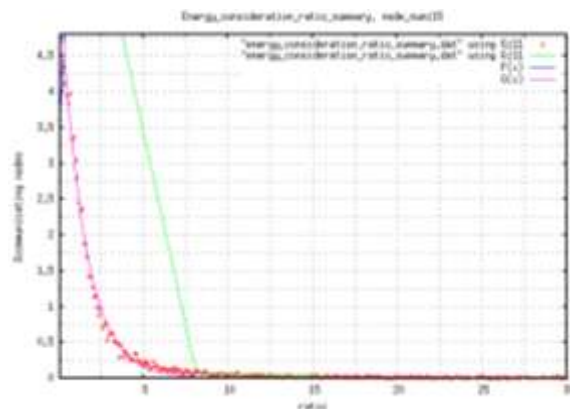**Figure 6: PCN_ECR_NN 12**

7. Node Number 13

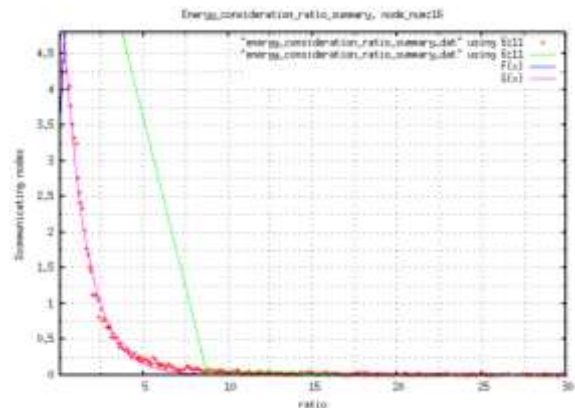**Figure 7: PCN_ECR_NN 13**

8. Node Number 14

Figure 8: PCN_ECR_NN 14
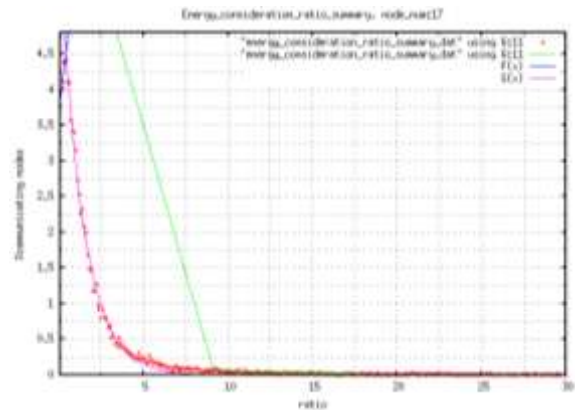
9. Node Number 15

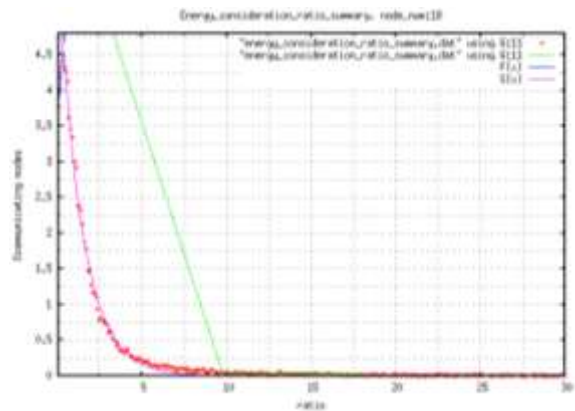**Figure 9: PCN_ECR_NN 15**

10. Node Number 16

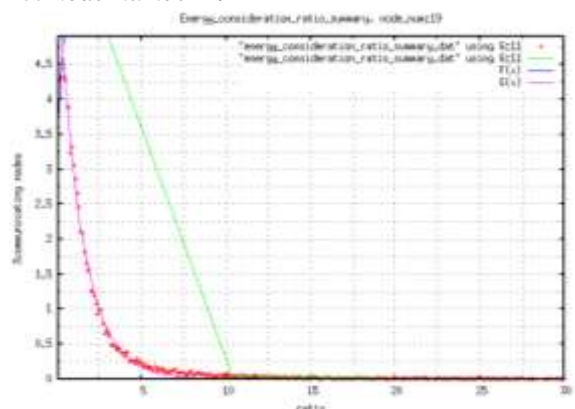**Figure 10: PCN_ECR_NN 16**

11. Node Number 17

Figure 11: PCN_ECR_NN 17

12. Node Number 18

Figure 12: PCN_ECR_NN 18

13. Node Number 19
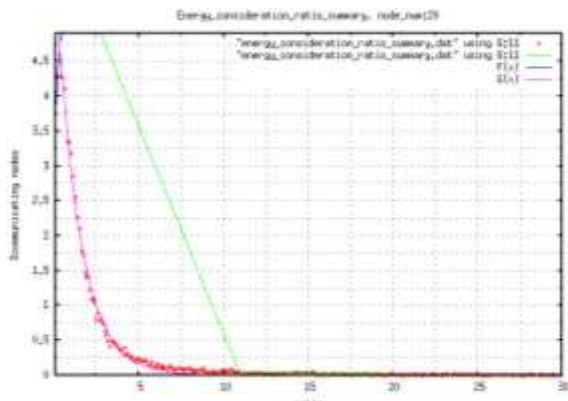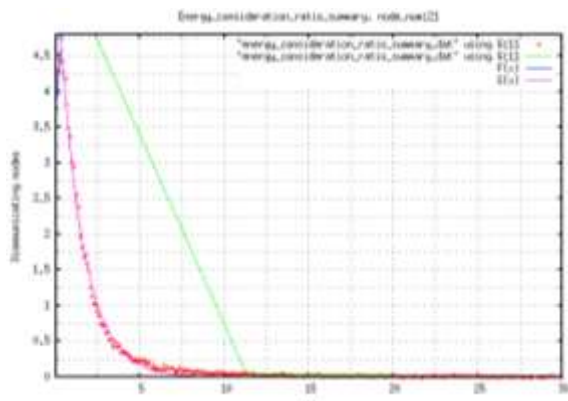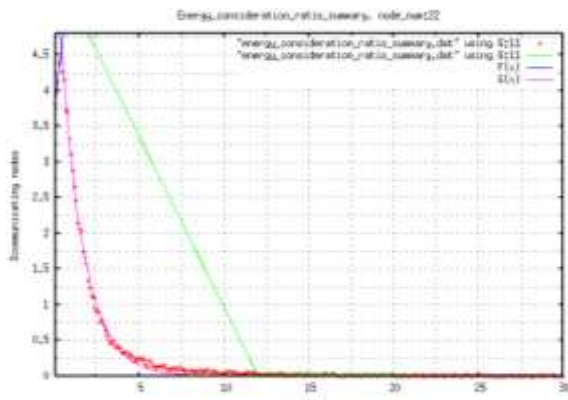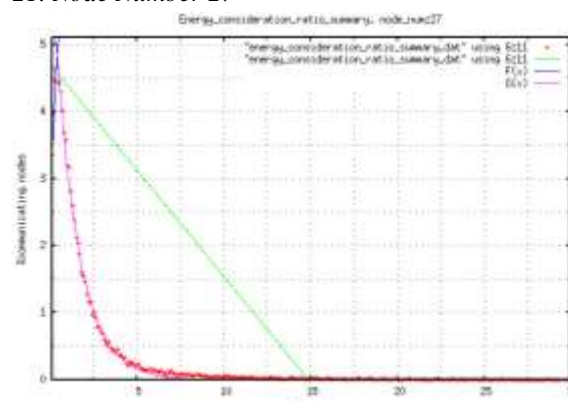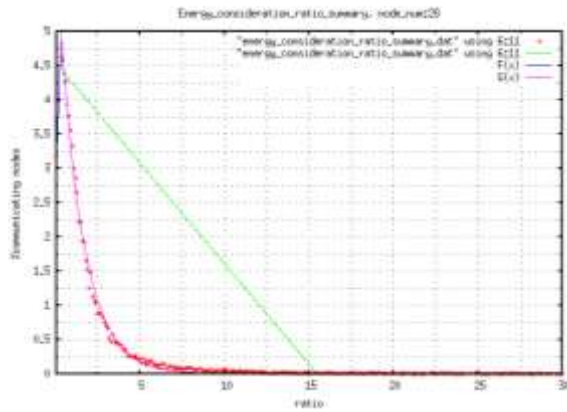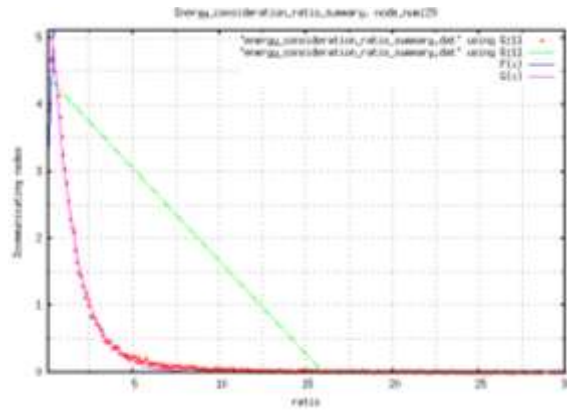

Figure 13: PCN_ECR_NN 19

14. Node Number 20

Figure 14: PCN_ECR_NN 20

15. Node Number 21

Figure 15: PCN_ECR_NN 21

16. Node Number 22

Figure 16: PCN_ECR_NN 22

17. Node Number 23
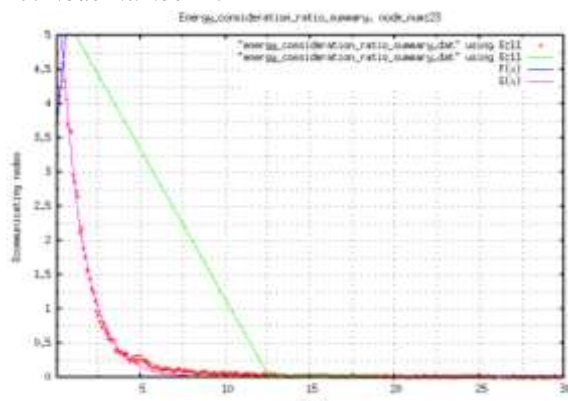
Figure 17: PCN_ECR_NN 23

18. Node Number 24
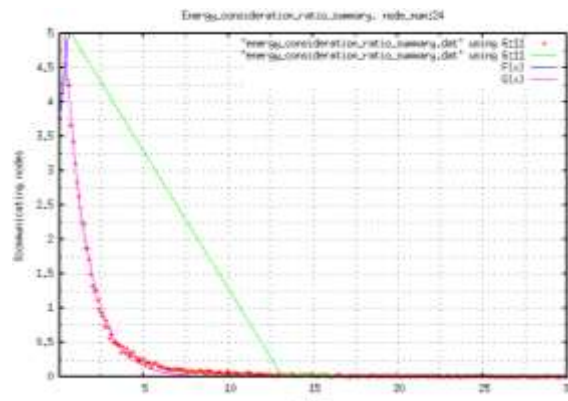
Figure 18: PCN_ECR_NN 24

19. Node Number 25
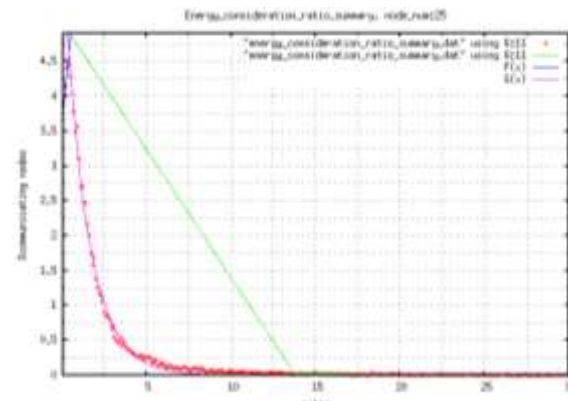
Figure 19: PCN_ECR_NN 25

20. Node Number 26
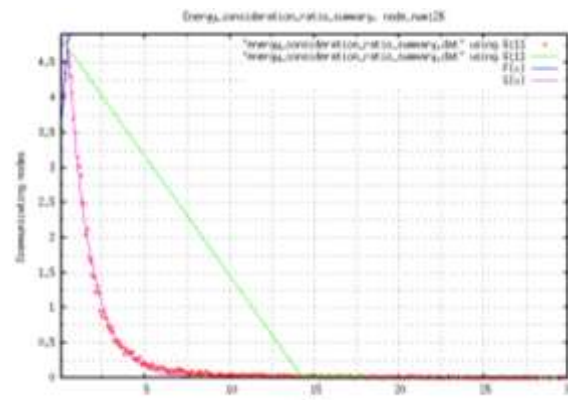
Figure 20: PCN_ECR_NN 26

21. Node Number 27

Figure 21: PCN_ECR_NN 27

22. Node Number 28

80

Figure 22: PCN_ECR_NN 28

23. Node Number 29

Figure 23: PCN_ECR_NN 29

24. Node Number 30
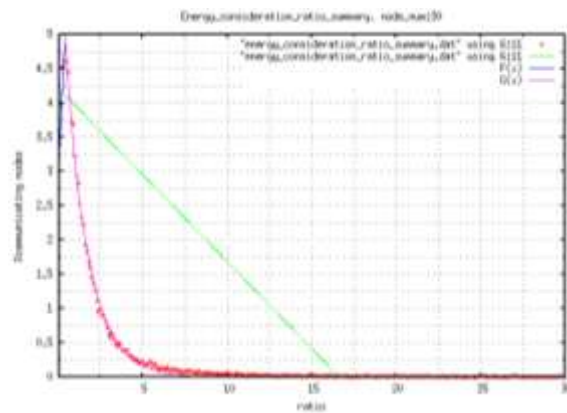
Figure 24: PCN_ECR_NN 30

25. Node Number 31
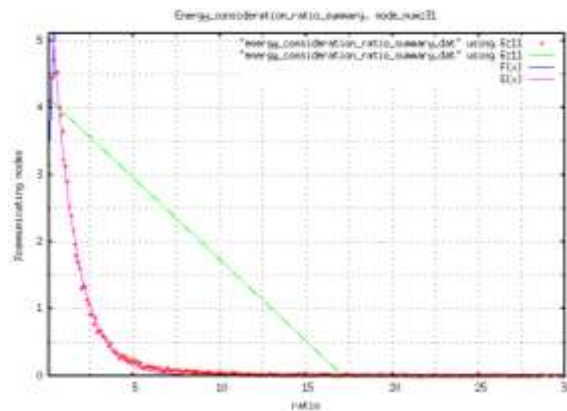
Figure 25: PCN_ECR_NN 31

26. Node Number 32
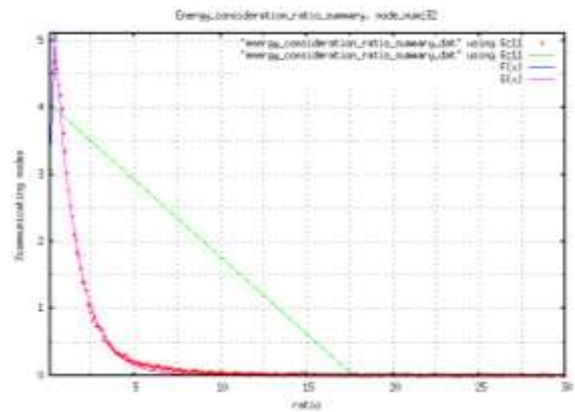
Figure 26: PCN_ECR_NN 32

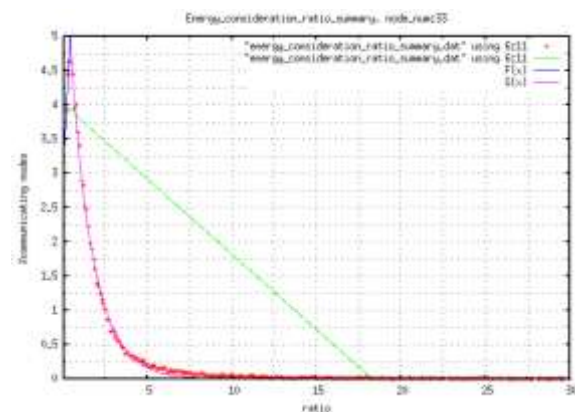*27. Node Number 33*

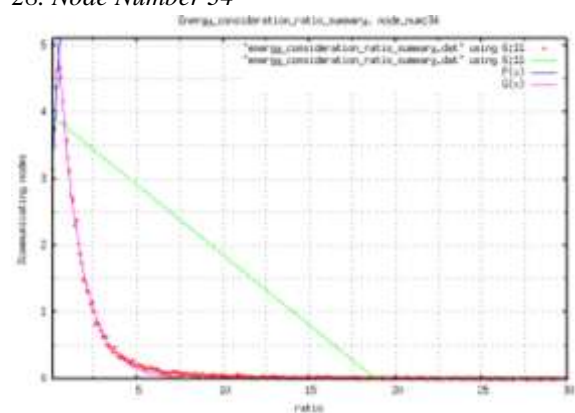**Figure 27: PCN_ECR_NN 33**

28. Node Number 34
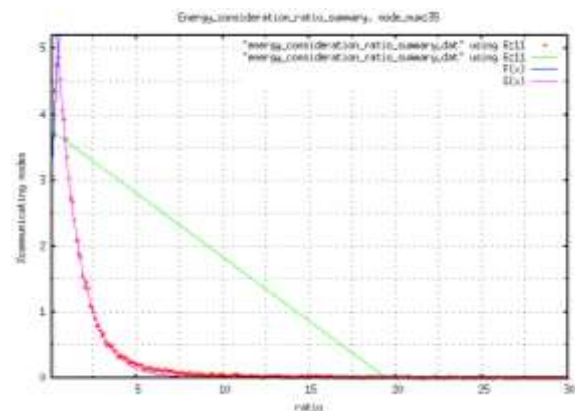

Figure 28: PCN_ECR_NN 34
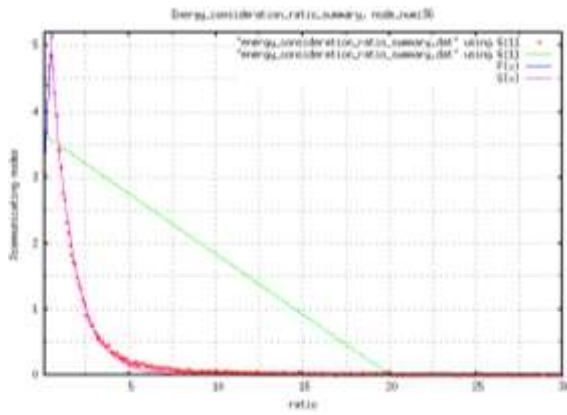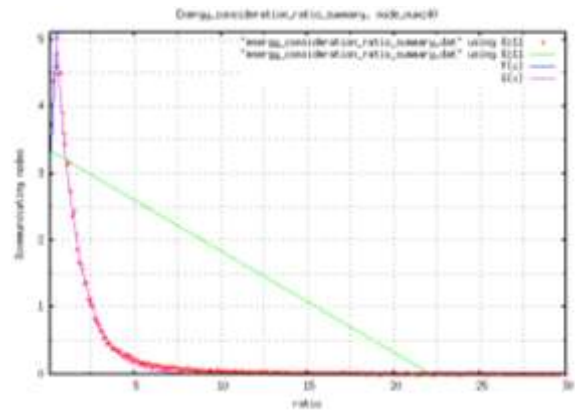
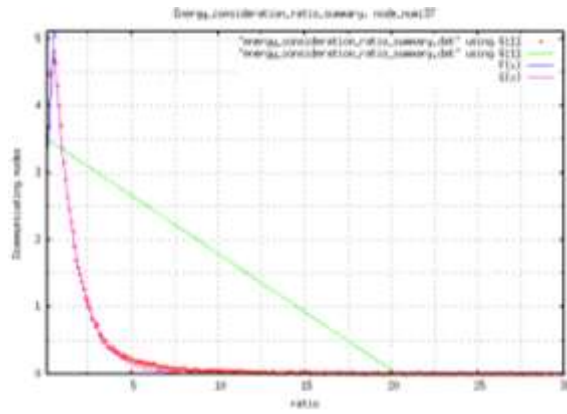*29. Node Number 35*

Figure 29: PCN_ECR_NN 35

30. Node Number 36

81

Figure 30: PCN_ECR_NN 36

31. Node Number 37

Figure 31: PCN_ECR_NN 37

32. Node Number 38

Figure 32: PCN_ECR_NN 38

33. Node Number 39

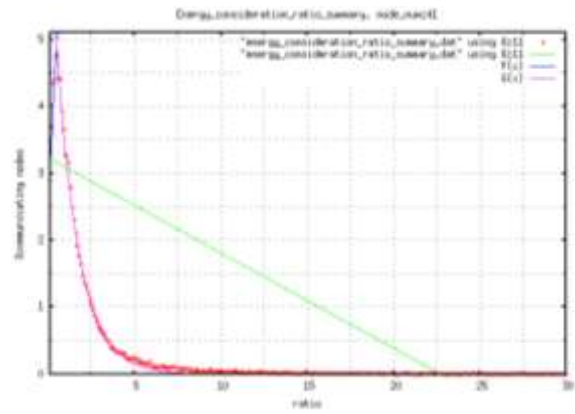**Figure 33: PCN_ECR_NN 39**

34. Node Number 40

Figure 34: PCN_ECR_NN 40

35. Node Number 41
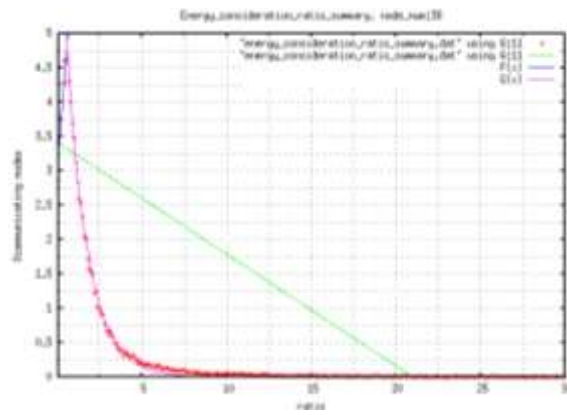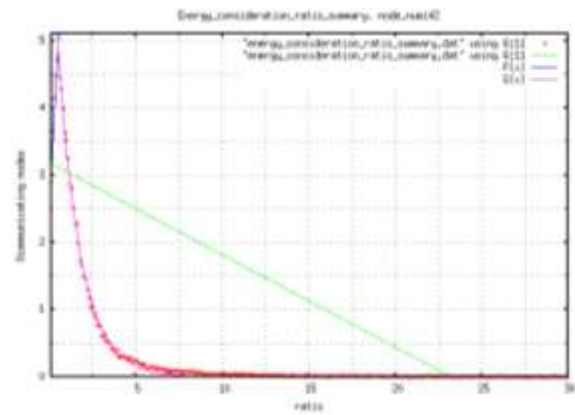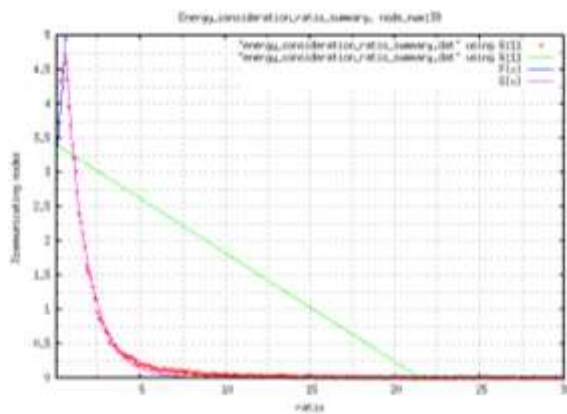

Figure 35: PCN_ECR_NN 41

36. Node Number 42

Figure 36: PCN_ECR_NN 42

37. Node Number 43

Figure 37: PCN_ECR_NN 43

38. Node Number 44

82

Figure 38: PCN_ECR_NN 44

39. Node Number 45

Figure 39: PCN_ECR_NN 45

40. Node Number 46

Figure 40: PCN_ECR_NN 46

41. Node Number 47

Figure 41: PCN_ECR_NN 47

42. Node Number 48

Figure 42: PCN_ECR_NN 48

43. Node Number 49

Figure 43: PCN_ECR_NN 49

44. Node Number 50

Figure 44: PCN_ECR_NN 50

45. Node Number 51

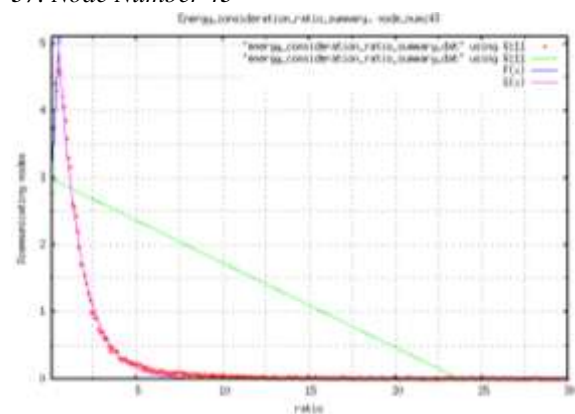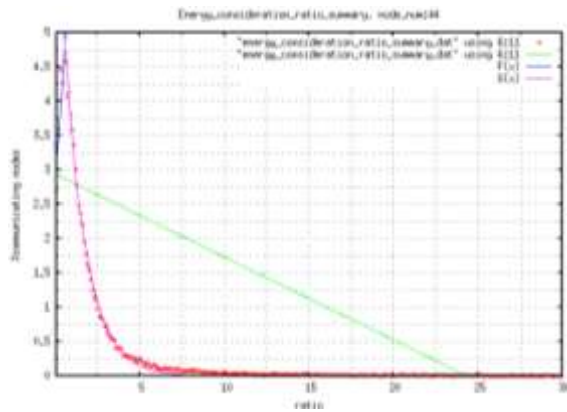**Figure 45: PCN_ECR_NN 51**

46. Node Number 52

Figure 46: PCN_ECR_NN 52

47. Node Number 53
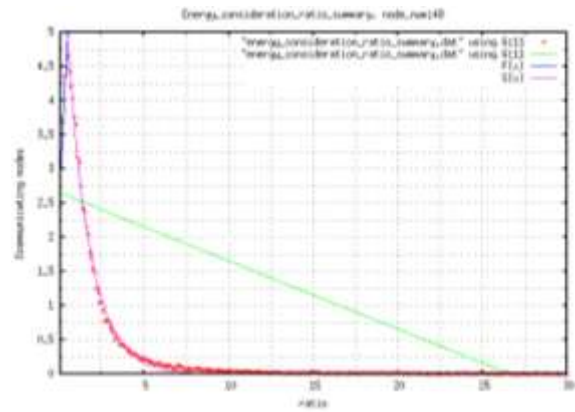

Figure 47: PCN_ECR_NN 53

48. Node Number 54
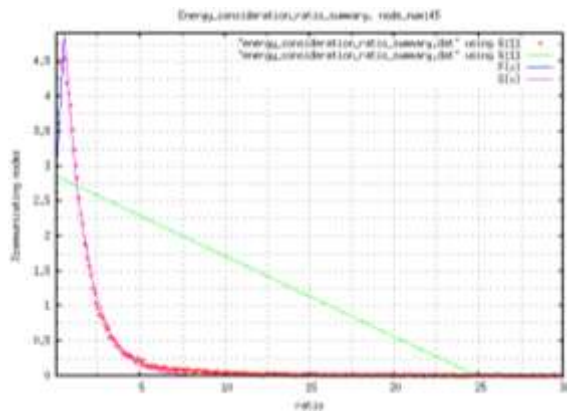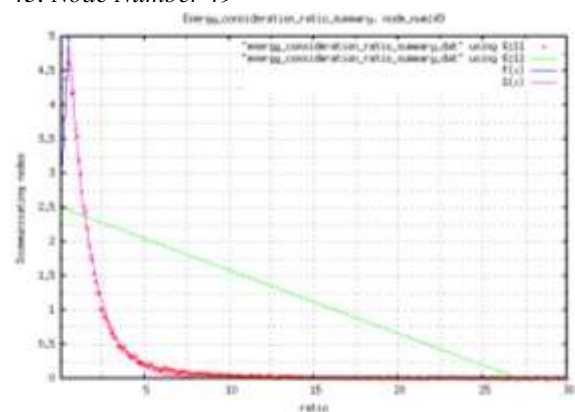

Figure 48: PCN_ECR_NN 54

49. Node Number 55
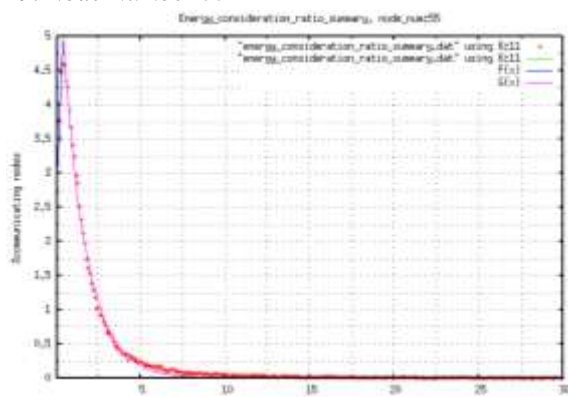
Figure 49: PCN_ECR_NN 55

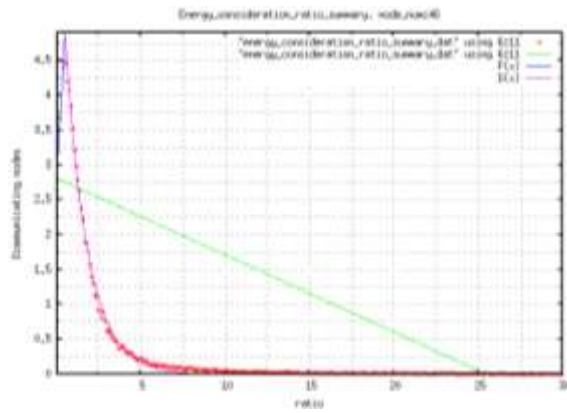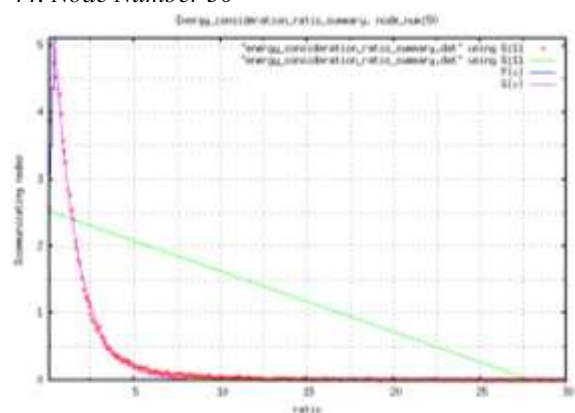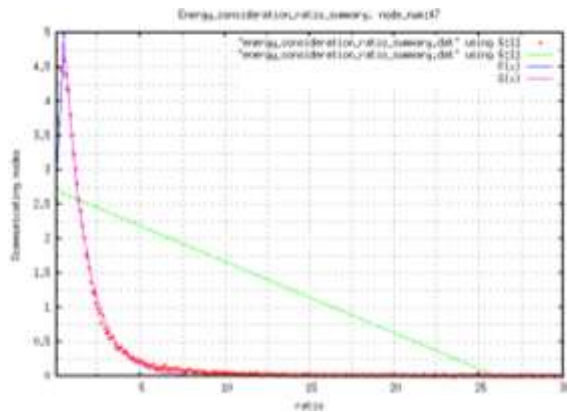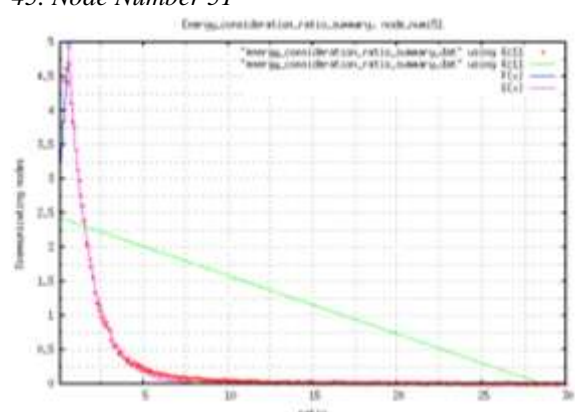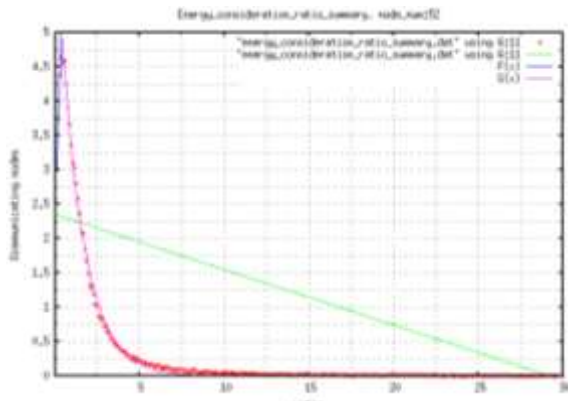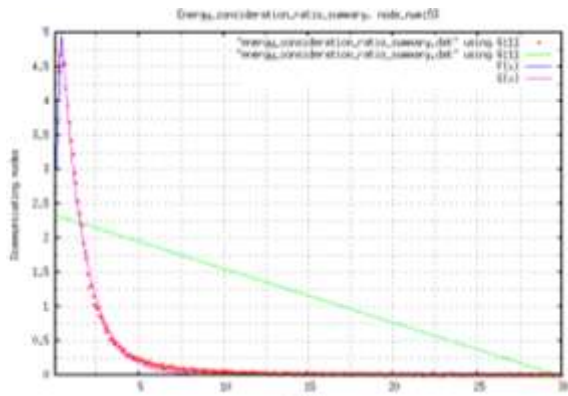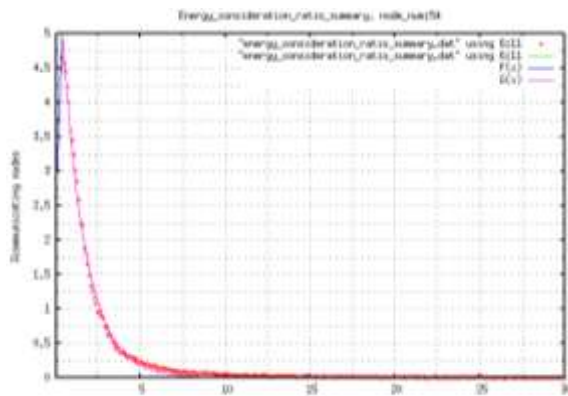*50. Node Number 56*
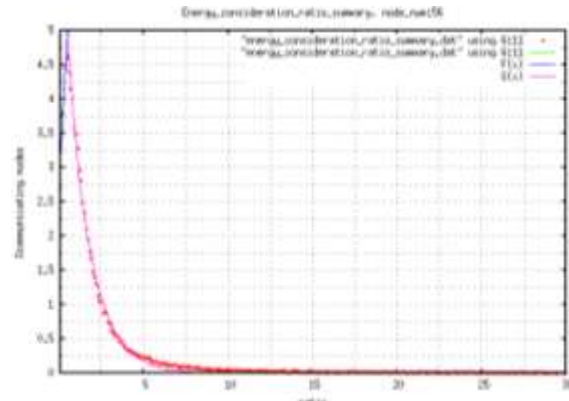
Figure 50: PCN_ECR_NN 56

4. Conclusion.

This piece of research was aimed at studying a resulting situation of transmission over MANET topography of 300 x 300 m^2. For this purpose, one metric was devised: ECR and corresponding model of trend over varying number of node densities have been put forward. The purposes that this metric and its trend analysis will serve have also been put forward. This research remains empirical based and was implemented over same components as explained in another paper [15]. The model put forward comprises of 2 equations F(x) and G(x) which applies with respect to a peak value. Here also, many components are assumed as available even if they remain subjects of research, e.g. lightweight algorithms for location-aware transmission in mobile environments, lightweight MAUC OS support for efficient and very rapid binding/unbinding of MANET nodes and appropriate multi-threading communication module in MANET nodes.

The further works identified may include: trend analyses of parameters of equation for the model, formulating method of predictability for metric ECR and its trend and reporting observations of certain values identified. Other research questions also crop up, e.g. "Is the CBR transmission achieving overall fairness towards sender node? Or, are the MANET nodes spending much more energy than proportionately to the sender?" Further probing remains desirable.

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