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Model of Overall Energy Consumption Fairness Proportion Achievable in MANET Using Location-Aware Transmission for Ubicomp.

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***Abstract* – Managing energy consumption in ubicomp is a serious topic of research. MANET transmission may help in energy containment in ubicomp [57]. Location-aware transmission can enhance this method for energy containment. It is assumed that in a MANET for ubicomp, nodes present will work in an automated collective fashion to achieve transmission, thereby sharing the workload. It is a conception that for sharing of workload is achieved equitably among all nodes present and hence energy consumption is reduced for each contributing node with increasing node density.**

In situations of cooperation, it remains important for each cooperating node to gauge what is the degree of effort it is providing, in forms of metric and trends achievable, presented in previous research [19-21] which is referenced against sender node's effort. Another set of metrics for gauging Fairness compared to an assumed equitable energy amount reached if the total energy consumed for a CBR transmission is divided equally among all nodes present in a topography, is also possible. A first metric in this direction, presented in this paper, is ECFP, along with its corresponding trends over varying node densities.

This paper adds up to the area of modelling in ubicomp for designers to better provision for resources and architecture needs. This paper is a follow-up of previous research [1-21].

Key terms: Ubicomp- Ubiquitous Computing, MAUC- Mobile and Ubiquitous Computing, ECR- Energy Consumption Ratio, Min_R- Minimum Ratio, Max_R- Maximum Ratio, OFR- Overall Fairness Ratio, MANET- Mobile Adhoc Network, BFEA- Basic Fairness Energy Amount, ECFP- Energy Consumption Fairness Proportion, CBR- Constant Bit Rate.

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1. Introduction

MANET transmission remains a considerable factor affecting energy consumption in MAUC [21], whereby workload is distributed among nodes in MANET routes to achieve cooperative and complete transmission till receiver. Since, the situation is cooperation here, the first conception is that the workload may be distributed equitably among all nodes present. This workload would be assumed to be decreasing if the topography has greater number of nodes. This conception remains an assumption even if mostly, it will not be achieved as only nodes concerned in MANET routes will be spending energy. The concept of equitable energy consumption distribution may not apply for short duration CBR where only certain nodes might have been used. However, as CBR durations tend to increase significantly, and MANET topologies experience high volatility, more and more nodes in the topography may be concerned and hence this "equitable distribution" of energy needs become relevant for study.

Previously defined metrics ECR [18], Min_R [19], Max_R [20] and OFR [21] give indication of energy consumption gauged against sender's effort only. One big limitation of this method of measurement remains that overall contribution and effectiveness of all nodes present in the topography cannot be appropriately estimated and questions like "How reliable is the topography nodes present for distributing workload fairly?" remain unanswered.

There is need for ubicomp reliability studies to well define the equitable distribution of overall energy requirements among all nodes with appropriate mathematical bounds. This definition may then be used for further studies about Fairness. It is desirable in the field of ubicomp to define appropriate metrics, among which some will be relevant to this equitable distribution, and well define its rationale and purposes.

The key contributions of this paper is firstly, the development of two metrics BFEA and ECFP which follow from previous experiments [14]. The two metrics are defined and the rationale of metric ECFP is sufficiently elicited. Secondly, the model of trend is put forward for the metric ECFP with results for varying node densities from 7 until 56 in a topography of 300 x 300 m^2. The model proposed combines linear and exponential model. The rest of this paper is organised as follows: section 2- Metrics BFEA and ECFP, section 3- ECFP Trend Assessment over Varying Node Numbers, 4- Conclusion and References.

2. Metrics BFEA and ECFP.

Strictly assuming that all nodes in the MANET are expected to contribute equally, a new metric is introduced here: the “Basic Fairness Energy Amount” (BFEA).

$$BFEA = \frac{\text{Overall energy spent for a CBR transmission}}{\text{Number of nodes in the topography.}}$$

Following the above definition, another metric ECFP is developed using results obtained in previous experiments [14].

$$ECFP = \frac{\text{energy spent by a node for a CBR transmission}}{\text{BFEA}}$$

Another way of understanding the ECFP is by what factor is the energy expenditure of a node deviating from that value obtained in the scenario whereby the overall energy expenditure was equally distributed among all nodes in the topography. It can also serve as a measure of reliance on topography nodes to share work of CBR transmission. This metric if appropriately gauged or even predicted, may also serve purposes elaborated in previous paper [21].

3. ECFP - Trend Assessment over Varying Node Numbers.

3.0 Major Observations.

For many plots, the leftmost point has been found to be very outlying and hence the leftmost coordinate at x-value 0.0 is not considered.

A peak value after the 5th point is observed. Previous to this peak value, the plot is convincingly linear of form:

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F(x) = d * x + f
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As from the peak value onwards, the exponential tendency is found with equation of form:

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G(x) = a * exp ( b * ( x - c ) )
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3.1 Tabular Summary of Results.

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

A	B	C	D	E
7	2.718 57	-1.308 98	1.475 91	0.049 949 9
8	2.749 61	-1.182 5	1.595 23	0.034 359 7
9	2.752 53	-1.358 26	1.607 21	0.016 200 1
10	2.741 47	-1.231 1	1.564 32	0.039 397 5
11	2.740 71	-1.302 15	1.561 18	0.021 292 3
12	2.740 38	-1.212 82	1.560 55	0.044 142 2
13	2.737 25	-1.270 98	1.547 98	0.043 591 8
14	2.735 93	-1.330 76	1.542 72	0.035 632 6
15	2.731 28	-1.499 66	1.524 53	0.011 759 1
16	2.731 94	-1.420 91	1.527 17	0.028 328
17	2.705 14	-1.459 01	1.519 38	0.015 368 5
18	2.703 06	-1.506 6	1.511 38	0.021 478 6
19	2.700 94	-1.550 88	1.503 13	0.010 017 6
20	2.699 23	-1.587 63	1.496 47	0.008 919 23
21	2.698 45	-1.621 36	1.493 22	0.013 648 1
22	2.694 93	-1.678 87	1.479 3	0.013 832 6
23	2.694 08	-1.681 79	1.476 29	0.011 033 9
24	2.691 66	-1.720 99	1.466 7	0.009 465 68
25	2.691 14	-1.739 69	1.464 5	0.009 552 61
26	2.691 21	-1.761 29	1.464 57	0.011 109 7
27	2.689 01	-1.793 35	1.455 84	0.006 043 57
28	2.687 59	-1.802 58	1.450 46	0.009 803 26
29	2.693 9	-1.630 6	1.476 71	0.034 521 7
30	2.686 48	-1.820 4	1.446 16	0.009 248 71
31	2.685 26	-1.893 67	1.440 17	0.005 359 8
32	2.683 92	-1.883 1	1.435 46	0.008 153 49
33	2.683 72	-1.893 83	1.434 58	0.009 260 95
34	2.683 84	-1.894 72	1.435 17	0.008 191 1
35	2.683	-1.920 48	1.431 66	0.007 860 14
36	2.682 15	-1.933 36	1.428 45	0.007 175 78
37	2.688 8	-1.730 84	1.457 45	0.035 902 9
38	2.688 14	-1.740 14	1.454 92	0.0346 124
39	2.686 29	-1.764 21	1.447 77	0.030 318
40	2.686 55	-1.761 31	1.448 86	0.027 321 2
41	2.678 61	-1.987 03	1.414 4	0.007 589 03
42	2.685 97	-1.785 1	1.446 32	0.028 430 1
43	2.686 31	-1.780 42	1.447 62	0.023 320 8
44	2.679 75	-1.968 71	1.418 82	0.005 055 03
45	2.685 02	-1.808 5	1.442 52	0.021 451 6
46	2.684 69	-1.824 37	1.441	0.020 567 7
47	2.684 22	-1.834 15	1.439 25	0.018 980 8
48	2.683 46	-1.840 86	1.436 37	0.020 730 5
49	2.682 28	-1.862 2	1.431 87	0.021 828 1
50	2.680 97	-1.867 78	1.427 19	0.022 150 3
51	2.680 52	-1.883 06	1.425 5	0.022 265 6
52	2.679 53	-1.898 14	1.421 83	0.022 970 2
53	2.678 81	-1.909 36	1.418 84	0.023 956 9
54	2.678 13	-1.923 73	1.416 01	0.018 367 5
55	2.677 92	-1.920 94	1.415 26	0.019 886 1
56	2.677 81	-1.925 25	1.414 89	0.021 106 8

Table 1(a): summary of results for OFR equations of curves node numbers 7-56

A	F	G	H	I
7	7.485 2	0.021 396 6	0.077 439 6	1
8	6.440 62	-0.342 55	0.048 086 3	2
9	5.998 75	0.212 095	0.181 385	3
10	7.413 53	0.525 959	0.171 797	4
11	8.767 91	0.079 886 5	0.121 207	5
12	9.341 61	0.096 122 4	0.101 858	6
13	10.456 2	-0.115 705	0.159 502	7
14	11.652 2	-0.470 805	0.156 011	8
15	10.24	0.150 817	0.470 1	9
16	12.482 9	-0.575 501	0.196 619	10
17	11.466 7	0.315 508	0.341 54	11
18	11.893 3	0.195 458	0.468 112	12
19	12.616 2	0.016 171 3	0.461 486	13
20	13.458 2	-0.233 766	0.579 002	14
21	13.242 8	-0.124 927	0.562 364	15
22	13.757 5	-0.225 939	0.572 17	16
23	14.258 6	-0.328 156	0.801 312	17
24	14.564 7	-0.376 96	0.693 879	18
25	14.967 4	-0.511 128	0.710 069	19
26	14.636 2	-0.347 342	0.717 674	20
27	15.603 1	-0.619 78	0.914 949	21
28	15.499 9	-0.541 17	0.940 157	22
29	16.742	-0.883 635	1.243 67	23
30	16.028 4	-0.669 476	0.964 785	24
31	16.853 8	-0.962 903	1.085 42	25
32	16.777	-0.909 314	1.031 2	26
33	16.788 6	-0.907 57	0.857 766	27

34	16.967 3	-0.965 285	0.975 781	28
35	17.291 4	-1.066 89	0.975 787	29
36	17.378 6	-1.059 94	0.998 23	30
37	18.589 9	-1.332 89	1.312 09	31
38	18.882	-1.413 76	1.286 08	32
39	19.099 8	-1.430 88	1.350 59	33
40	19.27	-1.473 32	1.367 53	34
41	18.139 9	-1.190 65	1.246 3	35
42	19.518 1	-1.577 72	1.430 16	36
43	19.916 5	-1.677 33	1.411 67	37
44	18.586 2	-1.324 72	1.327 84	38
45	20.261 9	-1.781 01	1.637 35	39
46	20.402 5	-1.846 64	1.583 82	40
47	20.821 8	-1.972 9	1.757 1	41
48	21.086 3	-2.037 11	1.717 29	42
49	21.202 1	-2.054 99	1.761 17	43
50	21.205 7	-1.975 98	1.547 88	44
51	21.435 2	-2.055 71	1.644 11	45
52	21.504	-2.060 76	1.679 38	46
53	21.616	-2.079 24	1.699 56	47
54	21.957	-2.164 29	1.797 53	48
55	22.120 4	-2.200 29	1.777 63	49
56	22.042 9	-2.180 74	1.770 67	50

Table 1(b): summary of results for OFR equations of curves node numbers 7-56

3.2 Graphical Plots for Results Obtained.

This analysis is performed in gnuplot in Linux.

1. Node Number 7

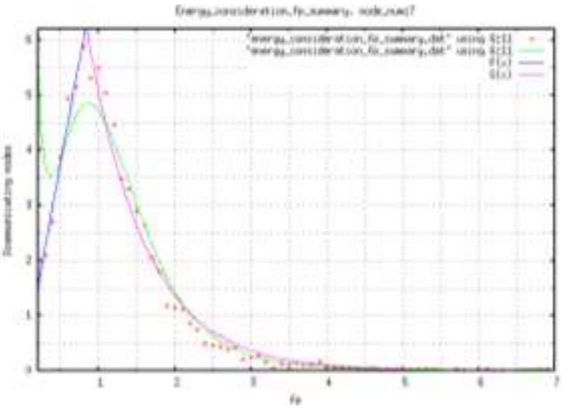

Figure 1: % communicating nodes for ECFP node_number 7

2. Node Number 8

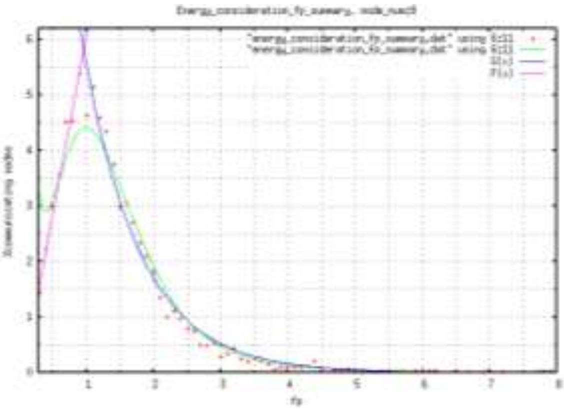

Figure 2: % communicating nodes for ECFP node_number 8

3. Node Number 9

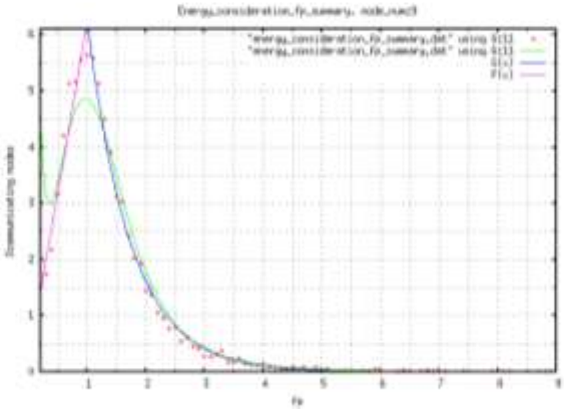

Figure 3: % communicating nodes for ECFP node_number 9

4. Node Number 10

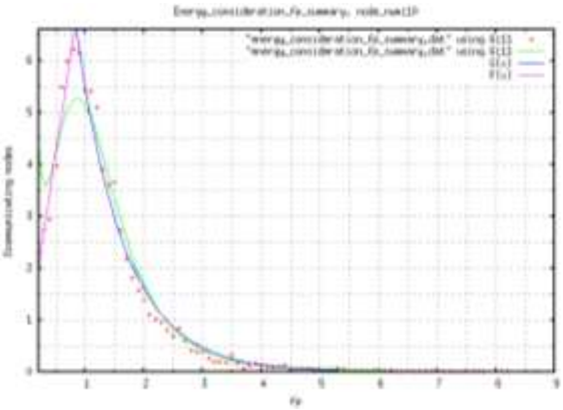

Figure 4: % communicating nodes for ECFP node_number 10

5. Node Number 11

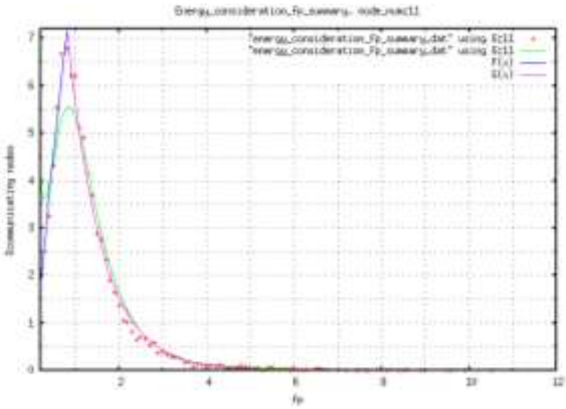

Figure 5: % communicating nodes for ECFP node_number 11

6. Node Number 12

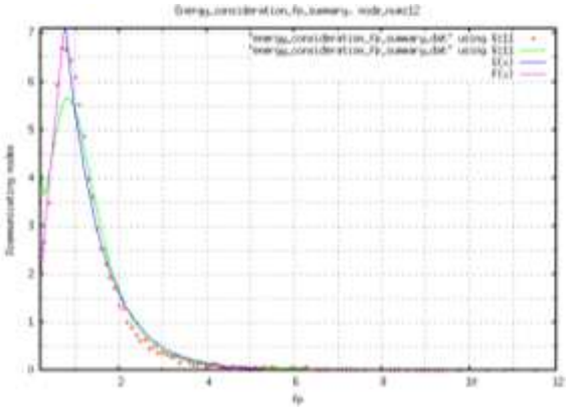

Figure 6: % communicating nodes for ECFP node_number 12

7. Node Number 13

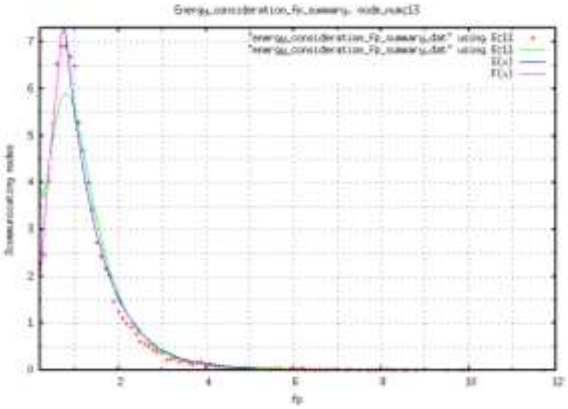

Figure 7: % communicating nodes for ECFP node_number 13

8. Node Number 14

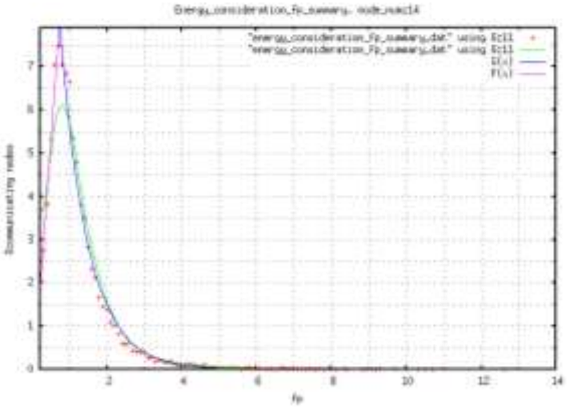

Figure 8: % communicating nodes for ECFP node_number 14

9. Node Number 15

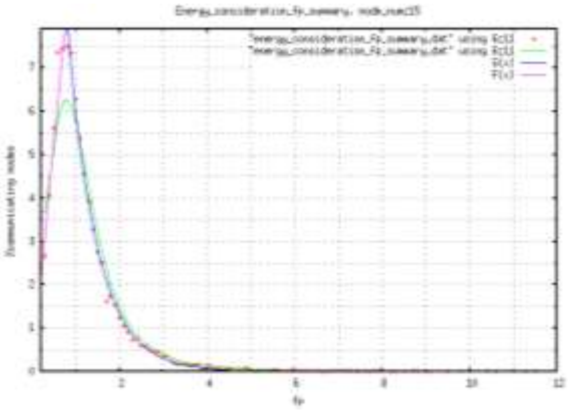

Figure 9: % communicating nodes for ECFP node_number 15

10. Node Number 16

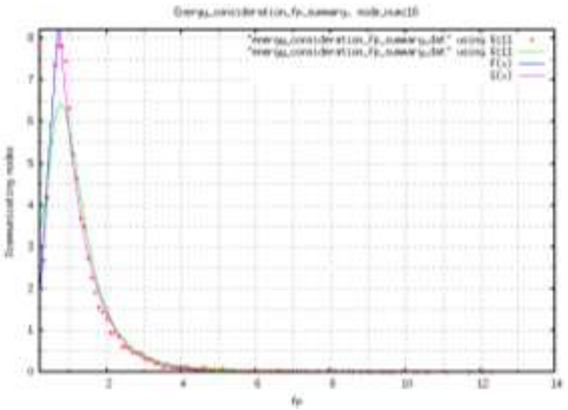

Figure 10: % communicating nodes for ECFP node_number 16

11. Node Number 17

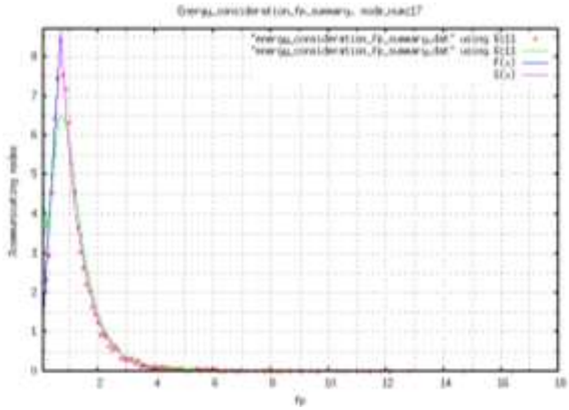

Figure 11: % communicating nodes for ECFP node_number 17

12. Node Number 18

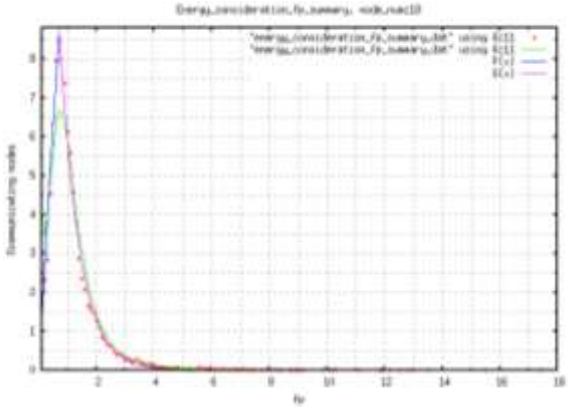

Figure 12: % communicating nodes for ECFP node_number 18

13. Node Number 19

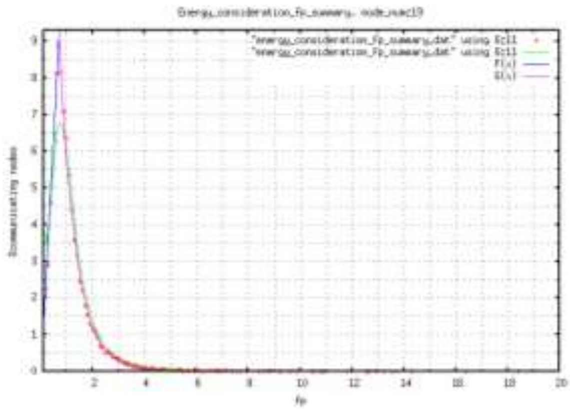

Figure 13: % communicating nodes for ECFP node_number 19

14. Node Number 20

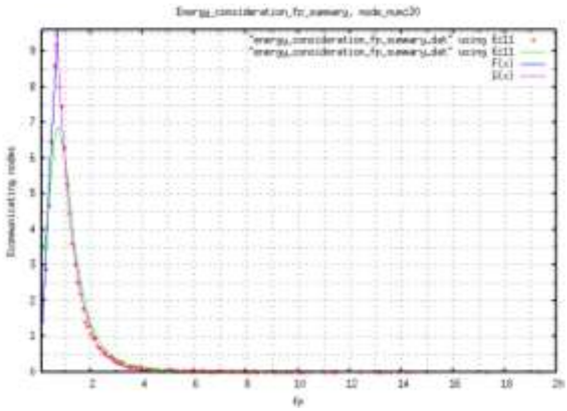

Figure 14: % communicating nodes for ECFP node_number 20

15. Node Number 21

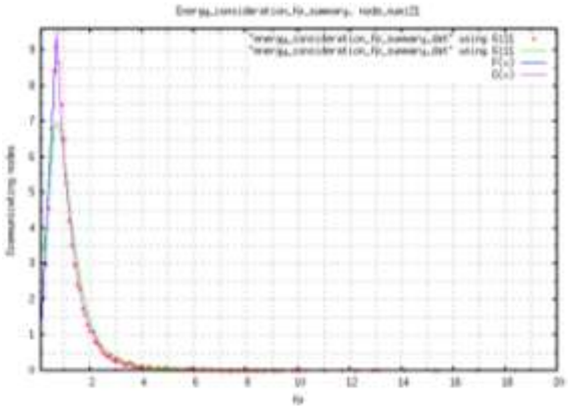

Figure 15: % communicating nodes for ECFP node_number 21

16. Node Number 22

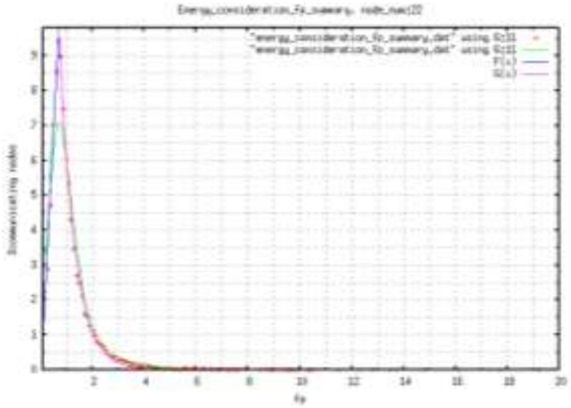

Figure 16: % communicating nodes for ECFP node_number 22

17. Node Number 23

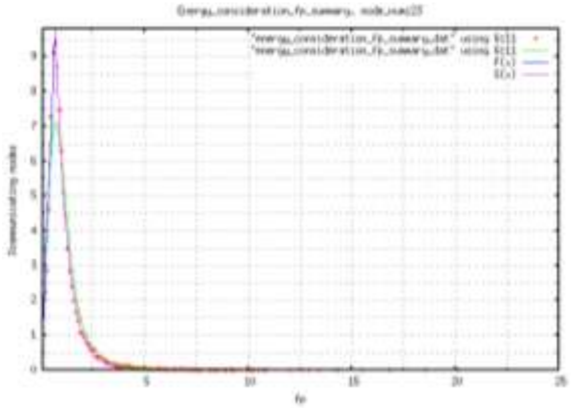

Figure 17: % communicating nodes for ECFP node_number 23

18. Node Number 24

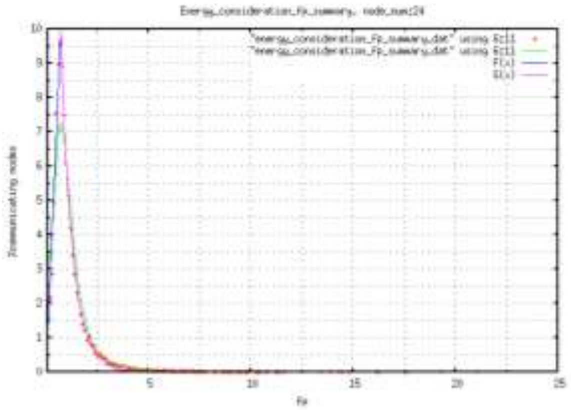

Figure 18: % communicating nodes for ECFP node_number 24

19. Node Number 25

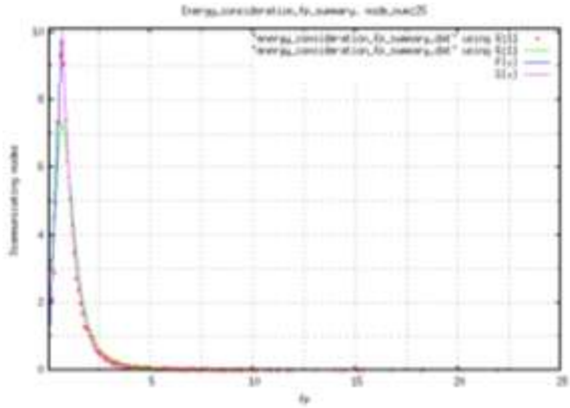

Figure 19: % communicating nodes for ECFP node_number 25

20. Node Number 26

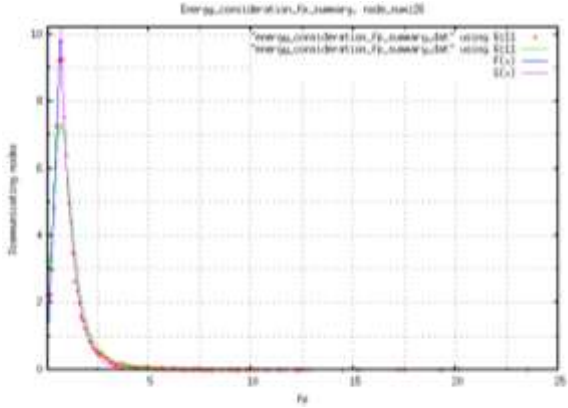

Figure 20: % communicating nodes for ECFP node_number 26

21. Node Number 27

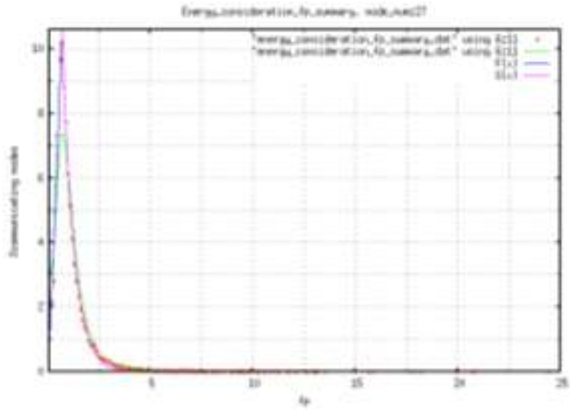

Figure 21: % communicating nodes for ECFP node_number 27

22. Node Number 28

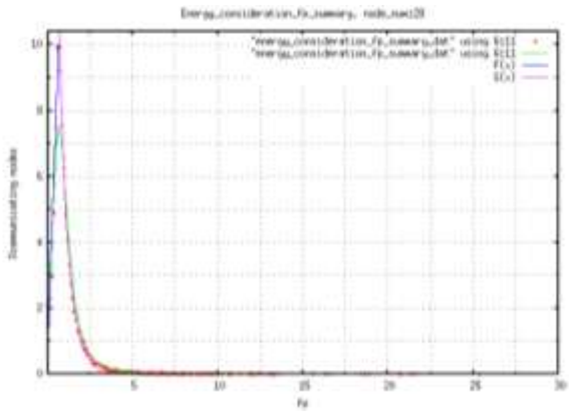

Figure 22: % communicating nodes for ECFP node_number 28

23. Node Number 29

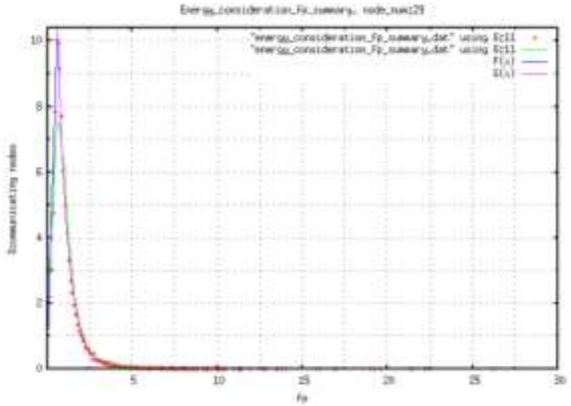

Figure 23: % communicating nodes for ECFP node_number 29

24. Node Number 30

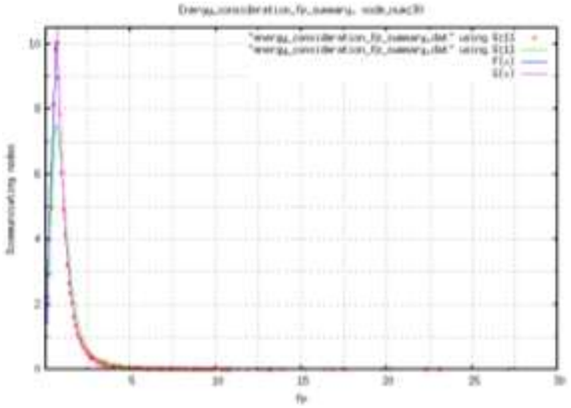

Figure 24: % communicating nodes for ECFP node_number 30

25. Node Number 31

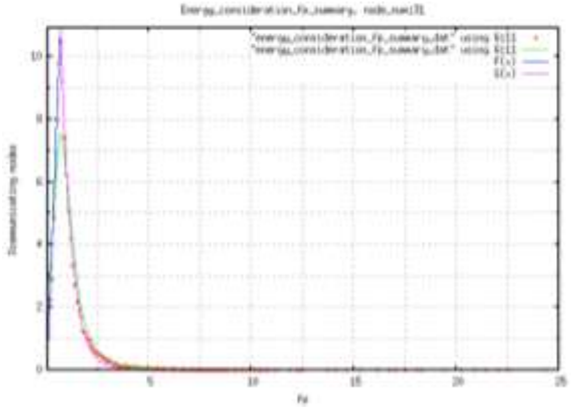

Figure 25: % communicating nodes for ECFP node_number 31

26. Node Number 32

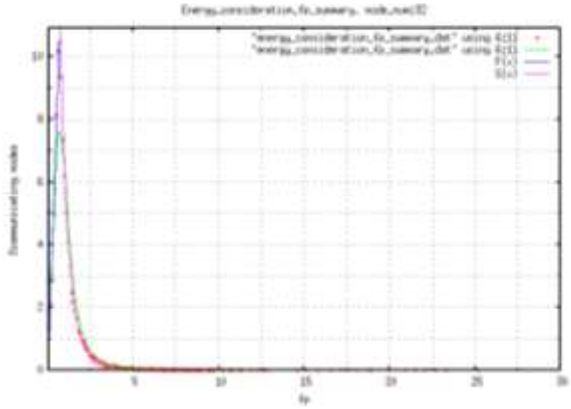

Figure 26: % communicating nodes for ECFP node_number 32

27. Node Number 33

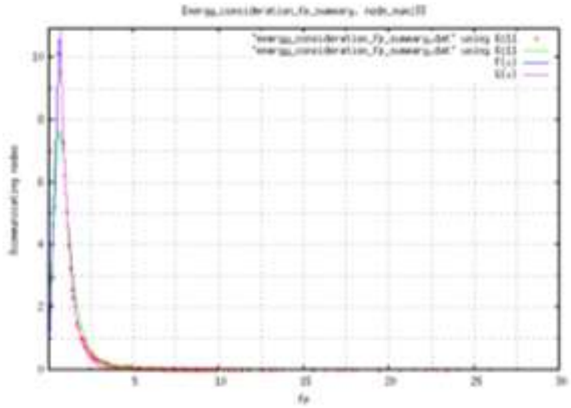

Figure 27: % communicating nodes for ECFP node_number 33

28. Node Number 34

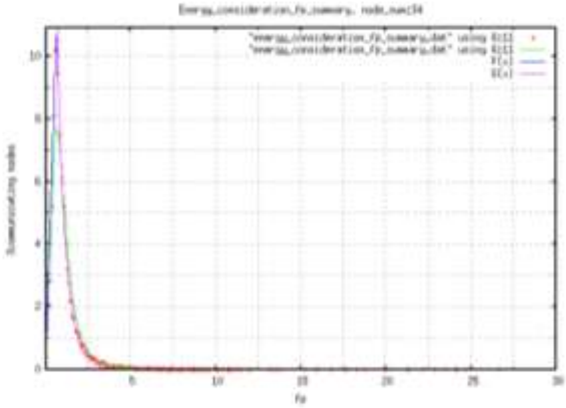

Figure 28: % communicating nodes for ECFP node_number 34

29. Node Number 35

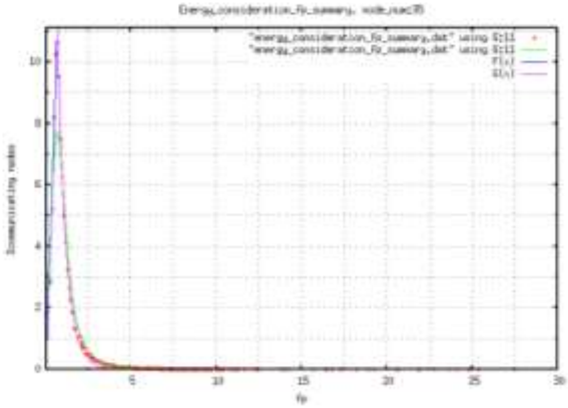

Figure 29: % communicating nodes for ECFP node_number 35

30. Node Number 36

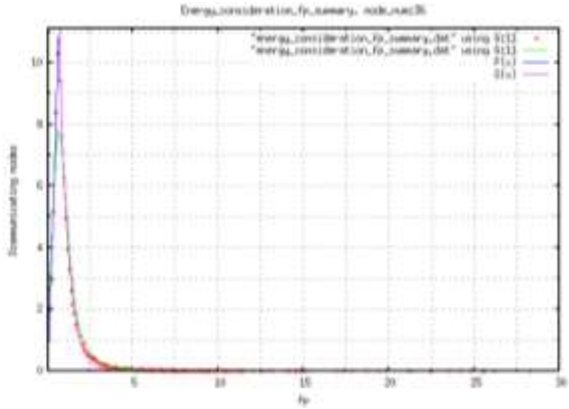

Figure 30: % communicating nodes for ECFP node_number 36

31. Node Number 37

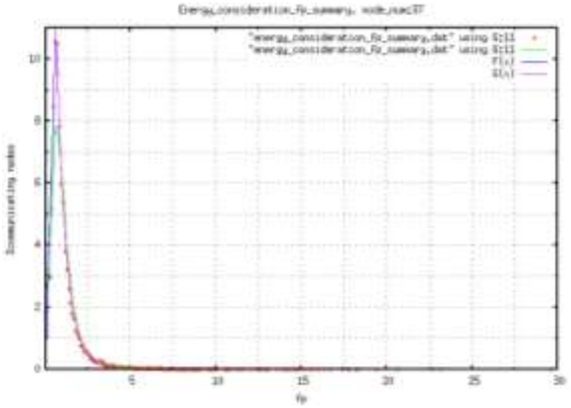

Figure 31: % communicating nodes for ECFP node_number 37

32. Node Number 38

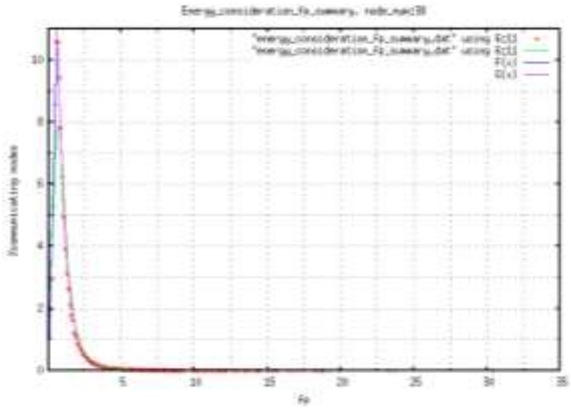

Figure 32: % communicating nodes for ECFP node_number 38

33. Node Number 39

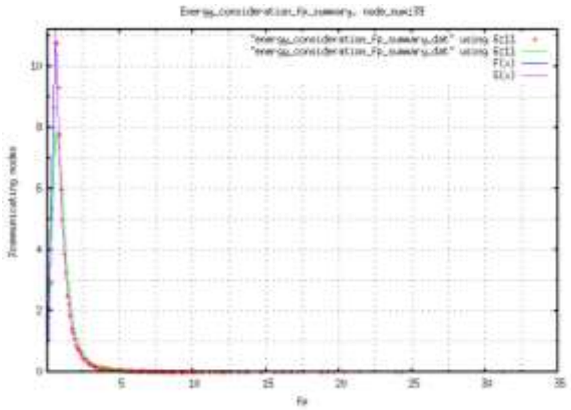

Figure 33: % communicating nodes for ECFP node_number 39

34. Node Number 40

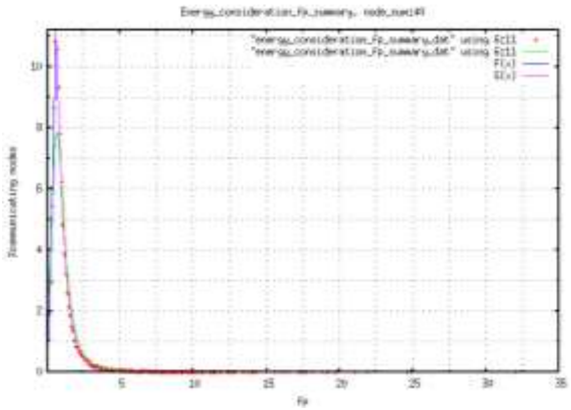

Figure 34: % communicating nodes for ECFP node_number 40

35. Node Number 41

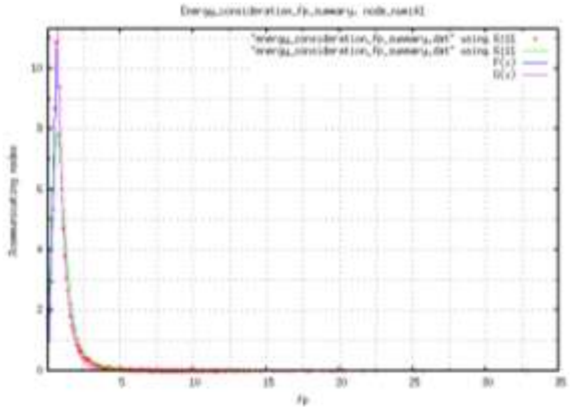

Figure 35: % communicating nodes for ECFP node_number 41

36. Node Number 42

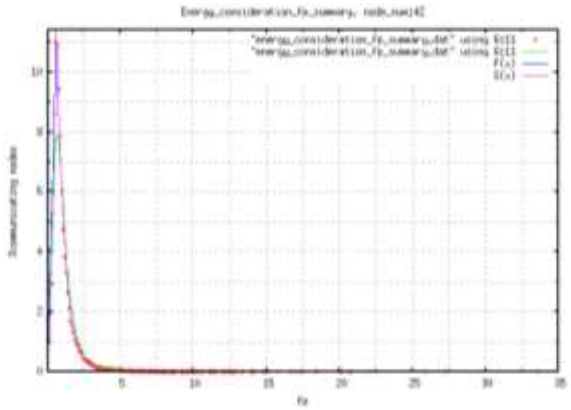

Figure 36: % communicating nodes for ECFP node_number 42

37. Node Number 43

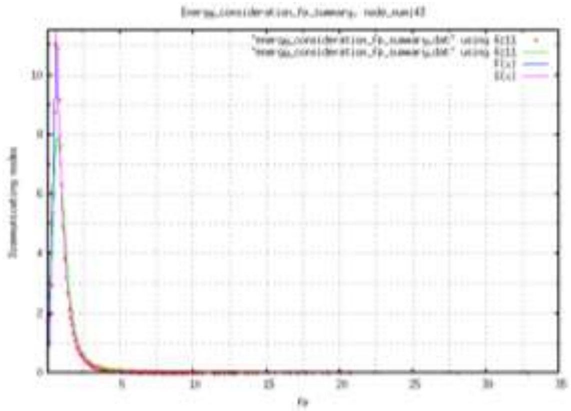

Figure 37: % communicating nodes for ECFP node_number 43

38. Node Number 44

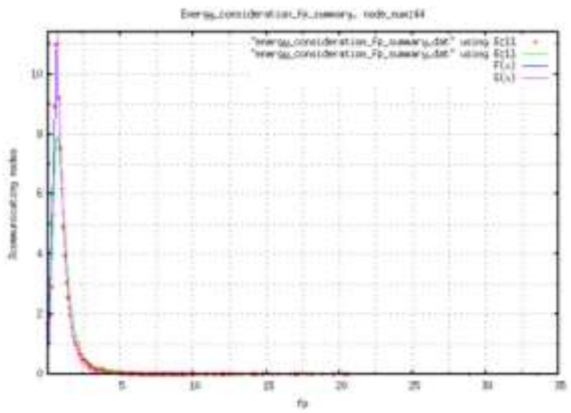

Figure 38: % communicating nodes for ECFP node_number 44

39. Node Number 45

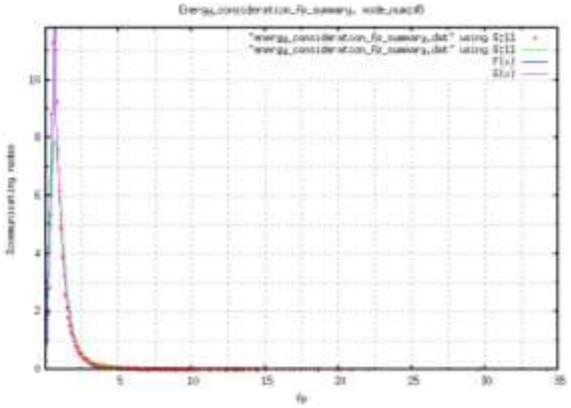

Figure 39: % communicating nodes for ECFP node_number 45

40. Node Number 46

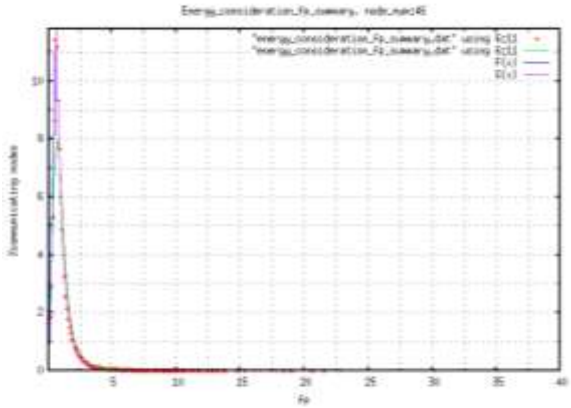

Figure 40: % communicating nodes for ECFP node_number 46

41. Node Number 47

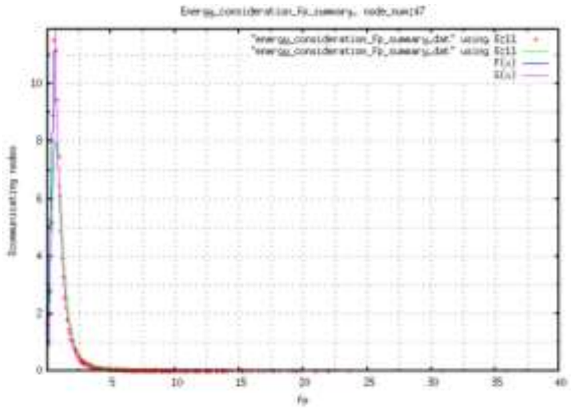

Figure 41: % communicating nodes for ECFP node_number 47

42. Node Number 48

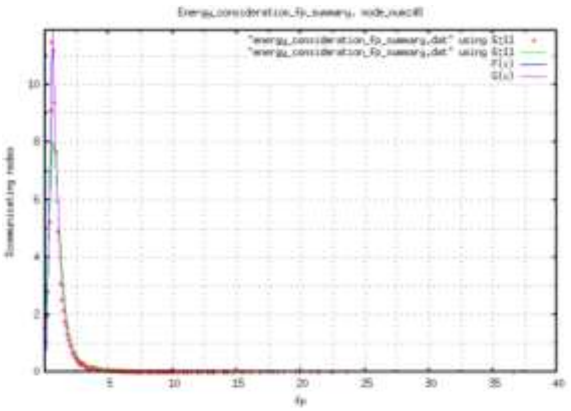

Figure 42: % communicating nodes for ECFP node_number 48

43. Node Number 49

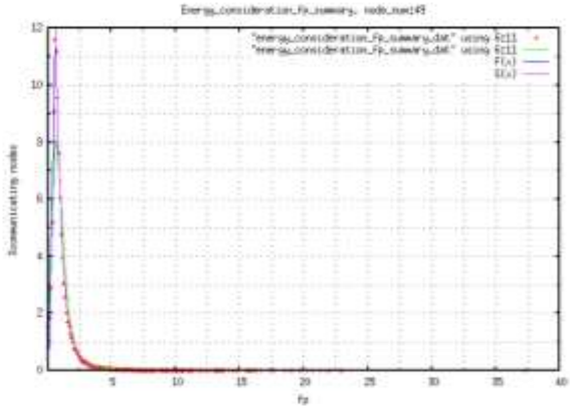

Figure 43: % communicating nodes for ECFP node_number 49

44. Node Number 50

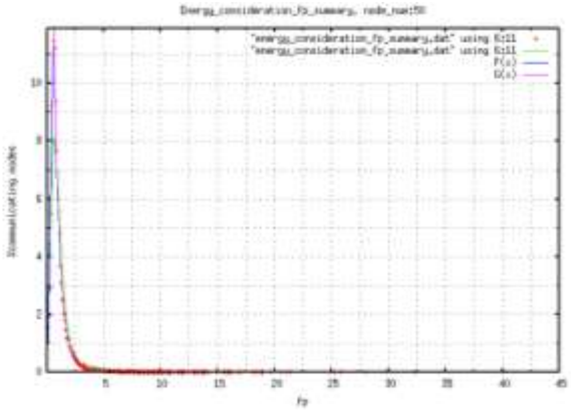

Figure 44: % communicating nodes for ECFP node_number 50

45. Node Number 51

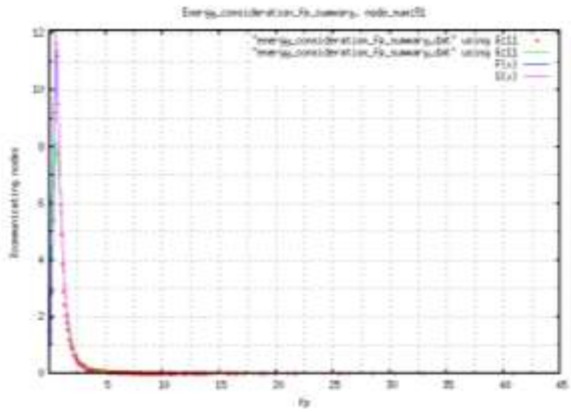

Figure 45: % communicating nodes for ECFP node_number 51

46. Node Number 52

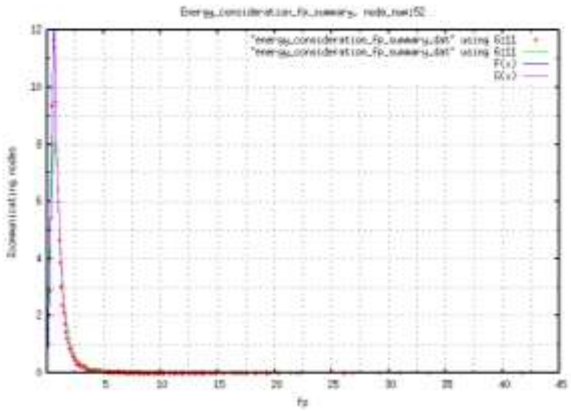

Figure 46: % communicating nodes for ECFP node_number 52

47. Node Number 53

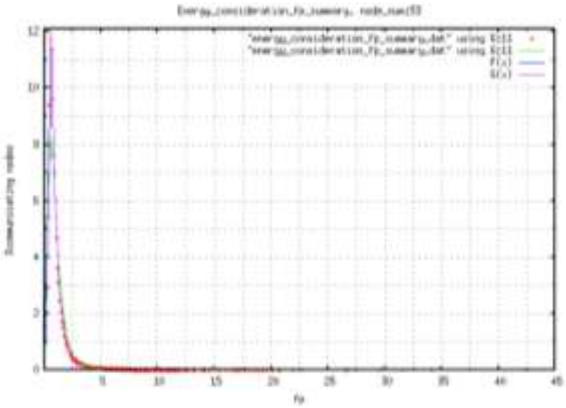

Figure 47: % communicating nodes for ECFP node_number 53

48. Node Number 54

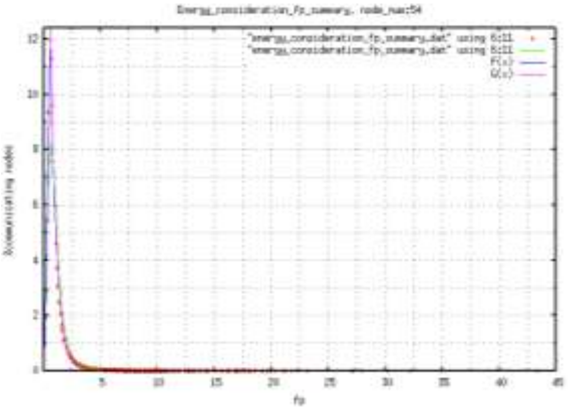

Figure 48: % communicating nodes for ECFP node_number 54

49. Node Number 55

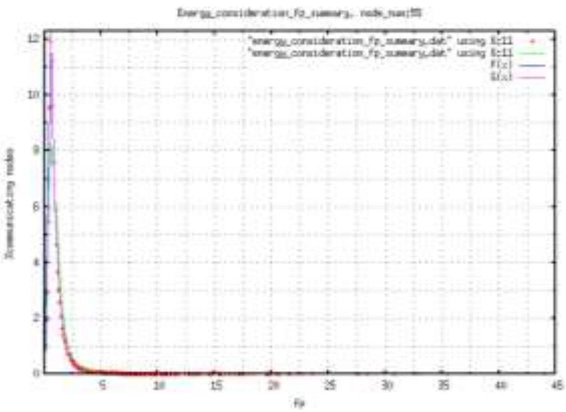

Figure 49: % communicating nodes for ECFP node_number 55

50. Node Number 56

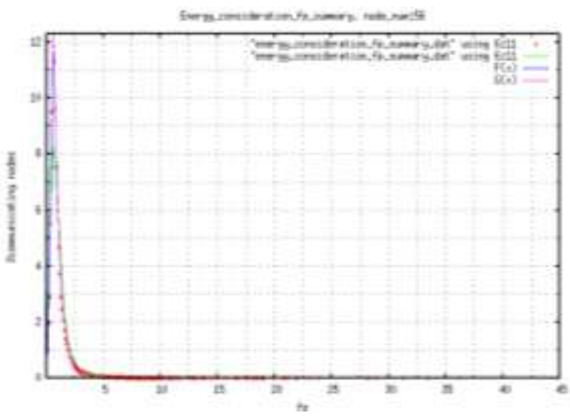

Figure 50: % communicating nodes for ECFP node_number 56

4. Conclusion.

This piece of research was aimed at studying trends of fairness reached in ubicomp as concerns energy load distribution. This research differs from previous work [18-21] in the sense that here, equitable distribution of energy among all topographic nodes present is assumed. For this purpose, a metric BFEA has been developed to define this equitable distribution of energy. Following definition of BFEA, another metric, ECFP, has been developed and its rationale and purposes also put forward. This study remains empirical-based and was implemented over same experiment as explained previously [15]. The model put forward combines the exponential and linear models. Again, previously stated assumptions [21] hold, e.g. availability of lightweight algorithms for location-aware transmission in mobile environments, lightweight MAUC OS supports for efficient binding/unbinding of MANET nodes and appropriate multi-threading/parallel communication in modules of MANET nodes.

The further work identified may include: trend analyses of parameters of equations for the model, formulating methods of predictability for metric ECFP and its trend and reporting observations of certain critical values identified. Development of further metrics for studying Fairness in ubicomp remain desirable. Other research avenues remain development of further metrics and methods for assessing Fairness in energy expenditure of participating nodes in MANET transmission, together with the trend analyses.

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