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

M. Kaleem GALAMALI, Assoc. Prof Nawaz MOHAMUDALLY

***Abstract* – Many researchers in mobile networking are of the opinion that MANET transmission helps to contain energy in ubicomp [56]. Location-aware transmission can complement the objective of saving energy in MANETs. MANET transmission will achieve the functionality using automatic cooperative strategy with nodes present in the topography. In such situations, gauging degree of cooperation and Fairness of load distributions, taking into consideration all underlying features like hardware specifications, battery power, and more specifically, ratio of energy being required by the MANET node compared to the sender node itself, together with known corresponding trends, is desirable. Such studies have been presented [19, 20]. Following these research [19, 20], a third set of answers to address issue of "how to gauge Fairness features being reached in MANETs", is provided in this paper, with a metric OFR along with its corresponding model of trend 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 for ubicomp. This paper is a follow-up of previous research [1-20].

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, CBR- Constant Bit Rate.

M. Kaleem GALAMALI,
University of Technology Mauritius (student)
Mauritius

Assoc. Prof Nawaz Mohamudally
University of Technology Mauritius,
Mauritius

1. Introduction

Among all the factors affecting energy consumption in MAUC [2], MANET transmission remains a considerable factor whereby the workload of transmission is distributed along MANET routes to achieve cooperative and complete transmission to receiver. It is expected that node density in MANETs will also affect the energy consumption. MANET transmission adopts a cooperative strategy of communication and hence, methods including metrics, must be devised to properly gauge, assess and track degrees of cooperation of each node and Fairness criteria reached, compared to sender node itself. Such a previous study has been carried out [18] followed by studies over two derived metrics together with their purposes: Min_R [19] and Max_R [20].

Both metrics Min_R and Max_R stated above have their use. However, both have limitations. It is recalled that in previous work [19, 20], categories of the corresponding metrics were defined with respect to value 1. Values of Min_R and Max_R will not indicate how many contributing nodes in a CBR transmission are achieving the ECR values below and above 1. With these two values, the overall Fairness achieved by contributing nodes can be gathered. It is recalled that Fairness is considered with contributing nodes spending energy less or equal to the sender node itself in a CBR transmission. The next logical metric to be derived is hence, OFR, which is also heavily affected by changes in MANET routes [18].

The key contributions of this paper is firstly, the development of a third derived metric OFR, which is derived from ECR [18], including its definition and rationale, and secondly, the model of trend put forward for the metric OFR with results for varying node densities from 7 until 56 in a topography of 300 x 300 m^2. The model for "%CBR" against OFR has been too scattered and difficult to observe. Hence, model of trend for "cumulative % CBR" against OFR values has been studied, which is much more convincing as a combination of exponential and linear tendencies. The rest of this paper is organised as follows: section 2- New Derived Metric- Overall Fairness Ratio, section 3- OFR Trend Assessment over Varying Node Numbers, 4- Conclusion and References.

2. New Derived Metric: Overall Fairness Ratio.

Following previous studies [18-20] concerning ratio of energy spent compared to sender, it is projectable that the situations of "complete unfairness" or "complete fairness" may seldom be reached. Most of the time, for a CBR transmission, part of the nodes in the MANET routes will have ECR value less than 1 and part of them

will have ECR value greater than 1. Hence, the metric OFR is initially devised as:

$$OFR = \frac{\text{Number of nodes with ECR less than 1}}{\text{Number of nodes with ECR greater than 1}}$$

The bigger the OFR value above 1, the greater Fairness reached in MANET nodes energy consumption, i.e. more than half of the nodes concerned will have ECR value less than 1. On the other hand, the smaller the OFR value below 1, the greater the unfairness reached in MANET nodes energy consumption, i.e. more nodes have had ECR value greater than 1.

The problem with the above formula for OFR crops up in the situation where there is a number of ECR values less than 1 but there has been no ECR values greater than 1; it will generate a divide by 0 error. Mathematically, it generates value of infinity, which is nonsensical here and computationally processing blocks with program blocking (failure, which did happen in program execution). There is no related error-handling inherent in TCL as in JAVA. The solution adopted has been simple: consider the ECR of the sender also. It has to be 1 since its energy consumption is divided by itself. The formula is then amended as:

$$OFR = \frac{\text{Number of nodes with ECR less than 1}}{\text{(1 + Number of nodes with ECR greater than 1)}}$$

Now, the denominator will never be 0 and program will not block for divide by 0 errors. OFR values and trends, if appropriately gauged or predicted can serve purposes such as:

i. Measuring needs for Ferry Transport Protocols [57].
ii. Deciding an amount of infrastructure support needed and formulating policies of deployment.
iii. Formulating decisions for forwarding/not forwarding packets and for what durations.
iv. Better assigning trust levels to nodes or node group.
v. With appropriate history tracking and recording, further policy refinements may be formulated after previous work [19, 20].

3. OFR Trend Assessment over Varying Node Numbers.

3.0 Major Observations.

Initially, the study of % CBR against OFR was attempted but as shown in figure 1(a), the plots are sparsely distributed with difficult to establish convincing trends. The problem was addressed by using "cumulative % CBR" against OFR. As expected, the plot obtained shows an increasing trend. The equation of model has been established at:

```
F(x) = a * exp (b*x) + (c*x) + d
```

Only for node number 7 has part of the parameter "c" multiplied by x^2, given better fit with lesser reduced Chi-square value (17.660 7 against 19.722 1) but this has not sustained over successive node numbers.

3.1 Tabular Summary of Results.

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

A	B	C	D	E	F	G
7	-56.362 4	-1.369 5	5.484 04	53.865 8	19.722 1	1(b)
8	-52.391 4	-1.685 59	5.048 39	59.239 2	9.327 88	2
9	-54.775 8	-1.519 37	4.054 68	62.457 5	7.454 64	3
10	-56.561	-1.779 9	3.198 4	67.411 8	7.213 67	4
11	-55.846 5	-1.885 8	3.134 95	67.120 9	8.383	5
12	-55.5	-1.770 09	2.701 71	68.503 5	6.632 31	6
13	-56.524	-1.680 2	2.452 05	69.927 3	7.098 21	7
14	-54.873	-1.775 89	2.334 29	69.466 9	7.587 95	8
15	-55.105	-1.760 49	2.147 06	70.364 2	7.964 4	9
16	-55.419 5	-1.575 03	1.825 69	72.242 7	7.749 42	10
17	-53.414 2	-1.565 64	1.735 42	71.830 6	8.402 33	11
18	-52.564 5	-1.356 45	1.566 26	73.220 2	9.375 72	12
19	-52.932 8	-1.546 46	1.609 24	71.809 6	14.379 1	13
20	-50.520 3	-1.354 35	1.461 51	72.711 9	11.847 1	14
21	-51.851 9	-1.446 91	1.374 68	73.116 5	11.453 4	15
22	-51.451 8	-1.398 85	1.290 75	73.545 3	11.819 6	16
23	-50.802 4	-1.259 39	1.135 12	74.923 1	11.448	17
24	-51.146	-1.260 72	1.086 59	75.162 3	12.305 3	18
25	-50.729 2	-1.243 37	1.081 32	75.189 4	12.096 5	19
26	-49.830 7	-1.090 13	0.990 481	76.253 5	10.464 4	20
27	-49.999 5	-1.109 83	0.977 65	76.118 5	11.621	21
28	-49.813 8	-0.961 965	0.836 092	78.066 1	11.361 3	22
29	-51.695 8	-1.047 43	0.860 307	77.638 1	12.523	23
30	-51.367 8	-0.913 971	0.776 13	79.130 1	12.243 4	24
31	-51.464 4	-0.905 127	0.728 13	79.117	11.548 2	25
32	-50.715 845	-0.891 195	0.728 208	78.968 603 2	11.105 1	26
33	-51.019 9	-0.905 753	0.713 612	79.029 4	11.976 2	27
34	-49.772 3	-0.877 03	0.676 164	79.023 3	13.143 3	28
35	-50.084 1	-0.837 359	0.669 318	79.613 3	13.653 8	29
36	-50.131 4	-0.782 973	0.620 927	80.434 5	14.651 4	30
37	-52.177 8	-0.809 139	0.567 344	81.353 6	11.813 8	31
38	-52.014 3	-0.842 491	0.588 883	81.003 9	11.746 4	32
39	-52.745 866	-0.818 367 5	0.523 069 3	81.775 305 5	10.973 3	33
40	-52.824 4	-0.847 01	0.507 126	81.554 8	12.299 4	34
41	-53.389 4	-0.862 381	0.508 266	81.980 7	12.188 1	35
42	-54.036 9	-0.896 433	0.500 511	81.855 8	11.761 3	36
43	-54.76	-0.809 072	0.454 625	83.101 6	10.758 4	37
44	-54.370 5	-0.818 725	0.417 527	83.202 3	10.305 9	38
45	-53.414 4	-0.747 548	0.371 753	84.052 4	10.324 3	39
46	-52.629 1	-0.743 907	0.392 876	83.743 8	10.073 2	40
47	-53.63	-0.745 699	0.381 611	83.813 7	10.958 4	41
48	-53.041 1	-0.710 952	0.355 911	84.43	10.927 1	42
49	-52.736 4	-0.722 065	0.374 309	84.078 2	11.338 3	43
50	-50.130 6	-0.755 781	0.412 817	82.614 8	11.643 7	44
51	-49.734 5	-0.732 467	0.410 79	82.786 7	11.775 7	45
52	-49.379 3	-0.739 38	0.397 828	82.570 3	12.090 4	46
53	-50.243 7	-0.679 807	0.354 411	83.870 9	11.827 9	47
54	-49.227 1	-0.685 031	0.386 847	83.222 7	11.914 3	48
55	-48.979 7	-0.720 348	0.390 089	82.707 4	12.443 7	49
56	-49.608 3	-0.671 79	0.346 928	83.880 4	13.077	50

Table 1: 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.

3.2.1. The unconvincing plot

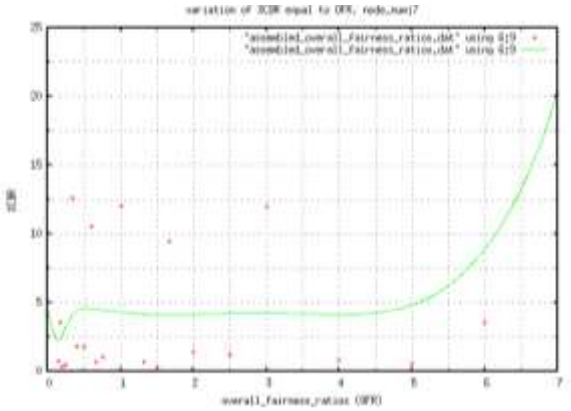

Figure 1(a): % cbr for OFR node_number 7

3.2.2 Plots for Observable Trends.

1. Node Number 7

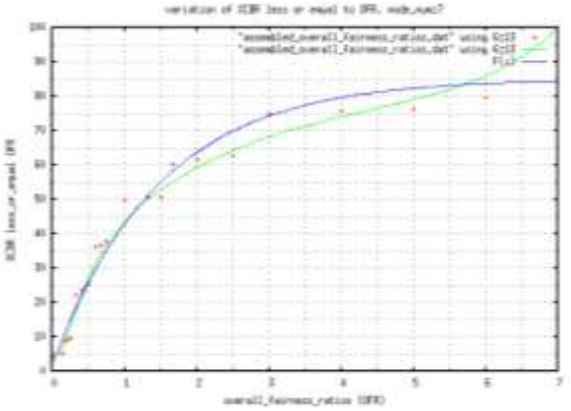

Figure 1(b): %cbr (≤)for OFR node_number 7

2. Node Number 8

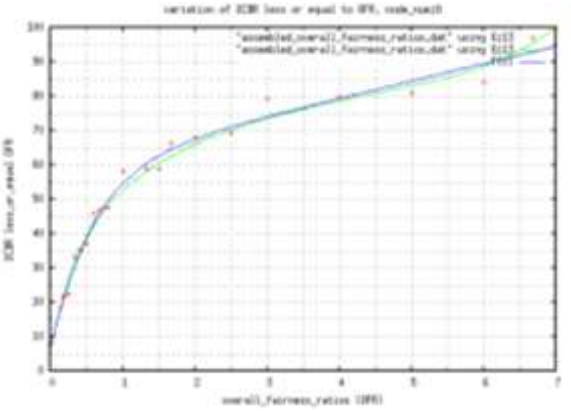

Figure 2: %cbr (≤)for OFR node_number 8

3. Node Number 9

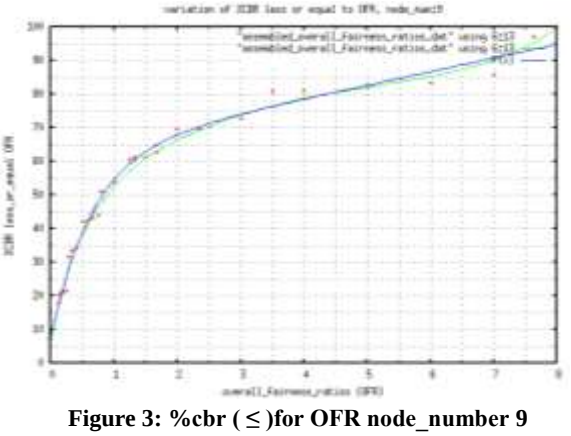

Figure 3: %cbr (≤)for OFR node_number 9

4. Node Number 10

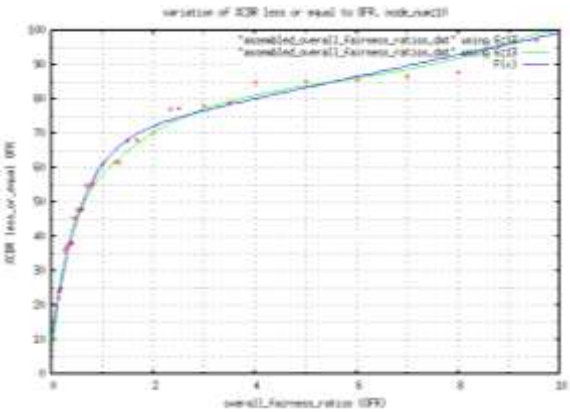

Figure 4: %cbr (≤)for OFR node_number 10

5. Node Number 11

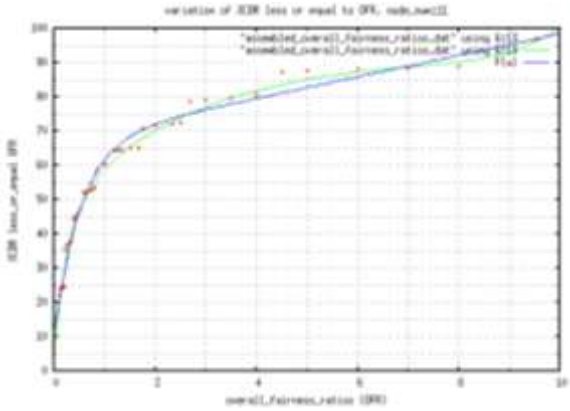

Figure 5: %cbr (≤)for OFR node_number 11

6. Node Number 12

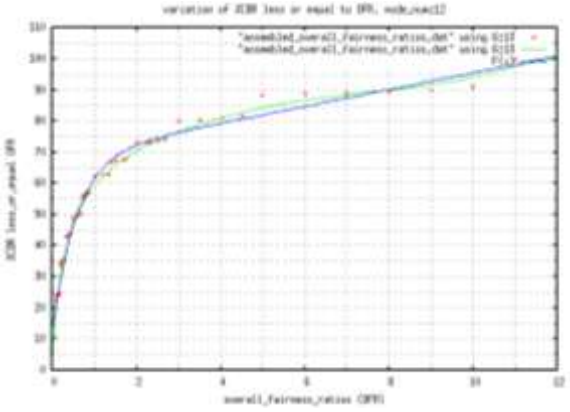

Figure 6: %cbr (≤)for OFR node_number 12

7. Node Number 13

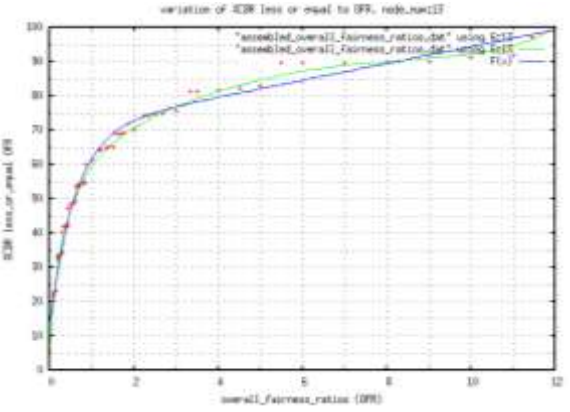

Figure 7: %cbr (≤)for OFR node_number 13

8. Node Number 14

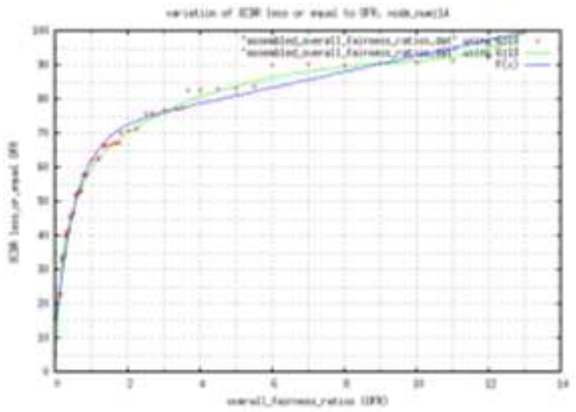

Figure 8: %cbr (≤)for OFR node_number 14

9. Node Number 15

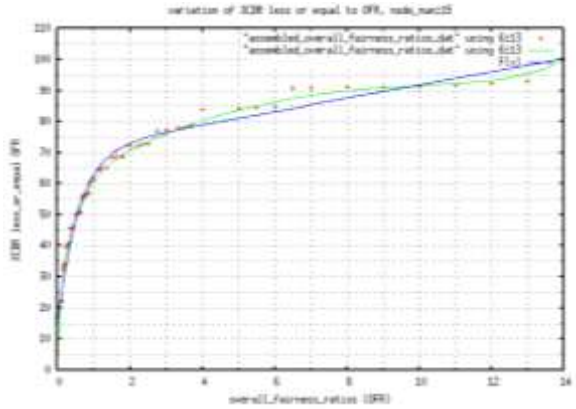

Figure 9: %cbr (≤)for OFR node_number 15

10. Node Number 16

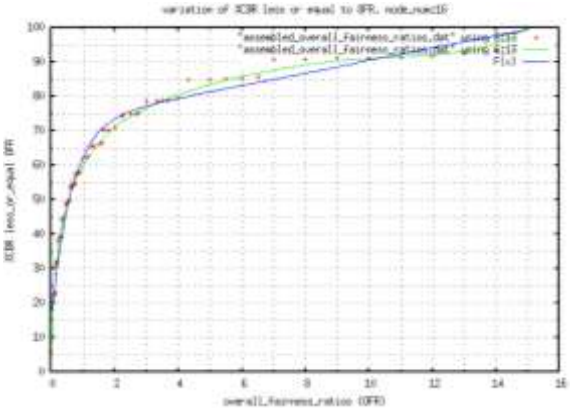

Figure 10: %cbr (≤)for OFR node_number 16

11. Node Number 17

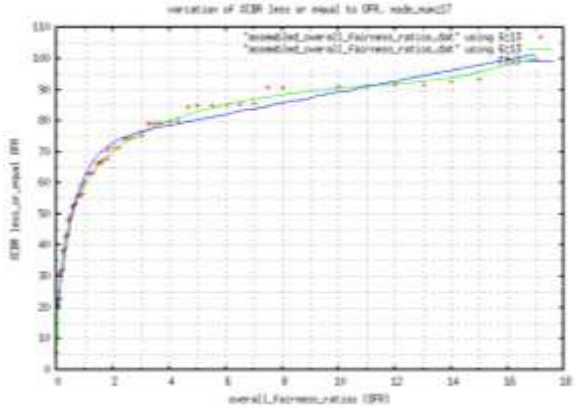

Figure 11: %cbr (≤)for OFR node_number 17

12. Node Number 18

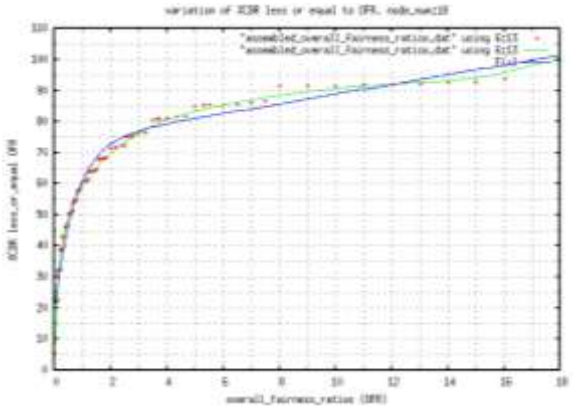

Figure 12: %cbr (≤)for OFR node_number 18

13. Node Number 19

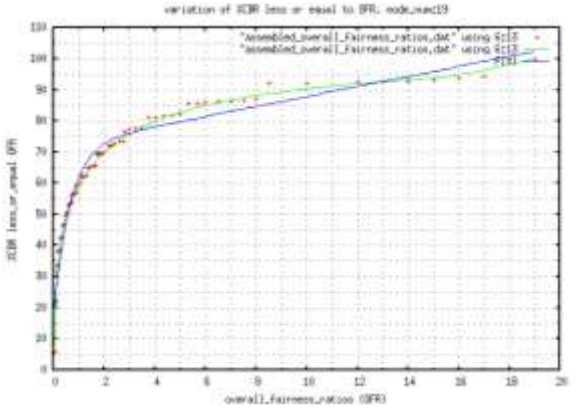

Figure 13: %cbr (≤)for OFR node_number 19

14. Node Number 20

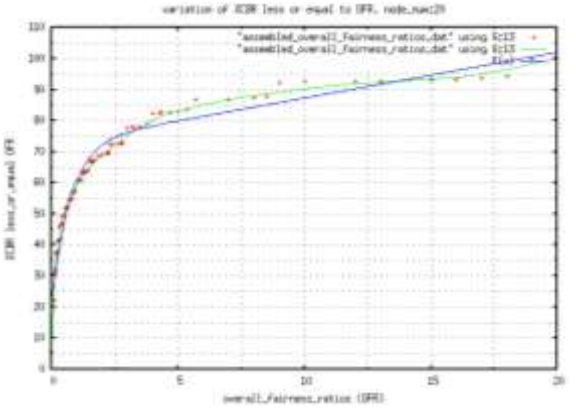

Figure 14: %cbr (≤)for OFR node_number 20

15. Node Number 21

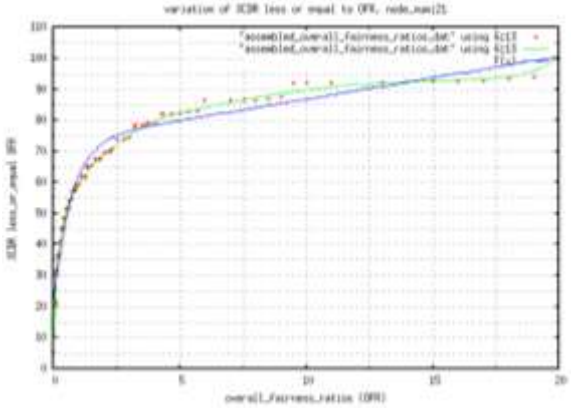

Figure 15: %cbr (≤)for OFR node_number 21

16. Node Number 22

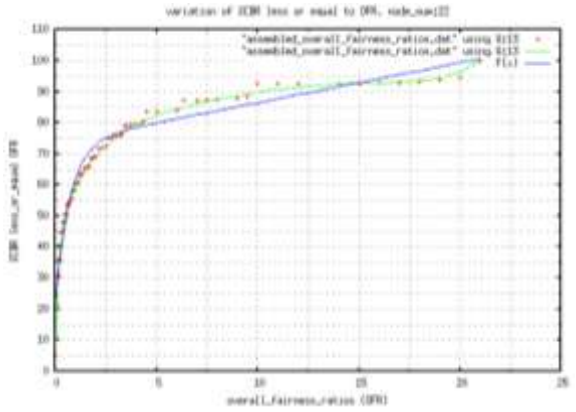

Figure 16: %cbr (≤)for OFR node_number 22

17. Node Number 23

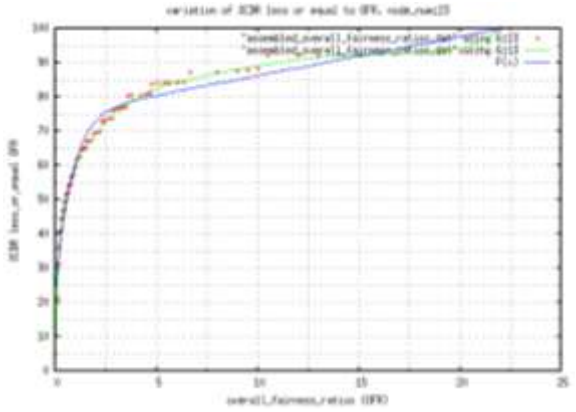

Figure 17: %cbr (≤)for OFR node_number 23

18. Node Number 24

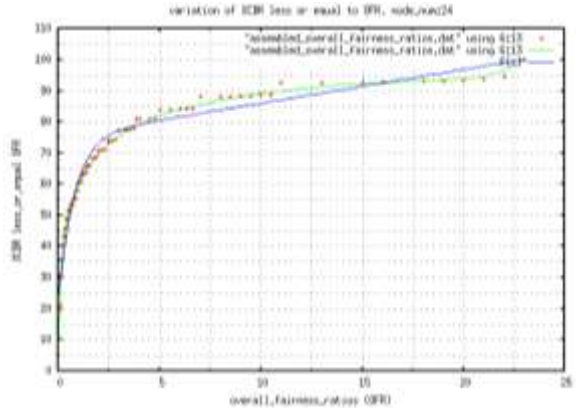

Figure 18: %cbr (≤)for OFR node_number 24

19. Node Number 25

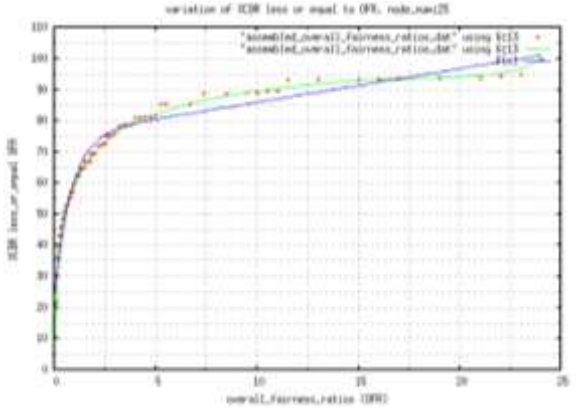

Figure 19: %cbr (≤)for OFR node_number 25

20. Node Number 26

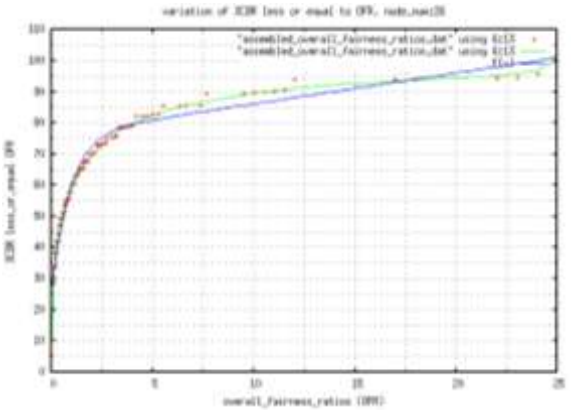

Figure 20: %cbr (≤)for OFR node_number 26

21. Node Number 27

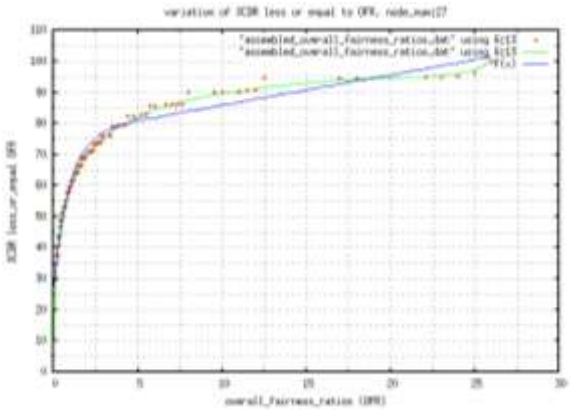

Figure 21: %cbr (≤)for OFR node_number 27

22. Node Number 28

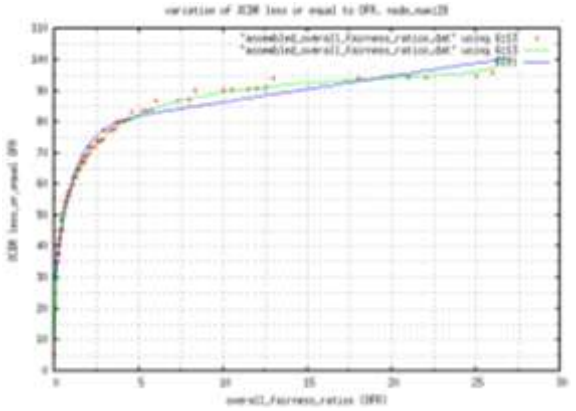

Figure 22: %cbr (≤)for OFR node_number 28

23. Node Number 29

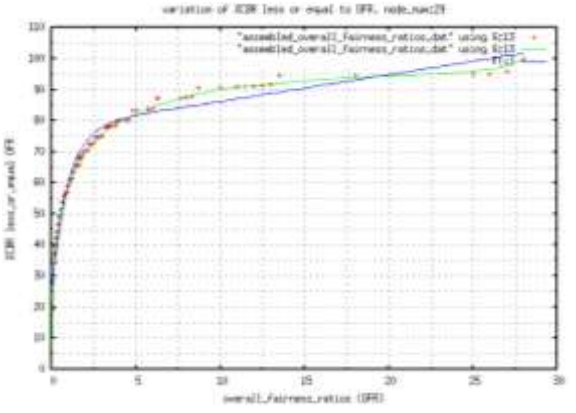

Figure 23: %cbr (≤)for OFR node_number 29

24. Node Number 30

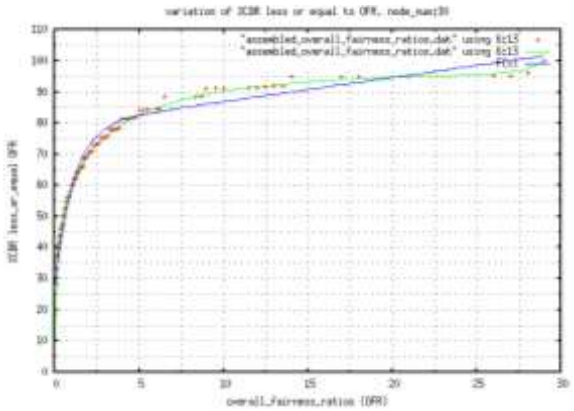

Figure 24: %cbr (≤)for OFR node_number 30

25. Node Number 31

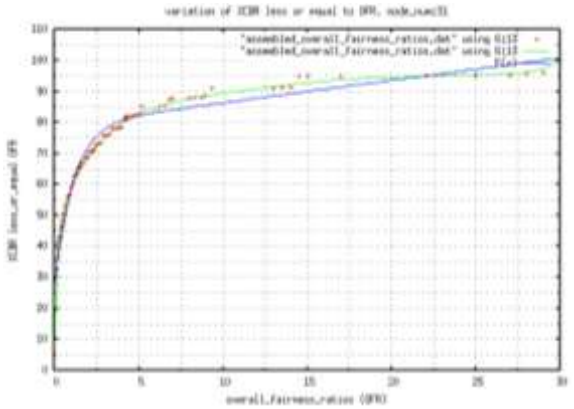

Figure 25: %cbr (≤)for OFR node_number 31

26. Node Number 32

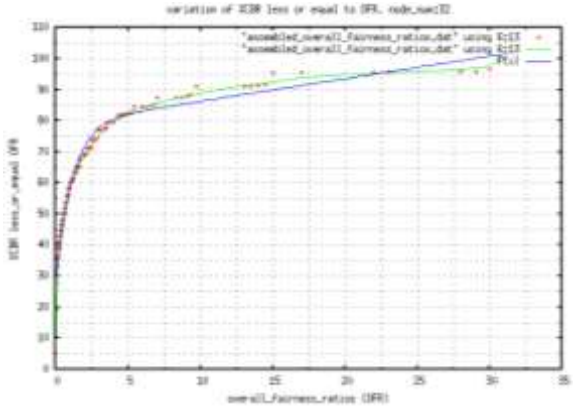

Figure 26: %cbr (≤)for OFR node_number 32

27. Node Number 33

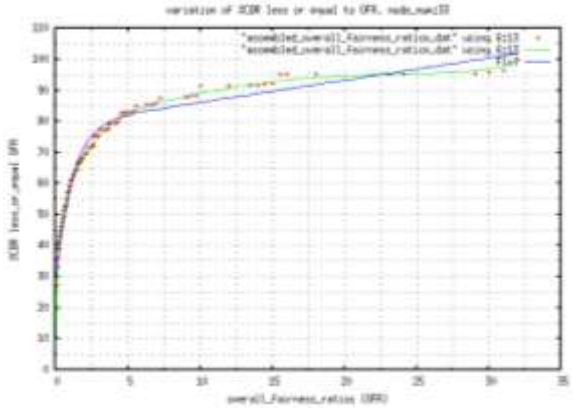

Figure 27: %cbr (≤)for OFR node_number 33

28. Node Number 34

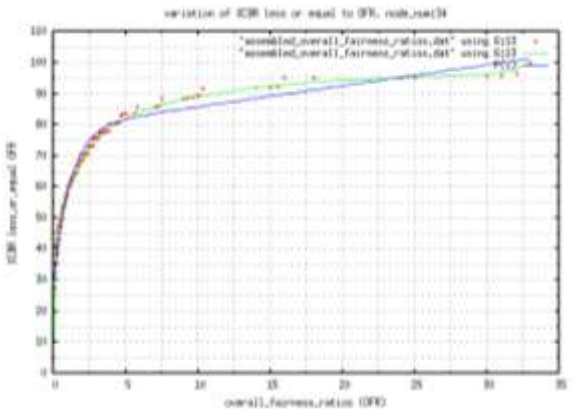

Figure 28: %cbr (≤)for OFR node_number 34

29. Node Number 35

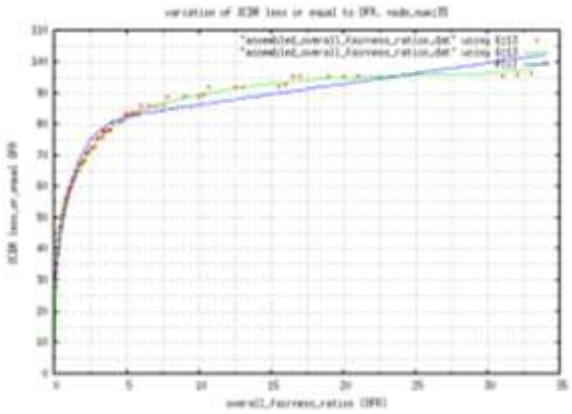

Figure 29: %cbr (≤)for OFR node_number 35

30. Node Number 36

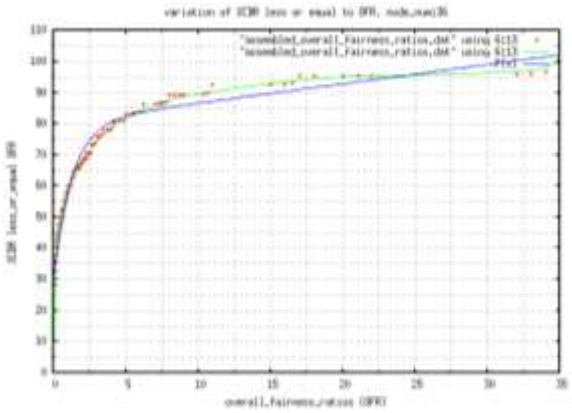

Figure 30: %cbr (≤)for OFR node_number 36

31. Node Number 37

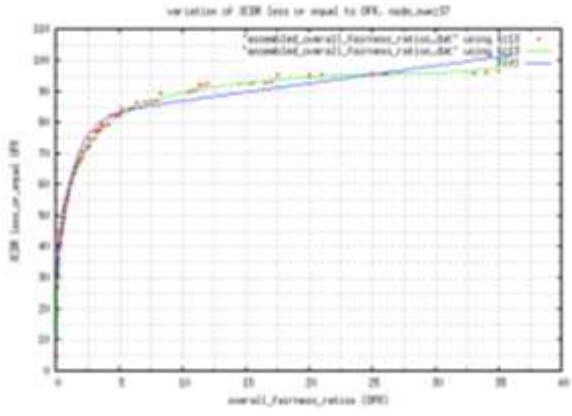

Figure 31: %cbr (≤)for OFR node_number 37

32. Node Number 38

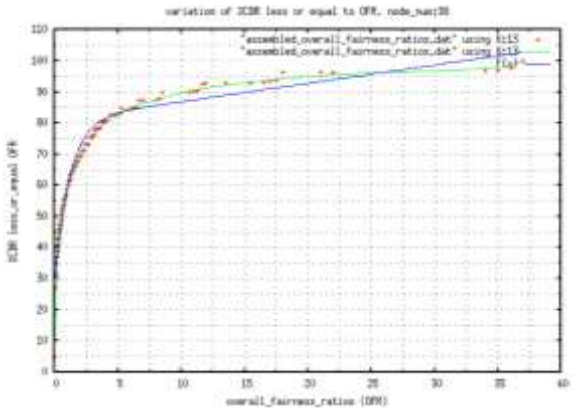

Figure 32: %cbr (≤)for OFR node_number 38

33. Node Number 39

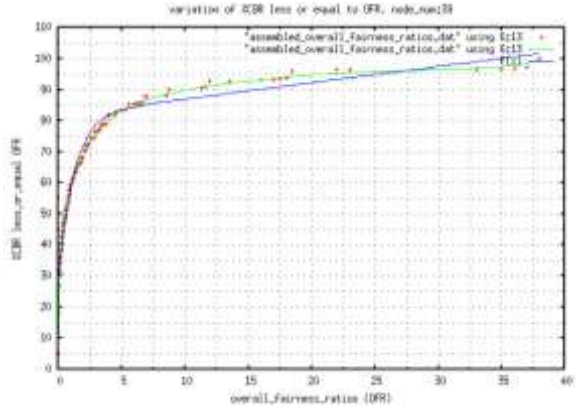

Figure 33: %cbr (≤)for OFR node_number 39

34. Node Number 40

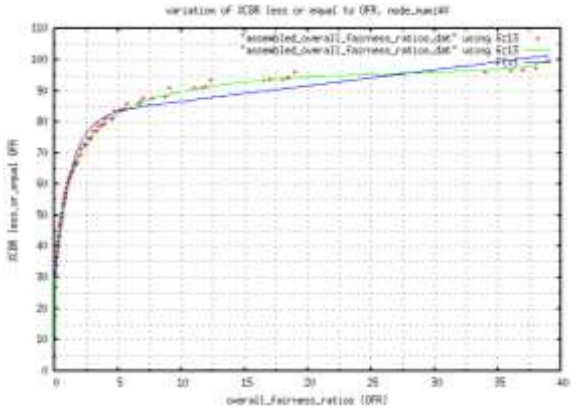

Figure 34: %cbr (≤)for OFR node_number 40

35. Node Number 41

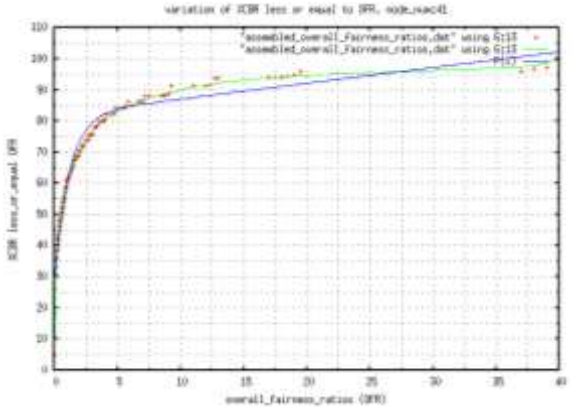

Figure 35: %cbr (≤)for OFR node_number 41

36. Node Number 42

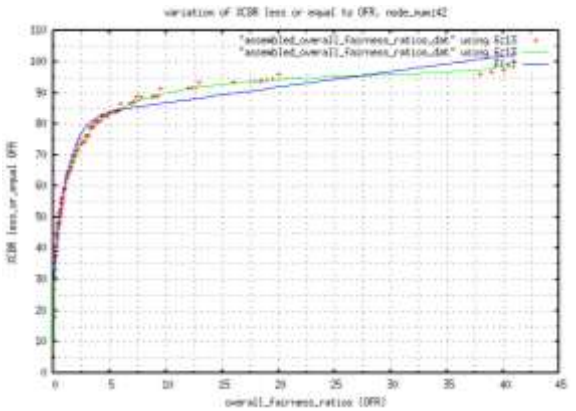

Figure 36: %cbr (≤)for OFR node_number 42

37. Node Number 43

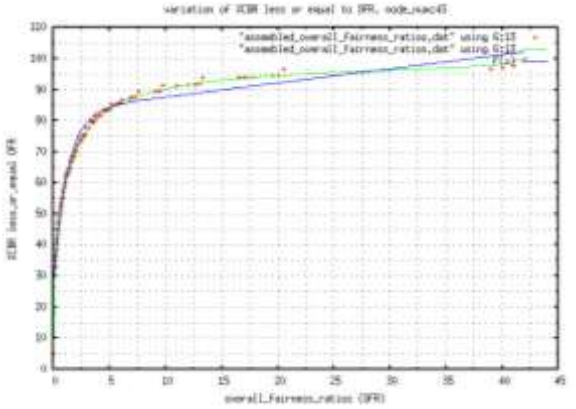

Figure 37: %cbr (≤)for OFR node_number 43

38. Node Number 44

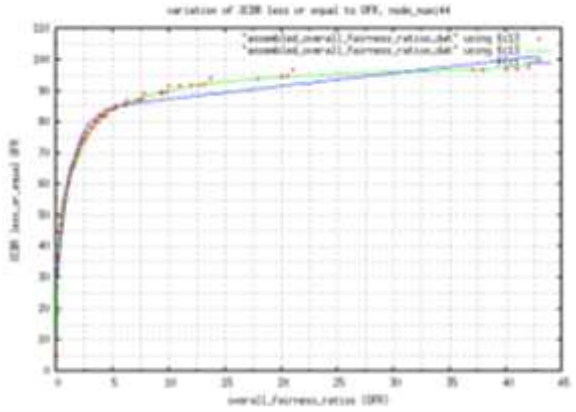

Figure 38: %cbr (≤)for OFR node_number 44

39. Node Number 45

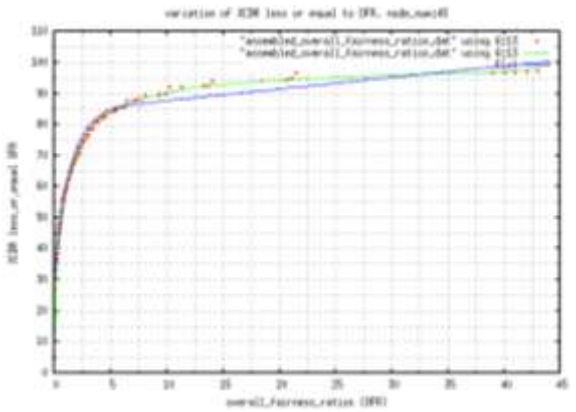

Figure 39: %cbr (≤)for OFR node_number 45

40. Node Number 46

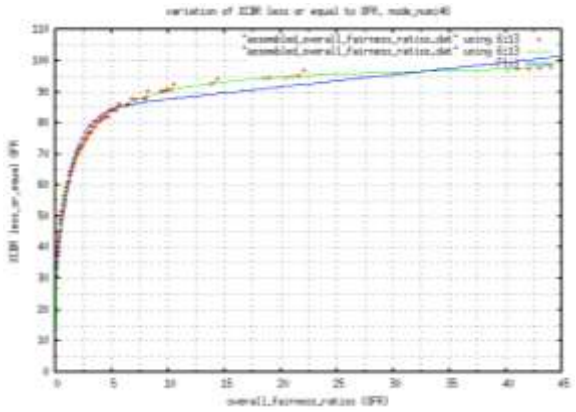

Figure 40: %cbr (≤)for OFR node_number 46

41. Node Number 47

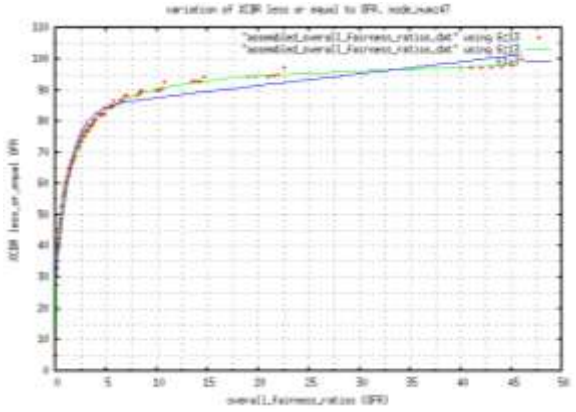

Figure 41: %cbr (≤)for OFR node_number 47

42. Node Number 48

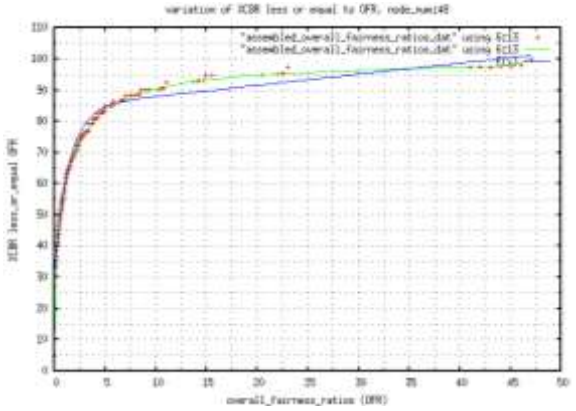

Figure 42: %cbr (≤)for OFR node_number 48

43. Node Number 49

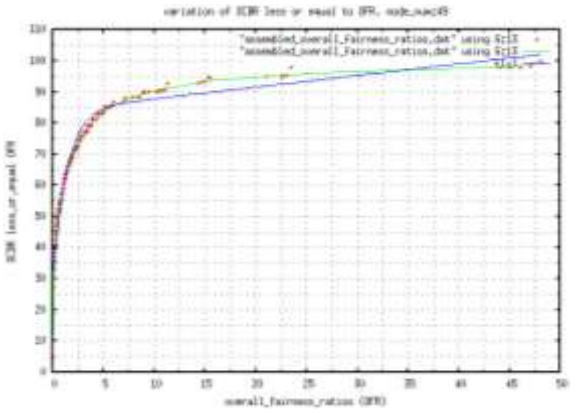

Figure 43: %cbr (≤)for OFR node_number 49

44. Node Number 50

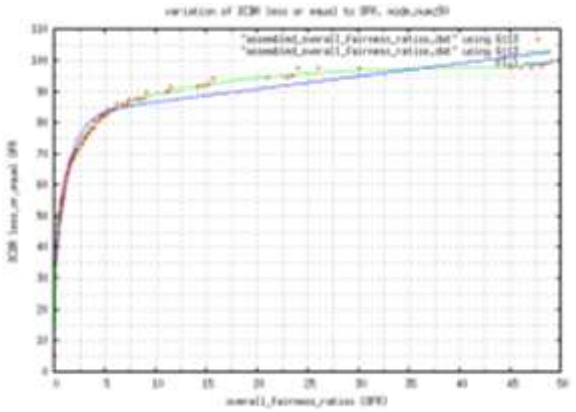

Figure 44: %cbr (≤)for OFR node_number 50

45. Node Number 51

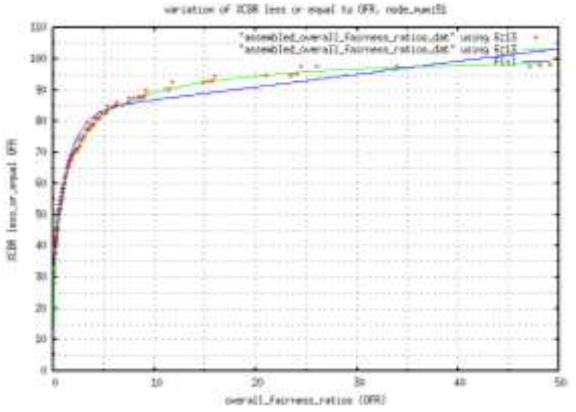

Figure 45: %cbr (≤)for OFR node_number 51

46. Node Number 52

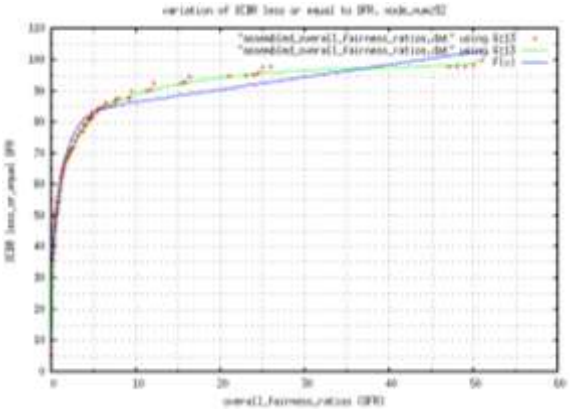

Figure 46: %cbr (≤)for OFR node_number 52

47. Node Number 53

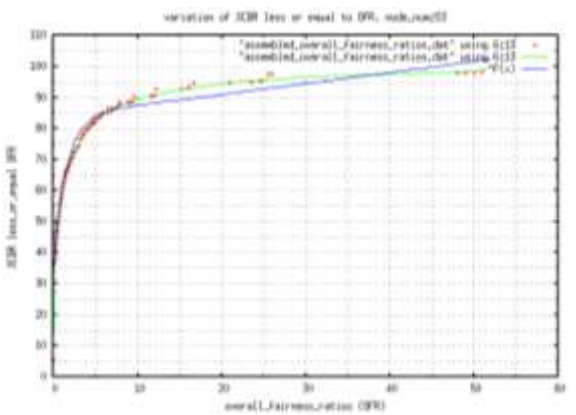

Figure 47: %cbr (≤)for OFR node_number 53

48. Node Number 54

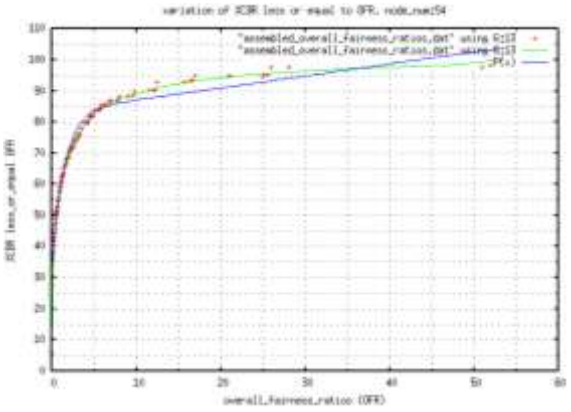

Figure 48: %cbr (≤)for OFR node_number 54

49. Node Number 55

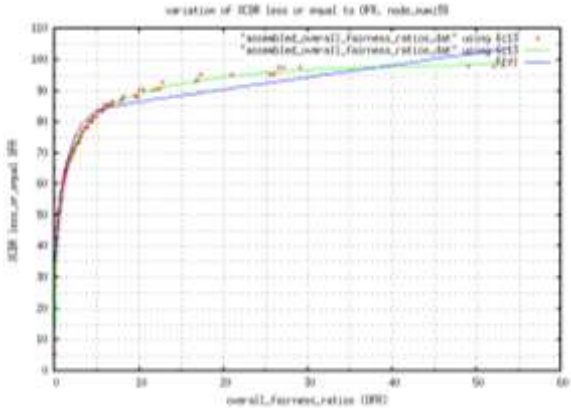

Figure 49: %cbr (≤)for OFR node_number 55

50. Node Number 56

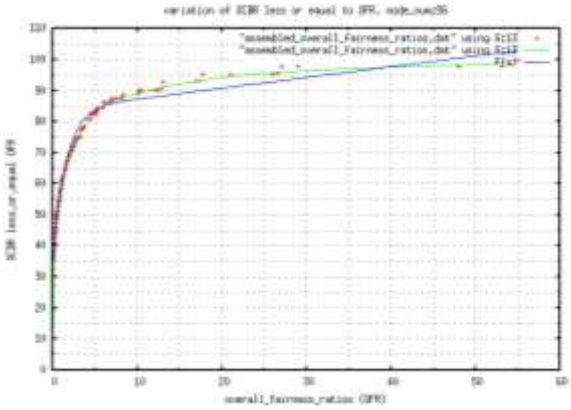

Figure 50: %cbr (≤)for OFR node_number 56

4. Conclusion.

This piece of research was aimed at developing a third method towards studying Fairness reachable in energy consumption by nodes participating in a MANET transmission, in a topography of 300 x 300 m^2, following previous methods put forward [19, 20]. For this purpose, a third metric, OFR, has been derived from another previously explained metric, ECR [18]. The trend for metric OFR, in form of "cumulative % CBR" against OFR values have also been put forward for node numbers 7 until 56. This study remains empirical based and was implemented over same experiment as explained in another paper [15]. The model put forward combines the exponential and the linear models. Again, the assumption remains that certain highly developed components are available even if at present level of technology, these are still subjects of research. These include lightweight algorithms for location-aware transmission in mobile environments, lightweight MAUC OS support for efficient binding/unbinding of MANET nodes and appropriate multi-threading/parallel communication in modules of MANET nodes.

The further works identified may include: trend analyses of parameters of equation for the model, formulating method of predictability for metric OFR and its trend and reporting observations of certain critical values identified. 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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About Author (s):

Associate Professor Nawaz Mohamudally works at University of Technology, Mauritius (UTM) and has undertaken supervision of MPhil/PhD Students for many years.

M. Kaleem Galamali is a part-time student (achieved M Phil Transfer on 28.10.2014, currently PhD student) at UTM under supervision of A.P. Nawaz Mohamudally.