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Model of Sender Node Energy Savings Achievable with Location-Aware MANET Transmission in Ubicomp.

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***Abstract* – Tracking location in mobile environment has been a subject of research for quite long and significant progress has been reached [33-48]. The next stage remains devising new functionalities/applications and improving ways of doing existing activities making use of location-awareness. One area of such an improvement will be in the field of MANET communication over which ubicomp will rely. A big area missing in MAUC remains the software engineering approaches into metrics development, gathering and modelling which can be used for prediction and better gearing of future investments of resources [2]. The particular area of concern here is energy considerations in ubicomp. How much energy savings can be achieved by a sender node in location-aware MANET transmission? Is there any pattern of trend that the sender energy savings follow under different sets of node densities? How to gather information on probabilities of saving less or greater than a particular percentage of energy?**

Need for formulating applicable models is felt since it involves lots of work and results will be used by designers to formulate better ubicomp component architectures. This paper is a follow-up of previous papers [1-13].

Key terms: Ubicomp-Ubiquitous Computing, MAUC-Mobile and Ubiquitous Computing, SES-Sender Energy Savings, MANET-Mobile Adhoc Network, CBR-Constant Bit Rate, BRE-Basic Reference Energy.

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1. Introduction

Many factors energy consumption in MAUC [2]. Another pertinent factor is type of transmission and if it is MANET transmission the subsequent pertinent factor is node densities. An attempt has been made to find a particular trend/model which depicts energy savings that can be reached by senders in MAUC to rate the effectiveness of location-aware MANET transmission strategies compared to the theoretical/empirical models derived in simulations.

The key contributions of this paper is firstly, the development of a new metric SES, including its definition and rationale, and secondly, the model of trend put forward for the metric SES with results for varying node densities from 7 until 56. The model suggested in this paper is the exponential model. The rest of this paper is organised as follows: section 2- Experiment Design, section 3-New Metric- Sender Energy Savings, section 4- SES Trend Assessment over Varying Node Numbers, 5- Conclusion and References.

2. Experiment Design.

The software and platform used are as in previous paper [2]. Other characteristics like experiment topography, types of movement scenarios and communication used also follow as in previous paper [2]. Additional components which were developed to enable this study are as follows:

2.1 Exact Location Tracking of node positions.

Here, 60 movement scenarios have been analysed for 50 scenarios of varying node numbers. The exact positions for each node are recorded for time intervals of 0.001 seconds

Design and Optimisation Concerns: the program was designed in such that it could run for all sets of node densities identified. For optimising storage space, the tracking records were saved only if node positions values change compared to previous record saved. The percentage saving was estimated at 60%. Overall 113 GB were needed. Each of the 660 simulations identified took about 15-20 minutes over 1 laptop. 3 laptops working in parallel was made use of.

2.2 MANET Route Formulation and Nodes Energy Expenditure.

The processing needed to find the closest neighbour to the sender node, its square distance (sq_d) and corresponding energy consumed (e_c) and repeating the procedure for successive MANET nodes, for each packet transmitted. An example of a record is:

cbr(998) t: 9.411639639 pkt_size: 471 s-x: 250 s-y: 40 r-x: 150 r-y: 40 v_n: 8 sq_d: 57.995521280170983 e_c: 27315.890522960533 15 sq_d: 236.68607123397172 e_c: 111479.13955120069 14 sq_d: 647.96950328513549 e_c: 305193.63604729879 24 sq_d: 1313.6847436724611 e_c: 618745.51426972914 16 sq_d: 1219.776792579818 e_c: 574514.86930509424 22 sq_d: 936.2954315674865 e_c: 440995.14826828614 6 sq_d: 747.42427331514045 e_c:

352036.83273143118 7 sq_d: 0 e_c: 0 5 sq_d: 1369 e_c: 644799 56 sq_d: 3385 e_c: 1594335 hops 10 endl

Again, same program was made to work for varying CBRs and node densities and loop execution was enabled to achieve more execution rapidity, simplicity and continued overnight uninterrupted. Overall file sizes required is 5 833.7 GB.

2.3 Processing of MANET_Routes_Packets_Per_CBR.

Broadly three areas were identified for study: Energy Consumption considerations, Link/Route information, Packets per distance information.

Again here, triple nested loop execution approach was sought to, with assistance of progress monitoring files. Here, overall 2 267.68 MB was required. Program optimisation and concurrent running of 6 streams was also applied.

2.4 MANET Results Generations.

This has concerned gathering summarised tabular results from data obtained in previous sections. Overall storage requirements here is 370.5 MB.

2.5 Automated Extractions of data from Files.

The successive operations required were automated extractions of data into datasheets followed by automated extraction of data from datasheets into tabular displays.

3. New Metric: Sender Energy Savings (SES).

When using MANETs, mostly the sender will just send each packet to the closest node instead of directly to the destination node. Further MANET routing is not the problem/concern of the sender. The nodes in the MANET may be regarded as an available infrastructure and that routing concern is freed from sender "legitimately", i.e. in an accepted way as provided by a service provider.

Prior to defining SES, another term "the Basic Reference Energy (BRE) is put forward as the amount of energy spent by a sender in Direct Node-to-Node transmission if all CBR packets were transmitted at maximum distance noted between sender and receiver.

SES is hence defined as the result of computing the total energy spent by the sender only, for every packet in a CBR, and the energy savings achieved together with corresponding % with respect to the BRE.

Definitely here, the % SES cannot be below 0, since otherwise it would be better to achieve Node-to-Node (NTN) transmission and not use MANET.

4. SES Trend Assessment over Varying Node Numbers.

4.0 Major Observations.

The trends for SES achieved for node numbers 7-56 tend to follow an exponential distribution of the form:

```
F(x) = a * exp (b * (x-c) )
```

The minimum value of SES has been 2 % Energy Savings achieved by less than 1 % of CBRs for node numbers 7 until 9; 3 % Energy Savings for node number 10 until 16; 4% for node numbers 17 until 56. A smooth gradual increase for this minimum SES is observed for increasing node numbers.

The maximum value of SES has been 100 % ES (i.e. 99.5 until less than 100, rounded to 100). However the % CBRs reaching this maximum has shown increasing tendency for increasing number of nodes.

Already, for smallest node number 7, the % Energy Savings where peak value of % CBR occurs is as high as 94 and shows an increasing tendency for increasing node numbers. The peak value also shows an increasing tendency.

Only for node number 7, there is a linear tendency noted after the peak value. It has applied for no other node numbers. Equation of the linear tendency is

```
G(x)=(-1.76134*x)+176.333
```

4.1 Tabular Summary of Results.

A tabular summary for results of equations of curves (F(x)) observed here 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, F→Corresponding figure number

A	B	C	D	E	F
7	0.253 423	0.175 689	72.995 6	0.082 096 6	1
8	0.734 057	0.092 199 2	72.982 6	1.441 17	2
9	0.922 076	0.102 698	76.953 5	1.473 48	3
10	1.787 79	0.126 755	84.787 9	1.097 98	4
11	1.893 69	0.137 475	85.840 4	1.272 16	5
12	2.009 39	0.146 938	86.715 5	1.296 3	6
13	2.171 71	0.156 73	87.634	1.875 86	7
14	2.042 44	0.166 625	87.662 3	1.901 95	8
15	2.224 46	0.177 123	88.560 9	2.205 9	9

16	2.483 68	0.184 85	89.415 3	2.515 06	10
17	2.408 52	0.192 616	89.482 4	3.077 36	11
18	2.299 47	0.201 279	89.515 3	3.169 74	12
19	2.575 03	0.211 646	90.359 9	2.677 75	13
20	2.493 3	0.218 505	90.385 2	2.845 23	14
21	2.814 91	0.223 275	91.015	3.556 55	15
22	2.701 76	0.232 994	91.059 4	4.003 06	16
23	2.618 39	0.240 51	91.092 5	4.245 6	17
24	2.624 38	0.247 979	91.261 2	4.691 49	18
25	3.102 43	0.254 33	92.037 5	5.335 98	19
26	3.138 36	0.225 618	92.070 9	6.635 39	20
27	2.836 33	0.261 977	91.793 2	7.309 78	21
28	3.247 33	0.268 459	92.416 2	8.117 98	22
29	3.109 73	0.275 003	92.361 4	8.768 22	23
30	3.057 47	0.280 714	92.390 9	9.399 71	24
31	2.964 44	0.290 582	92.436 7	9.898 56	25
32	2.885 31	0.297 096	92.448 9	10.061 4	26
33	2.860 88	0.302 277	92.500 3	10.887	27
34	3.210 96	0.308 675	92.972 1	10.927	28
35	3.132 61	0.314 507	92.971 6	11.491 4	29
36	3.106 17	0.318 594	92.994 3	12.212 1	30
37	3.126 77	0.317 186	92.970 8	13.280 1	31
38	3.091 81	0.321 311	92.985 8	13.829 4	32
39	3.040 2	0.327 929	93.027 5	15.015 3	33
40	3.999 28	0.333 338	93.057 9	16.252 7	34
41	3.535 9	0.339 403	93.622 5	17.852 4	35
42	3.396 38	0.346 912	93.595	17.986 5	36
43	3.093 05	0.349 875	93.358 3	20.025 2	37
44	3.303 12	0.356 703	93.622 5	20.665	38
45	2.809 52	0.362 238	93.236 4	21.517	39
46	2.786 8	0.366 807	93.270 7	21.876 3	40
47	2.748 54	0.370 688	93.278 8	21.056 1	41
48	2.725 86	0.375 712	93.315 5	21.866 2	42
49	2.680 44	0.379 945	93.319 8	24.443 3	43
50	2.625 45	0.389 108	93.366 1	25.378 4	44
51	2.595 5	0.393 784	93.391 2	25.559 8	45
52	2.574 54	0.396 793	93.404 8	25.569	46
53	2.561 7	0.400 767	93.437 8	26.385 9	47
54	2.535 08	0.406 156	93.473 5	26.137 8	48
55	2.472 81	0.414 5	93.513 5	24.705 3	49
56	2.443 13	0.418 696	93.528 7	26.409 3	50

Table 1: results for SES equations of curves node numbers 7-56

4.2 Graphical Plots for Results Obtained.

This analysis is performed in gnuplot in Linux.

1. Node Number 7

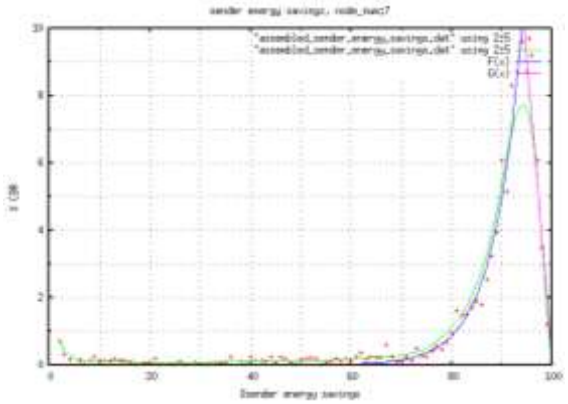

Figure 1: % cbr for SES node_number 7

2. Node Number 8

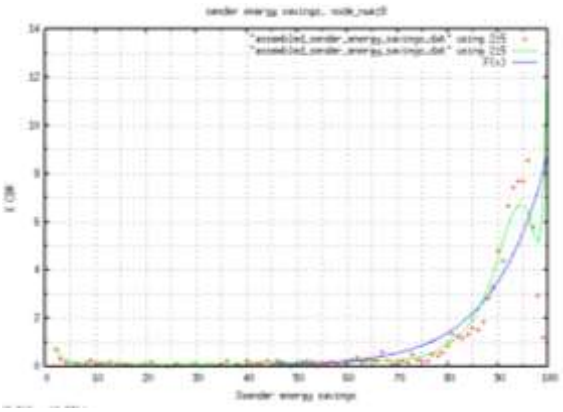

Figure 2: % cbr for SES node_number 8

3. Node Number 9

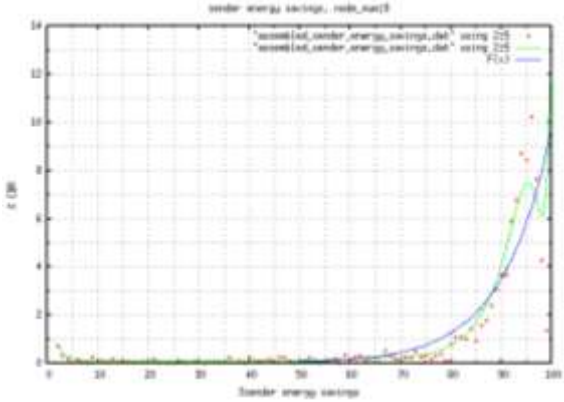

Figure 3: % cbr for SES node_number 9

4. Node Number 10

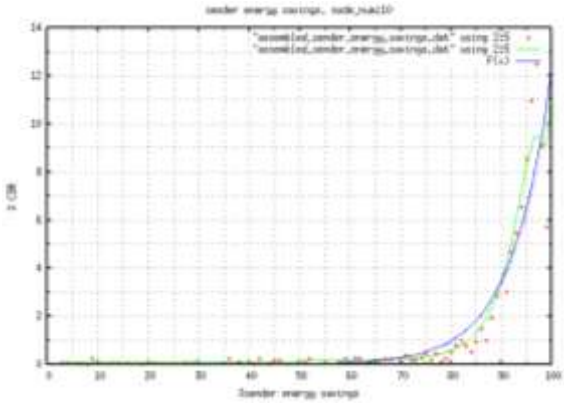

Figure 4: % cbr for SES node_number 10

5. Node Number 11

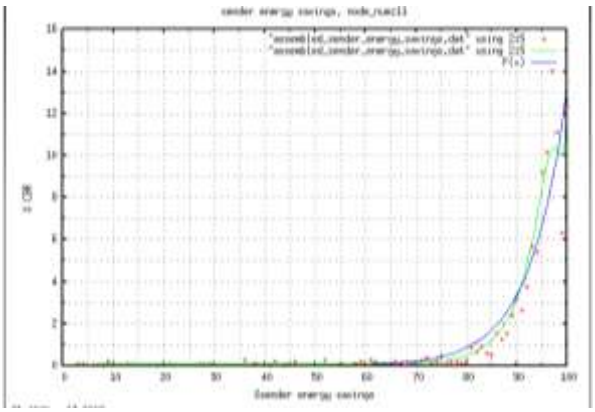

Figure 5: % cbr for SES node_number 11

6. Node Number 12

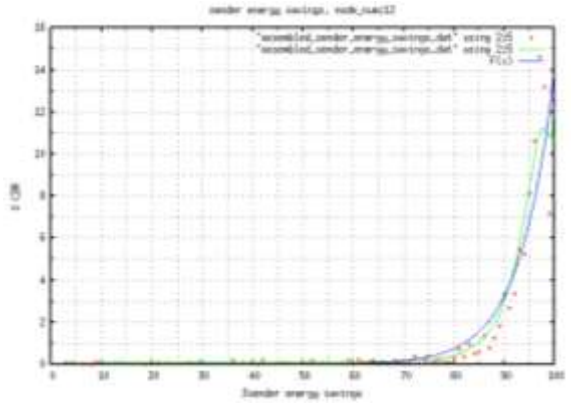

Figure 6: % cbr for SES node_number 12

7. Node Number 13

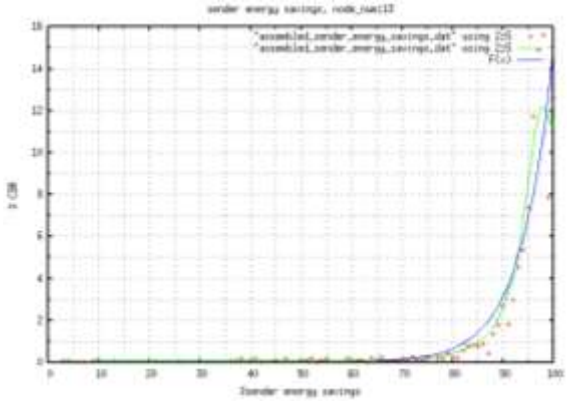

Figure 7: % cbr for SES node_number 13

8. Node Number 14

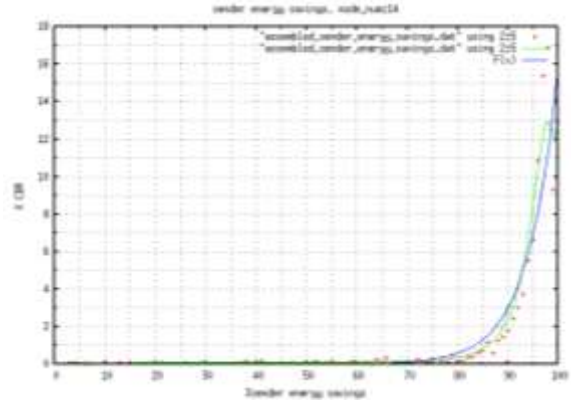

Figure 8: % cbr for SES node_number 14

9. Node Number 15

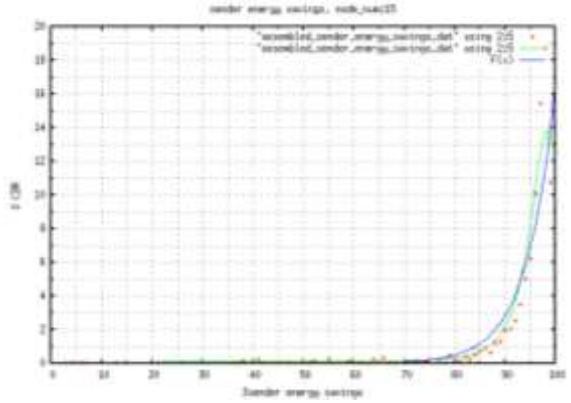

Figure 9: % cbr for SES node_number 15

10. Node Number 16

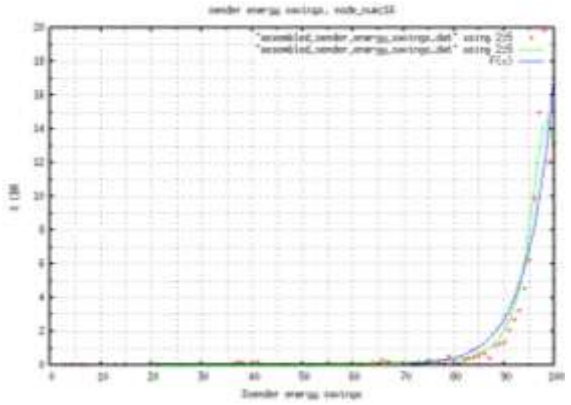

Figure 10: % cbr for SES node_number 16

11. Node Number 17

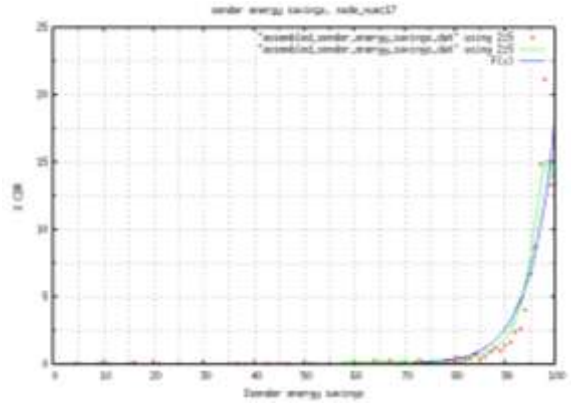

Figure 11: % cbr for SES node_number 17

12. Node Number 18

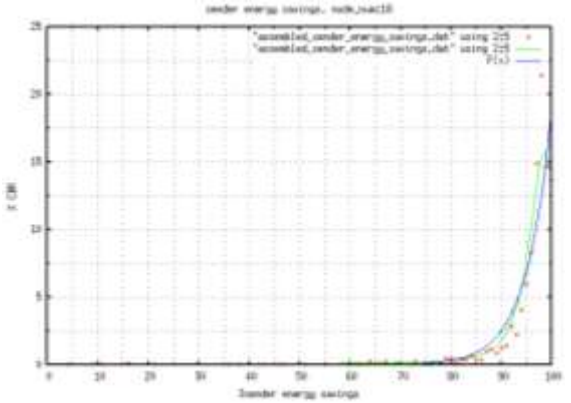

Figure 12: % cbr for SES node_number 18

13. Node Number 19

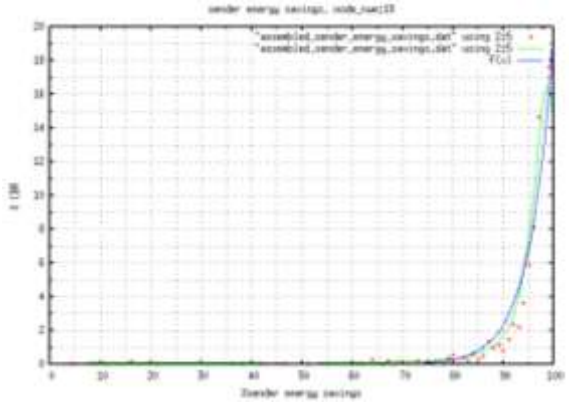

Figure 13: % cbr for SES node_number 19

14. Node Number 20

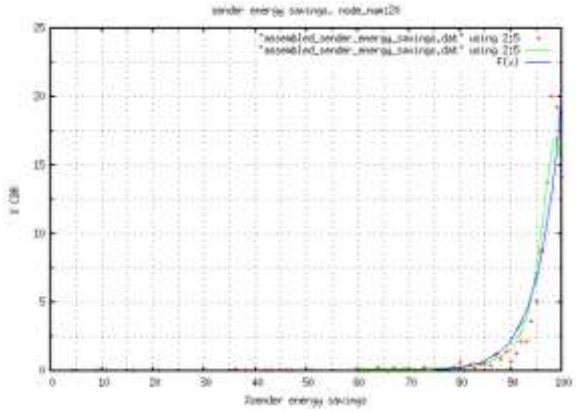

Figure 14: % cbr for SES node_number 20

15. Node Number 21

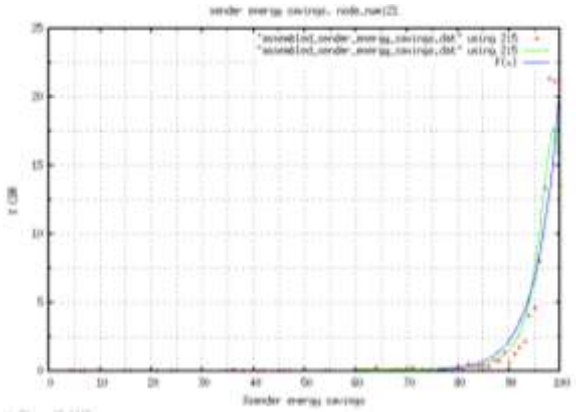

Figure 15: % cbr for SES node_number 21

16. Node Number 22

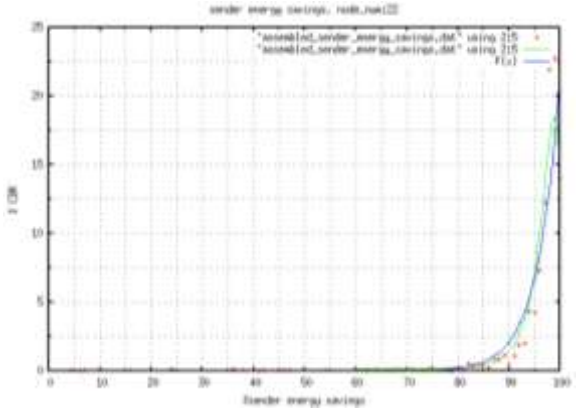

Figure 16: % cbr for SES node_number 22

17. Node Number 23

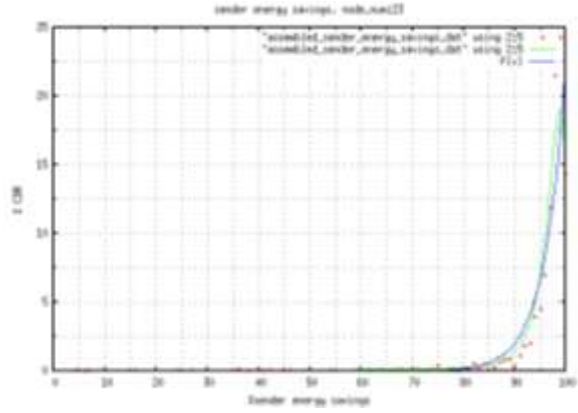

Figure 17: % cbr for SES node_number 23

18. Node Number 24

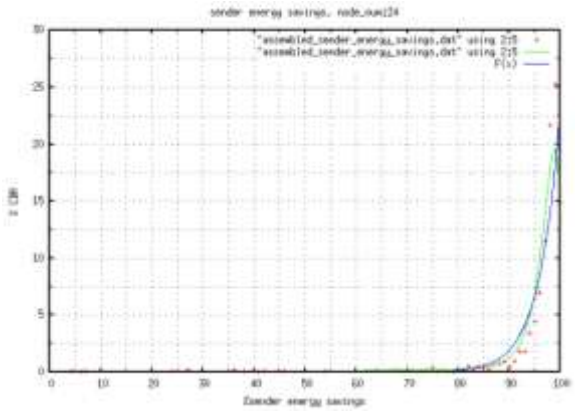

Figure 18: % cbr for SES node_number 24

19. Node Number 25

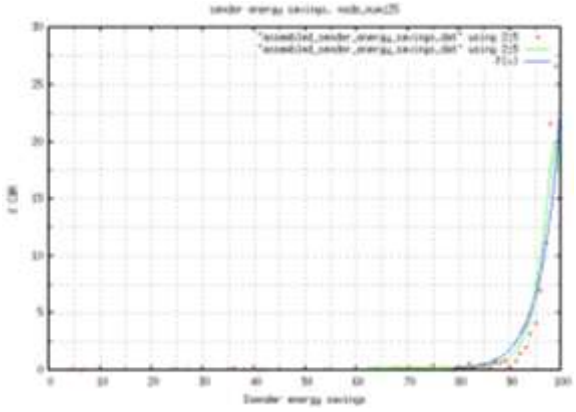

Figure 19: % cbr for SES node_number 25

20. Node Number 26

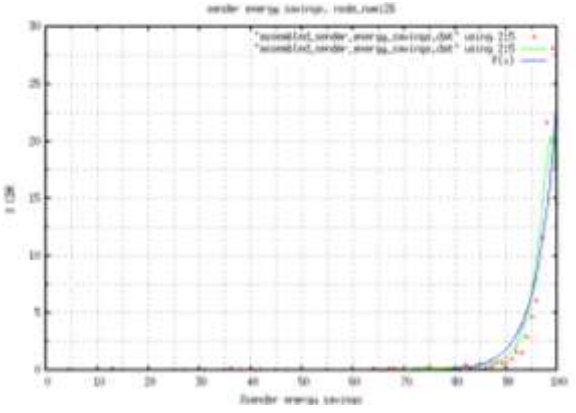

Figure 20: % cbr for SES node_number 26

21. Node Number 27

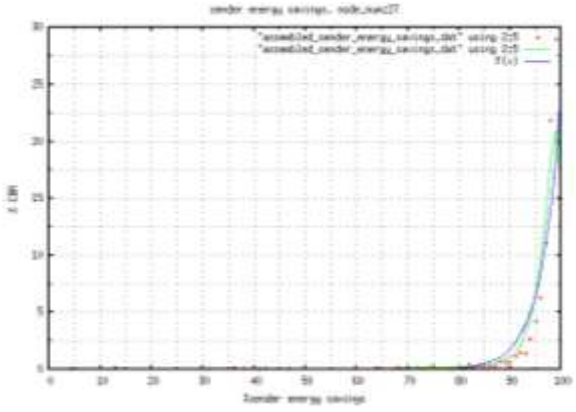

Figure 21: % cbr for SES node_number 27

22. Node Number 28

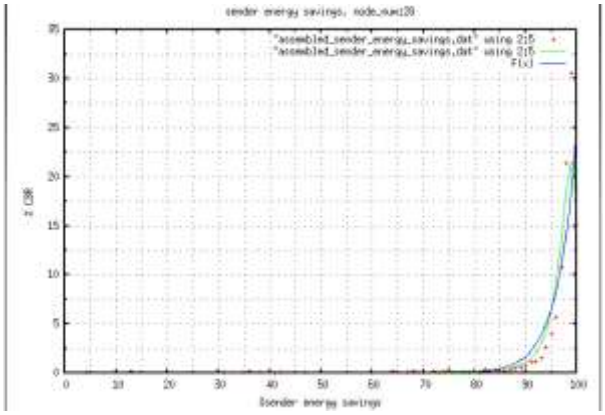

Figure 22: % cbr for SES node_number 28

23. Node Number 29

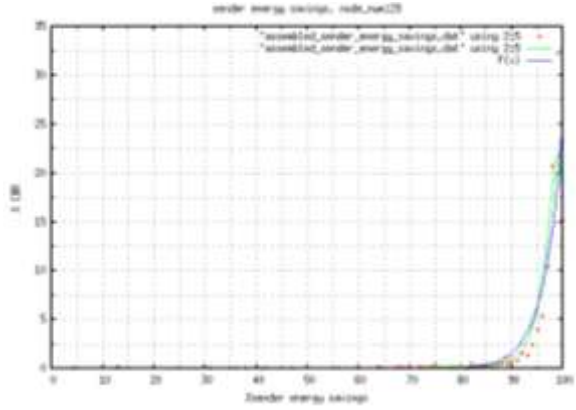

Figure 23: % cbr for SES node_number 29

24. Node Number 30

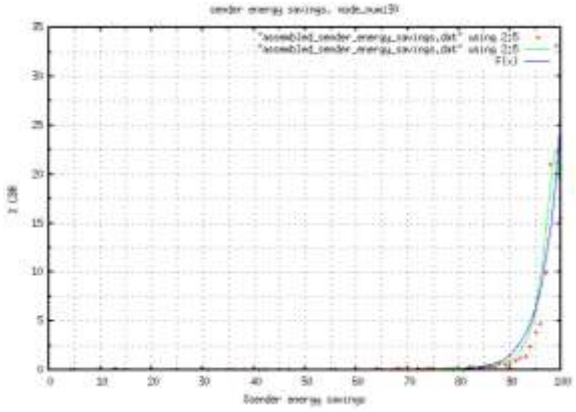

Figure 24: % cbr for SES node_number 30

25. Node Number 31

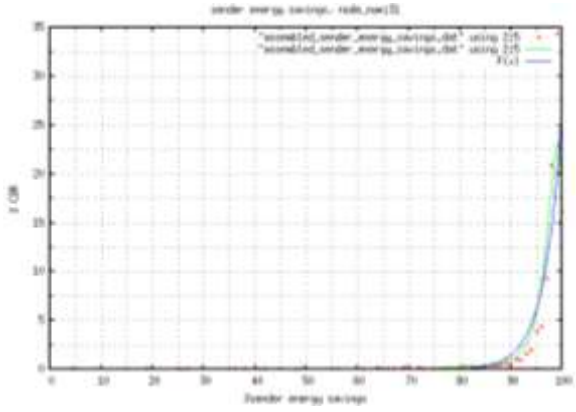

Figure 25: % cbr for SES node_number 31

26. Node Number 32

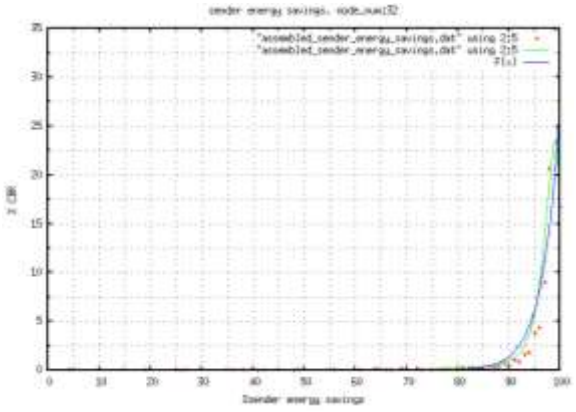

Figure 26: % cbr for SES node_number 32

27. Node Number 33

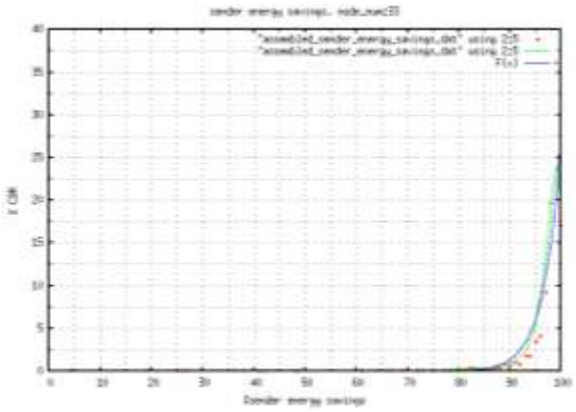

Figure 27: % cbr for SES node_number 33

28. Node Number 34

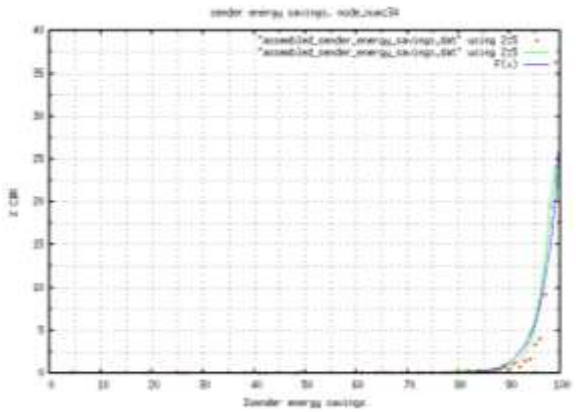

Figure 28: % cbr for SES node_number 34

29. Node Number 35

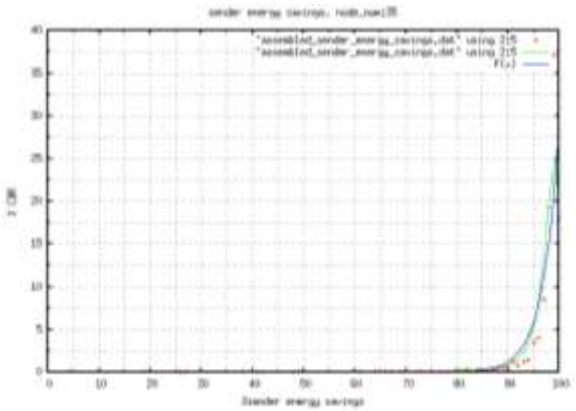

Figure 29: % cbr for SES node_number 35

30. Node Number 36

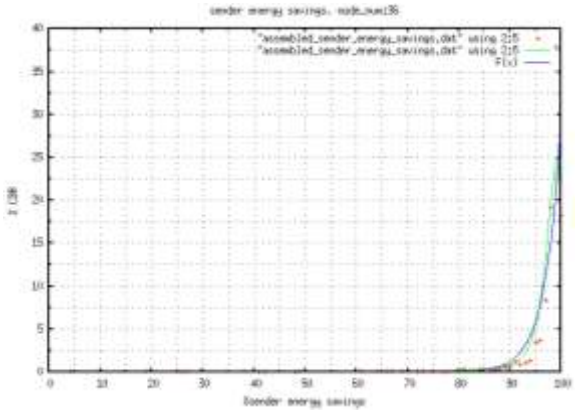

Figure 30: % cbr for SES node_number 36

31. Node Number 37

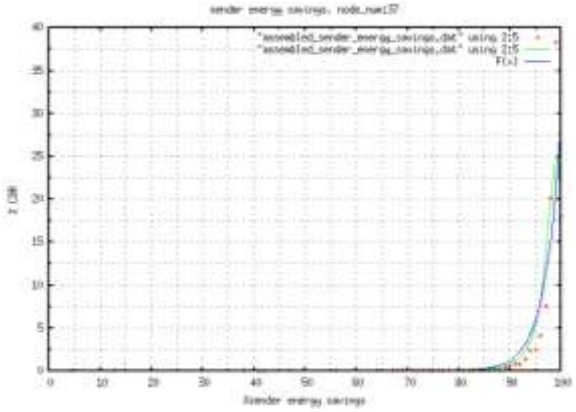

Figure 31: % cbr for SES node_number 37

32. Node Number 38

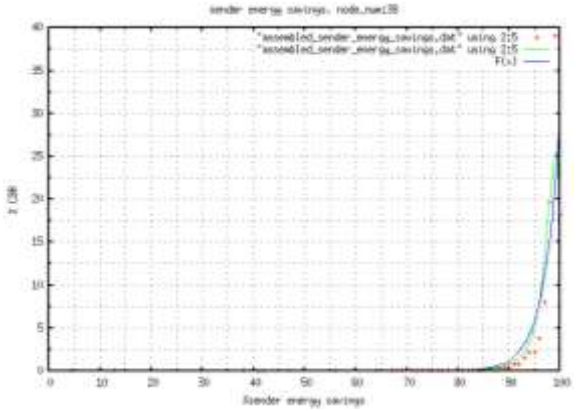

Figure 32: % cbr for SES node_number 38

33. Node Number 39

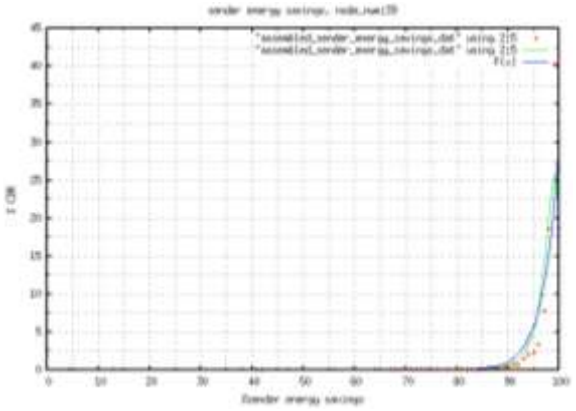

Figure 33: % cbr for SES node_number 39

34. Node Number 40

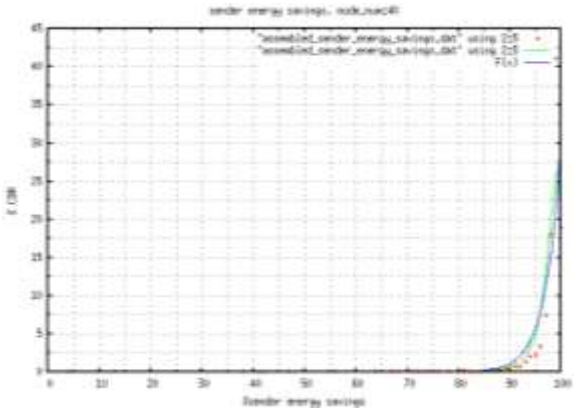

Figure 34: % cbr for SES node_number 40

35. Node Number 41

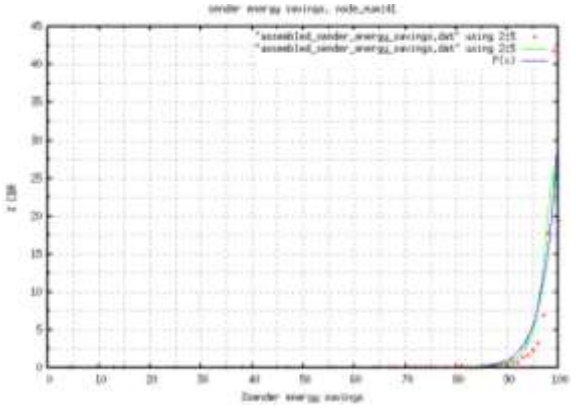

Figure 35: % cbr for SES node_number 41

36. Node Number 42

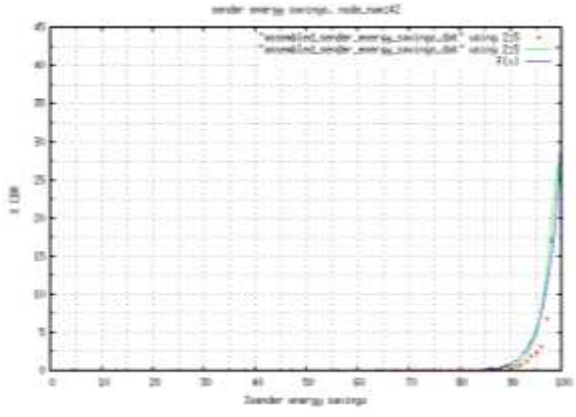

Figure 36: % cbr for SES node_number 42

37. Node Number 43

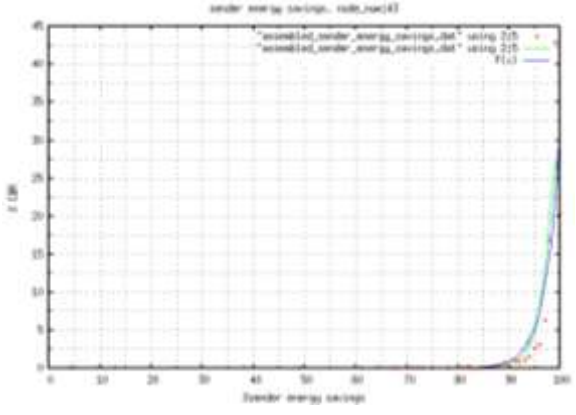

Figure 37: % cbr for SES node_number 43

38. Node Number 44

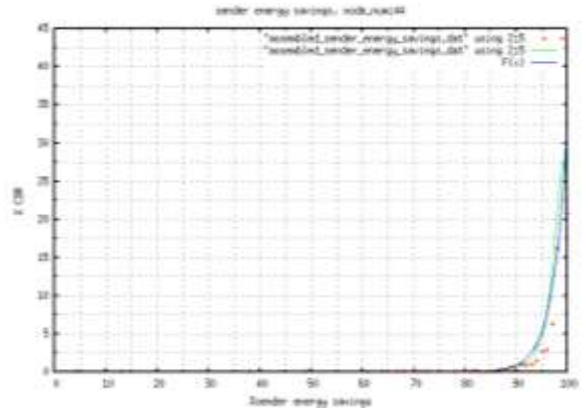

Figure 38: % cbr for SES node_number 44

39. Node Number 45

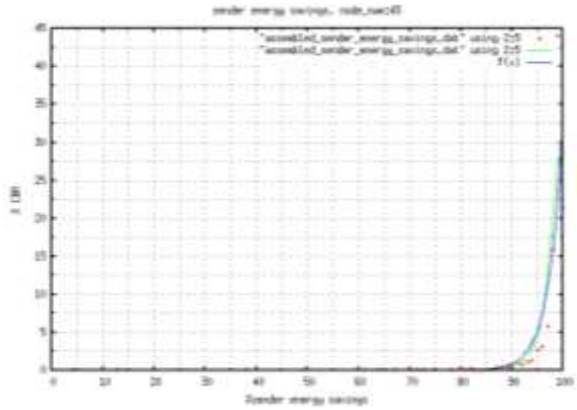

Figure 39: % cbr for SES node_number 45

40. Node Number 46

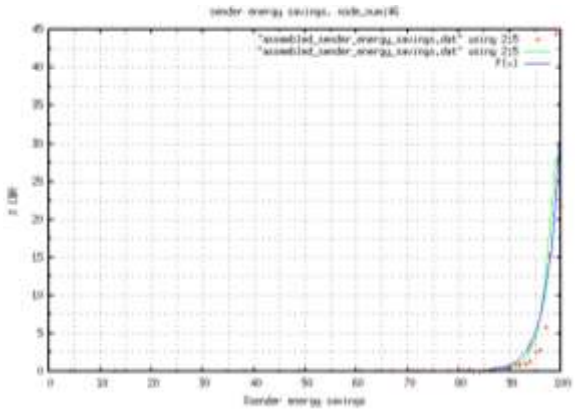

Figure 40: % cbr for SES node_number 46

41. Node Number 47

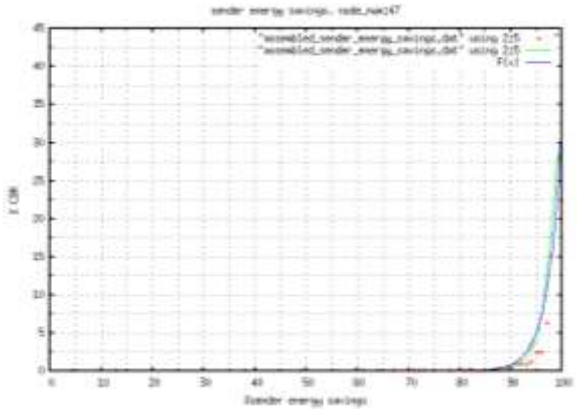

Figure 41: % cbr for SES node_number 47

42. Node Number 48

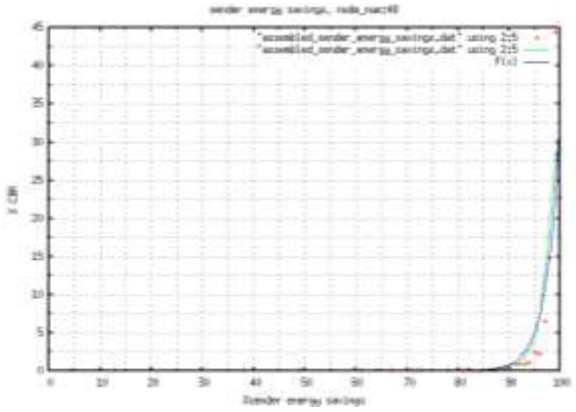

Figure 42: % cbr for SES node_number 48

43. Node Number 49

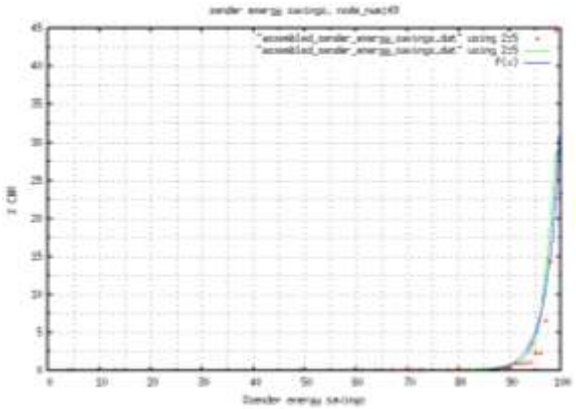

Figure 43: % cbr for SES node_number 49

44. Node Number 50

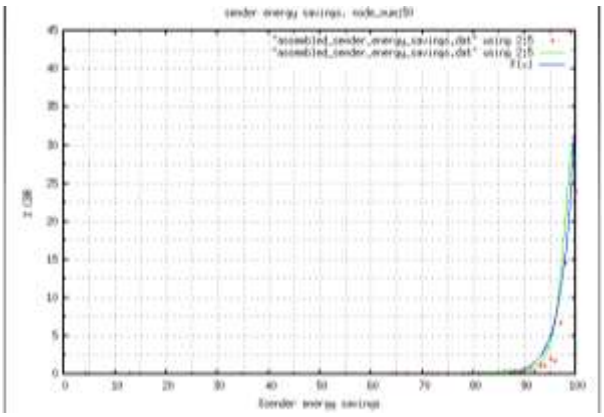

Figure 44: % cbr for SES node_number 50

45. Node Number 51

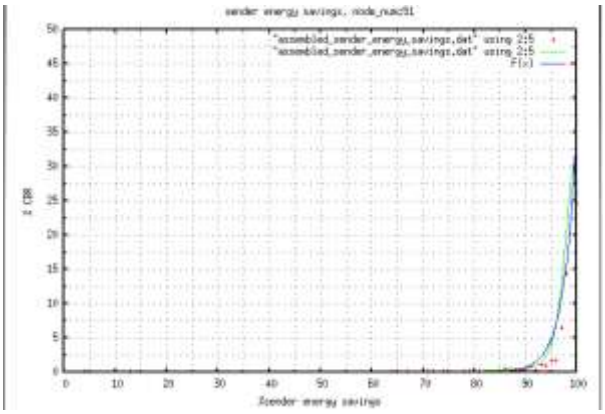

Figure 45: % cbr for SES node_number 51

46. Node Number 52

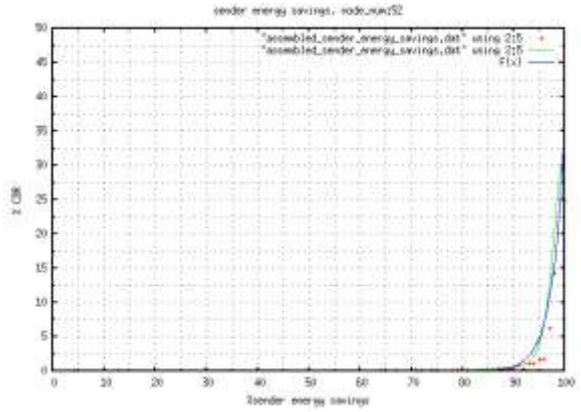

Figure 46: % cbr for SES node_number 52

47. Node Number 53

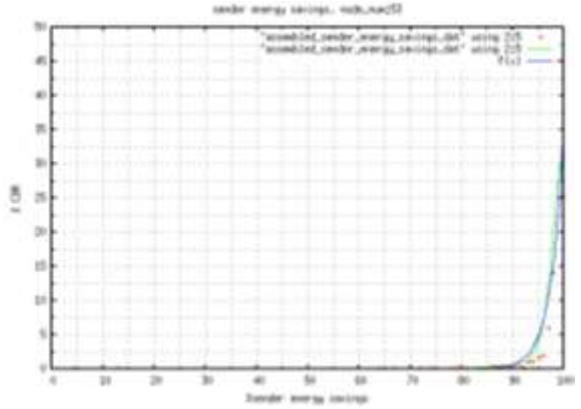

Figure 47: % cbr for SES node_number 53

48. Node Number 54

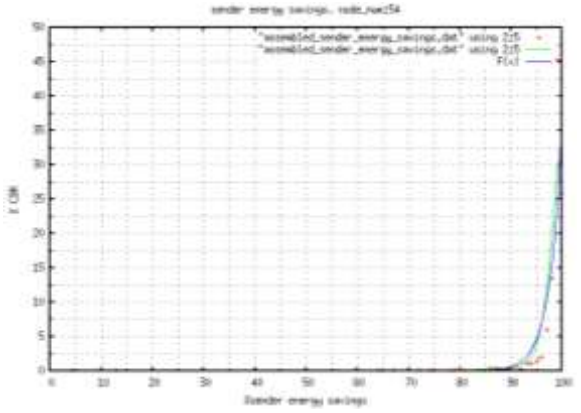

Figure 48: % cbr for SES node_number 54

49. Node Number 55

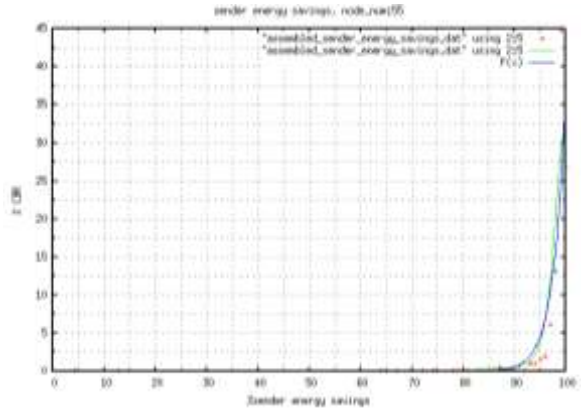

Figure 49: % cbr for SES node_number 55

50. Node Number 56

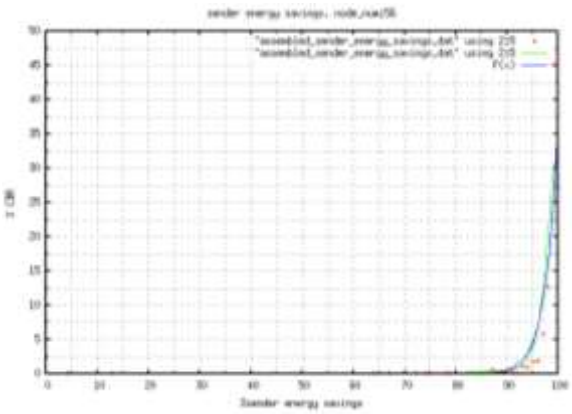

Figure 50: % cbr for SES node_number 56

5. Conclusion.

This piece of research was aimed at and has developed a new model of expected trend of sender energy savings in a MANET topography of 300 x 300 m^2. The model obtained will help to study MANETs for MAUC environment from a software engineering perspective. This model, though empirical based, has put forward novel results which would necessitate quite huge investments if experimented in real environment implementations. Besides, many components over which these experiments would be built are still subject to further research, e.g. lightweight algorithms for location-aware transmission in a MAUC environment, development of land-based location support with appropriate algorithms and surrogate devices and lightweight MAUC OS supports.

The experiment was carried out in NS-s over Linux on VMware. The experiments were designed, implemented and executed over many months. Tremendous amount of data has been generated and abundant storage space has been required.

The further works identified may include: trend analysis of parameters of equation for the model, formulating method of predictability for metric SES and its trend and reporting observations of certain critical values.

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