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Trend Analyses of Critical Values Obtained for Overall Nodes Extra Energy Savings Achievable in Ubicomp MANET Against Direct Node-to-Node Location-Aware Transmission.

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***Abstract* – Quite extensive research is well ongoing concerning enhancements of location-tracking, MANET transmission and location-aware transmission for ubicomp [1-48]. Presently, more significant developments must be awaited before these three undergo successful merging and bring desirable improvements in ubicomp. One essential factor for success of this merging is correct protocol designs. At present era of technology, research in protocol designs are claimed as inapt for implementations due to present heuristic approaches [86]. Enhancements are also awaited in middleware services and applications [87]. Rework in ubicomp network architecture is also demanded [88]. A distant milestone in this direction of study is to fulfil realism in design and evaluation of wireless routing protocols [89]. Such direction of research will also output more usable components for predictability in ubicomp. Realism is tiresome to fulfil since it will cover each aspect related to ubicomp. One aspect was studied in a past research [17] to assess trend of extra energy savings achievable by overall nodes in MANETs (OLNTNES) against direct Node-to-Node transmission under different sets of node densities in a ubicomp environment. This study was reinforced by the corresponding study of trends for each OLNTNES parameter of equations [33].**

To upgrade realism of these trends, in this paper, the next level of probing that is required is stated as: "What are the observable critical values in OLNTNES trends and the trends of these critical values?"

Such knowledge will gradually lead to the design of more realistic ubicomp scenarios over which experimental ubicomp features and communication protocols are tested validly. This paper follows-up from previous ones [1-48].

Key terms: Ubicomp- Ubiquitous Computing, MAUC- Mobile and Ubiquitous Computing, ES- Energy Savings, OLNTNES- Overall Less Node-to-Node ES, CBR- Constant Bit Rate, MANET- Mobile Adhoc Network, CV- Critical Value.

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1. Introduction

A significantly wide range of factors affect energy consumption in MAUC [2]; type of transmission and node density remain predominant ones. In a past research [17], a simulation endeavour was carried out to derive the particular trend/model which depicts the overall nodes extra energy savings achievable against direct node-to-node transmission in MANET (OLNTNES) compared to theoretical/empirical models derived in simulations. The model put forward for metric OLNTNES was the normal distribution model:

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F(x)=b*(1/(a*sqrt(2*pi)))*exp(-(x-c)^2/2*a*a)
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Obviously, the study which followed [33] was mathematical modelling of the trends of the three parameters of equation obtained, so that the results may serve towards better understanding of the evolution and predictability of ubicomp environments. As progress is made in this direction, designers may produce a platform of newly developed components, including communication protocols and middleware functions, can be exercised convincingly.

The next stage of investigation required for metric OLNTNES is identifying observable critical values obtained during experimentations and formulating the corresponding mathematical trend of variations over varying node densities for each critical value. Nine such critical values have been observed.

The key contribution of this paper is the derivation of the trend of variation for each of the nine critical values observed for metric OLNTNES introduced in prior papers [17, 33], covering node numbers 7 until 56. Such data, if properly produced, will assist designers to better understand the evolution and predictability of ubicomp behaviour and derive more acceptable simulation scenarios over which new communication protocols being implemented could be reliably tested. The rest of this paper is organised as follows: section 2- OLNTNES Critical Values, section 3- Critical Values Trend Analyses- Metric OLNTNES, section 4- Conclusion and References.

2. OLNTNES Critical Values.

2.0 Critical Values Identified.

Nine critical values have been identified as follows: Column headings are: C1→OLNTNES CV, C2→ Meaning of OLNTNES CV, C3→ Corresponding figure number for the OLNTNES CV.

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C1	C2	C3
1	Smallest OLNTNES value obtained.	1
2	Highest value of OLNTNES obtained.	2
3	Experimental Modal value of OLNTNES.	3
4	%CBR with OLNTNES < modal value.	4
5	%CBR with OLNTNES > modal value.	5
6	%CBR with negative OLNTNES values.	6
7	%CBR with OLNTNES value 0.	7
8	%CBR with positive OLNTNES values.	8
9	95% CBR have OLNTNES value as from.	9

Table 1: OLNTNES Critical Values

2.1 Experimental Critical Values Obtained.

The values obtained in experiments are summarised below. Values have been rounded to a maximum of 9 decimal places. Column heading NN → Node Number.

NN	CV1	CV2	CV3	CV4	CV5
7	-1397	48	2	77.539682540	18.650793651
8	-1397	48	2	77.570837313	18.656478828
9	-1188	52	2	78.095238095	17.539682540
10	-1208	67	-5	66.031746032	30.952380952
11	-1175	65	-5	67.460317460	29.841269841
12	-1204	63	-11	58.251192369	39.268680445
13	-1225	62	-13	53.650793651	43.571428571
14	-1293	62	-14	54.365079365	42.666666667
15	-1690	62	-20	45.761904762	51.857142857
16	-2321	62	-5	74.190476190	23.031746032
17	-3555	66	-30	35.158730159	62.380952381
18	-4365	66	-15	59.238095238	38.015873016
19	-3911	66	-17	56.825396825	40.793650794
20	-4021	66	-9	73.253968254	24.285714286
21	-1790	70	-12	67.698412698	29.682539683
22	-2887	70	-12	69.126984127	28.253968254
23	-3824	70	-17	60.317460317	37.301587302
24	-3153	70	-15	65.222222222	32.460317460
25	-2283	70	-13	69.761904762	27.873015873
26	-3238	72	-13	68.888888889	28.730158730
27	-3220	72	-17	62.857142857	34.682539683
28	-3138	72	-15	67.857142857	29.936507937
29	-3188	72	-17	64.841269841	32.936507937
30	-3233	72	-23	56.031746032	41.507936508
31	-1637	72	-19	61.746031746	36.063492063
32	-1682	72	-26	50.000000000	47.698412698
33	-1689	72	-25	52.777777778	44.920634921
34	-1694	72	-28	47.857142857	49.603174603
35	-1711	72	-20	62.444444444	51.158730159
36	-1781	72	-28	50.317460317	47.619047619
37	-1636	65	-25	55.881886014	41.974916653
38	-1736	65	-14	73.015873016	24.761904762
39	-1759	65	-26	55.396825397	42.698412698
40	-1657	65	-31	47.539682540	50.158730159
41	-1591	65	-28	53.095238095	44.523809524
42	-1934	65	-17	69.761904762	28.015873016
43	-1506	70	-17	69.523809524	28.015873016
44	-1493	70	-18	68.646759848	29.129606099
45	-1669	70	-17	70.555555556	27.253968254
46	-1520	70	-29	52.539682540	45.444444444
47	-1520	70	-29	52.253968254	45.555555556
48	-2501	70	-28	54.920634921	42.984126984
49	-2421	70	-28	55.317460317	42.650793651
50	-3149	74	-28	54.809523810	42.857142857
51	-3469	74	-26	58.269841270	39.365079365
52	-4919	74	-26	58.746031746	38.809523810
53	-4925	74	-31	50.650793651	46.873015873
54	-5725	74	-19	70.793650794	26.984126984
55	-5694	74	-27	59.126984127	38.809523810
56	-5111	74	-31	51.507936508	46.190476190

Table 2a: Experimental Critical Values Obtained(1)

NN	CV6	CV7	CV8	CV9
7	71.984126984	2.698412698	25.317460317	-195
8	72.015281757	2.690226043	25.294492200	-195
9	74.523809524	2.142857143	23.333333333	-266
10	76.190476190	2.460317460	21.349206349	-239
11	78.253968254	1.746031746	20.000000000	-246
12	79.332273450	2.082670906	18.585055644	-253
13	79.682539683	2.095238095	18.222222222	-286
14	81.349206349	1.857142857	16.793650794	-304
15	82.619047619	1.984126984	15.396825397	-309
16	83.809523810	1.428571429	14.761904762	-279
17	84.841269841	1.269841270	13.888888889	-315
18	85.476190476	1.349206349	13.174603175	-294
19	86.269841270	1.904761905	11.825396825	-299
20	87.142857143	1.111111111	11.746031746	-314
21	87.698412698	1.031746032	11.269841270	-344
22	88.095238095	1.587301587	10.317460317	-358
23	88.095238095	1.746031746	10.158730159	-374
24	88.730158730	1.587301587	9.682539683	-377
25	88.968253968	1.587301587	9.444444444	-384
26	88.968253968	1.031746032	10.000000000	-386
27	89.047619048	1.269841270	9.682539683	-393
28	89.920634921	0.873015873	9.206349206	-415
29	90.238095238	1.031746032	8.730158730	-411
30	90.015873016	0.936507937	9.047619048	-424
31	89.682539683	1.253968254	9.063492063	-418
32	90.634920635	0.714285714	8.650793651	-428
33	90.365079365	0.904761905	8.730158730	-424
34	90.317460317	0.873015873	8.809523810	-435
35	90.396825397	0.476190476	9.126984127	-427
36	90.396825397	0.714285714	8.888888889	-437
37	90.950944594	0.555643753	8.493411653	-439
38	91.428571429	0.555555556	8.015873016	-437
39	91.349206349	0.952380952	7.698412698	-436
40	92.063492063	0.634920635	7.301587302	-431
41	91.428571429	0.634920635	7.936507937	-458
42	91.666666667	0.634920635	7.698412698	-441
43	91.984126984	0.714285714	7.301587302	-406
44	92.137865311	0.635324015	7.226810673	-439
45	91.666666667	0.634920635	7.698412698	-428
46	91.825396825	0.793650794	7.380952381	-403
47	91.984126984	0.634920635	7.380952381	-411
48	92.380952381	0.793650794	6.825396825	-422
49	92.619047619	0.476190476	6.904761905	-424
50	92.777777778	0.873015873	6.349206349	-409
51	92.777777778	0.952380952	6.269841270	-435
52	92.857142857	0.634920635	6.507936508	-446
53	92.698412698	0.873015873	6.428571429	-480
54	92.936507937	1.031746032	6.031746032	-438

55	93.015873016	0.873015873	6.111111111	-437
56	93.095238095	0.793650794	6.111111111	-444

Table 2b: Experimental Critical Values Obtained(2)

3. Critical Values Trend Analyses- Metric OLNTNES.

3.0 General Procedure Adopted.

The tabulated data for each OLNTNES CV is plotted on gnuplot over Linux. Graphical analysis using smooth bezier support and “Fit” command is performed. General observations, for each such graph obtained is reported. Again, various equations of fit are attempted and their summary report is presented for each OLNTNES critical value. Ultimately, choice is made considering firstly value of least reduced chi-square and secondly on most plausible extendability produced at node numbers 80, 100 and 120. Finally, the values of parameters for each equation of each OLNTNES critical value is also noted.

3.1 Trend Analysis – OLNTNES CV1.

The curve obtained appears to be oscillating along a mildly decreasing straight line.

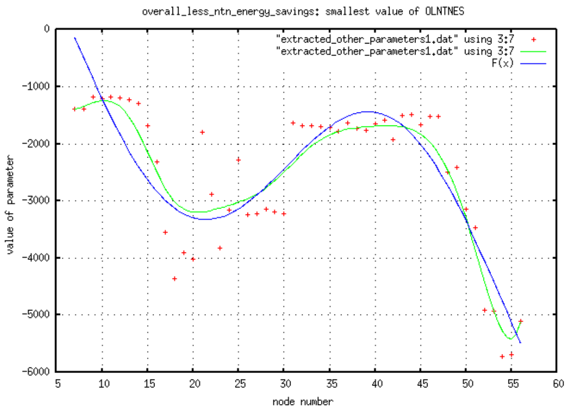

Figure 1: OLNTNES Critical Value 1

The applicable equation is:

F(x) = a * sin (b*(x-c)) + (d*x) + f

Ch_sq = 435 165 F(80) = -6 928.628 224 615

F(100)=-9 045.150 284 556 F(120)=-12 903.691 101 643

The parameters for best fit are: a = -2 008.26 , b = -0.131 905 , c = 30.317 5 , d=-102.241 , f= 714.647

3.2 Trend Analysis – OLNTNES CV2.

The curve obtained appears to be oscillating along a mildly increasing straight line.

The applicable equation is:

F(x) = a * sin (b* (x-c)) + (d*x) + f

Ch_sq = 8.556 6 F(80) = 131.103 575 167

F(100) = 161.356 675 540 F(120) = 159.897 731 328

The parameters for best fit are:

a = -17.751 8 , b = 0.080 438 2 , c = 34.771 6 , d=1.171 65 , f= 28.915 4

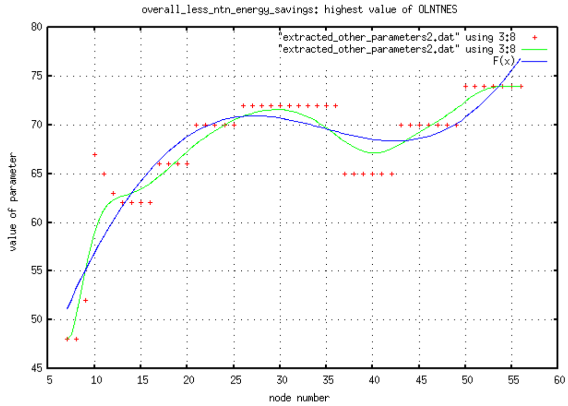

Figure 2: OLNTNES Critical Value 2

3.3 Trend Analysis – OLNTNES CV3.

The curve appears to be an oscillation along an axis which is itself mostly decreasing at a decreasing rate.

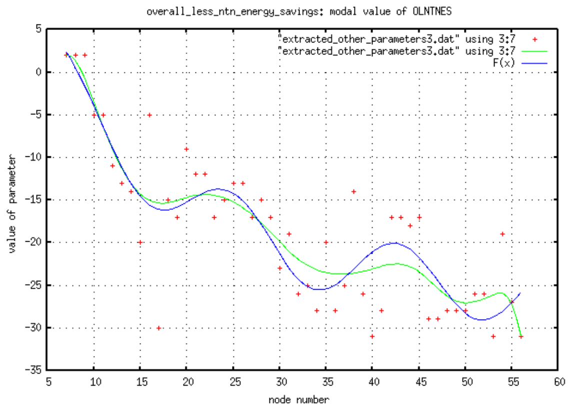

Figure 3: OLNTNES Critical Value 3

The applicable equation is:

F(x) = a*exp((b*x)+c) +d+ f*sin (g*(x-h))

Ch_sq = 23.576 2 F(80) = -23.652 835 588

F(100) = -26.051 612 639 F(120) = -28.844 576 575

The parameters for best fit are:

a = 0.466 63 , b = -0.056 687 1 , c = 4.413 03 , d=-27.333 8 , f= 3.797 18 , g= 0.350 609 , h= 38.154 2

3.4 Trend Analysis – OLNTNES CV4.

The curve appears to be a damped oscillation along a straight line axis.

The applicable equation is:

F(x)=a*exp(-b*(x-c))*cos (2*b*pi*(x-c))+d

Ch_sq = 60.045 2 F(80) = 60.611 214 791

F(100) = 60.409 652 824 F(120) = 60.396 045 522

The parameters for best fit are: a = 0.326 901 , b = 0.056 740 9 , c = 77.643 8 , d=60.420 3

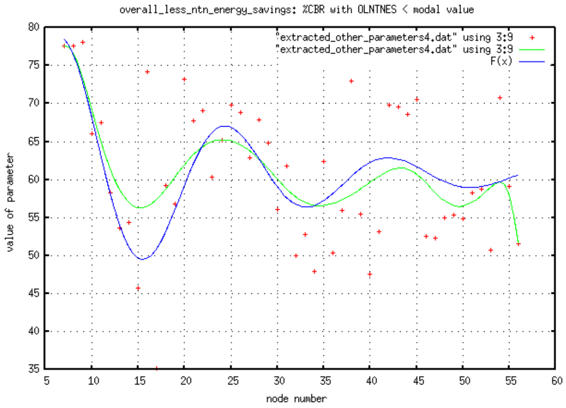

Figure 4: OLNTNES Critical Value 4

3.5 Trend Analysis – OLNTNES CV5.

The curve appears to be a case of damped oscillation along a straight line of positive gradient.

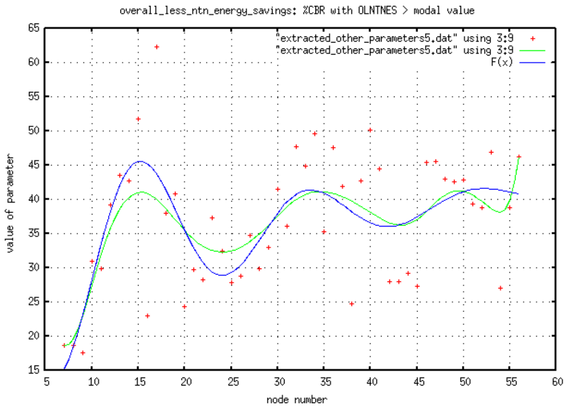

Figure 5: OLNTNES Critical Value 5

The applicable equation is:

$F(x)=a*\exp(-b*(x-c))*\cos(2*b*pi*(x-c))+d*x+f$

Ch_sq = 58.232 F(80) = 44.208

F(100) = 47.587 F(120) = 50.784

The parameters for best fit are: a = 0.555 039 , b = 0.055 223 4 , c = 69.935 6 , d= 0.156 838 , f= 31.960 5

3.6 Trend Analysis – OLNTNES CV6.

Generally, the curve obtained here increases at a decreasing rate.

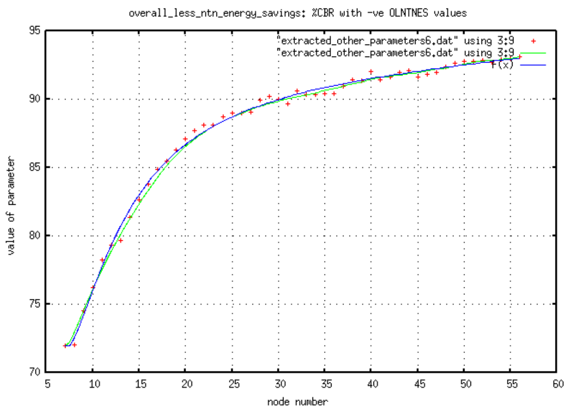

Figure 6: OLNTNES Critical Value 6

The potentially applicable equations are:

1. $F(x)= a * \exp(b * x) +(c*x) + d$
   Ch_sq = 2.022 36 F(80) = 73.229 969 576
   F(100)=41.240 240 974 F(120)= -9.402 767 677
2. $F(x)= a * \log(b * x) +(c*x) + d$
   Ch_sq = 0.337 59 F(80)= 90.215 653 731
   F(100)=87.021 027 428 F(120)=83.050 373 205
3. $F(x)= a * x * \log(b*x) +(c*x) + d$
   Ch_sq = 1.479 37 F(80) = 79.133 546 229
   F(100)=60.833 938 529 F(120)=35.779 809 566
4. $F(x)= a * x^{-1} * \log(b*x) +(c*x)+ d$
   Ch_sq = 0.276 054 F(80) = 91.772 595 111
   F(100)= 90.024 681 483 F(120)=87.669 003 515
5. $F(x)= a * x^{-2} * \log(b*x) +(c*x)+ d$
   Ch_sq = 0.154 076 F(80)=93.525 391 724
   F(100)= 93.783 756 188 F(120)=93.918 874 884
6. $F(x)= a * x^{-2.5} * \log(b*x) +(c*x)+d$
   Ch_sq = 0.125 2 F(80) = 94.763 990 385
   F(100) = 96.198 222 062 F(120)=97.708 848 375

Choice of best fit for SLNTNES Critical Value 6

The equation in part 6 above has been selected because of smallest reduced chi-square value obtained and good extendability. The parameters obtained for best fit are:

a = -6 979.98, b= 0.207 054, c= 0.004 582 22, d= 91.827 5

3.7 Trend Analysis – OLNTNES CV7.

Generally, the curve depicts a decreasing tendency until a minimum point, then shows an increasing tendency. The curve obtained depicts about half a wave:

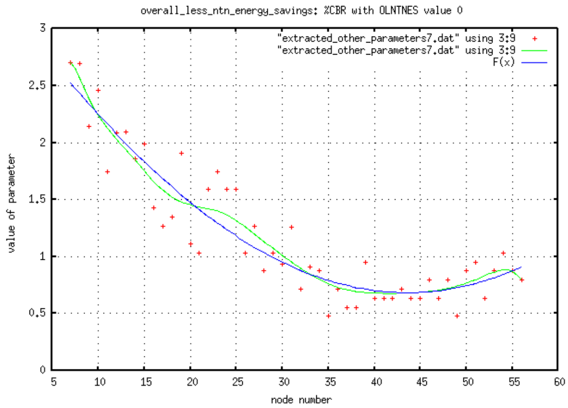

Figure 7: OLNTNES Critical Value 7

The applicable equation is:

$F(x) = a * \sin((b* x) + c) + d$

Ch_sq = 0.051 681 1 F(80) = 2.511 931 649

F(100) = 4.714 178 503 F(120)=7.217 407 852

The parameters obtained for best fit are:

a= 5.462 12, b= 0.023 133 4, c= -3.704 69, d= 6.145 59

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3.8 Trend Analysis – OLNTNES CV8.

Generally, the curve depicts a decreasing tendency at a decreasing rate.

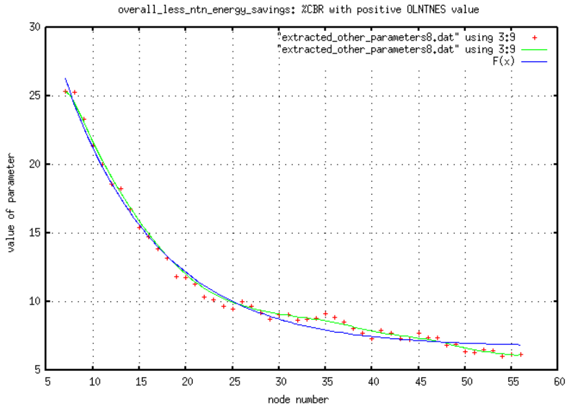

Figure 8: OLNTNES Critical Value 8

The potentially applicable equations are:

1. $F(x) = a * \exp((b * x) + c) + d$

   Ch_sq = 0.313 578 F(80) = 6.714 650 734
   F(100)=6.702 133 122 F(120)=6.700 395 627
2. $F(x) = a * x * \exp((b*x) + c) + d$

   Ch_sq = 0.458 186 F(80) = 7.297 253 417
   F(100)= 7.297 017 203 F(120)=7.297 010 154
3. $F(x) = a * x^{0.25} * \exp((b*x)+c) + d$

   Ch_sq = 0.330 081 F(80) = 6.906 314 392
   F(100)=6.901 578 184 F(120) = 6.901 129 765
4. $F(x) = a * \exp((b*x)+c) + (d * x)$

   Ch_sq = 0.553 51 F(80)= 9.312 487 067
   F(100)=11.474 049 413 F(120)=13.728 599 970

Choice of best fit for SLNTNES Critical Value 8

The equation in part 1 above has been selected because of smallest reduced chi-square value obtained and good extendability. The parameters obtained for best fit are:

a = 4.207 32, b= -0.098 734 6, c= 2.230 76, d= 6.700 12

3.9 Trend Analysis – OLNTNES CV9.

The curve obtained here shows decreasing tendency at a decreasing rate.

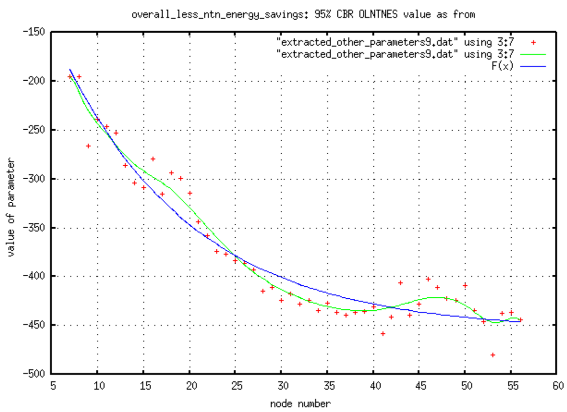

Figure 9: OLNTNES Critical Value 9

The potentially applicable equations are:

1. $F(x) = a / \log((b * x) + c) + d$

   Ch_sq = 457.98 F(80)=-476.583 896 683
   F(100)=-487.959 017 824 F(120)=-495.801 903 894
2. $F(x) = a * \exp((b * x) + c) + d$

   Ch_sq = 392.467 F(80) = -453.443 377 428
   F(100)=-454.705 519 396 F(120)=-455.020 239 560
3. $F(x) = a * \exp((b*x)+c) + (d*x^{0.25})$

   Ch_sq = 388.584 F(80)=-391.151 211 570
   F(100)=-308.479 987 522 F(120)=-188.195 841 981
4. $F(x) = a * \exp((b*x)+c) + (d*x^{0.5})$

   Ch_sq = 366.868 F(80) = -216.488 730 936
   F(100)=252.313 505 313 F(120)= 1 210.880 853 749

Choice of best fit for SLNTNES Critical Value 9

The equation in part 2 above has been selected because of smallest reduced chi-square value obtained and good extendability. The parameters obtained for best fit are:

a = 14.178 1, b= -0.069 444 1, c= 3.423 46, d= -455.125

4. Conclusion.

This piece of research was aimed at and has as achievement the identification of some critical values relevant to metric OLNTNES and modelling of their corresponding trends over varying node densities in a MANET topography of 300 x 300 m^2. The models put forward comprise of mathematical equations of varying complexity levels which will assist in studying MANETs for MAUC environment from a software engineering perspective. These mathematical models may fairly easily be implemented as programming algorithms, to generate more rigorously realistic simulation scenarios with the help of which newly developed communication protocols and middleware components for ubicomp may be tested.

This experiment has been conducted in NS-2 over Linux. The plottings and "Fit" attempts were carried out in gnuplot. Best fit was selected based on least reduced chi-square values and best extendability of equations at higher node numbers have been used. Assumptions stated in previous papers [17, 33] are continued here also.

This work is a follow-up of previous papers [1-13, 17, 33] and remains open for future upgrades. One such further work identified is formulating a method of predictability for metric OLNTNES and its trend.

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