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

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***Abstract* – Quite extensive research is ongoing concerning strategies of transmission and location aware transmission [1-47], though they are not fully merged. Such an eventuality is projected to bring betterment in ubicomp. The key factor over which such a merging will depend is correct protocol designs. At present stage, related research attempts are inappropriate for accurate implementations [85] due to present heuristic approaches for protocol designs. Middleware services and applications are also subject to enhancements [86]. More adapted network architecture for ubicomp is also required [87]. A distant objective in this direction is to achieve realism in design and evaluation of wireless routing protocols [88]. Such direction of research will also yield more precise components for predictability in ubicomp. Realism is quite laborious to achieve since it has to cover each aspect related to ubicomp. One such aspect was studied in a prior research [16] to assess the trend of extra sender node energy savings achievable in MANETs (SLNTNES) against direct node-to-node transmission under different sets of node densities in a ubicomp environment. This was followed by the study of trends for each SLNTNES parameter of equations [32].**

To elevate the components with better realism in knowledge of these trends, in this paper, the successive probing that is required is stated as: "What are the observable critical values in SLNTNES trends and the trends of these critical values?"

Such knowledge will doubtlessly foster the design of more realistic ubicomp scenarios over which experimental ubicomp features and protocols can be tested more validly. This paper follows-up from previous ones [1-47].

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

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1. Introduction

Energy consumption in MAUC is affected by a wide range of factors [2], among which type of transmission and node density remain momentous ones. In a prior research [16], an effort was made through simulation experiments, to derive the particular trend/model which depicts the sender node extra energy savings achievable against direct node-to-node transmission in MANET (SLNTNES) compared to the theoretical/empirical models derived in simulations. The model put forward for metric SLNTNES was the normal distribution model of form:

$$F(x)=b*(1/(a*sqrt(2*pi)))*exp(-(x-c)^2/2*a*a)$$

Logically, the study which followed [32] that such knowledge will assist designers towards better understanding the evolution and predictability of ubicomp environments. In doing so, designers may produce a platform of realistic simulation scenarios over which testing strategies of newly developed components, including communication protocols, can be exercised congruously.

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

The key contribution of this paper is the establishment of the trend of variation covering node numbers 7 until 56, for each of the eight critical values observed for metric SLNTNES introduced in prior papers [16, 32]. Such data, if properly presented, will certainly assist designers to better understand the evolution and predictability of ubicomp behaviour and derive more plausible simulation scenarios over which new communication protocols being developed could be validly tested. The rest of this paper is organised as follows: section 2- SLNTNES Critical Values, section 3- Critical Values Trend Analyses- Metric SLNTNES, section 4- Conclusion and References.

2. SLNTNES Critical Values.

2.0 Critical Values Identified.

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

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C1	C2	C3
1	%CBR at smallest value of SLNTNES	1
2	Highest value of SLNTNES reached.	2
3	%CBR at highest value of SLNTNES	3
4	Experimental Modal value of SLNTNES.	4
5	%CBR at modal value of SLNTNES.	5
6	%CBR with SLNTNES value less than modal value.	6
7	%CBR with SLNTNES value above modal value.	7
8	95% CBR with SLNTNES value as from.	8

Table 1: SLNTNES 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	0.571428571	98	0.079365079	23	4.698412698
8	0.557147405	98	0.079592486	22	4.186564788
9	0.492063492	98	0.079365079	21	4.428571429
10	0.317460317	100	0.079365079	28	4.746031746
11	0.317460317	100	0.079365079	26	3.809523810
12	0.238473768	100	0.079491256	21	3.910969793
13	0.317460317	100	0.079365079	21	4.222222222
14	0.238095238	100	0.079365079	21	4.285714286
15	0.238095238	100	0.079365079	21	4.174603175
16	0.158730159	100	0.079365079	24	4.031746032
17	0.174603175	100	0.079365079	33	4.269841270
18	0.174603175	100	0.079365079	33	4.222222222
19	0.174603175	100	0.079365079	27	4.031746032
20	0.158730159	100	0.079365079	33	3.968253968
21	0.158730159	100	0.079365079	22	3.920634921
22	0.158730159	100	0.079365079	26	4.015873016
23	0.158730159	100	0.079365079	26	4.031746032
24	0.158730159	100	0.079365079	33	4.444444444
25	0.158730159	100	0.079365079	33	4.428571429
26	0.158730159	100	0.079365079	33	4.031746032
27	0.158730159	100	0.079365079	33	4.079365079
28	0.158730159	100	0.079365079	33	4.238095238
29	0.158730159	100	0.079365079	33	4.317460317
30	0.158730159	100	0.079365079	33	4.301587302
31	0.158730159	100	0.079365079	33	4.126984127
32	0.158730159	100	0.079365079	26	3.761904762
33	0.158730159	100	0.079365079	32	3.777777778
34	0.158730159	100	0.079365079	33	3.952380952
35	0.158730159	100	0.079365079	33	3.888888889
36	0.158730159	100	0.079365079	29	3.904761905
37	0.158755358	100	0.079377679	33	3.889506271
38	0.158730159	100	0.079365079	33	4.063492063
39	0.158730159	100	0.079365079	29	4.047619048
40	0.158730159	100	0.079365079	33	3.984126984
41	0.158730159	100	0.079365079	29	4.015873016
42	0.158730159	100	0.079365079	29	4.031746032
43	0.158730159	100	0.079365079	29	4.285714286
44	0.158831004	100	0.079415502	29	4.415501906
45	0.158730159	100	0.079365079	29	4.666666667
46	0.158730159	100	0.079365079	29	4.666666667
47	0.158730159	100	0.079365079	29	4.666666667
48	0.158730159	100	0.079365079	29	4.746031746
49	0.079365079	100	0.079365079	29	4.825396825
50	0.079365079	99	0.555555556	29	4.349206349
51	0.079365079	99	0.555555556	29	4.349206349
52	0.079365079	99	0.555555556	29	4.190476190
53	0.079365079	99	0.555555556	29	4.111111111
54	0.079365079	99	0.555555556	29	4.111111111
55	0.079365079	99	0.555555556	29	4.111111111
56	0.079365079	99	0.555555556	29	4.031746032

Table 2a: Experimental Critical Values Obtained(1)

NN	CV6	CV7	CV8
7	38.492063492	56.809523810	68
8	31.232091691	64.581343521	68
9	23.936507937	71.634920635	70
10	42.190476190	53.063492063	80
11	34.047619048	62.142857143	81
12	15.278219396	80.810810811	81
13	13.396825397	82.380952381	81
14	12.619047619	83.095238095	82
15	11.857142857	83.968253968	82
16	21.126984127	74.841269841	82
17	50.952380952	44.777777778	83
18	50.285714286	45.492063492	83
19	29.920634921	66.047619048	83
20	49.825396825	46.206349206	83
21	12.015873016	84.063492063	84
22	24.555555556	71.428571429	84
23	24.222222222	71.746031746	85
24	48.095238095	47.460317460	85
25	47.761904762	47.809523810	86
26	47.619047619	48.349206349	86
27	47.222222222	48.698412698	86
28	47.063492063	48.698412698	86
29	46.904761905	48.777777778	86
30	46.746031746	48.952380952	86
31	46.761904762	49.111111111	86
32	22.539682540	73.698412698	86
33	42.746031746	53.476190476	86
34	46.206349206	49.841269841	86
35	46.190476190	49.920634921	86
36	32.174603175	63.920634921	87
37	45.800920781	50.309572948	88
38	45.619047619	50.317460317	88
39	31.015873016	64.936507937	88
40	45.333333333	50.682539683	88
41	30.492063492	65.492063492	88
42	30.317460317	65.650793651	88
43	30.174603175	65.539682540	89
44	29.987293520	65.597204574	89
45	29.761904762	65.571428571	89
46	29.761904762	65.571428571	89

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47	29.761904762	65.571428571	89
48	29.682539683	65.571428571	89
49	29.603174603	65.571428571	89
50	29.682539683	65.968253968	89
51	29.682539683	65.968253968	89
52	29.603174603	66.206349206	89
53	29.603174603	66.285714286	89
54	29.603174603	66.285714286	89
55	29.603174603	66.285714286	89
56	29.603174603	66.365079365	89

Table 2b: Experimental Critical Values Obtained(2)

3. Critical Values Trend Analyses- Metric SLNTNES.

3.0 General Procedure Adopted.

The tabulated data for each SLNTNES CV is plotted onto gnuplot over Linux. Graphical analysis using smooth bezier support and "Fit" command is performed. General observations, for each such graph obtained is reported. Numerous equations of fit are attempted and the summary report is presented for each SLNTNES critical value. Ultimately, for CV2, CV3 and CV4, choice is based on flat values and for other CVs, choice is based on 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 SLNTNES critical value is also noted.

3.1 Trend Analysis – SLNTNES CV1.

The curve obtained here tends to decrease at a decreasing rate towards stabilisation.

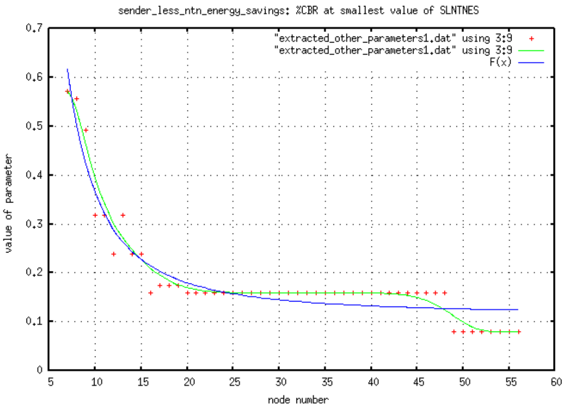

Figure 1: SLNTNES Critical Value 1

The potentially applicable equations are:

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

   Ch_sq = 0.001 193 22   F(80) = 0.137 022 430

   F(100) = 0.137 022 383   F(120) = 0.137 022 382

2. $F(x) = a * x^{0.25} * \exp((b*x)+c) + d$

   Ch_sq = 0.001 195 36   F(80) = 0.137 712 924

   F(100) = 0.137 712 912   F(120) = 0.137 712 911

3. $F(x) = a * x^{-0.25} * \exp((b*x)+c) + d$

   Ch_sq = 0.001 191 12   F(80) = 0.136 215 772

   F(100) = 0.136 215 590   F(120)= 0.136 215 587

4. $F(x) = a * x^{f} * \exp((b*x)+c) + d$

   Ch_sq = 0.001 168 56   F(80) = 0.119 617 428

   F(100) = 0.118 010 810   F(120)= 0.117 170 071

Choice of best fit for SLNTNES Critical Value 1

The equation in part 4 above has been selected because of smallest reduced chi-square value obtained and good extendability. The parameters obtained for best fit are:

a = 2.066 23 , b= 0.011 569 9 , c= 2.506 38 , d= 0.111 697 , f=-2.052 93

3.2 Trend Analysis – SLNTNES CV2.

Three ranges of observations are made here

$$F(x) = \begin{cases} 98 & 7 \le x \le 9 \\ 100 & 10 \le x \le 49 \\ 99 & x \ge 50 \end{cases}$$

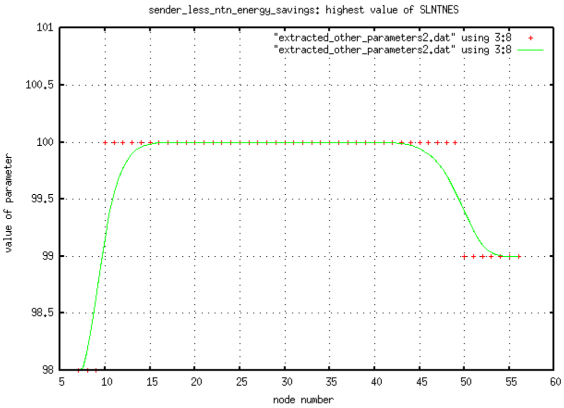

Figure 2: SLNTNES Critical Value 2

3.3 Trend Analysis – SLNTNES CV3.

Two ranges of observations are made here:

$$F(x) = \begin{cases} 0.079\,3 & 7 \le x \le 49 \\ 0.555\,6 & x \ge 50 \end{cases}$$

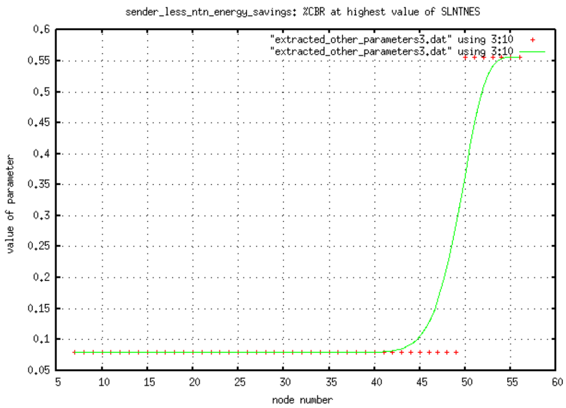

Figure 3: SLNTNES Critical Value 3

3.4 Trend Analysis – SLNTNES CV4.

Broadly, three ranges are defined in the plots, even if they are quite scattered.

$$F(x) = \begin{cases} 21 & 7 \le x \le 16 \\ 33 & 17 \le x \le 38 \\ 29 & x \ge 39 \end{cases}$$

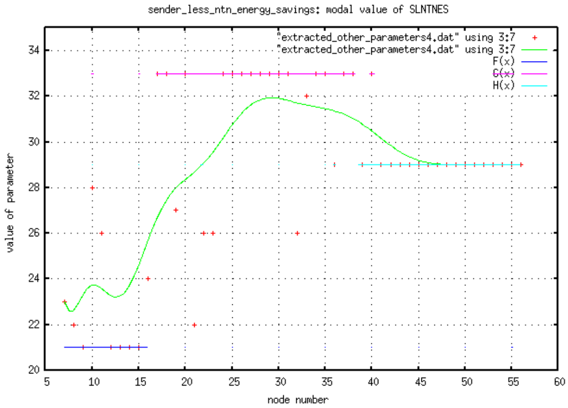

Figure 4: SLNTNES Critical Value 4

3.5 Trend Analysis – SLNTNES CV5.

The plots are quite scattered but overall, an oscillating tendency is observed.

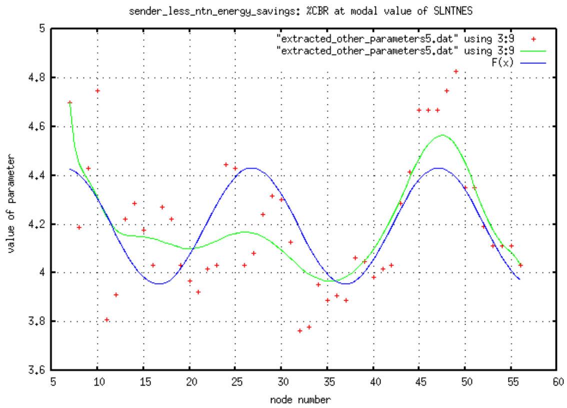

Figure 5: SLNTNES Critical Value 5

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

Ch_sq = 0.048 706 7   F(80) = 4.018 578 972

F(100)= 4.003 545 419   F(120)= 3.990 284 226

The parameters of fit are: a=0.238 465 , b=0.309 309 , c=-0.426 499 , d=4.192 04

3.6 Trend Analysis – SLNTNES CV6.

The plots obtained here are more scattered in the beginning but their trends become clearer as node number increases. Three distinct trends are observable for the following ranges:

$$F(x) = \begin{cases} a*\exp((b*x)+c) + d & 7 \le x \le 15 \\ f*\exp((g*x)+h) + i & 16 \le x \le 40 \\ j*\exp((k*x)+l) + m & 41 \le x \le 56 \end{cases}$$

For node number 7-15 : ch_sq = 84.642 4,

a= 3.211 84, b= -0.021 905 5 , c=4.138 93 , d=-133.819

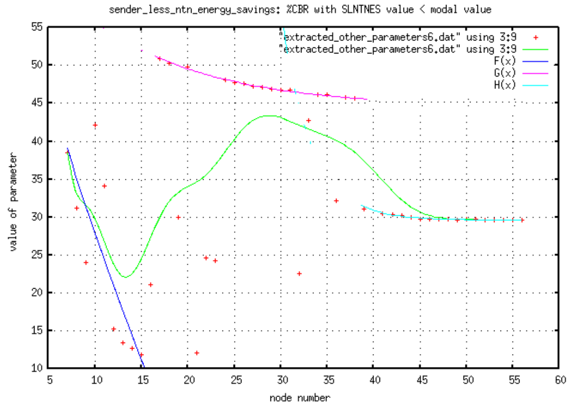

Figure 6: SLNTNES Critical Value 6

For node number 16-40 : ch_sq = 0.021 02 ,

f= 1.667 57 , g= -0.080 333 2 , h=2.718 71 , i=44.478 5

For node number 41-56 : ch_sq = 0.002 480 94 ,

j= 4.589 95 , k= -0.306 475 , l=10.989 4 , m=29.584 7

3.7 Trend Analysis – SLNTNES CV7.

Here also three distinct trends are observable as follows:

$$F(x) = \begin{cases} a*\log((b*x)+c) + d & 7 \le x \le 15 \\ f*\log((g*x)+h) + i & 16 \le x \le 40 \\ j*\log((k*x)+l) + m & 41 \le x \le 56 \end{cases}$$

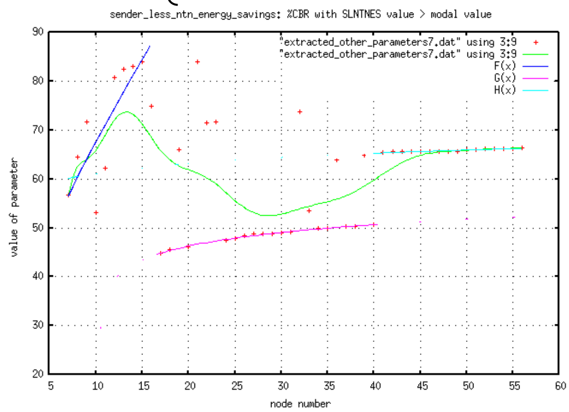

Figure 7: SLNTNES Critical Value 7

For node number 7-15 : ch_sq = 85.914 9 ,

a= 213.277 , b= 0.017 758 9 , c=0.891 927 , d=53.073

For node number 16-40 : ch_sq = 0.019 318 1 ,

f= 3.900 18 , g= 0.179 941 , h=-1.863 76 , i=44.131 3

For node number 41-56 : ch_sq = 0.030 140 1 , j= 3.062 83 , k= 11.939 4 , l=6.263 7 , m=46.340 6

3.8 Trend Analysis – SLNTNES CV8.

Generally an increasing trend at a decreasing rate is observed here:

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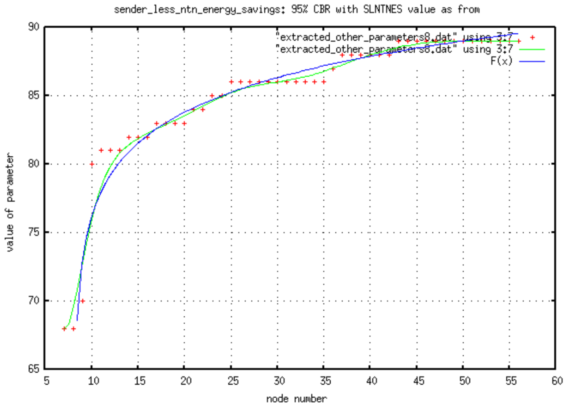

Figure 8: SLNTNES Critical Value 8

The potentially applicable equations are:

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

   Ch_sq = 1.943 5 F(80) = 91.241 557 323

   F(100)=92.252 255 323 F(120)= 93.062 956 199

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

   Ch_sq = 1.688 84 F(80) = 89.362 763 655

   F(100)=89.070 234 873 F(120)=88.469 960 945

Choice of best fit for SLNTNES Critical Value 8

The equation in part 1 above has been selected even if the reduced ch_sq is not smallest, it has good extendability. The parameters obtained for best fit are:

a = 4.113 49 , b= 5.080 13 , c= -41.616 4 , d= 66.974 7

4. Conclusion.

This piece of investigation was aimed at and has realised the identification of some critical values pertaining to metric SLNTNES and 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 can be implemented in programming algorithms, to generate improved realistic simulation scenarios using which newly developed communication protocols and middleware 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. For three critical values, best fit was evaluated with flat values and for remaining five critical values, least reduced chi-square and most plausible extendability of equations at higher node numbers have been used.

Assumptions stated in previous papers [16, 32] are upheld here also. Gnuplot is also assumed as appropriate for this study.

This work is a follow-up of previous papers [1-13, 16, 32] and subsists as prone to future upgrades. One such further work identified is formulating a method of predictability for metric SLNTNES and its trend.

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