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Trend Analyses of Critical Values Obtained for Sender Node Energy Savings Achievable in Ubicomp MANETs Using Location-Aware Transmission.

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***Abstract* – MANET transmission strategies coupled with location-awareness is welcome in ubicomp [1-45] and hence remain good topics of research. The success of these strategies depend heavily on the correct protocol designs being adopted. Current research attempts assume present methods for protocol design as heuristic in nature [83] and hence not so suitable for "correct the first time implementations". Optimisation methods for tuning parameters in middleware services and applications [84] is needed and suitability of traditional layered architecture in networking is also questioned [85] in terms of QoS and node densities. A further aim in this direction is to achieve realism in design and evaluation of wireless routing protocols [86]. This can be enhanced towards predictability in ubicomp. Achieving realism is a very long process since it will involve realism in each aspect concerned with ubicomp. Such an aspect was studied in a previous research [14] to assess the trend of energy savings achievable by sender node (SES) in Location-Aware MANET Transmission, followed by the study of trends for each SES parameter of equations [30].**

To enhance the components towards realism in knowledge of these trends, in this paper, the next set of questions to be investigated is put forward as: "What are the observable critical values in SES trends? What are the trends of variation observable within each critical value for metric SES over varying node densities?"

Such knowledge will assist designers in producing more realistic ubicomp scenarios over which new ubicomp features and protocols can be tested more realistically. This work follows-up from previous work [1-45].

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

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1. Introduction

Many factors [2] are known to affect energy consumption in MAUC. Type of transmission and node density also remain pertinent factors. In a previous research [14], an effort was made to find a particular trend/model which depicts energy savings that can be reached by senders in MAUC (SES) to rate the effectiveness of location-aware MANET transmission strategies compared to the theoretical/empirical models derived in simulations. The model put forward for metric SES was the exponential model of form:

$$F(x) = a * \exp(b * (x-c))$$

The study which followed [30] was mathematical modelling of the trends of the three parameters of equation obtained. Mention was also made in that same paper [30] that such knowledge will help designers to better understand evolution and predictability of ubicomp environments. To help in such aspect, one feature that can be produced is a platform of realistic simulation scenarios over which testing of newly developed components, including communication protocols, can be carried out.

The next probing that is required for the metric SES is identifying certain key critical values obtained during experimentations and formulating the corresponding trend of variations over varying node densities for each critical value. Seven such critical values were obtained.

The key contribution of this paper is the establishment of the trend of variation covering node numbers 7 until 56, for each of the seven critical values observed for metric SES introduced in previous papers [14, 30]. Availability of such data will aid ubicomp designers to better understand the evolution and predictability of ubicomp environment and formulate more realistic simulation scenarios over which new communication protocols designed could be tested. The rest of this paper is organised as follows: section 2- SES Critical Values, section 3- Critical Values Trend Analyses-Metric SES, section 4- Conclusion and References.

2. SES Critical Values.

2.0 Critical Values Identified.

Seven critical values have been identified as follows: Column headings are: C1→SES Critical Value, C2→ Meaning of SES Critical Value, C3→ Corresponding figure number for the SES Critical Value.

C1	C2	C3
1	Smallest SES value obtained.	1
2	%CBR at highest value of SES obtained.	2
3	Modal value of SES.	3
4	%CBR at modal value of SES.	4
5	%CBR with SES value below modal value.	5
6	%CBR with SES value greater than modal value.	6
7	SES value reached by 90% CBR.	7

Table 1: SES 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
7	2	0.079365079	94	9.603174603
8	2	13.482967208	100	13.482967208
9	2	13.571428571	100	13.571428571
10	3	12.063492063	97	12.476190476
11	3	12.380952381	97	14.031746032
12	3	12.496025437	97	14.642289348
13	3	12.571428571	98	15.603174603
14	3	12.888888889	98	16.888888889
15	3	13.047619048	98	18.730158730
16	3	13.206349206	98	19.857142857
17	4	13.365079365	98	21.142857143
18	4	13.761904762	98	21.428571429
19	4	14.079365079	98	19.984126984
20	4	14.158730159	98	20.063492063
21	4	13.539682540	98	21.380952381
22	4	13.984126984	99	22.777777778
23	4	14.349206349	99	24.285714286
24	4	14.825396825	99	25.206349206
25	4	14.984126984	99	26.634920635
26	4	14.507936508	99	28.174603175
27	4	14.904761905	99	28.968253968
28	4	15.063492063	99	30.619047619
29	4	15.222222222	99	32.253968254
30	4	15.507936508	99	33.095238095
31	4	16.174603175	99	34.396825397
32	4	16.730158730	99	34.984126984
33	4	17.000000000	99	36.158730159
34	4	17.730158730	99	36.301587302
35	4	18.095238095	99	37.142857143
36	4	18.253968254	99	37.904761905
37	4	18.050484204	99	38.307667884
38	4	18.285714286	99	39.079365079
39	4	18.682539683	99	40.253968254
40	4	19.000000000	99	41.158730159
41	4	19.444444444	99	41.809523810
42	4	20.126984127	99	42.317460317
43	4	20.269841270	99	43.000000000
44	4	20.822744600	99	43.694409149
45	4	21.412698413	99	44.031746032
46	4	21.777777778	99	44.412698413
47	4	22.333333333	99	44.126984127
48	4	22.825396825	99	44.380952381
49	4	23.269841270	99	44.619047619
50	4	24.142857143	99	44.825396825
51	4	24.555555556	99	45.063492063
52	4	24.841269841	99	45.158730159
53	4	25.269841270	99	45.190476190
54	4	25.825396825	99	45.269841270
55	4	26.730158730	99	44.825396825
56	4	27.047619048	99	45.222222222

Table 2a: Experimental Critical Values Obtained(1)

NN	CV5	CV6	CV7
7	61.619047619	28.777777778	73
8	86.517032792	0.000000000	73
9	86.428571429	0.000000000	77
10	60.666666667	26.857142857	85
11	56.126984127	29.841269841	86
12	52.480127186	32.877583466	87
13	63.968253968	20.428571429	88
14	60.936507937	22.174603175	88
15	57.476190476	23.793650794	89
16	54.857142857	25.285714286	90
17	52.190476190	26.666666667	91
18	50.111111111	28.460317460	91
19	48.317460317	31.698412698	92
20	46.476190476	33.460317460	92
21	43.920634921	34.698412698	92
22	63.238095238	13.984126984	92
23	61.365079365	14.349206349	92
24	59.968253968	14.825396825	92
25	58.380952381	14.984126984	93
26	57.317460317	14.507936508	93
27	56.126984127	14.904761905	93
28	54.317460317	15.063492063	94
29	52.523809524	15.222222222	94
30	51.396825397	15.507936508	94
31	49.428571429	16.174603175	94
32	48.285714286	16.730158730	94
33	46.841269841	17.000000000	94
34	45.968253968	17.730158730	95
35	44.761904762	18.095238095	95
36	43.841269841	18.253968254	95
37	43.641847912	18.050484204	95
38	42.634920635	18.285714286	95
39	41.063492063	18.682539683	95
40	39.841269841	19.000000000	95
41	38.746031746	19.444444444	95
42	37.555555556	20.126984127	95
43	36.730158730	20.269841270	95
44	35.482846252	20.822744600	95
45	34.555555556	21.412698413	96
46	33.809523810	21.777777778	96
47	33.539682540	22.333333333	96
48	32.793650794	22.825396825	96
49	32.111111111	23.269841270	96

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50	31.031746032	24.142857143	97
51	30.380952381	24.555555556	97
52	30.000000000	24.841269841	97
53	29.539682540	25.269841270	97
54	28.904761905	25.825396825	97
55	28.444444444	26.730158730	97
56	27.730158730	27.047619048	97

Table 2b: Experimental Critical Values Obtained(2)

3. Critical Values Trend Analyses- Metric SES.

3.0 General Procedure Adopted.

The tabulated data for each CV for metric SES is plotted onto gnuplot and analysed graphically with support from smooth bezier plot. General observations, for each such graph obtained is reported. Several equations of fit are attempted and summary is reported for each SES CV. Ultimately, choice was based firstly on least reduced chi-square value and most plausible extendability produced at node numbers 80, 100 and 120. Finally values of parameters for equation of each SES CV, is noted.

3.1 Trend Analysis – SES CV1.

The tendency can safely be assumed to be increasing at a decreasing rate. A staircase feature is also observed, which is probably due to rounding off to nearest unit, and hence is ignored.

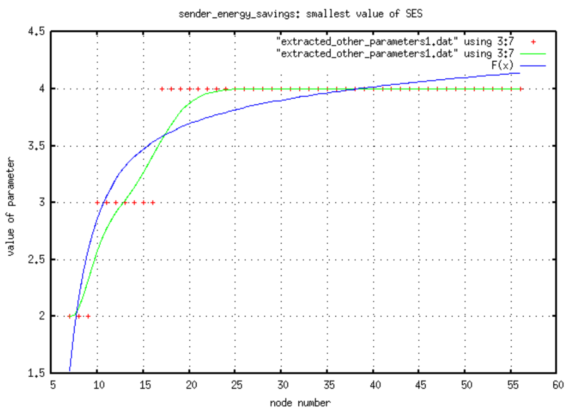

Figure 1: SES Critical Value 1

Below is a summary of potentially applicable equations of trend followed by best choice.

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

   Ch_sq = 0.070 875 2 F(80)= 4.435 549 934 591
   F(100)=4.555 990 267 756 F(120)= 4.652 965 020 367

2. $F(x) = a*\log((b*x) + c) + (d * x^{-1})$

   Ch_sq = 0.066 46 F(80) = 4.393 071 020 479
   F(100)=4.483 396 104 741 F(120) = 4.552 414 979 261

3. $F(x) = a * \log((b*x) + c) + (d*x^{-2})$

   Ch_sq = 0.062 854 3 F(80)=4.396 900 642 521
   F(100)=4.510 345 750 292 F(120)=4.601 967 773 706

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

   Ch_sq = 0.053 948 1 F(80) = 4.263 995 035 112
   F(100)=4.339 000 180 150 F(120) = 4.399 512 409 190

Choice of best fit for SES 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 = 0.317 491, b= 9 021.77, c= -39 034.5, d= -576.052

3.2 Trend Analysis – SES CV2.

The curve obtained mostly depict an increasing tendency at a mildly increasing rate.

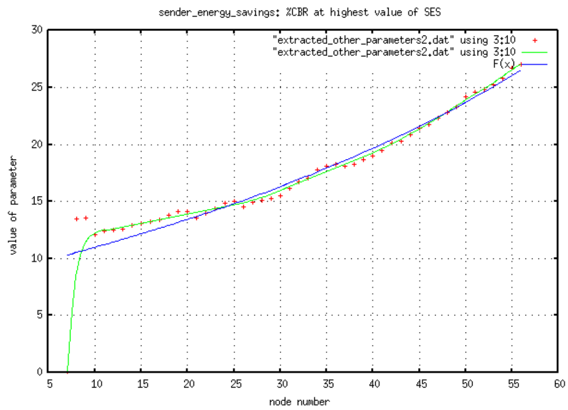

Figure 2: SES Critical Value 2

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

   Ch_sq = 2.970 18 F(80) = 44.142 900 815
   F(100)=67.776 891 249 F(120)=104.900 807 164

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

   Ch_sq = 3.160 02 F(80) = 35.818 032 106
   F(100)=44.378 015 422 F(120)=53.075 553 631

3. $F(x) = a * \exp((b*x)+c) + (d*x^{0.5})$

   Ch_sq = 2.976 18 F(80)= 41.350 311 112
   F(100)=60.004 098 463 F(120)= 87.250 931 212

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

   Ch_sq = 2.737 46 F(80) = 62.650 134 158
   F(100)= 159.186 188 068 F(120)= 456.827 399 422

Choice of best fit for SES Critical Value 2

The equation in part 4 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 = 1.894 374 , b= 0.019 182, c= 1.500 255 , d= 0.218 274

3.3 Trend Analysis – SES CV3.

It is safe to consider the curve depicting an increasing tendency at a decreasing rate, despite the staircase feature observed due to rounding off to nearest unit.

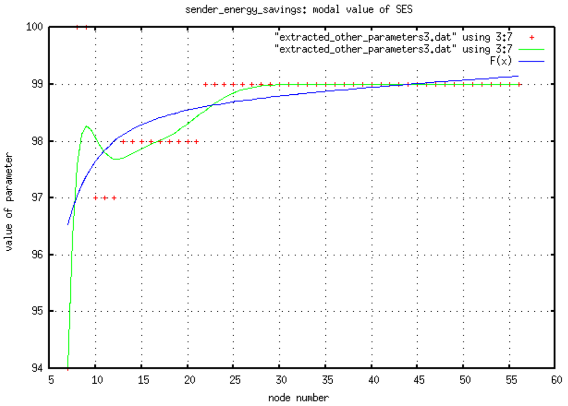

Figure 3: SES Critical Value 3

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

   Ch_sq = 0.675 841 F(80) = 100.183 888 715

   F(100)= 100.828 072 517 F(120)= 101.476 409 732

2. `F(x) = a * log ((b*x)+ c) + (d*x`$^{-1}$`)`

   Ch_sq = 0.581 711 F(80)= 99.118 493 094

   F(100) = 99.114 621 521 F(120)=99.094 291 978

3. `F(x) = a * log ((b*x)+ c) + (d*x`$^{-2}$`)`

   Ch_sq = 0.579 284 F(80)= 99.408 436 630

   F(100)= 99.620 761 846 F(120)= 99.830 808 143

4. `F(x) = a * log ((b*x)+ c) + (d*x`$^{-3}$`)`

   Ch_sq = 0.570 972 F(80) = 99.564 200 455

   F(100)= 99.878 395 218 F(120)=100.193 187 921

Choice of best fit for SES Critical Value 3

The equation in part 3 above has been selected even if the reduced ch_sq is not smallest, it has good extendability over larger node numbers. The parameters obtained for best fit are:

a = 1.894 37 , b= 0.019 182 1, c= 1.500 26 , d= 0.218 274

3.4 Trend Analysis – SES CV4.

Generally, the curve observed depicts an increasing tendency at a decreasing rate.

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

   Ch_sq = 3.004 15 F(80) = 59.549 194 386

   F(100) = 66.929 705 139 F(120)= 73.208 604 173

2. `F(x) = a * log ((b*x)+c) + (d*x`$^{-1}$`)`

   Ch_sq = 2.503 35 F(80) = 58.502 089 959

   F(100) = 65.004 763 470 F(120) = 70.405 056 903

3. `F(x) = a * log ((b*x)+c) + (d*x`$^{-2}$`)`

   Ch_sq = 2.479 7 F(80) = 57.655 892 326

   F(100) = 63.700 691 214 F(120)= 68.683 379 825

4. `F(x) = a * log ((b*x)+c) + (d*x`$^{-3}$`)`

   Ch_sq = 2.529 75 F(80) = 57.662 186 814

   F(100) = 63.780 602 046 F(120)= 68.840 599 146

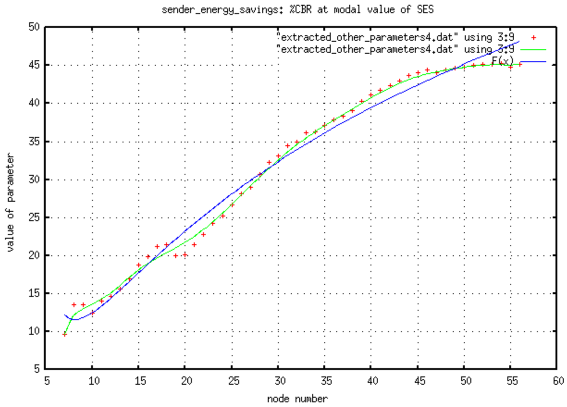

Figure 4: SES Critical Value 4

Choice of best fit for SES Critical Value 4

The equation in part 3 above has been selected because of smallest ch_sq and good extendability over larger node numbers. The parameters obtained for best fit are:

a = 28.286 3, b= 0.091 750 1, c= 0.309 486, d= 662.803

3.5 Trend Analysis – SES CV5.

Three different trends are observed here with decreasing tendency at a decreasing rate, for the following ranges:

i. For node number 7-12.
ii. For node number 13-21.
iii. For node number 22-56.

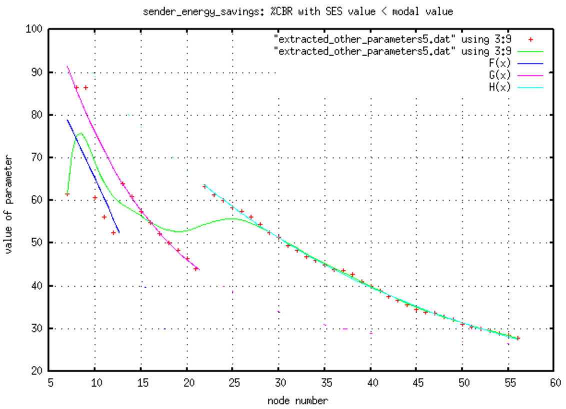

Figure 5: SES Critical Value 5

The applicable equations have been:

$$F(x) = \begin{cases} d*x + f & \text{for node number 7-12} \\ a * \exp((b*x) + c) + g & \text{for node number 13-21} \\ i * \exp((j*x) + k) + l & \text{for node number 22-56} \end{cases}$$

For node number 7-12: Ch_sq = 194.529 , d= -4.646 48 , f= 111.448

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For node number 13-21 : 2 equations were attempted here. The second one is better.

1. F(x) = d * x + f

   Ch_sq = 0.594 302, d= -2.443 92 , f=94.685 9

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

   Ch_sq = 0.114 024 , a = 1.512 12, b = -0.089 780 1, c = 4.400 79 , d = 25.623 24

For node number 22-56

F(x) = i * exp ((j*x) +k) +l

Ch_sq = 0.161 405 F(80) = 17.714 460 388

F(100)= 13.729 327 669 F(120)= 11.632 574 350

Parameters of fit are:

i = 2.139 62 , j = -0.032 109 , k = 3.937 51 , l=9.304 45.

3.6 Trend Analysis – SES CV6.

Here also, three different trends are observed with decreasing tendency at a decreasing rate :

i. For node number 7-12.
ii. For node number 13-21.
iii. For node number 22-56.

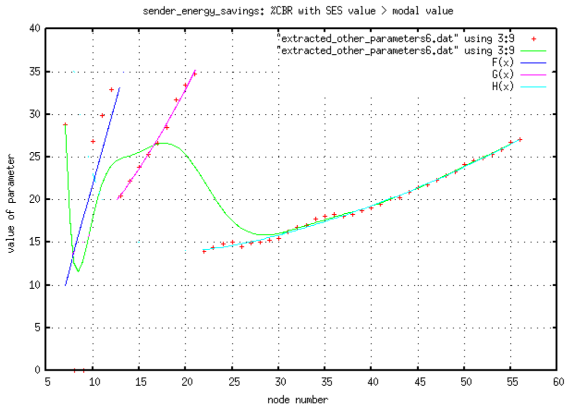

Figure 6: SES Critical Value 6

$$F(x) = \begin{cases} d*x + f & \text{for node number 7-12} \\ a * \exp((b*x) + c) + g & \text{for node number 13-21} \\ i * \exp((j*x) + k) + (l*x^{-3}) & \text{for node number 22-56} \end{cases}$$

For node number 7-12

F(x) = d*x + f

Ch_sq= 229.66 , d=3.91086 , f=-17.427 5

For node number 13-21

F(x) = a * exp ((b*x) +c) + g

Ch_sq = 0.304 171 , a = 0.262 796 , b= 0.048 835 2 , c=4.126 16 , d=-10.227 1

For node number 22-56: Here several equations were tried before choosing the **fourth one** for best extendability even if the ch_sq is not least.

1. F(x) = i * exp ((j*x) +k) +l

   Ch_sq = 0.083 855 8 F(80) = 49.488 875 228

   F(100)= 85.676 839 485 F(120)= 152.493 205 884

2. F(x) = i * exp ((j*x) +k) + $(l*x^{-1})$

   Ch_sq = 0.081 781 8 F(80) = 46.759 586 417

   F(100) = 74.282 022 556 F(120)= 118.409 249 666

3. F(x) = i * exp ((j*x) +k) + $(l*x^{-2})$

   Ch_sq = 0.081 735 2 F(80) = 49.950 426 799

   F(100)= 71.577 935 658 F(120) = 111.598 261 113

4. F(x) = i * exp ((j*x) +k) + $(l*x^{-3})$

   Ch_sq = 0.082 182 2 F(80) = 45.452 166 973

   F(100) = 70.074 572 645 F(120)= 108.063 678 764

The parameters of fit are: i= 0.133 173 9 , j= 0.021 663 9, k=4.099 079 8, l=13 193.933 634

3.7 Trend Analysis – SES CV7.

Here the curve obtained depicts an increasing trend at a decreasing rate. Some staircase feature is also noticed but is not of big amplitude and hence ignored.

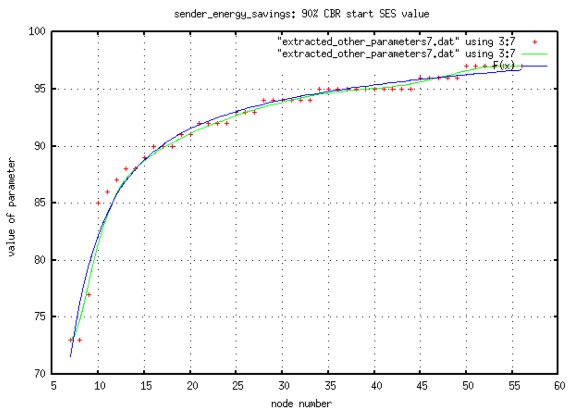

Figure 7: SES Critical Value 7

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

   Ch_sq = 1.600 47 F(80) = 99.708 689 563

   F(100)= 100.998 687 149 F(120)= 102.037 356 703

2. F(x) = a * log ((b*x)+ c) $+(d*x^{-1})$

   Ch_sq = 1.756 85 F(80) = 98.883 092 380

   F(100) = 99.707 846 237 F(120)= 100.327 115 790

3. F(x) = a * log ((b*x)+ c) $+(d*x^{-2})$

   Ch_sq = 0.862 664 F(80) = 98.277 283 184

   F(100) = 99.230 925 379 F(120)= 100.025 048 012

4. F(x) = a * log ((b*x)+c) $+(d*x^{-2.5})$

   Ch_sq = 0.865 156 F(80) = 98.653 079 912

   F(100) = 99.737 070 180 F(120)= 100.630 922 354

5. $F(x) = a * \log((b*x)+c) + (d*x^{-1.75})$

Ch_sq = 0.895 46 F(80) = 97.991 679 069
F(100) = 98.811 670 426 F(120) = 99.492 831 454

Choice of best fit for SES Critical Value 7

The equation in part 4 above has been selected even if the reduced ch_sq is not smallest, it has good extendability over larger node numbers. The parameters obtained for best fit are:

a = 4.710 31 , b= 9.538 17(e^{+06}) , c= 3.959 52(e^{+08}) , d= -677.022

4. Conclusion.

This piece of research was aimed at and has achieved the identification of some critical values concerned for metric SES and their corresponding trends over varying node densities in a MANET topography of 300 x 300 m^2. The models put forward will help to study MANETs for MAUC environment from a software engineering perspective. The models put forward in this paper, are mathematical in nature and can be used by designers towards producing more realistic simulation scenarios for testing newly developed protocols and middleware for ubicomp. The experiment was carried out in NS-2 over Linux. The plottings and fitting attempts were done in gnuplot. Best fit was evaluated from reduced chi-square values and best extendability of equations obtained.

Assumptions stated in previous papers [14, 30] hold here also. Gnuplot is also assumed as appropriate. The intrinsic constructs of gnuplot is not questioned here.

This work is a follow-up of previous papers [1-13, 14, 30] and remain open for further refinements. One such further work identified is formulating a method of predictability for metric SES and its trend.

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