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Trend Analyses of Critical Values Obtained for Minimum Energy Consumption Ratio Achievable in Ubicomp MANETs Using Location-Aware Transmission Strategies.

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Abstract **– Research concerning location-tracking, MANET transmission and location-aware transmission for ubicomp [1-50]. Nevertheless, the fruitful merging of these fields still has a long way ahead. One determinant factor over which such merging will be based is correct protocols design methodologies, which are currently claimed to be heuristic in nature [88] and hence are ill-suited for implementation. Refinements are also looked forward to, as concerns middleware services and architecture [89, 90].**

A more advanced objective in this direction of developments is arriving at "realism" in design and evaluation of wireless routing protocols [91]. Such kinds of research will also yield more usable components for predictability in ubicomp. "Realism" is tediously wide scope since it encrusts into each feature related to ubicomp. Such a feature was investigated in a prior paper [19] to assess the trend of Minimum Energy Consumption Ratio (Min_R) recordable for a CBR under different sets of node densities in ubicomp environments. This study was reinforced by the corresponding study of trends for each Min_R parameter of equations [35].

To consolidate realism in knowledge of these trends, in this paper, the next investigation required is framed as: " What are observable critical values in Min_R trends over varying node densities and trends of such critical values?"

Such knowledge will steadily lead to the design of more realistic ubicomp scenarios which are better suited for advanced testing of newly designed middleware components and communication protocols. This paper is a follow-up of previous investigations [1-50].

Key terms: Ubicomp- Ubiquitous Computing, MAUC-Mobile and Ubiquitous Computing, Min_R- Minimum Energy Consumption Ratio, CBR- Constant Bit Rate, MANET- Mobile Adhoc Network, CV- Critical Value.

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1. Introduction

A commendable solution to poor resource availability in ubicomp is use of MANETs in which distribution of energy consumption load is heavily influenced by node density. A past study [19] was aimed at finding the trends observable for metric Min_R for node densities varying between 7 until 56. The model suggested in that paper is the exponential model of the form:

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G(x) = a * exp (b * (x -0.01)) + c
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Following this study, another study [35] was conducted to model mathematically the trends of the three parameters of the equation obtained, with the belief that such results may serve towards better understanding of the evolution and predictability of ubicomp environments. With slowly happening progresses, designers may produce a serious platform of realistic simulation scenarios over which testing tasks for newly built components, including communication protocols and middleware functions are efficiently undertaken.

The type of exploration for metric Min_R now called for is the identification of observable critical values obtained during experimentations and formulation of corresponding theoretical trend of such critical values over varying node densities. Five such critical values were observed.

The key contribution of this paper is the resolving of the trend of variations for each of the five critical values observed for metric Min_R introduced previously [19, 35] covering node numbers 7 until 56. Such information must be rightly presented so as to help ubicomp designers to more valuably understand the evolution and predictability of ubicomp behaviour and prepare more appropriate simulation scenarios with which novel communication protocols could be earnestly tested. The rest of this paper is organised as follows: section 2- Min_R Critical Values, section 3- Critical Values Trend Analyses- Metric Min_R, section 4- Conclusion and References.

2. Min_R Critical Values.

2.0 Critical Values Identified.

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

C1	C2	C3
1	% CBR at modal value of min_ratio.	1
2	Second modal value of min_ratio.	2
3	%CBR at second modal value of min_ratio.	3
4	Highest value of min_ratio.	4
5	% CBR at highest value of min_ratio.	5

Table 1: Min_R Critical Values

2.1 Experimental Critical Values Obtained.

The values obtained during experiments have been 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	84.063492063	0.01	1.619047619	1.0	4.301587302
8	70.853231455	0.01	1.862464183	1.0	7.672715696
9	70.920634921	0.01	2.000000000	1.0	6.952380952
10	59.428571429	0.01	6.380952381	1.0	7.095238095
11	58.920634921	0.01	6.619047619	1.0	6.793650794
12	57.901430843	0.01	7.011128776	1.0	6.486486486
13	58.714285714	0.01	7.396825397	1.0	6.333333333
14	58.015873016	0.01	7.047619048	1.0	6.222222222
15	57.603174603	0.01	7.063492063	1.0	6.269841270
16	57.190476190	0.01	7.047619048	1.0	6.333333333
17	52.412698413	0.01	7.920634921	1.0	5.746031746
18	52.380952381	0.01	8.301587302	1.0	5.714285714
19	51.746031746	0.01	8.698412698	1.0	5.793650794
20	51.904761905	0.01	8.523809524	1.0	5.714285714
21	50.873015873	0.01	8.206349206	1.0	5.253968254
22	50.904761905	0.01	7.952380952	1.0	5.158730159
23	50.936507937	0.01	7.301587302	1.0	5.190476190
24	50.666666667	0.01	7.142857143	1.0	5.349206349
25	50.539682540	0.01	7.015873016	1.0	5.222222222
26	48.253968254	0.01	7.238095238	1.0	5.507936508
27	48.222222222	0.01	7.634920635	1.0	5.492063492
28	47.777777778	0.01	7.968253968	1.0	5.460317460
29	47.650793651	0.01	7.587301587	1.0	5.301587302
30	47.555555556	0.01	7.666666667	1.0	5.412698413
31	47.174603175	0.01	8.603174603	1.0	5.126984127
32	47.142857143	0.01	8.238095238	1.0	5.206349206
33	47.412698413	0.01	8.079365079	1.0	5.047619048
34	47.380952381	0.01	7.730158730	1.0	4.888888889
35	47.206349206	0.01	7.349206349	1.0	4.952380952
36	46.714285714	0.01	7.793650794	1.0	5.174603175
37	47.451976504	0.01	7.143991110	1.0	4.540403239
38	47.380952381	0.01	6.920634921	1.0	4.587301587
39	47.444444444	0.01	6.793650794	1.0	4.682539683
40	47.365079365	0.01	6.619047619	1.0	4.587301587
41	47.349206349	0.01	6.301587302	1.0	4.571428571
42	46.523809524	0.01	6.666666667	1.0	4.603174603
43	47.222222222	0.01	6.079365079	1.0	4.634920635
44	47.585768742	0.01	5.368487929	1.0	4.653748412
45	47.190476190	0.01	5.714285714	1.0	4.714285714
46	47.206349206	0.01	5.873015873	1.0	4.936507937
47	46.841269841	0.01	5.888888889	1.0	4.777777778
48	46.619047619	0.01	6.063492063	1.0	4.730158730
49	46.476190476	0.01	5.936507937	1.0	4.555555556
50	45.873015873	0.01	5.730158730	1.0	5.539682540
51	45.666666667	0.01	5.539682540	1.0	5.714285714
52	45.460317460	0.01	5.666666667	1.0	5.603174603
53	45.333333333	0.01	5.666666667	1.0	5.603174603
54	45.444444444	0.01	5.555555556	1.0	5.825396825
55	45.650793651	0.01	5.365079365	1.0	5.682539683
56	45.492063492	0.01	5.476190476	1.0	5.666666667

Table 2: Experimental Critical Values Obtained

3. Critical Values Trend Analyses- Metric Min_R.

3.0 General Procedure Adopted.

The tabulated data for each Min_R CV is plotted on gnuplot over Linux. Graphical analyses using the "Fit" command has been undertaken here. Assistance from smooth bezier plot has also been sought. For each graph of critical value obtained, the general observations are reported. Here also, various equations of fit are attempted and their corresponding summary report is detailed hereunder, for each Min_R critical value. Concludingly, for two critical values choice of best fit is made based on flat values and for the remaining three critical values, choice is based on least reduced chi-square and most acceptable extendability produced at node numbers 80, 100 and 120. Lastly, the values of parameters for each equation corresponding to Min_R critical value, is recorded.

3.1 Trend Analysis – Min_R CV1.

Generally, a decreasing tendency at a decreasing rate is observed here. A minor oscillation is also noticed but its amplitude is very small and hence is ignored.

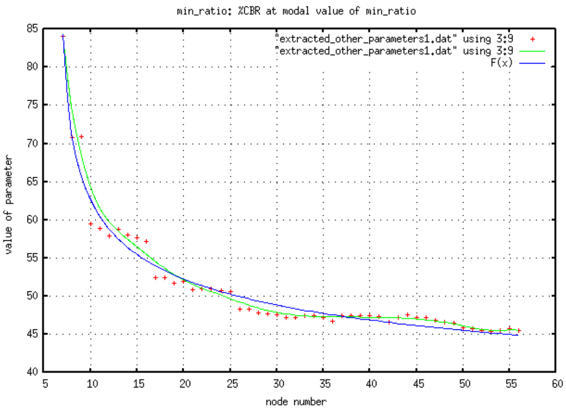

Figure 1: Min_R Critical Value 1

The potentially applicable equations are:

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

   Ch_sq = 1.869 06 F(80) = 42.994 567 769

   F(100)= 41.934 947 393 F(120)= 41.118 380 377

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

   Ch_sq = 1.967 09 F(80) = 46.266 826 802

   F(100)= 46.530 344 023 F(120) = 46.921 809 576

3. F(x)=(a * $x^{0.5}$)/(log ((b*x)+c)+d)
   Ch_sq = 2.301 77 F(80) = 47.311 596 421
   F(100)= 48.240 209 958 F(120)= 49.246 003 693
4. F(x)= (a * $x^{0.25}$)/(log ((b*x)+c)+d)
   Ch_sq = 1.885 06 F(80) = 45.721 158 561
   F(100)= 45.723 177 847 F(120)= 45.834 505 107

Choice of best fit for Min_R Critical Value 1

The equation in part 1 above has been selected because of smallest ch_sq and good extendability. The parameters obtained for best fit are:

a = 408.529 , b= 3.400 18 , c= -21.420 9 , d = 3.978 04

3.2 Trend Analysis – Min_R CV2.

For all node numbers, the value of this critical value remains at 0.01.

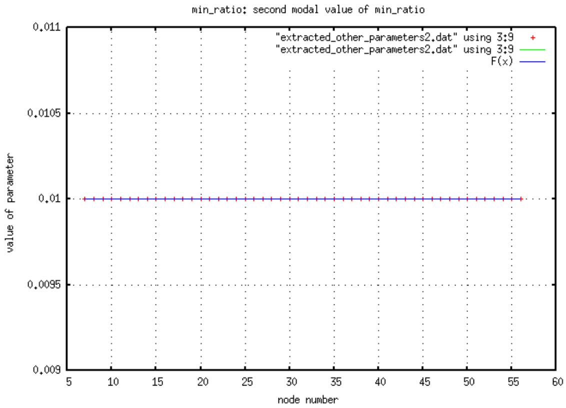

Figure 2: Min_R Critical Value 2

F(x) = 0.01

It is expected that for higher node numbers, the same value will apply.

3.3 Trend Analysis – Min_R CV3.

The curve obtained depicts an initial rapid increase until a maximum point is reached and then a slow decrease in value with an oscillation is obtained.

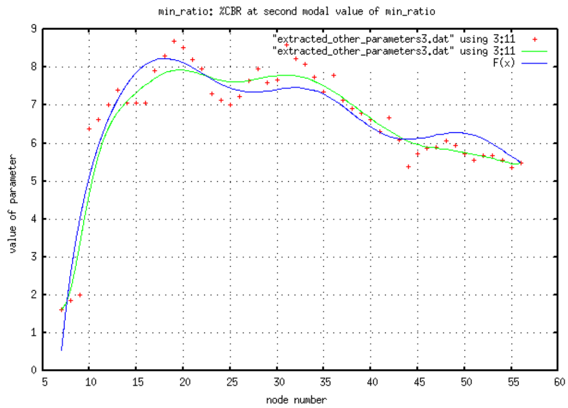

Figure 3: Min_R Critical Value 3

This section has been tackled in two parts:

i. Find equation of best fit for axis of oscillation.
ii. Find equation of best fit for oscillation along axis.

Step1: Find equation of best fit for axis of oscillation

1. F(x)= (a*x^{-1}+f)/(log ((b*x)+c)+d)
   Ch_sq = 0.426 389 F(80) = 4.604 813 948
   F(100)= 4.028 292 838 F(120)= 3.604 506 387
2. F(x)= (a*$x^{-0.75}$+f)/(log ((b*x)+c)+d)
   Ch_sq = 0.430 509 F(80) = 4.674 689 825
   F(100)= 4.120 362 246 F(120) = 3.712 748 938
3. F(x)= (a*$x^{-1.25}$+f)/(log ((b*x)+c)+d)
   Ch_sq = 0.430 909 F(80) = 4.599 209 573
   F(100)= 4.016 100 995 F(120)= 3.586 184 668

Choice of best fit for axis of oscillation

The equation in part 1 above has been selected because of smallest reduced chi-square value.

Step 2: Finding equation of best fit for oscillation

F(x)=(a*x^{-1}+f)/(log((b*x)+c)+d)+ g*sin((h*x)+i)

Ch_sq = 0.407 6 F(80) = 4.633 986 446
F(100) = 4.333 108 740 F(120) = 3.767 992 263

The parameters of fit are: a = -16.033 7 , b = 84.397 5 , c = 84.397 5 , d = -5.041 13 , f = 2.389 94 , g = -0.307 226 , h = 0.377 039 , i = 10.773 3

Here, definitely, oscillation in the equation yield better predictability.

3.4 Trend Analysis – Min_R CV4.

Here, the critical value stays at 1.0 throughout.

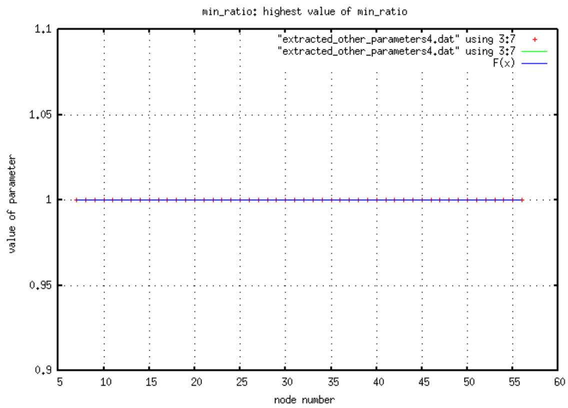

Figure 4: Min_R Critical Value 4

F(x) = 1.0

Projected value for higher node numbers will be at 1.0 also.

3.5 Trend Analysis – Min_R CV5.

Generally, the curve depicts a decreasing tendency until a minimum point and then shows an increasing tendency. This trend is assumed to be about half a wave to form an oscillation.

F(x)= a * sin ((b * x) – c) + d

Ch_sq = 0.215 242 F(80) = 6.068 855 419
F(100) = 4.726 046 609 F(120) = 5.813 683 947

The parameters of fit are: a = 0.871 105 , b = 0.099 851 4 , c = -0.848 875 , d = 5.585 81

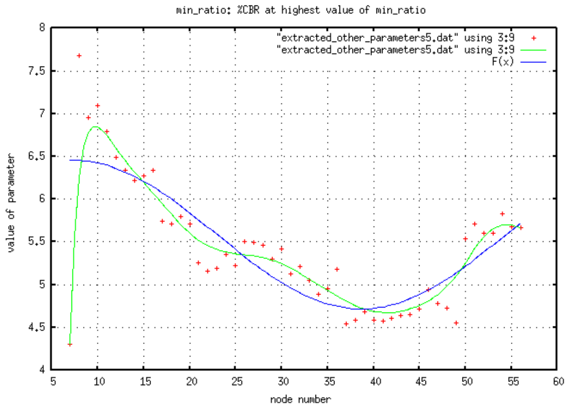

Figure 5: Min_R Critical Value 5

4. Conclusion.

This piece of study was targeted at identifying some critical values proper to metric Min_R and study their corresponding trends over varying node densities in a MANET topography of 300 x 300 m^2. The models successful detailed here are of varying complexity of mathematical nature. These output will help in studying MANETs for MAUC environment viewed from software engineering. Such mathematical models can objectively be implemented in computational algorithms to produce more realistic simulation schemes befitting which, novel communication protocols and middleware components produced for ubicomp may be rigorously tested.

The experiments were executed in NS-2 over Linux. The plottings and "Fit" attempts were conducted in gnuplot. Best fit was selected based on flat values for two critical values and on a combination of least reduced chi-square values and best extendability of equations observed at higher node numbers. Assumptions put down in past papers [19, 35] are inherited in this paper also.

This work dwells as a follow-up of previous work [1-13, 19, 35] and remains prone for future upgrades. One such further work identified is the formulation of predictability for metric Min_R and its trend.

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