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

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Abstract – **Location-tracking, ubicomp functionalities and MANET transmission strategies are subject to quite promising research [1-51]. It still remains that the worthwhile merging of these fields has a lot to undergo. One key factor over which success of this merging is based is correct protocol design approaches. In the current era of technology, such approaches are alleged as heuristic in nature and hence are unsuitable for implementation [89]. Fine-tunings in middleware services and network architecture reforms are also expected [90, 91].**

A significantly better elaborated objective following such technological progress would be achieving realism in design and evaluation of wireless routing protocols [92]. The output of such studies will also be more suitable for studies in predictability in ubicomp. "Realism" is slow progressing since it creeps in every feature related to ubicomp. One such feature was scrutinised in a previous paper [20] to assess the trend of Maximum Energy Consumption Ratio (Max_R) readable for CBRs under different sets of node densities in ubicomp environments. This study was supported by the corresponding study of trends for each Max_R parameter of equations [36].

To take in "realism" in knowledge of these trends, in this paper, the next probing needed is put forward as: "What are observable critical values in Max_R trends over varying node densities and trends of such critical values?"

Such knowledge will step by step lead to the design of more realistic ubicomp scenarios which are better suited for more worthy testing of newly designed middleware components and communication protocols. This paper remains a follow-up of previous investigations [1-51].

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

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1. Introduction

Use of MANETs is praised as a valuable solution to meagrely provisioned ubicomp topographies. In MANETs, energy consumption load is distributed among contributing nodes; this is drastically affected by node densities. A recent study [20] was targeted at finding the trends observable for metric Max_R for node densities varying between 7 until 56. The model suggested in that paper [20] was split into three:

- For node numbers 7 until 25, the exponential model was observed of form:
  `G(x) = a * exp (b*(x - 1.0 )) + c`
- For node numbers 26 onwards, previous to the peak value observed, tendency is linear of form:
  `F(x) = d * x + f`
- For node numbers 26 onwards, as from the peak value onwards, tendency is exponential of form:
  `G(x) = a * exp (b*(x - 2.0 )) + c`

Following this study, another study [36] was conducted to model mathematically the trends of the six parameters observed above; the sixth parameter being k, representing the value of node number where applicable equation changes from first to third equation above. The results obtained will serve towards better understanding of the evolution and predictability of ubicomp environments. With such progresses happening crawlingly, designers will produce more solemn platforms of realistic simulation scenarios over which testing functionalities for newly built components, including communication protocols and middleware functions, can be efficiently executed.

The probing now required for metric Max_R is the identification of observable critical value obtained during experimentations and formulation of corresponding theoretical trend of such critical values over varying node densities. Four such critical values were observed.

The key contribution of this paper is the establishment of the trends of variations for each of the four critical values observed for metric Max_R introduced previously [20, 36] covering node numbers 7 until 56. Such information should mandatorily be presented in an appropriate order so as to unimpedingly assist ubicomp designers to understand the evolution and predictability of ubicomp behaviour and provision for

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better suitable simulation scenarios over which novel communication protocols could be tested. The rest of this paper is organised as follows: section 2- Max_R Critical Values, section 3- Critical Values Trend Analyses- Metric Max_R, section 4- Conclusion and References.

2. Max_R Critical Values.

2.0 Critical Values Identified.

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

C1	C2	C3
1	Minimum value of Max_R	1
2	%CBR at modal value of Max_R	2
3	Second modal value of Max_R	3
4	%CBR at second modal value of Max_R	4

Table 1: Max_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
7	1.0	44.555555556	2.0	22.079365079
8	1.0	37.312957657	2.0	18.990767272
9	1.0	35.365079365	2.0	18.603174603
10	1.0	27.920634921	2.0	16.904761905
11	1.0	25.904761905	2.0	17.507936508
12	1.0	25.135135135	2.0	16.740858506
13	1.0	23.444444444	2.0	17.174603175
14	1.0	22.126984127	2.0	16.666666667
15	1.0	20.777777778	2.0	15.666666667
16	1.0	20.015873016	2.0	14.825396825
17	1.0	18.428571429	2.0	16.317460317
18	1.0	17.825396825	2.0	16.698412698
19	1.0	17.507936508	2.0	15.539682540
20	1.0	16.476190476	2.0	15.730158730
21	1.0	16.507936508	2.0	14.539682540
22	1.0	15.825396825	2.0	14.428571429
23	1.0	14.698412698	2.0	14.396825397
24	1.0	14.920634921	2.0	13.317460317
25	1.0	14.238095238	2.0	13.174603175
26	1.0	13.222222222	2.0	15.841269841
27	1.0	12.380952381	2.0	15.888888889
28	1.0	12.238095238	2.0	15.349206349
29	1.0	11.888888889	2.0	15.682539683
30	1.0	12.523809524	2.0	13.365079365
31	1.0	11.825396825	2.0	13.714285714
32	1.0	11.968253968	2.0	12.587301587
33	1.0	11.190476190	2.0	13.984126984
34	1.0	10.873015873	2.0	13.793650794
35	1.0	10.253968254	2.0	13.317460317
36	1.0	9.841269841	2.0	12.634920635
37	1.0	10.112716304	2.0	12.049531672
38	1.0	9.603174603	2.0	11.555555556
39	1.0	9.444444444	2.0	11.634920635
40	1.0	8.968253968	2.0	12.190476190
41	1.0	8.920634921	2.0	11.714285714
42	1.0	8.936507937	2.0	11.333333333
43	1.0	9.365079365	2.0	11.349206349
44	1.0	8.560991105	2.0	11.372299873
45	1.0	8.507936508	2.0	10.761904762
46	1.0	8.047619048	2.0	11.015873016
47	1.0	8.507936508	2.0	10.333333333
48	1.0	8.238095238	2.0	10.857142857
49	1.0	7.682539683	2.0	10.555555556
50	1.0	7.349206349	2.0	11.031746032
51	1.0	7.317460317	2.0	10.682539683
52	1.0	7.047619048	2.0	10.190476190
53	1.0	7.174603175	2.0	9.888888889
54	1.0	6.793650794	2.0	10.111111111
55	1.0	6.984126984	2.0	10.253968254
56	1.0	6.746031746	2.0	10.015873016

Table 2: Experimental Critical Values Obtained

3. Critical Values Trend Analyses- Metric Max_R.

3.0 General Procedure Adopted.

The tabulated data for each Max_R CV is plotted on gnuplot. Graphical analyses are conducted, general observations are reported, and various equations of fit are tried. Assistance from smooth bezier plot is retained here. In conclusion, for two CVs choice of best fit is based on flat values and for remaining two CVs, it 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 Max_R CV, is recorded.

3.1 Trend Analysis – Max_R CV1.

Here, the value stays at 1.0 throughout, i.e. predicted value for any node number stays at 1.0.

$$F(x) = 1.0$$

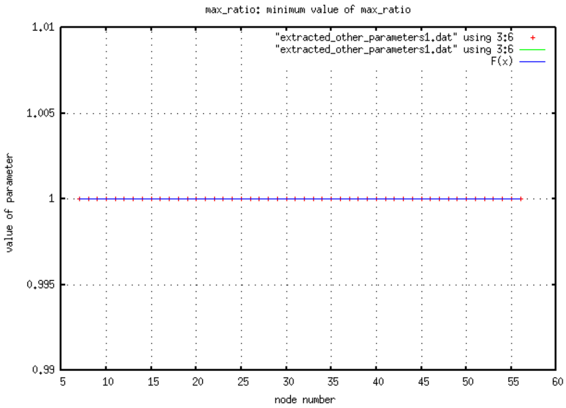

Figure 1: Max_R Critical Value 1

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3.2 Trend Analysis – Max_R CV2.

The curve obtained here is mostly decreasing at a decreasing rate.

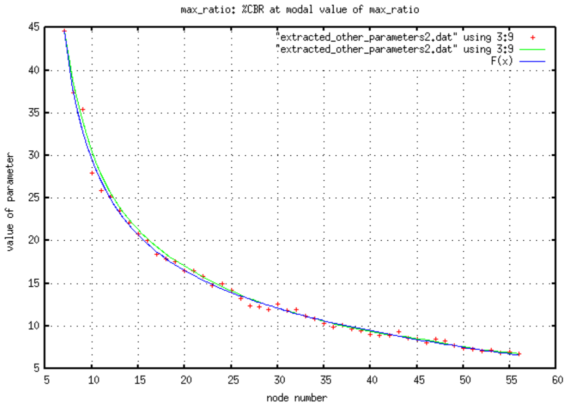

Figure 2: Max_R Critical Value 2

The potentially applicable equations are:

1. $F(x) = (a*x^2 + f)/(\exp((b*x)+c)+d)$
   Ch_sq = 0.383 382 F(80) = 3.015 871 542
   F(100) = 1.473 254 535 F(120) = 0.673 579 251
2. $F(x) = (a*x^{1.5} + f)/(\exp((b*x)+c)+d)$
   Ch_sq = 0.340 667 F(80) = 3.498 411 642
   F(100) = 1.993 015 807 F(120) = 1.092 042 496
3. $F(x) = (a*x^{1.75} + f)/(\exp((b*x)+c)+d)$
   Ch_sq = 0.357 927 F(80) = 3.258 922 343
   F(100) = 1.723 910 529 F(120) = 0.865 100 843
4. $F(x) = (a*x^g + f)/(\exp((b*x)+c)+d)$
   Ch_sq = 0.332 881 F(80) = 3.898 476 223
   F(100) = 2.487 060 843 F(120) = 1.561 797 634

Choice of best fit for Max_R Critical Value 2

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 = 2.585 98 , b= 0.031 269 9 , c= 2.007 09 , d= -8.112 82 , f=30.144 4 , g = 1.078 81

3.3 Trend Analysis – Max_R CV3.

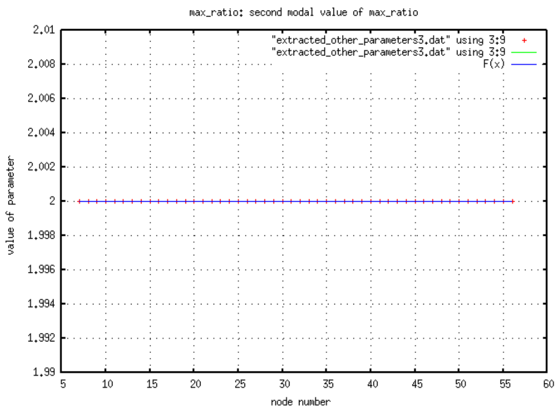

Figure 3: Max_R Critical Value 3

In the plots here, the value of this critical value has remained at 2.0 throughout.

$$F(x) = 2.0$$

3.4 Trend Analysis – Max_R CV4.

Here the plots depict a decreasing tendency.

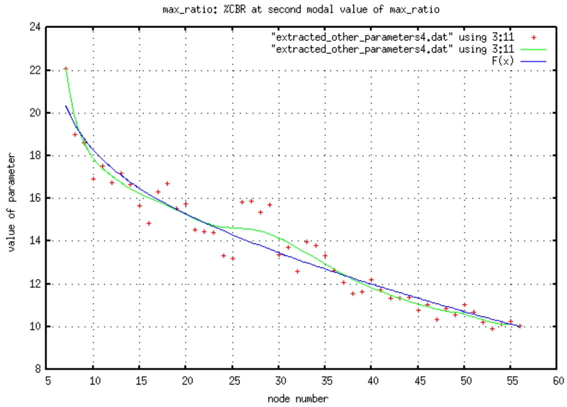

Figure 4: Max_R Critical Value 4

The potentially applicable equations are:

1. $F(x) = d * x + f$
   Ch_sq = 0.936 45 F(80) = 4.891 736 389
   F(100)= 1.264 742 681 F(120)= -2.362 251 026
2. $F(x) = (a * x)/(\exp((b*x)+c) + d)$
   Ch_sq = 0.687 8 F(80) = 7.584 790 751
   F(100)= 5.971 593 883 F(120)= 4.661 296 004
3. $F(x) = (a*x+f)/(\exp((b*x)+c)+d)$
   Ch_sq = 0.689 756 F(80) = 7.592 457 650
   F(100)= 5.973 639 731 F(120) = 4.658 560 137

Choice of best fit for Max_R Critical Value 4

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 = 0.326 577 , b= 0.018 634 4 , c= 0.009 364 22 , d= -1.037 65

4. Conclusion.

This piece of probing was intended to identify some critical values applicable to metric Max_R and study their corresponding trends over varying node densities in a MANET topography of 300 x 300 m^2. The models elaborated here comprise of mathematical equations of varying complexity levels. These output will reinforce the existing tools, for more prosperous studies of MANETs for ubicomp environment as viewed by software engineers. These output can discerningly be implemented in computational algorithms to produce more realistic simulation schemes with the advantage of which novel communication protocols and middleware components devised for ubicomp may be more integrally 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 expounded in previous papers [20, 36] are sustained in this paper also.

This work remains a follow-up of previous endeavours [1-13, 20, 36] and subsists as a subject for future polishing. One such task identified is the formulation of predictability for metric Max_R and its trend.

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