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

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Abstract **– A promising future lies ahead as concerns research related to location-tracking, MANET transmission and location-aware transmission for ubicomp [1-49]. It is presently accepted that more notable developments must be produced before these fields are subject to fruitful merging and bring about commendable results. One substantial factor for success of such integrated development approach is correct protocol designs. Current methodology of research in protocol designs are heuristic in nature [87] and hence are unsuitable for implementation. Enhancements are awaited in middleware services and architecture [88, 89].**

A relatively further objective in this direction of study is accomplishing realism in design and evaluation of wireless routing protocols [90]. Such formats of research will also yield more usable components for predictability in ubicomp. "Realism" is a broad topic to consider since it will cover each feature related to ubicomp. Such a feature was studied in a prior paper [18] to assess the trend of Energy Consumption Ratio (ECR) achievable under different sets of node densities in a ubicomp environment. This study was upgraded by the corresponding study of trends for each ECR parameter of equations [34].To intensify realism in knowledge of these trends, in this paper, the next stage of investigation that is needed is propounded as: "What are the observable critical values in ECR trends and the trends of these critical values?"

Such knowledge will progressively lead to the design of more realistic ubicomp scenarios which are more distinctly suited for scrupulous testing of newly designed middleware features and communication protocols. This paper is a follow-up of previous investigations [1-49].

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

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1. Introduction

MANET transmission is accepted as a solution to poor resource availability in ubicomp. It does have significant impacts on the distribution of energy consumption in ubicomp environment [2], which is also heavily influenced by node density. A previous study [18] was aimed at finding the trends observable for metric ECR for varying node densities 7 until 56. The model suggested in that paper [18] was split into two:

- A straight line F(x) from left of the graph towards right until a peak value (at around ECR value 0.3)
  `F(x) = d*x + f`
- As from the peak value, trend is smoothly exponentially decreasing and asymptotic to x-axis
  `G(x) = a * exp ( b * ( x -c ))`

Following this study, another study [34] was formulated to model mathematically the trends of the five parameters of the equations obtained, with the hope that such results may serve towards better understanding of the evolution and predictability of ubicomp environments. With some more progress, designers may produce a platform of realistic simulation scenarios over which testing activities of newly developed components, including communication protocols and middleware functions can be judiciously carried out.

The type of investigation for metric ECR required now is identification of observable critical values obtained during experimentations and formulation of corresponding theoretical trend of such critical values over varying node densities. Eight such critical values have been observed.

The key contribution of this paper is the determination of the trend of variation for each of the eight critical values observed for metric ECR introduced in past papers [18, 34], covering node numbers 7 until 56. Such information, if properly assembled, will aid ubicomp designers to better understand the evolution and predictability of ubicomp behaviour and draw more convenient simulation scenarios over which new communication protocols being implemented could be trustworthily tested. The rest of this paper is organised as follows: section 2- ECR Critical Values, section 3- Critical Values Trend Analyses- Metric ECR, section 4- Conclusion and References.

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2. ECR Critical Values.

2.0 Critical Values Identified.

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

C1	C2	C3
1	Effective total number of communicating nodes.	1
2	% communicating nodes at smallest value of energy ratio.	2
3	least value of 1st five records of energy ratio	3
4	% communicating nodes at smallest of 1st five records of ECR.	4
5	Modal value of energy ratio after first record	5
6	% communicating nodes at modal value of ECR after 1st record.	6
7	% communicating nodes with energy ratio less than modal value.	7
8	% communicating nodes with energy ratio greater than modal value.	8

Table 1: ECR 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	39726	26.496501032	0.1	3.947037205	0.3
8	39598	22.367291277	0.1	3.515329057	0.3
9	45729	19.580572503	0.1	3.426709528	0.3
10	52462	13.838587930	0.1	3.976211353	0.3
11	58297	12.576976517	0.1	3.624543287	0.3
12	64293	11.309162739	0.1	3.843342199	0.4
13	70845	10.281600678	0.1	3.945232550	0.3
14	76746	9.494957392	0.1	3.541552654	0.3
15	82882	8.911464492	0.1	3.608744963	0.3
16	89052	8.324349818	0.1	3.448546916	0.3
17	95628	7.626427406	0.1	3.778182122	0.4
18	101666	7.225621152	0.1	3.792811756	0.3
19	107775	6.898631408	0.1	3.603804222	0.3
20	113850	6.531400966	0.1	3.737373737	0.3
21	120413	6.069112139	0.1	3.772848447	0.3
22	126393	5.755065550	0.1	3.816667062	0.4
23	132559	5.520560656	0.1	3.714572379	0.4
24	138628	5.293302940	0.1	3.780621519	0.4
25	144722	5.057973218	0.1	3.655283924	0.4
26	151847	4.868057979	0.1	3.556869744	0.4
27	157821	4.700261689	0.1	3.332256164	0.4
28	164089	4.560939490	0.1	3.172059066	0.3
29	170191	4.424440775	0.1	3.008972272	0.4
30	176428	4.227786973	0.1	3.017094792	0.4
31	182026	4.156549064	0.1	3.140210739	0.4
32	188211	4.070431590	0.1	3.080053769	0.4
33	194318	4.020728908	0.1	3.147932770	0.4
34	200385	3.958380118	0.1	3.130473838	0.5
35	206622	3.776945340	0.1	3.074212814	0.5
36	212735	3.660892660	0.1	3.081298329	0.5
37	219868	3.522568086	0.1	3.008623356	0.5
38	226002	3.420323714	0.1	2.860594154	0.6
39	232193	3.420430418	0.1	2.905341677	0.6
40	238523	3.356489731	0.1	2.963655497	0.5
41	244729	3.227243196	0.1	2.900759616	0.5
42	250725	3.189151461	0.1	2.887625885	0.5
43	257048	2.998272696	0.1	2.765242289	0.5
44	263097	2.947582070	0.1	2.691022703	0.6
45	269502	2.871963844	0.1	2.642280948	0.5
46	275426	2.823989021	0.1	2.620304546	0.3
47	281453	2.713063993	0.1	2.572720845	0.5
48	287436	2.657635091	0.1	2.445761839	0.5
49	293877	2.515678328	0.1	2.485053271	0.4
50	299163	2.533401524	0.0	2.533401524	0.6
51	305322	2.441356994	0.0	2.441356994	0.6
52	311348	2.359738942	0.0	2.359738942	0.4
53	318046	2.343371714	0.0	2.343371714	0.4
54	324300	2.292013568	0.0	2.292013568	0.4
55	330262	2.300597707	0.0	2.300597707	0.4
56	336488	2.274078125	0.0	2.274078125	0.5

Table 2a: Experimental Critical Values Obtained(1)

NN	CV6	CV7	CV8
7	5.135175955	35.012334491	59.852489553
8	4.416889742	29.887873125	65.695237133
9	4.233637298	26.930394279	68.835968423
10	4.395562502	22.052152034	73.552285464
11	4.489081771	20.426437038	75.084481191
12	4.460827773	23.560885322	71.978286905
13	4.401157456	18.527771896	77.071070647
14	4.411956323	17.404164386	78.183879290
15	4.350763736	16.784102700	78.865133563
16	4.396307775	16.016484750	79.587207474
17	4.407704856	19.900029280	75.692265864
18	4.419373242	15.199771802	80.380854956
19	4.456506611	14.806773370	80.736720019
20	4.506807202	14.560386473	80.932806324
21	4.437228538	14.136347404	81.426424057
22	4.447239958	18.069829817	77.482930226
23	4.597198229	17.585377077	77.817424694
24	4.560406267	17.476988776	77.962604957
25	4.472022222	17.260679095	78.267298683
26	4.539437723	16.829440160	78.631122116
27	4.657174901	16.452816799	78.890008301
28	4.633461110	11.705842561	83.660696329
29	4.671222333	16.006134284	79.322643383
30	4.626816605	15.758269662	79.614913733
31	4.722402294	15.840594201	79.437003505
32	4.674540808	15.673366594	79.652092598
33	4.633641762	15.528669501	79.837688737
34	4.676996781	19.844299723	75.478703496
35	4.868310248	19.650376049	75.481313703
36	4.835593579	19.516299622	75.648106800
37	4.681445231	19.176960722	76.141594047
38	4.626065256	23.521473261	71.852461483
39	4.615987562	23.465823690	71.918188748
40	4.597460203	18.884971261	76.517568536
41	4.746474672	18.562981911	76.690543417
42	4.715923821	18.344002393	76.940073786
43	4.588637142	18.196212381	77.215150478
44	4.601724839	22.512609418	72.885665743
45	4.549502416	18.016934939	77.433562645
46	4.486867616	9.108798734	86.404333650
47	4.593306875	17.876164049	77.530529076
48	4.651818144	17.648450438	77.699731418
49	4.610091977	17.707408201	77.682499821
50	4.739222431	13.346904530	81.913873039
51	4.677684543	22.288600232	73.033715225
52	4.639181880	13.051633542	82.309184578
53	4.683913648	13.127346359	82.188739994

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54	4.648165279	13.135676842	82.216157879
55	4.605131683	13.267042530	82.127825787
56	4.625424978	17.790233233	77.584341789

Table 2b: Experimental Critical Values Obtained(2)

3. Critical Values Trend Analyses- Metric ECR.

3.0 General Procedure Adopted.

The tabulated data for each ECR CV is plotted on gnuplot over Linux. Graphical analyses using the "Fit" command is performed supported by the smooth bezier plot. For each such graph obtained, the major observations are reported. Again, various equations of fit are exerted and their summary report is produced for each ECR CV. In the end, for one CV, choice is made based on flat values, and for the remaining seven critical values, choice is based on values of least reduced chi-square and most plausible extendability produced at node numbers 80, 100 and 120. Finally, the values of parameters for each equation corresponding to ECR CV is also recorded.

3.1 Trend Analysis – ECR CV1.

The tendency here is clearly linear increasing.

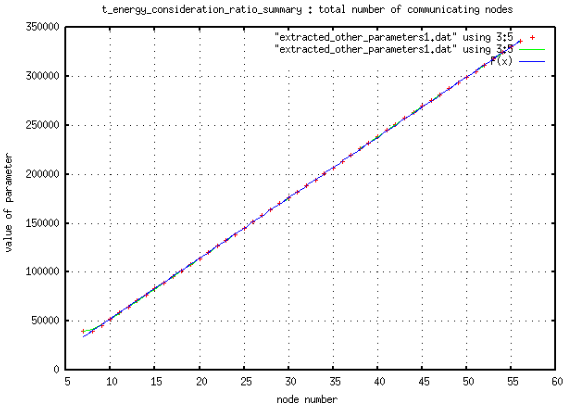

Figure 1: ECR Critical Value 1

F(x) = d* x + f

Ch_sq = 870 696 F(80) = 484 951.386 746 697

F(100)=608 471.587 466 984 F(120)=731 991.788 187 272

Parameters for best fit are: d = 6 176.01 , f = -9 129.42

It should be noted that ch_sq is not 0 and that the y-intervals are very large 0-50 000. Hence, it is understandable that if the figure is expanded significantly, the distances of the plots from the line of best fit will be visible.

3.2 Trend Analysis – ECR CV2.

Generally, the curve decreases at a decreasing rate.

The potentially applicable equations are:

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

   Ch_sq = 0.682 329 F(80) = 3.227 912 143

   F(100) = 3.227 819 754 F(120) = 3.227 816 609

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

   Ch_sq = 0.135 493 F(80) = 1.593 923 521

   F(100) = 1.275 138 817 F(120) = 1.062 615 681

3. F(x)= a * exp((b*x)+c) + (d*$x^{-1.5}$)

   Ch_sq = 0.237 172 F(80) = 2.194 165 859

   F(100) = 2.142 040 428 F(120) = 2.173 598 709

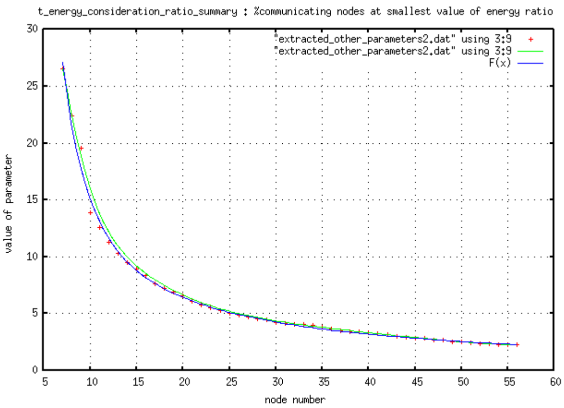

Figure 2: ECR Critical Value 2

Choice of best fit for ECR Critical Value 2

The equation in part 2 above has been selected because of smallest ch_sq and good extendability. The parameters obtained for best fit are:

a = 3.997 81 , b= -0.427 801 , c= 3.791 35 , d= 127.514

3.3 Trend Analysis – ECR CV3.

Two sets of observation are made here:

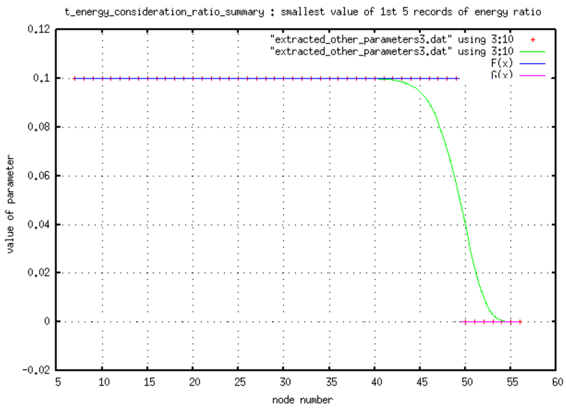

Figure 3: ECR Critical Value 3

$$F(x) = \begin{cases} 0.1 & \text{node numbers } 7\text{-}49 \\ 0.0 & \text{node numbers } 50\text{-}56 \end{cases}$$

Projected values for F(x) for node numbers larger than 56 are 0.0 .

3.4 Trend Analysis – ECR CV4.

For node number 7 till 24, value is quite stable between 3.5 and 3.9. After node number 24, trend is decreasing.

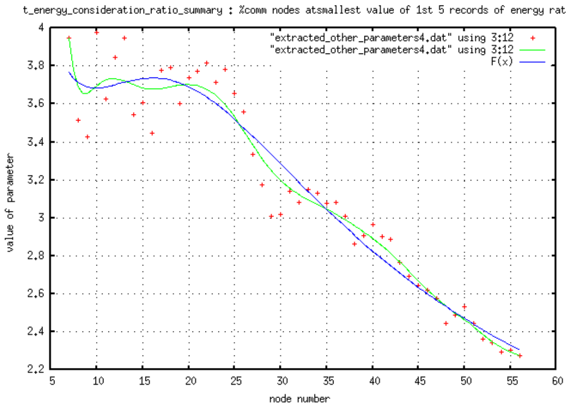

Figure 4: ECR Critical Value 4

The potentially applicable equations are:

1. $F(x) = (a * (x + h)^{f} + g)/(\exp((b * (x + h)) + c) + d$
   Ch_sq = 0.021 819 4 F(80) = 1.884 168 148
   F(100) = 1.682 300 417 F(120) = 1.546 365 345
2. $F(x) = (a * (x+h)^{f} + g)/(\exp((b*(x+h))+c) + (d * x^{-0.5})$
   Ch_sq = 0.021 071 1 F(80) = 1.376 199 047
   F(100) = 0.904 254 571 F(120) = 0.582 724 244
3. $F(x) = (a * (x+h)^{f} + g)/(\exp((b*(x+h))+c) + (d * x^{-0.25})$
   Ch_sq = 0.021 710 7 F(80) = 1.850 437 223
   F(100) = 1.621 705 093 F(120) = 1.461 227 192

Choice of best fit for ECR Critical Value 4

The equation in part 3 above has been selected because of better extendability even if ch_sq is not smallest. The parameters obtained for best fit are:
a = 2.938 65 , b= -0.162 908 , c= -1.490 21 , d = 0.080 098 8 , f = -0.956 381 , g = 0.005 267 42 , h = 0.334 4 .

3.5 Trend Analysis – ECR CV5.

Plottings depict a staircase feature because values are rounded to nearest 1 d.p. trend appears oscillating.

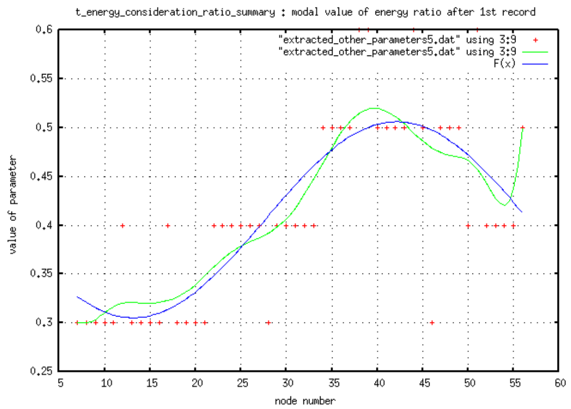

Figure 5: ECR Critical Value 5

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

Ch_sq = 0.003 450 64 F(80) = 0.348 174 193
F(100)= 0.506 140 615 F(120)= 0.350 366 335

The parameters of fit are: a = -0.100 442 , b = 0.108 376 , c = 0.144 795 , d = 0.405 707 .

3.6 Trend Analysis – ECR CV6.

The trend obtained appears to be a damping oscillation along an axis with a positive gradient.

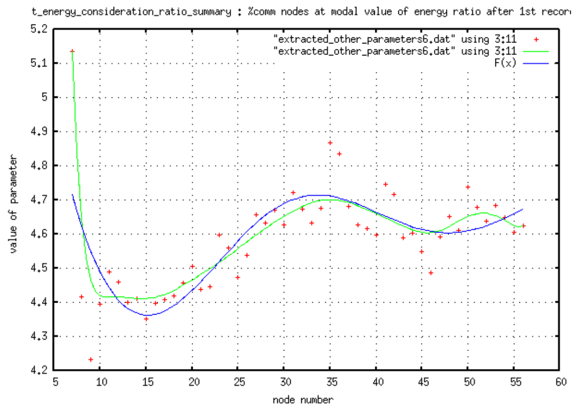

Figure 6: ECR Critical Value 6

$F(x) = f * x^{-1} * \sin((a*x)+b) + c*x + d$

Ch_sq = 0.011 161 2 F(80) = 4.737 649 052
F(100) = 4.871 689 596 F(120) = 4.894 547 771

The parameters of fit are: a = 0.193 604 , b = 4.509 13 , c = 0.003 344 7 , d = 4.506 59 , f = -3.206 96

3.7 Trend Analysis – ECR CV7.

Mostly, three ranges for trends are observed here. Each range shows decreasing trend at decreasing rate. The ranges and applicable equations are:

$$F(x) = \begin{cases} a * \exp((b*x) + c) + d & 7 \le x \le 21 \\ f * \exp((g*x) + h) + i & 22 \le x \le 33 \\ j * \exp((k*x) + l) + m & 34 \le x \le 56 \end{cases}$$

For node number 7 until 21:

ch_sq = 3.137 61 , a = 2.755 72 , b = -0.250 89 , c = 3.742 82 , d = 14.450 9

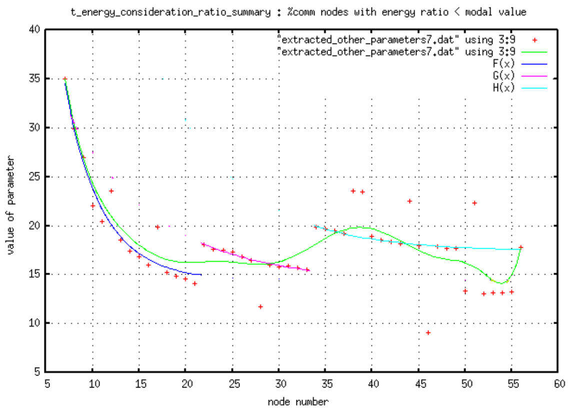

Figure 7: ECR Critical Value 7

For node number 22 until 33:

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ch_sq = 0.018 071 3 , f = 2.571 87 , g = -0.103 559 , h = 2.678 95 , i = 14.252 9

For node number 34 until 56:

ch_sq = 0.022 958 4 , j = 3.054 8 , k = -0.117 119 , l = 3.819 38 , m = 17.357 4

Suggestion: Last equation for F(x) may be used for predictability over larger node numbers.

3.8 Trend Analysis – ECR CV8.

Here also, three ranges of trends are observed here. Each range shows an increasing trend at a decreasing rate. The ranges and applicable equations are:

$$F(x) = \begin{cases} a * \log((b*x) + c) + d & 7 \le x \le 21 \\ f * \log((g*x) + h) + i & 22 \le x \le 33 \\ j * \log((k*x) + l) + m & 34 \le x \le 56 \end{cases}$$

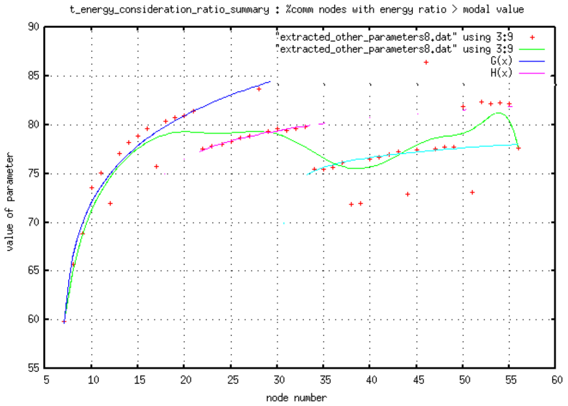

Figure 8: ECR Critical Value 8

For node number 7 until 21:

ch_sq = 2.949 88 , a = 6.742 01 , b = 4.354 8 , c = -27.971 , d = 53.446 4

For node number 22 until 33:

ch_sq = 0.015 635 6 , f = 2.445 68 , g = 4.294 09 , h = -66.785 , i = 69.31

For node number 34 until 56:

ch_sq = 0.053 128 8 , j = 1.346 44 , k = 5.371 95 , l = -164.916 , m = 71.391 6

It is suggested that the last equation for F(x) may be used for predictability over larger node numbers.

4. Conclusion.

This piece of research was aimed at identifying some critical values pertaining to metric ECR and study their corresponding trends over varying node densities in a MANET topography. The report of this investigation is successfully produced here. The models detailed here are of mathematical nature of varying levels of complexity which will assist in studying MANETs for MAUC environment from the angle of software engineering. Such mathematical models may pretty easily be implemented as programming algorithms to engender more rigorously realistic simulation scenarios using which, novel communication protocols and middleware components developed for ubicomp may be tested.

This experiments were executed in NS-2 over Linux. The plottings and “Fit” attempts were done in gnuplot. Best fit was selected based on least reduced chi-square values and best extendability of equations at higher node numbers except for one critical value where flat values have been used. Assumptions stated in past papers [18, 34] are upheld here also.

This work is a follow-up of previous papers [1-13, 18, 34] and stays succeptible for future extensions. One such further work identified is the formulation of a method of predictability for metric ECR and its trend.

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