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Trend Analyses of Critical Values Obtained for Range CBR Distance Achievable in Ubicomp MANETs Using Location-Aware Transmission Strategies.

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Abstract **– Many fields of research are concerned with pervasive computing, e.g., location-tracking, ubicomp functionalities and MANET transmission strategies. In spite of all intense research put in these sub-fields [1-60], their merging still lies along a long way ahead before yielding useful results. More distinctly here, the exertion of location-aware transmission strategies is envisioned to enhance energy management in ubicomp. Such enhancements expected [1] encompass improvements in location accuracy and refresh rates, the application of land-based GPS systems, development of better protocols optimised for transmission according to distance criteria and fine-tuning the precision of the distance criteria to apply the protocol. The know-how of distance coverages by transmitted packets in ubicomp environments and corresponding variations over different node densities, is assuredly profitable for refining transmission protocols in MANETs. One particular empirical study was carried out formerly [29] in which the metric Range CBR Distance, R_CBR_Dis, was exposed. This was further substantiated by a successive study [45] in which trends of parameters of equations for metric R_CBR_Dist were analysed.**

In this paper, the successive investigation of good importance is laid as: "What are the observable critical values in R_CBR_Dist trends? What are the trends of variation observable within each critical value for metric R_CBR_Dist over varying node densities?" Designers will use these results in order to produce more sophisticated and "realistic" ubicomp schemes for future ubicomp tools.

This study remains a follow-up of previous studies [1-60].

Key terms: Ubicomp- Ubiquitous Computing, MAUC-Mobile and Ubiquitous Computing, R_CBR_Dist- Range CBR Distance, CBR- Constant Bit Rate, MANET- Mobile Adhoc Network, CV- Critical Value.

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1. Introduction

It is anticipated that for quite long in the future, quite a lot of ubicomp environments will be sub-standardly equipped with network resources on top of which other heterogeneities may be adding complexities. Among these heterogeneities, there can be differences in accuracy level of distance measurement, location refresh rates and performance characteristics of existing protocols. Environments with substandard solution support, will welcome MANETs as the applicable solution. The performance features of MANETs, more strictly energy consumption features, may be intensified with location-aware transmission. Metrics analyses in ubicomp remain a method of compelling importance for studying distance coverage attributes. One such linked metric was produced in a previous paper [29] in which metric R_CBR_Dist was expounded as following the normal distribution model:

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

The associated follow-up study [45] was undertaken to mathematically model the three parameters of equation observed above. Results will be contributory towards more befitting understanding of the evolution and predictability of ubicomp environments. There are slowly developing progresses in this direction which will empower designers to produce better realistic scenarios for simulations, based on which more beneficial test cases can be prepared and ran over experimental components for middleware and communication protocols.

The analysis hence yearned for metric R_CBR_Dist is the identification of observable critical values obtained during experiments execution and formulation of relative theoretical tendencies of such CVs over varying node densities. Eight such CVs were observed.

The key contribution of this paper is the founding of the trends of variations for each of the eight CVs observed for metric R_CBR_Dist illustrated previously [29, 45] over node numbers ranging from 7 until 56. Such extension of information must necessarily be rendered available in a conducive format to more fruitfully assist designers in understanding the evolution and predictability of ubicomp behaviour and be favourably equipped to carry out reliable simulation scenarios testing of newly designed communication components. The rest of this paper is organised as follows: section 2- R_CBR_Dist Critical Values, section 3- Critical Values Trend Analyses- Metric R_CBR_Dist, section 4- Conclusion and References.

2. R_CBR_Dist Critical Values.

2.0 Critical Values Identified.

Eight CVs were identified as follows: Column headings are: C1→R_CBR_Dist CV, C2→Meaning of R_CBR_Dist CV, C3→Corresponding figure number for R_CBR_Dist CV.

C1	C2	C3
1	Smallest range distance noted.	1
2	% CBR at smallest range distance.	2
3	Largest range distance noted.	3
4	% CBR at largest range distance.	4
5	% CBR at peak value of range distance.	5
6	% CBR with range < modal range value.	6
7	% CBR with range > modal range value.	7
8	95 % CBR with max range as from	8

Table 1: R_CBR_Dist Critical Values

2.1 Experimental Critical Values Obtained.

Values obtained during 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	0.555555556	359	0.079365079	1.555555556
8	0	0.557147405	359	0.079592486	1.560012735
9	0	0.555555556	359	0.079365079	1.428571429
10	1	0.238095238	363	0.238095238	1.507936508
11	1	0.238095238	363	0.317460317	1.380952381
12	1	0.238473768	363	0.317965024	1.589825119
13	1	0.158730159	363	0.238095238	1.507936508
14	1	0.158730159	363	0.317460317	1.507936508
15	1	0.158730159	363	0.317460317	1.666666667
16	1	0.158730159	363	0.317460317	1.380952381
17	1	0.079365079	363	0.317460317	1.349206349
18	1	0.079365079	363	0.317460317	1.587301587
19	1	0.079365079	363	0.317460317	1.507936508
20	1	0.079365079	363	0.317460317	1.349206349
21	1	0.079365079	369	0.079365079	1.428571429
22	1	0.079365079	369	0.079365079	1.428571429
23	1	0.079365079	389	0.238095238	1.714285714
24	1	0.079365079	389	0.238095238	1.349206349
25	1	0.079365079	389	0.238095238	1.349206349
26	1	0.079365079	381	0.238095238	1.666666667
27	1	0.079365079	381	0.238095238	1.507936508
28	1	0.079365079	388	0.158730159	1.507936508
29	1	0.079365079	388	0.158730159	1.507936508
30	1	0.079365079	389	0.079365079	1.507936508
31	1	0.079365079	389	0.238095238	1.587301587
32	1	0.079365079	389	0.238095238	1.428571429
33	1	0.079365079	389	0.238095238	1.507936508
34	1	0.079365079	389	0.238095238	1.428571429
35	1	0.079365079	389	0.079365079	1.460317460
36	1	0.079365079	389	0.079365079	1.349206349
37	1	0.079377679	389	0.238133037	1.508175901
38	1	0.079365079	389	0.238095238	1.587301587
39	1	0.079365079	389	0.238095238	1.507936508
40	1	0.079365079	389	0.238095238	1.587301587
41	1	0.079365079	389	0.238095238	1.666666667
42	1	0.079365079	389	0.238095238	1.587301587
43	1	0.079365079	389	0.238095238	1.507936508
44	1	0.079415502	389	0.238246506	2.303049555
45	1	0.079365079	389	0.238095238	1.507936508
46	1	0.079365079	389	0.238095238	1.746031746
47	1	0.079365079	389	0.238095238	1.428571429
48	1	0.079365079	389	0.238095238	1.507936508
49	1	0.079365079	389	0.238095238	1.428571429
50	1	0.079365079	368	0.158730159	1.666666667
51	1	0.079365079	368	0.158730159	1.428571429
52	1	0.079365079	368	0.158730159	1.507936508
53	1	0.079365079	368	0.158730159	1.746031746
54	1	0.079365079	368	0.158730159	1.587301587
55	1	0.079365079	368	0.158730159	1.349206349
56	1	0.079365079	368	0.158730159	1.587301587

Table 2(a): Experimental Critical Values Obtained(1)

NN	CV6	CV7	CV8
7	50.301587302	38.619047619	282
8	59.710283349	38.729703916	283
9	39.269841270	59.301587302	285
10	29.126984127	69.365079365	285
11	44.523809524	54.095238095	285
12	54.260731320	44.149443561	296
13	81.031746032	17.460317460	296
14	43.507936508	54.984126984	295
15	46.031746032	52.301587302	298
16	33.952380952	64.666666667	303
17	46.269841270	52.380952381	303
18	74.126984127	24.285714286	303
19	78.492063492	20.000000000	303
20	43.000000000	55.650793651	303
21	62.365079365	36.206349206	299
22	68.206349206	30.365079365	304
23	39.873015873	58.412698413	306
24	46.507936508	52.142857143	308
25	65.825396825	32.825396825	312
26	65.873015873	32.460317460	314
27	70.873015873	27.619047619	314
28	53.206349206	45.285714286	314
29	47.380952381	51.111111111	314
30	41.571428571	56.920634921	314
31	48.730158730	49.682539683	314
32	70.158730159	28.412698413	314
33	68.650793651	29.841269841	314
34	54.603174603	43.968253968	314
35	54.174603175	44.365079365	314
36	46.111111111	52.539682540	314
37	90.315923162	8.175900937	314
38	56.190476190	42.222222222	315
39	33.968253968	64.523809524	317
40	33.095238095	65.317460317	320
41	42.301587302	56.031746032	319
42	41.666666667	56.746031746	322
43	61.190476190	37.301587302	319
44	59.593392630	38.103557814	319
45	59.682539683	38.809523810	317
46	60.079365079	38.174603175	318
47	63.809523810	34.761904762	318
48	79.920634921	18.571428571	320
49	73.412698413	25.158730159	322
50	58.412698413	39.920634921	323
51	64.523809524	34.047619048	323
52	48.888888889	49.603174603	321
53	43.015873016	55.238095238	323
54	57.777777778	40.634920635	323
55	36.031746032	62.619047619	322
56	57.460317460	40.952380952	321

Table 2(b): Experimental Critical Values Obtained(2)

3. Critical Values Trend Analyses- Metric R_CBR_Dist.

3.0 General Procedure Adopted.

A four-step procedure has been defined:

i. The tabulated data for each R_CBR_Dist CV is plotted onto gnuplot.
ii. Graphical analyses are performed and general observations noted.
iii. Different equations of fit are attempted. For three CVs choice of best fit is made based on flat values and for remaining five CVs, it is based on values of least reduced chi-square and best extendability produced at node numbers 80, 100 and 120.
iv. The subsequent parameter values for each R_CBR_Dist CV equation are noted.

3.1 Trend Analysis – R_CBR_Dist CV1.

The plots depict two distinct ranges as follows:

$$F(x) = \begin{cases} 0 & 7 \le x \le 9 \\ 1 & x \ge 10 \end{cases}$$

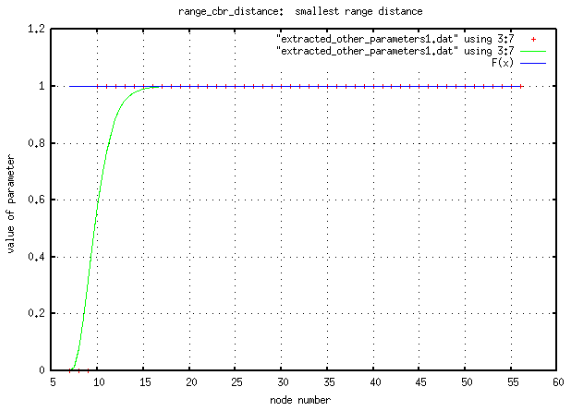

Figure 1: R_CBR_Dist Critical Value 1

3.2 Trend Analysis – R_CBR_Dist CV2.

Four series of observations are made here as follows:

Node	Y-axis
7 - 9	0.555
10 – 12	0.238
13 – 16	0.159
17 -	0.079

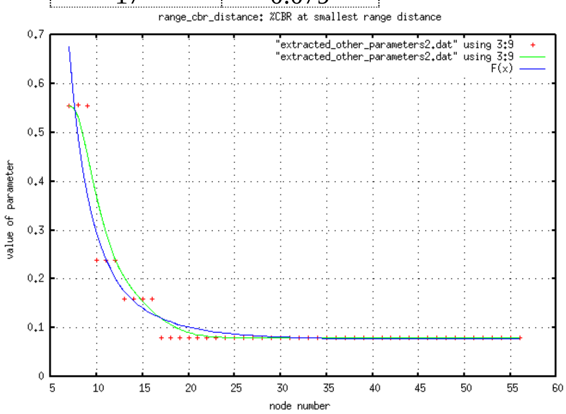

Figure 2: R_CBR_Dist Critical Value 2

For node number 17 and above, the projected value can safely be assumed at 0.079.

The potentially applicable equations are:

1. $F(x) = ((a * x^{-1})/\log(x)) + b$
   Ch_sq = 0.002 139 96
2. $F(x) = (((a*x^{-1})+b)/\log(x+c)) + d$
   Ch_sq = 0.001 110 38 F(80) = 0.122 230 167
   F(100)= 0.142 421 090 F(120)= 0.159 337 046
3. $F(x) = (((a*x^{-2})+b)/\log(x+c) + d$
   Ch_sq = 0.001 169 49 F(80) = 0.126 519 388
   F(100)= 0.157 740 250 F(120)= 0.188 924 115
4. $F(x) = (((a*x^{-2.8})+b)/\log(x+c) + d$
   Ch_sq = 0.001 416 84 F(80) = 0.079 943 120
   F(100)= 0.082 866 289 F(120)= 0.085 878 074

Choice of best fit for R_CBR_Dist Critical Value 2

The equation in part 4 above has been selected because of best extendability even if ch_sq is not least. The parameters for best fit are:

a = 974.855 , b = -8.273 27 , c = 966.745 , d = 1.269 09

3.3 Trend Analysis – R_CBR_Dist CV3.

Instead of a consistent curve of tendency, 4 distinct levels of largest range distance are noted.

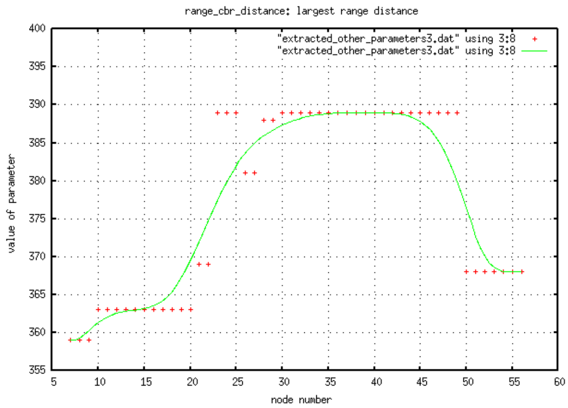

Figure 3: R_CBR_Dist Critical Value 3

Level Number	Node Numbers	Y-axis Value
1	7 – 9	359
2	10 – 22	363
3	23 – 49	389
4	50 - 56	368

Range of Node_numbers for level 1 until 3 depict an increasing value. It can be suggested that level 4 will hold for node numbers around 50 - 90.

The observations resemble those of PPD CV3 [58], but are not identical.

3.4 Trend Analysis – R_CBR_Dist CV4.

Here, mostly 3 distinct levels are noted in the plots. A few exceptions to these levels is acknowledged.

Node Numbers	Y-axis Value
7 – 9	0.079
10 – 20	0.317
21 -	0.238

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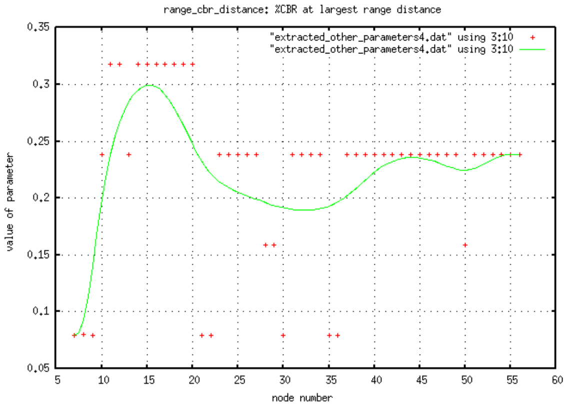

Figure 4: R_CBR_Dist Critical Value 4

3.5 Trend Analysis – R_CBR_Dist CV5.

Mostly a mildly increasing linear tendency is observed.

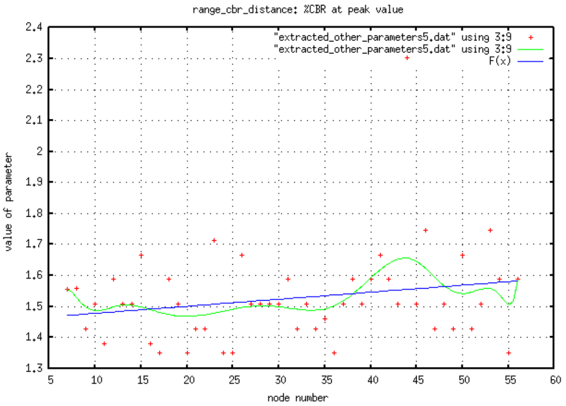

Figure 5: R_CBR_Dist Critical Value 5

The applicable equation is: $F(x) = d*x + f$

Ch_sq = 0.023 096 7 F(80) = 1.637 285 588

F(100)= 1.682 699 120 F(120)= 1.728 112 652

Parameters for best fit: d= 0.002 270 68 , f= 1.455 63

A tolerance of ± 0.2 is also suggested.

3.6 Trend Analysis – R_CBR_Dist CV6.

The plots are very scattered. Mostly a very mildly increasing linear tendency is observed.

The applicable equation is: $F(x) = d*x + f$

Ch_sq = 199.322 F(80) = 59.425 895 617

F(100)= 61.180 254 691 F(120)= 62.934 613 764

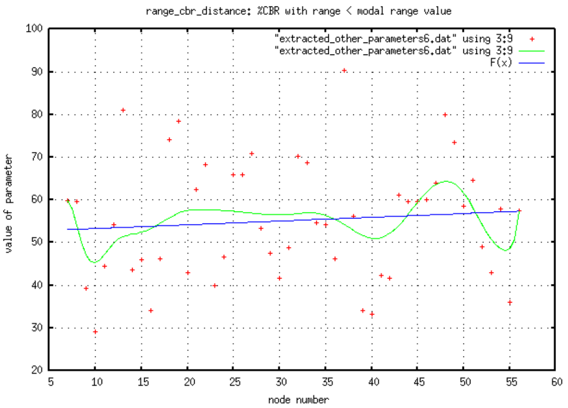

Figure 6: R_CBR_Dist Critical Value 6

Parameters for best fit are: d= 0.087 718 , f= 52.408 5

A tolerance of ± 15 is also suggested.

3.7 Trend Analysis – R_CBR_Dist CV7.

Here also the plots are very scattered. Mostly a very mildly decreasing linear tendency is observed. A tolerance of ± 15 is also suggested.

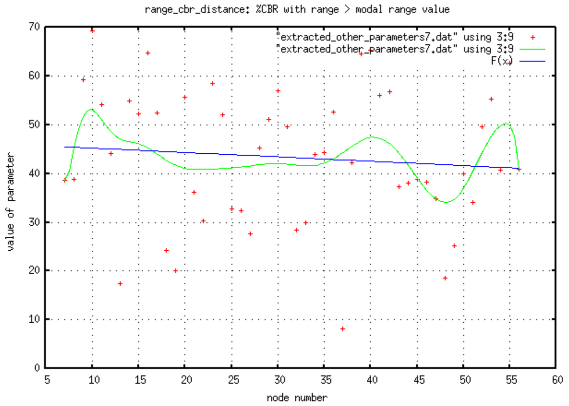

Figure 7: R_CBR_Dist Critical Value 7

The applicable equation is: $F(x) = d*x + f$

Ch_sq = 199.41 F(80) = 38.936 818 793

F(100)= 37.137 046 188 F(120)= 35.337 273 582

Parameters for best fit are: d= -0.089 988 6 ,f= 46.135 9

3.8 Trend Analysis – R_CBR_Dist CV8.

The plots obtained here depict an increasing tendency at a decreasing rate. Some staircase features due to rounding off distance values are also noted.

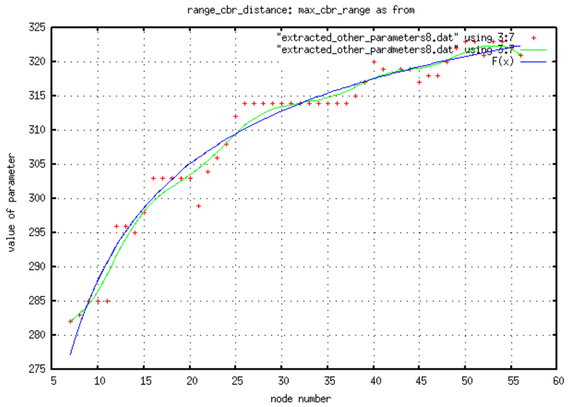

Figure 8: R_CBR_Dist Critical Value 8

The potentially applicable equations are:

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

   Ch_sq = 5.870 03 F(80) = 329.910 734 899

   F(100)= 333.799 355 886 F(120)= 336.953 832 213

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

   Ch_sq = 5.324 38 F(80) = 324.132 113 899

   F(100)= 323.358 918 897 F(120)= 321.282 940 355

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

   Ch_sq =5.771 22 F(80) = 329.838 981 295

   F(100)= 333.672 024 386 F(120)= 336.771 464 703

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

   Ch_sq = 10.563 3 F(80) = 322.228 357 523

   F(100)= 323.285 278 074 F(120)= 323.997 260 041

5. $F(x) = a * x^{-0.5} * \log((b*x)+c) + d$

   Ch_sq = 5.763 18 F(80) = 326.747 839 244

   F(100)= 329.148 274 666 F(120)= 330.939 664 370

6. `F(x)= a*x^-0.25 * log ((b*x)+c) + d` — $F(x)= a*x^{-0.25} * \log((b*x)+c) + d$

   Ch_sq = 5.712 52 F(80) = 329.535 900 100
   F(100)= 333.047 201 745 F(120)= 335.807 762 148

7. $F(x)= a * x^{-0.75} * \log((b*x)+c) + d$

   Ch_sq = 7.421 98 F(80) = 324.328 018 252
   F(100)= 325.939 514 600 F(120)= 327.082 046 714

Choice of best fit for R_CBR_Dist Critical Value 8

The equation in part 5 above has been selected because of best extendability even if ch_sq is not least. The parameters obtained for best fit are:

a= -10.980 6, b= 9.148 66(e^{+06}), c= 1 883.39, d= 351.806

4. Conclusion.

This empirical study was intended to identify the relevant CVs observable for metric R_CBR_Dist and analyse their corresponding trends over varying node densities in a MANET topography of 300 x 300 m^2. The models depicted in this paper, are composed of quite complex mathematical equations. The output displayed here will fortify the existing tools for better studies of MANETs for ubicomp environments as viewed by software engineers. These results may be suitably implemented into computational methods to generate better simulation scenarios which will subsequently serve for allowing more refined testing over communication and middleware components.

This experiment was executed in NS-2 over Linux. Attempts for plottings and “fit” were done with gnuplot. Designation of best fit was based on values of least reduced chi-square and best extendability observed at higher node numbers for five CVs and on flat values for three CVs. The assumptions mentioned in previous paper [29, 45] are maintained here also.

This investigation stands as a follow-up of previous ones [1-60]. The results presented here remain open for future upgrades. One such possible work identified remains the formulation of predictability for metric R_CBR_Dist and its trend.

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