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Trend Analyses of Critical Values Obtained for Minimum Fairness Proportion Achievable in Ubicomp MANETs Using Location-Aware Transmission Strategies.

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***Abstract* – The fields of location-tracking, ubicomp functionalities and MANET transmission strategies remain serious topics of research and development [1-54]. Presently, the merging of these fields has a lot to undergo, especially as concerns correct protocol design approaches which is determinant for such successful merging. Nevertheless, such approaches are considered as heuristic and poorly adapted for implementation [92]. Upgrades in middleware services and ubicomp network architecture is also desired [93, 94].**

A judiciously defined objective in such vision for ubicomp advancement is accomplishing "realism" in design and evaluation of wireless routing protocols [95]. Such studies will yield components better suited for further studies of predictability in ubicomp. Such components are non-negligible since "realism" will propagate into every feature related to ubicomp, one of which was pondered over previously [23] to assess the trend of Minimum Fairness Proportion (Min_FP) observable for CBRs under different sets of node densities in ubicomp environments. This study was supplemented by the study of Min_FP parameter of equations [39].

To assimilate "realism" in knowledge of these trends, in this paper, the next study needed is: "What are observable critical values in Min_FP trends over varying node densities and trends of such critical values?" Such refinements will engender the design of more realistic ubicomp scenarios which are more convenient for better sustained testing of experimental middleware components and communication protocols. This study follows-up from previous investigations [1-54].

Key terms: Ubicomp- Ubiquitous Computing, MAUC-Mobile and Ubiquitous Computing, Min_FP- Minimum Fairness Proportion, CBR- Constant Bit Rate, MANET-Mobile Adhoc Network, CV- Critical Value.

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1. Introduction

It is anticipated that future ubicomp environments may suffer from poorly equipped networking devices and hence MANETs remain a hopeful solution. The task of transmission is repartitioned among a hopeful solution. The task of transmission is repartitioned among cooperating nodes in ubicomp leading to energy consumption also being repartitioned. In such circumstances, the notion of Fairness must be well devised. This can also be viewed from various related metrics. One such metric, the Min_FP, was studied before [23] for node densities varying between 7 until 56. The trend was observed to be the decreasing exponential equation of form:

```
G(x) = a * exp (b * (x - 0.1)) + c
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A follow-up study [39] was conducted to mathematically model the three parameters observed above. Results obtained are utilisable for better understanding of the evolution and predictability of ubicomp environments. These progresses, though slowly but surely getting constructed will enable designers to prepare more realistic simulation scenarios using which testing procedures can be exerted over freshly developed components for middleware and communication protocols.

The probing now required for metric Min_FP is the identification of observable critical values obtained during experiments execution and formulation of corresponding theoretical trend of such CVs over varying node densities. Ten such CVs were observed.

The key contribution of this paper is the setting up of the trends of variations for each of the ten CVs observed for metric Min_FP illustrated before [23, 39] over node numbers ranging from 7 until 56. Such kinds of information should imperatively be produced in the right way to more fluidly assist ubicomp designers to understand the evolution and predictability of ubicomp behaviour and be appropriately equipped to carry credulous simulation scenarios over which new communication protocol features could be tested. The rest of this paper is organised as follows: section 2- Min_FP Critical Values, section 3- Critical Values Trend Analyses- Metric Min_FP, section 4- Conclusion and References.

2. Min_FP Critical Values.

2.0 Critical Values Identified.

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

C1	C2	C3
1	Minimum value of Min_FP	1
2	% CBR at modal value of Min_FP	2
3	Second modal value of Min_FP	3
4	% CBR at second modal value of Min_FP	4
5	Highest value of Min_FP	5
6	% CBR at highest value of Min_FP	6
7	Value of Min_FP previous to rightmost outlier.	7
8	% CBR at second highest value of Min_FP.	8
9	% CBR within range (excluding outlier)	9
10	% CBR with Min_FP value ≤ 1	10

Table 1: Min_FP 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	0.0	88.809523810	0.1	3.492063492
8	0.0	88.538681948	0.1	2.992677491
9	0.0	89.079365079	0.1	3.126984127
10	0.0	85.873015873	0.1	6.126984127
11	0.0	85.904761905	0.1	6.603174603
12	0.0	86.406995231	0.1	6.502384738
13	0.0	86.253968254	0.1	7.031746032
14	0.0	86.158730159	0.1	7.253968254
15	0.0	86.269841270	0.1	7.158730159
16	0.0	85.698412698	0.1	7.793650794
17	0.0	83.730158730	0.1	9.396825397
18	0.0	83.746031746	0.1	9.587301587
19	0.0	83.126984127	0.1	9.825396825
20	0.0	83.158730159	0.1	9.920634921
21	0.0	82.238095238	0.1	11.746031746
22	0.0	81.777777778	0.1	12.000000000
23	0.0	81.507936508	0.1	12.126984127
24	0.0	81.698412698	0.1	11.904761905
25	0.0	82.174603175	0.1	11.984126984
26	0.0	81.079365079	0.1	12.825396825
27	0.0	81.079365079	0.1	13.000000000
28	0.0	81.095238095	0.1	12.634920635
29	0.0	80.873015873	0.1	12.841269841
30	0.0	81.063492063	0.1	12.873015873
31	0.0	81.317460317	0.1	12.063492063
32	0.0	81.126984127	0.1	12.000000000
33	0.0	81.587301587	0.1	11.873015873
34	0.0	81.095238095	0.1	12.682539683
35	0.0	81.047619048	0.1	12.793650794
36	0.0	80.857142857	0.1	13.047619048
37	0.0	79.377678997	0.1	14.414986506
38	0.0	79.412698413	0.1	14.206349206
39	0.0	79.031746032	0.1	14.936507937
40	0.0	79.777777778	0.1	14.349206349
41	0.0	79.698412698	0.1	14.650793651
42	0.0	79.523809524	0.1	14.698412698
43	0.0	79.333333333	0.1	14.682539683
44	0.0	79.209021601	0.1	15.088945362
45	0.0	78.492063492	0.1	15.380952381
46	0.0	78.476190476	0.1	15.492063492
47	0.0	78.285714286	0.1	15.650793651
48	0.0	78.142857143	0.1	15.841269841
49	0.0	77.444444444	0.1	16.619047619
50	0.0	76.714285714	0.1	16.666666667
51	0.0	76.539682540	0.1	16.857142857
52	0.0	76.444444444	0.1	16.984126984
53	0.0	76.460317460	0.1	16.952380952
54	0.0	76.365079365	0.1	16.952380952
55	0.0	76.920634921	0.1	16.111111111
56	0.0	76.142857143	0.1	16.714285714

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

NN	CV5	CV6	CV7	CV8
7	7.0	1.714285714	3.2	0.015873016
8	8.0	1.703279210	3.6	0.095510984
9	9.0	1.634920635	4.1	0.015873016
10	10.0	0.634920635	5.0	0.079365079
11	11.0	0.634920635	5.5	0.079365079
12	12.0	0.556438792	6.0	0.079491256
13	13.0	0.476190476	5.9	0.079365079
14	14.0	0.396825397	6.4	0.079365079
15	15.0	0.396825397	6.8	0.079365079
16	16.0	0.396825397	7.3	0.079365079
17	17.0	0.158730159	6.5	0.079365079
18	18.0	0.158730159	6.9	0.079365079
19	19.0	0.158730159	7.2	0.079365079
20	20.0	0.158730159	7.6	0.079365079
21	21.0	0.238095238	6.9	0.158730159
22	22.0	0.238095238	7.2	0.158730159
23	23.0	0.238095238	7.5	0.158730159
24	24.0	0.238095238	7.9	0.079365079
25	25.0	0.238095238	8.2	0.158730159
26	26.0	0.238095238	10.9	0.079365079
27	27.0	0.238095238	11.3	0.079365079
28	28.0	0.238095238	11.7	0.079365079
29	29.0	0.238095238	12.1	0.079365079
30	30.0	0.238095238	12.6	0.079365079
31	31.0	0.158730159	9.6	0.079365079
32	32.0	0.158730159	9.9	0.079365079
33	33.0	0.158730159	10.2	0.079365079
34	34.0	0.158730159	10.5	0.079365079
35	35.0	0.158730159	10.9	0.079365079
36	36.0	0.158730159	11.2	0.079365079
37	37.0	0.238133037	6.7	0.079377679
38	38.0	0.238095238	6.9	0.079365079
39	39.0	0.238095238	7.0	0.079365079
40	40.0	0.238095238	7.2	0.079365079
41	41.0	0.238095238	7.4	0.079365079
42	42.0	0.238095238	7.6	0.079365079
43	43.0	0.238095238	11.0	0.079365079
44	44.0	0.238246506	11.3	0.079415502
45	45.0	0.238095238	11.5	0.079365079
46	46.0	0.238095238	11.8	0.079365079
47	47.0	0.238095238	12.0	0.079365079

48	48.0	0.238095238	12.3	0.079365079
49	49.0	0.238095238	12.5	0.079365079
50	50.0	0.238095238	7.9	0.079365079
51	51.0	0.238095238	8.0	0.079365079
52	52.0	0.238095238	8.2	0.079365079
53	53.0	0.238095238	8.3	0.079365079
54	54.0	0.238095238	8.5	0.079365079
55	55.0	0.238095238	8.6	0.079365079
56	56.0	0.238095238	8.8	0.079365079

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

NN	CV9	CV10
7	9.476190476	97.333333333
8	9.758038841	97.246099968
9	9.285714286	97.634920635
10	13.492063492	97.698412698
11	13.460317460	97.539682540
12	13.036565978	97.297297297
13	13.269841270	98.317460317
14	13.444444444	98.317460317
15	13.333333333	98.317460317
16	13.904761905	98.142857143
17	16.111111111	99.285714286
18	16.095238095	99.206349206
19	16.714285714	99.126984127
20	16.682539683	99.126984127
21	17.523809524	98.968253968
22	17.984126984	98.968253968
23	18.253968254	98.888888889
24	18.063492063	98.968253968
25	17.587301587	98.968253968
26	18.682539683	99.047619048
27	18.682539683	98.968253968
28	18.666666667	98.968253968
29	18.888888889	98.888888889
30	18.698412698	98.968253968
31	18.523809524	99.047619048
32	18.714285714	99.047619048
33	18.253968254	99.047619048
34	18.746031746	99.047619048
35	18.793650794	99.047619048
36	18.984126984	99.047619048
37	20.384187966	99.126845531
38	20.349206349	99.126984127
39	20.730158730	99.126984127
40	19.984126984	99.126984127
41	20.063492063	99.126984127
42	20.238095238	99.126984127
43	20.428571429	99.206349206
44	20.552731893	99.205844981
45	21.269841270	99.126984127
46	21.285714286	99.126984127
47	21.476190476	99.126984127
48	21.619047619	99.126984127
49	22.317460317	99.206349206
50	23.047619048	99.206349206
51	23.222222222	99.206349206
52	23.317460317	99.206349206
53	23.301587302	99.206349206
54	23.396825397	99.206349206
55	22.841269841	99.206349206
56	23.619047619	99.206349206

Table 2(c): Experimental Critical Values Obtained(3)

3. Critical Values Trend Analyses- Metric Min_FP.

3.0 General Procedure Adopted.

The first step is to plot the tabulated data for each Min_FP CV on gnuplot. The second step is to accomplish graphical analyses and report general observations. The third step is to explore the applicability of some selected equations of fit. Choice of best fit is made considering values of least reduced chi-square and best extendability at node numbers 80, 100 and 120 for 6 CVs; on flat values for 3 Cvs and a combination of least reduced chi-square and flat values for 1 CV. The fourth step is to record the values of parameters for each Min_FP CV equation.

3.1 Trend Analysis – Min_FP CV1.

This value stays constant at 0 only.

F(x) = 0

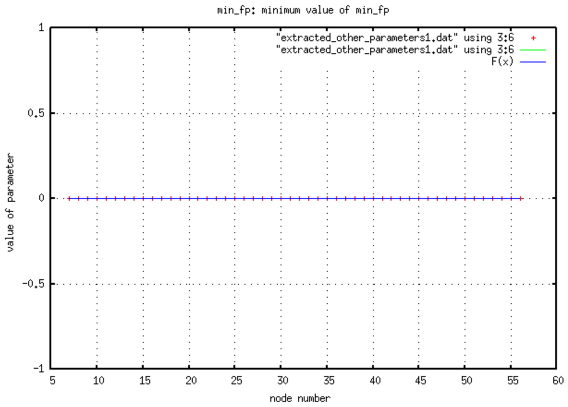

Figure 1: Min_FP Critical Value 1

For node numbers above 56, the projected Critical value will be at 0 only.

3.2 Trend Analysis – Min_FP CV2.

The curve depicts a general decreasing tendency.

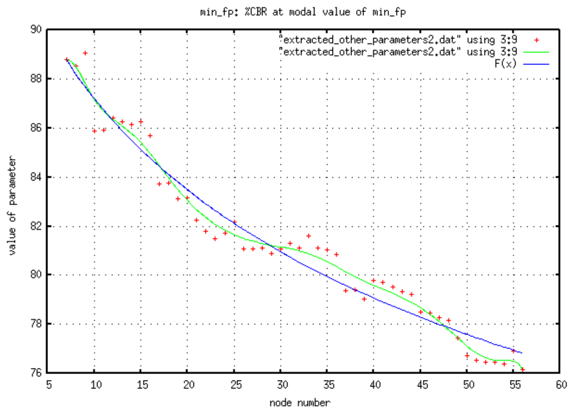

Figure 2: Min_FP Critical Value 2

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The potentially applicable equations are:

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

   Ch_sq = 0.907 673 F(80) = 70.207 833 041

   F(100)= 65.624 116 370 F(120)=61.040 399 699

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

   Ch_sq = 0.605 867 F(80)= 74.955 570 000

   F(100)= 74.126 269 581 F(120)= 73.657 701 907

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

   Ch_sq = 0.567 51 F(80)= 74.441 385 356

   F(100)= 72.967 807 165 F(120)= 71.780 704 171

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

   Ch_sq = 0.578 11 F(80) = 74.652 117 136

   F(100)= 73.285 867 281 F(120)= 72.193 128 348

Choice of best fit for Min_FP Critical Value 2

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

a = 724.06 , b = 3.298 , c = 40.057 4 , d = 4.009 89

3.3 Trend Analysis – Min_FP CV3.

Here, the value stays constant at 0.1 only.

F(x) = 0.1

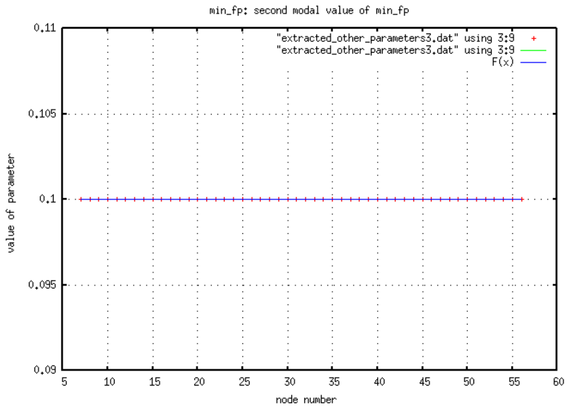

Figure 3: Min_FP Critical Value 3

Projected value of this critical value for any node number above 56 will remain at 0.1.

3.4 Trend Analysis – Min_FP CV4.

An increasing tendency at a decreasing rate is found with a mild non-uniform oscillation.

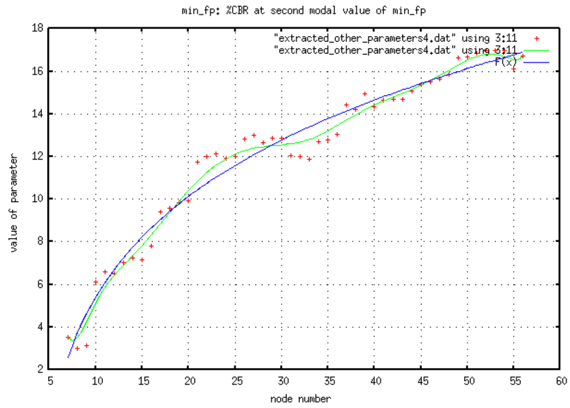

Figure 4: Min_FP Critical Value 4

The potentially applicable equations are:

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

   Ch_sq = 0.513 715 F(80) = 19.078 729 979

   F(100)= 20.483 734 068 F(120)= 21.628 064 600

2. F(x) = $(a*x^{0.25}$ * log ((b*x)+c))+ d

   Ch_sq = 0.565 973 F(80) = 20.244 029 298

   F(100)= 22.361 599 449 F(120)= 24.217 989 334

3. F(x) = $(a*x^{-0.25}$*log ((b*x)+c)) + d

   Ch_sq = 0.513 982 F(80) = 18.968 882 557

   F(100)= 20.295 386 338 F(120)= 21.353 238 967

4. F(x) =$(a*x^{-0.3}$*log ((b*x) + c)) + d

   Ch_sq = 0.515 656 F(80) = 18.905 267 914

   F(100)= 20.186 959 540 F(120)= 21.198 861 646

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

   Ch_sq = 0.512 262 F(80) = 19.359 035 472

   F(100)= 20.989 928 239 F(120)= 22.386 915 141

Choice of best fit for Min_FP Critical Value 4

The equation in part 5 above has been selected because of smallest ch_sq and good extendability. The parameters obtained for best fit are:

a= 5.449 91, b= 0.340 066, c= -0.823 998, d= 0.019 042 1

3.5 Trend Analysis – Min_FP CV5.

The trend observed here is very cleanly linear

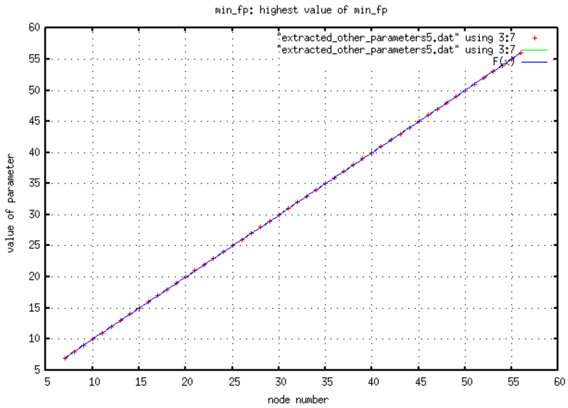

Figure 5: Min_FP Critical Value 5

F(x) = d * x + f

Sum F(80) = 80.0

F(100) = 100.0 F(120) = 120.0

The parameters obtained for best fit are: d = 1 , f = 0 ;

Effectively: F(x) = x

3.6 Trend Analysis – Min_FP CV6.

In this plot, an initial descending tendency is observed in the initial range of node number 7-16. Then, mostly curve is at a constant value between 0.158 and 0.238 .

$$F(x) = \begin{cases} d*x + f & 7 \leq x \leq 16 \\ 0.218\ 259 & x \geq 17 \end{cases}$$

For node number 7-16 : ch_sq = 0.086 550 5 , d = -0.168 166 , f = 2.788 46

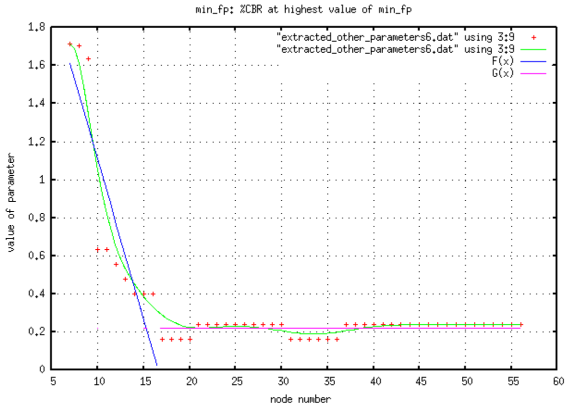

Figure 6: Min_FP Critical Value 6

3.7 Trend Analysis – Min_FP CV7.

Here, although the plots are very scattered and different subsets of linear trend are observed, the overall tendency is increasing at a decreasing rate.

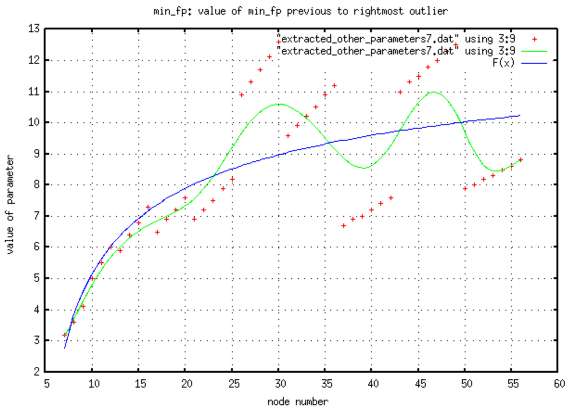

Figure 7: Min_FP Critical Value 7

The potentially applicable equations are:

1. $F(x) = (a * \log((b*x) + c)) + d$
   Ch_sq = 3.220 13 F(80) = 10.793 359 600
   F(100)= 11.171 015 629 F(120)= 11.473 783 081
2. $F(x) = (a * \log(b*(x+c))) + (d*x)$
   Ch_sq = 3.222 27 F(80) = 11.051 227 153
   F(100)= 11.509 201 070 F(120)= 11.878 384 403
3. $F(x) = (a*\log(b*(x+c))) + (d*x^{0.5})$
   Ch_sq = 2.840 27 F(80) = 7.606 624 831
   F(100)= 5.886 834 F(120)= 4.011 106
4. $F(x) = (a*\log(b*(x+c))) + (d*x^{0.25})$
   Ch_sq = 2.937 68 F(80) = 8.963 463 943
   F(100)= 8.307 987 025 F(120)= 7.589 317 303
5. $F(x) = (a*\log(b*(x+c))) + (d*x^{-0.25})$
   Ch_sq = 3.22 06 F(80) = 11.050 872 083
   F(100)= 11.511 246 811 F(120)= 11.883 076 196
6. $F(x) = (a*\log(b*(x+c))) + (d*x^{-1})$
   Ch_sq = 3.133 17 F(80) = 10.813 872 894
   F(100)= 11.147 156 695 F(120)= 11.405 226 776

Choice of best fit for ECFP Critical Value 7

The equation in part 6 above has been selected because of good extendability even if ch_sq is not smallest. The parameters obtained for best fit are:

a = 1.077 8 , b = 436.979 , c = -5.109 16 , d = -31.269 1

3.8 Trend Analysis – Min_FP CV8.

Here, most plots are at y-value of 0.079 3. As from node number 24 onwards, all plots are at 0.079 3.

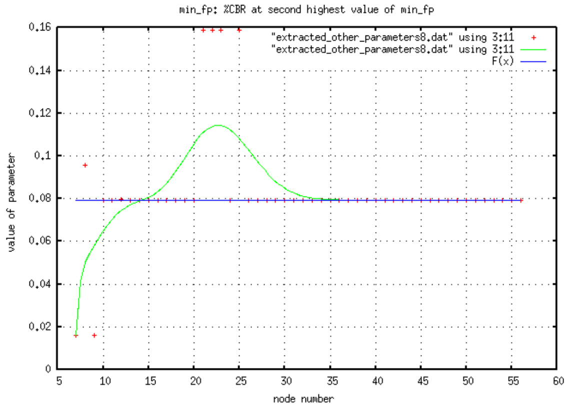

Figure 8: Min_FP Critical Value 8

$$F(x) = 0.079\ 3$$

The outliers can be considered as exceptional cases.

3.9 Trend Analysis – Min_FP CV9.

Here an increasing tendency at a decreasing rate is generally observed. A slight oscillation is also noticed but it is not uniform nor significant in amplitude.

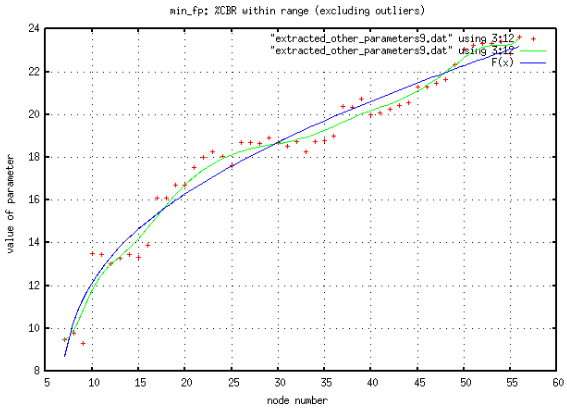

Figure 9: Min_FP Critical Value 9

The potentially applicable equations are:

1. $F(x) = (a*\log(b*(x+c))) + d$
   Ch_sq = 0.637 183 F(80)= 25.035 721 990
   F(100)= 26.410 928 031 F(120)= 27.532 038 531
2. $F(x) = (a*x^{0.5}*\log(b*(x+c)))+d$
   Ch_sq = 0.701 858 F(80) = 27.453 978 602
   F(100)= 30.434 331 510 F(120)= 33.223 077 891
3. $F(x) = (a*x^{0.25}*\log(b*(x+c))) + d$
   Ch_sq = 0.601 039 F(80) = 26.395 042 027
   F(100)= 28.699 007 084 F(120)= 30.776 363 984

Choice of best fit for Min_FP Critical Value 9

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

a = 3.900 16 , b = 0.005 380 38 , c = -4.835 55 , d = 36.954 9

3.10 Trend Analysis – Min_FP CV10.

An increasing tendency at a decreasing rate is observed.

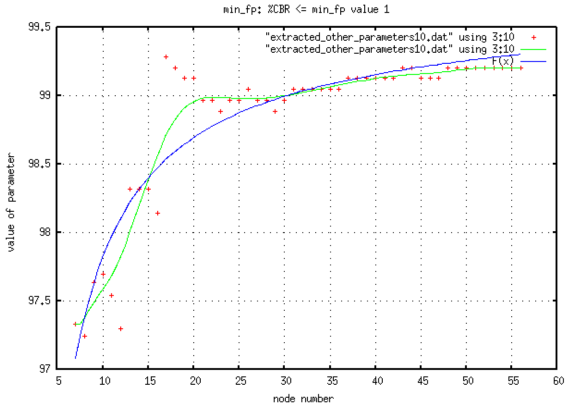

Figure 10: Min_FP Critical Value 10

The potentially applicable equations are:

1. F(x) = (a*log (b*(x+c))) + d
   Ch_sq = 0.064 451 1 F(80) = 99.524 934 496
   F(100)= 99.637 181 615 F(120)= 99.727 181 413
2. F(x) = (a*log (b*(x+c))) + (d/x)
   Ch_sq = 0.057 796 7 F(80) = 99.434 565 965
   F(100)= 99.509 094 438 F(120)= 99.569 172 124
3. F(x) = (a*log (b*(x+c))) + (d/x^2)
   Ch_sq = 0.062 555 F(80) = 99.468 089 627
   F(100)= 99.617 559 111 F(120)= 99.761 739 749

Choice of best fit for ECFP Critical Value 10

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 = 6.524 16, b = 1 044.74, c = 4 034.78, d = -17.157 8

4. Conclusion.

The major aim of this study has been to identify some CVs observable for metric Min_FP and study their corresponding trends over varying node densities in a MANET topography of 300 x 300 m^2. The models described in this paper, do constitute of quite complex mathematical equations. The output illustrated here will reinforce our existing tools for better studies of MANETs for ubicomp environments as viewed from software engineering. These output can systematically be implemented in computational algorithms to produce more precise simulation schemes which may, in turn, serve for adopting better testing procedures over communication and middleware components.

This experiment was conducted in NS-2 over Linux. Plottings and "Fit" attempts were done using gnuplot. Best fit was chosen using a combination of flat values, least reduced chi-square values, and best extendability produced at higher node numbers. Assumptions illustrated previously [23, 39] are upheld here also.

This study follows up from previous studies [1-54]. Upgrades to output presented here are possible in the future. A possible future work remain the formulation of predictability for metric Min_FP and its trend.

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