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# Trend Analyses of Critical Values Obtained for Overall Fairness Ratio 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 are prone to quite a lot of productive research [1-52]. It remains undeniable that the merging of these fields has a long way before fruitfully materialising. An essential factor determining the success of such merging is correct protocol design approaches, which is currently agreed as heuristic in nature and hence unsuitable for implementation [90]. Refinement in middleware and rework in network architecture is also needed [91, 92].**

**A sharpened objective in this direction of technological progress is achievement of "realism" in design and evaluation of wireless routing protocols [93]. Such studies may yield more suitable components for studies in predictability in ubicomp. "Realism" is a tardy process since it drags along each and every feature related to ubicomp. One such feature was explored in a prior paper [21] to assess the trend of Overall Fairness Ratio (OFR) readable for CBRs under different sets of node densities in ubicomp environments. This study was corroborated by the related study of trends for each OFR parameter of equations [37].**

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

**Such knowledge will eventually lead to the design of more realistic ubicomp scenarios which are better suited for more sustained testing of freshly designed middleware components and communication protocols. The work presented here is a follow-up of previous ones[1-52].**

**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

MANETS remain a fulfilling solution to scant resource availability in ubicomp, in which the load of energy requirements is distributed among cooperating nodes in the topography. This load is radically influenced by varying node densities. An anterior study [21] was designed for finding the trends observable for metric OFR for node densities varying between 7 until 56. The model suggested in that paper [21] combined the exponential and linear models of form:

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

Following this study, a successive study [37] was conducted to model mathematically the trends of the four parameters observed above. Results obtained are expected to serve towards better understanding of the evolution and predictability of ubicomp environments. With such gently occurring progresses, designers will produce more authentic simulation scenarios over which testing exercises can be conducted for newly built middleware and communication components.

The quest now required for metric OFR 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 setting up of the trends of variations for each of the five critical values observed for metric OFR expounded previously [21, 37] englobing node numbers 7 until 56. Such information should compulsorily be presented in an orderly fashion to more fluidly assist ubicomp designers to understand the evolution and predictability of ubicomp behaviour and be better 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- OFR Critical Values, section 3- Critical Values Trend Analyses- Metric OFR, section 4- Conclusion and References.

# 2. OFR Critical Values.

*2.0 Critical Values Identified.*

Five critical values have been identified as follows: Column headings are: C1→OFR CV, C2→ Meaning of

OFR CV, C3→ Corresponding figure number for the OFR CV.

| C1 | C2 | C3 |
|---|---|---|
| 1 | %CBR at minimum value of OFR | 1 |
| 2 | Maximum OFR value reached. | 2 |
| 3 | Modal value of OFR as from 10 nodes | 3 |
| 4 | % CBR at modal value of OFR | 4 |
| 5 | % CBR in OFR range 0 until <1 | 5 |

**Table 1: OFR 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 | 4.301587302 | 7.0 | 7.00 | 20.253968254 | 37.857142857 |
| 8 | 7.640878701 | 7.0 | 7.00 | 15.934415791 | 47.723654887 |
| 9 | 6.920634921 | 8.0 | 8.00 | 14.190476190 | 51.142857143 |
| 10 | 7.095238095 | 10.0 | 0.11 | 14.952380952 | 55.523809524 |
| 11 | 6.714285714 | 10.0 | 0.10 | 15.174603175 | 58.539682540 |
| 12 | 6.470588235 | 12.0 | 0.09 | 15.421303657 | 56.979332273 |
| 13 | 6.333333333 | 12.0 | 0.08 | 13.666666667 | 59.984126984 |
| 14 | 6.206349206 | 13.0 | 0.08 | 15.682539683 | 58.285714286 |
| 15 | 6.238095238 | 14.0 | 0.07 | 14.269841270 | 60.460317460 |
| 16 | 6.285714286 | 15.0 | 0.07 | 15.888888889 | 58.095238095 |
| 17 | 5.746031746 | 17.0 | 0.06 | 15.349206349 | 59.380952381 |
| 18 | 5.714285714 | 18.0 | 0.06 | 16.253968254 | 58.238095238 |
| 19 | 5.793650794 | 19.0 | 0.06 | 15.968253968 | 59.238095238 |
| 20 | 5.698412698 | 20.0 | 0.05 | 14.968253968 | 57.317460317 |
| 21 | 5.238095238 | 20.0 | 0.05 | 15.603174603 | 59.222222222 |
| 22 | 5.142857143 | 21.0 | 0.05 | 16.126984127 | 58.222222222 |
| 23 | 5.190476190 | 22.0 | 0.05 | 15.968253968 | 59.126984127 |
| 24 | 5.349206349 | 23.0 | 0.04 | 14.587301587 | 58.000000000 |
| 25 | 5.206349206 | 24.0 | 0.04 | 16.095238095 | 59.555555556 |
| 26 | 5.492063492 | 25.0 | 0.04 | 14.111111111 | 57.873015873 |
| 27 | 5.460317460 | 26.0 | 0.04 | 14.333333333 | 59.428571429 |
| 28 | 5.460317460 | 27.0 | 0.04 | 14.111111111 | 58.158730159 |
| 29 | 5.301587302 | 28.0 | 0.04 | 14.079365079 | 58.619047619 |
| 30 | 5.396825397 | 29.0 | 0.03 | 13.444444444 | 58.126984127 |
| 31 | 5.126984127 | 30.0 | 0.03 | 13.777777778 | 58.634920635 |
| 32 | 5.206349206 | 31.0 | 0.03 | 13.904761905 | 58.174603175 |
| 33 | 5.047619048 | 32.0 | 0.03 | 14.142857143 | 58.873015873 |
| 34 | 4.888888889 | 33.0 | 0.03 | 14.158730159 | 58.000000000 |
| 35 | 4.952380952 | 34.0 | 0.03 | 14.412698413 | 58.333333333 |
| 36 | 5.158730159 | 35.0 | 0.03 | 14.619047619 | 58.126984127 |
| 37 | 4.540403239 | 36.0 | 0.03 | 13.811716145 | 57.977456739 |
| 38 | 4.587301587 | 37.0 | 0.03 | 13.809523810 | 58.650793651 |
| 39 | 4.666666667 | 38.0 | 0.03 | 13.555555556 | 59.222222222 |
| 40 | 4.571428571 | 39.0 | 0.03 | 13.396825397 | 58.888888889 |
| 41 | 4.523809524 | 40.0 | 0.03 | 13.619047619 | 60.634920635 |
| 42 | 4.603174603 | 41.0 | 0.02 | 13.126984127 | 59.428571429 |
| 43 | 4.634920635 | 42.0 | 0.02 | 13.396825397 | 59.714285714 |
| 44 | 4.653748412 | 43.0 | 0.02 | 13.881829733 | 59.386912325 |
| 45 | 4.698412698 | 44.0 | 0.02 | 14.158730159 | 59.317460317 |
| 46 | 4.904761905 | 45.0 | 0.02 | 14.063492063 | 59.460317460 |
| 47 | 4.746031746 | 46.0 | 0.02 | 14.301587302 | 59.428571429 |
| 48 | 4.730158730 | 47.0 | 0.02 | 14.444444444 | 58.380952381 |
| 49 | 4.555555556 | 48.0 | 0.02 | 14.539682540 | 58.587301587 |
| 50 | 5.539682540 | 49.0 | 0.02 | 14.206349206 | 59.174603175 |
| 51 | 5.650793651 | 50.0 | 0.02 | 14.238095238 | 59.714285714 |
| 52 | 5.492063492 | 51.0 | 0.02 | 14.460317460 | 59.174603175 |
| 53 | 5.539682540 | 52.0 | 0.02 | 14.825396825 | 59.317460317 |
| 54 | 5.825396825 | 53.0 | 0.02 | 14.317460317 | 59.063492063 |
| 55 | 5.682539683 | 54.0 | 0.02 | 14.444444444 | 59.777777778 |
| 56 | 5.666666667 | 55.0 | 0.02 | 13.936507937 | 59.539682540 |

**Table 2: Experimental Critical Values Obtained**

# 3. Critical Values Trend Analyses- Metric OFR.

*3.0 General Procedure Adopted.*

Firstly, the tabulated data for each OFR CV is plotted on gnuplot. Secondly, graphical analyses are carried out and general observations are detailed. Thirdly, various equations of fit are tried. Choice of best fit was made depending on value of reduced chi-square and projected best extendability produced at higher node numbers. Fourthly, parameters values for each OFR CV is noted.

*3.1 Trend Analysis – OFR CV1.*

Generally, the curve obtained depicts a decreasing tendency until a minimum point and then shows an increasing tendency. The plots appear appears to be about half of an oscillation.

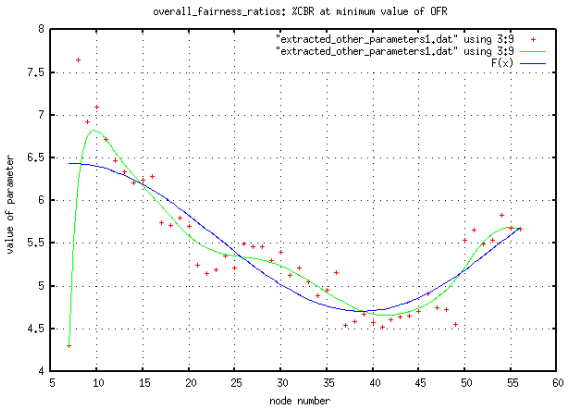


**Figure 1: OFR Critical Value 1**

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

Ch_sq = 0.209 599 F(80) = 6.064 192 019

F(100) = 4.720 639 314 F(120) = 5.767 278 285

The parameters for best fit are: a = -0.863 871 , b = 0.099 586 5 , c = -3.989 1 , d=5.569 06

*3.2 Trend Analysis – OFR CV2.*

Here, a very strong linear relationship is observed.

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

Ch_sq = 0.097 793 1 F(80) = 78.592 701 080

F(100)= 98.367 010 804 F(120)= 118.141 320 528

Values of F(x) obtained may simply be rounded off to nearest unit. The parameters for best fit are:

d = 0.988 715 , f = -0.504 538

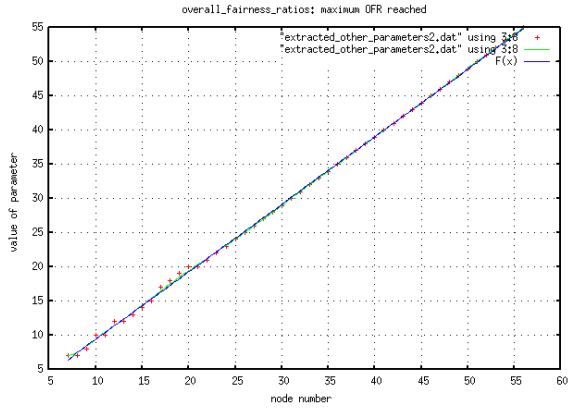


**Figure 2: OFR Critical Value 2**

*3.3 Trend Analysis – OFR CV3.*

Generally, the curve shows a decreasing tendency at a decreasing rate. Some staircase feature is observed possibly due to rounding off to 2 d.p.

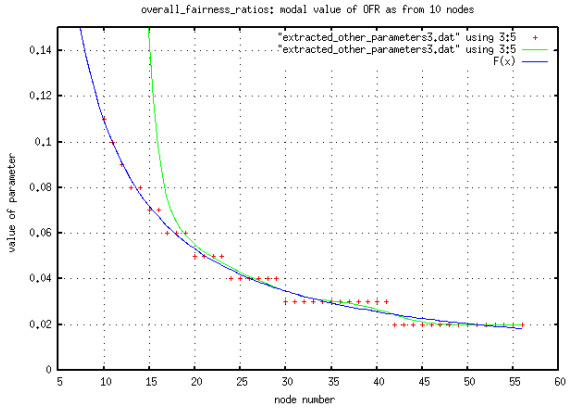


**Figure 3: OFR Critical Value 3**

The potentially applicable equations are:

1. `F(x)= a * exp( ( b * x ) + c ) + d`
   Ch_sq = 9.415 64 ($e^{-06}$) F(80) = 0.018 979 903
   F(100) = 0.018 839 344 F(120) = 0.018 815 667
2. `F(x)= a * x^0.25 * exp((b*x)+c) + d`
   Ch_sq = 1.050 82($e^{-05}$) F(80) = 0.019 827 133
   F(100) = 0.019 754 780 F(120) = 0.019 745 649
3. `F(x)= a * x^-0.25 * exp((b*x)+c) + d`
   Ch_sq = 8.528 05($e^{-06}$) F(80) = 0.017 959 684
   F(100)= 0.017 686 937 F(120)= 0.017 625 395
4. `F(x)= a * x^-0.5 * exp((b*x)+c) + d`
   Ch_sq = 7.871 24($e^{-06}$) F(80) = 0.016 703 630
   F(100) = 0.016 172 176 F(120) = 0.016 010 324
5. `F(x)= a * x^-1.0 * exp((b*x)+c) + d`
   Ch_sq = 7.355 65($e^{-06}$) F(80) = 0.013 002 501
   F(100) = 0.010 817 854 F(120) = 0.009 505 016
6. `F(x)= a * x^1.1 * exp((b*x)+c) + d`
   Ch_sq = 7.449($e^{-06}$) F(80) = 0.013 101 126
   F(100)= 0.010 702 134 F(120)= 0.009 139 649

**Choice of best fit for OFR Critical Value 3**

The equation in part 5 above has been selected because of smallest reduced chi-square value obtained and good extendability. The parameters obtained for best fit are:

a = 0.857 52 , b = -0.010 246 3 , c = 0.284 021 , d = 0.006 729

*3.4 Trend Analysis – OFR CV4.*

Here, the plots are quite scattered with an oscillation along a decreasing axis line.

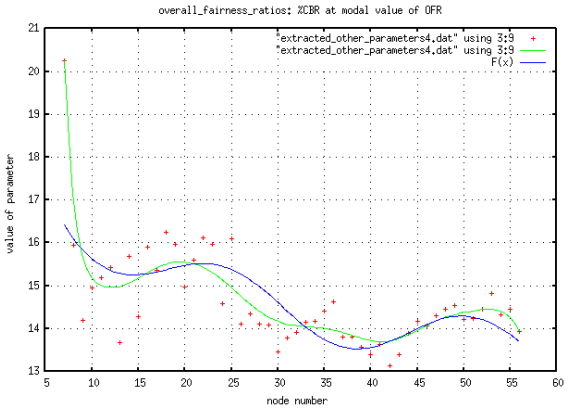


**Figure 4: OFR Critical Value 4**

The potentially applicable equations are:

1. `F(x)= d*x + f + a * sin ((b*x)+c)`
   Ch_sq = 0.805 444 F(80) = 12.823 375 174
   F(100) = 11.684 310 044 F(120) = 9.801 559 629
2. `F(x)=d*log (x) +f+ a*sin ((b*x)+c)`
   Ch_sq = 0.751 422 F(80) = 13.432 240 255
   F(100) = 12.991 114 255 F(120) = 11.865 002 951

**Choice of best fit for OFR 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 = -0.603 058 , b = 0.236 804 , c = -0.999 732 , d = -1.570 82 , f = 19.841 4

*3.5 Trend Analysis – OFR CV5.*

The curve here depicts an initial increase and then drops the rate of increase very suddenly.

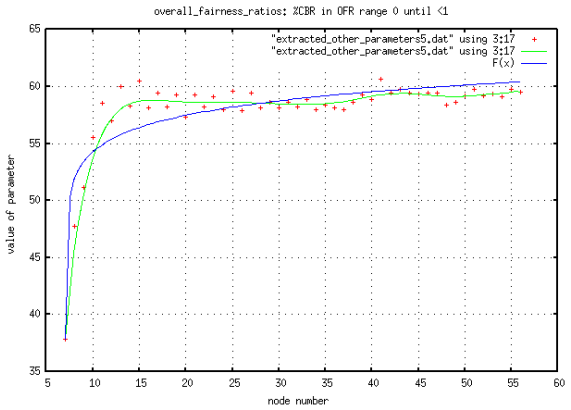


**Figure 5: OFR Critical Value 5**

$F(x) = a * \log((b*x)+c) + (d*x^g) + f$

Ch_sq = 2.698 3 F(80) = 61.297 344 867

F(100) = 61.833 907 747 F(120) = 62.265 544 944

The parameters for best fit are:
a = 2.215 97 , b = 5.329 29 , c= -37.295 1 , d= 0.005 646 79 , f= 48.082 , g= -5.013 71

# 4. Conclusion.

This piece of investigation was meant to identify some critical values applicable to metric OFR and study their corresponding trends over varying node densities in a MANET topography of 300 x 300 $m^2$. The models formulated here consist of quite complex mathematical equations. The outputs detailed here will enrich our existing tools for more propitious studies of MANETs for ubicomp environment from the context of computational algorithms to produce better pragmatic simulation schemes. These will in turn be utilised for more precocious testing of communication protocols and middleware components.

This experiment was executed in NS-2 over Linux. Gnuplot was used to carry out the plottings and "fit" attempts. Best fit was selected based on values of least reduced chi-square and best extendability of equations observed at higher node numbers. Assumptions adopted in previous papers [21, 37] are carried forward in this paper also.

This study remains a follow-up of earlier studies [1-13, 21, 37] and prevails as a subject for future upgrades. One such task identified is the formulation of predictability for metric OFR and its trend.

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