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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].


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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:

\[ G(x) = a * \exp (b * (x - 0.1)) + c \]

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.


2.0 Critical Values Identified.
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.

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.

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

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<th>CV10</th>
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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.

\[ F(x) = 0 \]

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 1: Min_FP Critical Value 1

Figure 2: Min_FP Critical Value 2
The potentially applicable equations are:

1. \( F(x) = d \times x + f \)
   
   \[ \text{Ch}_sq = 0.907673 \quad F(80) = 70.207833041 \]
   
   \[ F(100) = 65.624116370 \quad F(120) = 61.040399699 \]

2. \( F(x) = \exp((a \times x) + b) + c \)
   
   \[ \text{Ch}_sq = 0.605867 \quad F(80) = 74.955570000 \]
   
   \[ F(100) = 74.126599449 \quad F(120) = 73.657701907 \]

3. \( F(x) = \frac{a}{\log((b \times x) + c) + d} \)
   
   \[ \text{Ch}_sq = 0.56751 \quad F(80) = 74.441385356 \]
   
   \[ F(100) = 72.967807165 \quad F(120) = 71.780704197 \]

4. \( F(x) = \frac{a}{\log((b \times x) + c) + \frac{d}{x}} \)
   
   \[ \text{Ch}_sq = 0.57811 \quad F(80) = 74.652117136 \]
   
   \[ F(100) = 73.285867281 \quad F(120) = 72.193128348 \]

### Choice of best fit for Min_FP Critical Value 2

The equation in part 3 above has been selected because of smallest \( \text{ch}_sq \) and good extendability. The parameters obtained for best fit are:

\[ a = 724.06 \quad b = 3.298 \quad c = 40.0574 \quad d = 4.00989 \]

### 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. \( F(x) = (a \times \log((b \times x) + c)) + d \)
   
   \[ \text{Ch}_sq = 0.513715 \quad F(80) = 19.078832979 \]
   
   \[ F(100) = 20.483734068 \quad F(120) = 21.628064600 \]

2. \( F(x) = (a \times x^{0.25} \times \log((b \times x) + c)) + d \)
   
   \[ \text{Ch}_sq = 0.565973 \quad F(80) = 20.295383368 \]
   
   \[ F(100) = 22.361599449 \quad F(120) = 24.217989334 \]

3. \( F(x) = (a \times x^{-0.25} \times \log((b \times x) + c)) + d \)
   
   \[ \text{Ch}_sq = 0.515656 \quad F(80) = 18.905267914 \]
   
   \[ F(100) = 20.186959540 \quad F(120) = 21.198861646 \]

4. \( F(x) = (a \times \log((b \times x) + c)) + (d \times x) \)
   
   \[ \text{Ch}_sq = 0.512262 \quad F(80) = 19.359035472 \]
   
   \[ F(100) = 20.989928239 \quad F(120) = 22.386915141 \]

### Choice of best fit for Min_FP Critical Value 4

The equation in part 5 above has been selected because of smallest \( \text{ch}_sq \) and good extendability. The parameters obtained for best fit are:

\[ a = 5.44991 \quad b = 0.340066 \quad c = -0.823998 \quad d = 0.0190421 \]

### 3.5 Trend Analysis – Min_FP CV5.

The trend observed here is very cleanly linear.

**Figure 5: Min_FP Critical Value 5**

\[ F(x) = d \times x + f \]

\[ \text{Sum} = F(80) = 80.0 \]

\[ F(100) = 100.0 \quad F(120) = 120.0 \]

The parameters obtained for best fit are: \( d = 1 \quad f = 0 \); 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.

\[ F(x) = \begin{cases} 
  d \times x + f & 7 \leq x \leq 16 \\
  0.218259 & x \geq 17 
\end{cases} \]

For node number 7-16: \( \text{ch}_sq = 0.0865505 \quad d = -0.168166 \quad f = 2.78846 \)
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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.

The potentially applicable equations are:

1. \( F(x) = (a \cdot \log (b \cdot x + c)) + d \)
   - \( Ch_{sq} = 3.220 \)
   - \( F(80) = 10.793359600 \)
   - \( F(100) = 11.171015629 \)
   - \( F(120) = 11.473783081 \)

2. \( F(x) = (a \cdot \log (b \cdot (x+c))) + (d \cdot x) \)
   - \( Ch_{sq} = 3.222 \)
   - \( F(80) = 11.051227153 \)
   - \( F(100) = 11.509201070 \)
   - \( F(120) = 11.878384403 \)

3. \( F(x) = (a \cdot \log (b \cdot (x+c))) + (d \cdot x^{0.5}) \)
   - \( Ch_{sq} = 2.840 \)
   - \( F(80) = 7.606624831 \)
   - \( F(100) = 5.886834 \)
   - \( F(120) = 4.011106 \)

4. \( F(x) = (a \cdot \log (b \cdot (x+c))) + (d \cdot x^{0.25}) \)
   - \( Ch_{sq} = 2.937 \)
   - \( F(80) = 8.963463943 \)
   - \( F(100) = 8.307987025 \)
   - \( F(120) = 7.589317303 \)

5. \( F(x) = (a \cdot \log (b \cdot (x+c))) + (d \cdot x^{-0.25}) \)
   - \( Ch_{sq} = 3.222 \)
   - \( F(80) = 11.050227153 \)
   - \( F(100) = 11.171015629 \)
   - \( F(120) = 11.473783081 \)

6. \( F(x) = (a \cdot \log (b \cdot (x+c))) + (d \cdot x^{-1}) \)
   - \( Ch_{sq} = 3.133 \)
   - \( F(80) = 10.813872894 \)
   - \( F(100) = 11.147156695 \)

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:

\[ a = 1.0778, \ b = 436.979, \ c = -5.10916, \ d = -31.2691 \]

3.8 Trend Analysis – Min_FP CV8.
Here, most plots are at y-value of 0.0793. As from node number 24 onwards, all plots are at 0.0793.

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.

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:

\[ a = 3.90016, \ b = 0.00538038, \ c = -4.83555, \ d = 36.9549 \]
3.10 Trend Analysis – Min_FP CV10.

An increasing tendency at a decreasing rate is observed.

![Graph](image)

Fig. 10: Min_FP Critical Value 10

The potentially applicable equations are:

1. \( F(x) = (a \times \log(b \times (x+c))) + (d/x) \)
   \( \text{Ch}_\text{sq} = 0.0644511 \)
   \( F(80) = 99.524934496 \)
   \( F(100) = 99.637181615 \)

2. \( F(x) = (a \times \log(b \times (x+c))) + (d/x) \)
   \( \text{Ch}_\text{sq} = 0.0577967 \)
   \( F(80) = 99.434565965 \)
   \( F(100) = 99.509094438 \)

3. \( F(x) = (a \times \log(b \times (x+c))) + (d/x^2) \)
   \( \text{Ch}_\text{sq} = 0.062555 \)
   \( F(80) = 99.468089627 \)
   \( F(100) = 99.617559111 \)

Choice of best fit for ECFP Critical Value 10

The equation in part 2 above has been selected because of smallest \( \text{ch}_\text{sq} \) and good extendability. The parameters obtained for best fit are:

\( a = 6.52416 \), \( b = 1044.74 \), \( c = 4034.78 \), \( d = -17.1578 \)

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 m². 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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