International Journal of Advance in Computer Science & its application – IJCSIA 2018
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Volume 7 : Issue 2 [ISSN : 2250-3765] - Publication Date: 25 June , 2018

Extending Overall Node Battery Availability in Ubicomp with Location-Aware MANET Transmission.

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***Abstract* – The field of location-tracking in mobile environments is subject to serious research endeavours [1-10]. Several development pieces are also being deployed and people have more expectations as concern new functionalities and applications on top of improving existing components for mobile and ubiquitous environments [2]. In such approach of evolution of ubicomp, several questions will crop up, as in advanced software engineering reliability concepts, whose answers depend on components not yet available in ubicomp. It is accepted in research community that ubicomp is still in its infancy stages [104]. Noteworthy answers to these upcoming questions will be developed as more sophisticated components are built. In MANETs, it is expected that all users in the topography be required to contribute for overall routing purposes. In such cases, no infrastructure support nodes will be available for routing. Consequently, in such circumstances, by applying cooperative communication packet delivery, energy is expected to be saved. This effect can be reinforced by applying location-aware transmission. A preceding study was conducted to study this effect [15].**

Following results presented [15], the next level of probing required is set as: "By what factor can the overall nodes' batteries availability be extended? How does this factor vary over different node numbers present in a topography for ubicomp?"

The results of this study will serve towards formulating ubicomp architecture upgrade and reducing load of maintenance procedures required for ubicomp. This study follows from previous ones [1-62].

Key terms: Ubicomp- Ubiquitous Computing, MAUC-Mobile and Ubiquitous Computing, CBR- Constant Bit Rate, MANET- Mobile Adhoc Network, ES- Energy Savings, OES-Overall ES, EC-Energy consumed, OEC- Overall EC, MEC-Mean EC, BAEF- Battery Availability Extension Factor, MBAEF- Mean BAEF.

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1. Introduction

Optimising energy consumption and achieving energy savings is among the crucial components in ubicomp. Achieving good batteries development with long durability, lesser heat generation, lower cost and improved recharging characteristics will not be so meaningful if they are not accompanied by appropriate methods of using it which includes algorithmic methods prone to extend their availability or uptime. To achieve this objective, one decisive area to fine-tune is spending just enough energy for transmission to cover the just enough energy for transmission to cover the just exact range required [2].

Location-awareness feature requires continual update of location information. The granularity or exactness of this location information varies as per technology used. Current levels of technology, however, require overly high overheads to achieve high refresh rates. However, simulation models retain their importance in delimiting bounds of achievements in this direction [2]. Assuming that the ability to channel exact location refresh rates into transmission strategies is available, the more refined location refresh rates, the more efficient energy savings will be reached, until a stable limit is observed, following which, forecasts of battery availability extensions can be undertaken, from theoretical perspective. This will serve as an upper bounding of extension of battery uptime to subsequently study how to enhance ubicomp architectures and decide directions of investments needed.

The key contributions of this paper is firstly, the extension of the simple mathematical method, introduced previously [10-13], for calculating the amount by which the overall nodes' battery availability can be extended by applying exact location-aware transmission strategies in MANETs and secondly to model the trend of these extensions varying over different node numbers in a ubicomp topography of 300 x 300 m^2. The rest of this paper is organised as follows: section 2- Experimental Set-up used, section 3- Results Obtained, section 4- Conclusion and References.

2. Experimental Set-Up Used.

The same experimental design used in previous paper [10] and referred to in another previous paper [62] is re-used here.

The metric of concern for this set of experiment is Overall Energy Savings (OES) [15].

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Volume 7 : Issue 2 [ISSN : 2250-3765] - Publication Date: 25 June , 2018

3. Results Obtained.

The study here is split into four subsections: OES Minimum BAEF (Min_BAEF), OES Mean BAEF (MBAEF), OES Maximum BAEF (Max_BAEF) and certain critical values obtainable. The work is basically some further processing applied over certain results obtained previously. Floating points Values instead of integers, are used to get exact results for processing.

3.1 OES Min_BAEF

This section follows from section 3.1 in previous paper [47], i.e. OES critical value 1, representing smallest OES value obtained. All OES values concerned here were below 0 (i.e. negative values). Minimum OES is obtained in a situation where the overall nodes have spent a maximum Overall Energy Consumption (OEC), whereby related OES Min_BAEF is computed as:

```
Max_OEC = 100.00 - (Min_OES)
OES_Min_BAEF = 100.00/(Max_OEC)
```

The values of OES Min_BAEF for node numbers 7-56 have been computed and the corresponding plot is given in figure 1.

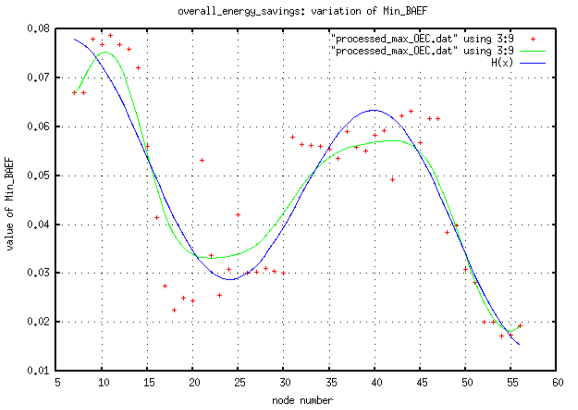

Figure 1: OES Min_BAEF Trend

The curve obtained appears as oscillating along a straight line axis with decreasing gradient. The equation of best fit here, H(x), has been recomputed using "Fit" command in gnuplot and the best fit obtained is as follows:

```
H(x)=a*sin (b*(x+c))+(d*x)+f
```

The ch_sq is 8.473 91(e^{-05}). The parameters of fit are: a= 0.020 906 9 , b= 0.185 401 , c=31.965 9 , d= -0.000 441 995, f= 0.060 218 3

The pertinent observation here is that all values are below 0.1, which depicts the worst case situation that some nodes may have their battery availability reduced to less than one tenth of its initial use in direct node-to-node transmission strategy.

Note: A BAEF value '1' implies mostly a direct transmission from sender to receiver (1 hop).

3.2 SES MBAEF

This section follows from section 2.3 in previous paper [31], i.e. OES parameter c of OES equation of trend. The corresponding Modal BAEF is computed as:

```
Modal_OEC = 100.00 - (Modal OES)
OES_Modal_BAEF = 100.00/(Modal_OEC)
```

The values of OES_Modal_BAEF were computed for node numbers 7 until 56 and corresponding plot is given in figure 2.

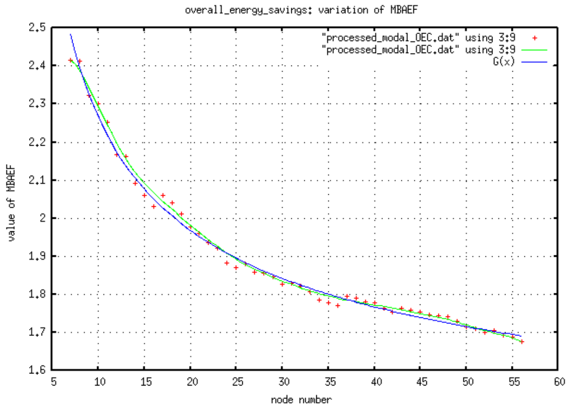

Figure 2: OES MBAEF

Equation of best fit, G(x), has followed similar computation over the equation F(x) obtained in section 2.3 of previous paper [31] while retaining values of parameters a, b and c.

```
F(x) = (a/log (b*x) ) + c
G(x) = 100.00/(100.00-F(x))
```

3.3 OES Max_BAEF.

This section follows from section 3.3 in previous paper [47] for OES critical value 3 representing highest value of OES reached. Maximum OES (Max_OES) is obtained when Minimum Overall Energy Consumption (OEC) occurs. The corresponding OES Max_BAEF is computed as follows:

```
Min_OEC = 100.00 -(Max_OES)
OES_Max_BAEF = 100.00/(Min_OEC)
```

The values of OES Max_BAEF were computed and figure 3 shows the corresponding plot.

Equation of best fit, G(x), followed similar computation over F(x) obtained in section 3.3 in previous paper [47], retaining values of parameters a, b and c.

$$F(x) = a/\log((b*x)+(c*x^{-1}))$$
$$G(x) = 100.00/(100.00 - F(x))$$

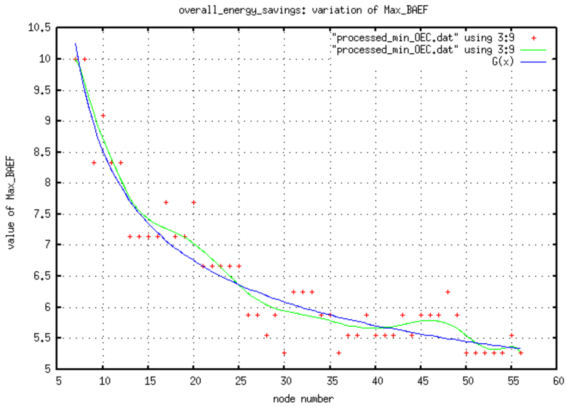

Figure 3: OES Max_BAEF Trend

3.4 Certain OES BAEF Critical Values.

Seven critical values have been identified as presented in Table 1, which correspond to certain critical values studied previously [47]. Colum headings are: C1→ OES BAEF critical value, C2→ Meaning of OES BAEF critical value, C3→ section in previous paper [47] the OES BAEF critical value corresponds to.

C1	C2	C3
1	% nodes reaching Min_BAEF	3.2
2	% nodes reaching Max_BAEF	3.4
3	% nodes with BAEF value<1, i.e. actually, battery availability reduces	3.5
4	% nodes with BAEF value=1, i.e. no effect on battery availability	3.6
5	% nodes with BAEF value>1, i.e. actually, battery availability extends	3.7
6	% nodes reaching MBAEF	3.8
7	% nodes reaching BAEF < MBAEF	3.9

Table 1: OES BAEF Critical Values

4. Conclusion.

This study has probed into the extension of a mathematical method for predicting the extents to which battery availability of overall nodes present in a ubicomp topography of 300 x 300 m^2, could be extended over varying node densities. MANET nodes may be considered as user nodes and not supplied as infrastructure nodes. The method introduced before [10] and extended here, has been applied over results put forward in previous papers [15, 31, 47]. This paper supplements to the study of ubicomp environment from the angle of software engineering. It also provides additional components for prediction and gauging reliability of ubicomp environment. Moreover, in this study, certain new metrics developed previously [10] to further fortify models in ubicomp and better fashion the architecture of ubicomp are presented.

This study has been devised over previous empirical studies done in simulator software NS-2 over Linux. Gnuplot has been the graphical analysis tool used. Floating point calculations have been used to get accurate answers. This study is intended at providing values of BAEF in an objective mathematical perspective. Interpretation of values and trends obtained, as to whether they represent good/bad or workable/unworkable, are not provided. These remain open for designers' analysis.

Further work identified remains refinement of the model and equations of trend obtained and subjecting the metrics defined to more rigorous software engineering approaches.

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