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Extending Node Battery Availability in Ubicomp with Location-Aware Node-to-Node Transmission Using Location Refresh Intervals.

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Abstract – **Location tracking remains of vital importance in mobile computing and explains the amount of research in this field [11-27]. The feature of location tracking is at the heart of several functionalities and applications and also of improving existing applications. Location-awareness depends on resource and support equipment availability. Present level of development applies trade-offs between cost, bandwidth consumed, performance, span of smallest unit of location [3]. One overall effect remains that location information is gathered at varying refresh intervals. A question put forward is "By how much can nodes' battery availability be extended in ubicomp with location-aware Node-to-Node transmission in ubicomp at different location refresh intervals?".**

To answer this question, underlying information should be achievable as concerns energy considerations/savings achievable in such a ubicomp topography using location refresh intervals. Such a component is presented in a previous paper [3].

This paper is a follow-up of several previous papers [2,3,10] where a future work identified in paper [10] is being tackled with the method put forward in that same paper [10]. The objective of this paper is to present the MBAEF and max-BAEF of batteries for varying location refresh intervals. Min-BAEF will be 0. This information may serve towards better formulation of ubicomp architectures.

Key terms: Ubicomp-Ubiquitous Computing, ES-Energy Savings, EC-Energy Consumed, MES-Mean ES, MEC-Mean EC, BAEF-Battery Availability Extension Factor, MBAEF-Mean BAEF.

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1. Introduction

Energy consumption and savings in transmission is of unquestionable importance in ubicomp. Ultimately, consumer's and designer's expectation is that batteries of nodes can last reliably longer. It is a legitimate expectation which must be catered in appropriate metrics so that appropriate foundations for further research and developments can be proposed. Location-awareness remains a matter of available technology and cost trade-offs [3].

The study aims at formulating the MBAEF and max-BAEF derivable from 24 sets of experiments and results proposed in previous paper [3]. Interpretation of results will be left open for designer's further considerations. The results of this study may serve as follows:

i. Better bounding of MBAEF and max-BAEF for circumstances of varying location refresh intervals.
ii. Estimate what refresh intervals give optimal MBAEF.
iii. Subsequently design for nodes features, environment support, bandwidth support and transmission strategies may be put forward.

The rest of this paper is organised as follows: section 2-Experiment Result Used, section 3-Observation and Mathematical Method Applied, section 4- Graphical Analyses, section 5- Conclusion and References.

2. Experiment Used.

The same experiment with the corresponding experiment design issues as described in a previous paper [3] is worked over in this paper. The mathematical method proposed in section 3 of a previous paper [10] is applied in this paper.

3. Observations and Mathematical method applied for varying refresh Intervals.

3.1 Tabulated Results.

This section follows from section 3 in previous paper [3]. The formulae used throughout will be as follows:

% max EC = 100% - %max ES
Max BAEF = (100%)/(%max EC)
%MEC = 100% - %MES

MBAEF = (100%)/(%MES).

The results are presented in a tabular fashion with headings: A→Refresh Interval, B→%max ES, C→%max EC, D→max BAEF, E→ %MES, F→ %MEC, G→ MBAEF.

A	B	C	D	E	F	G
0.1	89	11.0	9.091	67	33.0	3.030
0.2	88	12.0	8.333	66	34.0	2.941
0.5	87	13.0	7.692	64	36.0	2.778
0.8	86	14.0	7.143	61	39.0	2.564
1.0	84	16.0	6.250	60	40.0	2.500
1.5	83	17.0	5.882	57	43.0	2.326
2.0	80	20.0	5.000	55	45.0	2.222
2.5	79	21.0	4.762	52	48.0	2.083
3.0	78	22.0	4.545	50	50.0	2.000
3.5	73	27.0	3.704	49	51.0	1.961
4.0	72	28.0	3.571	44	56.0	1.786
4.5	64	36.0	2.778	41	59.0	1.695
5.0	63	37.0	2.703	37	63.0	1.587
5.5	62	38.0	2.632	33	67.0	1.493
6.0	60	40.0	2.500	37	63.0	1.587
6.5	58	42.0	2.381	31	69.0	1.449
7.0	54	46.0	2.174	31	69.0	1.449
7.5	50	50.0	2.000	30	70.0	1.429
8.0	48	52.0	1.923	32	68.0	1.471
8.5	47	53.0	1.887	28	72.0	1.389
9.0	46	54.0	1.852	26	74.0	1.351
9.5	45	55.0	1.818	26	74.0	1.351
10.0	43	57.0	1.754	24	76.0	1.316
10.5	42	58.0	1.724	23	77.0	1.299

3.2 General Observations.

Both metrics max BAEF and MBAEF show gradual decrease with increasing location refresh intervals. They have both, however, stabilised to value above 1.

4. Graphical Analyses.

Two graphical analyses have been identified in this course of study.

i. Graphical analysis of max BAEF.

ii. Graphical analysis of MBAEF.

Analysis for the first metric (Max BAEF) is of lesser importance since its occurrence is of extremely small probabilities. Nevertheless, the availability of this empirical behaviour is deemed to be important to better situate upper boundings possible (though least probable) for Battery Availability Extension Factor. The plottings were done in gnuplot in Linux and the screenshots are shown below.

4.1 Graphical Analysis of max BAEF.

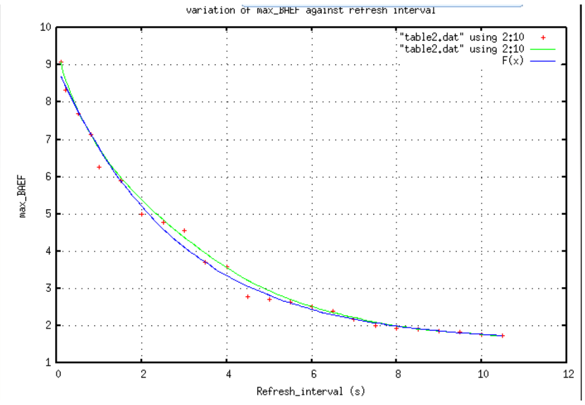

Fig 1: Variation of max BAEF against Refresh Interval

The smooth Bezier plot is very convincing as an inverse exponential tendency. The equation of this best fit is hypothesised as follows in gnuplot:

$$F(x)= c * \exp(-d*x) + f$$

where x is the Refresh Interval and F(x) is the max BAEF. The reduced chi-square value is very satisfactory (0.0397541). It is obtained after several iterations and constant values are:

c= 7.40086, d=0.354307 and f= 1.5514

It can be observed that the max BAEF is high for very short Refresh Intervals and is still at an interesting value (1.724) for highest Refresh Interval noted (10.5 s). However, the very low probability of occurrence of this max BAEF value makes it quite unworkable.

The above equation put forward can be used for predicting the max BAEF value for any refresh interval ranging from 0.0 to 10.5 sec. it is important to note that the max BAEF corresponding to 0.0 s from graph corroborates with value of max BAEF obtained in part (v) of section 3 of a previous paper [10].

4.2 Graphical Analysis of MBAEF.

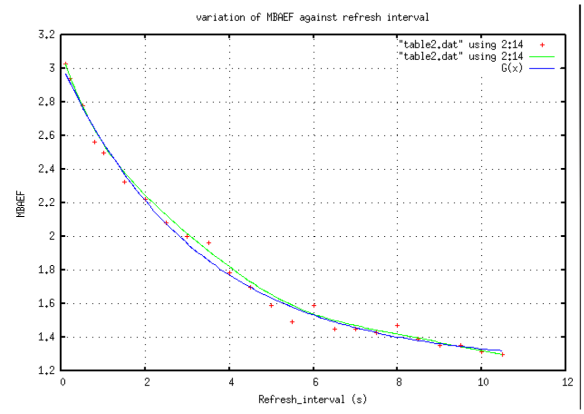

Fig 2: Variation of MBAEF against Refresh Interval

The smooth Bezier plot is also very convincing as an inverse exponential tendency. Again, the equation of this best fit is hypothesised as follows in gnuplot:

$$G(x)= h * \exp(-i*x) + j$$

where x is the Refresh Interval and G(x) is the MBAEF. The reduced chi-square value is even more satisfactory (0.00227788). It is obtained after several iterations and constant values are:

$$h= 1.77681,\ i = 0.305898,\ j = 1.24804.$$

It can be observed that MBAEF is already quite small for very short refresh intervals starting at 3.03. This corroborates with value obtained in part (iii) of section 3 in previous paper [10].

The value of MBAEF drops to very low (though above 1) at 10.5 s refresh intervals. It shows that even at refresh intervals of 10.5 s, there is still hope that the nodes batteries availability is extended though by a small factor. **It is hence put forward that additional methods to increase nodes' batteries availability is desirable**. One method suggested as future work in previous paper [10] would be use of relays.

The above equation put forward can be used to predict the MBAEF of nodes battery availability in a ubicomp topography of 300 x 300 m^2 if using location refresh intervals varying between 0.0 and 10.5 seconds. Since the mean Energy consumptions occur much more frequently than the max Energy Consumption, this equation here for MBAEF will be of more significance and predicted values of MBAEF may be more prone to be observable.

5. Conclusion.

In this piece of study, the mathematical method put forward in a previous paper [10] for predicting extents to which nodes' battery availability can be extended empirically using Location-aware transmission strategy, has been applied over results of another previous paper [3] whereby location information is refreshed at variable intervals.

In this paper, graphical analyses for two metrics, max BAEF and MBAEF have been provided and equations of best fits provided for each, which can be used for predicting the max BAEF and MBAEF at varying location refresh intervals. The two trends examined follow the inverse exponential model. It has also been suggested, based on trends of MBAEF, that additional methods to assist in extending battery availability is desirable.

This paper adds an additional component to the study of ubicomp environment from a software engineering perspective. The models put forward in this paper adds to the components for prediction and gauging reliability of ubicomp environment by better applicability of two metrics put forward in previous paper [10]. Ultimately, the results of this study will assist in formulating reliability concepts and support features towards shaping the future architecture of ubicomp.

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