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Model of Energy Savings achievable with Location-aware Node-to-Node Transmission in UbiComp Using Location Refresh Intervals.

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Abstract **– A key area in MAUC is location tracking of nodes. Achievements in this area are commendable [1-16]. Researchers have also undertaken applying location-awareness to devise new functionalities and applications and also to improve ways of doing existing activities. Software engineering approaches into forming metrics and models in the field of MAUC are also gaining in value. Location-awareness remains a matter of resource consumption and support equipment available. It ends up having trade-offs between cost, amount of bandwidth consumed, performance, span of smallest unit of location and other factors. One overall effect is that location-tracking is done at varying refresh-intervals.**

This paper is a follow-up of a previous paper titled "Model of Energy Savings achievable with Location-aware Node-to-Node transmission in UbiComp"[18], in which one future work identified was to study effects of different location refresh intervals on percentage of energy savings achievable and models that can be formulated. The objective of this paper is to present the results of 24 different sets of experiments in the form of graphical displays and conclusions that can be drawn from them.

Key terms: MAUC-Mobile and Ubiquitous Computing

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1. Introduction

1.1 Technology for supporting Location-awareness.

Location refresh is a matter of available technology and its associated cost. It depends on dedicated hardware resources in environment. GPS is a very common location device available. It however, uses satellite communication involving much energy usage and high delays which render frequent requests for location updates impractical. Ground infrastructure for GPS included into a MAUC topography may be a very plausible alternative. Programming with GPS is quite well known.

High location refresh rates may involve some change in node hardware where a dedicated component for tracking location information working in parallel may be required.

1.2 Scope to be investigated.

The study aims at investigating behaviour of nodes at particular rates of location tracking. The results may serve as follows:

i. Understand the savings trend achievable at different refresh rates/intervals, i.e. behaviour of the distribution for different refresh intervals.
ii. Estimate what refresh-rate/interval will give optimal energy savings for costs of operation.
iii. Use the result of (ii) above to design for nodes features, environment support, bandwidth support etc to assist the application of transmission energy saving strategies.
iv. The result from all above can serve as guidelines for research into what level of performance must be achieved to help in this mechanism and usually the limit to stop at since performance beyond this level would not bring significant returns.

The rest of this paper is organised as follows: section 2-Particularities of experiment design, section 3-Study of Results obtained and observations, and section 4-Conclusion and References.

2. Experiment Design

This follows from previous paper[18] mentioned in abstract.

2.1 Distance Tolerance Considerations.

Sender and receiver can both be moving. Transmissions should be feasible taking into consideration the maximum additional distance possible between the sender and receiver before nest location update. The maximum speed allowable in the experiments were just below 20 m/s and hence 2 nodes moving way from each other would be at 40 m apart in

1 second. Hence, the worst case factor of 40 m must be added to distance prior to squaring.

$(d+40)^2=d^2 + 40(2)(d) + 1600$

If the location refresh is done at x seconds, the formula used is:

$(d+40(x))^2=d^2+40(2)(x)(d)+1600(x^2)$

In the experiments, due to application of Pythagoras theorem, d^2 is available first and hence square root to find value of d has to be found using the TCL code:

```
Set ans [expr {sqrt($num)}]
```

2.2 Biggest Refresh Interval to use.

This is limited by the diagonal/longest distance in the topography. In the topography of 300 x 300 m^2, the diagonal distance is about 425 m. If 2 nodes are distancing at 40 m/s. This maximum distance will be covered in 10.625 seconds. If bigger refresh interval is used, then it's preferable to use transmission covering whole topography.

Maximum refresh time interval has hence been taken at 10.5 seconds. This interval would have been limited by the maximum speed (y).

Max refresh interval = 425/y.

If maximum speed allowed is 2 m/s (walking speed), maximum refresh interval would be 106.25 sec (a very large margin for study).

2.3 Refresh Time Intervals to be used.

The refresh intervals chosen are: 0.1 s, 0.2 s, 0.5 s, 0.8 s, 1.0 s, 1.5 s, 2.0 s, 2.5 s, 3.0 s, 3.5 s, 4.0 s, 4.5 s, 5.0 s, 5.5 s, 6.0 s, 6.5 s, 7.0 s, 7.5 s, 8.0 s, 8.5 s, 9.0 s, 9.5 s, 10.0 s, 10.5 s. A total of 24 sets of experiments/processing has been devised to observe appropriate trends.

2.4 Process Design.

Some optimisations were felt necessary compared to previous paper to improve on time required for processing. The processing was done over 2 laptops and lasted just above 48 hours of continuous processing.

3. Results and observations.

Since the study involved 24 sets of processing, 24 graphs have been generated and used for study.

3.1 Energy Savings trends for different Refresh Intervals(RI).

1. For Refresh Interval of 0.1 sec.

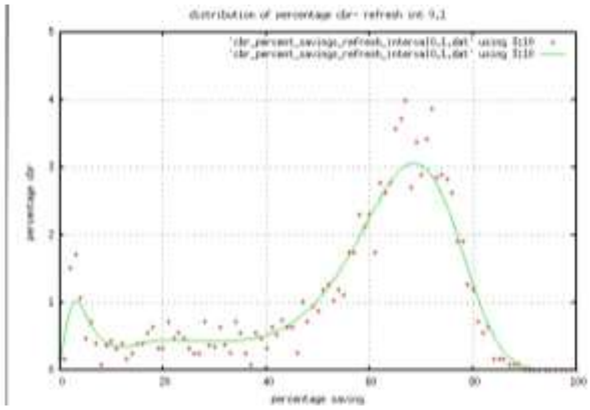

Fig 1: Distr. of %cbr for energy saving, RI 0.1 sec

2. For Refresh Interval of 0.2 sec.

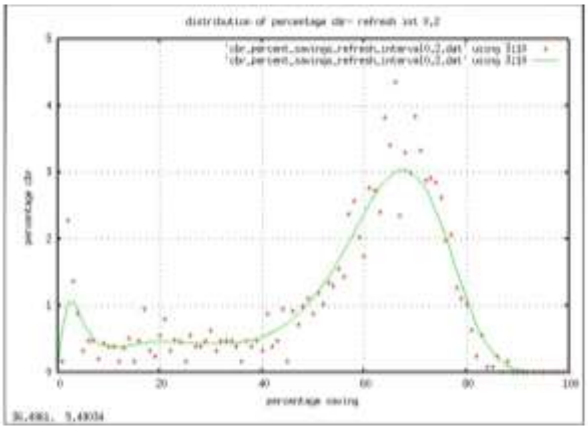

Fig 2: Distr. of %cbr for energy saving, RI 0.2 sec

3. For Refresh Interval of 0.5 sec.

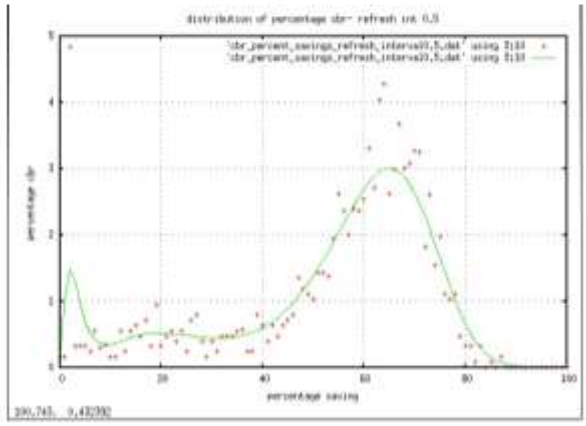

Fig 3: Distr. of %cbr for energy saving, RI 0.5 sec

4. For Refresh Interval of 0.8 sec.

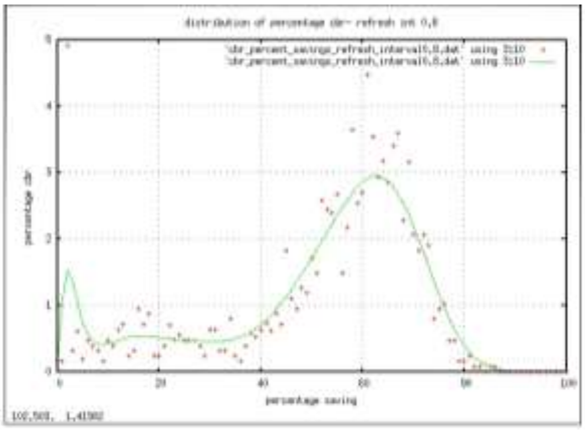

Fig 4: Distr. of %cbr for energy saving, RI 0.5 sec

5. For Refresh Interval of 1.0 sec.

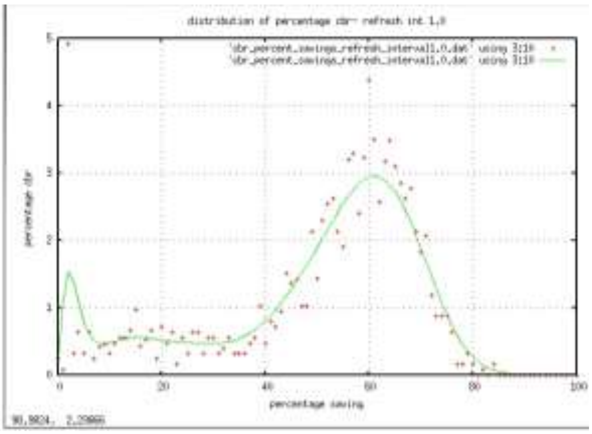

Fig 5: Distr. of %cbr for energy saving, RI 1.0 sec

6. For Refresh Interval of 1.5 sec.

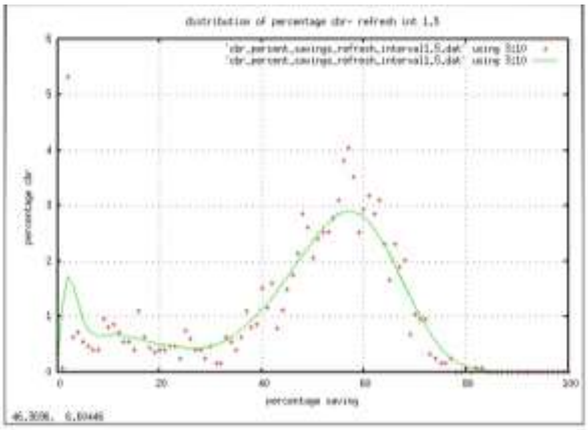

Fig 6: Distr. of %cbr for energy saving, RI 1.5 sec

7. For Refresh Interval of 2.0 sec.

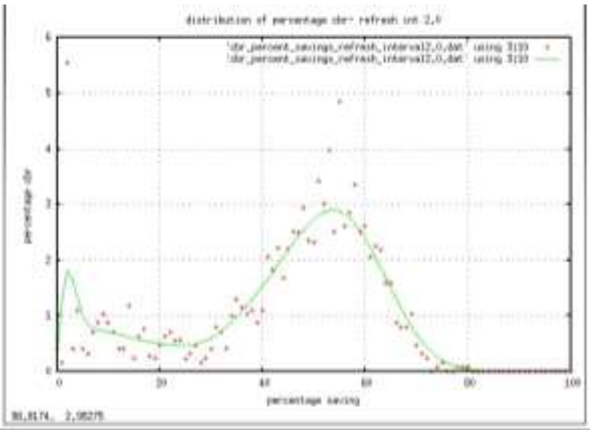

Fig 7: Distr. of %cbr for energy saving, RI 2.0 sec

8. For Refresh Interval of 2.5 sec.

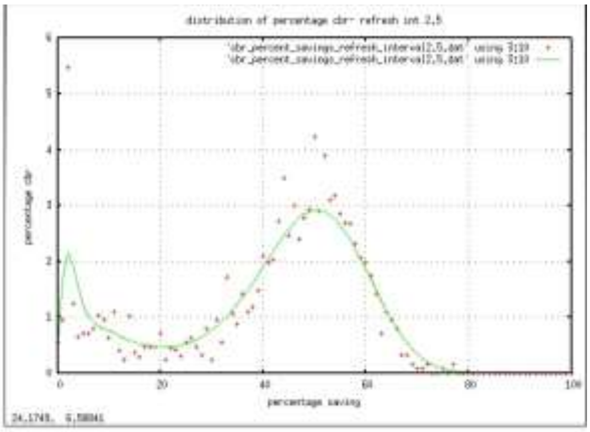

Fig 8: Distr. of %cbr for energy saving, RI 2.5 sec

9. For Refresh Interval of 3.0 sec.

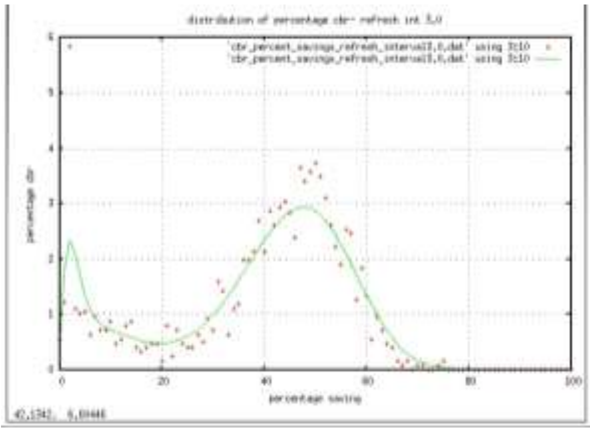

Fig 9: Distr. of %cbr for energy saving, RI 3.0 sec

10. For Refresh Interval of 3.5 sec.

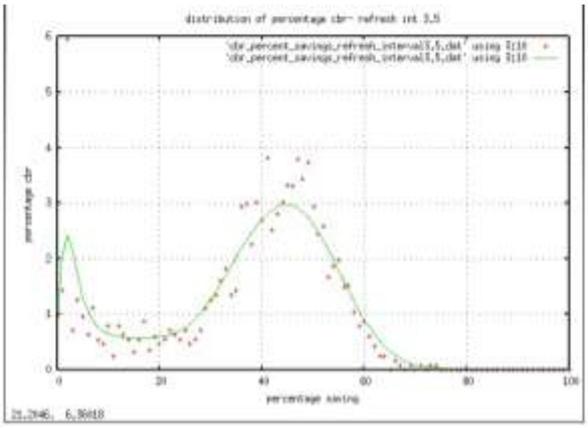

Fig 10: Distr. of %cbr for energy saving, RI 3.5 sec

11. For Refresh Interval of 4.0 sec.

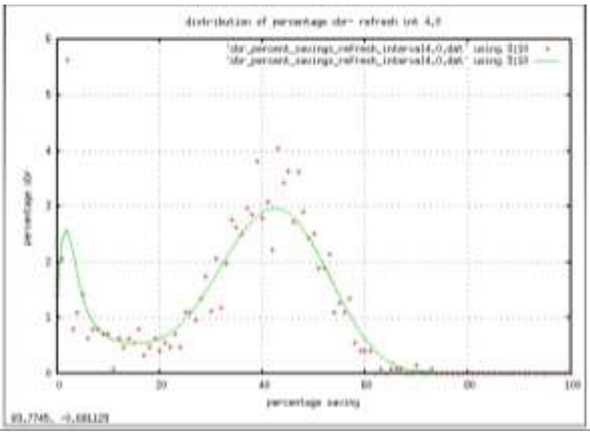

Fig 11: Distr. of %cbr for energy saving, RI 4.0 sec

12. For Refresh Interval of 4.5 sec.

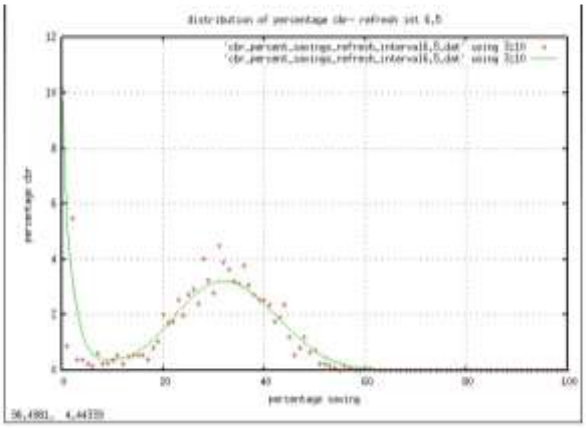

Fig 12: Distr. of %cbr for energy saving, RI 4.5 sec

13. For Refresh Interval of 5.0 sec.

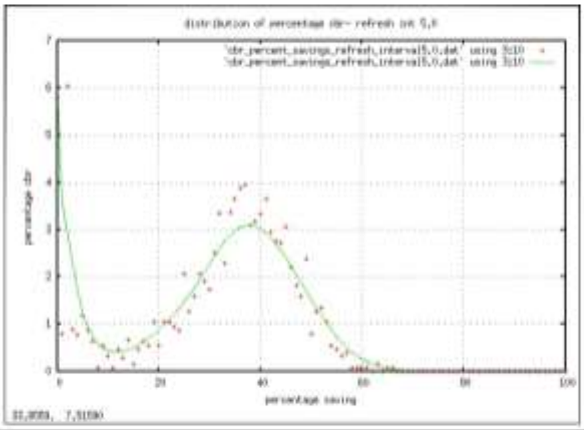

Fig 13: Distr. of %cbr for energy saving, RI 5.0 sec

14. For Refresh Interval of 5.5 sec.

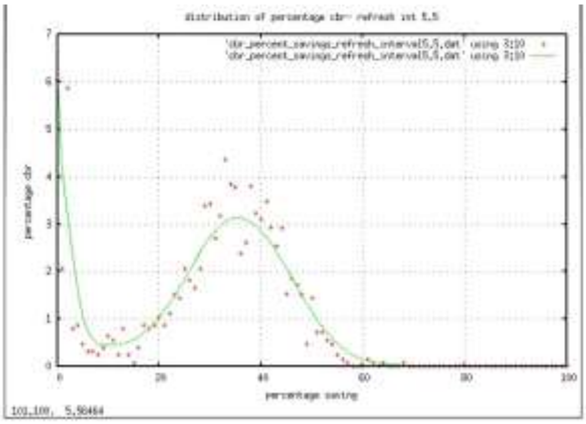

Fig 14: Distr. of %cbr for energy saving, RI 5.5 sec

15. For Refresh Interval of 6.0 sec.

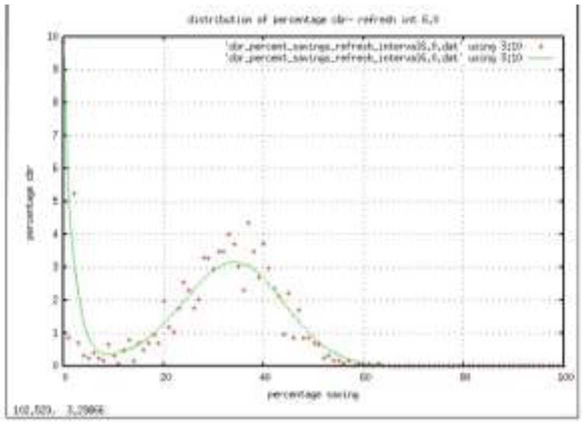

Fig 15: Distr. of %cbr for energy saving, RI 6.0 sec

16. For Refresh Interval of 6.5 sec.

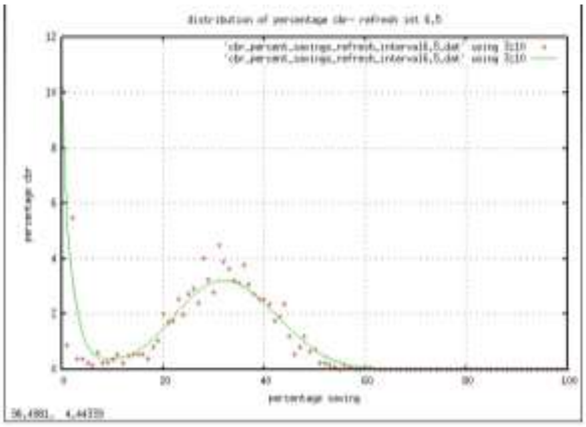

Fig 16: Distr. of %cbr for energy saving, RI 6.5 sec

17. For Refresh Interval of 7.0 sec.

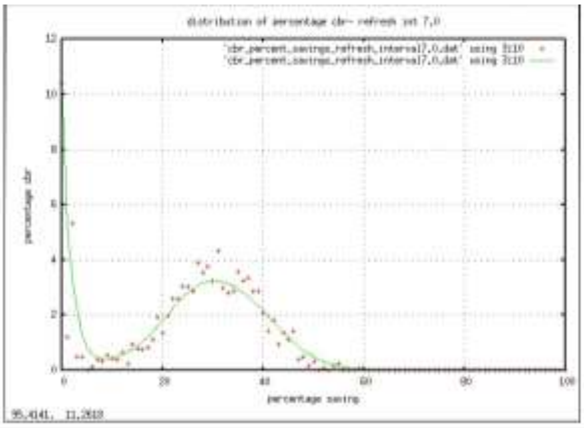

Fig 17: Distr. of %cbr for energy saving, RI 7.0 sec

18. For Refresh Interval of 7.5 sec.

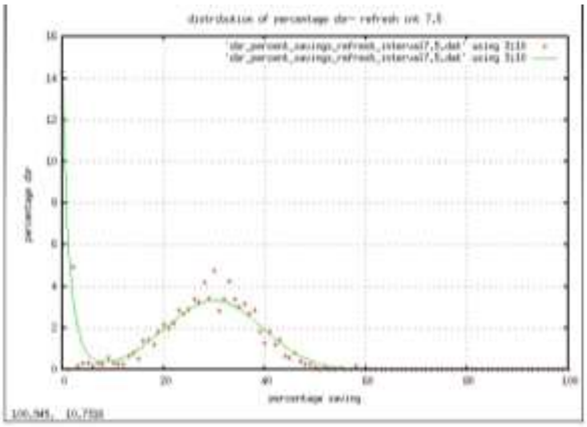

Fig 18: Distr. of %cbr for energy saving, RI 7.5 sec

19. For Refresh Interval of 8.0 sec.

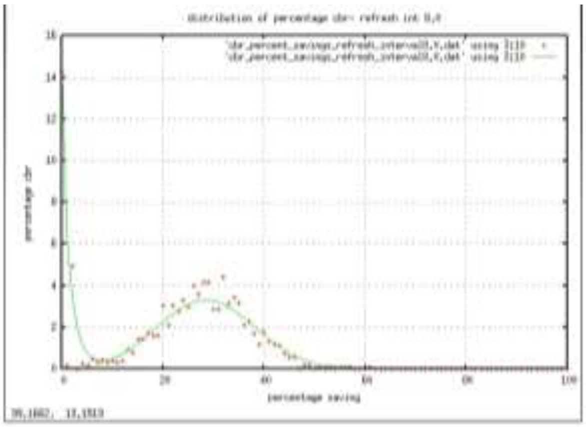

Fig 19: Distr. of %cbr for energy saving, RI 8.0 sec

20. For Refresh Interval of 8.5 sec.

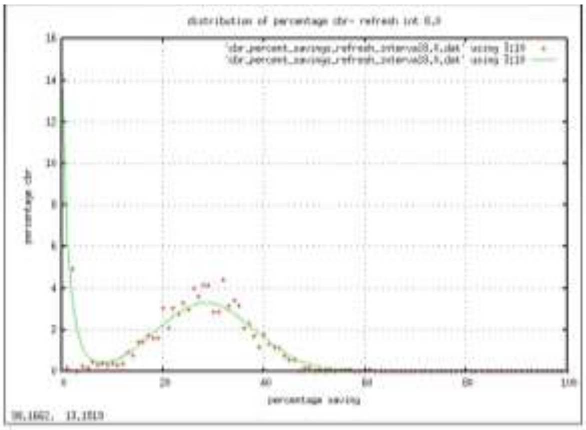

Fig 20: Distr. of %cbr for energy saving, RI 8.5 sec

21. For Refresh Interval of 9.0 sec.

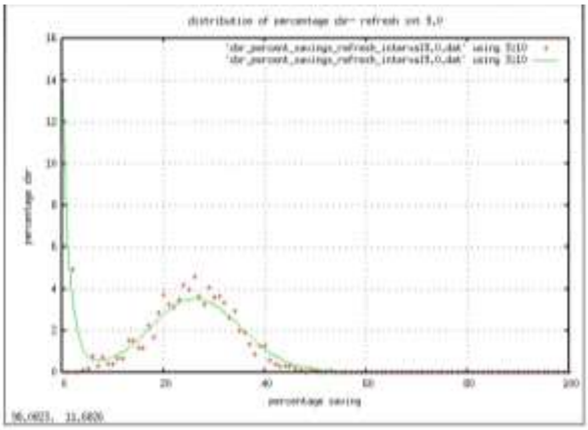

Fig 21: Distr. of %cbr for energy saving, RI 9.0 sec

22. For Refresh Interval of 9.5 sec.

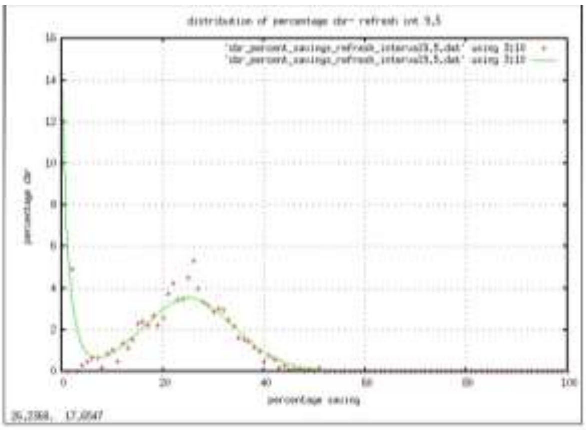

Fig 22: Distr. of %cbr for energy saving, RI 9.5 sec

23. For Refresh Interval of 10.0 sec.

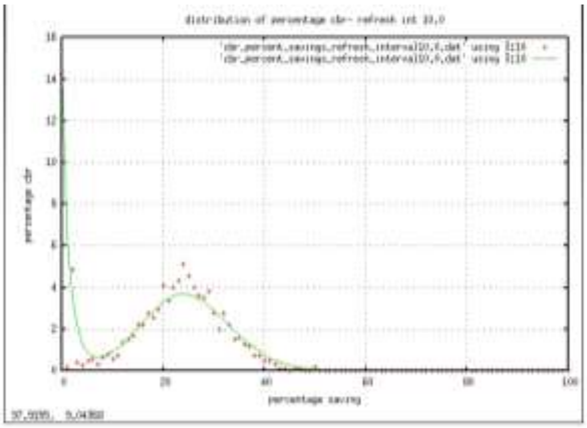

Fig 23: Distr. of %cbr for energy saving, RI 10.0 s

24. For Refresh Interval of 10.5 sec.

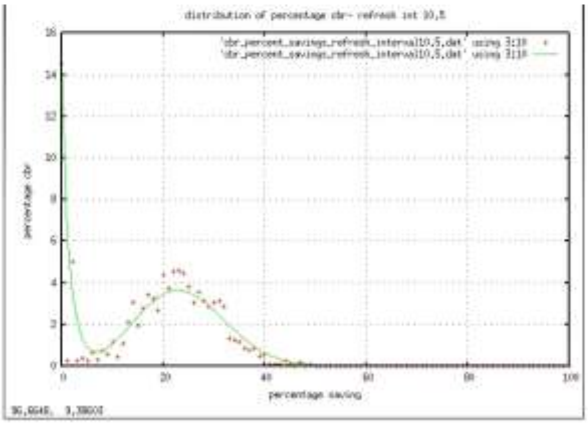

Fig 24: Distr. of %cbr for energy saving, RI 10.5 s

3.2 Observations from these Results.

1. All distributions of all CBR at every refresh intervals studied, i.e. 0.1 – 10.5 seconds depict a normal distribution. For intervals of 0.1 sec, 0.2 sec, 0.5 sec, the shapes of the graphs obtained is not significantly different from that obtained in figure 1 of the previous paper[18]. The mean is very near to 67% but as expected, it is shifting to the left.
2. For distributions in fig 1, 2 and 3, it shows that an average projected percentage of nodes not making savings is around 2%. It shows that potentially 98% of transmissions will benefit from location aware transmission strategies and mean savings achievable remains above 60%.
   For fig 4, average projected percentage of nodes not making savings is 5%. For fig 5-14 successively, average projected percentage of nodes not making savings is 6%.
   For fig 15, 16,17, i.e. for intervals 6.0, 6.5 and 7.0 seconds, this figure is 10-11%. For figures 4.40 until 4.47, this figure is at 15%. Hence, three consequent ranges have been identified here.
   A:Range of Refresh Interval. B:Projected % cbrs not making energy savings.

A	B
0.1 – 0.5 sec	2%
0.8 – 5.5 sec	About 6%
6.0 – 10.5 sec	About 15%

   The implications of the above observation are quite significant. If making more cbrs save energy is of concern:
   a. There is no point decreasing refresh interval from 0.5 sec to 0.2 sec, since projected percentage not saving energy remains 2%.
   b. Similar case for 5.5 sec to 1.5 sec and 10.5 sec to 6.0 sec.
   c. There is significance in decreasing refresh interval from 6.0 sec to 5.5 sec, since expected output will change significantly from 15% to 6%.
   d. Similar case for 1.0 sec to 0.5 sec and 10.5 sec to 0.5 sec.

   This observation can serve as guideline for investigating in resources for location tracking and indicate whether it is worth to upgrade or not. This will give a guideline for investing in what is most worthy.
3. The means(C) of the graphs for each refresh interval (D) are as follows:

D	C	D	C	D	C	D	C
0.1	67	2.0	55	5.0	37	8.0	32
0.2	66	2.5	52	5.5	33	8.5	28
0.5	64	3.0	50	6.0	37	9.0	26
0.8	61	3.5	49	6.5	31	9.5	26
1.0	60	4.0	44	7.0	31	10.0	24
1.5	57	4.5	41	7.5	30	10.5	23

This can be analysed graphically. Two best fits are possible. The 2nd one seems better.

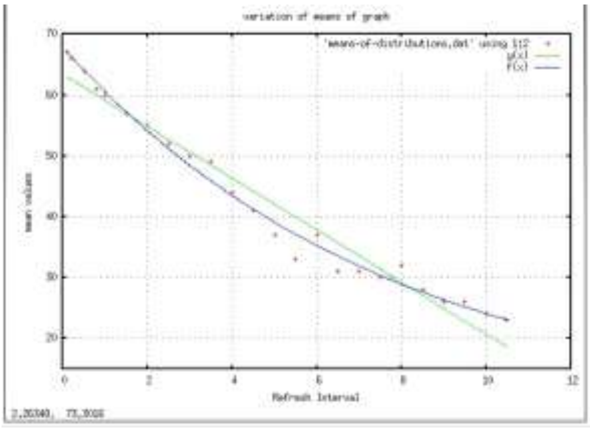

Fig 25: Means of distr. v/s Refresh Intervals.

i. Y(x) = a*x +b
Where a=-4.26875, b=63.4057

ii. F(x) = c*e power(-d*x) + f
Where c=60.2799, d=0.0639856 and f=7.5584

This graph and equations of best fit can be used to find the expected means of the distributions for any refresh intervals used. This can be used to find an interval which satisfies a particular expected performance level for energy savings.

If F(x) is used as best fit, it shows that the impact of change in mean value decreases as refresh interval increases. Reducing refresh interval by 2 seconds from:

a. 10.0 sec to 8.0 sec increases mean from 24% to 29% (5% increase).
b. 8.0 sec to 6.0 sec increases mean from 29% to 36% (7% increase).
c. 6.0 sec to 4.0 sec increases mean from 36% to 44% (8% increase).
d. 4.0 sec to 2.0 sec increases mean from 44% to 54%(10% increase).
e. 2.0 sec to 0.1 sec increases mean from 54% to 67%(13% increase)

This can further serve to evaluate whether investments into achieving a particular reduction in refresh interval is worthwhile or not (for reducing from 10.0 sec to 8.0 sec, it is clearly not so good)

4. Concerning maximum percentage savings achieved, the figures have also experienced a drop from 89% (at interval 0.1 sec) to about 42% (at interval 10.5%).

As from 7.5 sec and above, maximum energy saved is below 50% and mean energy saved is lesser than 30%. This is the regions which prove unworthiness of location aware transmissions.

5. My Recommendation after these studies is that a refresh interval of above 5.0 seconds will prove of lesser return and hence if investment in location tracking is to be undertaken, it must aim at tracking at 5.0 seconds or less to achieve good reliability and good enough performance.

For smaller refresh intervals, more study has to be undertaken to see if they give good enough performance, amount of extra traffic generated, if bandwidth available can contain it etc and appropriate trade-offs made.

4. Conclusion.

This piece of study is a follow-up from a previous paper titled “Model of energy savings achieved with Location-aware Node-to-Node Transmission in Ubicomp”. This conclusion, hence, adds to the conclusion of the previous paper. The nature of the study of this research has been to study 24 experiments sets and hence explains the vast number of graphs obtained.

This piece of research has investigated the effect of varying location refresh intervals on trends on savings of energy achieved. Mostly, the model remains Normal Distribution but with increasing refresh interval, the mean value tends to decrease. This research has given a model, from a software engineering perspective, to depict the variation of the mean value against refresh interval used. This model, also, can be used for prediction in a MAUC topography and serve as a reference against which reliability of a MAUC environment can be rated. It can also help in formulation of appropriate metrics and shape the development of new architecture support in a MAUC environment.

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