

Investigation of Prominence of Placements of Optimised Number of Relays in a UbiComp Topography using Location-Aware Transmission.

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Abstract–Relays are beneficial in ubiComp [7]. The benefits go mostly for mobile nodes in the topography. Relay densities and their placements have significant impacts on energy containment [7]. Some locations of relays may be more prominent than others [7][8] and this may hold true despite optimising the number of relays by removing the least prominent ones starting from a uniform distribution of moderately large number of relays. Hence, appropriate knowledge of tendencies of prominence in “optimised number” of relays is required so as to better plan for power requirements and efficiency of relays, future upgrades, continued use of lower power relays and reshuffling of relays needed.

This paper is a follow-up of 8 previous papers [1-8] aimed at producing models of behaviours towards reliability in ubiComp with more focus from papers [4][7][8]. In this paper, one set of behaviour patterns, for amount of data reaching each relay as transit relay over topography with optimally placed relays is presented. The results are presented in the form of graphs and tabular summaries of data, following which conclusions are drawn. The results of this study can help in further optimisations of relay densities and to avoid new arrangements or architectures of relays for ubiComp.

Key terms: MAUC-Mobile and Ubiquitous Computing, CBR-Constant Bit Rate, PDT-Percentage Data Transits, PR-Prominence Ratios, Transit Relay-1st relay of transmission reached by sender node, CPoI-Central Point of Intersection.

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1. Introduction

1.1 Brief of Optimising Number of Relays.

It is general engineering principle to identify resources which are being useful but below a threshold limit (sometimes referred as redundant) [22-25] and decide whether removing them is better. Same applies for number of relays in ubiComp topography as this

can help in better costs containment. Optimising number of relays towards the objective of performance of energy containment has been attempted and described in previous paper [8]. Removing the least useful relays did not have the objective of uniformising the PDT over each relay in ubiComp topography. It cannot be expected that the PDT will be significantly levelled across each relays with this optimisation technique. It certainly does not imply that older lesser powerful relays are useless, nor that the resultant relay placements cater for fault tolerance.

1.2 What is needed?.

Basically, what is described in section 1.1 in previous paper [7] continues to apply over optimised number of relays in ubiComp topography. Here also, one aim is to note the upper bounds and lower bounds of tendencies of behaviours of PDT.

1.3 Purposes of this Study.

This also follows from section 1.2 in previous paper [7] being applied over topography of optimised number of relays.

The key contribution of this paper is to provide another set of behaviour of prominence of relays in ubiComp topography of 300x300 m², using varying optimal numbers of relays, and after plotting results graphically. Observations and Conclusions concerning prominence of placements of the optimal number of relays will be made followed by recommendations.

The rest of this paper is organised as follows: section 2-Implementation Processing for this Study, section 3-‘Results and observations’ subdivided in two main sections: 3.1-Trend Analyses of % prominence of optimal number of relays, 3.2-Specific Observations and Formulations, section 4- Conclusion and References.

2. Implementation Processing For this Study.

Here also, progresses from previous papers [2][3][4][7][8] are used. More particularly, the 11 sets of

processing devised in previous paper [8] are used here again. For each movement scenario running for each number of optimally placed relay, additional provisions have been made as stated in section 2 of previous paper [8]. Each of these additional provisions generates data that are saved in separate files. For each movement and relay scenario, the amount of data transiting through each relay is taken, and the corresponding percentage of total traffic received by relays directly from sending nodes is computed and saved in a summary file.

3.Results and observations- Prominence of Relays.

Here each result should be studied in conjunction with their corresponding parts in section 3.1 in previous paper [8].

3.1 Trend Analyses of % Prominence of Relays.

1. Using 4 optimal relays.

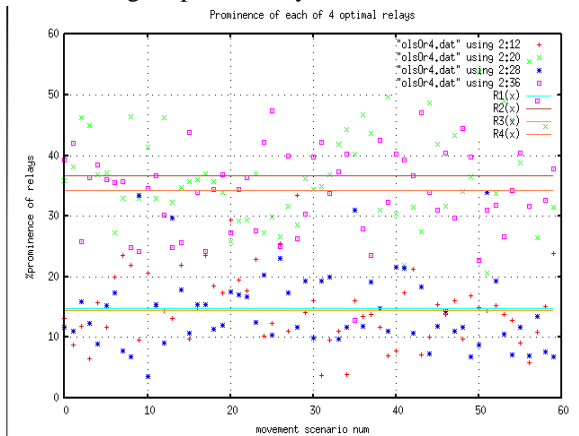


Fig 1: Prominence of relays –4 optimal relays

Relays	R1	R2	R3	R4
PDT	14.76	36.61	14.43	34.20
PR	1.02	2.54	1.00	2.37

The PRs show very big discrepancies (maximum of 1.54). R2 and R4 seem to be much more important than R1 and R3. This shows that refinement in optimal positioning of 4 relays may be possible and is most probably the reason which explains the reduced performance observed in part 1 under section 3.1 in previous paper [8].

As such, this arrangement of 4 relays is not good to consider, especially since addition of 1 relay, i.e. a total of 5 relays can give a very enhanced scenario as seen next.

2. Using 5 optimal relays.

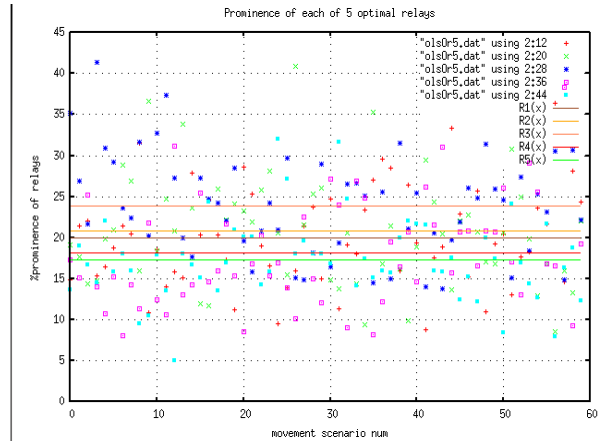


Fig 2: Prominence of relays –5 optimal relays

Relays	R1	R2	R3	R4	R5
PDT	20.02	20.75	23.83	18.12	17.28
PR	1.16	1.20	1.38	1.05	1.00

The PRs show very small discrepancies (maximum 0.38). The lines in the plotting are very close together. It indicates that a high level of optimisation has been reached in the placement of the relays. Minor refinements may still be possible but will be mostly subjective and achieved with trial and error and subject to availability of appropriate location in a topography. Here, all five relays need to be mostly equally powerful.

This corroborates further the success of such a placement of 5 relays, as described in previous paper [8], as good and apt for later improvements also. It also reinforces the notion of central placements of relays along axes as bringing greater value.

3. Using 8 optimal relays.

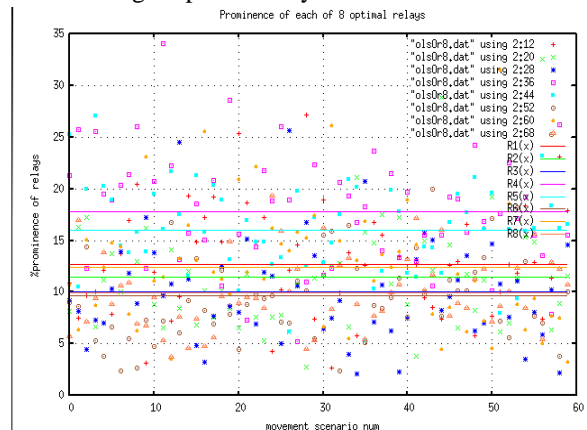


Fig 3: Prominence of relays –8 optimal relays

Relays	R1	R2	R3	R4	R5
PDT	12.72	11.48	10.04	17.84	16.00
PR	1.32	1.19	1.04	1.85	1.66

Relays	R6	R7	R8
PDT	9.62	12.40	9.90
PR	1.00	1.29	1.03

The prominence ratios do not show big discrepancies (maximum 0.85). The lines in the plotting are quite close to each other indicating good levels of optimisation. Minor refinements may be attempted by trial and error but improvements in performance will not be so big. This placement of relays reinforces notion of central placement of relays along axes. This placement of relays is, hence, a feasible choice, especially if future addition of more relays is envisaged.

4. Using 9 optimal relays.

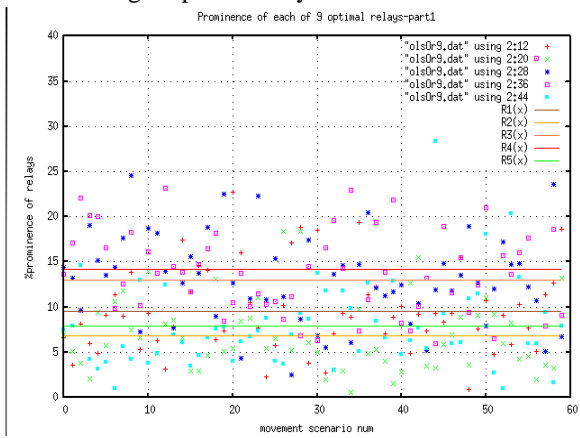


Fig 4(i): Prominence of relays –9 optimal relays (R1-R5)

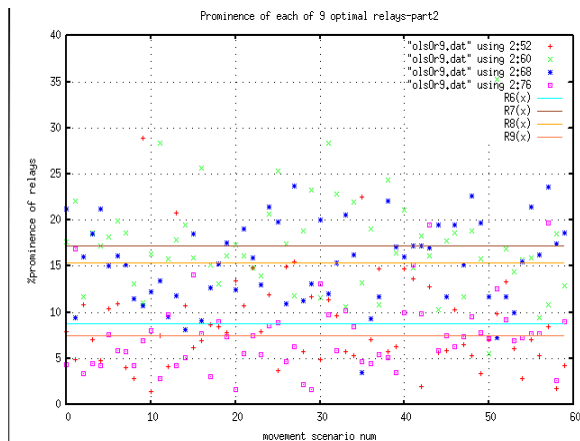


Fig 4(ii): Prominence of relays –9 optimal relays (R6-R9)

Relays	R1	R2	R3	R4	R5
PDT	9.57	6.83	12.96	14.13	7.88
PR	1.40	1.00	1.90	2.07	1.15

Relays	R6	R7	R8	R9
PDT	8.73	17.16	15.33	7.42
PR	1.28	2.51	2.24	1.09

The PRs do show quite big discrepancies (maximum 1.51). It can indicate either of the following:

- i. This placement of 9 relays is not good enough and should be reworked or improved with trial and error.
- ii. Some locations will remain more prominent than others despite removing the least prominent ones and that energy savings for transmissions is good.

5. Using 10 optimal relays.

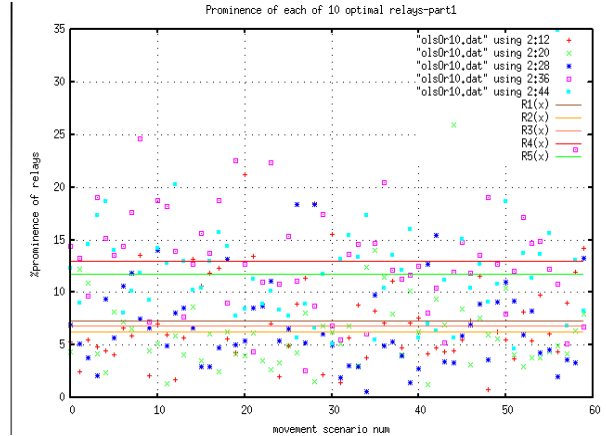


Fig 5(i): Prominence of relays –10 optimal relays(R1-R5)

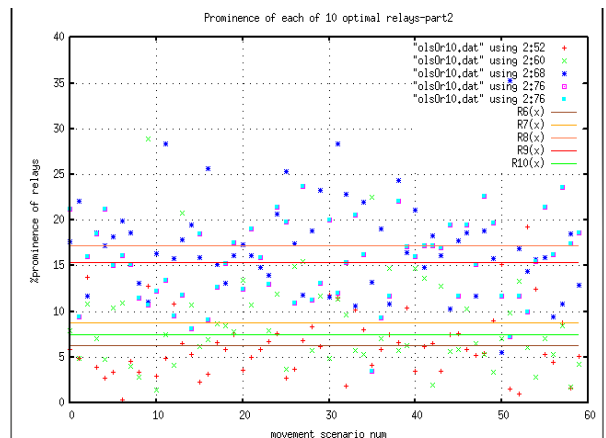


Fig 5(ii): Prominence of relays –10 optimal relays(R6-R10)

Relays	R1	R2	R3	R4	R5
PDT	7.33	6.24	6.83	12.96	11.69
PR	1.17	1.00	1.09	2.08	1.87

Relays	R6	R7	R8	R9	R10
PDT	6.33	8.73	17.16	15.33	7.42
PR	1.01	1.40	2.75	2.46	1.19

There tends to be two groups of prominence: one below 9% and one above 11%. This disparity does indicate possibility of re-arranging the relays by trial and error to get better repartitioning of relays to get better results in terms of energy savings achievable and prominence ratios.

6. Using 11 Optimal relays.

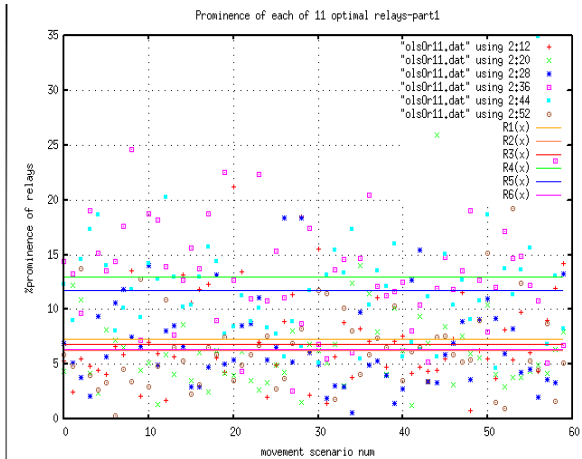


Fig 6(i): Prominence of relays –11 optimal relays (R1-R6)

Relays	R11	R12
PDT	7.34	7.49
PR	1.77	1.81

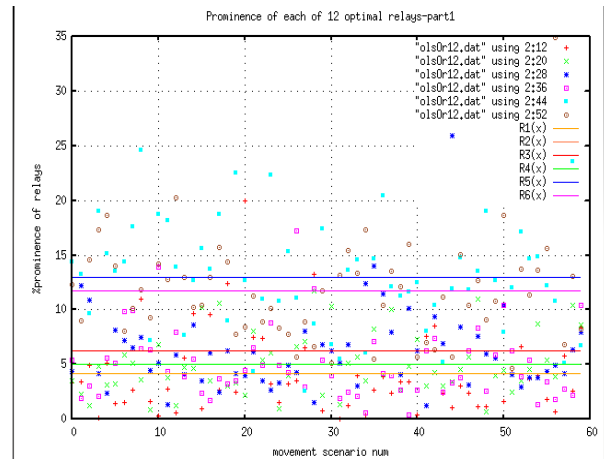


Fig 7(i): Prominence of relays –12 optimal relays (R1-R6)

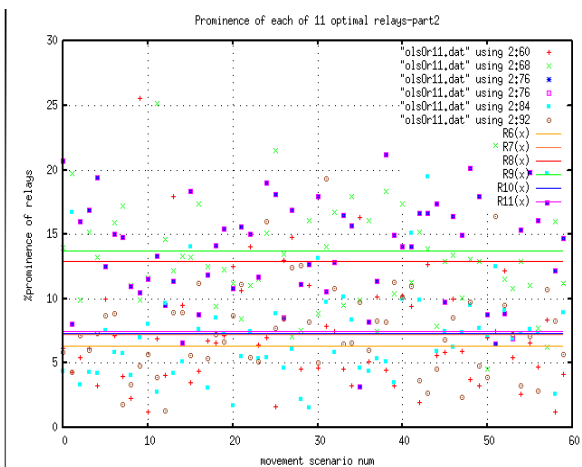


Fig 6(ii): Prominence of relays –11 optimal relays (R6-R11)

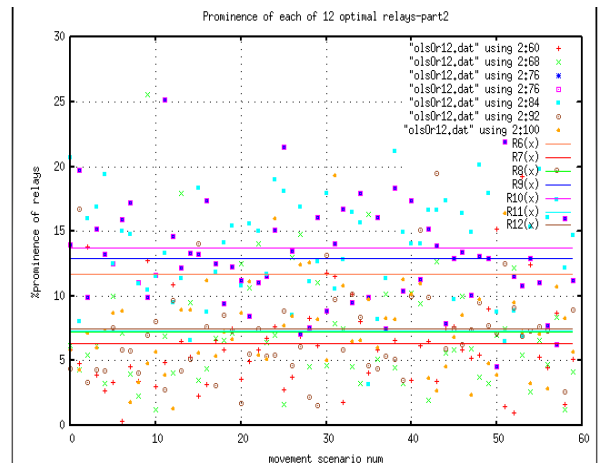


Fig 7(ii): Prominence of relays –12 optimal relays (R6-R12)

Relays	R1	R2	R3	R4	R5
PDT	7.33	6.24	6.83	12.96	11.69
PR	1.17	1.00	1.09	2.08	1.87

Relays	R6	R7	R8	R9	R10
PDT	6.33	7.22	12.90	13.70	7.34
PR	1.01	1.16	2.07	2.20	1.18

Relays	R11
PDT	7.49
PR	1.20

Again, there tends to be two ranges of prominence: one below 8% and one above 11%. Again, this disparity indicates possibility of re-arranging the relays by trial and error to get better performance.

7. Using 12 optimal relays.

Relays	R1	R2	R3	R4	R5
PDT	4.14	4.97	6.24	5.04	12.96
PR	1.00	1.20	1.51	1.22	3.13

Relays	R6	R7	R8	R9	R10
PDT	11.69	6.33	7.22	12.90	13.70
PR	2.82	1.53	1.74	3.12	3.31

8. Using 13 Optimal relays.

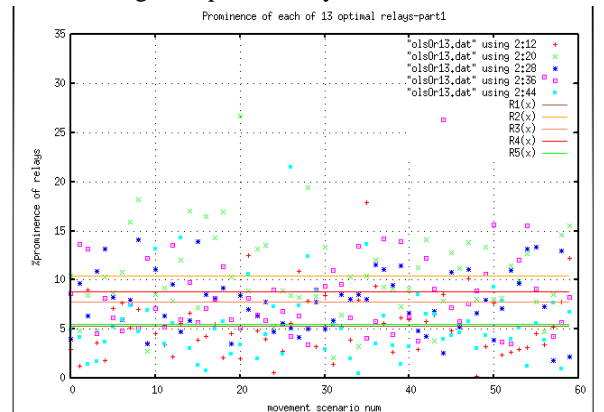


Fig 8(i): Prominence of relays –13 optimal relays (R1-R5)

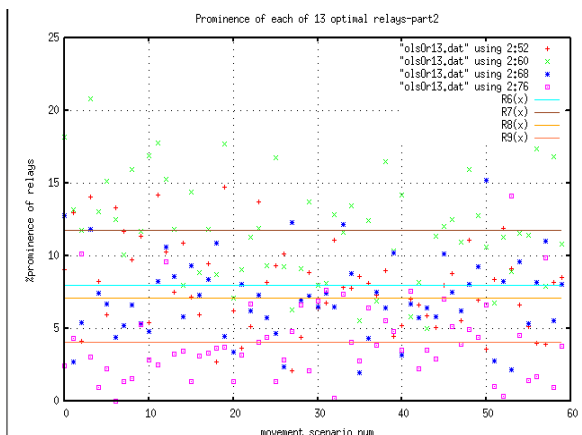


Fig 8(ii): Prominence of relays –13 optimal relays (R6-R9)

Relays	R11	R12	R13	R14
PDT	11.14	9.74	6.63	3.87
PR	2.88	2.52	1.71	1.00

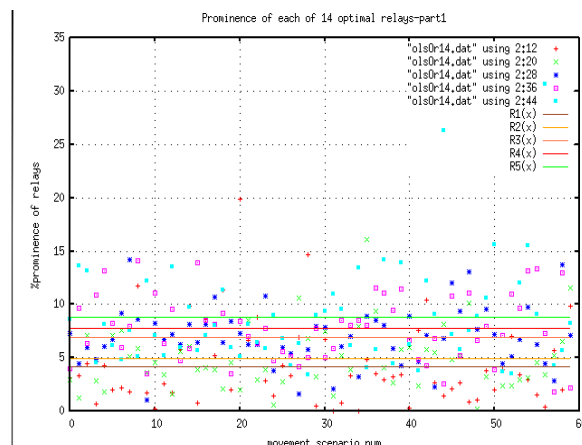


Fig 9(i): Prominence of relays –14 optimal relays (R1-R5)

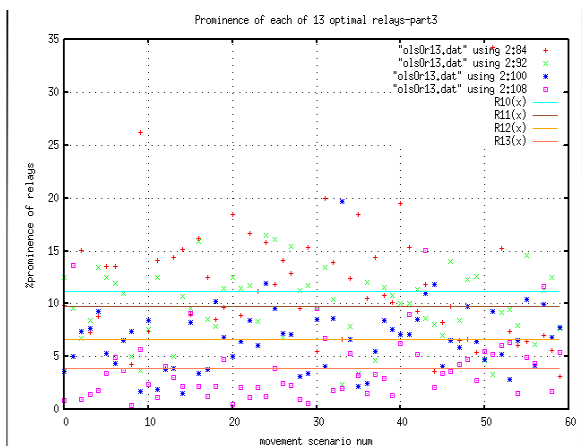


Fig 8(iii): Prominence of relays –13 optimal relays (R10-R13)

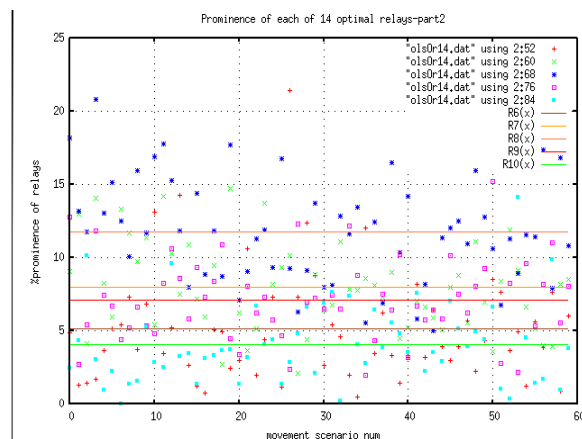


Fig 9(ii): Prominence of relays –14 optimal relays (R6-R10)

Relays	R1	R2	R3	R4	R5
PDT	5.32	10.43	7.72	8.76	5.47
PR	1.37	2.70	1.99	2.26	1.41

Relays	R6	R7	R8	R9	R10
PDT	7.96	11.77	7.13	4.08	11.14
PR	2.06	3.04	1.84	1.05	2.88

Relays	R11	R12	R13
PDT	9.74	6.63	3.87
PR	2.52	1.71	1.00

There is quite some significant disparities in the prominence ratios. This clearly indicates possibility of re-arranging the relays by trial and error to get better performance. This arrangement can, however, serve as a good starting point or an intermediate state for future upgrades.

9. Using 14 Optimal relays.

Relays	R1	R2	R3	R4	R5
PDT	4.20	4.93	6.95	7.72	8.76
PR	1.09	1.27	1.80	1.99	2.26

Relays	R6	R7	R8	R9	R10
PDT	5.14	7.96	11.77	7.13	4.08
PR	1.33	2.06	3.04	1.84	1.05

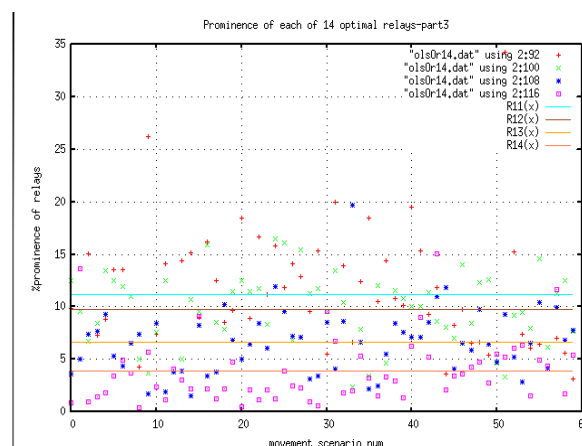


Fig 9(iii): Prominence of relays –14 optimal relays (R11-R14)

There are some disparities but most relays are having % prominence between 5 and 10. Rearrangement of these relays to improve performance may be attempted

by trial and error but the margin of improvement is expected to be small.

10. Using 15 optimal relays.

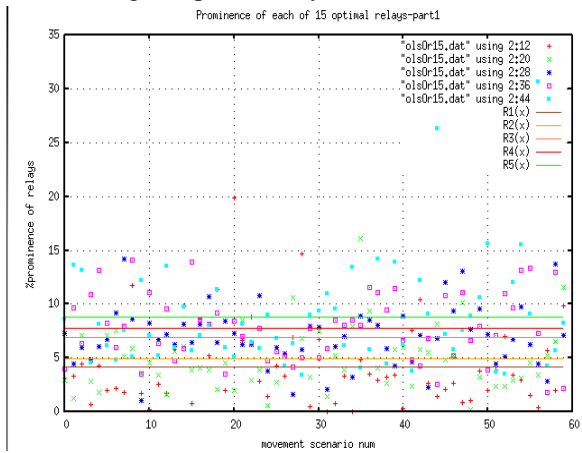


Fig 10(i): Prominence of relays –15 optimal relays (R1-R5)

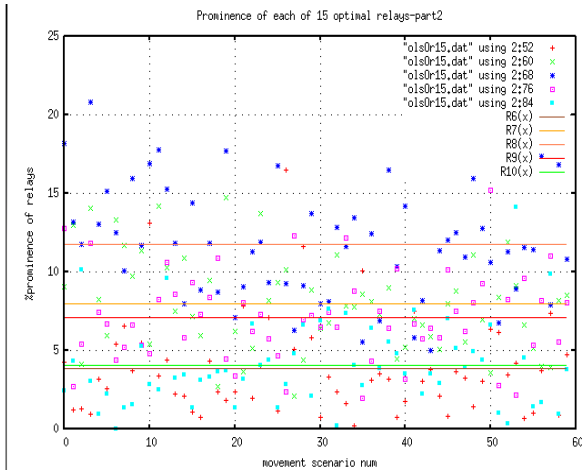


Fig 10(ii): Prominence of relays –15 optimal relays (R6-R10)

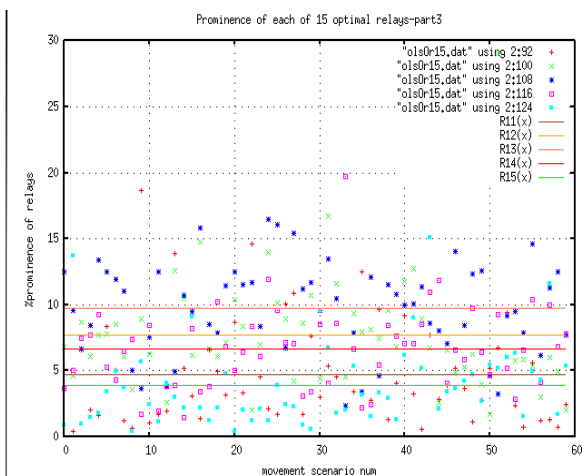


Fig 10(iii): Prominence of relays –15 optimal relays (R11-R15)

Relays	R1	R2	R3	R4	R5
PDT	4.20	4.93	6.95	7.72	8.76
PR	1.09	1.28	1.81	2.01	2.28

Relays	R6	R7	R8	R9	R10
PDT	3.85	7.96	11.77	7.13	4.08
PR	1.00	2.07	3.06	1.85	1.06

Relays	R11	R12	R13	R14	R15
PDT	4.68	7.74	9.74	6.63	3.87
PR	1.22	2.01	2.53	1.72	1.01

There are some disparities but most relays are having % prominence between 5% and 10%. Rearrangement may be attempted but margin of improvement is expected to be small.

11. Using 16 optimal relays.

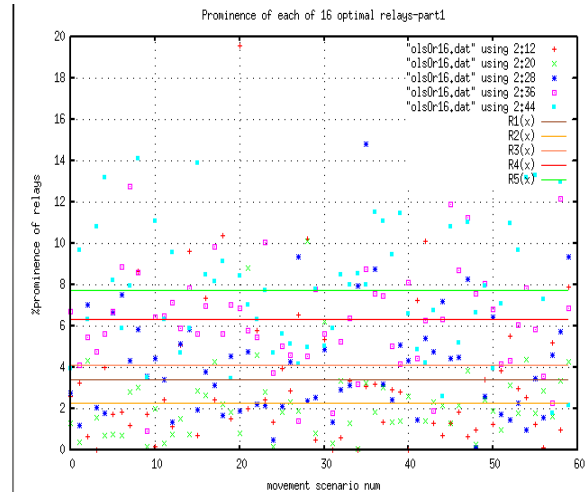


Fig 11(i): Prominence of relays –16 optimal relays (R1-R5)

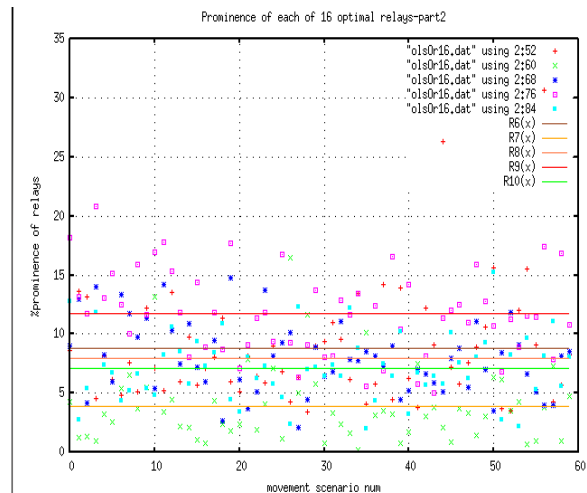


Fig 11(ii): Prominence of relays –16 optimal relays (R6-R10)

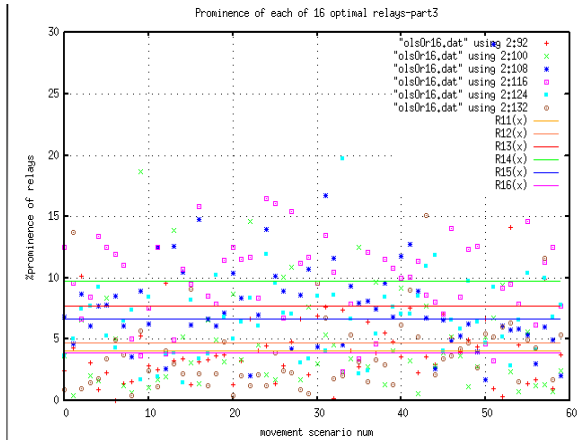


Fig 11(iii): Prominence of relays –16 optimal relays (R6-R10)

Relays	R1	R2	R3	R4	R5
PDT	3.39	2.29	4.09	6.31	7.72
PR	1.48	1.00	1.79	2.76	3.37
Relays	R6	R7	R8	R9	R10
PDT	8.76	3.86	7.96	11.77	7.13
PR	3.83	1.69	3.48	5.14	3.31
Relays	R11	R12	R13	R14	R15
PDT	4.08	4.68	7.74	9.74	6.63
PR	1.78	2.04	3.38	4.25	2.90
Relays	R16				
PDT	3.87				
PR	1.69				

The prominence ratios depict very few disparities except for a few lines R9, R14 (the high side) and R2, R16 (the low side). Relatively smaller margin for further optimisation through rearrangement for performance improvement can be envisaged.

This arrangement remains a viable one and the performance offered also is good.

3.2 Specific Observations and Formulations.

- i. Uniformising data traffic across relays not possible.
Starting from the attempt of optimising energy savings described in previous paper [8], amount of data transits through each relay will not be uniformised. There will still be certain places where relays will be more prominent than others in aubicomp topography. This implies that there will be need to ensure tailoring of relay powers according to certain minimal thresholds observed.
- ii. Further support for suitability of relays close to central axes.
Scenarios of optimisation of number of relays, bringing remaining relays closer to central axes or the CPOI, have brought better success for energy savings scenarios as well as

uniformising data traffic across each relay. This adds support to the notion of suitability of relays close to the central axes.

- iii. All arrangements suitable towards further upgrade.
Continued from previous paper [8], here also all arrangements remain acceptable despite uniformising data traffic across each relay is not reached. They remain suitable for future upgrades.
- iv. Study of Prominence Ratios.
This piece of study does give indication of further optimisation possible by trial and error. But this will be more subjective to the designer’s choice and its minute details will certainly vary with different sets of random movement and communication scenarios. This possibility of refinement will be decided by a designer on a particular project following the more exact movement and communication scenarios applicable in the respective project.
- v. Formulation of Relay Omission Criteria.

Mention was made in part 1 under section 3.2 in previous paper [7] about need for plausible criteria for omission of relays. After several trials (and errors), the following simple method is being put forward as follows:

Step 1: Calculate Expected %data transits, E(PDT), following the number of relays being used (n).

$$E(PDT) = (100/n)\%$$

Step 2: Establish threshold value of E(PDT) using a chosen threshold fraction/percentage. The value of this threshold fraction may certainly vary from each designer’s perspective taking in consideration, also, the initial relay density. It is proposed that the threshold fraction may be high if starting from a high node density (above 50 in a topography of 300 x 300 m²). If threshold fraction is assumed at 0.75,

$$\text{Threshold Value of } E(PDT) = \text{threshold fraction} * PDT = 0.75 * E(PDT)$$

Step 3: Identify relays that can be omitted, i.e., relays having PDT less than the threshold value, can be good candidates to be omitted.

4. Conclusion.

This piece of study is a follow-up from 8 previous papers [1-8]. The nature of this investigation has been to study the average prominence ratios of relays over 11 scenarios of optimally placed relays in aubicomp topography of 300 x 300 m². For each relay density

scenarios, the study was made over 60 different movement scenarios and hence graphical plot is used to display the results obtained.

This piece of study has provided another set of observations about prominence of placements of relays after a previous study [7]. Here, the least prominent relays identified [7] have been removed and scenarios of optimal placement of relays are investigated. Again, a further workable idea of lower and upper bounds of PDT through each relay is obtained from tabular displays. This may provide additional assistance to designers to better plan for relay capacities needed in ubicomp topography. The differences in prominence ratios are also clear in each tabular result displays. The indication of feasibility of each scenario is also expressed. More such studies are recommended for better bounding of tendencies observable. A basic relay omission criteria is also put forward and suitability of relays close to central axes is reinforced.

Overall, this study has explored one avenue of investigation identified in previous paper [7] over optimised number of relays. Finally, these sets of studies will contribute towards formulating reliability models and accompanying metrics sets for enhancements of ubicomp reliability features and architecture support needed in the near future.

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