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

M. Kaleem GALAMALI, Assoc. Prof Nawaz MOHAMUDALLY

Abstract - **Tracking Location in mobile environment has been a subject of research for quite long and significant progress has been reached. [1-16]. The next stage has been to make use of this Location-awareness to devise new functionalities and application and also to improve ways of doing existing activities like transmission change from omnidirectional, whole area coverage to directed location-aware and adapted transmission. A big area missing in MAUC is the software engineering approaches into metrics development, metrics gathering and modelling which can be used for prediction and better gearing of future investments of resources. The particular area of concern here is about energy consideration in Ubicomp. How much energy savings can be achieved? Is there any pattern that the trend of energy savings follow under different sets of conditions? Can these conditions be controlled to achieve a particular desirable energy savings trend? How to gather information on probabilities of saving less than a particular percentage of energy?**

The need of formulating applicable models is felt specially since these will involve lots of work. The models can be made use of by designers to formulate better architectures of ubicomp components.

Key terms: MAUC-Mobile and Ubiquitous Computing

M. Kaleem GALAMALI,
University of Technology Mauritius, (student)
Mauritius

Assoc. Prof Nawaz Mohamudally
University of Technology Mauritius,
Mauritius

1. Introduction

Energy consumption is among the most important features in MAUC. It varies proportional to the square of distance. Energy also depend on amount of information being transmitted, i.e. number and size of packets, and duration of transmission. Other factors like speed of motion, peculiarities of topography, noise levels and flow control strategies may also be considerable. An attempt has been made to find a particular trend/model which depicts energy savings that can be reached in MAUC to rate the effectiveness of Location-aware transmission strategies when compared to the theoretical/empirical models derived in simulations.

Location-awareness is a matter of continual update of information. Current levels of technology [referenced in abstract] may not provide so high refresh rates, but to begin with, in simulation, the model that can be achieved, in case of very exact high refresh-rate location update, has to be formulated to see the limits of the model beyond which very little progress could be reached and to rate amounts of investments needed to reach a particular progress, in terms of energy management.

The key contribution of this paper is the development of an empirical, simulation-based model of savings reachable by applying location-aware transmission strategy in direct node-to-node communication in mobile environment. The model suggested in this paper is the normal distribution model. The rest of this paper is organised as follows: section 2- Particularities of experiment design, section 3- Study of Results obtained and Observations from results, section 4- Conclusion and References

2. Experiment Design

2.1 Software and Platform Used.

An appropriate simulation software chosen is NS-2 [17]. It is an Event-driven simulation software and has lots of added features [18]. It was designed for unix and linux platforms. There is no windows version for NS. Attempts for middleware like cywin [19-20] have not kept up with new developments. Solutions being adopted by many technicians is installing NS over Linux over VMWare over Windows.

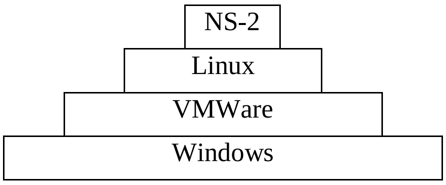

Figure 1: Layout of NS2 over Linux on VMWare.

In this way obtaining a functional NS is achievable for Linux and Windows users. Some Linux knowledge help in.

2.2 Experiment Topography.

Most documents from the Internet have referred to a topography of 300x300 m^2 as a granule of MAUC environment. For larger areas, use of relays would be more evident. Movement over 2D topography is available in NS (section 2.6)

2.3 Initial Positionings of relays.

This is taken to be uniformly distributed over the topography. Random positioning could also have been used. It does not affect the overall random movement and communication patterns to be observed.

2.4 Types of movement scenarios used.

Use of Random feature would make scenarios not reproducible. Hence use of pre-established movement scenarios stored in files have been considered. These were generated using "random" feature. Such movements though random, remain reproducible.

2.5 Type of Communication used.

Constant Bit rate (CBR) over UDP has been used.

2.6 Overview of Design Issues for Random Movement Scenarios.

- The following feature was used [17]
  $ns at 50.00 "$node(1) setdest 25.0 20.0 15.0"
  It means that at time 50.0 seconds, node(1) moves to (25.0, 20.0) at speed 15.0 m/s. The code allows for 2D movements.
- Time Consideration to 12 d.p to simulate more real environment.
- Coordinates also taken to 12 d.p.
- Speed of movement of nodes: 0- less than 20 m/s and to 12 d.p
- Number of nodes: 60 have been pre-built.
- Duration of experiment: 250 seconds and number of nodes limited to 7, since beyond these values, experiment generates too much data and can cause system crashes.
- A program for creating 60 Random movement scenarios was built and run.
- Recursion is avoided since program running is very memory consuming.

2.7 Overview of Design issues for creating Random CBR communication scenarios.

- An algorithm catering for any number of nodes is used.
- The number of CBR a node has, varies with number of nodes present and duration of experiment. Limit of 3 has been used, since it reflects a plausible scenario over 250 seconds.
- Size of packets used is between 100 and 1000 bytes.
- Time interval between packet sending varies between 0.001 to 0.010.
- CBR start and stop times taken at 12 d.p.
- Context of CBR is reproducible.

2.8 Simulation Executions.

- 300 simulations have been carried out one after another manually over 2 laptops. Loop execution failed as NS allows only 1 time declaration of an NS simulation (set ns [New Simulator]). Solving this problem would have involved lots of redesign (success is not guaranteed).
- Storage requirements: each simulation has generated about 112 MB of data. A total of 31-40 GB was felt needed to accommodate the experiment.
- Granularity of files to save: 5 simulation results were grouped into 1 file as a compromise between number of files to generate and size of file to generate.

3. Results and observations.

A file for gathering a summary of each CBR transmission containing 6600 records has been extracted and used for investigation.

3.1 % CBR achieving % energy savings.

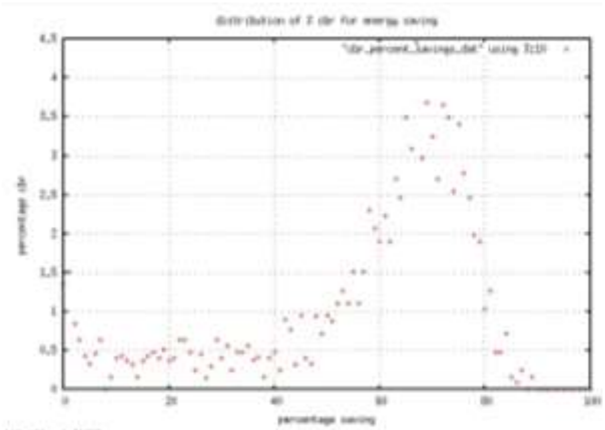

Fig 1: Distribution of % cbr for energy saving.

3.2 Observations from Graph.

i. 1.35% of CBR will be subject to 0% (i.e. less than 0.5% or no energy savings). This may be due to very low or no mobility of the sender and receiver nodes during transmission.

ii. From i. above, it can be implied that 98.65% of CBR will be subject to energy savings by applying location-awareness of per packet transmission. This is also an indication of the importance of applying location aware transmission strategies.

iii. The maximum energy savings reached is 89%. It is reached by 0.16% of CBRs. This proves that there is hope for a very high amount of energy saving though very few transmissions will reach this maximum saving.

iv. The % CBR making savings from above 0.5% to 45% tends to be mostly constant. This will represent around 20% of all CBRs concerned. It also means that more than 80% of the CBRs will make more than 45% energy savings. **This observation gives very strong ground of the efficiency of applying location/distance aware transmissions.**

v. From iv above, we can also observe that attempts to improve energy savings will try to make more CBRs save more than 45% in order to be considered significant improvement.

vi. Beyond 45%, the curve tends to follow a normal distribution with the mode % energy saved is 67% achieved by 3.8% of CBRs (in summary table, it had been 4.46%) of total CBR transmissions. **This observation gives strong suggestion that the tendency of energy savings follows a normal distribution.**

vii. Mostly, the distribution is positively skewed.

viii. Probabilities of energy savings are: 0-10%:6.746%, 0-25%:12.937%, 25-50%:12. 778%, 40-80%:77.937, 60-70%: 32.143%, 45-90%: 78.81%, less than or equal to 50%: 25. 476%, less than or equal to 80%: 96.429%

<u>*3.3 Equation of best fit curve and observations.*</u>

Using the functionalities present in gnuplot, the equation of a normal curve was fed in with mean 67 as follows:

F(x)=(1/(a*sqrt(2*pi)))*exp(-(x-67)*(x-67)/2*a*a)

The value of 'a' obtained is 0.112161. The smooth curve and the smooth bezier plot corresponding to fig 1 is:

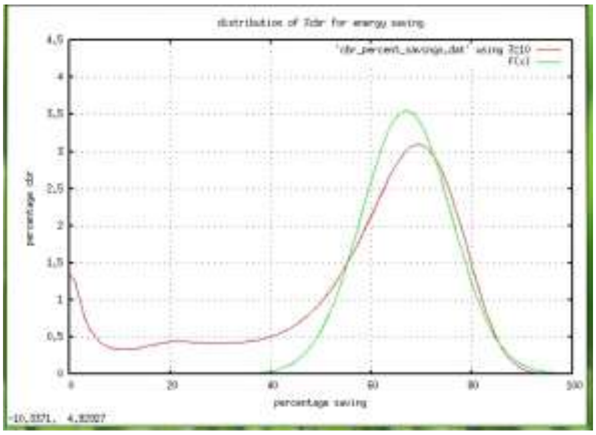

Fig 2: Distribution of % cbr for energy saving-line of best-fit

The plot is very convincing that the model for % energy savings is a normal distribution at mean 67. The curve also suggest that algorithms to save energy on transmission should aim at saving more than 40% for the algorithm to be valid. Algos achieving less than 40% energy savings will have significant resource consumption for processing the algo for lesser significant improvements. The curve remains not appropriate to model energy savings at less than 40%.

The high value of mean is also a very strong suggestion that the model would remain valid (though with decreasing mean) if location updates is done at increasing refresh intervals.

<u>*3.4 Energy savings trend for different time ranges.*</u>

The question investigated here is "Do transmissions of all durations tend to follow the same trend or are there different tendencies for different ranges of transmissions?". It can serve to better adapt transmission strategies and better tailor resource requirements for different transmission ranges. The results are:

i. For duration 0-20 seconds

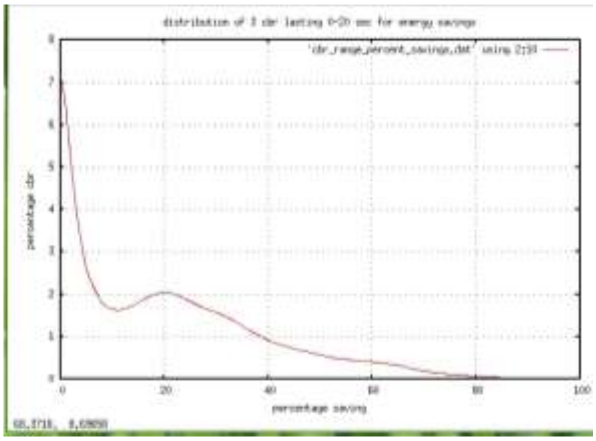

Fig 3: Distribution of % cbr lasting 0-20 sec for energy saving-smooth Bezier

ii. For duration 20-40 seconds

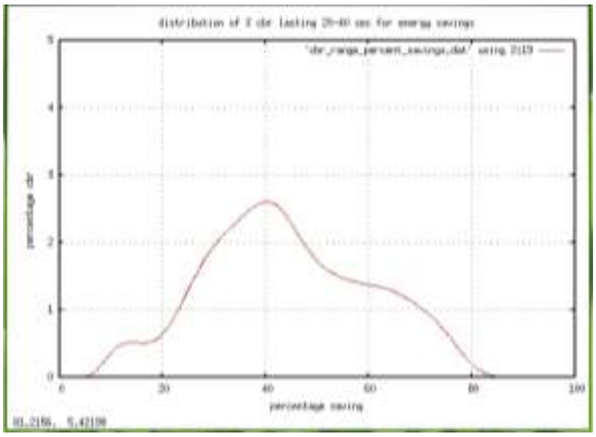

Fig 4: Distribution of % cbr lasting 20-40 sec for energy saving-smooth Bezier

iii. For duration 40-60 seconds

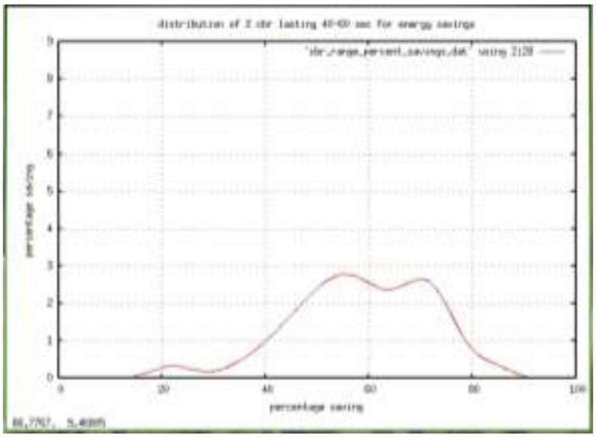

Fig 5: Distribution of % cbr lasting 40-60 sec for energy saving-smooth Bezier

iv. For duration 60-80 seconds

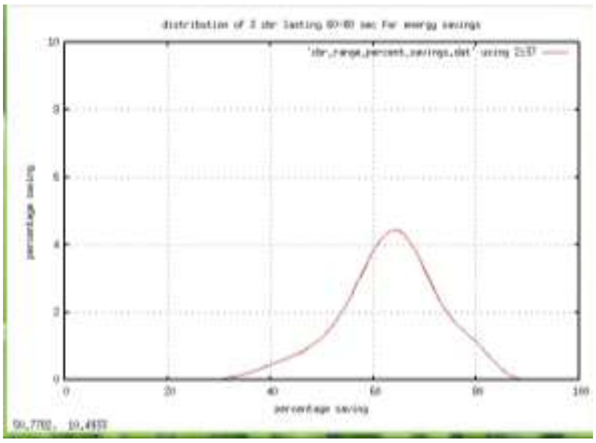

Fig 6: Distribution of % cbr lasting 60-80 sec for energy saving-smooth Bezier

v. For duration 80-100 seconds

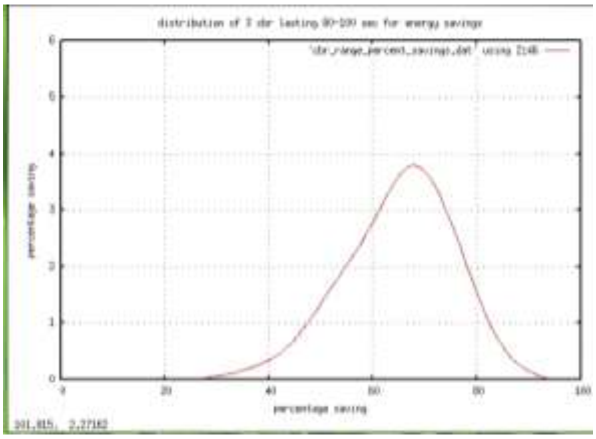

Figure 7: Distribution of % cbr lasting 80-100 sec for energy saving-smooth Bezier

vi. For duration 100-120 seconds

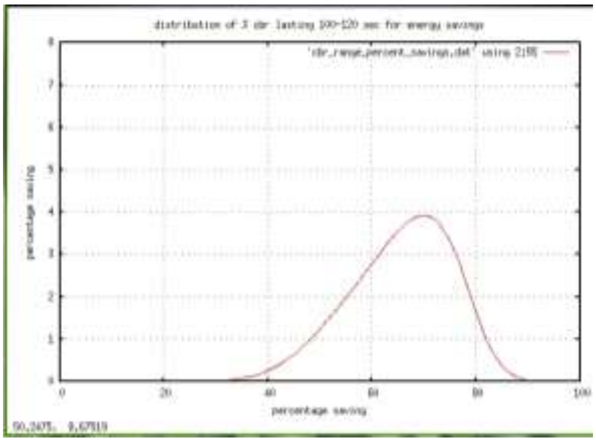

Fig 8: Distribution of % cbr lasting 100-120 sec for energy saving-smooth Bezier

vii. For duration 120-140 seconds

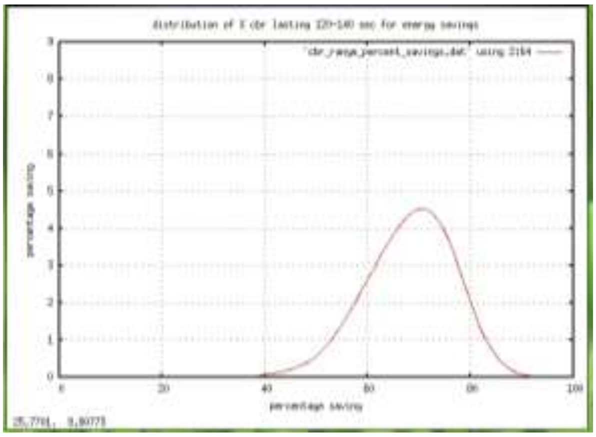

Fig 9: Distribution of % cbr lasting 120-140 sec for energy saving-smooth Bezier

viii. For duration 140-160 seconds

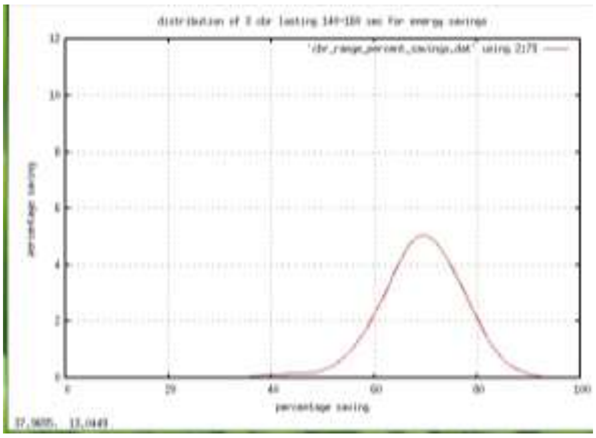

Fig 10: Distribution of % cbr lasting 140-160 sec for energy saving-smooth Bezier

ix. For duration 200-220 seconds

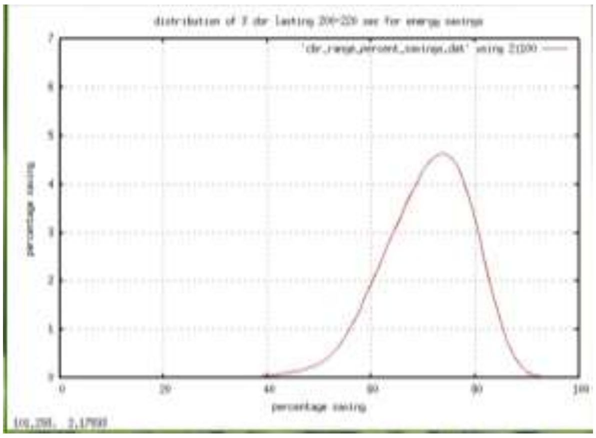

Fig 11: Distribution of % cbr lasting 200-220 sec for energy saving-smooth Bezier

3.5 Observations from graphs in section above.

i. For range 0-20 seconds, most CBRs achieve around 10-45% savings. The trend followed is not a normal curve. Maybe other factors like mobility (speed and direction), bandwidth and packet size are of higher impact. About 5-7% CBRs have no savings, indicating that 5-7% of communications happen during sender and receiver node's immobility. Less than 1% of CBRs achieve more than 40% savings and less than 0.5% CBRs achieve more than 60% savings. Hence, algorithms for managing Location-aware transmission will be of low return. Working towards achieving higher bandwidth, more reliable transmission and other architecture support may be more valuable.

ii. For range 20-40 seconds, again, distribution is not normal. All CBRs tend to have savings above 11%. It indicates that as transmission duration increases, probability of saving energy also increases. Highest saving is 76% and it may apply to very fast moving nodes. Hence, the potential of energy saving with location-aware transmission remains considerably high.

iii. For range 40-60 seconds, the graph gives more distribution between 40%-80%. The normal curve is quite visible but lacks conviction. Maybe other factors are still very consequent. Minimum energy saved is 22%. It indicates that algorithms for location-aware transmission has good return as from 40 seconds of transmission, if location-refresh rates also are very high.

iv. All ranges above 60 seconds show certain similar characteristics. Minimum savings is about 40 % and highest savings is about 80%. The normal curves are very convincing with peaks around 67-70 on the x-axis. However, application of smooth bezier plotting have dampened the peak values. Above 60 seconds, duration of transmission is a major factor which governs potential savings and algorithms for location-aware transmissions will have good return.

v. The expected energy savings achievable is around 67%. This implies that a transmitting node will use only one third of energy required with location-aware transmission than by transmitting at highest intensity required.

vi. The mean value of savings is far from 0; it is at 67%. The minimum value of savings for transmissions above 60 seconds, is far from 0; it is at 40%. This accommodates a lot the application of refresh intervals.

4. Conclusion.

This piece of research has developed a new model of expected trend of energy savings in a topography of 300 x 300 m^2. The model obtained will help to study MAUC environment from a software engineering perspective. This model can be used for prediction and serve as a reference against which reliability of a MAUC environment can be rated. It will also help in formulation of new metrics involved to accompany these models and help to shape the architecture of the MAUC environment.

The study has mostly been empirical study done in simulations. The aim of the study itself was to find the theoretical/empirical limits of the trends observable and models that can be formulated. Real environment implementation would be a much bigger task involving phases like development of lightweight algorithms for location-aware transmission in a MAUC environment, development of land-based location support and integrating them into appropriate algorithms, development of efficient surrogate components with lightweight/rapid OS and accompanying software, new architecture support in MAUC environment and many others. Each such phase is in itself an area of research.

The simulation was carried out in NS-2 installed over Linux. It can be adapted over windows with use of Virtual machines. The experiments were designed and implemented over several weeks and simulation run was done on 2 laptops over many days. Tremendous amount of data has been generated and abundant storage space has been required.

The further study works identified may include: repeating the study with varying refresh intervals and observe trends and models achieved, repeat the experiment using relays, redesign for a study of trends in complete ad hoc environment.

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About Author (s):

Associate Professor Nawaz Mohamudally works at University of Technology, Mauritius and has undertaken supervision of MPhil/PhD Students for many years.

M. Kaleem Galamali is a part-time student at University of Technology, Mauritius under the supervision of A.P. Nawaz Mohamudally.