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

Methodology Formulation for Generating MANET Results for Energy Consumption and Packet Distance Considerations in Ubicomp MANETs.

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***Abstract* – Reliability is among the key features that must be addressed in all pieces of technology in order to undertake wide deployment and integration of the technology in everyday life [1]. This also affects ubicomp whereby knowledge of trends of metrics formulated will serve towards constructing reliability frameworks. Quite some work has been conducted based on simulator in this direction [14-65] and new metrics for ubicomp have been laid forward. In former papers [66-68], it was mentioned that the methodology devised for producing the results concerning the sixteen metrics was also novel and necessitated implementing components not existent so far. The methodology was split into five steps.**

In this paper, the fourth step concerning methodology for generating MANET results for ubicomp MANETs, along with its design and implementation particularities is elaborated. The MANET nodes are assumed as behaving properly and no concern for nodes being supplied as infrastructure or not is taken.

The results of this study may serve towards more refined methodology formulation for generating MANET results for "Energy Consumption" and "Packet Distance" considerations in ubicomp MANETs. This approach may also be adopted for generating many off-the-shelf such components, which would in turn facilitate further empirical research activities. This paper is a retrospective delivery of the fourth of five parts of the methodology designed, over which previous work [14-65] was built over. It also follows the delivery of the first three parts of the methodology [66-68].

Key terms: Ubicomp- Ubiquitous Computing, CBR- Constant Bit Rate, MANET- Mobile Adhoc Network, NS2- Network Simulator 2.

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1. Introduction

A lot of future ubicomp upgrades will be based on probabilistic metrics-based adaptations to provide optimal performance in ubicomp topographies. To help in this aim, knowledge about applicable metrics and their theoretical trends will prove useful and such work have been provided before [14-65]. It would also be beneficial to know the novel methodology developed, including its pertaining design concerns. As mentioned in prior three papers [66-68], the methodology has been split into five components.

i. Tracking of exact positions of ubicomp MANET nodes.
ii. MANET Route formulation and tracking nodes energy expenditure.
iii. Processing of MANET_Routes_Packets_Per_CBR
iv. MANET Results Generations.
v. Automated Extraction of Data From Files

The work published precedingly [14-65] were based on application of exact location-awareness at per packet transmission level. The first three parts have been developed in previous papers [66-68]. The fourth part of the methodology mentioned above, is illustrated as a key contribution of this paper, is built over the first three parts. Again, precision is brought forward that simulator NS2 has been used with a topography of 300 x 300 m^2 with TCL as programming language. The rest of this paper is organised as follows: section 2: Experimental set-up used, section 3: Methodology Details and Section 4: Conclusion and References.

2. Experimental Set-Up Used.

The same experimental set-up described in previous papers [66- 68] is applied here again.

3. Methodology Details.

This concerns programs to gather summarised tabular results from data obtained in previous paper [68] from which section 3.1 is followed.

3.1 Energy Consumption Considerations.

3.1.1 Need for Result of Previous Work and Attempts for Optimisation.

Results needed here, required comparison against data gathered in "Per_CBR_streams_track.dat" obtained in previous work [2]. This file was opened and data required from each record is extracted and assigned to appropriate array variables. This gives advantage of rapidity for further processing as the file consisting of 6300 records and going through it is visibly time consuming. Having assigned values to arrays meant that the need for going through the file is only once. Whenever any information was required, it could then be retrieved from appropriate indices from appropriate array variables.

3.1.2 Identifying Metrics to Analyse.

The metrics over which the empirical study could proceed further have been identified as:

i. Percentage energy saved by sender node.
ii. Percentage energy saved by overall nodes participating in a CBR transmission.
iii. Sender Fairness Proportion.
Fairness proportion is that value obtained when overall energy consumed for a CBR is divided equally by all nodes present in the topography. It is the mean energy to be consumed by each node if the transmission task was equally shared by all nodes.
iv. Overall fairness proportions.
v. Maximum fairness proportion being noted.
vi. Minimum fairness proportion being noted.
vii. Overall energy consumption ratio summary, i.e. the measure of how many nodes and corresponding percentages are achieving what ratios.
viii. Maximum ratios noted, i.e. the measure of number of CBRs and corresponding percentages achieving maximum ratio values compared against sender.
ix. Minimum ratios noted.
x. Overall fairness ratios, i.e. ratio of number of nodes spending less than sender node against the sum of sender node plus number of nodes spending equal or more than sender node.
xi. Overall node savings less node-to-node energy savings.
This will be the measure of extra savings achieved against node-to-node energy savings.

Sender node savings less node-to-node energy savings, i.e. the measure of extra savings being effected by sender only compared to node-to-node energy savings.

3.1.3 Methodology Sequence Adopted.

For each node number, a file "energy_consideration_summary.dat" is to be derived with information towards reaching the above 12 metrics calculated. Each record would be the summary record for each CBR. The work is thus done in nested loops as follows:

```
 for {set movement_num 0} {$movement_num <=59} {incr
movement_num} {
  for {set CBR_index 0} {$CBR_index <=104} {incr
CBR_index} {
            Processing for deriving
        energy_consideration_summary.dat
           }
         }
```

Previous to the above loop, the following is initialised

```
        for {set i 0} {$i <=104} {incr i} {
              set num_nodes_ratio($i) 0
              set num_nodes_fp($i) 0
        }
              Set total_num_nodes_ratio 0
              Set total_num_nodes_fp 0
```

The above four initialised variables defined are also processed during the single execution of the nested loop above, to increase speed of execution.

To have a workable/observable number of records, the metrics defined are rounded as:

- *Rounded to nearest unit*: overall energy savings, overall less node-to-node energy savings, sender energy savings, sender less node-to-node energy savings.
- *Rounded to nearest 1 d.p*: overall fp, overall ratio, max fp, max ratio, min fp, sender fp.
- *Rounded to nearest 2 d.p*: min ratio, overall fairness ratio.

A record in file "energy_consideration_summary.dat" consists of the CBR number, the BRE value and each of the metrics name followed by their unrounded value.

Following the initialisation of the four variables, overall fp and overall ratio are compiled with the following pieces of data: actual fp, num_nodes with corresponding fp, total number of nodes, corresponding % of nodes, num_nodes less than or equal to the actual fp, num_nodes greater than or equal to the actual fp. For each of these two metrics, a separate file is saved for graph plottings.

For each of the metrics in section 3.1.2 of this paper except metrics number (iv) and (vii), the file energy_consideration_summary.dat is opened for the processing calculation.

For each node number, the processing is quite rapid, each taking about 2 minutes. There is no big need for monitoring progresses as suspending program execution is not envisaged here. Overall, this processing is very rapid and can be applied over complete data for each node numbers explained in previous paper [68] as and when they are ready. Here also, results are compiled including the following: actual value, corresponding number of nodes and percentage, corresponding number of nodes less than or equal actual value, corresponding number of nodes greater or equal and respective percentages.

Loop execution for node numbers 7 until 56 could be attempted but is preferably avoided since it would have required additional testings which do not enhance the value here, and data for all node numbers are not all available at once. These data are ready in a piecemeal fashion.

3.1.4 Folder Structure Needed to Save Results.

A parent folder named "MANET_Results_gen" is created with a subfolder "Energy_considerations" containing 50 subfolders named node_num_7, node_num_8,…. Until node_num_56, whereby in each 13 output files will be stored.

3.1.5 Storage Requirements.

The storage requirements are expected to be smaller than previous files since mostly summary files are being dealt with. Need for assistance from external hard disk is not felt here. The detailed storage space needed here are as follows in **Table 1** with headings A→ node_number, B→Storage size.

A	B	A	B
7	4.7 MB	32	7.5 MB
8	5.5 MB	33	7.5 MB
9	6.1 MB	34	7.6 MB
10	5.5 MB	35	7.7 MB
11	5.6 MB	36	7.8 MB
12	5.7 MB	37	7.9 MB
13	5.8 MB	38	8.1 MB
14	5.9 MB	39	8.0 MB
15	6.0 MB	40	8.1 MB
16	6.1 MB	41	8.2 MB
17	6.1 MB	42	8.3 MB
18	6.2 MB	43	8.4 MB
19	6.3 MB	44	8.5 MB
20	6.4 MB	45	8.5 MB
21	6.5 MB	46	8.6 MB
22	6.6 MB	47	8.9 MB
23	6.7 MB	48	8.8 MB
24	6.8 MB	49	8.9 MB
25	6.9 MB	50	9.0 MB
26	6.9 MB	51	9.1 MB
27	7.0 MB	52	9.2 MB
28	7.1 MB	53	9.3 MB
29	7.2 MB	54	9.3 MB
30	7.3 MB	55	9.4 MB
31	7.4 MB	56	9.6 MB
Overall Space needed here			**370.5 MB**

Table 1: Energy Consumption Considerations-storage space

3.1.6 Program Optimisation.

The expected sections that could cause delay in execution had already been identified and explained in section 3.1.1 of this paper and no further optimisation is felt necessary since the program completion time for each node number is satisfactory.

3.1.7 Major Problems Encountered.

The program as described in section 3.4.1.3 has worked only for node number 7. For node number 8, a big problem was noticed since the values of ratios increased drastically. Certain values were greater than 20 million. An initial attempt of increasing loop range from 0-100000 to 0-20 million in the initialisation section failed with memory allocation error (not enough RAM memory to sustain operation).

This problem was affecting data gathering for 2 sections:

i. Energy_consideration_ratio_summary
ii. Assembling max_ratio_summary.

These two sections were initially commented to test if remaining sections work correctly, which was the case.

To solve this problem, a serious program redesign was important. It was noticed that in initialisation loop described in section 3.1.3 of this paper, not all values were needed in program execution. It was hence decided to initialise values of ratios as and when they were discovered and confirmed to be new. The number of CBRs corresponding to the discovered ratios was incremented accordingly. The newly discovered ratios were stored in an array is subjected to a bubble sort to arrange the ratios discovered in ascending order. This process was implemented for assembling max_ratio_summary. It worked though bubble sorting took a perceptible amount of time. It was then applied for energy_consideration_ratio_summary. Here, for node number 8, about 12 000 new ratios were discovered and bubble sorting took long but overall, the whole process could be completed in about 7 minutes. For larger node numbers, the sorting was done with increasing number of values and took longer time but overall, the process has been successful. For node number 15, time taken is 20 minutes; for node number 21, time is 35 minutes; for node number 28, it is 45 minutes. (Mostly, when the program were launched, other activities were being carried out in parallel: Studying gnuplot, performing certain graphical plots, writing next programs to run etc.)

3.2 Packets Per Distance Considerations.

3.2.1 General Design Guidelines.

The processing required here is relatively small to gather the summary of number of packets being sent over each distance rounded in metre.

Minimum distance of a transmission is 0 m (i.e. 0 until less than 0.5 m). The maximum distance could be considered as the diagonal distance (around 424 m). Correspondingly the following is initialised.

```
for {set i 0} {$i <=500} {incr i} {
      set total_num_packet_distance($i) 0
  }
```

For each node number 7 until 56, a file "pkts_per_dist_summary.dat" is created. The program is run in a nested loop as follows:

```
 for {set movement_num 0} {$movement_num <=59} {incr
movement_num} {
  for {set CBR_index 0} {$CBR_index <=104} {incr
CBR_index} {
```

```
            Processing pkts per distance
        }
    }
```

As processing pkts per distance, the files "summary_num_pkts_dist_CBR_$i" are opened successively and the info about total_num_packets corresponding to each meter distance is updated. The corresponding information for num packets less_than_or_equal_to and greater_than_or_equal_to each distance and corresponding percentages are saved. An example record is

```
dist(m): 0 total_num_pkts 4152834 of_total 422948945
rep_%_of 0.98187595668314054 <= 4152834 %<=
0.98187595668314054 >= 422948945 %>= 100.0
```

Saving is done for a record only if value of total_num_packets_distance ($i) is greater than 0. This is to save on storage space and facilitate data analysis.

For each node number, the processing is again quite rapid, each taking about 2 minutes. Again, no big need for monitoring progresses is felt and program execution is satisfactorily rapid, involving no anticipated suspension.

3.2.2 Folder Structure Needed.

Inside the folder "MANET_Results_gen" explained in section 3.1.4 of this paper, a subfolder "distance_pkt_sent_considerations" is created inside which 50 sub folders corresponding to node_numbers 7 until 56 is created. Each node_number subfolder will host 1 file "pkts_per_dist_summary.dat".

3.2.3 Storage Requirements.

The output files are quite small as seen in the following **table 2** with headers A→node number, B→Storage Size (in KB).

A	B	A	B
7	894.4	32	892.4
8	890.1	33	894.1
9	890.8	34	893.0
10	889.6	35	893.0
11	889.9	36	902.9
12	890.0	37	904.0
13	891.3	38	903.3
14	890.6	39	904.9
15	893.0	40	907.1
16	893.2	41	905.4
17	890.8	42	903.5
18	891.5	43	907.4
19	891.4	44	904.4
20	891.8	45	901.7
21	893.7	46	903.4
22	892.4	47	903.7
23	895.0	48	904.2
24	898.0	49	903.5
25	896.6	50	902.6
26	894.4	51	901.7
27	891.8	52	900.2
28	892.3	53	900.6
29	892.9	54	901.3
30	892.0	55	900.0
31	890.8	56	901.1
Overall Space Needed here			44 847.7

Table 2: Packets_Per_distance – Storage Space

3.2.4 Other Metrics Studied.

Three additional topics of study have been identified:

i. Number and percentage CBRs experiencing minimum distance from each unit of 0 until 450 m.
ii. Number and percentage CBRs experiencing maximum distance from each unit of 0 until 450 m.
iii. Number and percentage CBRs experiencing range distance between minimum and maximum distance from each unit of 0 until 450 m.

These required values are gathered during the running of program as described in section 3.2 of this paper and a one-line summary corresponding to each movement and CBR index is saved in a file "dist_range_summary.dat".

For each of the three topics of study identified above, the file "dist_range_summary.dat" is opened for reading and appropriate processing is performed to assemble tabular data which includes values for the "less_than_or_equal_to", the also necessary value of "greater_than_or_equal_to" and percentages. Each of these three processing is implemented in one file which are called in sequence at the end of the loop described in section 3.2 of this paper after closing files opened for writing.

It results that 4 tabular data files are generated in a single round of program execution.

3.2.5 Execution Times Noted.

One round of execution is effected for each node number. The times taken for initial rounds for node numbers 7 and 8 were noted at roughly 2 minutes (very rapid). The time taken increases gradually for increasing node numbers; for node number 25, a time of roughly 5 minutes is noted. Overall, this process of summary gathering is extremely rapid as compared to programs described in section 3.3.

3.2.6 Major Problems Encountered.

A major problem in processing results has been found in total number of packets as from node_num 36 and onwards in files "*pkts_per_dist*". Indeed, as number of nodes increases, there is a tendency for total number of packets in circulation to increase. At a point, it becomes negative, which is a computational malfunction dealing with limits of TCL.

After investigation, it was found that the maximum integer allowable in TCL (programming Language used in NS-2) is 2^{31}-1 (2 147 483 647), since a maximum of 32 bits is used, with one bit for the sign [Cleverl, 2005]. The total number of packets were exceeding this maximum value for successive node_num as from 36.

The impact must also be analysed in the results. The consequence was that the required percentages and cumulative data were being garbled. Percentages like -167.2034…(to 12 d.p) could be found. The number of packets for each distance in each record was **not** garbled.

A solution was devised using simple mathematics concepts to prevent data from exceeding the limit of 2^{31}-1. Usually,

$\sum x = x1 + x2 + x3 + \ldots$ Where x1, x2, x3,….. are data from successive records in file

Here, x will be number of packets for each recorded distance. The problem is though each x value is correct, the sum will exceed the maximum limit.

What is done is simply that each data retrieved is multiplied by a multiplication factor of 0.1 after which the results are added.

$$y1 = x1 * 0.1$$
$$\sum y = y1 + y2 + y3$$

Here, $\sum y$ will be smaller (reduced to one tenth of the original $\sum x$), and hence may not exceed the maximum limit. To calculate the percentage represented by x1, the process is simple.

$$\text{Percentage } x1 = [[x1 * 0.1] / \sum y] * 100.$$

Hence, using the "pkts_per_dist" files and applying the above, described procedure, the problem could be solved and the corrected data saved in another file.

The solution is more fault tolerant, since in case $\sum y$ is also exceeding the max limit, the multiplication factor used here (0.1) could be reduced to 0.01 or 0.001 (or lesser) to make the work continue. This solution has been successfully applied as from node_num 36 onwards.

4. Conclusion.

This piece of investigation has delivered, to good levels of details, the formulation of a methodology and implementation of a method for generating MANET results for Energy Consumption and Packet Distance Considerations in ubicomp MANETs. TCL was the programming language used to implement the programs required. Processed data were stored and rounded to appropriate decimal places. Such a methodology with modifications/refinements may be used by other researchers embarking on empirical research in ubicomp to unveil new metrics. This methodology has been novel and such components were not pre-existing. This methodology has been the fourth of five components formulations over which empirical research [14-65] have been feasible; this study, however, remains a complete one standing on its own.

This methodology was designed without concern for nodes in the MANET being supplied as infrastructure or not and assuming that all nodes behave properly in the topography. The results of this study can serve towards better formulation of methodology for generating MANET results for Energy Consumption and Packet Distance considerations in ubicomp. Many off-the-shelf empirical components may also be generated for further research to be facilitated.

Further work identified remains developing the methodology for the last component identified in section 1 of this paper.

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