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Methodology of Processing MANET Routes for each Transmission Packet of a CBR in Ubicomp MANETs Using NS2.

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Abstract – **For engineering fields to evolve, the concept of reliability must be brought in and fine-tuned towards excellent implemented achievements. Different engineering fields will be having different reliability notions but one common trend of progress among these fields is the need to devise metrics for quantifiable measurement and producing the knowledge of the theoretical trends for these metrics. Ubicomp also faces the need for dependability [1] and quite some work in producing metrics and their theoretical trends have been carried out [14-65]. In former papers [66, 67], it was mentioned that the methodology used for developing the results concerning the sixteen metrics has also been novel and involved implementing components not available formerly. This methodology was split into five steps.**

In this paper, the third step concerning methodology for processing MANET Routes for each transmission packet of a CBR in ubicomp MANETs, along with its design and implementation particularities are reported. Here also, no concern for nodes being supplied as infrastructure or not, nor misbehaviour in MANETs nodes are catered for.

The results of this study may serve towards better formulation of processing for MANET Routes for each transmission packet of CBRs in other ubicomp topographies or using this methodology for preparing many off-the-shelf such components over different movement and communication scenarios. Such availability of off-the-shelf components will facilitate further empirical research activities. This paper is a retrospective delivery of the third of five parts of the methodology designed over which previous work [14-65] was built over. It also follows the delivery of the first 2 parts of the methodology [66, 67].

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

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1. Introduction

Knowledge of ubicomp and MANET behaviour is becoming increasingly necessary to apply probabilistic metric based adaptations to optimise on energy consumption and fairness features. For this purpose, knowledge about applicable metrics and their theoretical trends will be useful and have been provided before [14-65]. It is also needful to know the novel methodology developed, including its pertaining design concerns. As mentioned in prior two papers [66, 67], the methodology was 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 formerly [14-65] were based on application of exact location-awareness at per packet transmission level. The first two parts have been illustrated in previous papers [66, 67]. The third part of the methodology mentioned above and illustrated as a key contribution of this paper is built over the first two parts. Again, it is pointed out that simulator software NS2 has been used with a topography of 300 x 300 m^2. 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, 67] is applied here again.

3. Methodology Details.

3.1 Identifying Aspects to Process.

After having generated the data detailed in previous paper [67] and summarised in section 3.2.9 in that paper [67], the next step will be to identify what data has to be extracted from it or generated by further processing. This will result from identifying the streams of analysis that may follow from it. Three areas have been identified as follows:

i. Energy Consumption Considerations

These can include total energy consumed by sending nodes, energy savings achieved by sending node, total energy consumed by all nodes in CBR and corresponding energy savings achieved, ratios of energy consumed by each node with respect to sending node, fairness proportion reached by each node.

ii. *Link/Route information analysis and trend formulation.*

These can include hop_count, route stability and individual link stability (in form of duration), number of unbindings and rebindings, degree of change in route when a change is encountered, nodes disappearing from route but reappearing.

iii. *Packets per distance (in meter) analysis and trend formulation.*

These can include % packets per each distance in meters for varying node densities, probabilities of link failures due to unreachable distance, degree of needs for Ferry Protocol Approaches, Policies of decisions of amounts of reinforcements needed in the topography through fixed/mobile relays and surrogate devices.

3.2 Need for Processing All in One Program.

The three parts mentioned in section 3.1 of this paper must preferably be executed in one program mostly to save on time and complexity of executions. Quite a lot of time will be consumed from copying data from external hard disks to other hard disks for processing. Maximum processing in single copying will save time. Moreover, the processings needed will be carried over same files for MANET_Routes_Packets_Per_CBR and many different processings will follow from same intermediate process results like error filtrations detailed in successive parts of this section, which may be obtained from each record in each of the files for MANET_Routes_Packets_Per_CBR. Hence, a significant amount of time will be saved in processing all at one go. This is achievable as the program will be built in a piecemeal fashion. Complexity of program execution is containable as it will not involve too many nested loops.

3.3 File and Folder Design for MANET Processing.

The folder design, as shown in **figure 1**, must be suitably extensively designed right from beginning so as to accommodate quite vast results of the processes briefed in section 3.1 of this paper.

Building the structure requires caution but will not be difficult since it will involve quite some copy-pasting of sub-structures.

3.4 Error Filtration from Re-use of Previously Designed Components.

Since position tracks are taken at intervals of 1 ms, a tolerance of 0.06 m must be considered. The square_distance tolerance will be 0.0036 as mentioned in section 3.3 of previous paper [66]. It implies that, in files for MANET_Routes_Packets_Per_CBR, a link square distance from a sender node to closest node of less than or equal to 0.0036, sender node and closest node must the same node. Same reasoning applies for the receiving node and its preceding node on the route.

The aspects are analysed in program for sender and receiver nodes and appropriate software corrections are brought forward to correct the information and obtain more reliable data and sender energy consumption and that last intermediate node before receiver and better link information and hop counts.

3.5 Loop Execution of Program.

Loop execution strategy has been adopted since the beginning of this research study. It is the key execution methodology over which this set of experimentations could be carried out with greatest output. Here also, since data files to be processed are available in well indexed folders for node_number and movement number and well indexed files for MANET_Routes_Packets_Per_CBR, loop execution for MANET Processing is envisaged. Three nested loops will be needed as in following algorithm.

```
for {set opt(nn) 7} {$opt(nn) <=50} {incr opt(nn)} {
  for {set movement_num 0} {$movement_num <=59} {incr
movement_num} {
     for {set CBR_index 0} {$CBR_index <=104} {incr
CBR_index} {
               execute program for MANET Processing
      }
    }
}
```

The values for node_numbers, movement_numbers and CBR_indexes will carry forward in variables and will also decide in which target folders the outputs should be stored in. this will require meticulous design but similar experience acquired in previous programs will help rendering this job feasible.

Furthermore, it may be expected that due to varying reasons, loop executions may get blocked with program or data errors. Provisions to re-continue processing, after correction is made, will also be provisioned in 3 steps. Assume program completes for node_number 21, movement number 52 and CBR number 23, resetting program is done as follows

Step i: the innest loop is continued as follows:

```
 for {set opt(nn) 21} {$opt(nn) <=21} {incr opt(nn)}
{
  for {set movement_num 52} {$movement_num <=52}
{incr movement_num} {
   for {set CBR_index 24} {$CBR_index <=104} {incr
CBR_index} {
               execute program for MANET Processing
            }
          }
      }
```

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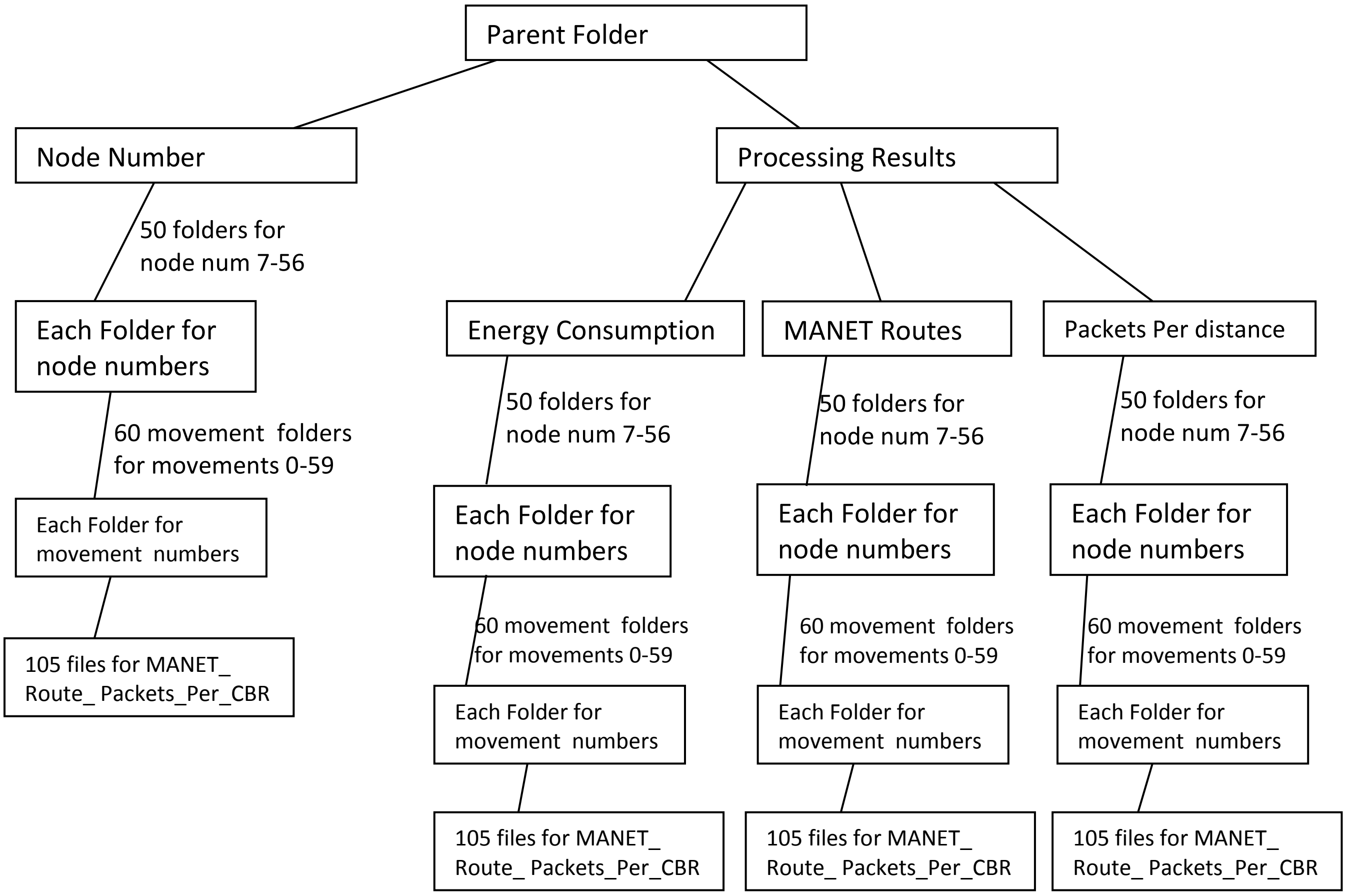

Figure 1: file and folder design for MANET Processing

Step ii: Once the above is completed, another loop for movement number is continued as follows:

```
for {set opt(nn) 21} {$opt(nn) <=21} {incr opt(nn)} {
  for {set movement_num 53} {$movement_num <=59}
{incr movement_num} {
   for {set CBR_index 0} {$CBR_index <=104} {incr
CBR_index} {
      execute program for MANET Processing
            }
          }
      }
```

Step iii: then the triple loop is reset as follows:

```
for {set opt(nn) 22} {$opt(nn) <=56} {incr opt(nn)} {
 for {set movement_num 0} {$movement_num <=59} {incr
movement_num} {
  for {set CBR_index 0} {$CBR_index <=104} {incr
CBR_index} {
      execute program for MANET Processing
            }
          }
      }
```

This design will facilitate loop execution of program over very long hours of work. If no program block occurs, the code described for parts (i-ii) above will simply be commented. They will be activated when necessary in conjunction with the progress monitoring described in section 3.6 of this paper.

3.6 Monitoring Progress Reached.

It is important to keep an explicit record of which files have been processed in the sequence started in for loop in cases of stopping the execution (program/OS crash or electricity gone out). The information in such a monitoring file may then be re-used to manually reset the above mentioned loops to continue. In a way, the monitoring files will be used as a time-stamping component. The information needed for this functionality will comprise of the set of node_number, movement number and CBR file completed. An example of a record is as follows.

```
node_number 7 movement_num 20 CBR 35
```

The words "node_number", "movement_num", and "CBR" are retained for clarity of reading the file and ease of program debugging.

3.7 Hard disk Requirement.

The program was expected to run in loops and hence hard disk space must be appropriately provisioned. The output of the process is like a summarisations gathered from MANET_Routes_Packets_Per_CBR files and is expected to consume lesser space than has been described in section 3.2.9 of previous paper [67]. The limiting factor remains that the input file sizes as described in section 3.2.9 of previous paper [67] to feed in to ensure good continuity of loop execution. This has required purchase of an external 3 TB "Transcend" hard-disk in which the folders "node number" and "processing Results" described in section 3.3 of this paper are placed and the external hard disk is mounted as a virtual folder to the "parent folder".

As and when the processing was continued, the data compiled was as shown in **Table 1** whereby column headings are: C1→Node Number, C2→Energy Consumption, C3→Packets Per Distance

C1	**Processing Results**	
	C2	**C3**
7	4.67 MB	27.6 MB
8	4.65 MB	27.5 MB
9	5.11 MB	27.7 MB
10	5.61 MB	27.9 MB
11	6.05 MB	27.9 MB
12	6.50 MB	28.0 MB
13	6.99 MB	28.1 MB
14	7.4 MB	28.3 MB
15	7.9 MB	28.4 MB
16	8.4 MB	28.4 MB
17	8.9 MB	28.5 MB
18	9.3 MB	28.5 MB
19	9.8 MB	28.6 MB
20	10.2 MB	28.6 MB
21	10.7 MB	28.6 MB
22	11.2 MB	28.6 MB
23	11.7 MB	28.6 MB
24	12.1 MB	28.7 MB
25	12.6 MB	28.8 MB
26	13.1 MB	28.8 MB
27	13.6 MB	28.9 MB
28	14.0 MB	29.0 MB
29	14.5 MB	29.1 MB
30	15.7 MB	29.8 MB
31	16.1 MB	29.8 MB
32	16.6 MB	29.8 MB
33	17.0 MB	29.8 MB
34	17.5 MB	29.9 MB
35	17.9 MB	29.9 MB
36	18.4 MB	29.9 MB
37	18.9 MB	29.9 MB
38	19.4 MB	29.9 MB
39	19.9 MB	29.9 MB
40	20.4 MB	30.0 MB
41	20.8 MB	30.0 MB
42	21.3 MB	30.1 MB
43	21.7 MB	30.0 MB
44	22.2 MB	30.1 MB
45	22.7 MB	30.1 MB
46	23.1 MB	30.1 MB
47	23.6 MB	30.2 MB
48	24.0 MB	30.2 MB
49	24.5 MB	30.3 MB
50	24.9 MB	30.5 MB
51	25.4 MB	30.5 MB
52	25.8 MB	30.5 MB
53	26.3 MB	30.6 MB
54	26.8 MB	30.6 MB
55	27.3 MB	30.6 MB
56	27.7 MB	30.7 MB
Total storage sizes	800.88 MB	1 466.8 MB
Grand Total Storage Sizes needed	**2 267.68 MB**	

Table 1: Storage sizes of processing Results of MANET_Routes_packets_per_CBR.

3.8 Program Optimisation.

One loop execution or even the program for individual CBR file processing was not further optimisable. The program was quite linear for every record of data and the loop was repeated for every record. With an initial study of program execution time noted, a strategy for running programs in parallel was sought of. After some trials, 6 parallel programs consisting of 6 varying ranges of node number, movement numbers and CBR file numbers were launched in 6 different terminals in Linux. This strategy was stopped at 6 terminals since the 6th terminal caused a slight reduction in speed of execution (noticed visually). Some disparities of speeds in different terminals were also noted with time but overall program results were being correct. An accompanying 6 process_monitoring files were created, one for each terminal execution.

On an average, in terminals 1 until 4 (each having about 26 CBRs to process), nine movements for a particular node_number were completed overnight and in terminals 5-6, 4 to 5 movements (each having about 52 CBRs to process) for a particular node number completed in one night.

The overall loop execution in the six different terminals over only one laptop were expected to take quite long, but initially, this could be accommodated since successive programs to be devised as explained in successive sections were also to be pondered over. Therefore this work was esteemed to be feasible to some extent in parallel.

3.9 Problems Encountered.

Sometimes electricity cuts and OS crashes after several days of continuous running required laptop resetting, remounting hard-disks, reset values in loops for the 6 programs to execute in terminals. This process, though trivial, is quite time consuming. Other major technical problems and their solutions are detailed below.

3.9.1 Integrity of Records Problems.

Some major technical problems were encountered which caused program execution to block. This would cause very serious loss of time. These regularly occurring program blocking were assessed as integrity problems with files for MANET_Routes_packets_per_CBR. The first problem has been a record giving an erroneous hop count of 0 (i.e. sender and receiver fully coinciding) after error filtration described in section 3.4 of this problem was performed. The second error occurs when a record is truncated and the explicit word of "endl" in the record is absent. This would lead to loops of finding "endl" to above 25 000 before OS halts the program. The third error occurs when the word "endl" is present but not found at the expected field number. This happens in 2 circumstances: first, when the hop_count is different from the nodes discovered in the record and second, when the record is corrupt after omission or duplication of a few fields within the record.

The data being of massive amounts, a solution of very negligible negative consequences was to just skip such records presenting above described integrity problems.

Codes for integrity checking and skipping the record when integrity errors were encountered were devised and records for lines not fulfilling the integrity checks were also kept in two different files namely "corrupt lines" and "skip_rec_hop_1". The errors occurring in corrupt lines were given error codes. This was important for later analysis of the errors to estimate their gravity and frequency of occurrence. Mostly, a maximum of 3-5 lines were noted in files having errors.

3.9.2 Divide by 0 errors.

Another frequently occurring problem has been the divide by 0 error occurring for cases where a sender has its first neighbour at less than 0.0036 m and the second next neighbour is fully coinciding with first neighbour at 0 m, for every record in the MANET_Routes_packets_per_CBR files. This leads to total energy spent by sender at 0 and leading to divide by 0 error whenever proportions are to be calculated. Solution to this problem was found by a series of steps.

The first solution to this problem was to manually delete the second hop of each record in files having this problem. Deleting is feasible using editor (gedit) "find and replace" commands but this is carried out after program block is detected and quite some time lost. The program would then need to be manually re-executed for the corresponding CBR. A better solution was needed.

Preventing this error in loop execution was felt necessary, hence if the situation of total energy consumed by sender is noted to be 0, a record is saved in a file "div_b_0.dat" about the node number, movement number and CBR file where this error occurred and the total energy is just changed to 1 to prevent program blocking. Data saved are wrong at this time but loop execution could be continued for other CBR files.

A copy of the program for MANET_Process is modified to simply undertake skipping of the first 2 nodes obtained in the route and continue processing. This was achieved and from records in file "div_b_0.dat", concerned CBR files were reprocessed, overwriting previously saved wrong data.

The next improvement is at the end of MANET_Process running; if a divide by 0 error is noted, the program MANET_Process_D_B_0.ns is simply executed for the corresponding node number, movement number and CBR number. This ensured better smoothness in loop executions leading to correct output in the loop itself without need for manual intervention. An additional information "D_B_0 corrected" is added in the concerned record for MANET_Process Monitor files.

3.9.3 Exceptional and rarely occurring errors.

Some rarely occurring errors like erroneously big square_distance were noticed. Program did block very few times but mostly manual intervention has been sufficient.

Another error rarely encountered was when the OS blocked execution when it encountered too many files open. The loop execution variables were reset and program relaunched.

4. Conclusion.

This design and implementation work follows up from previous ones [66, 67] and elaborates to fine level details, the formulation of a methodology and implementation of a method of processing MANET Routes for each transmission packet of a CBR in ubicomp MANETs based on exact positions of ubicomp nodes, which has been gathered using NS2. Here also, strictly for this paper, NS2 was not required; the processing was done in TCL programming language and using file manipulation. The number of decimal places for processed data was to the maximum allowable in TCL. Such a methodology with modifications/refinements remains available for other researchers embarking on empirical research in ubicomp. This methodology has been novel since such components were not pre-existing. The part of the methodology delivered in this paper is the third of five components formulations over which empirical research [14-65] have been possible; this study, however, remains a complete one standing on its own.

This methodology was created irrespective of MANET nodes being supplied as infrastructure or not. MANET nodes are also assumed to be well behaving. The results of this study can serve towards better formulation of processing MANET Routes for each transmission packet of CBRs, or to prepare many off-the-shelf such components and generate library files over various movement and communication patterns in ubicomp for

NS2. This would consequently facilitate work of further research by other researchers.

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

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