Impact of Simulation Results on Ad-Hoc Routing Networks

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Approval

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Abstract

A large amount of research has been done in ad-hoc networks. Most of the research uses simulation as a means of protocol evaluation., The credibility of the published simulation results is very important for productive contribution to research community. Despite of all the analysis and suggestions done in previous studies, repeatability and credibility of simulation based research still not reached the acceptable level of reliability. Most of the simulation studies published are unrealistic, non-reproducible and show statistically invalid results. These pitfalls directly damage the overall integrity of research involving simulation for testing and validation of results. We have conducted a survey to evaluate the current state of simulation studies for these pitfalls particularly in ad-hoc routing protocols. To make the analysis more rigorous, our survey adds mentioned three factors to evaluation criteria. We have also developed a tool for NS2 which helps in repeatability and credibility of simulations.

Certificate of Originality

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any degree or diploma at National University of Sciences & Technology (NUST) School of Electrical Engineering & Computer Science (SEECS) or at any other educational institute, except where due acknowledgement has been made in the thesis. Any contribution made to the research by others, with whom I have worked at NUST SEECS or elsewhere, is explicitly acknowledged in the thesis.

I also declare that the intellectual content of this thesis is the product of my own work, except for the assistance from others in the project's design and conception or in style, presentation and linguistics which has been acknowledged.

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Signature: _____

Acknowledgment

Up and above everything all glory to **ALMIGHTY ALLAH**. The Beneficent, The most Merciful and Most Compassionate. It's a great blessing from Almighty Allah that gives me the health and strength to do this research work.

I would like to special thank the my supervisor **Dr. Mian Hamayun** for his patience, guidance, useful impact and availability throughout my research work.

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My special thanks to **Dr.Rizwan Ahmad** and **Ms.Sarah Shafiq Khan**for being my committee members.

Maria Khalid

Contents

List of Abbreviations

Abbreviations	Descriptions
PRNG	Psudo Random Number Generator
RPGM	Reference Point Group Mobility model
MG	Manhattan Grid Model
GM	Gauss Markov Model
CM	Column Mobility Model
MB	Mobility Models
RPM	Radio Propagation Models

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Chapter 1

INTRODUCTION

The credibility of a research is a major concern among researchers. Research papers are being published in every domain of studies whether its science or arts. To ensure the effectiveness of work done, the content of the publication should reflect all the factors that other researcher may need to reproduce or enhance the idea. Since research is a chain of innovation in which one work leads to another, a research study published which damages the accuracy in anyway is a serious threat to all the work that may follow the flawed work to make further advancement or use it in any reference. The issue of validity and credibility has been repeatedly addressed by many studies in different fields of science [1-4]. Previous studies showed there is no significant improvement towards the problem.

Simulation being a powerful testing tool is very popular among the researchers worldwide. Its usage increases when it comes to computer and telecommunication research for it provides a flexible model construction and verification mechanism. The actual purpose of simulation is to validate the methodology, so it is important that it produces accurate and credible results. However, most of the published research fails to report and document the simulation experiments, which damages the real essence of research.

In this paper we have conducted a survey to know the current state of simulation studies particularly for routing protocols in MANET. A similar analysis was done by Kurkowski et al. (2005). In this study we have found very little improvement in simulation pitfalls identified in it.

Considering the possible downfalls in current studies, we have added three factors to the evaluation criteria. i.e. realistic simulation scenarios, statistical validity and repeatability. The realistic scenario verifies whether the simulation is modeling real world situations, or just a collection of random nodes. The statistical validity verifies whether the methods opted to perform the analysis are statistically sound or not. Repeatability verifies whether the

researcher has provided enough information to public to reproduce or improve upon the same work. These factors are further checked on basis of different parameters stated in published papers. The targeted conferences and journals for the survey includes International Conference on ad-hoc Networks and Wireless, IEEE Wireless Communications and Networking Conference, ACM International Conference on Mobile Computing and Networking, IEEE Transactions on Networking, IEEE International Conference on Computer Communications, and ACM Mobile a d-hoc Networking and Computing. We took all the papers published in last 6 years (2010– 2015) on routing protocols in MANET.

We have also developed an interface for NS2 which simplifies reporting of research work for repeatability and ensures a credible simulation studies in MANET.

1.1 Problem Statement

The present state of MANET simulation studies is not satisfactory as most of it is not taking care of three important aspects of simulation. Majority of the studies are not adopting a realistic scenario for testing, data is not statistically valid and repeatability is also not guaranteed. These three aspects of simulation are being violated hence damaging the credibility and validity of results.

1.2 Thesis Contribution

Our work contributes to check the present situation of MANET studies in terms of realistic, statically valid and repeatable. We also suggest how to do good simulation which may ensure these important factors. This will aid the researchers in conducting effective and reliable simulation studies. This survey will assist the researchers with a set of rules which will be a guideline for them to conduct a simulation study.

As the previous study on credibility of simulation shows that there is inconsistency in people reporting simulation parameters and statistical information, which results in damage of credibility, integrity and repeatability of proposed technique. We have developed an interface for a simulation tool to make the reporting easy. Our tool takes all the possible basic parameter and generates a partial TCL script. We have selected all the parameters which ensure the script to be realistic and credible. To protect repeatability, our tool also generates a report on all the parameters used in form of an XML

file. Which can be used to report and make repeatability possible. Our tool will simplify reporting and standardize things for simulation.

The goal of this research is to raise awareness on the lack of reliability of simulation-based studies and provide solution to counter this problem.

1.3 Thesis Organization

The rest of the thesis is organized as follows:
Chapter 2 discusses about the preliminaries and research carried out so far in the effect of simulation research in Af-Hoc Networks. Chapter 3 describes the approach and parameters to conduct the survey. Chapter 4 has the results of statistical analysis.Chapter 5 includes detailed working of tool. Chapter 6 concludes our thesis with a conclusion and future work direction.

Chapter 2

LITERATURE REVIEW

This chapter discusses previous work done in this domain and how our contribution is different from them. Research has been in done to know the state of MANET simulation studies in terms of credibility. Though credibility is dealt with different perspectives, however the outcomes in every case were alarming. The state of MANET previously is not satisfactory at all.

2.1 Related Work

In this section we will give a brief history of previously done work for this very problem. Research has been done to know the state of MANET simulation studies in terms of credibility. Though it was dealt with different perspectives by different studies, the outcomes were not satisfactory at all. Many studies have raised concerns about the of reliability of simulation research. A good contribution has been made towards finding the state of simulation studies by Kurkowski et al.(2005). The findings of the paper were not encouraging. They reviewed 114 papers published in MobiHoc published between 2000 and 2005 in terms of credibility and found less than 15% of the papers completely repeatable. Only 56 papers mentioned the simulation tool used to simulate and get results. Out of those 56 papers, 87.9% did not state the version of simulation tool which is necessary to get the exact same results as reported in paper. Out of 114 papers ,12% of the papers appeared to be statistically sound for mentioning number of runs and confidence interval in the representation of results. Some of the considered parameters were not enough to fully decide on the accuracy of the simulation. Since the nature of wireless network is very diverse, the transmission range and mobility speed is not enough to define a real scenario [5]. However, this was a good work done to identify the possible pitfalls in simulation studies which damages the

credibility of research published. But not much of their recommendations and suggestions are being followed by the wireless network community.

Another article raised awareness about this particular issue by Andel and Yasinas(2006). This study questions the validity of simulation studies, the working of simulation tool and how they are producing misleading results. The research highlights that the different packages available for simulation are prone to imprecision. It also addresses the repeatability issue due to lack of documentation of research work, simulation tool name, tool version and variable settings for simulation. Results should be accurate and statistically sound, which is possible by using PRNG, optimal number of simulation runs and confidence interval. These are the major findings of this paper and are quite usable for the road to more credible simulation studies. The paper made some addition for credibility criteria in comparison to [6] by discussing about packages, stack protocol layers and simulation model.

Previous studies had put emphasis on repeatability and statistical validity for a reliable simulation study [6][7] which is not a sufficient for credible results. Gunes et al(2006) presents realistic scenario as another aspects of valid simulation results. This study claims that the most important parameters for a realistic environment are mobility model and propagation model. It also conducted a survey on MobiHoc conference publications for realistic scenarios. Their results were quite distressing as only 2 out of 52 paper gave enough information about the mobility and the radio model used which brings up the issue of realistic environment for validation. Moreover, it has been repeatedly highlighted that the realistic scenario is important for authentic conclusions [9].

In past, many studies have raised awareness about the need for credible simulation studies. However, the state of credible research was found unsatisfactory. We also aimed to validate the current state of MANET simulation studies We basically merged the methodology of three big contribution to do the analysis [5-7]. We took the recommendations from [6-7] for repeatability and statistical validity, and added realistic scenario as a third criteria to check the state [5]. We did the analysis on recent proceeding of tier 1 conferences and journal for MANET studies. The other part of our work is the development of tool which will make the reporting easy in a way to ensure the credibility and repeatability of MANET studies.

Chapter 3

Methodology to Conduct Statistical Analysis

This section discusses about the details of the evaluation criteria used for the realization of our concerns. We will talk about the factors we have considered as criteria for reliability and their possible impact on the results. The details of the targeted papers are available is the reference section. In our study the areas of focus are

- How much work is tested against real world situation?
- How many papers have enough details to make them repeatable?
- How much of research published is statistically valid?

Table 3.1: Papers details

Conference or Journal	No of Papers
AdHoc-now	4
IEEE WCNC	25
Infocom	8
Transaction of Networking	3

3.1 Realistic Scenario

This is a major aspect which influences the accuracy of simulation results. A method tested in unrealistic environment does not represent the solution

required for the intended situation. We cannot assess the performance of the method as how it would work in real environment. Since ad-hoc networks are highly dynamic, the movement of the nodes and the radio propagation patterns greatly vary thus effect the performance of the solution. There are studies which proved that when protocol was tested a realistic scenario, the results were different [9]. This very reason made us include the realistic scenario as a criteria for reliable research. Realistic scenario can be tested upon various parameters, however we are considering mobility model and radio propagation model. Keeping in account the unpredictable patterns of mobility in ad-hoc networks, appropriate mobility model should never be omitted [10-11]. Along with mobility, the radio waves patterns should also be considered. Since ad-hoc nodes have a certain transmission range, specific mobility and obstacles, the radio propagation is not always smooth. Some other factors like signal reflection also have dramatic effects on radio signals [12].Radio propagation models offers such patterns implemented, which if not used impact the integrity of outcomes. For our survey we considered any mobility and radio model mentioned in paper.
So to evaluate the reaslistic scenaqrio we are considering two parameters i.e.

- Any mobility model mentioned
- Any radio propagation model mentioned

3.2 Repeatability

Repeatability is a major concern and a moral responsibility of a researcher. To make an effort available to other for testing and improvement, one must address and report his work properly to make it reproducible. To test the state how much studies are repeatable, we checked whether the simulation tool name and version and simulation parameters are reported in papers or not. It is important to mention the tool name because each simulation tool has its own working environment and produces different results for same method tested [7]. To reproduce the same result, one must run the proposed method in same tool as it was run initially. Every new version of a tool has upgradations. Each version may have a different process to evaluate the method hence causes change in results, which makes it important to state version of the tool when reporting your work. After that, simulation parameters should be stated properly. If any of the parameter is missing or not addressed, it is almost impossible to repeat the work in exact same way [8]. As with the growing advancements in studies, tools and requirements,

we cannot report all of the parameters used in paper. But we should address the changes made in default or refer to all the setting available somewhere. To evaluate the repeatability of a paper, the minimum criteria is these three factors

- Name of simulation tool mentioned
- Version of simulation tool mentioned
- Simlation parameters mentioned.The basic paramters for simulation we concidered are The minimum simulation parameters considered are
  - number of nodes
  - network area
  - transmission range
  - data rate
  - data packet size
  - mac and physical layer
  - bandwidth
  - application
  - simulation time

3.3 Statistically Validity

It is said that simulations are inherently imprecise. To do a sound simulation with accuracy, it is important to take care of few things like the data collection and the process adopted to collect and analyze the data. To make a simulation study statistically valid some things need to be taken care of. One simulation run is not enough to get the results. A simulation must be run for several times, each run with different seed values to produce the set of results. It ensures the analyst to do independent run and then conclude the average result. Then to ensure that the results are the representing the system they are being simulated for, confidence interval should be used. A good value of confidence interval makes sure the correctness of data collected. All these three parameters i.e. simulation runs, seed values and confidence interval addressed in a simulation study makes it acceptable as statistical valid [6-7].
The minimum criteria for statistically valid paper are these three parameters

- Number of runs of simulation
- Seeds used for diferent number of runs
- confidence interval mentioned

The papers were evaluated on the basis of the above mentioned parameters. We went through all the papers in detail to extract the parameters under consideration.

Chapter 4

RESULTS OF STATISTICAL ANALYIS

In this section we have presented the gathered results about the current state of simulation studies by collecting parameters described in our methodology. We have also explained the possible impact of these result on the integrity of research. This evaluation is out of 38 papers published in highly respected venues of IEEE and ACM on wireless networks, particularly on routing in ad-hoc network using simulation.

4.1 Results for Realistic Scenario

Starting with our first criteria i.e. realistic scenario for a simulation, we went through research paper to see if paper has mentioned the use of two parameters i.e. Mobility Model and Radio Propagation Model. We considered any mobility and propagation model stated. Our survey found out that 47% of the papers did not mention any mobility model used which is quite huge. 26% used random waypoint model that is non-human like and it is not marked as appropriate model given the real mobility patterns in MANET [13]. 11% reported only nodes speed which is not enough to define the actual mobility patterns. Remaining 13% papers referred to the realistic mobility model (figure 4.1). For the radio propagation model, 69% papers did not mention any information related to radio propagation.13% studies gave incomplete information by only mentioning the transmission range of the signals which is certainly not sufficient for modeling the propagation patterns. Only 18% studies have used propagation model (figure 4.2).
Further inspection on the outcomes of both mobility and propagation model, the paper which stated both the mobility and radio propagation model were

counted as adopted realistic scenarios.45% of the research papers did not mention any information related to mobility and propagation model.50% gave incomplete information. Only 5% of the paper worked with proper mobility and radio propagation model (figure 4.3). It leaves us with the fact that there are very small number of simulation studies which adopted the realistic scenario for the testing of their solutions. These results are quite surprising. Given the unpredictable working environment of ad-hoc networks, realistic mobility and realistic radio propagation are the main components which influence topology and the overall performance of ad-hoc simulation networks. A simulation run without a proper realistic scenario can turn the conclusions from accurate to inaccurate [5] [9].

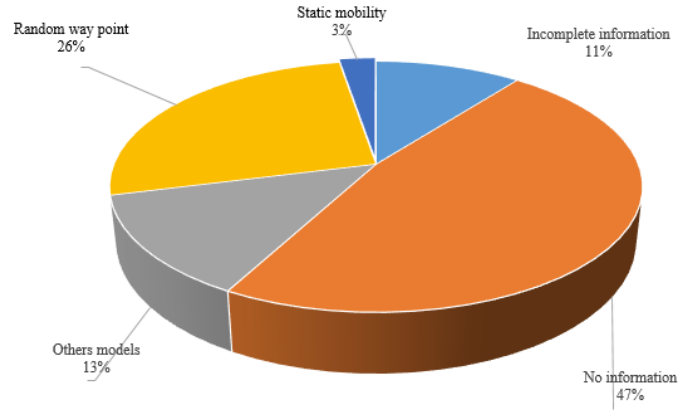

Figure 4.1: Mobility Model

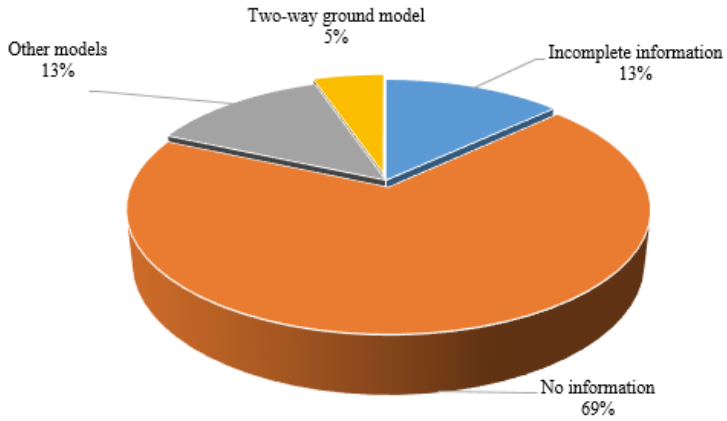

Figure 4.2: Radio Propagation Model

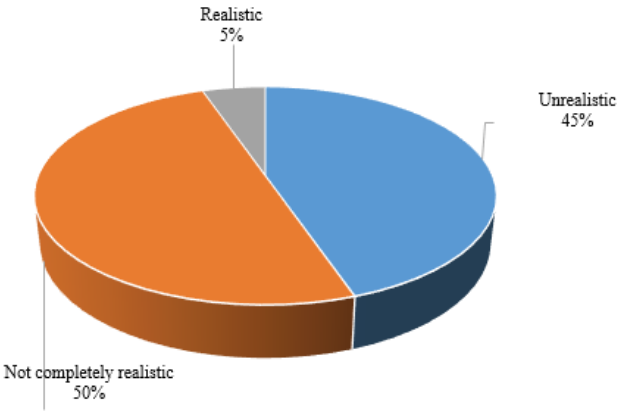

Figure 4.3: Realistic Scenario

4.2 Results for Statistical Validity

Taking the proceeding of our targeted conference and journal for statistical validity, we collected parameters i.e. seed value, Confidence Interval and number of simulation runs mentioned by each paper. Out of 38 papers 16% stated about the use of different seeds for testing the simulations (figure 4).66% did not report confidence interval used in their experiments (figure 4.5).61% of the research publish did not give any information about the number of runs of simulations (figure 4.6).
Accepting the three basic parameters to define a paper statistically valid, 3% of the papers are statistically valid as they have reported all the three factors. 29% of the research was not completely valid as they have just mentioned the number of runs or seeds, remaining 68% were not valid as they did not report any of the parameter (figure 4.7). The lack of statistical validity puts the authenticity of results in danger. It leads to the ambiguous and inaccurate conclusion [7].

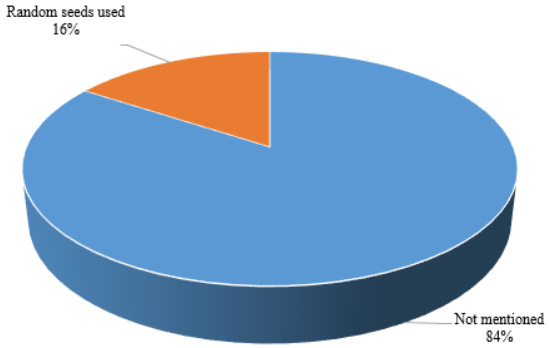

Figure 4.4: Seeds

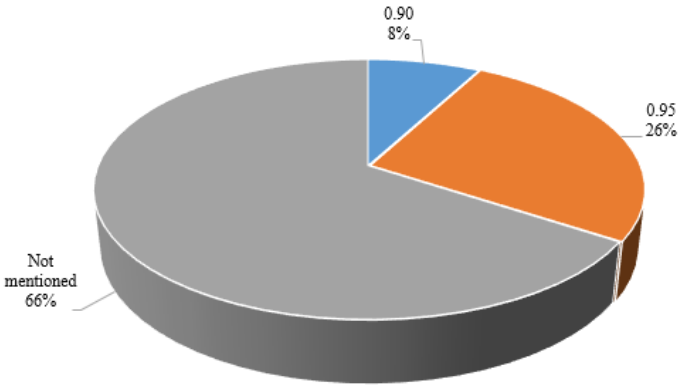

Figure 4.5: Confidence Interval

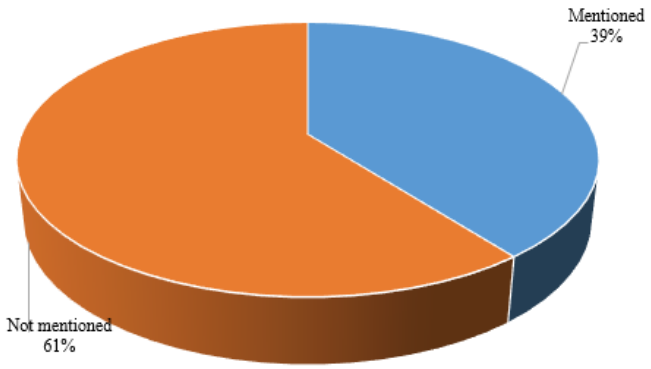

Figure 4.6: No Of Runs

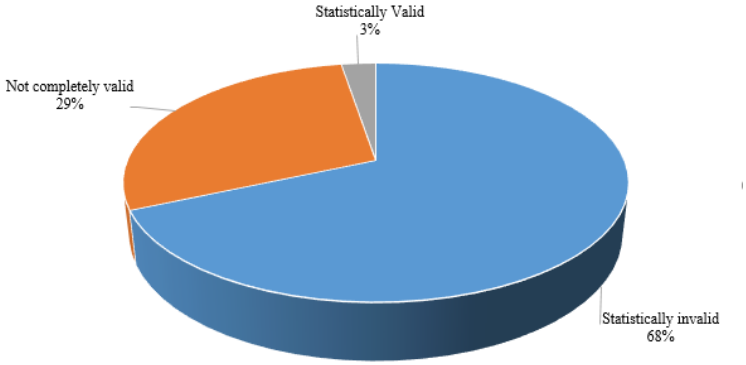

Figure 4.7: Statistically Valid

4.3 Results for Repeatability

For the third factor that is repeatability, we went through the proceeding to look for simulation tool name and version and simulation parameters. 16% studies did not report the simulation tool name (figure 4.8). Out of those 84% studies which reported the simulation tool, 45% mentioned the version of tool (figure 4.9). The minimum simulation parameters considered are number of nodes, network area, transmission range, data rate, data packet size, mac and physical layer, bandwidth, application, simulation time. Out of 38 simulation studies,58% papers reported the simulation parameters, 10% did not say anything about simulation parameters and remaining gave the incomplete information like number of nodes or area (figure 4.10).

Taking three parameters for repeatability and their state in papers, 21% of the papers were not repeatable for not mentioning the tool name, version, and simulation parameters.53% were not completely repeatable for skipping tool version, or giving incomplete simulation parameters. Remaining 26% are completely repeatable as they stated tool name, version and enough simulation parameters to reproduce the experiment and get the exact same results (figure 4.11). The situation of repeatability in ad-hoc simulation networks is serious violation of the ethics of research. We are populating the research with non-reproducible work, which makes it almost impossible to make careful further advancement

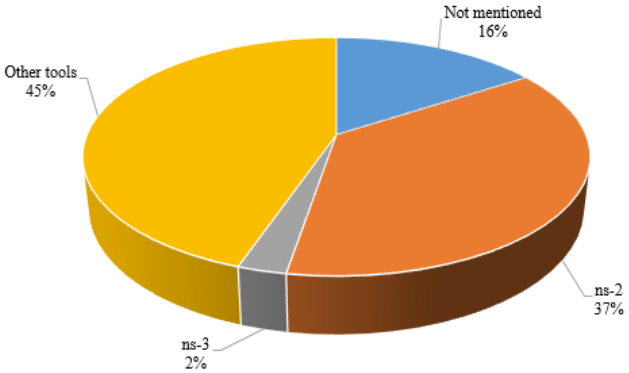

Figure 4.8: Tool Name

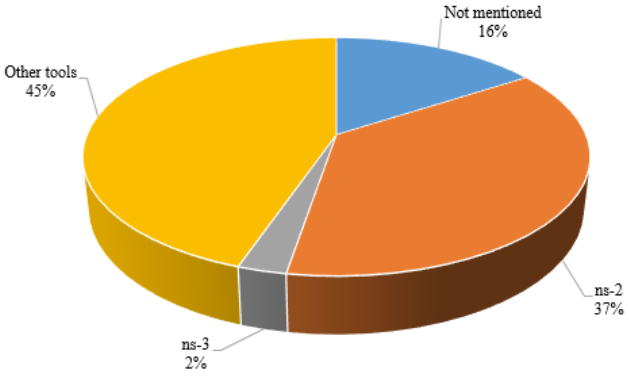

Figure 4.9: Tool Name

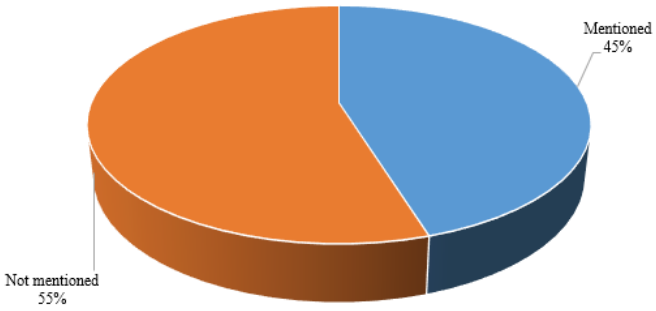

Figure 4.10: Tool Version

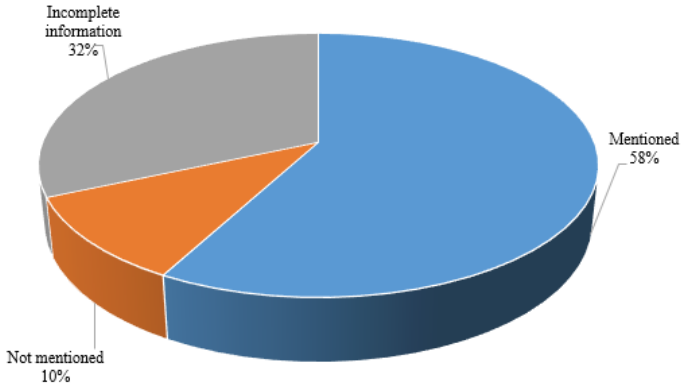

Figure 4.11: Simulation Parameters

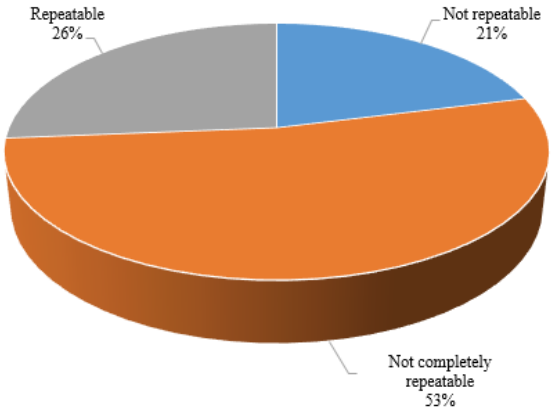

Figure 4.12: Repeatablity

4.4 Existing state of ad-hoc simulation networks

Our findings about the current state of ad-hoc simulation studies are disconcerting. The survey by Kurkowski et al. (2005) claimed less than 15% of the research papers completely repeatable. After ten years of continuous emphasis on the importance of repeatability very little improvement has been observed by our survey, only 26% papers were found repeatable. Beside repeatability, the statistical validity and realistic scenarios state is more unpleasant. Since this situation is jeopardizing the integrity of research by publishing unreliable work, there is a necessity to improve upon the credibility of research.

Chapter 5

TOOL FOR REPEATABLE CREDIBLE AD-HOC SIMULATIONS

We have developed a Linux based tool for NS2 to improve the situation of credibility and repeatability of ad-hoc routing networks We found 37% of the studies using NS2 for their simulations, which makes it most widely used simulation tool in ad-hoc network. Our tool ensures credibility, aids researchers to document the details about their simulation and make the reporting of their work easy. The tool comprises of two modules. The first module takes basic parameters required for a credible simulation and generates a partial script of TCL. The parameter for generating TCL script are:

- Number of Nodes: It takes the number of the nodes in the simulation.
- Area of Network: It takes x-dimension and y-dimension as simulation area.
- Seed value: Seed value can be added as any digit.
- Ifq length : Ifq length can be added as any digit.
- Simulation time: Simulation time is taken in seconds.
- Routing protocol: User can choose from three routing protocols for MANET i.e. DSR, AODV or DSDV.
- Traffic type: User can choose from two traffic types i.e. UDP or TCP.

- Node Connections: Connection between the nodes can be chosen at random or nodes can be linked manually.
- Mobility Model: User have to input the details for mobility model. Initially the tool uses random way point model.
- Radio Propagation Model: User has to select a radio propagation model. Initially the tool uses two ray ground model.

On taking these parameters, a partial TCL script is generated, which can be modified later on.Fig 5.3 and 5.4 show the interface which takes these paraameters in order to generate the TCL script(Fig 5.5).To ensure the documentation and reporting, it also generates a XML report(Fig 5.6). This report holds all the details taken to create the TCL script to help in documentation and to make reporting easy. It contains all the basic information required to repeat the same experiment with same results. The second module of the tool takes its own generated XML file as an input and generate the TCL on those parameters(Fig 5.2).The complete work flow of the tool is shown in Fig 5.1.
We have catered for all the factors involved in our evaluation criteria through this tool. It guards the realistic scenario implementation by taking information about mobility model and radio propagation model. All other parameters are necessary for producing a repeatable research. Information related to expected simulation run, confidence interval or any other setting can be added to XML report to guarantee the statistical validity.

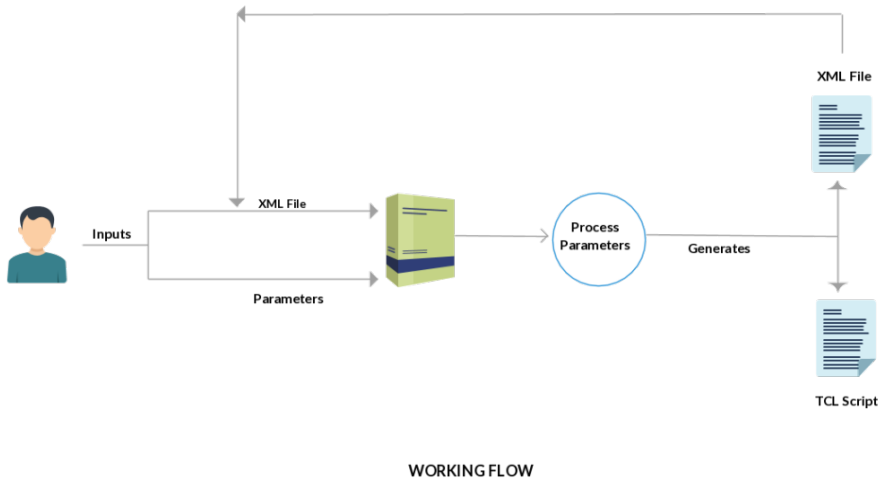

Figure 5.1: Working of Tool

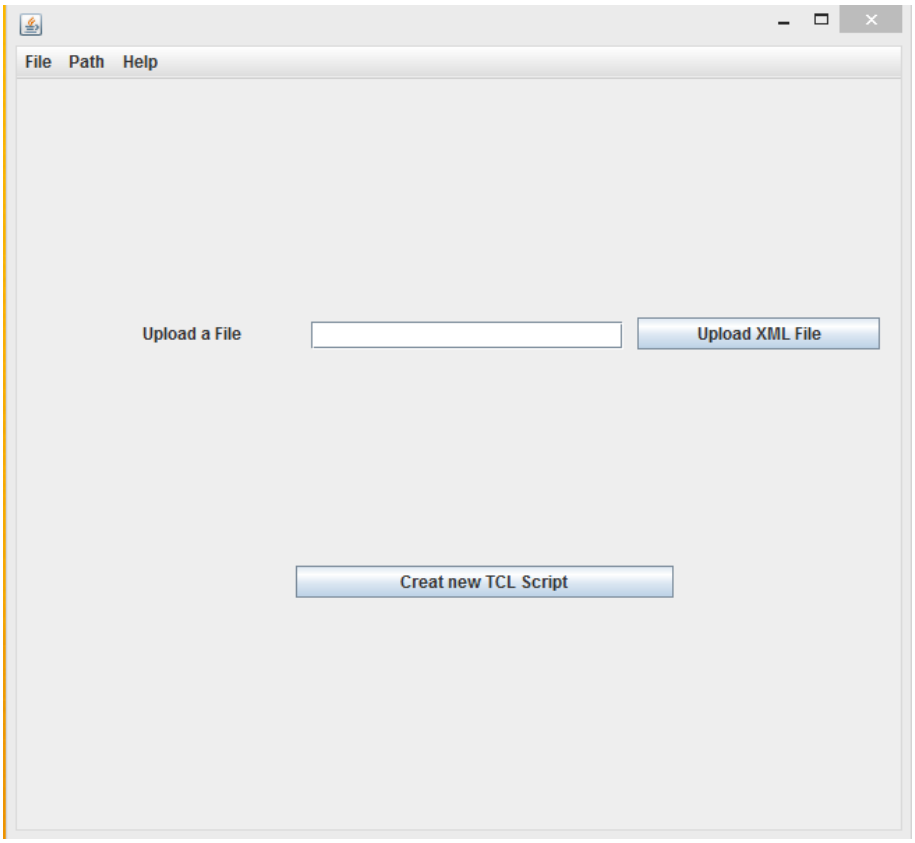

Figure 5.2: Interface for parameters intake

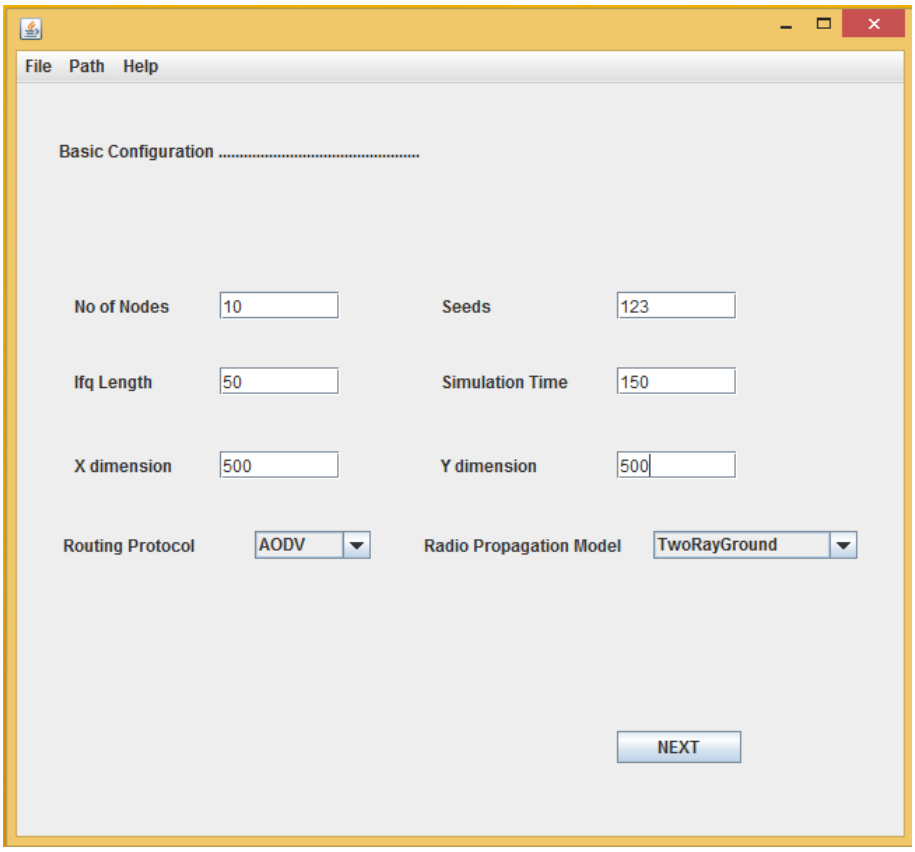

Figure 5.3: Interface for parameters intake

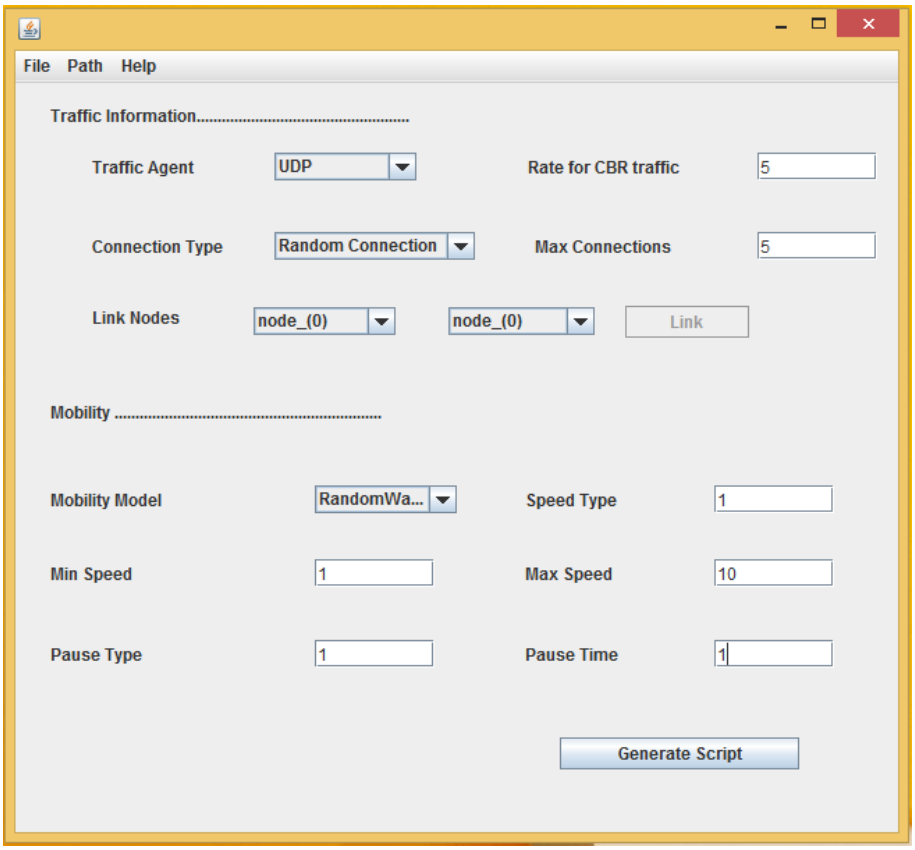

Figure 5.4: Interface for parameters intake

```
#----------------------------
# NODE CONFIGURATION OPTIONS     (using array 'n_opt')
#----------------------------
set n_opt(addressType)           hierarchical
set n_opt(MPLS)       OFF
set n_opt(wiredRouting)      OFF
set n_opt(llType)           LL
set n_opt(macType)          Mac/802_11
set n_opt(ifqType)          Queue/DropTail/PriQueue
set n_opt(phyType)          Phy/WirelessPhy
set n_opt(adhocRouting)     AODV
set n_opt(propType)         Propagation/TwoRayGround
set n_opt(propInstance)        Propagation/TwoRayGround
set n_opt(antType)          Antenna/OmniAntenna
set n_opt(channel)          [new Channel/WirelessChannel]
set n_opt(mobileIP)         OFF
set n_opt(energyModel)          EnergyModel
set n_opt(initialEnergy)    10000       ;# Value in Joules
set n_opt(rxPower)          0.01         ;# Value in Watts
set n_opt(txPower)          0.01        ;# Value in Watts
set n_opt(idlePower)        0           ;# Value in Watts
set n_opt(agentTrace)       ON
set n_opt(routerTrace)           OFF
set n_opt(macTrace)         OFF
set n_opt(movementTrace)    OFF

#-------------------------------
# TOPOLOGY CONFIGURATION OPTIONS (using array 't_opt')
#-------------------------------
set t_opt(x) 500
```

Figure 5.5: Output of TCL Script

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<Simulation_parameters_report>
    <cbrRate></cbrRate>
    <ifqLength>50</ifqLength>
    <links>5</links>
    <macType>Mac/802_11</macType>
    <maxConnection>5</maxConnection>
    <maxSpeed>10</maxSpeed>
    <minSpeed>1</minSpeed>
    <mobilityModel>RandomWayPoint</mobilityModel>
    <noOfNodes>10</noOfNodes>
    <packetSize>512</packetSize>
    <pauseTime>1</pauseTime>
    <pauseType>1</pauseType>
    <radioPropagationModel>TwoRayGround</radioPropagationModel>
    <routingProtocol>AODV</routingProtocol>
    <seed>1</seed>
    <simulationTime>50</simulationTime>
    <speedType>1</speedType>
    <trafficAgent>UDP</trafficAgent>
    <xaxis>500</xaxis>
    <yaxis>500</yaxis>
    <llType>LL</llType>
</Simulation_parameters_report>
```

Figure 5.6: Output of XML Report

Chapter 6

Conclusion

Scientific experiment is conducted to validate, accept or refute the hypothesis. If the experiment is flawed or not documented properly, it misinforms others who might make advancement in work by building upon unreliable foundations. We conducted a survey to know the state of ad-hoc simulation networks in terms of credibility and repeatability. The three aspects which were focused for credibility were how much of research published is repeatable, statistically valid and tested in realistic scenario. In our survey we observed that only 26% papers were completely repeatable. It damages the successful repetition and extension of analysis on original data, it also hinders the way to implement some previous methodology on new data, and reuse of code and result in new dimensions.
Only 3% of the papers mentioned the complete information required for the study to be statistically valid which can lead to unclear and imprecise outcomes. The findings of realistic scenario are not any different, as only 5% of the papers have given the complete details about mobility and radio propagation model, which directly affects the results reflecting the performance of solution. The learning from the survey raises a serious concern regarding the credibility of ad-hoc simulation networks and simulation studies in general. Though the situation is a little better than the previous surveys conducted, a lot of fine work needs to be done to make the situation satisfactory. Our tool which standardizes basic parameters and makes documentation easy is a step towards making it possible.

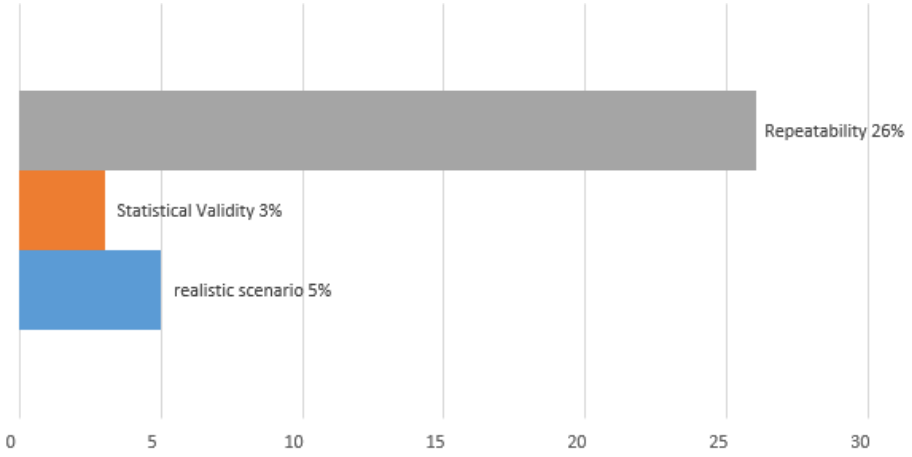

Figure 6.1: Final Results

Chapter 7

Future Work

The future work includes the addition of other feature in the tool and taking it to advance level where other details can be taken as input to generate script. Beside this feature enhancement in the tool, same work can be done for other simulators in order to ensure the credibility regardless of which simulator is used to get the results. As the configuration files, code and other information is necessary for integrity of research which is not always available to public, another potential direction can be a public deposition. This could be a web portal where researchers can upload all the content related to simulation to ensure credibility of their research.

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