# "T-MANET Method for Identification of Appropriate Parameters for Best Performance to Design MANET in Particular Scenario"

**Gouri M. Patil[1],**
Department of Computer Science,
Savitribai Phule Pune University,
Pune-411 007, India.

**Ajay H. Kumar[2],**
Jayawant Technical Campus- Jayawant Institute of Business Studies,
Pune-411 033, India.

**A. D. Shaligram[3]**
Department of Electronic Science,
Savitribai Phule University,
Pune-411 007, India.

**Abstract:** T-MANET algorithm uses Taguchi Method that helps in selecting multiple feasible parameters to setup the MANET for an application performance. Parameters selected by T-MANET helps in obtaining the better than best performance of MANET routing protocol. The need, popularity and easy deployment of MANET with less cost has increase the area of applications in realistic environment from military to day-to-day life and research to business. The applications uses MANET need best performance where application performance is dependent on various factors. Routing Load, Delay and Throughput metrics are used to evaluate MANET performance using OPNET simulator for a realistic application environment for 'Number of Nodes', 'Routing Protocols' and 'Transmission Data Rate' factors. The result story shows that optimized throughput for MANET is obtained with the combination factors as 100 nodes, AODV routing protocol with 11 mbps 'Transmission Data Rate' without affecting noise factor as pause time. Optimizing delay response variable for MANET the T-MANET result suggest that for 25 numbers of nodes, GRP Routing Protocol is as significant factor with the 'Transmission Data Rate' 11 mbps. With one of the response variable it is observed that any 'Number of Nodes' and AODV routing protocol having 1 mbps 'Transmission Data Rate' will perform best routing.
***Keywords:*** MANET, AODV, Taguchi, Orthogonal Array (OA), Routing Load, Throughput, Delay.

## I. INTRODUCTION

A Mobile Ad-hoc Network (MANET) is an autonomous system that is composed of mobile nodes which communicates through wireless links [8] without any preexisting infrastructure. Mobile nodes in ad-hoc wireless networks functions as a router and dynamically establishes routes among themselves by mean of a routing protocol. Therefore, selection of an appropriate routing protocol is an integral part of establishing a MANET in a scenario. The MANET environment is characterized by variables as "Number of Nodes", variable capacity wireless links and bandwidth constraints [6]. Due to infrastructureless, MANET topology is dynamic, in which the connectivity changes frequently and is unpredictable that makes routing complex [13] in MANET. The MANET performance is also dependent on Environment, Wireless Medium, Transmission Errors, Node Failures, Link Failures, Route Breakages, Congested Nodes or Links [9, 17, 22].

There are lots of 'Routing Protocols' have been proposed in the literature to solve the routing problem in MANETs and use different routing algorithms to accomplish the mission. A part from the

routing algorithm it can also be classified by their routing principle. Basically, the routing protocols are classified as proactive (table driven), reactive (on-demand), geographical (position based routing) and hybrid (combination of best feature of proactive and reactive) [6, 9]. Different Routing Protocols are suitable for different scenario having different scale of nodes. MANET nodes participating in a today's realistic environment are of different and limited 'Transmission Data Rate' [14]. Thus, selecting efficient routing protocol, protocol scalability and appropriate 'Transmission Data Rate' for a realistic environment of MANET is the challenge. Finding appropriate parameters will give better than best performance in a MANET.

There is a lot of research work done for evaluating performance of routing protocol in MANET and most of the work is limited to identifying the impact of factors on one or more performance metrics using one factor at a time approach. Taguchi method is a powerful technique in quantifying the effect of several factors simultaneously such as terrain, node speed, network size transmission range and transmission rates, pause time and maximum connections on the routing overheads.

The proposed T-MANET algorithm in this paper uses Taguchi Method of optimization to improve the performance of MANET Routing Protocol with best combination of parameters required to setup the network. This algorithm finds the best possible performance by determining the optimum combination of 'Number of Nodes', best Routing Protocol and 'Transmission Data Rate'. The consistency of performance is obtained by making the MANET routing protocol insensitive for the influence of the uncontrollable factor as Pause time. The performance of routing protocol is measure using routing load, end-to-end delay and throughput performance metrics using proposed T-MANET algorithm and OPNET-14.5 modeler simulator.

## II. TAGUCHI METHOD

Dr. Genichi Taguchi first introduced the Taguchi methods [21] in 1960. The target of Taguchi method is to produce high quality product at a lower cost; to reduce the variation in process where a robust experimental design are involved [7]. The Taguchi method is a kind of design of experiments that investigates how different factors affect the mean and variance of a process performance characteristic. It is an iterative optimization procedure based on orthogonal array (OA) which can be used to find near-optimal settings [3, 7]. OA is an important parameter in Taguchi's method which provides a systematic way to determine the control parameters of the experimental run and it is widely used in manufacturing processes, engineering fields, power electronics and wireless communications, etc. [3].

Taguchi method is used to improve the quality of products and processes. Quality of a products and processes improves when a higher level of performance is consistently obtained. The highest possible performance is obtained by determining the optimum combination of process design factors. The consistency of performance is obtained by making the product/process insensitive to the influence of the uncontrollable factor and consistency of performance is achieved by carrying out the trial conditions under the influence of the noise factors. The optimum design is determined by Taguchi's approach, using Orthogonal Array (OA) [3, 7] and Design Of Experiment (DOE) principles. It reduces the size of experiment due to which experimental process get speeding up [7]. The SNR evaluate the effect of change in a particular factor on the performance of process or product [7].

According to the nature of the problem Taguchi approach optimization is of two categories that are called static problems and dynamic problems. It uses log function for desired outputs and objective functions for optimization that is called Signal-to-Noise ratios [20].

## III. PROBLEM STATEMENT

MANET is a spontaneous communication network that can be formed at a marketplace, sport events, a conference, mobile classroom, etc. Such network performance is dependent on various factors as 'Number of Nodes', 'Routing Protocols', 'Transmission Data Rate', terrain size, node speeds, transmission ranges, pause times, and maximum connections [3, 4, 7, 12, 13, 16]. The MANET performance depends on these factors, so identification of appropriate factors for best performance is a need for today's realistic environment of MANET.

## IV. OBJECTIVE

- To develop a method to identify appropriate parameters and optimizing for the best *performance* of MANET routing protocols using Taguchi optimization method.

## V. ROUTING PROTOCOLS

According to the network circumstances, MANET routing protocols can be categorized as: proactive, reactive and hybrid [6, 9]. Proactive routing protocol also called as table driven routing protocols attempt to maintain up-to-date routing information to all nodes by periodically disseminating topology updates throughout the network. Reactive routing protocol also called as on demand driven routing protocols attempt to discover a route only when a route is needed and Hybrid protocols inherit features from both proactive and reactive routing protocol. Here, AODV, OLSR and GRP routing protocols are considered for investigation and are briefly described.

**Ad-hoc On Demand Vector protocol (AODV):** AODV is a reactive routing protocol. It is also refer as Source-initiated On-demand protocol [10]. It has minimum number of required broadcasts by creating routes on demand basis instead of maintaining a complete list of routes [5]. AODV routing protocol is considered for this study because of its on demand nature. The AODV can be the right selection for getting good performance for the applications like cafeteria, conferences, shopping mall, vehicular ad-hoc network etc., where one of the mobility models also exists.

**Optimized Linked State Routing (OLSR):** OLSR is a proactive or table driven link-state routing protocol. In this routing protocol detection and then announcement of link state information throughout the mobile ad-hoc network is perform using hello and topology control (TC) messages [1].

**Gathering-based Routing Protocol (GRP):** Gathering-based Routing Protocol offers an efficient framework that has strengths of proactive routing protocol and reactive routing protocol that collects network information at a source node at an expense of a small amount of control overheads. Source node collects all the information about the route to the designation [15, 18]. If the current route is disconnected, on the basis of the collected information, the source node can provide promising routes thereby continuously transmission of data packets happens. This protocol does fast packet transfer without delay and without any unduly compromise as control overhead [15] so it gives good performance. The advantage of this protocol is that routes can be altered node by node and packet by packet simply by considering additional Quality-of-Services parameters relating to the next-hop neighbors reachability information such as delay or available bandwidth. One of the major disadvantages of GRP is complexity and overhead required for a distributed location database service [11].

## VI. PROPOSED T-MANET PROCEDURE AND ALGORITHM

**T-MANET PROCEDURE:** In T-MANET algorithm first step is to identify main function, failure mode and side effects. The noise factor(s) and testing conditions are captured that can effects on the performance is identified. After identifying the noise factor(s) need to identify the quality characteristics and objective functions. Identification of Control Factors and their appropriate level is defined. Depending on these Control factors and their appropriate level, select the appropriate Orthogonal Array (OA). Experiments are conducted using obtained orthogonal array on simulator. Simulation results are input to Taguchi Excel Template. In excel sheets analysis of variance is calculated that gives the optimum level of the parameters for performance metrics. By analyzing the graph, one can quantify the control factors for optimization.

**T-MANET ALGORITHM:**

**Step 1 : Identify Main Function, failure mode and side effects.**
*OPTIMIZATION OF PERFORMANCE OFMANET.*

**Step 2 : Identify Noise factors, testing conditions (to capture the effects of noise).**
*The pause time between the data transmission is considered to be the Noise factors. Effect of the pause time will be captured by using 2 samples for each experiment (10 seconds/20 seconds).*

**Step 3 : Identify Quality Characteristics and Objective Function.**
*The objective of the Taguchi experimentation is to increase throughput, delay and routing load.*

**Step 4 : Identify Control Factors and their Levels**
*Control Factors are 1) Number of Nodes, 2) Routing Protocol and 3) Data Rate for transmission.*

**Step 5 : Identify Orthogonal Array (degrees of freedom for error)**
*L9 orthogonal array is chosen up to 3 control factors with 3 levels each are used in this research.*

**Step 6: Conduct the experiments using orthogonal array and OPNET simulator.**

**Step 7 : Run the Simulation**
*Simulation is carried out using OPNET modeler 14.5.*

**Step 8 : Input the measured data from simulation into Taguchi Excel template** [18]

**Step 9 : By Analysis of variance, determine optimum levels of the parameters for each performance metrics.**

**Step 10 : Quantify the control factor effects by graph.** *Various effects of factors on the performance improvement of MANET in terms of routing load, delay and throughput are shown in Figure-1, Figure-2 and Figure-3.*

**Step 11 : Obtain the optimized performance for MANET.**

This algorithm and procedure is tested using Taguchi Template sheet and OPNET simulator for MANET performance. The performance metrics routing load, end-to-end delay and throughput for optimal factors routing protocol, 'Number of Nodes' and 'Transmission Data Rate' are obtained for analysis.

## VII. FOR T-MANET SIMULATION SETUP

OPNET modeler 14.5 Network Simulator is used for the simulation of AODV, OLSR and GRP routing protocol to quantify affects on the performance of three control factors: 'Number of Nodes', Routing protocol and 'Transmission Data Rate' with pause time as noise factor. For the simulation in 500m x 500m area, Random Way Point Mobility Model, Traffic is generated for light weight video conference

**a) Control Factors: The three control factors that are** 'Number of Nodes' (25, 50 and 100), 'Transmission Data Rate' (1 mbps, 5.5 mbps and 11 mbps) and 'Routing Protocols' (AODV, OLSR and GRP) with three levels (Level-1, Level-2 and Level-3) are considered as per Table-1.

***Table-1: Control Factors***

| *Control Factors* | *LEVEL 1* | *LEVEL 2* | *LEVEL 3* |
|---|---|---|---|
| *Number of Nodes* | 25 | 50 | 100 |
| *Routing Protocol* | AODV | OLSR | GRP |
| *Transmission Data Rate(mbps)* | 1 | 5.5 | 11 |

b) **Noise Factor:** As node Pause at destination makes variation in performance of routing protocol. The Noise factor is node pause time that is 10 seconds and 20 seconds at destination as in Table-2.

***Table-2: Noise Factors***

| *Noise Factor* | *Noise Level 1* | *Noise Level 2* | *Number of levels* |
|---|---|---|---|
| ***Pause Time*** | **10** | **20** | **2** |

c) **Orthogonal Array for Design Of Experiment:** Through Taguchi excel sheet the Orthogonal Array is obtained for experiments based on control factors and noise factors. The Orthogonal Array (OA) considered for Taguchi's Design of Experiment (DOE) with parameters as in Table-3.

***Table-3: Orthogonal Array consider for Design Of Experiment***

| *Expt. No.* | *Number of Nodes* | *Routing Protocol* | *Transmission Data Rate (mbps)* |
|---|---|---|---|
| *1* | 25 | AODV | 1 |
| *2* | 25 | OLSR | 5.5 |
| *3* | 25 | GRP | 11 |
| *4* | 50 | AODV | 5.5 |
| *5* | 50 | OLSR | 11 |
| *6* | 50 | GRP | 1 |
| *7* | 100 | AODV | 11 |
| *8* | 100 | OLSR | 1 |
| *9* | 100 | GRP | 5.5 |

**d) Performance metrics for evaluation:**

The simulated results are analyzed for throughput, end-to-end delay and routing load performance metrics [18]:

1) Throughput: It is rate of successful data transfer in the network and measured as the ratio of total received packets in a particular unit of time from source to destination. Throughput is expressed in terms of bytes per second or bits per second.

$$Throughtput = \frac{\sum Received\,packet\,size}{Stop\,Time - Start\,Time} \quad \text{bytes/sec or bits/sec} \qquad (1)$$

2) End-to-End Delay (E2E): Average time taken by a specific packet is the time to travel from source to destination in a network. It is measure as the total number of time taken for each packets divided by total number of packet received at the destination, is expressed in terms of seconds.

$$End - To - End\ Delay(E2E) = \frac{\sum(\ Packet\,Sent\,Time - Packet\,Received\,Time)}{\sum(Packet\ Received)} \qquad (2)$$

2) Normalized Routing Load (NRL): The ratio of Number of Routing Packets Received to the Number of Data Packets Received is bits per second (bits/sec).

$$Normalized\ Routing\ Load\ (NRL) = \frac{NRpr}{NDpr} \qquad (3)$$

Where, *NRpr* is the Number of Routing Packets Received and *NDpr* is the Number of Data Packets Received.

## VIII. SIMULATION RESULTS AND ANALYSIS

After 'analysis of variance' (ANOVA), the method determines optimal parameters that are 'Number of Nodes', routing protocol and 'Transmission Data Rate' for appropriate combination for the performance metrics throughput, delay and routing load and is tabulated in Table-4, Table-5 and Table-6 respectively.

a) **Appropriate combination for Throughput:**

***Table-4: Analysis of Optimum level of parameters for throughput***

| Control Factor Names | Level 1 | Level 2 | Level 3 | Optimum Level | % Factor Effects | Contribution of SELECTed Level to S/N Ratio (in dB) | DOMINANT or Significant or neutral /negligible |
|---|---|---|---|---|---|---|---|
| **Number of Nodes** | 25 | 50 | 100 | **100** | 28 | 5.20 | Neutral /negligible |
| **Routing Protocol** | AODV | OLSR | GRP | **AODV** | 28 | 2.89 | Neutral /negligible |
| **Transmission Data Rate(mbps)** | 1 | 5.5 | 11 | **11** | 29 | 4.73 | Neutral /negligible |

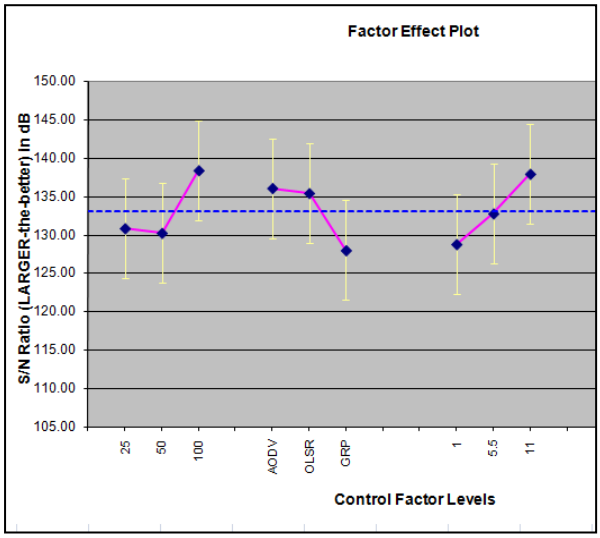


***Figure-1: Optimized Throughput***

**Observation:** For throughput optimization, Table-4 provides the combination of factors for MANET deployment can have 100 'Number of Nodes' using the AODV routing protocol with 11 mbps 'Transmission Data Rate' without affected by noise factor pause time. The SNR ratio higher then throughput is better as in Figure-1.

b) **<u>Appropriate combination for End-to-End Delay</u>:**

***Table-5: Analysis of Optimum levels of parameters for delay***

| *Control Factor Names* | *Level 1* | *Level 2* | *Level 3* | *Optimum Level* | *% Factor Effects* | *Contribution of SELECTed Level to S/N Ratio (in dB)* | *DOMINANT or Significant or neutral /negligible* |
|---|---|---|---|---|---|---|---|
| *Number of Nodes* | 25 | 50 | 100 | **25** | 20 | 6.16 | SIGNIFICANT |
| *Routing Protocol* | AODV | OLSR | GRP | **GRP** | 49 | 5.18 | DOMINANT |
| *Transmission Data Rate(mbps)* | 1 | 5.5 | 11 | **11** | 25 | 2.86 | DOMINANT |

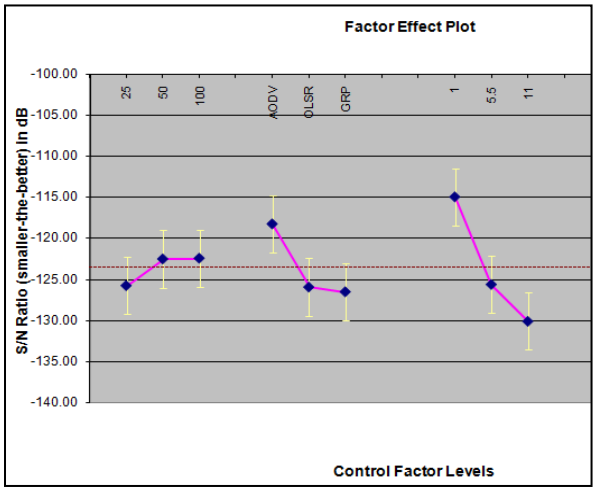


**Figure-2: Optimized Delay**

**Observations:** Optimizing the delay response variable the MANET parameters are suggested to consider 25 nodes using GRP Routing Protocol as significant factor with the 'Transmission Data Rate' of 11 mbps after analyzing Table-5 and Figure-2. For delay the dominant factor is 'Transmission Data Rate'. The dominant factor affects the response variable. As the 'Transmission Data Rate' change it will affects the response variable delay.

c) **Appropriate combination for Routing Load:**

***Table-6: Analysis of Optimum levels of parameters for routing load***

| *Control Factor Names* | *Level 1* | *Level 2* | *Level 3* | *Optimum Level* | *% Factor Effects* | *Contribution of SELECTed Level to S/N Ratio (in dB)* | *DOMINANT or Significant or neutral /negligible* |
|---|---|---|---|---|---|---|---|
| *Number of Nodes* | 25 | 50 | 100 | - | 4 | 0.00 | Neutral /negligible |
| *Routing Protocol* | AODV | OLSR | GRP | **GRP** | 24 | -2.94 | D O M I N A N T |
| *Transmission Data Rate(mbps)* | 1 | 5.5 | 11 | **5.5** | 69 | -2.05 | D O M I N A N T |

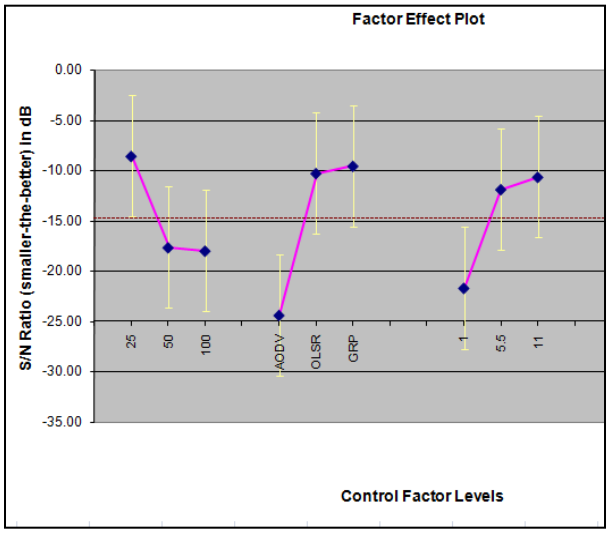


**Figure-3: Optimized Routing Load**

**Observations:** From Table-6, it is observed that the optimal level and 'Number of Nodes' value is dash (-) it means that any 'Number of Nodes' and AODV routing protocol with 5 mbps 'Transmission Data Rate' is the optimal solution. The routing load is best for smaller SNR is observed through Figure-3.

d) **Performance evaluation considering "DOMINANT"**

From Table-4, Table-5 and Table-6 it is observed that the **"DOMINANT"** are only in end-to-end delay and routing load tables. The **"DOMINANT"** is considered as factors that are to be taken further for simulation and performance analysis in MANET.

From Table-6, 'Transmission Data Rate' is dominating factor for end-to-end delay. To find the better than best results the GRP routing protocol is simulated further for 25 number of nodes with 1

mbps, 2 mbps, 5.5 mbps and 11 mbps transmission data rates and simulation results are graphically plotted in Figure-4 (a), (b) and (c).

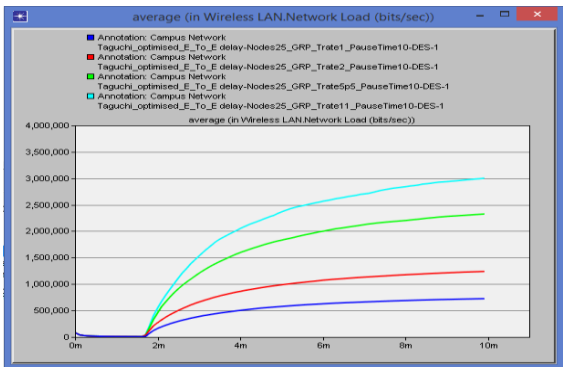


**Figure-4 (a): Network Load for 'Transmission Data Rate' (1-11 mbps)**

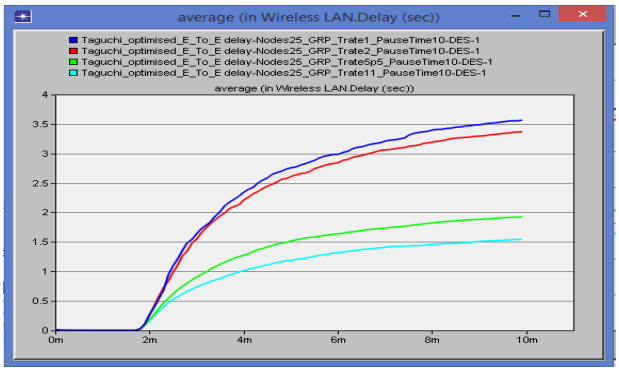


**Figure-4(b): Delay for 'Transmission Data Rate' (1-11 mbps)**

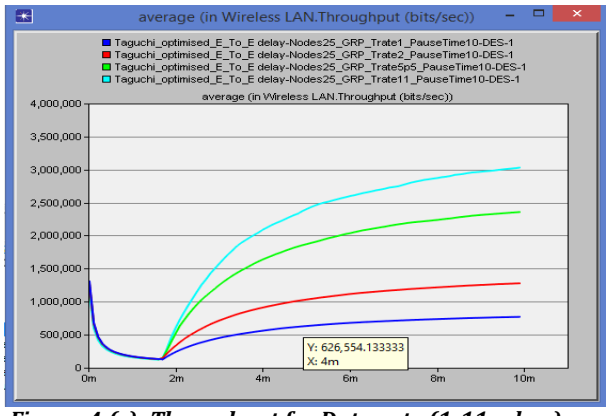


***Figure-4 (c): Throughput for Data rate (1-11 mbps)***

**Observations:** From Figure-4(a), (b) and (c) the observations are:

a) GRP routing protocol gives better than best performance at 11 mbps Transmission Data Rate for 25 numbers of nodes.

b) For all 'Transmission Data Rate' (1 mbps, 2 mbps, 5.5 mbps and 11 mbps), after 5 minutes of simulation Routing Load, Delay and Throughput are becoming constant at certain level.

c) As on duration of 5 minutes simulation the Routing Load, Delay and Throughput get varies for 'Transmission Data Rate' 1 mbps, 2 mbps, 5.5 mbps and 11 mbps. Further graphs are plotted in Figure-5(a), (b) and (c) to understand variation in routing load, end-to-delay and throughput.

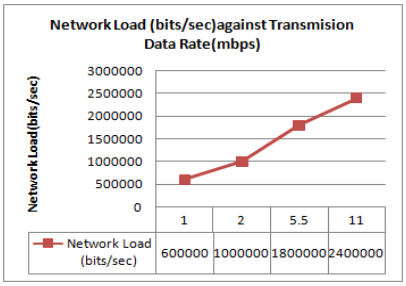


**Figure-5(a) Variation of Network Load for 'Transmission Data Rate' (1-11 mbps)**

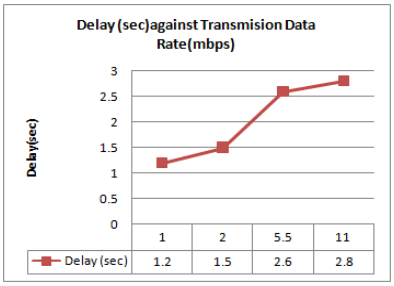


**Figure-5(b) Variation of end-to-end delay for 'Transmission Data Rate' (1-11 mbps)**

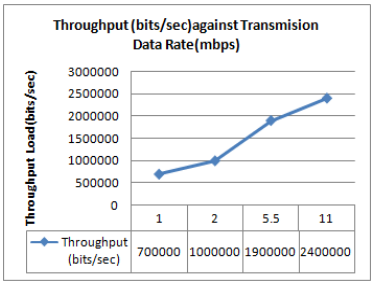


***Figure-5(c) Variation of Throughput for 'Transmission Data Rate' (1-11 mbps)***

From Figure-5 (a), (b) and (c) it is concluded that GRP routing protocol with 25 numbers of nodes and 11 mbps 'Transmission Data Rate' is reliable for delay performance and better transmission of packets.

## IX. CONCLUSIONS

The performance of MANET can influence very much by the routing protocol designs and quantity factors as geography, pause time, node speed, transmission range, traffic load, end-to-end delay and throughput. These factors along with inherent characteristics of MANET may result in unpredictable variation in the overall network performance. Taguchi method is powerful technique in quantifying several factors simultaneously. It is an iterative optimization procedure based on Orthogonal Array (OA) which can be used to find near-optimal settings. So, Taguchi method is systematic and efficient method for the identification of the effective factors which influences the process where robust experimental design is involved. The robust parameter design method has been successfully applied in many areas like environmental sciences, agriculture sciences, manufacturing processes, basic sciences, engineering, medicine, management sciences, biological science, physical science, power electronics, wireless communications and in many more areas where optimization is required to minimize process iteration and to compare the effects of multiple factors, together with their interactions simultaneously.

The researcher proposed T-MANET algorithm that uses Taguchi Method for identifying appropriate parameters for the best performance of MANET in realistic environment has used combination of control factors such as 'Number of Nodes', 'Routing Protocols' and 'Transmission Data Rate' with the noise factor pause time to achieve the optimized performance of MANET. Optimized throughput for MANET is obtained with the combination factors as 100 nodes using the AODV routing protocol with 11 mbps 'Transmission Data Rate' without affected by noise factor 'pause time'. Optimizing delay response variable for MANET is suggested to use the 25 number of nodes using GRP Routing Protocol as significant factor with the 'Transmission Data Rate' of 11 mbps. Response variable routing load is suggested to optimize with any 'Number of Nodes' routed with AODV routing protocol with 1mbps 'Transmission Data Rate'. In case of GRP routing protocol, 25 nodes with 11 mbps 'Transmission Data Rate' is reliable for delay performance metrics for transmission of packets

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