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Optimization of Number of Nodes for AODV Protocol with and Without Black Hole Attack in MANET by Using Taguchi Method

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ABSTRACT
MANET is a set of dissimilar types of mobile nodes. These nodes communicate with each other without any fixed infrastructure. Because of MANET's infrastructure less network it is unprotected from the attack of malicious nodes. These malicious nodes and other noise factors present in the network lowers the data transmission. This paper is focused to optimize the number of nodes to achieve the higher packet delivery ratio and throughput with lowest End to End delay for AODV protocol with and without black hole attack and then later on by applying the regression test we can see that up to how much percentage other noise factors can affect the whole transmission system.
Keywords: - MANET, AODV, OLSR, ZRP, Black hole and Taguchi.

I. INTRODUCTION

Mobile Ad hoc network is a temporary network between mobile devices (Nayyer et al.). All mobile nodes communicate with each other through wireless link. The mobile nodes that in radio range of each other can directly communicate, where as other nodes need some intermediate nodes to transmit their data packets. Each of the nodes has a wireless interface to communicate with other. These networks are fully distributed and can work at any place without the help of any fixed infrastructure such as access point or base station. Figure 1.1 shows a simple ad hoc network with three nodes. Node 1 and Node 3 are not in direct range of each other; however node 2 can be used to forward data packets between node 1 and node 3.

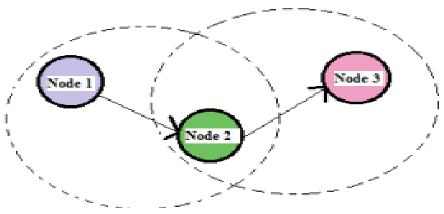

Figure 1 Communication between mobile nodes

Mobile ad hoc network has various characteristics like wireless connection, continuously changing topology, distributed operations, multi hop routing, autonomous terminals and ease of development. It is used in various situations like in case of emergency, disaster recovery, crowd control, battle field etc.

II. AD HOC ON-DEMAND DISTANCE VECTOR (AODV)

AODV [4] On-demand routing protocol inherits the good features of both DSDV and DSR. [8] algorithm. It uses the periodic beaconing and sequence numbering procedure of DSDV and an identical route discovery procedure as in DSR. However, there are two major differences between DSR and AODV. The most distinguishing difference is that in DSR each packet carries full routing information, whereas in AODV the packets carry only the destination address. This shows that AODV has potentially less routing overheads than DSR. The second difference is that the route replies in DSR Protocol carry the address of every node along the route, whereas in AODV protocol the route replies only carry the destination IP address and the sequence number. The merits of AODV are that it is adaptable to highly dynamic networks. However, node may experience large delays during route construction, and link failure may start/initiate another route discovery, which creates extra delays and consumes more bandwidth as the size of the network increases.

III. BLACK HOLE ATTACK

The attacks at network layer can be of two types- one that does not forward any data i.e. denies the service like black hole, DOS attacks while the other can be the ones which does selectively forward data but by modifying them like grey hole, wormhole or replay attacks. Black hole Attack falls under the first category because it does not forward any data packet which is intended for the destination. The attacker embeds itself into the route from Source to destination by sending a false RREP containing higher Sequence number giving an impression that it has the freshest route towards destination. Then the source will be captured into constructing a path through malicious node and rejecting all other available paths. After doing that, when the data packets are to be transmitted towards destination, the attacker will simply drops all of them and thus destination will not be able to receive even a single piece of information.

IV. TAGUCHI METHOD

Design of Experiment (DOE) methods were developed originally by Fisher. However, classical experimental design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out as the number of the process parameters increases. To solve this important task, the Taguchi method uses a special design or orthogonal array to study the entire parameter space with only a small number of experiments. The experimental results are then transformed into a signal-to-noise(S/N) ratio. The S/N ratio can be used to measure the deviation of the performance characteristics from the desired values. Furthermore, a statistical analysis of variance (ANOVA) is performed to identify the process parameters that are statistically significant. The optimal combination of the process parameters can then be predicted based on the analysis.

V. PERFORMANCE PARAMETERS

MANET has number of qualitative and quantitative metrics that can be used to compare ad hoc routing protocols. This paper has been considered the following metrics to evaluate the performance of ad hoc network routing protocols

1) End-to-end Delay:

This metric represents average end-to-end delay and indicates how long it took for a packet to travel from the source to the application layer of the destination. It includes all possible delay caused by buffering during route discovery latency, transmission delays at the MAC, queuing at interface queue, and propagation and transfer time. It is measured in seconds.

Average end to end delay = Receiver time – Sender Time

2) **Packet Delivery Ratio:**

Packet delivery ratio is calculated by dividing the number of packets received by the destination through the number of packets originated by the application layer of the source (i.e. CBR source). It specifies the packet loss rate, which limits the maximum throughput of the network.

Packet delivery ratio = Total number of packet send / Total number of packet received

3) Throughput:

It is the measure of the number of packets successfully transmitted to their final destination per unit time. It is the ratio between the numbers of received packets vs sent packets.

Throughput = Number of bits received / Simulation time

VI. RESULTS

In order to conduct the number of experiments Taguchi orthogonal L8 matrix has been formulated by using MINITAB 16 software. Afterwards Regression testing of various effecting parameters has been done in order to examine the significance of whole process.

Orthogonal Matrix of Taguchi For AODV (Packet Delivery Ratio)

No. of nodes	Packet Delivery Ratio	Packet Delivery Ratio with black hole
10	96	69
20	99	63
30	99	56
40	99	42
50	99	36
60	98	32
70	97	29
80	96	26

Table 1 Orthogonal Matrix of Taguchi for AODV (Packet Delivery Ratio)

Main Effect Plots for AODV Packet Delivery Ratio (With and without BH attack)

From main effect plot as shown in figure 2 it is observed that the value of AODV packet delivery ratio at 10 nodes is 99 and it remains same up to 50 number of nodes and later on from 50 to 80 it decreases continuously .

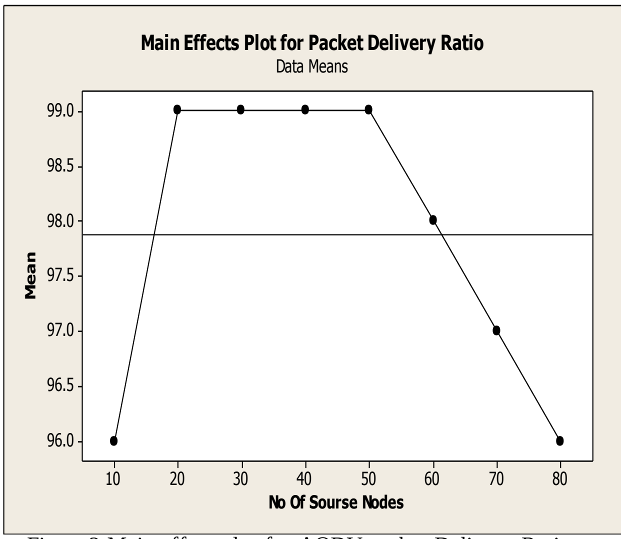

Figure 2 Main effect plot for AODV packet Delivery Ratio

Similarly from main effect plot as shown in Figure 3 it is observed that the packet delivery ratio is highest at 10 nodes i.e 65 and then later on it is continuously decreasing upto 80 number of nodes. The packet delivery ratio at 80 nodes is 25.

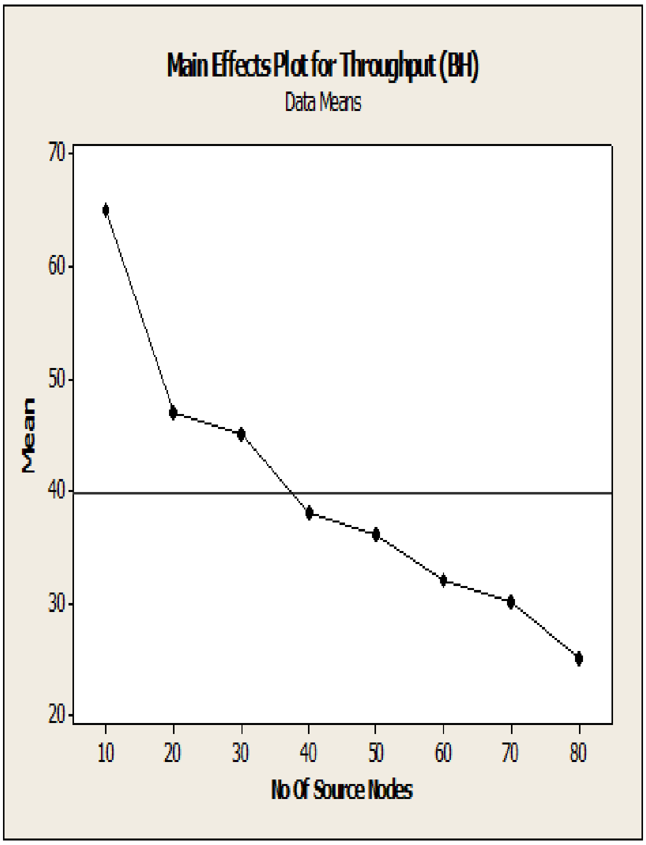

Figure 3 Main effect plot for AODV packet Delivery Ratio with Black hole attack

Statics for AODV Packet Delivery Ratio (with and without BH)

Data has been checked for its normality by probability plot as shown in figure 4 and 5. As shown in Normal Probability plot data points are distributed all along the normal line except few two or three data points, so data can be concluded as normally distributed. In the second plot versus fits data points are not along the line. This plot doesn't show any trend while plotting residual versus fitted values of data which implies Taguchi model chosen is well fitted with given data set. Third plot is frequency histogram showing data distribution and at last residue order versus order plot highlights the random data points which signify non-significance of experimental order.

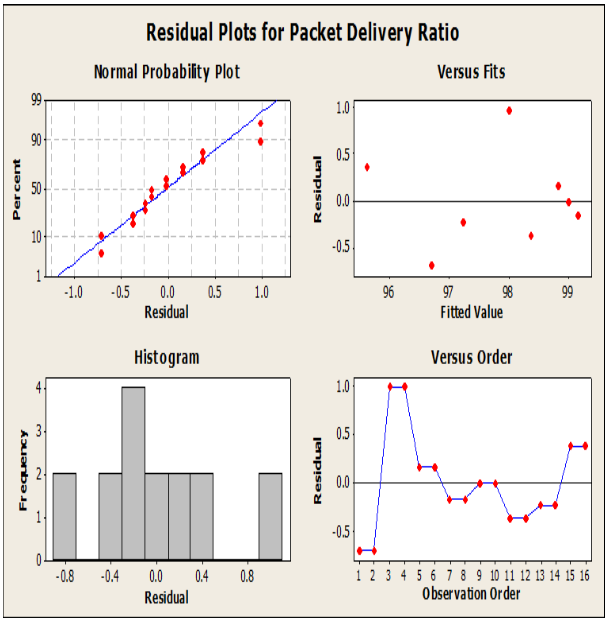

Figure 4 Residual Plots For AODV Packet Delivery ratio

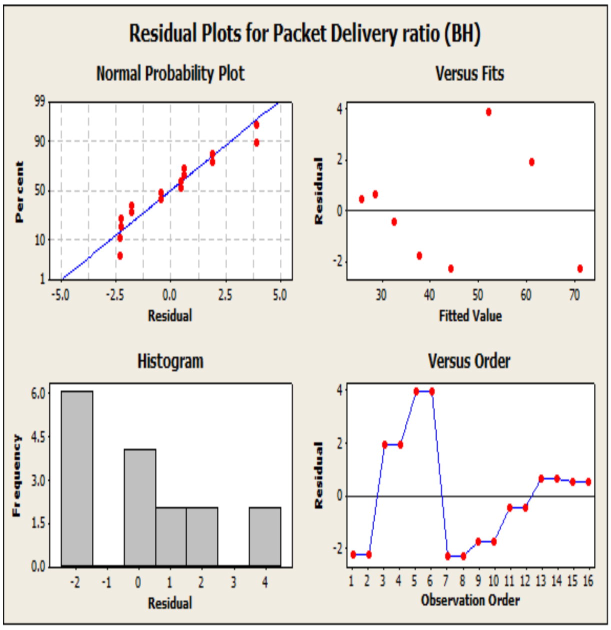

Figure 5 Residual Plots For AODV Packet Delivery ratio (BH)

Estimated Regression Coefficients for AODV Packet Delivery Ratio

Taguchi method for No of source nodes has been applied at 95% confidence, so all factors and their interactions having p (probability) value less than 0.05 will be statistically significant for No of source nodes and must be further taken care of. All the detail of statistical analysis of Taguchi for No of source nodes is shown in table 2. As the p values are less than 0.05 for No Of Source Nodes for packet delivery ratio hence this parameter is having significant impact on whole process.

Term	P	Significant / Not Significant
Constant	0.037	Significant
No Of Source Nodes	0.020	Significant
No Of Source Nodes	0.003	Significant

R-Sq(adj) = 98.30%

Table 2 Estimated Regression Coefficients for AODV Packet Delivery ratio

Estimated Regression Coefficients for AODV Packet Delivery Ratio (BH)

Again Taguchi method for No of source nodes has been applied at 95% confidence, so all factors and their interactions having p (probability) value less than 0.05 will be statistically significant for No of source nodes and must be further taken care of. All the detail of statistical analysis of Taguchi for No of source nodes is shown in table 3. As the p values are less than 0.05 for No of Source Nodes for packet delivery ratio (BH) hence this parameter is having significant impact on whole process.

Term	P	Significant / Not Significant
Constant	0.002	Significant
No Of Source Nodes	0.027	Significant
No Of Source Nodes	0.039	Significant
R-Sq(adj) = 97.95%		

Table 3 stimated Regression Coefficients for AODV Packet Delivery ratio (BH)

Optimization solution Taguchi for AODV Packet Delivery Ratio with and without black hole attack

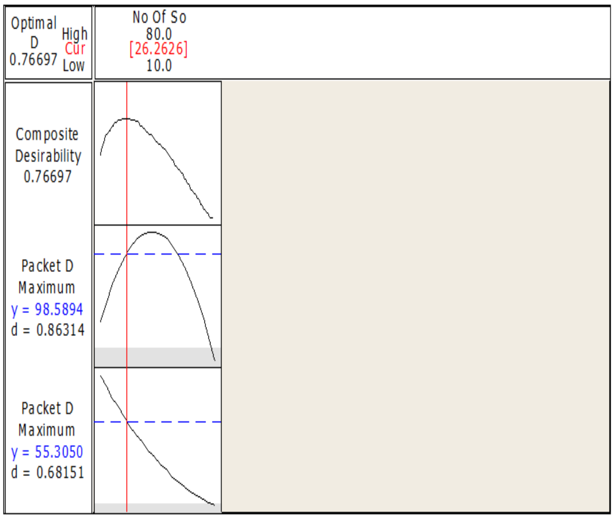

Figure 6 Optimization Plot for AODV Packet Delivery ratio (with and without BH)

From the optimization plot of AODV protocol we found that at 26 nodes highest packet delivery ratio can be achieved with and without black ole attack.

Orthogonal Matrix of Taguchi for AODV Average End to End Delay

No. of nodes	Average End to End Delay	Average End to End Delay with Black hole
10	0.29	0.05
20	0.49	0.15
30	0.51	0.16
40	0.54	0.15
50	0.68	0.24
60	0.63	0.18
70	0.62	0.25
80	0.6	0.14

Table 4 Orthogonal Matrix of Taguchi for AODV Average End to End Delay

Main Effect Plots for for AODV Average End to End Delay (With and without BH attack)

From main effect plot as shown in figure 7 it is observed that at 10 number of nodes average end to end delay is .3 and it is continuously increasing up to 50 nodes and later on it start decreasing.

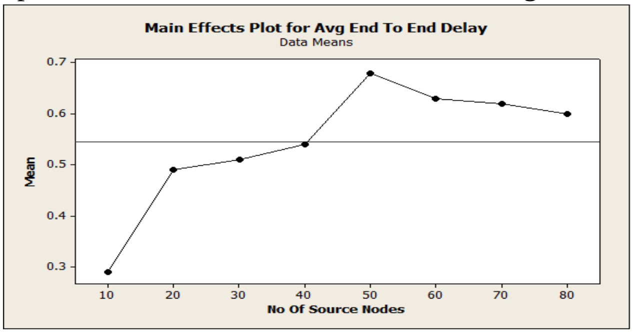

Figure 7 Main effect plot AODV Average End to End Delay

Similarly the variations in main effect plot for AODV Average End to End Delay with black hole attack is shown in figure 8

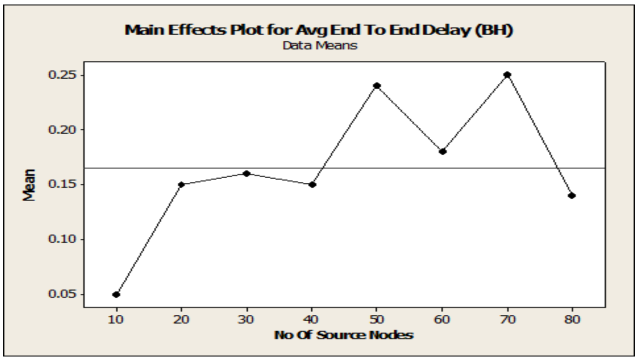

Figure 8 Main effect plot AODV Average End to End Delay (BH)

Statics for AODV Average End to End Delay (with and without BH)

After having values of Packet Delivery Ratio with and without Black hole attack for each experiment now time to check the data. So data has been checked for its normality by probability plot as shown in figure 9 and 10. As shown in Normal Probability plot data points are distributed all along the normal line except few two or three data points, so data can be concluded as normally distributed. In the second plot versus fits data points are not along the line. This plot doesn't show any trend while plotting residual versus fitted values of data which implies Taguchi model chosen is well fitted with given data set. Third plot is frequency histogram showing data distribution and at last residue order versus order plot highlights the random data points which signify non-significance of experimental order.

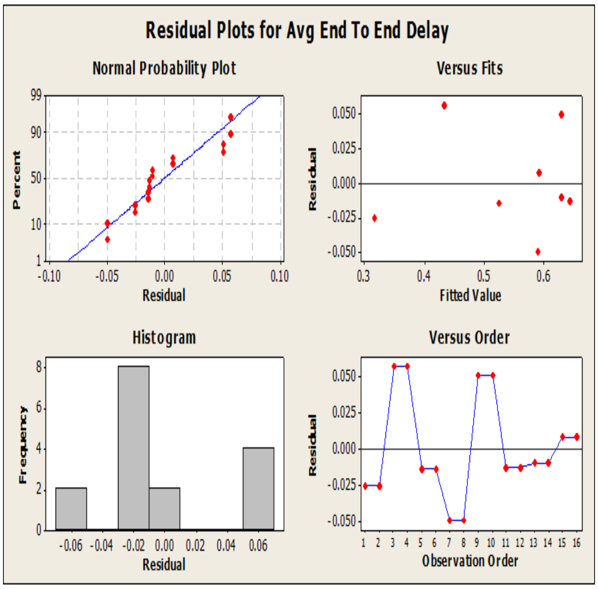

Figure 9 Residual Plots For AODV Average End to End Delay

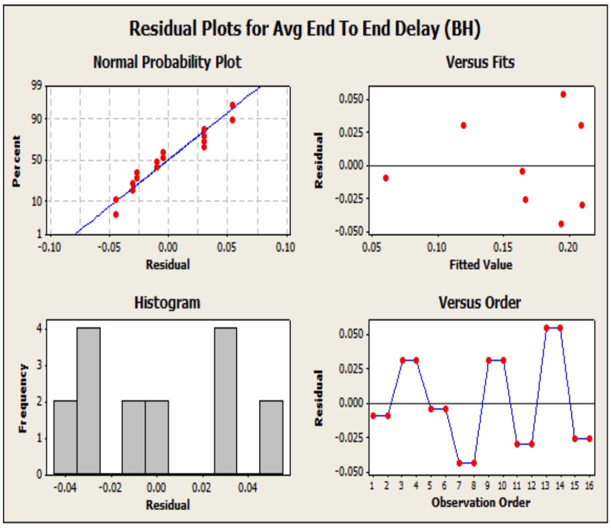

Figure 10 Residual Plots for AODV Average End to End Delay (BH)

Estimated Regression Coefficients for AODV Average End to End Delay

Taguchi method for No of source nodes has been applied at 95% confidence, so all factors and their interactions having p (probability) value less than 0.05 will be statistically significant for No of source nodes and must be further taken care of. All the detail of statistical analysis of Taguchi for

No of source nodes is shown in table 5 As the p values are less than 0.05 for No Of Source Nodes for packet delivery ratio hence this parameter is having significant impact on whole process.

Term	P	Significant / Not Significant
Constant	0.005	Significant
No Of Source Nodes	0.047	Significant
No Of Source Nodes	0.047	Significant
R-Sq(adj) = 97.40%		

Table 5 Estimated Regression Coefficients for AODV Average End to End Delay

Estimated Regression Coefficients for AODV Average End to End Delay (BH)

Again Taguchi method for No of source nodes has been applied at 95% confidence, so all factors and their interactions having p (probability) value less than 0.05 will be statistically significant for No of source nodes and must be further taken care of. All the detail of statistical analysis of Taguchi for No of source nodes is shown in table 6. As the p values are less than 0.05 for No of Source Nodes for packet delivery ratio (BH) hence this parameter is having significant impact on whole process.

Term	P	Significant / Not Significant
Constant	0.035	Significant
No Of Source Nodes	0.002	Significant
No Of Source Nodes	0.002	Significant
R-Sq(adj) = 97.23%		

Table 6 Estimated Regression Coefficients for AODV Average End to En
d Delay (BH)

Optimization solution Taguchi for AODV Average End to End delay with and without Black hole attack

Fig 11 shows that by taking No of Nodes 58.7 for the combined case of with and without black hole attack, we will achieve maximum data transfer of 0.80 (without BH) with 80.5 % desirability and 0.21 (with BH) with 80 % desirability . So the composite desirability will become 80.43%.

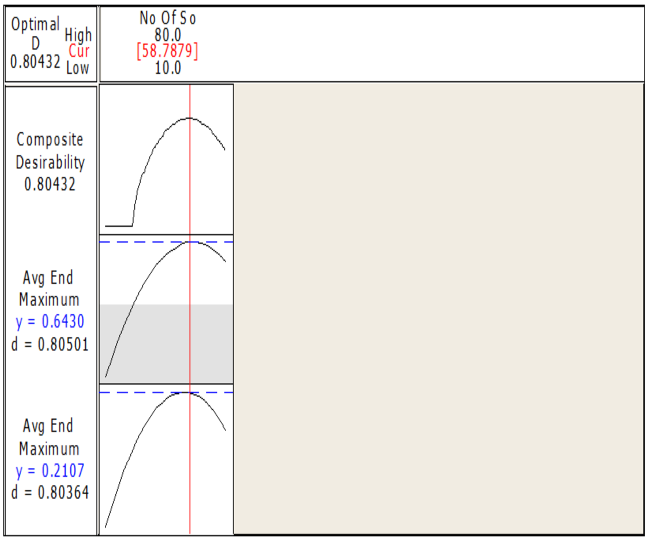

Figure 11 Optimization Plot for AODV Average End to End Delay (with and without BH)

Orthogonal Matrix of Taguchi for AODV Throughput

No. of nodes	Throughput	Throughput with black hole

10	91	65
20	95	47
30	95	45
40	93	38
50	93	36
60	92	32
70	91	30
80	89	25

Table 7 Orthogonal Matrix of Taguchi for AODV throughput

Main Effect Plots for AODV throughput (With and without BH attack)

From main effect plot as shown in figure 12 it is observed that the value of throughput for AODV protocol is 91 at 10 number of nodes then it suddenly increase up to 95 for 20 nodes then from 30 to 80 it goes on decreasing continuously.

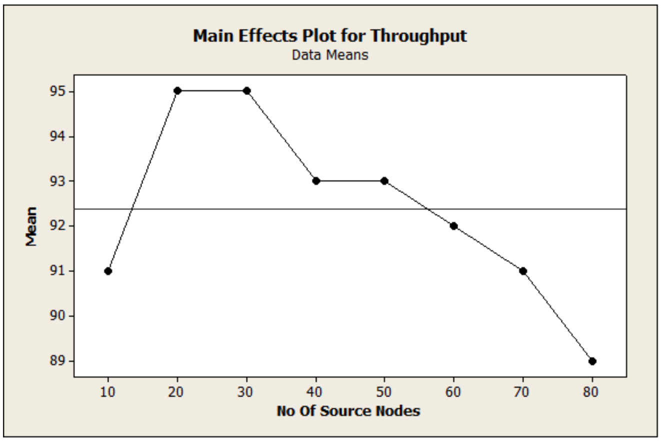

Figure 12 Main effect plot for AODV throughput

Similarly the variations in main effect plot for AODV Average End to End Delay with black hole attack is shown in figure 13.

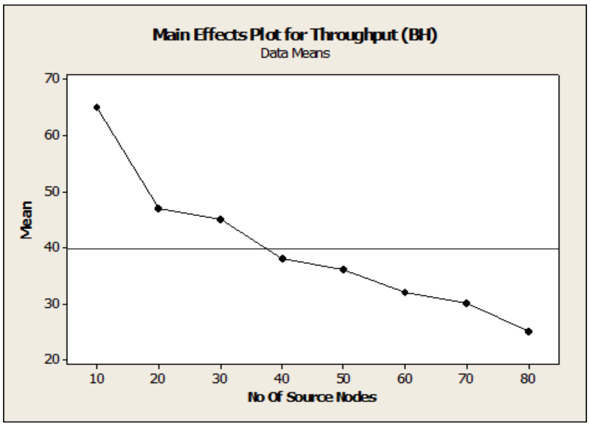

Figure 13 Main effect plot for AODV throughput (BH)

Statics for AODV throughput (with and without BH)

After having values of Packet Delivery Ratio with and without Black hole attack for each experiment now time to check the data. So data has been checked for its normality by probability plot as shown in figure 14 and 15. As shown in Normal Probability plot data points are distributed all along the normal line except few two or three data points, so data can be concluded as normally distributed. In the second plot versus fits data points are not along the line. This plot doesn't show any trend while plotting residual versus fitted values of data which implies taguchi model chosen is well fitted with given data set. Third plot is frequency histogram showing data distribution and at last residue order versus order plot highlights the random data points which signify non-significance of experimental order.

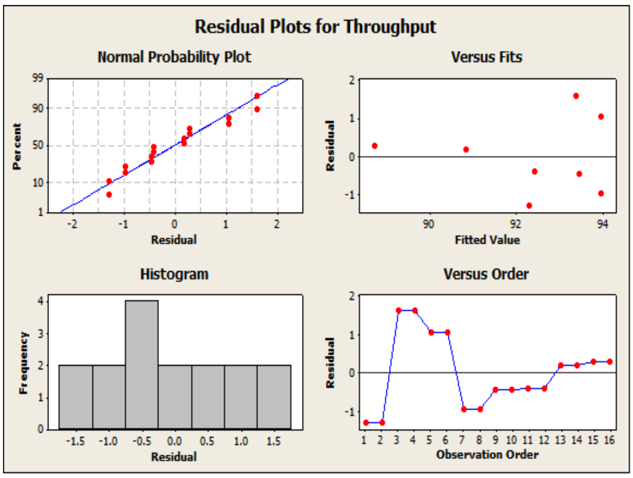

Figure 15 Residual Plots for AODV throughput

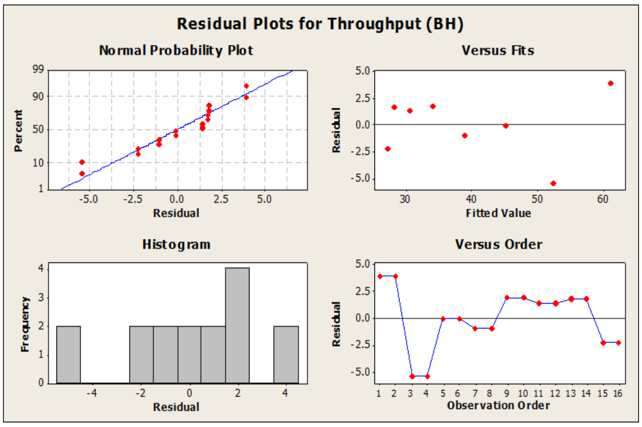

Figure 16 Residual Plots For AODV throughput (BH)

Estimated Regression Coefficients for AODV throughput

Taguchi method for No of source nodes has been applied at 95% confidence, so all factors and their interactions having p (probability) value less than 0.05 will be statistically significant for No of source nodes and must be further taken care of. All the detail of statistical analysis of Taguchi for No of source nodes is shown in table 8. As the p values are less than 0.05 for No Of Source Nodes for packet delivery ratio hence this parameter is having significant impact on whole process.

Term	P	Significant / Not Significant
Constant	0.029	Significant
No Of Source Nodes	0.001	Significant
No Of Source Nodes	0.052	Non Significant
R-Sq(adj) = 93.68%		

Table 8 Table Estimated Regression Coefficients for AODV throughput

Estimated Regression Coefficients for AODV Average End to End Delay (BH)

Again Taguchi method for No of source nodes has been applied at 95% confidence, so all factors and their interactions having p (probability) value less than 0.05 will be statistically significant for No of source nodes and must be further taken care of. All the detail of statistical analysis of Taguchi for No of source nodes is shown in table 9. As the p values are more than 0.05 for No of Source Nodes for packet delivery ratio (BH) hence this parameter is having non-significant impact on whole process. There could might be some noise factors affecting the whole process.

Term	P	Significant / Not Significant
Constant	0.002	Significant
No Of Source Nodes	0.040	Significant
No Of Source Nodes	0.002	Non Significant
R-Sq(adj) = 95.81%		

Table 9 Estimated Regression Coefficients for AODV throughput (BH)

Optimization solution Taguchi for AODV Average End to End Delay for with and without Black hole attack

Fig 6 shows that by taking No of Nodes 15.3 for the combined case of with and without black hole attack, we will achieve maximum data transfer of 92.9 (without BH) with 65 % desirability and 56.3 (with BH) with 78 % desirability . So the composite desirability will become 71.7%.

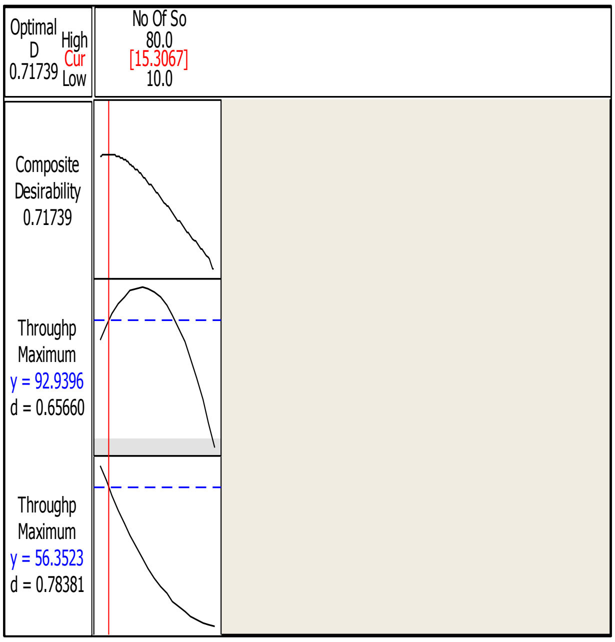

Figure 17 Optimization Plot for AODV throughput (with and without BH)

Optimization plot of AODV for packet delivery ratio,average end to end delay and throughput

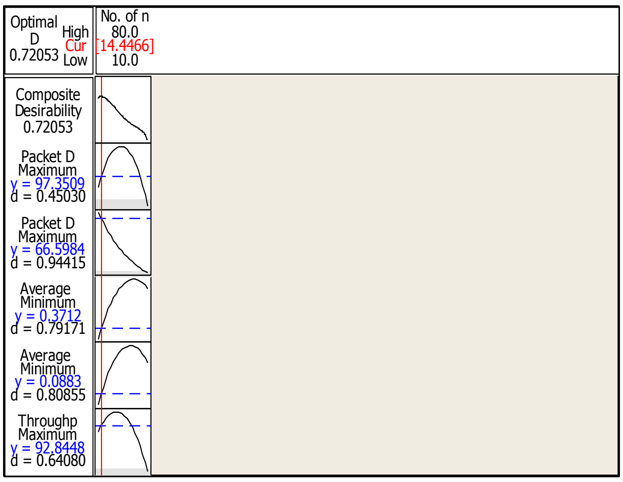

Figure 18 Optimization of AODV for Packet Delivery

Ratio , average end to end delay and throughput.

VIII. CONCLUSION

In the evaluation of number of nodes for AODV protocol for packet delivery ratio, average end to end delay and throughput it is found that for 14 nodes it provides high packet delivery ratio, average end to end delay and throughput.

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