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PROVISIONING RESTORABLE VIRTUAL PRIVATE NETWORKS USING BARABASI AND WAXMAN TOPOLOGY GENERATION MODEL

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Abstract
As internet usage grows exponentially, network security issues become increasingly important. Network security measures are needed to protect data during transmission. Various security controls are used to prevent the access of hackers in networks. They are firewall, virtual private networks and encryption algorithms. Out of these, the virtual private network plays a vital role in preventing hackers from accessing the networks. A Virtual Private Network (VPN) provides end users with a way to privately access information on their network over a public network infrastructure such as the internet. Using a technique called "Tunneling", data packets are transmitted across a public routed network, such as the internet that simulates a point-to-point connection. Virtual private networks provide customers with a secure and low-cost communication environment. The basic structure of the virtual circuit is to create a logical path from the source port to the destination port. This path may incorporate many hops between routers for the formation of the circuit. The final, logical path or virtual circuit acts in the same way as a direct connection between the two ports. Our proposed Provisioning Restorable Virtual Private Networks Algorithm (PRA) is used to combine the provisioning and restoration algorithms to achieve better results than the ones obtained by independent restoration and provisioning. In order to ensure service quality and availability in Virtual Private Networks, seamless recovery from failures is essential. The quality of service of the Virtual Private Networks is also improved due to the combination of provisioning and restoration. The bandwidth sharing concept is also applied in link to improve the quality of service in the Virtual Private Network. The performance analysis of the proposed algorithm is carried out in terms of cost, the number of nodes, the number of VPN nodes, delay, asymmetric ratio and delay with constraints with Disjoint Path Algorithm and Approximation Restoration Virtual Private Networks Algorithm. The Provisioning Restorable Virtual Private Networks Algorithm performs better than the Disjoint Path Algorithm.

Keywords:
Virtual Private Network, Restoration, Provisioning

1. INTRODUCTION

Better quality of service can be achieved by combining the provisioning and restoration algorithms. In order to meet the bandwidth requirements specified by customers, the Network Service Provider needs to reserve in a restorable VPN, a sufficient amount of bandwidth on data transmission paths between each endpoint pairs [2]-[5]. The primary bandwidth is the one needed on the paths under the non-failure case. The additional bandwidth needed on the alternative paths under the link failure case is called protected bandwidth [1],[7]-[10]. Here, we proposed to combine the provisioning and restoration algorithms to achieve better results than the ones obtained by independent restoration and provisioning methods.

1.1 RESTORABLE VPN

End-to-end restoration provides protection on disjoined paths from the source to the destination and may rely on fault signaling to effect recovery switching at the source [6]. Local restoration for its part effects protection switching at the upstream node from the point of failure, the point of local repair and do not require fault signaling. The local restoration is not efficient in capacity. Path protection, on the other hand, can optimize capacity allocation on an end-to-end basis [11]-[15]. Our research work investigates the problem of provisioning restorable virtual private networks algorithm paths that satisfy delay constraints.

1.2 BANDWIDTH SHARING IN RESTORABLE VPN

In general, bandwidth sharing reduces the total reservation cost of the virtual private networks. Identifying the optimal bandwidth reservation needs for supporting the different traffic is important for both; from the applying customer's perspective, it is necessary to minimize the bandwidth reservation cost, and for a network service provider to optimize the network utilization [16],[17]. Therefore, the bandwidth reservation, both in terms of the cost of reservation as well as network utilization, must be made in such a way that the unused bandwidth during non-peak periods can be utilized by the best effort data traffic [18]-[20].

2. PROVISIONING RESTORABLE VIRTUAL PRIVATE NETWORKS ALGORITHM (PRA)

Input: The topology graph, VPN nodes and ingress/egress bandwidth.

Output: Provisioned Restorable Virtual Private Networks Algorithm Tree.

Step 1: Get the number of nodes, VPN nodes and construct the topology using our program.

Step 2: Fix 10 to 50% of the boundary region nodes as VPN nodes.

Step 3: Assign the ingress/egress bandwidth for each of the VPN nodes and assign bandwidth and delay to the edges in the topology graph.

Step 4: Get the source and destination VPN nodes from the topology constructed, using our program.

Step 5: Find all the possible shortest paths from the source VPN node to the destination VPN nodes using the K-Optimized traffic lane algorithm.

Step 5.1 Find all the shortest paths from the source to other VPN nodes using the dijkstra algorithm and add it to the path set.

Step 5.2 For each path in the path set do the following steps

a. Take the first path from the path set.
b. Take the least cost link in the selected path and add to the least cost link.
c. Remove the least cost link from the network and find the new shortest path using the dijkstra algorithm.
d. If the new path exists then add the path to the path set.
e. Repeat steps b to d for each least cost link.
f. Reinsert the removed link into the network.

Step 5.3 Repeat the step 5.2 for each path in the path set until all the paths in the path set have been processed.

Step 6: Construct a BFS Tree by combining any two paths from the shortest path list randomly.

Step 7: Repeat step 6 for a different possible combination of the shortest paths.

Step 8: Construct the topology graph using the different combination of shortest paths.

Step 9: Get the random value of the delay constraint.

Step 10: Determine the primary path from the source to the destination.

Step 10.1 Assign the bandwidth and propagation delay values from the source to all the nodes.

Step 10.2 Find the minimum delay value from the source to all the adjacent nodes.

Step 10.3 Set the flag value for the visited node in the network.

Step 10.4 Find the minimum delay of the adjacent nodes in the network.

Step 11: Step 10 repeated until the destination node is reached.

Step 12: Display the primary quality of service path from the given source to destination node.

Step 13: Display the minimum propagation delay of the primary quality of service path that satisfies the delay constraint with an optimal cost.

Step 14: If any one of the link fails in the primary quality of service path, use the path restoration for finding the alternative path.

Step 15: Find a restoration path from the source to the destination.

Step 15.1 Construct the auxiliary directed graph, by reversing the links that belong to the primary quality of service path.

Step 15.2 Assign the delay value as zero for reversing the link and substitute the bandwidth of each link of the auxiliary graph.

Step 16: Use the adjustment delay concept for finding the minimum delay of the restoration path.

Step 16.1 Check if any one of the adjacent nodes belongs to the primary path. Also check if the delay of the adjacent nodes is less than or equal to the summation of the delay of the primary path from the source to the visited node along with the difference between the delay constraint and the delay of the primary path. If both these conditions are satisfied then find the minimum delay between the primary path of the source to the visited node and the delay of the adjacent nodes.

Step 16.2 If both the adjacent nodes belong to the primary path find if the delay of the route from the source to the previous node is less than or equal to the delay of primary path from the source to the previous node; then, find the delay of the primary path from the source to the visited node.

Step 16.3 If the above mentioned two constraints do not satisfy then add the delay of the route from the source to the previous node and delay of the previous node to the visited node.

Step 17: Step 16 repeated until the destination node is reached.

Step 18: Display the restoration path from the given source to the destination node.

Step 19: Display the minimum propagation delay of the restoration path that satisfies the delay constraint at the optimal cost.

Step 20: Find the delay of the route and cost of the route for the primary quality of service path and the restoration path, and whether the total cost for both the paths are optimum.

3. ALGORITHMS USED FOR COMPARISON

We have proposed a combination of the provisioning and restoration algorithm, named as the Provisioned Restorable Virtual Private Networks Algorithm (PRA) for the VPN which is the main criterion for reducing the total cost. Here, we have used the Waxman and Barabasi-Albert Model to generate a random topology of the virtual private network for symmetric as well as Asymmetric cases. The number of nodes chosen for analysis are 100 to 1000. Also, we have compared our Provisioned Restorable Algorithm with the disjoint path(DP) algorithm (Yigal Bejerano et al 2005), and the Adjustment Restoration Virtual Private Networks Algorithm(ARA) on the basis of the following parameters: cost, number of nodes, delay and various delay constraints.

4. SIMULATION RESULTS AND DISCUSSION (WAXMAN –MODEL)

4.1 NETWORK SIZE VS COST FOR THE SYMMETRIC VPN USING THE WAXMAN MODEL

Figures 1, 2, 3, 4 and 5 depict the symmetric provisioning cost of the PRA, ARA and DP algorithms for 500 boundary

VPN nodes among the 1000 nodes with various delay constraints of 3, 4, 8, 9 and 10 seconds respectively. The model used for topology creation is the Waxman Model. The bandwidth of each link is assigned randomly by simply specifying the minimum and maximum values in the range of 0 to 2500 Mbps. The VPN nodes are randomly assigned with a symmetric bandwidth so that the bandwidth is higher than any randomly assigned bandwidth for the links. The value plotted in the graph was the average of the readings taken from fifteen different runs of the experiment.

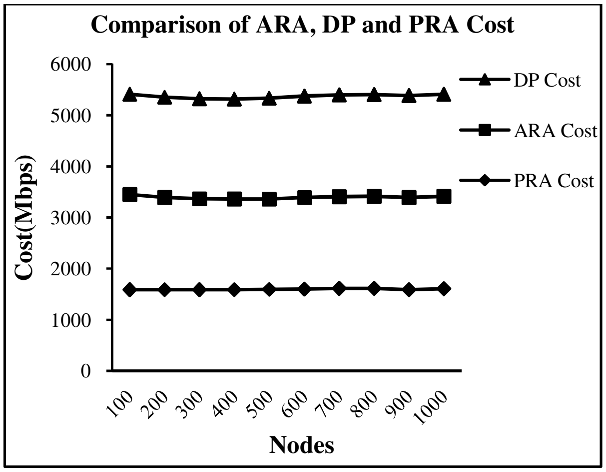

Fig.1. Effect of the Number of nodes on cost for the Symmetric case of the Waxman Model with a delay constraint of 3 seconds (500 VPN nodes among 1000 nodes)

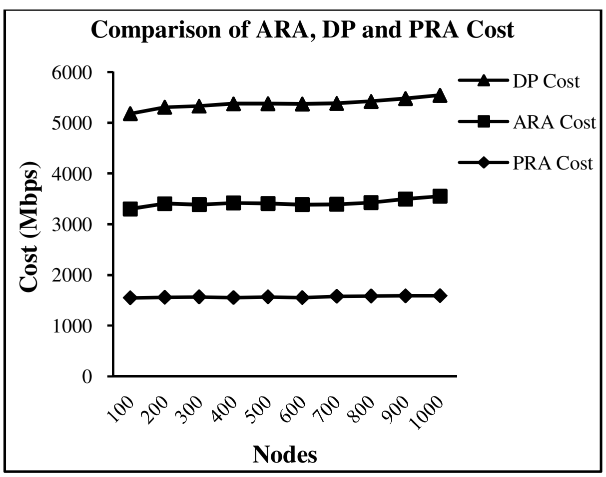

Fig.2. Effect of the Number of nodes on cost for the Symmetric case of the Waxman Model with a delay constraint of 4 seconds (500 VPN nodes among 1000 nodes)

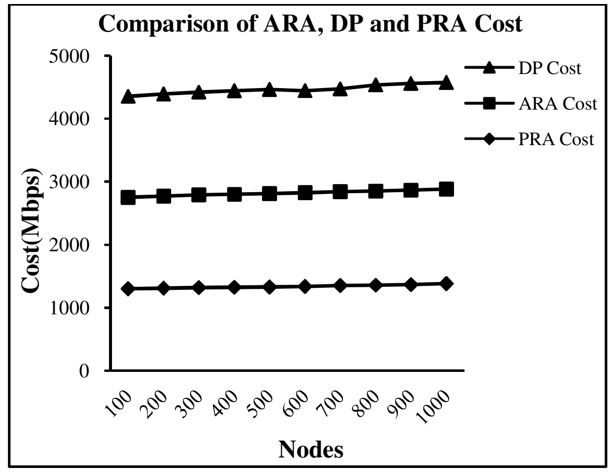

Fig.3. Effect of the Number of nodes on cost for the Symmetric case of the Waxman Model with a delay constraint of 8 seconds (500 VPN nodes among 1000 nodes)

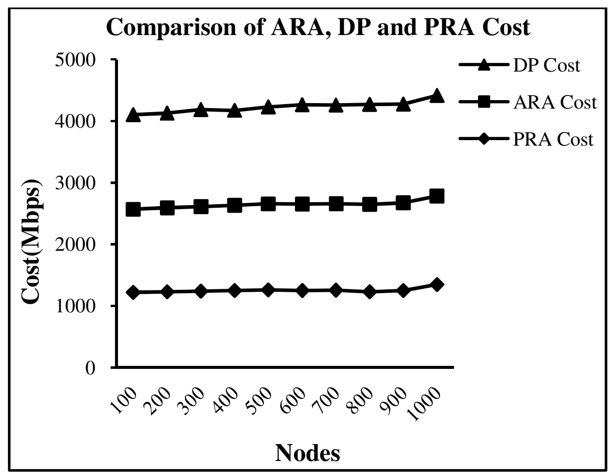

Fig.4. Effect of the Number of nodes on cost for the Symmetric case of the Waxman Model with a delay constraint of 9 seconds (500 VPN nodes among 1000 nodes)

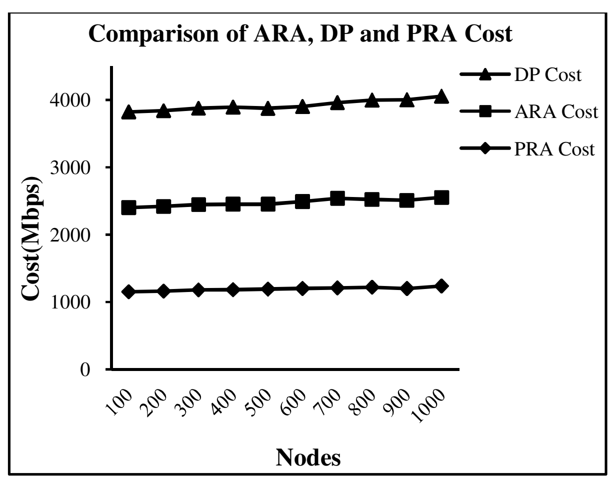

Fig.5. Effect of the Number of nodes on cost for the Symmetric case of the Waxman Model with a delay constraint of 10 seconds (500 VPN nodes among 1000 nodes)

Figures 1, 2, 3, 4 and 5 show that our PRA algorithm is certainly optimal for the symmetric case than the ARA and DP. The cost of the PRA is lesser than that of the ARA and DP algorithms.

4.2 NETWORK SIZE VS DELAY FOR THE SYMMETRIC VPN USING THE WAXMAN MODEL

Figures 6, 7, 8 and 9 depict the symmetric provisioning delay of the PRA, ARA and DP algorithms for 500 boundary VPN nodes among the 1000 nodes with various delay constraints of 11, 9, 8 and 6 seconds respectively. The model used for topology creation is the Waxman Model. The value plotted in the graph was the average of the readings taken from fifteen different runs of the experiment.

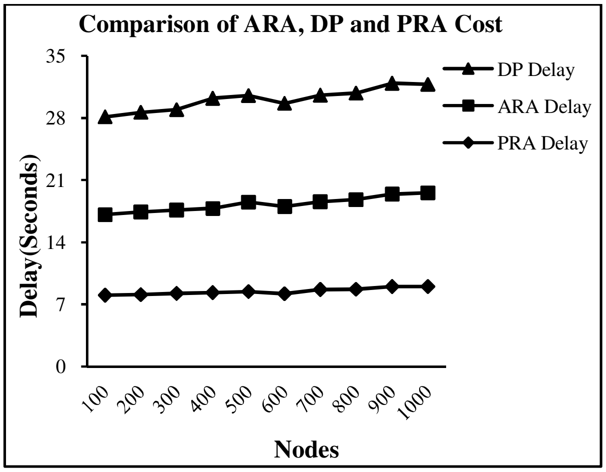

Fig.6. Effect of the Number of nodes on delay for the Symmetric case of the Waxman Model with a delay constraint of 11 seconds (500 VPN nodes among 1000 nodes)

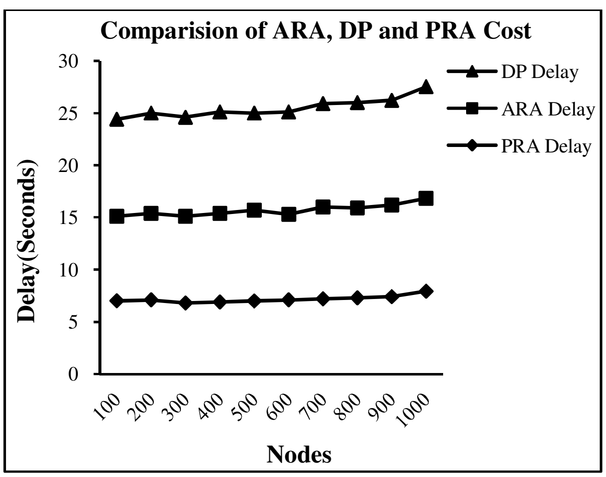

Fig.7. Effect of the Number of nodes on delay for the Symmetric case of the Waxman Model with a delay constraint of 9 seconds (500 VPN nodes among 1000 nodes)

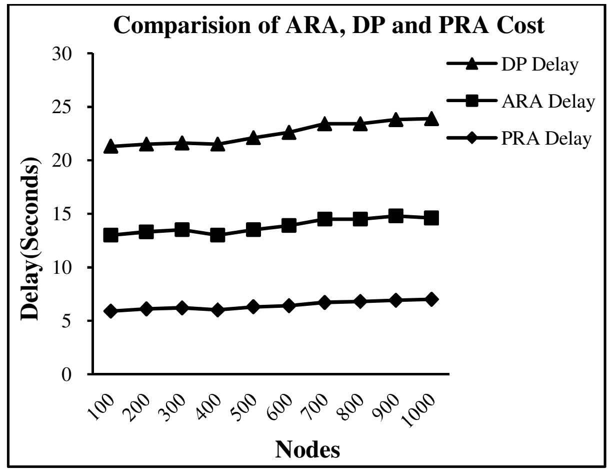

Fig.8. Effect of the Number of nodes on delay for the Symmetric case of the Waxman Model with a delay constraint of 8 seconds (500 VPN nodes among 1000 nodes)

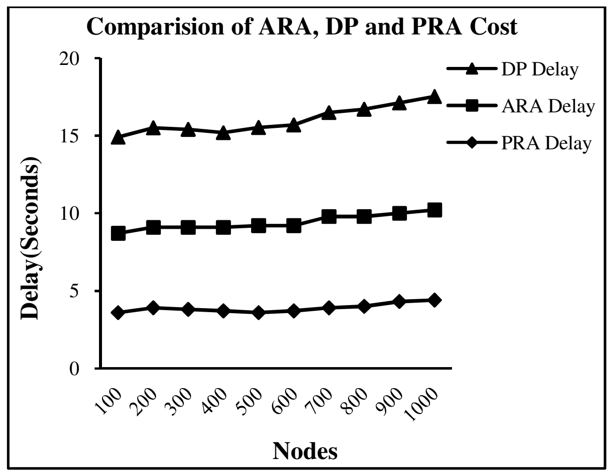

Fig.9. Effect of the Number of nodes on delay for the Symmetric case of the Waxman Model with a delay constraint of 6 seconds (500 VPN nodes among 1000 nodes)

Figures 6, 7, 8 and 9 show that our PRA algorithm is certainly optimal for the symmetric case than the ARA and DP. The delay of the PRA is lesser than that of the ARA and DP algorithms.

4.3 ASYMMETRIC RATIO VS COST OF VPN USING THE WAXMAN MODEL

Figures 10, 11, 12, 13 and 14 depict the Asymmetric provisioning cost of the PRA, ARA and DP algorithms for 500 boundary VPN nodes among the 1000 nodes with various delay constraints of 3, 4, 8, 9 and 10 seconds respectively. We have varied the asymmetric ratio ranging from 50 to 250. The model used for topology creation is the Waxman Model. The bandwidth of each link is assigned randomly by simply specifying the minimum and maximum values in the range of 0 to 2000 Mbps. VPN nodes are randomly assigned with Asymmetric bandwidth so that the bandwidth is higher than any randomly assigned bandwidth for the links. The value plotted in the graph was the average of the readings taken from fifteen different runs of the experiment.

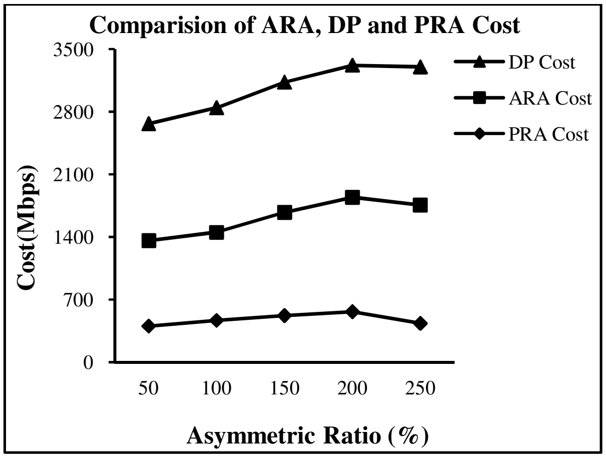

Fig.10. Effect of the Asymmetric Ratio on cost of the Waxman Model with a delay constraint of 3 seconds (500 VPN nodes among 1000 nodes)

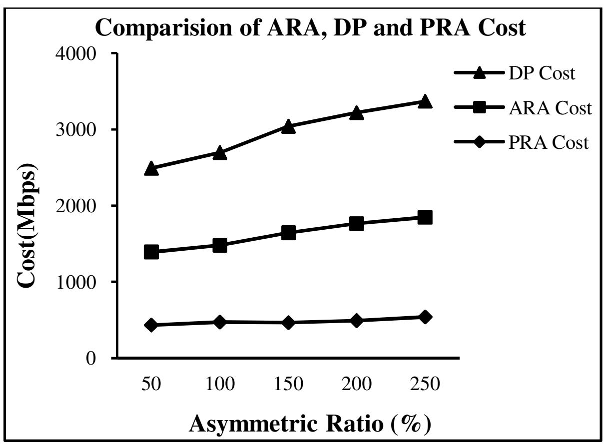

Fig.11. Effect of the Asymmetric Ratio on cost of the Waxman Model with a delay constraint of 4 seconds (500 VPN nodes among 1000 nodes)

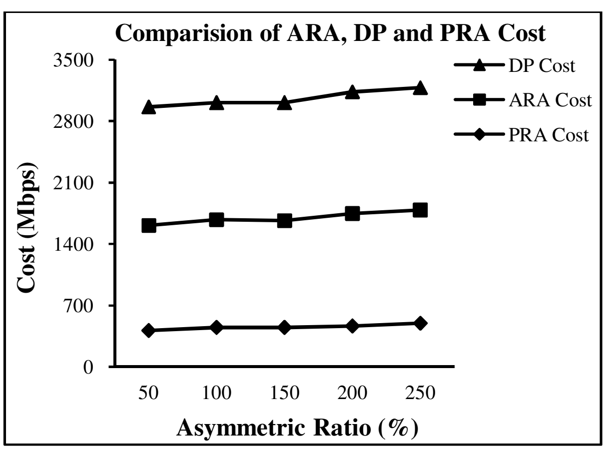

Fig.12. Effect of the Asymmetric Ratio on cost of the Waxman Model with a delay constraint of 8 seconds (500 VPN nodes among 1000 nodes)

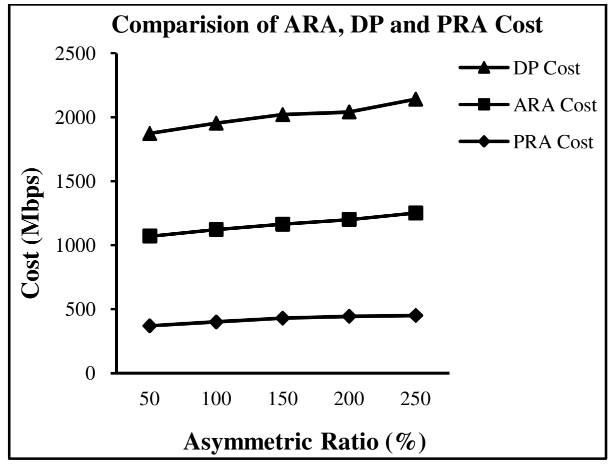

Fig.13. Effect of the Asymmetric Ratio on cost of the Waxman Model with a delay constraint of 9 seconds (500 VPN nodes among 1000 nodes)

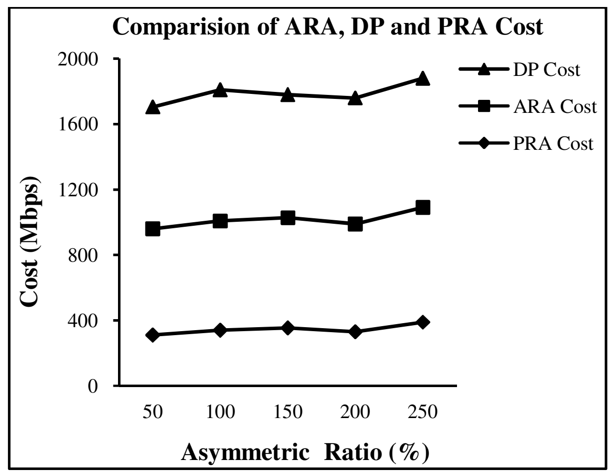

Fig.14. Effect of the Asymmetric Ratio on cost of the Waxman Model with a delay constraint of 10 seconds (500 VPN nodes among 1000 nodes)

Figures 10, 12, 13 and 14 show that our PRA algorithm is certainly optimal for the Asymmetric case than the ARA and DP. The cost of the PRA is lesser than that of the ARA and DP algorithms.

4.4 ASYMMETRIC RATIO VS DELAY OF VPN USING THE WAXMAN MODEL

Figures 15, 16, 17 and 18 depict the Asymmetric provisioning delay of the PRA, ARA and DP algorithms for 500 boundary VPN nodes among the 1000 nodes with various delay constraints of 10, 6, 5 and 4 seconds respectively. The model used for topology creation is the Waxman Model. The value plotted in the graph was the average of the readings taken from fifteen different runs of the experiment.

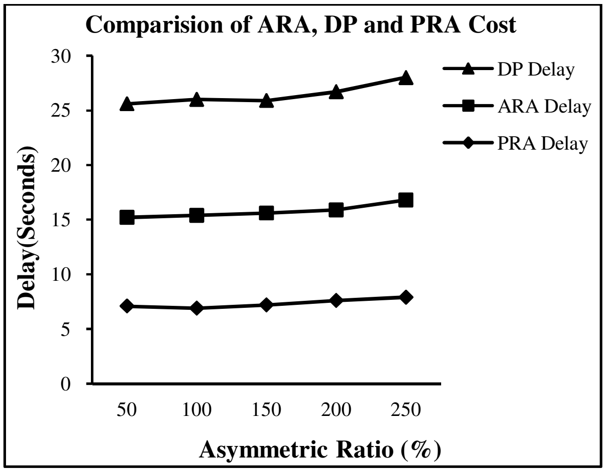

Fig.15. Effect of the Asymmetric Ratio on delay of the Waxman Model with a delay constraint of 10 seconds (500 VPN nodes among 1000 nodes)

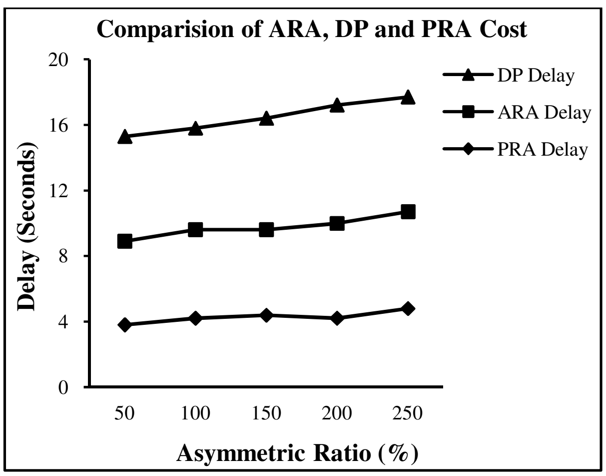

Fig.16. Effect of the Asymmetric Ratio on delay of the Waxman Model with a delay constraint of 6 seconds (500 VPN nodes among 1000 nodes)

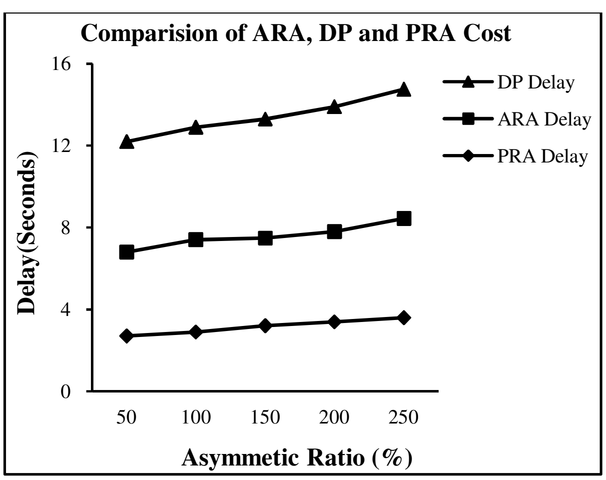

Fig.17. Effect of the Asymmetric Ratio on delay of the Waxman Model with a delay constraint of 5 seconds (500 VPN nodes among 1000 nodes)

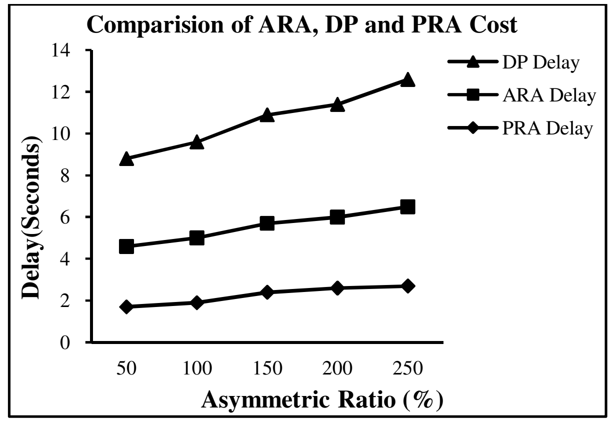

Fig.18. Effect of the Asymmetric Ratio on delay of the Waxman Model with a delay constraint of 4 seconds (500 VPN nodes among 1000 nodes)

Figures 15, 16, 17 & 18 show that PRA algorithm is certainly optimal for the Asymmetric case than the ARA & DP. The delay of the PRA is lesser than that of the ARA and DP algorithms.

5. SIMULATION RESULTS AND DISCUSSION (BARABASI-ALBERT MODEL)

5.1 NETWORK SIZE VS COST FOR THE SYMMETRIC VPN USING THE BARABASI-ALBERT MODEL

Figures 19, 20, 21, 22 and 23 depict the symmetric provisioning cost of the PRA, ARA and DP algorithms for 500 boundary VPN nodes among the 1000 nodes with various delay constraints of 3, 4, 8, 9 and 10 seconds respectively. The model used for topology creation is the Barabasi-Albert Model. The bandwidth of each link is assigned randomly by simply specifying the minimum and maximum values in the range of 0 to 1000 Mbps. VPN nodes are randomly assigned with symmetric bandwidth so that the bandwidth is higher than any randomly assigned bandwidth for the links. The value plotted in the graph was the average of the readings taken from fifteen different runs of the experiment.

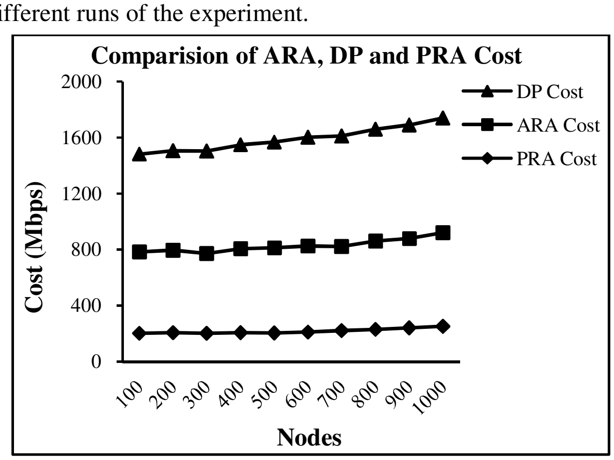

Fig.19. Effect of the Number of nodes on cost for the Symmetric case of the Barabasi-Albert Model with a delay constraint of 3 seconds (500 VPN nodes among 1000 nodes)

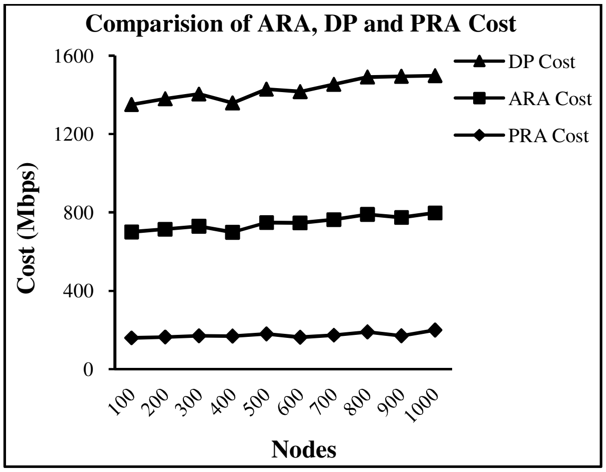

Fig.20. Effect of the Number of nodes on cost for the Symmetric case of the Barabasi-Albert Model with a delay onstraint of 4 seconds (500 VPN nodes among 1000 nodes)

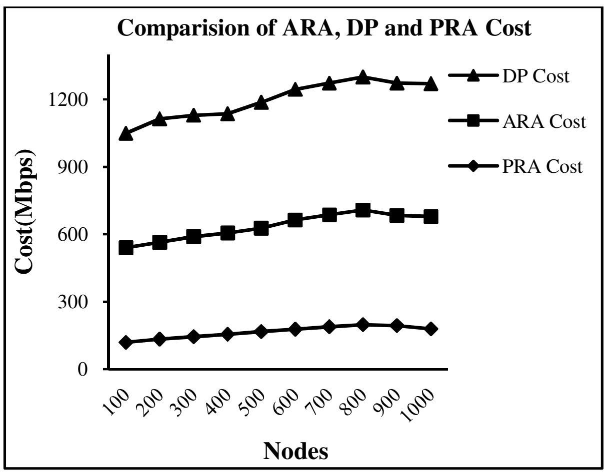

Fig.21. Effect of the Number of nodes on cost for the Symmetric case of the Barabasi-Albert Model with a delay constraint of 8 seconds (500 VPN nodes among 1000 nodes)

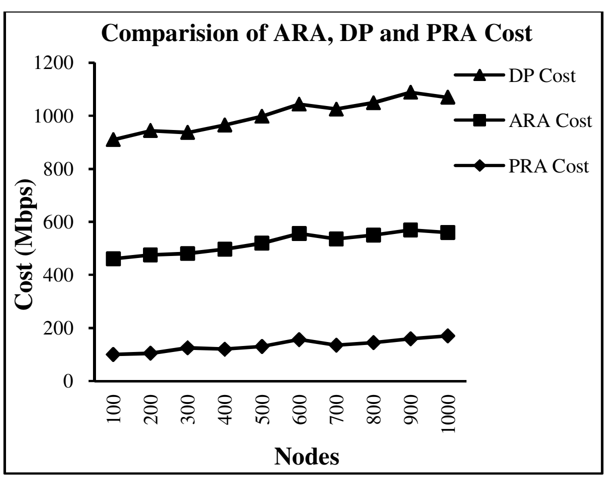

Fig.22. Effect of the Number of nodes on cost for the Symmetric case of the Barabasi-Albert Model with a delay constraint of 9 seconds (500 VPN nodes among 1000 nodes)

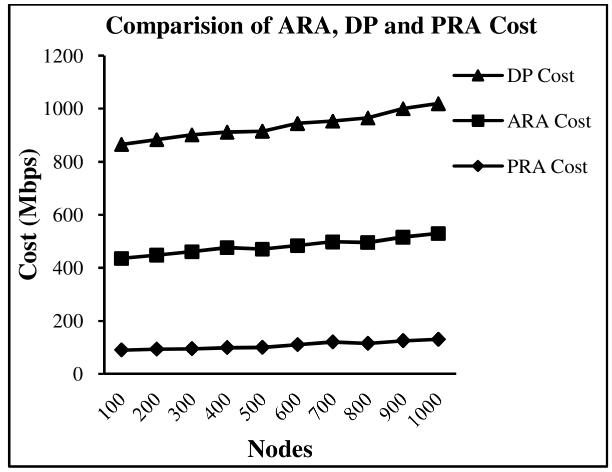

Fig.23. Effect of the Number of nodes on cost for the Symmetric case of the Barabasi-Albert Model with a delay constraint of 10 seconds (500 VPN nodes among 1000 nodes)

Figures 19, 20, 21, 22 and 23 show that our PRA algorithm is certainly optimal for the symmetric case than the ARA and DP. The cost of the PRA is lesser than that of the ARA and DP algorithms.

5.2 NETWORK SIZE VS DELAY FOR THE SYMMETRIC VPN USING THE BARABASI-ALBERT MODEL

Figures 24, 25, 26 and 27 depict the symmetric provisioning delay of the PRA and ARA and DP algorithms for 500 boundary VPN nodes among the 1000 nodes with various delay constraints of 6, 7, 8 and 9 seconds respectively. The model used for topology creation is the Barabasi-Albert Model. The value plotted in the graph was the average of the readings taken from fifteen different runs of the experiment.

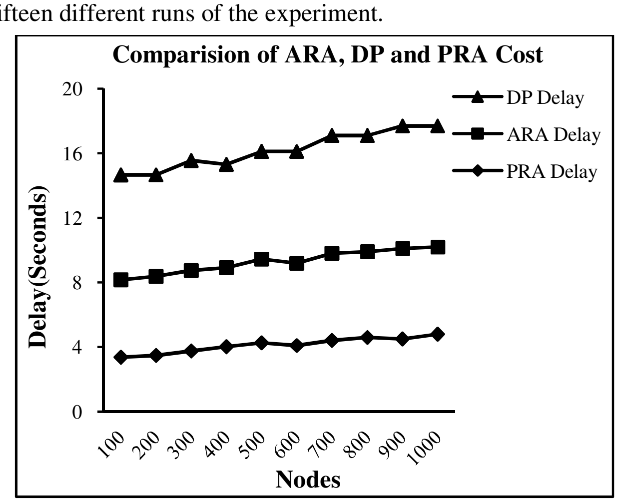

Fig.24. Effect of the Number of nodes on delay for the Symmetric case of the Barabasi-Albert Model with a delay constraint of 6 seconds (500 VPN nodes among 1000 nodes)

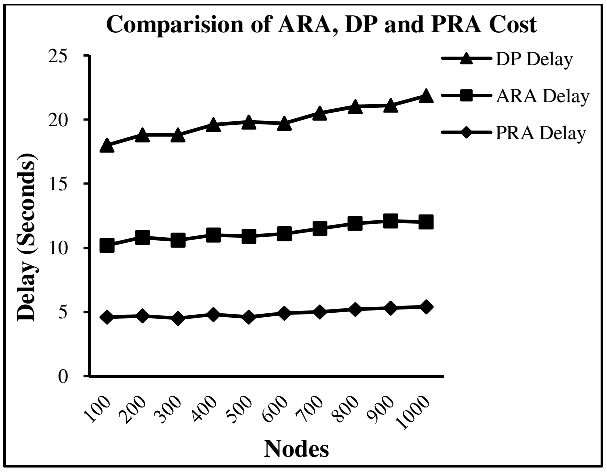

Fig.25. Effect of the Number of nodes on delay for the Symmetric case of the Barabasi-Albert Model with a delay constraint of 7 seconds (500 VPN nodes among 1000 nodes)

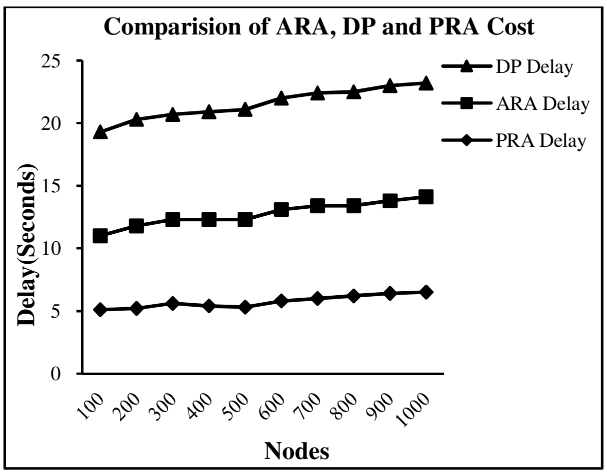

Fig.26. Effect of the Number of nodes on delay for the Symmetric case of the Barabasi-Albert Model with a delay constraint of 8 seconds (500 VPN nodes among 1000 nodes)

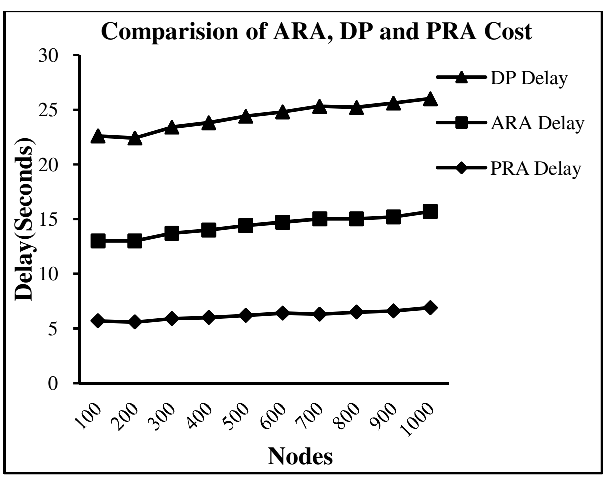

Fig.27. Effect of the Number of nodes on delay for the Symmetric case of the Barabasi-Albert Model with a delay constraint of 9 seconds (500 VPN nodes among 1000 nodes)

Figures 24, 25, 26 and 27 shows that our RA algorithm is certainly optimal for the symmetric case than the ARA and DP. The delay of the PRA is lesser than that of the ARA and DP algorithms.

5.3 ASYMMETRIC RATIO VS COST OF VPN USING THE BARABASI-ALBERT MODEL

Figures 28, 29, 30, 31 and 32 depict the Asymmetric provisioning cost of the PRA and ARA and DP algorithms for 500 boundary VPN nodes among the 1000 nodes with various delay constraints of 3, 4, 8, 9 and 10 seconds respectively. We have varied the asymmetric ratio ranging from 50 to 250. The model used for topology creation is the Barabasi-Albert Model. The bandwidth of each link is assigned randomly by simply specifying the minimum and maximum values in the range of 0 to 1000 Mbps. VPN nodes are randomly assigned with Asymmetric bandwidth so that the bandwidth is higher than any randomly assigned bandwidth for the links. The value plotted in the graph was the average of the readings taken from fifteen different runs of the experiment.

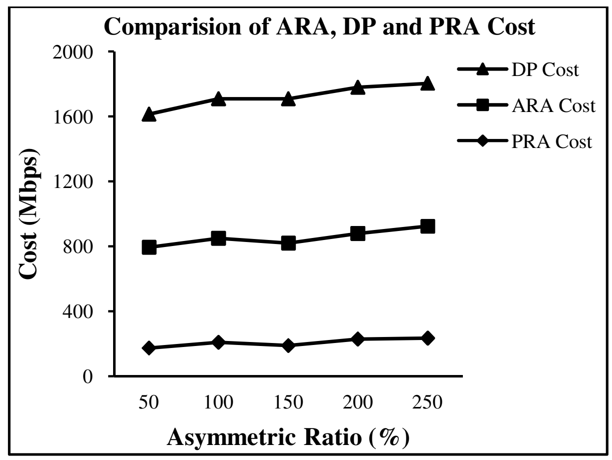

Fig.28. Effect of the Asymmetric Ratio on cost of the Barabasi-Albert Model with a delay constraint of 3 seconds (500 VPN nodes among 1000 nodes)

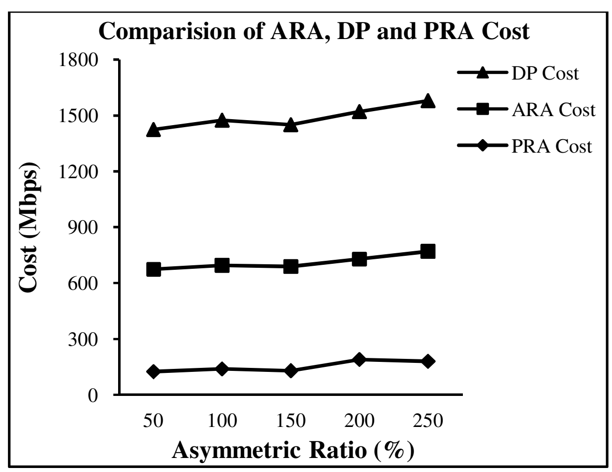

Fig.29. Effect of the Asymmetric Ratio on cost of the Barabasi-Albert Model with a delay constraint of 4 seconds (500 VPN nodes among 1000 nodes)

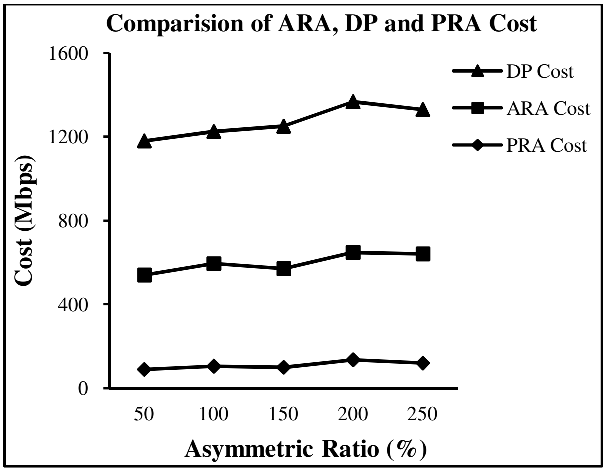

Fig.30. Effect of the Asymmetric Ratio on cost of the Barabasi-Albert Model with a delay constraint of 8 seconds (500 VPN nodes among 1000 nodes)

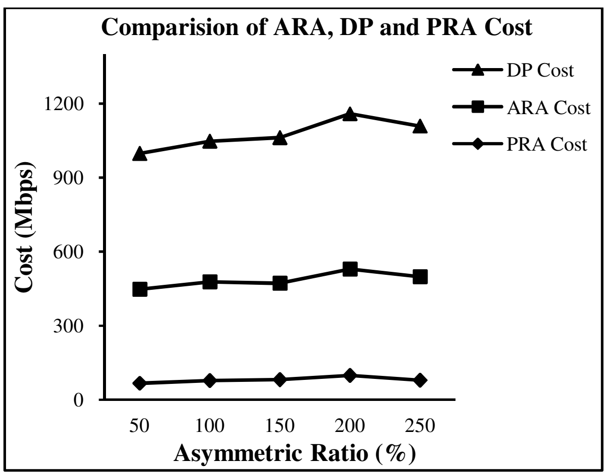

Fig.31. Effect of the Asymmetric Ratio on cost of the Barabasi-Albert Model with a delay constraint of 9 seconds (500 VPN nodes among 1000 nodes)

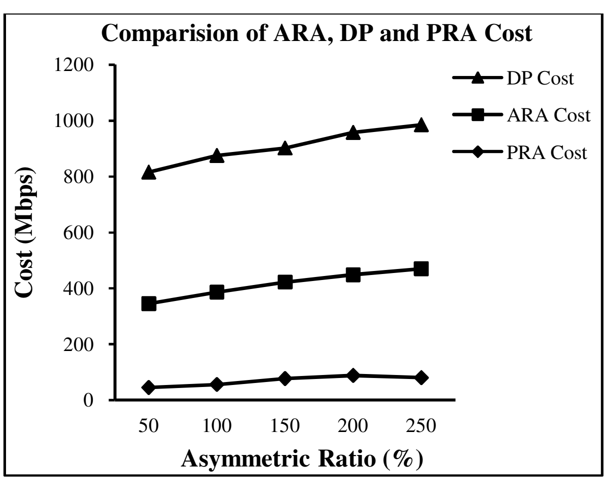

Fig.32. Effect of the Asymmetric Ratio on cost of the Barabasi-Albert Model with a delay constraint of 10 seconds (500 VPN nodes among 1000 nodes)

Figures 28, 29, 30, 31 and 32 show that our PRA algorithm is certainly optimal for the Asymmetric case than the ARA and DP. The cost of the PRA is lesser than that of the ARA and DP algorithms.

5.4 ASYMMETRIC RATIO VS DELAY OF VPN USING THE BARABASI-ALBERT MODEL

Figures 33, 34, 35 and 36 depict the Asymmetric provisioning delay of the PRA and ARA and DP algorithms for 500 boundary VPN nodes among the 1000 nodes with various delay constraints of 4, 5, 7 and 8 seconds respectively. The model used for topology creation is the Barabasi-Albert Model. The value plotted in the graph was the average of the readings taken from fifteen different runs of the experiment.

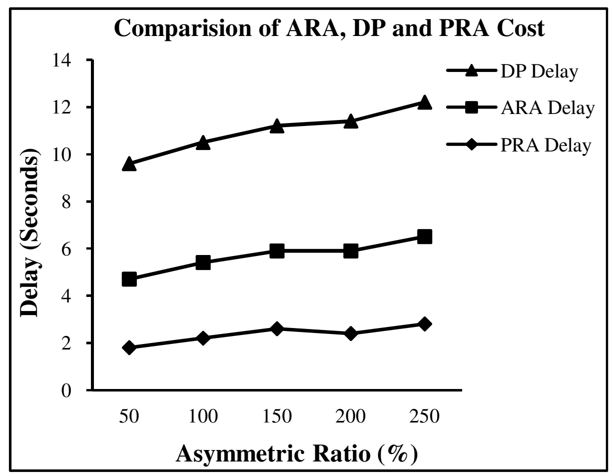

Fig.33. Effect of the Asymmetric Ratio on delay of the Barabasi-Albert Model with a delay constraint of 4 seconds (500 VPN nodes among 1000 nodes)

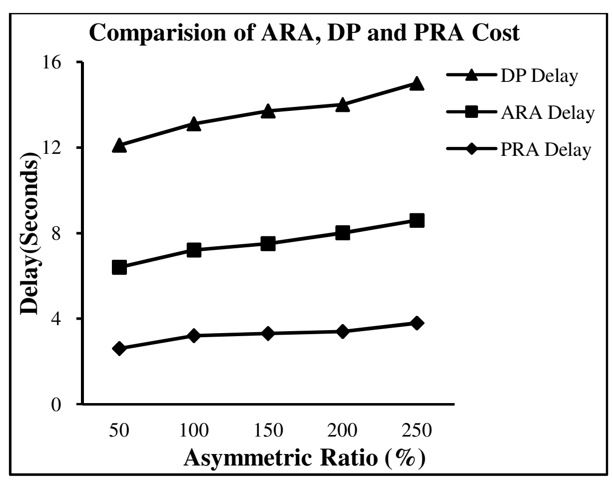

Fig.34. Effect of the Asymmetric Ratio on delay of the Barabasi-Albert Model with a delay constraint of 5 seconds (500 VPN nodes among 1000 nodes)

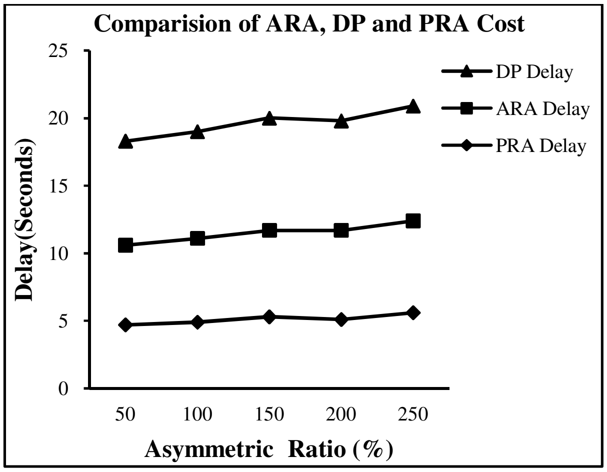

Fig.35. Effect of the Asymmetric Ratio on delay of the Barabasi-Albert Model with a delay constraint of 7 seconds (500 VPN nodes among 1000 nodes)

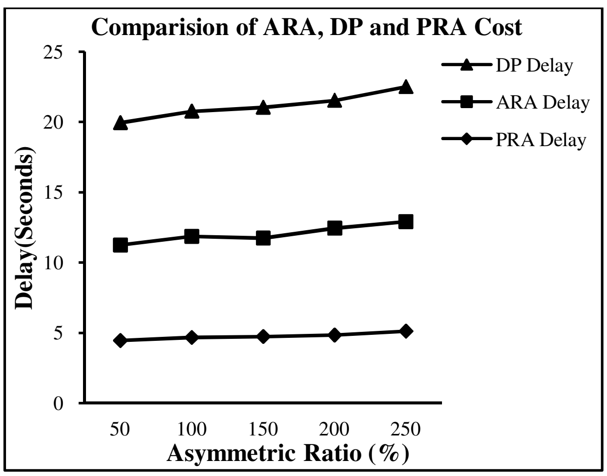

Fig.36. Effect of the Asymmetric Ratio on delay of the Barabasi-Albert Model with a delay constraint of 8 seconds (500 VPN nodes among 1000 nodes)

Figures 33, 34, 35 and 36 show that our PRA algorithm is certainly optimal for the Asymmetric case than the ARA and DP. The delay of the PRA is lesser than that of the ARA and DP algorithms.

6. SUMMARY OF CONTRIBUTIONS

In the above simulation study, we have used both the Waxman and Barabasi - Albert Model for topology generation. The numbers of nodes are varied from 0 to 1000 and the numbers of VPN nodes are fixed as 500. The delay constraint is varied from 3 to 10 seconds. Both symmetric and Asymmetric bandwidths were studied. The Asymmetric Ratio is also varied from 0 to 250.

Our Provisioning Restorable Virtual Private Networks Algorithm (PRA) shows better performance than the Disjoint Path Algorithm (DP) and Adjustment Restoration Virtual Private Networks Algorithms (ARA) by optimizing the total bandwidth reserved on the edges of the Restorable VPN tree. The PRA reserves less bandwidth when compared to the DP and ARA. The Provisioning Restorable Virtual Private Networks Algorithm (PRA) requires minimum delay when compared to the Disjoint Path Algorithm and the Adjustment Restoration Virtual Private Networks Algorithm, even though the delay threshold is specified in the networks.

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