Routing with the Clue (RC) over IP Networks

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Abstract: - Internet Protocol (IP) becomes the most important protocol as the core protocol used in the world's largest network. The larger IP network size it becomes the higher IP addressing delay the network has to consume, so many techniques are invented to increase the performance of the IP lookup process. One of the most interesting ideas is Routing with a Clue (RC) which introduces the distributed IP lookup. This paper compares the performance of the distributed IP lookup with conventional IP lookup process by applying to expandable meshed network. We simulated up to three meshed nodes network. Then, the performance matrices such as throughput, mean queue length (MQL), mean waiting time (MWT), and utilization factor, is collected by the simulation in order to explain the effect of expanding network (scalability) versus the performance of both networks. Results indicate that RC network outperforms vis-à-vis the conventional IP network in terms of expanding the network size. Moreover, the performance of the RC network is not dropping much compared to those of the IP network. The input traffic fluctuates into the first mesh causing higher burden for nodes in the first mesh than ones in the next adjacent mesh, so performance parameters for nodes in the first mesh is clearly to be lower than those in the next meshes. Results from nodes in the higher mesh indicate that the nodes will handle little low traffic, in other words they experience fewer packets waiting in the queue. Especially in RC network, MWT for nodes in the last mesh is next to zero. The reason is that over RC network, IP lookup process is distributed to all nodes along the path, so packet holding (check for address) is reduced reflecting all performance parameters, such as throughputs, MQL, MWT, and utilization factor to be better than the conventional IP network. Moreover, once the mesh network is increased, RC network can still stabilize throughputs while the conventional IP networks cannot be maintained. This can be proven by conducting the "O" notation for both RC network and IP network. From mathematical point of view, the "O" notation as of processing time in packet holding for both networks will be derived. The calculation results from the notation are relevant to the simulation results. That is, the performance of RC network depends solely on the address length existing in the RC packets, but the performance of IP network depends on both address length as well as number of prefixes utilized in the table.

Key-Words: - IP Routing, Routing with a Clue, Distributed IP Lookup, Mesh Topology

1 Introduction

Routing with a Clue [1] is the newly evolving routing technology introduced in the new millennium year. Applying the distributed IP lookup process, the technique can reduce the excessive time used in redundant IP lookup for each node. Routing with a Clue utilizes a small overhead unit called "a clue" to transmit the IP lookup parameters from the current node to the next-hop node. The next-hop node learned from the clue shows where to start its lookup processes.

Distributed IP lookup was already compared with the label switching process in Multiprotocol Label Switching (MPLS) [2]. The two techniques share similar concept in adding a small unit, a label in MPLS and a clue in distributed IP lookup, onto the packet header to help routing the packet to the destination. The experimental results showed that distributed IP lookup process is better than label switching process in terms of network throughput.

In this paper, we try to compare the distributed IP lookup process with the conventional IP lookup process by changing the network topology to be more complex. We apply mesh topology to the simulation because the topology is the most complex topology with every node connected together. Each node in the meshed network can transmit frames to each other by only one hop. We begin the simulation from one mesh up to three cascaded meshes of nodes. As the number of meshes increased, the network size is enlarged by the increasing numbers of nodes. We also varied the input data rates from 500kbps to 2mbps to see whether the data rates affected the performance parameters in both meshed networks. We retrieve the network throughput parameter, and network management parameters such as Mean Queue Length, Mean Waiting Time, and Utilization Factor from the simulations.

We concentrate on how numbers of meshes affect the parameters, and on why distributed IP lookup process is better than conventional IP lookup while the packets are communicating in this circumstance.

2 IP Networks

There are several directions to improve the throughput of routing packets from source to destination. For example, new hardware may be developed to increase forwarding interval, parallel processing may be applied to process IP forwarding, new data structures may be used to store the IP prefixes, and new searching methodology may be invented in order to process the packet faster. However, IP network is widely used and accepted worldwide. The new technique invented must be compatible with the conventional IP network.

Distributed IP lookup [1] is the extension of IP routing by adding 5 bits overhead into IPv4 packet [3]. The 5-bit clue is the encoded prefix of the packet destination address. The clue is used to acknowledge the next hop router where should the router begin searching. All prefixes are stored in a Trie [1] or Patricia data structure. The root of the tree represents the empty string. Each edge going to the left from a vertex represents 0, and an edge going to the right represents 1. Not all the vertices in the tree represent prefixes. The ones that represent prefix are specially marked. All the leaves of a trie are marked because those leaves that are not marked to be the prefix must be removed from the system.

Traditional IP lookup is performed by scanning the destination address bit by bit and matching it along the path of a trie. The worst case of IP lookup is O(L) where L is the length of an IP address. Applying binary search can improve the worst case of IP lookup to O(log L) [4]. The problem on traditional IP lookup is the redundancy of lookup process in each hop. After the router receives the packet from the previous router, it has to perform IP lookup from the beginning until it retrieves the best matching prefix (BMP) [5] from the trie.

Mesh topology is the network that every node is connected with every other node in the network. Implementing the mesh network is very expensive because redundancy may not be avoided. In contrast, redundancy helps increasing the availability in the network. If some link in the network is down, in mesh network, any other alternate route will always be available for the node to redirect the traffic to the new path. Because mesh topology is usually used as a backbone network, we applied the topology in our experiments in order to study the performance of the two different IP lookup processes in the same backbone network environment.

In this paper, distributed and conventional IP lookup processes are compared in the three different mesh networks. First, we applied a mesh network of 4 nodes, then, we cascaded another mesh network with the existing mesh by adding 2 nodes to build the two cascaded mesh network. Finally, another 2 nodes are added to the previous experiment, so that the final results come from the three cascaded mesh networks.

3 Meshed Network Model

In this paper, we simulated the two networks, Routing with a Clue network and conventional IP network, by utilizing the model as shown in figure 1. Four nodes are meshed together resulting in the mesh network. Then, another two nodes are attached to the existing mesh to build cascaded mesh network of two and three meshes.

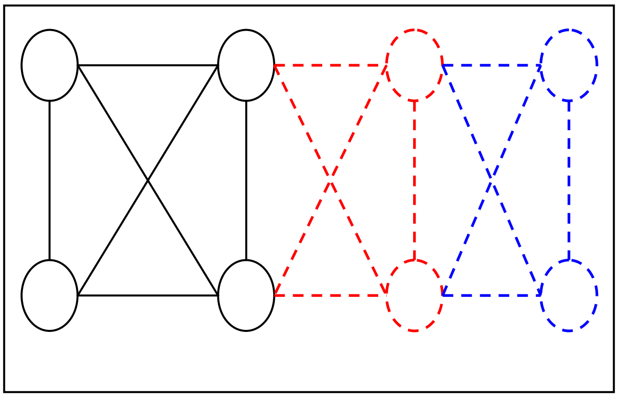

Fig. 1 Simulation model

3.1 Input Traffic

We varied the input data rates for the simulation into several rates from 500kbps to 2mbps. Each link speed in the mesh network is considered to be 1mbps. The pattern of arrivals input traffic mostly is characterized by the Poisson arrival processes [6]. The probability of the inter-arrival time between events is explained in [2].

3.2 Queue

All Queues in the nodes in this paper are assumed to be of First-in-First-out (FIFO) discipline. Both queue capacity and the maximum waiting time for entities in queue are considered to be infinity.

3.3 Packet Holding Time

In [4], the binary search is applied to the IP lookup process resulting in the cost of O(log L) steps, and each test in binary search required breaking the prefixes into several hash tables which require O(N log L), while N is total numbers of prefixes in the forwarding table. However, in distributed IP lookup, the processes are distributed to each node along the path, so each node requires only 0-1 time to consult the hash table. Therefore, only O(log L) steps are consumed in Routing with a Clue network resulting in the simulation program to utilize the big O notation as its packet holding time.

4 Simulation Results

4.1 Number of Mesh = 1

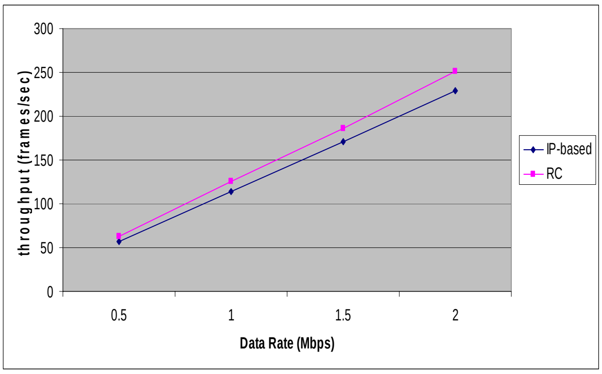

Fig. 2 Throughputs for 1 mesh

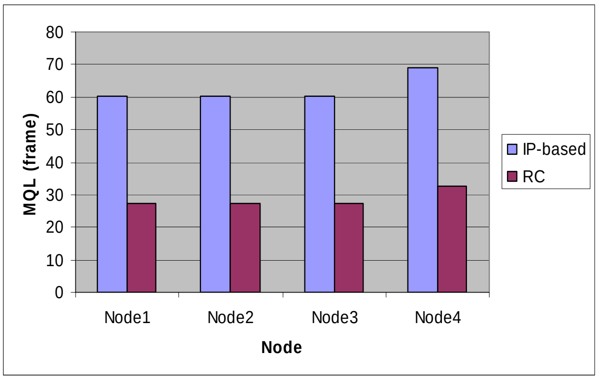

Fig. 3 MQL for 1 mesh (2Mbps)

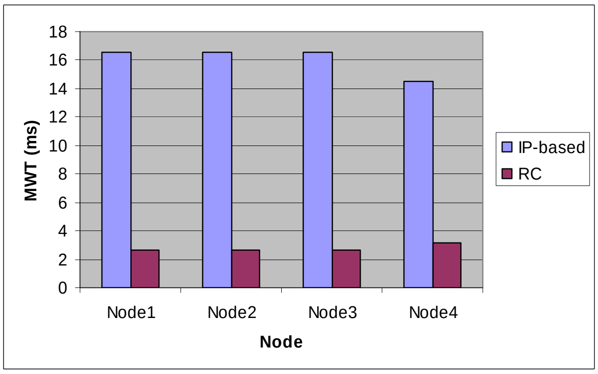

Fig. 4 MWT for 1 mesh (2Mbps)

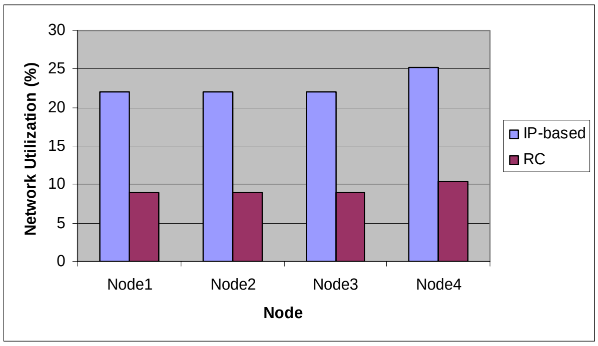

Fig. 5 Utilization Factor for 1 mesh (2Mbps)

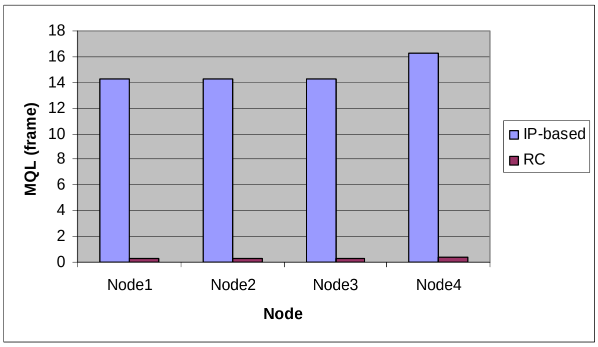

Fig. 6 MQL for 1 mesh (500kbps)

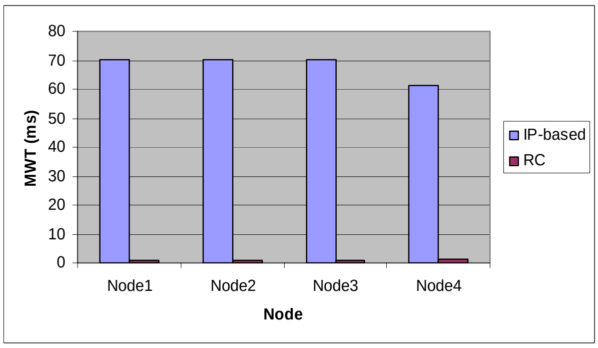

Fig. 7 MWT for 1 mesh (500kbps)

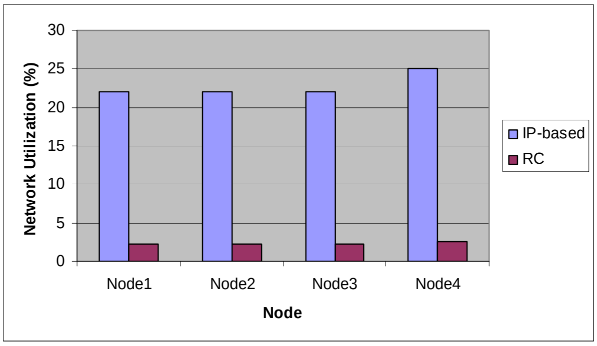

Fig. 8 Utilization Factor for 1 mesh (500kbps)

From figure 2, the throughput of Routing with a Clue network is outnumbered by that of the conventional IP network in every data rate because the IP lookup process has been distributed to every node along the path. However, throughputs of both networks are not distinctly different as the number of nodes is still small, especially in low data rates.

We obviously see that the queue length of every node in RC network is lower than that of IP network in every data rate from figure 3 and 6, especially in 500kbps data rate where the MQL of RC is negligible. However, MQL increased according to the increasing data rate. From figure 4 and 7, Mean Waiting Time of nodes in RC network is less than that of IP network because distributing IP lookup process reduces packet processing time in RC network. In low data rates, less job enter the system resulting in the Utilization Factor to have smaller value than in higher data rates. From figure 5 and 8, we observe that RC network nodes have less Utilization Factor than the IP-based network nodes.

4.2 Number of Mesh = 2

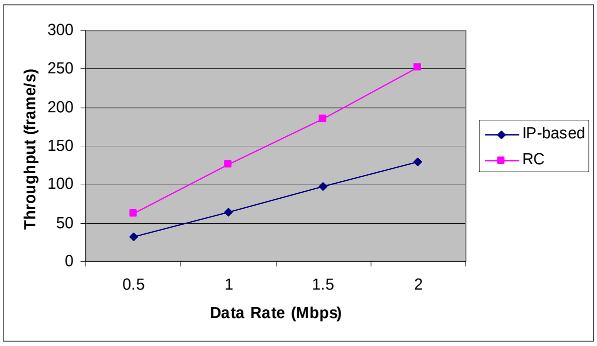

Fig. 9 Throughputs for 2 meshes

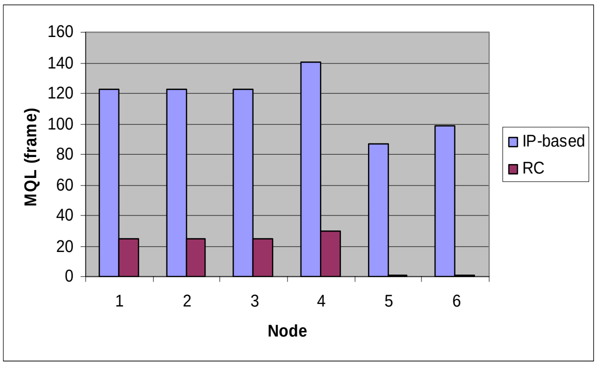

Fig. 10 MQL for 2 meshes (2Mbps)

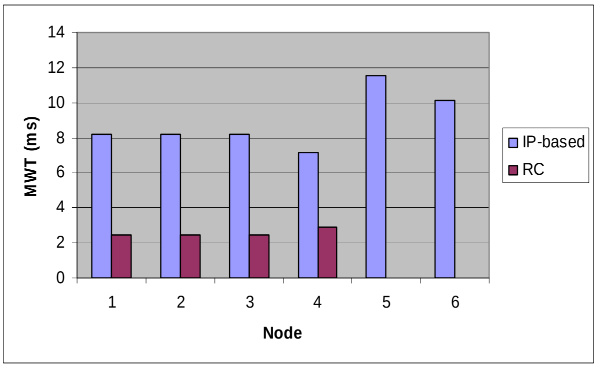

Fig. 11 MWT for 2 meshes (2Mbps)

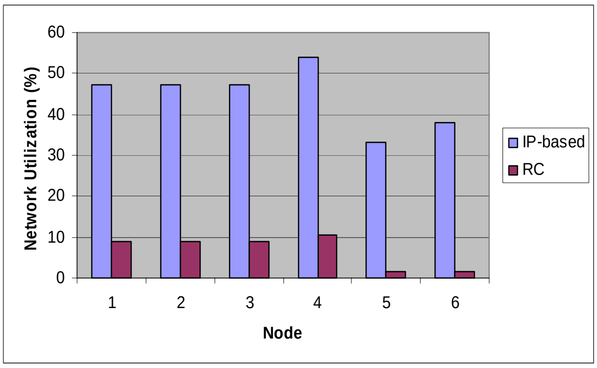

Fig. 12 Utilization Factor for 2 meshes (2Mbps)

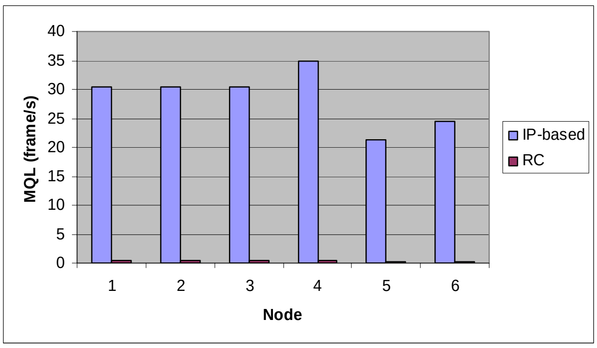

Fig. 13 MQL for 2 meshes (500kbps)

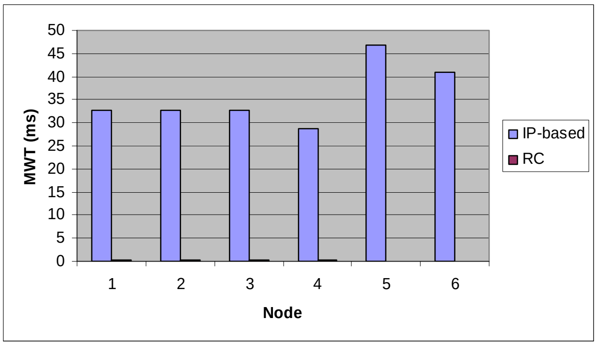

Fig. 14 MWT for 2 meshes (500kbps)

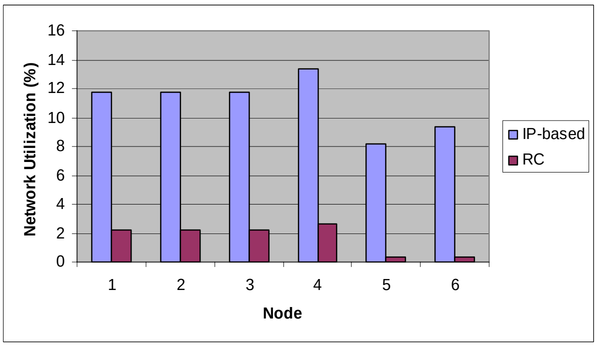

Fig. 15 Utilization Factor for 2 meshes (500kbps)

In the two cascaded mesh network, the difference between the throughputs of RC and IP networks can be observed more obviously than in one mesh network from figure 9. As the node is increased, the throughput of IP network dropped, but RC network still maintained the level of its throughput to stay unchanged from the one mesh network. From figure 10, 11, 13 and 14, the nodes of the first mesh have more queue length, and waiting time than those in the next mesh because most traffic waits in the queue of the first mesh nodes, so traffic that passed the first mesh can enter the second mesh nodes immediately causing less queue and waiting time in the second mesh nodes. From the figures, RC nodes still outperform IP network nodes in both meshes. Especially in node 5 and 6, queue length is very low, and mean waiting time is nearly 0. From figure 12 and 15, node5 and 6 have fewer loads than the nodes in the first mesh, and the utilization factor for RC is distinctly less than that of IP network in every data rate, and in every node.

4.3 Number of Mesh = 3

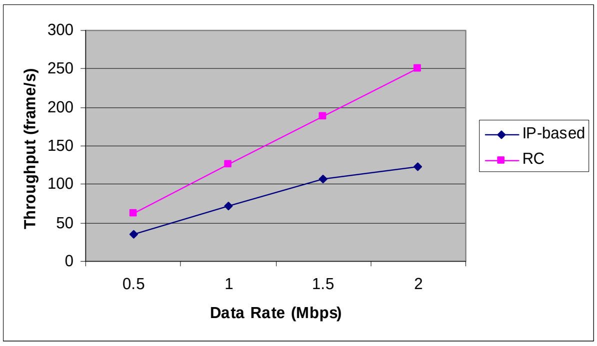

Fig. 16 Throughputs for 3 meshes

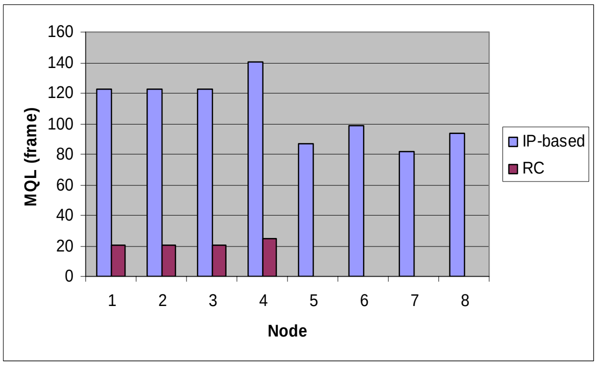

Fig. 17 MQL for 3 meshes (2Mbps)

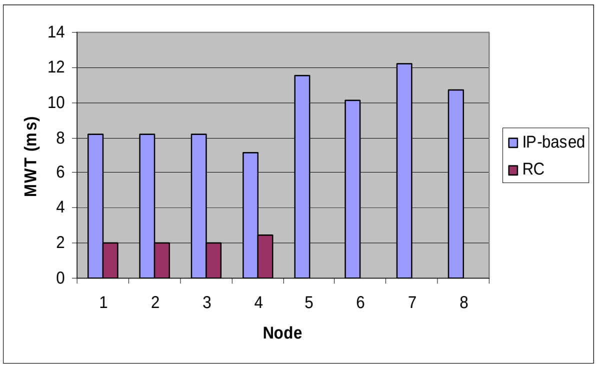

Fig. 18 MWT for 3 meshes (2Mbps)

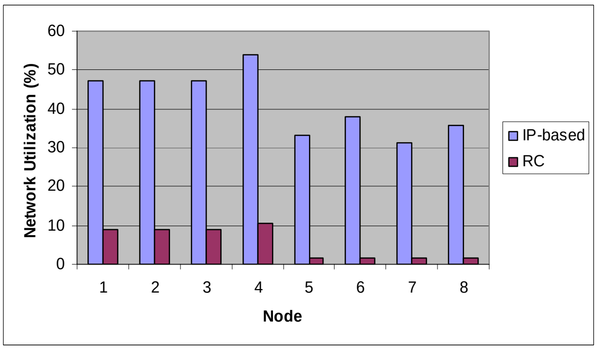

Fig. 19 Utilization Factor for 3 meshes (2Mbps)

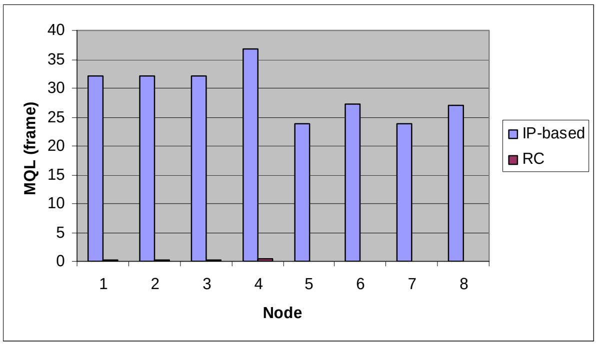

Fig. 20 MQL for 3 meshes (500kbps)

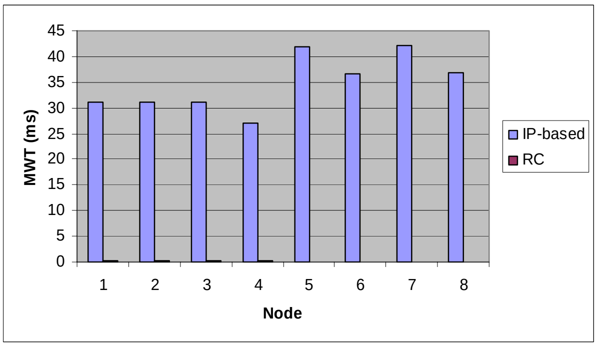

Fig. 21 MQL for 3 meshes (500kbps)

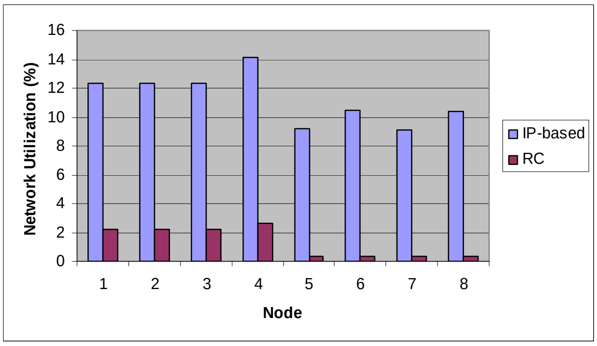

Fig. 22 MQL for 3 meshes (500kbps)

The results from every parameter in every data rates and every node still indicate that the performance of distributed IP lookup is superior to conventional IP lookup. RC throughputs are higher than IP. RC has fewer packets in queues than IP, so packets enter each RC node faster than IP node.

5 CONCLUSION

When the data rates are increased, throughputs in both RC and IP networks also increased, but the throughputs of RC network are better than that of IP network. The network traffic fed into the first mesh causing nodes in the first mesh to process more traffic than in the next meshes, so performance parameters for nodes in the first mesh are inferior to those in the next meshes. We can obviously perceive that nodes in the last mesh will have very low traffic, so there are very few packets waiting in queues. Especially in RC network, Mean Waiting Time for nodes in the last mesh is nearly zero. In RC network, IP lookup process is distributed to all nodes along the path, so packet processing intervals are reduced causing all performance parameters, such as throughputs, MQL, MWT, and Utilization Factor to be better than the IP network. Moreover, in the mesh network, when we increase the number of nodes by cascading another two nodes to the existing mesh network, RC network can maintain its throughputs in all meshes. In Big Oh notation of RC network, the performance relied only on the address length of the packets. In contrast, the performance of IP network relied on both address length and number of prefixes in the table. As number of nodes increases, the number of prefixes in the hash table also increases, so we can assume that number of nodes directly influences the performance of IP network. This results in the IP network's throughputs to be lowered when we increase the number of nodes in the backbone network.

Reference: -

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