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Dynamic Load Balancing with Multipath Routing in Software Defined Networking

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***Abstract*—Traditional Ethernet networks were limited to routing schemes. A single best path was used by the Spanning Tree Protocol (STP). This was a major cause for the limitation in the throughput and the increased network latency. Multipath routing scheme is one of the solutions where multiple paths available in the network are used for traffic forwarding. If the load is being forwarded to the multiple paths, load balancing finds its application to balance the load among different paths. In this paper, a multipath routing scheme is proposed along with the load balancing among the available multiple paths in Software Defined Networking (SDN) environment. SDN is an emerging networking paradigm where control plane is separated from the data plane. Mininet is used as the network simulation tool along with the Ryu controller to support network programmability feature on the control plane.**

***Index Terms*—Software Defined Networking, Multipath Routing, Load Balancing**

I. Introduction

Software Defined Networking (SDN) is an emerging network paradigm where the control plane is separated from the data plane[1]. In previous network systems the control plane and the data plane were embedded in the same physical hardware. Thus, a single change in the configuration needed to be changed in all the network elements individually. Moreover the change would be vendor specific in the physical layer as well. The data layer of SDN consists of open flow switches which work on the Open Flow protocol[2]. Each open flow switch consists of a flow table where flow rules are written in accordance to the centralized controller. For example, if a new packet arrives at the switch port, the switch asks the controller what action is to be taken, the controller's instruction is then written as a rule on the flow table of the open flow switch and the necessary action is taken by the switch (forwarding or dropping packet flow). Network elements are connected to one another via different physical links. Sending traffic in the only best suited path may rise to traffic overloading in that path. Traditional networks used Spanning Tree Protocol (STP) to find the shortest path and route traffic only through that path which causes single path overloading. Thus, all we need is to send traffic via multiple path between source and destination so that not only one path gets overloaded. This concept is the load balancing concept with multipath routing. Depth First Search (DFS) is implemented to find the multiple available paths between source and the destination. The amount of traffic that is divided among the multiple paths in the network can be controlled. Allowing too much traffic through one link again causes congestion on that particular link. Hence, the amount of traffic that is sent through a path is dependent on the path cost. In this paper, the total traffic of the network is divided among the available multiple paths in accordance with their path cost.

A. Problem Statement

Ethernet uses single best path for forwarding traffic from source to destination such as using STP (Spanning Tree Protocol). This alone cannot provide good performance because maximizing the network throughput and minimizing latency is important in networks. Multipath routing provides an efficient way to manage the flow of traffic through different available paths in the network and thus can contribute to the maximum bandwidth utilization. Load balancing with multipath routing can provide higher throughput at reduced network latencies. Dynamic load balancing is the flexible technique where the network traffic is scheduled according to the updated traffic statistics on each switch. In static routing, routes cannot be changed while transmission process is still running. Similarly, traditional networks cannot provide the network programmability feature hence the simulation in carried on the SDN environment.

B. Research Objectives

The main objectives of this research work are as follows:

- To evaluate multipath routing in SDN environment and
- To evaluate load balancing mechanism on the optimal paths from the set of available multiple paths between source and destination.

The rest of the paper is organized as follows: The second section is the "Related Works". The third section is "Methodology" which explains the system framework and the way the research is carried on as a whole. The fourth section is the "Results and Discussion" that explains and discusses about system observations carried on. A graphical presentation of the results are expalained in this section.The fifth section is the "Conclusion" that concludes the paper and the last section is the "Future Enhancements" that suggests for future recommendations.

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II. RELATED WORKS

S.Shin et al [3] presents a survey on the features of Software Defined Networking. It discusses about the issues while working on this platform and present how a network can be built as a secure network with the help of SDN. The main features of SDN presented are the Dynamic flow control, Network-wide visibility, Centralized control, Network programmability and Simplified data plane. The paper discusses on how network security can be benefited by using each of these features of SDN. As an example building our own firewall system as a network application can be taken where any of the new data packets are first sent to the firewall system and then only to the main system. M.Fajar et al [4] presents a multipath routing scheme taking DFS algorithm for finding multiple paths in the network. The paper discusses that load balancing mechanism in the network give better results than that of single path routing. It further talk about admitting certain amount of traffic through the paths of the network based on the threshold specified. It finally conclude that the load balancing mechanism along with the admission control give better results than load balancing only and obviously that of single path routing. S.U.Back et al [5] discusses the use the multipath routing in SDN environment. The proposed work insists to make use of multipath routing instead of using single best path between source and destination. Flow statistics is collected from the open flow switches and based on the information collected; multiple paths between source and destination are calculated. These weighted multiple paths between source and destinations are helpful for traffic distribution among those paths. The paper finally reaches to the conclusion that the throughput of the weighted multipath routing is far better than the single path routing. A.Fares et al [6] mentions that the data center operators want a scalable network with higher bandwidth and host mobility which can be obtained by designs with specific wiring technologies in Ethernet that can result in the deployment problems and the changes in the network switches that deviates from the commodity pricing of those parts. Thus, Ethernet somehow solves the problem of scalability but traditional Ethernets do not scale because of their spanning tree protocols. The proposed work introduces Smart Path Assignment In Networks (SPAIN) that pre-computes a set of paths exploiting the redundancy in the given network topology, merges these paths into a set of trees and each tree is mapped into a separate VLAN tree onto the physical network. Butler et al [7] proposes multipath routing in fat tree data center network with SDN environment. The proposed work uses Beacon controller to run their algorithm that manages the traffic flow along multiple paths between source and destination with load balancing emulating on the Mininet. It is stated that the proposed method of multipath routing in the SDN environment achieves increased throughput and reduced delay compared to the traditional multipath routing algorithms (Equi-Cost Multipath(ECMP)) that is only able to choose among the available paths with same minimum cost and does not consider the bandwidth requirement of the traffic flow. R.Banner et al [8] states that the use of multipath routing with the distribution of traffic along the different available paths is far better than using the single best path. The proposed work focuses on the optimal congestion reduction scheme based on multiple routing paths. The consideration on choosing the multiple paths focuses on the length of the path and number of paths between the source and the destination pair. It is stated that not only the availability of multiple path is better because of the difficulties in establishing and maintaining different paths results to the increased overheads. Thus, the proposed work makes use of the link state protocol where a each node maintains a network map that helps in computing the routes. In case of the change in network link status, the information is flooded all over the network and the network map is updated accordingly. X.Li et al [9] proposes a state-aware and load-balanced routing model for low earth orbit (LEO) satellite networks. In the proposed method, the lighter load paths are preferred to achieve load balancing. This is done by dynamically adjusting the weight of the path when the queue occupancy rate is low. The proposed work also considers the situation of link/node failure and recovery. J.Li et al [10] proposes a fuzzy synthetic evaluation model for load balancing in SDN. First, the K-shortest paths are selected from the available multiple paths. Then the fuzzy synthetic algorithm is used among those paths with respect to hop count, packet count, byte count and port forwarding rate to choose the final optimal paths from the set of available paths. A.Khaliq et al [11] discusses about the approaches to utilize the multipath topology by forwarding the different traffic flows to different paths in the network. The proposed work talks about the experiments performed to measure the throughput of the network that has direct impact on the performance of the system by changing the TCP window size. The change in the TCP window size affects the data transfer in the network and thus an increased TCP window size leads to the improved performance of the system. V.P.Koryachko et al [12] discusses the multipath routing with load balancing in computer networks. The proposed work discusses about the use of Dijkstra's algorithm for the computation of multiple paths from source to destination. Selection of optimal paths is taken and load balancing is done according to the jitter values of the corresponding paths. Y.-L.Lan et al [13] proposes a DLPO (Dynamic Load Balancing Path Optimization) algorithm in which the traffic flow are redirected dynamically to the worst fit links with higher residual bandwidth available. It discusses about the increase in throughput and the higher bandwidth utilization of the link after implementing the proposed algorithm. X.Sun et al [14] presents a Dijkstra's-Repeat algorithm in a SDN/OSPF hybrid network for disjoint multipath routing. The routing of the traffic flow according to the resource availability is presented so that the problem of link congestion is minimized. The proposed work presents its own algorithm fast fully polynomial time approximation schemes (FPTAS) and LRU (Lazy Routing Update) to spread the traffic among all the feasible links and where the capacity exists. Z.Shu et al [15] presents traffic engineering in SDN.

It presents two important aspects for traffic engineering: measurement and management. Measurement is that of the system parameters which then help to manage the traffic such as load balancing. Thus, the traffic engineering helps in the overall QoS improvement of the network system.

III. METHODOLOGY

Software Defined Networking provides the modularity on the control functions. The Open Flow switches are there only to forward the network traffic according to the flow rules installed on their flow tables.In this paper work, four different modules are used to perform the control functions. Since SDN provides the network wide visibility, dynamic flow control and network programmability functions; it is easier to implement different modules to perform different actions on the control plane. The first thing to do is to discover the network topology. Once the network topology is discovered, a simple test flow helps to get the information about the paths between the source and the destination nodes. Similarly, network monitoring should be carried in a regular basis to gather the updated information of the network components. Finally, the optimal paths are set up and installed on the flow/group table of the open flow switches. Figure 1 shows the different modules[5] of the general system architecture and are briefly described as follows:

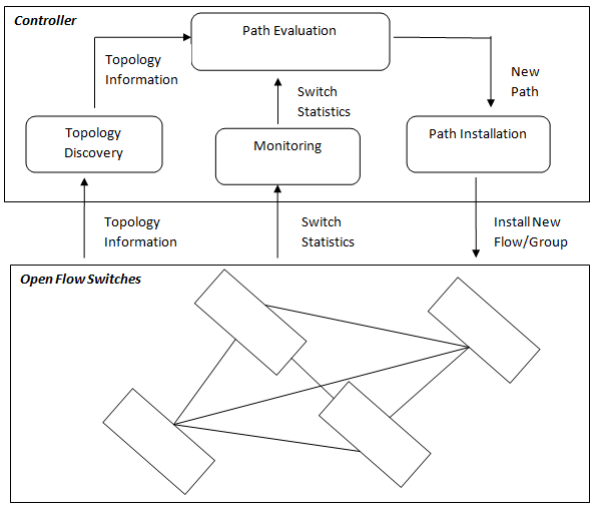

Fig. 1. General System Architecture for Dynamic Load Balancing with Multipath Routing in SDN

A. Topology Discovery

The first step to begin is to build an example topology. Mininet provides the network simulation platform where we can build our own network topology. Next, this topology has to be integrated to the SDN controller.

B. Path Evaluation

The path evaluation section includes finding all possible paths in the network using depth first search (DFS) algorithm which plunge down to the network before it backtracks to find other possible nodes using a stack. The cost of each link is calculated using the formula:

Link Cost = Reference bandwidth / bandwidth of the link

After finding the cost of different paths, the optimal paths are calculated. Practically, the source and the destination nodes are chosen. A host connected to the node when sends the ARP (Address Resolution Protocol) packets, these packets are flooded over the network. Another host connected to a different node in the network when replies those packets, gives the information of the available paths between those hosts and thus the paths are established.

C. Monitoring

This section stores the timely statistical information of the open flow switches. This includes the links addition or deletion, switch port information such as the packet in information.

D. Path Installation

Each time a new packet enters the network, the switch asks the controller for further action. If the action to be taken is same that to the previous one, asking controller each time is a waste of time. Hence, a flow is written to the open flow switch itself so that it can act on the same types of problems. For this the paths need to be installed on the open flow switches. The path installation includes:

- Listing of available paths from source to destination.
- Looping through all the switches that contain the path i.e.
  - Listing all the ports in the switch that contain a path.
  - If multiple ports on a switch contain a path, a group table is created or else a normal path is installed.

Installing a normal flow means what action is taken to the normal flow of packet that has a source and the destination address. Packet matching is done depending on the Ethernet type such that for the ARP or the IP packet.If multiple ports on a switch form a path, then the group action is revoked where bucket action is specified based on the open flow protocol. This means that there are multiple paths for the packet to be sent from a single switch; hence a bucket weight is calculated for each path based on the cost of that path. A simple formula for the calculation of the bucket weight[5] is:

Bucket Weight = [1 - (path cost / total path cost)]*10

Thus, the path with higher cost has lower bucket weight. As the path with lower cost is better, the path with higher bucket weight is considered better. The calculation of bucket weight is helpful for balancing the load among the multiple available paths. The load is said to be balanced if the load ratio of two paths is similar to that of the bucket weight ratio of those paths.

E. Observations

A number of observations were taken for three different topologies. One the simple with two paths, another considering the heterogenous link conditions and the third the mesh topology, all consisting of equal number of switches. First the latency of the different paths was checked based on the heterogeneous link conditions i.e. considering the bandwidth

of the links. Then the latency of the paths was checked on homogenous link conditions. Similarly, throughput of the system was observed considering both the un-balanced network and when it was load balanced.

IV. RESULTS AND DISCUSSION

Evaluation of single path routing and multipath routing was carried considering various system parameters viz. delay, latency, bandwidth and throughput. The single path routing and multipath routing schemes were evaluated under different network scenarios of load balancing and without load balancing. A number of observations were carried for the different system parameters and different network scenarios. Latency was measured in milli seconds and was observed during no load condition of the network in all different types of topologies taken. Similarly, delay was measured in seconds and was measured with the increasing traffic load conditions for single path routing, multipath routing without load balancing and multipath routing with load balancing. Throughput was measured in received packets per second and was observed for both single path routing and multipath routing schemes in an unbalanced network as well as load balanced network considering both the simple topology and the mesh topology.

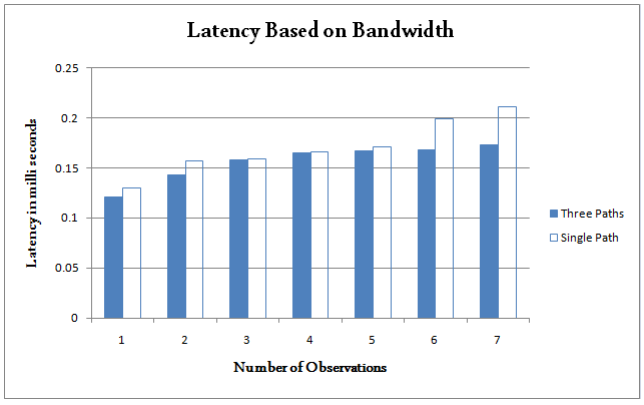

Fig. 2. Latency Based On Bandwidth

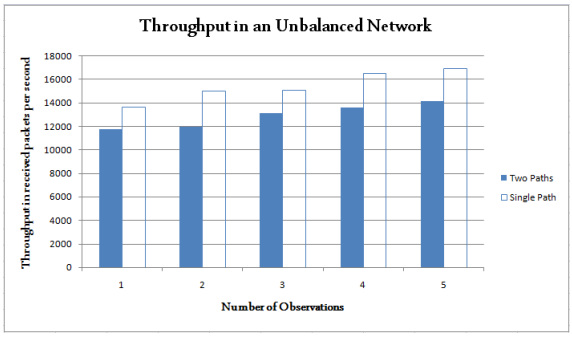

Fig. 3. Throughput in an Unbalanced Network

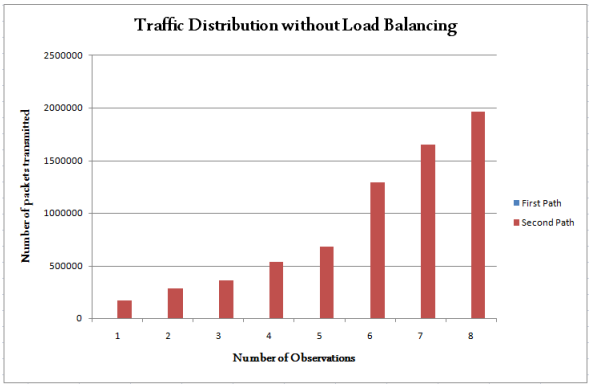

Fig. 4. Traffic Distribution Without Load Balancing

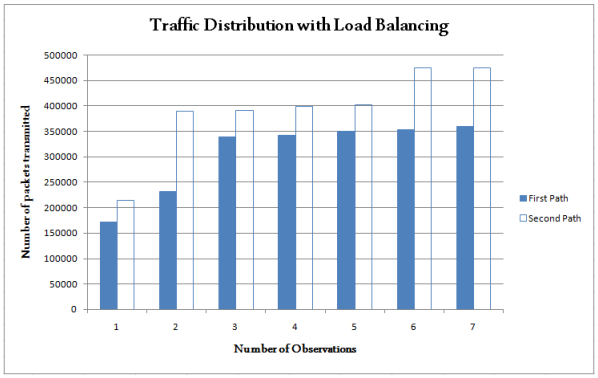

Fig. 5. Traffic Distribution With Load Balancing

V. CONCLUSION

From a series of observations it was concluded that latency in case of multipath routing in simple, mesh and bandwidth dependent topology is better than that of the single path routing scheme. Delay was observed to be better in single path routing than the multipath routing without load balancing but it was best of all in multipath routing with load balancing even when there was an increase in the traffic load. Similarly, throughput was observed to be better in single path routing than in multipath routing without load balancing but when

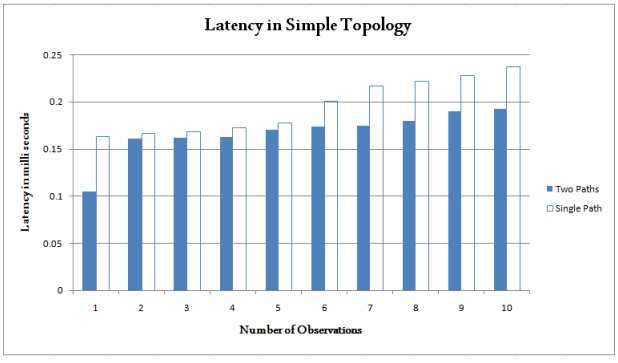

Fig. 6. Latency in a Load Balanced Network Considering the Simple Topology

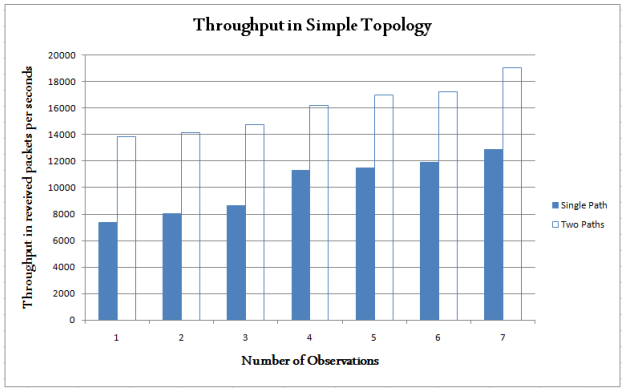

Fig. 7. Throughput in a load balanced network considering the simple topology

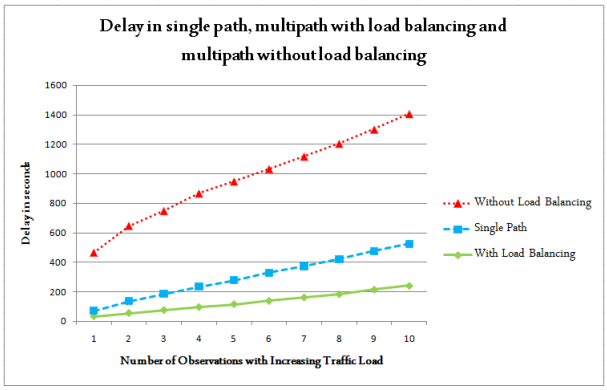

Fig. 10. Delay in single path, multipath without load balancing and multipath with load balancing

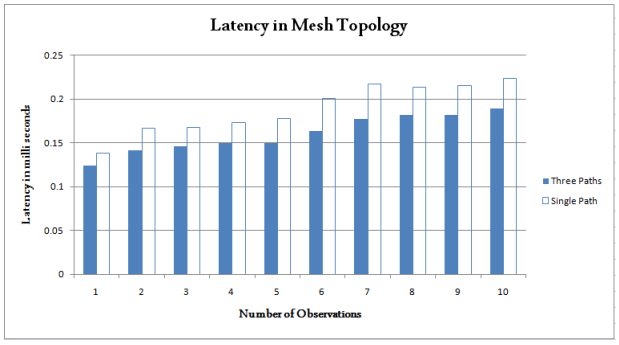

Fig. 8. Latency in a load balanced network considering the mesh topology

considering the load balanced network, multipath routing with load balancing was far better than the single path routing scheme.

VI. FUTURE ENHANCEMENTS

In this paper work, a network emulation tool Mininet was used to realize the network topology. Practically, there exists a different network scenario than that considered in this research. Software Defined Networking is a broad field for research. It has many applications in different fields of study. Education, industry, telecom operators and data centers are some of the big platforms where new things are happening day by day. Multipath routing and load balancing can be tested in the real SDN environment considering different routing algorithms. Similarly, security is a very important aspect that can be studied at.

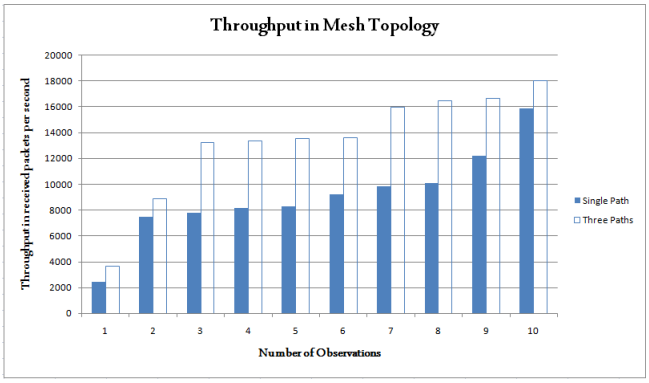

Fig. 9. Throughput in a load balanced network considering the mesh topology

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