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A Review on Issues, Challenges, and Solutions of Scalability and Optimization Problems in Software Defined Networks

Deepak Bishla[1], Prof.(Dr.) Brijesh Kumar[2]
Manav Rachna International Institute of Research Studies (MRIIRS), Faridabad

Abstract

The time has come, when; Software Defined Networking (SDN) will be an essential service in the world for those who are using a large network in their organization. To improve the traditional network; SDN/open Flow Protocol will play a major role. Presently open flow protocol is not supported by all southbound hardware devices. Most of the organization depends on single-vendor support. But it seems the scope of open flow protocol will be strong. The monopoly of the single-vendor support will be overcome, once every OEM of network device gives the priority to the open flow protocol implementation in the network devices, and then SDN will become a powerful tool in the networking field. Software defined network divides the network into three planes; control plane, data plane, and management plane. In this paper, we present scalability and optimization issues, challenges, and their solutions as well. Also, cover the issue and solution faced while implementing the SDN in the traditional network.

Keywords: Software Defined Networks (SDN), Northbound and Southbound Interface, Open flow protocol, control plane, Data plane, Management plane.

1. Introduction: Software defined networking (SDN) is replacing the traditional network architecture by separating the control plane from the network device attached with the southbound interface, these device work, just for data plane, means just forward the data as per the SDN control plane instructions, shown below in figure-1. SDN Architecture divides the network into three layers i.e. SDN management plane, SDN control plane, and SDN data plane. In between these three layers, there are two interfaces called the southbound interface and the northbound interface. The southbound interface communicates between the control plane and data plane; forward the rules applied by the control plane to the infrastructure layer types of equipment via open flow protocol. The northbound interface sits in between the SDN management plane and the SDN control plane. SDN also supports the virtual storage servers and virtualization systems. It makes the network administrator's life easier. [5] Using the control plane in the network the technical person/ network administrator can push the policies in the whole network devices instead of configuring all network devices like L2/L3 switches one by one manually. The control plane in SDN is programmable by the network administrator to manage the whole network devices just sitting at a single place. SDN control plan directs the southbound types of equipment (switches, routers) path as per the policy defined by the network administrator. Sometimes we faced the issue when network scaled up in different topology of the network. The network design raises the scalability issues and bases on the implementation control plane face the optimization issue. [1]

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The main objective of this paper is, how the conventional network can take benefit if they use the SDN control plan; Topology and machine learning based issues and challenges in SDN with respect to scalability and optimization. And finally, find the gap and provide a solution on how to resolve these issues and challenges.

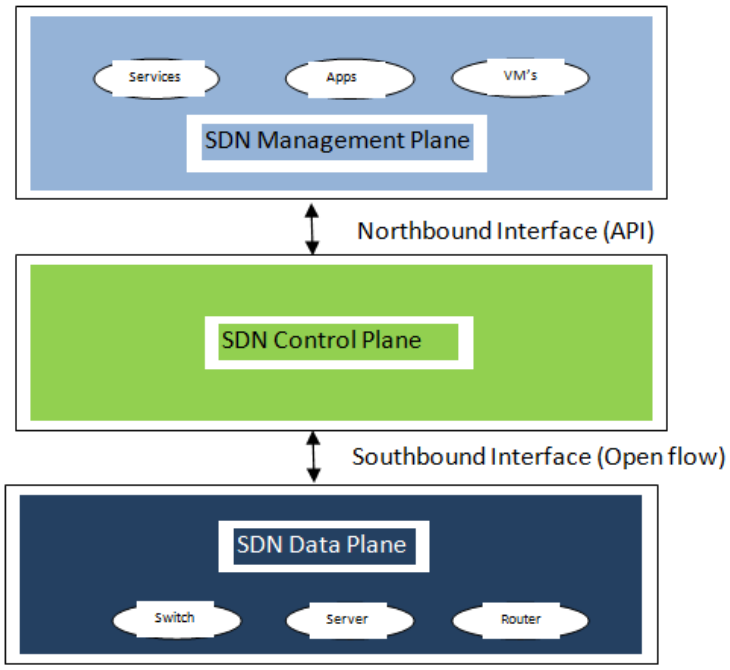

Figure1: SDN Architecture

Management Plan: With the help of the northbound interface, the management plane communicates to the control plane and share the information about the network behaviour and its requirement. The management plane is programmable and keeps the abstracted view of the global network and also keeps the internal decision of the network [8].

Control Plane: It is the heart of the SDN and the control logic resides in this. The network administrator/ designer define the logic, rule, and the policies here. The Control plane makes the decision based on the management plane requirement and forwards it to the data plane. The Control plane can have more than one northbound interface agent. Control planes communicate to the data plane via the southbound interface, which is also called an open-flow based protocol [8]. Open flow provides the communication between controller to network types of equipment like switches and routers to configure and monitor. Open flow allowed the network path decision taken by the controller on the network switches.

Data Plane: It is the lower level of SDN architecture and a combination of networking types of equipment like switches and routers. The Data plane is responsible for forwarding the data packets as per the instruction received from the control plane. Physical switches, routers connectivity via network cables includes in the data plane. The Control plane connected to the data place via the southbound interface and instructs to forward the data packet from one

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node to another node between the physical network switches. The southbound interface provides an abstract view of physical network connectivity to the control plane [8].

A lot of work has been done in the area of SDN, but still, a lot of work needs to be done using AI techniques. The main difference between the SDN network and the traditional network is: *How to manage the data packets? [9]*

2. Network topology based scalability issues: Initially SDN was made for the centralized control system; one control plane is responsible for the whole network. If the network is very large, then users have to face latency in the data packet, because of all traffic pass by one controller. Also, the central control system has too much dependency; in case, the controller fails, the whole network will be disturbed. In the following section, the issues and challenges based on the network topologies, viz star, bus, hierarchical, mesh [9] are being discussed.

2.1 Start / Centralised Topology: In the medium size of the network generally star topology is implemented. Star topology is also called centralized network shown below in figure 2, it's easy to maintain. But that topology does not work in a large scale network due to the heavy traffic load on the central server and control plane not able to serve the all network request on time and in a response delay happened in the network. Hence star topology is less scalable as compared to mesh topology. Also, there is the risk if the central controller fails then the whole network will not work. Network designers can use the network switches as well to forward the packet on the self decision but its defect the purpose of real SDN. [9]

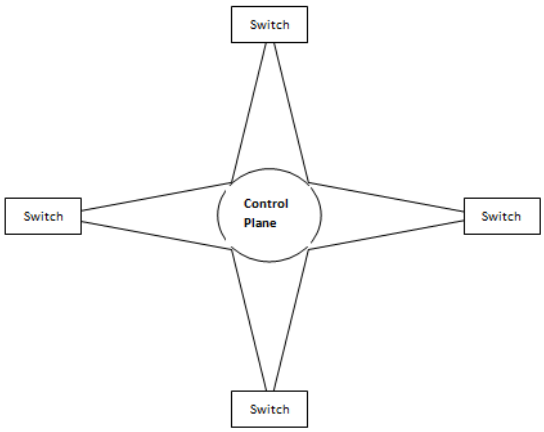

Figure 2: Start Topology

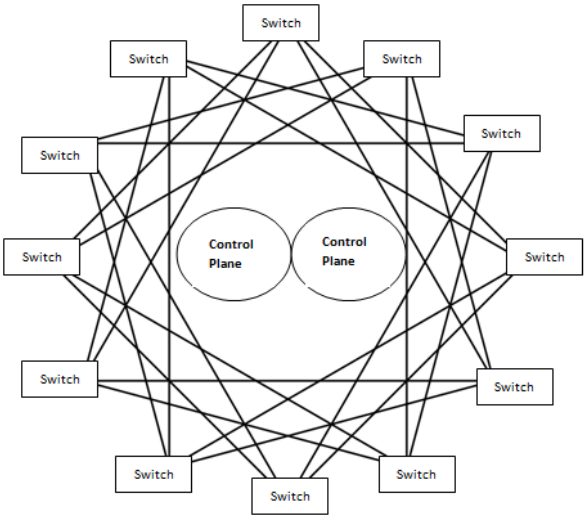

Figure 3: Mesh Topology

2.2 **Mesh / Hybrid Topology**: Mesh topology network architecture is much beneficial compare to star because there is more than one control plain in this design and load balancing between the controllers manages the delay in the large network as shown in figure 3. Besides, it safeguards the failure risk of a single controller. However, there are some challenges like delays in network packet due to control plane synchronization and policy consistency in all the controllers. In the multiple controls plane network administrator can first take a global view of all control planes and further can go locally in the individual control plane. All

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control plane talk to each other and sync the rules and policy applied by the administrator. In that way, multiple controls divide the load of the network and improve the network scalability. In the case of multiple controllers, each controller looks after the sub-network.

3. Optimization: If we integrate the machine learning with the control plane, in peak time when traffic is in the high state; we feel a delay in the network. All networks forwarding decision was taken by control plane and in peak time, the system may take more time to make a decision about the routing path of the packet. It may happen because of the long queue with the controller. In spite of all this, it eases the job of a network administrator or technical support. [4]

3.1 **Parallelism control plane based optimization**: When more than one control plane is working in the network and all are parallel connected than load sharing is an easier task among the all control plane. Multi control planes do the multithreading in a sharing manner. In the absence of synchronization of the controller to each other, there is packet loss and latency in the network. On the other hand, If in case the control planes are integrated with hierarchical architecture, then the lower-level control plane looks after the local application and then shares the information to the upper-level control plane for the global view. Lower level control plane does not have the complete view of the network. [9]

3.2 **Machine learning based optimization:** This approach can reduce human interventions in the management of a network. The technical expert/ network administrator can define the set of rules and policies to run the network traffic only once. But the problem occurs when the physical network update frequently and where new rule needs to be implemented, based on the requirement. In such a case the network administrator has to intervene, in the control plane forwarding rule and it may cause of network failures [1][11].

3.3 **Artificial intelligence based optimization:** Artificial intelligence integration provide less human interaction into the control plane. Based on the history and metadata, the control plane takes the new decision to forward the packet via a data plane on the fly. In case of physical infrastructure frequent updates, the AI based technique automatically decides to forward the packet via a new path. AI based control plane rules can be implemented proactively. Suppose in peak time control plane automatically update the rules and when traffic is less, apply the different set of rules. However, there are many advantages in AI based optimization; still, there are certain issues while applying the new rules e.g. it gives rise to forwarding packet latency in the network. Some expert advice for adding more processing units and memory to process the new rules speedily, but that will increase the overall cost of network management. The aim is to manage the network in the best possible way with a lesser overall budget. [9]

4. Challenges with Existing network: It has become a challenging job to implement the SDN in the existing network consisting of multivendor based equipment. The designer must implement the SDN with the existing hardware to cut down the cost and should meet the quality of services (QoS).To update the existing network with SDN it is very costly if the network designer plans to replace all the existing hardware. The biggest challenge in the existing network is, multiple type/brand of products/switches exists in a network and most of

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them do not support the open flow protocol. There are multiple solutions suggested by the authors in the many articles. [12]

One of the approaches that set a middleware which create a communication channel between multiple type/brand/proprietary of old hardware using the minimal instance of Open-Shortest-Path-First (OSPF) protocol to communicate with the middleware and further middleware connect with the SDN controller. The controller uses the remote access protocol like SSH or Telnet to communicate the old hardware via VLAN. Mostly all switches support routing table algorithm and the controller takes advantage of this algorithm and with the help of the routing table creates a global view of the network.[9]

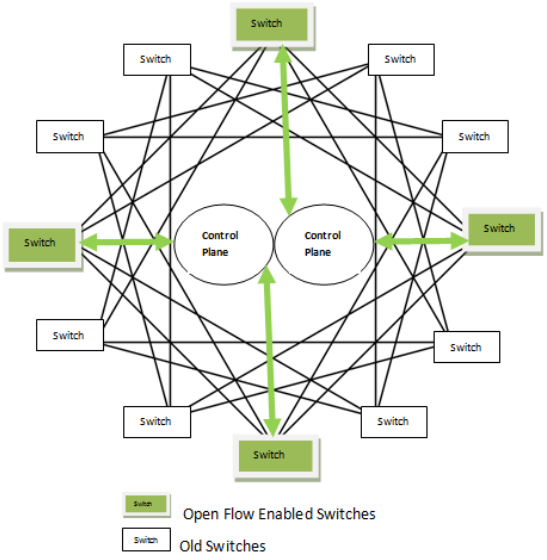

Figure 4: SDN in existing network

In the mesh/ Hybrid topology based network again there are biggest challenges if all old hardware needs to replace, which becomes very costly and any network designer's aim should be to implement the SDN with minimum cost and utilities the existing hardware. Figure 4 shows that SDN can be implemented using some of the open flow based switches. Network administrators/designers have to identify first a fixed gap or nodes in the mesh/ hybrid network to place open flow based switches. That open flow based switches provide the global view to the controller instead of replacing all the existing hardware. The existing and open flow based switch using the minimal instance of Open-Shortest-Path-First (OSPF) protocol to communicate with the Controller to provide a global view. [1]

Since open flow based switches are managed by the controller, hence load distribution becomes easily possible. This way old hardware utilization and optimization are possible.

However, the above suggested solution to implement the SDN in the existing network is not a true SDN. The controller is not able to give the suggestion on which node SDN switches need to be install, which depends on network designer/ administrator. In the literate review we also able to find that some authors suggested the different types of solutions like to identify the SDN based nodes; *graph based heuristic approach, unified network controller, etc.*

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5. Conclusion: SDN is an effective step in big networking environments like data centers, cloud networks, enterprises network, etc. The biggest advantage of SDN is it provides the best environment managing console to network administration via his programmability and best staggering decisions. SDN divides the data plane and control plane and many more benefits. If we are looking at SDN, another side we can see some limitations and challenges with respect to scalability and performance. The scalability of the control plane in SDN is one of the biggest challenges. It starts with when the SDN control plane is used in the existing network and after due course of time not able to expend the network via SDN technologies. To overcome these challenges we can distribute the control plane in the network, by doing this will reduce the traffic on a single controller and distributing the load as well between the control planes. We need to take in the case, if all SDN control plane added parallels, and then it will give a better result. One more suggestion, In addition to this, if the machine learning techniques are integrated into the control plane, then the control plane can predicate the traffic and, take an intelligent decision and optimize the data flow routing own to route the traffic it's own, without any intervention of network administrator. Machine learning integration improves optimization as well. Finally, we can say SDN is a tool, and research organizations should work on developing a new protocol or need to strengthen the existing protocol like Open Flow.

Future work: We cannot ignore the security and cost challenges in the SDN. In traditional way network security depend on the physical safety of networking types of equipment (switches router), In the SDN; the control plane is the center point to manage the network. Nowadays SDN also implemented on Internet on things (IoT). Security is a big concern and that needs to tackle first. The next research paper will cover the security and cost-effective perspective as well.

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