International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 21 (2018) pp. 14871-14875
© Research India Publications. http://www.ripublication.com

Controller Placement in Scalable SDN Environments

Smitha Vinod
Research Scholar, Department of Computer Applications,
Karpagam Academy of Higher Education, Eachanari, Coimbatore– 641 021, India.
Orcid Id: 0000-0002-5547-5981

X. Agnise Kala Rani
Professor, Department of Computer Applications,
Karpagam Academy of Higher Education, Eachanari, Coimbatore 641 021, India.
Orcid Id: 0000-0002-1465-0595

Abstract

The separation of control plane from the data plane makes Software-defined network (SDN) a controller specific network which monitors and manages all the data flows through the network. The popularity and usages of network in daily life are important factors in the future of SDN. All SDN networks are expected to go for a scalability test due to the rapid growth in the networking sector. The scalability of any network depends on few major parameters. Few of it are: the manner in which the network is connected, the network traffic, controller placement, and then the load balancing capabilities of the controller. The controller placement in any huge network is a challenging work. It requires a total optimization of activities, i.e. latency, capacity, fault tolerance and load balancing.

This paper discusses the various issues faced when the controllers are placed in a SDN network. Various test cases were tried by taking into consideration to obtain a fair solution which was again based on the conditions and circumstances. There is no permanent all-time solution available for controller placement in scalable SDN networks.

Keywords: SDN; Controllers; Controller placement.

INTRODUCTION

Here in the test scenario various cases were tried for obtaining a fair solution under specified conditions and scenarios. There is no all-time solution available for the best placement of controllers at all various possible scenarios. Some of the cases taken for considerations include: Best possible controller placement by reducing latency, maximizing the workload balance, and taking into consideration of low energy consumption. In general, all the SDN enabled networks bring flexibility to the network management and in a way, they help to reduce the energy consumption of the networks. However, positioning a set of SDN controllers to manage a vast network is still a challenge, because it requires the right number of controllers to manage the right number of nodes.

In this paper, we suggest a key performance way that will be taken into consideration in all the possible criteria's discussed earlier to provide an optimum solution to it. At present the SDN controllers address scalability keeping in mind the multicontroller possibilities and various clustering strategies. The controller placement under various constraints gives an optimum solution to that situation but that cannot be considered for another similar situation if the nodes are connected in different way or the load of the network goes above the controller's capacity. So, solutions are completely proportional to the situation in which it is applied.

LITERATURE REVIEW

SDN brings problems, as well as solutions, and various research opportunities. For example, any solution implementation may arise another research problem if all the possibilities are not taken into consideration. Scalability, performance and controller placement all are inter connected possibilities or opportunities. Any scalable option should be given good amount of importance to make sure the switch entries can be minimized. This cannot be completely avoidable because without switch entry updation the network is not possible to scale. This will definitely affect the performance at least for a small amount of time. The communication between the switches and nodes, controllers are the switches all are real important issues to be taken care with utmost care. The logically centralized controllers are expected to be always in synchronization or communication with the switches. Any flow through the switches to be monitored and guided by the controller. To get an optimum solution to this blockage, several solutions can be tried. Proactive rule placement, using short-live and long-live flows and physical distribution of the controller are few of them. One of the major requirements with SDN is its requirement of fault tolerance. Single point control is its most important advantage at the same time single point failure threat cannot be neglected.

All eyes are on the performance upgradation, then without thinking of controller placement we cannot imagine performance improvement. One of the reasons to this is that the functionalities of the northbound interface is not standardized. The applications are completely customizable. This standardization is one of the reasons for SDN's advantage and at the same time disadvantage too. One of the architecture diagrams of SDN given by Sezer et al. [1], with some sample applications are given below:

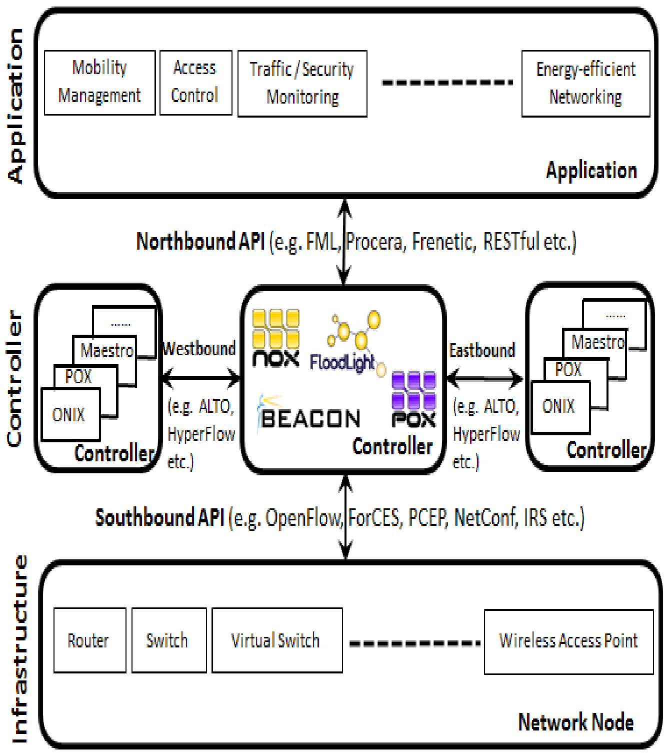

Figure 1: SDN Architecture diagram illustrating the components, control and elements of application. [1]

SDN architecture provides many opportunities. Few of them are programmability, flexibility, simplicity, modularity, etc. At the same time SDN creates few loopholes with some of the features of it, few of them are scalability, reliability, fault tolerance, and finally performance variation depending on controller placement. Here we suggest some solution to controller placement on traditional average sized networks which are already established and with many nodes, many users using different services. The creation of the SDN network begins with the identification of the controller system. The probable node which can be made as the controller will be evaluated for its functionality and performance. Once the node is identified, then the probable controller load on the network will be calculated to make sure that it will not exceed the capacity of the probable controller. After that, the positioning of the controller comes into picture. The selected node is expected to have a very good processing capability.

According to Han et al. in [2] the controller is that one node responsible for all the nodes connected to the network. It is an essential job with responsibility and of course with high cost too, the layout of controllers affects the network's ability to respond to network events. Therefore, the controller placement is an essential problem in SDN networking. When latency and reliability metrics are both considered, there is usually no single best controller placement solution. Most of the deployment schemes are based on latency and are focused on transmission delay or propagation delay at present. However, to the best knowledge, no existing works have considered the influence of control latency on SDN controller placement problem while control latency makes excellent sense in quick response to network events. Thus, in their paper, a minimum-control-latency optimized algorithm is proposed. What's more, the accuracy of latency measurement is also the primary concern in SDN research.

The SDN controller controls the various switches providing traffic forwarding rules which takes care of all the packets passing through the network all the time. According to Y. Zhang et al. [3] In any network environment the placement of the controller is mainly used to optimize network connectivity. According to Heller et al. [4], the connections among the controllers and switches in the network require less latency for an endless number of operations.

In situations where one controller may not be able to handle the stress of the network more than one controllers will be usually used. This sort of modifications are possible only in networks with scalability provisions. Multiple controllers mostly give better performance but with an amount of redundancy within it. Great amount of research is happening in this area which usually supports the multiple controllers in different network locations and in such cases the controller placement becomes difficult and important [3–8].

The controller placement problem was initially discussed by Heller et al. in [4]. The focus of that time was on the determination of the number of controllers and its optimal location. In the paper authors pointed out that examining fundamental limits to control plane propagation latency on the network is very important. The authors concluded saying answer to where and how many controllers to deploy depends on desired reaction bounds, metric choice(s), and the network topology itself. This is one of the available earliest research discussions about the controller placement problem.

Sallahi and St-Hilaire [5] considered the controller placement problem from the financial aspect. Given a set of switches that must be managed by the controllers, the model simultaneously determines the optimal number, location, and type of controllers as well as the interconnections between all the network elements. The goal of the model was to minimize the cost of the network while considering different constraints. The model designed by them were more suitable to plan small-scale SDN rather than for a bigger system. In the case of the bigger network, the model was taking too much time and also ran out of memory.

Yao et al. [8] focused on the capacitated controller placement problem, taking into consideration the load of controllers, introduced an efficient algorithm to solve the problem. The the new strategy significantly reduced the number of required controllers, lowered the pressure of the maximum-load controller. F. A. Ozsoy and M. C. Pınar [9] proposed a placement solution using K -center algorithm [6] to minimize the number of controllers that meet the capacity requirements. In later work, Yao et al. [10] discussed a new controller placement metric considering the node weight for a single domain at first, and then propose a dynamic switch migration algorithm to adapt to the flow dynamics and realize controller load balance in multiple SDN domains. Finally, a simple simulation platform is built to verify the proposed scheme.

Ros and Ruiz [11] considered network reliability highlighting positive correlation between fault tolerance and controller placement. In order to deploy fault-tolerant SDNs, a logically centralized controller must be physically distributed among different devices. Here authors focused on determining how many controllers need to be instantiated, where they must be deployed, and which network nodes are under control of each of them, in order to achieve high reliability in the southbound interface between controllers and nodes. For this, they defined the fault tolerant controller placement problem and developed a heuristic algorithm that computes placements with the required reliability. They run their algorithm on a set of 124 publicly available network topologies. The results are thoroughly analyzed and provided insight on the feasibility of achieving fault tolerant SDNs by carefully determining the placement of controllers.

Zhang et al. [3] demonstrated that the location of controllers have high impact on the network resilience using a real network topology. They proposed a min-cut based controller placement algorithm and compared it with the approach discussed in [9] to compute the maximum number of disjoint paths which separate the network into smaller networks, each having its own controller. Similarly Guo and Bhattacharya [13] generated a hierarchical tree [14] of network nodes, dividing it into clusters or subnetworks. Nodes with maximum closeness to other nodes were selected for controller deployment. In [15] a greedy algorithm was used to enhance controller placement reliability in the event of network state changes as well as single link failures in a network with the optimal controller placement. Hu et al. [16] addressed the problem of placing controllers in SDNs, so as to maximize the reliability of control networks. After presenting a metric to characterize the reliability of SDN control networks, several placement algorithms are developed. Authors evaluated these algorithms and further quantified the impact of controller number on the reliability of control networks using real topologies.

The authors Zhao et al. [17] proposed a method to minimize the system total cost. In particular, authors tried to minimize the number of controllers and meanwhile cluster the controllers into multiple sets called controller sets (CSs). Controller sets are placed in the control plane at a proper set of nodes to achieve scalability and load balancing. This method increased inter-CS link delay because of the distributed CS placement, although it can reduce the response time/delay of packet in messages as controller interfaces are closer to data plane. Therefore, trade-off between the 2 kinds of delays is important. Besides, distributed placement also brings some extra basic cost (e.g., warehouse rent, power supply, and man power). To achieve a joint design by leveraging multiple factors, authors first formulate an integer linear program (ILP) to find the optimal solution under a predefined set of demands and link delay settings and then proposed a corresponding heuristic algorithm distributed SDN placement (DSP) for fast design to meet the requirement of practical engineering design.

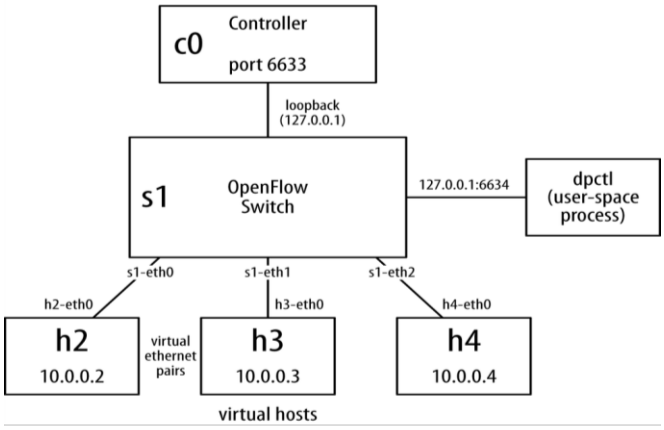

Figure 2: A simple controller example. [30]

IMPLEMENTATION

SDN controller placement calculation module has been implemented as a part of our application and is integrated with the SDN network. This given below section describes the implementation details of our application.

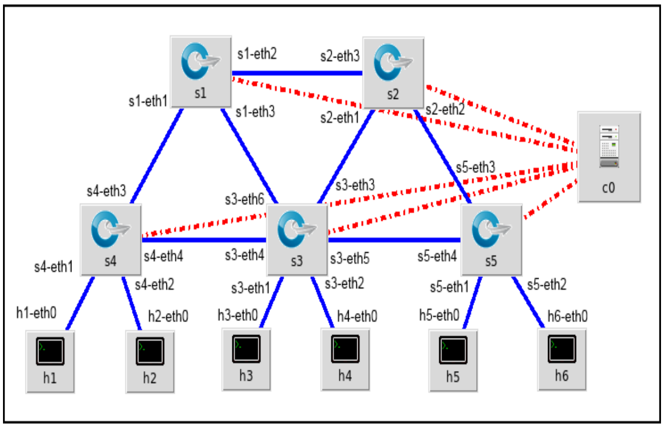

Figure 3: A sample SDN network with one controller, five switches and six nodes and with port number details.

The experimental setup is with Mininet Network Emulator, which is used to create the virtual network. The controller used is POX, is a simple-to-use SDN controller that is bundled with the Mininet SDN network emulator and is used in education and research as a learning and prototyping tool. The Mininet emulator is installed on an Oracle VM VirtualBox Manager. POX components are Python programs that implement networking functions. POX comes with a few stock components ready to use. Since our host computer is a Windows computer, we have used a PuTTY terminal program and ensure X Forwarding is enabled. Also, ensured that an X Server like Xming is running too. Experiments were performed using tree topology. The controller placement is an optimization problem. Hence the following points are very important whenever designing a placement strategy:

(1) The latency of control signaling.

(2) The server capacity limitation

(3) The required number of controllers

(4) Fault tolerance.

(5) Inter-controller communication.

The authors Liu et al. [18] proposed a method of controller placement in their research work, that was considered as the base of this work.

The Graph taken is ***G(V, E)***

V: Set of Nodes

E: Set of edges

S: Number of switches

C: Number of controllers, The number of controllers should always less than the number of nodes in the netwok.

r: The number of switches controlled by a controller in the network

a: One of the nodes

b: One of the nodes

l: link

n: node

p: Paths between nodes, there may exist many different paths between two nodes

$p_{a,b}$: Shortest path between the nodes a and b

r_l: Possible reliability of link l, $0 < r_l < 1$

r_n: Possible reliability of node n, $0 < r_n < 1$

$X_l, p_{a,b} = \{0,1\}$ or **$X_n, p_{a,b} = \{0,1\}$** : These index functions denotes that whether the link l and node n are on the shortest path $p_{a,b}$ respectively. Value 1 denotes yes, Value 0 denotes No.

$X_1, p_{a,b}=0$ or **$X_n, p_{a,b} = 0$**: Here the value is 0, means the link l and node n are not on the shortest path $p_{a,b}$.

$X_l, p_{a,b}=1$ or **$X_n, p_{a,b} = 1$**: Here the value is 1, means the link l and node n are on the shortest path $p_{a,b}$.

Algorithm used for Controller Placement

INPUT: For the various SDN network elements involved in the calculation i.e. The set of nodes, links, switches, and one or many controllers.

OUTPUT: SDN network with one or more controllers, which is placed in the optimum location to have better control over the network.

Let count = 0

start

for node a and node b belongs V **do**

calculate the $R_{a,b}$ for node a and node b, $b \in V$, where $a \neq b$

end for

sort the $R_{a,b}$ for node a as descending, and select the first r node, and then return $R_a = \sum_r R_{a,b}$

find a node a with Maximum Ra, and add this node to the controller set C

select the first r node for the node a as a switch set Wa

remove the node a and add the node a in set W_a from set V

Let count = count + 1

if i < m **then**

repeat steps so goto the label start

else

i = m

end if

if $V \neq \emptyset$ **then**

for $b \in V$ **do**

compute the reliable connection Rb,c_i between b and controller in set C

add b to the control domain with maximum Rb,c_i

end for

else

stop

end if

RESULTS

The algorithm was tested successfully in an SDN network with one controller, five switches and six nodes by introducing second controller into the network then the performance was improved by 35%. When tried to add one controller to a network with three controllers, fifteen switches and eighteen nodes the performance was improved only by 9%. Most of the test runs showed improvements in performance but few tests with worst locations for the controller positioning showed the same level of performance. The experiment, an optimum placement of controller has been implemented and tested in a limited simulated environment.

CONCLUSION

The major element of any SDN network will be the controller. In order to fulfill its responsibility its right placement in the network is also important.

REFERENCES

[1] Sezer, S., et al. "Are We Ready for SDN? Implementation Challenges for Software-Defined Networks" IEEE Communications Magazine, July 2013.

[2] L. Han, Z. Li, W. Liu, K. Dai and W. Qu, "Minimum Control Latency of SDN Controller Placement," 2016 IEEE Trustcom/BigDataSE/ISPA, Tianjin, 2016, pp. 2175-2180.

[3] Y. Zhang, N. Beheshti, and M. Tatipamula, "On resilience of split-architecture networks," in Proceedings of the IEEE Global Telecommunications Conference (GLOBECOM '11), pp. 1–6, 2011.

[4] B. Heller, R. Sherwood, and N. Mckeown, "The controller placement problem," 420 Acm Sigcomm Computer Communication Review, vol. 42, no. 4, pp. 7–12, 2012.

[5] A. Sallahi and M. St-Hilaire, "Optimal model for the controller placement problem in software defined networks," IEEE Communications Letters, vol. 19, no. 1, pp. 30–33, 2015.

[6] G. Yao, J. Bi, Y. Li, and L. Guo, "On the capacitated controller placement problem in software defined networks," IEEE Communications Letters, vol. 18, no. 8, pp. 1339–1342, 2014.

[7] M. F. Bari, A. R. Roy, S. R. Chowdhury et al., "Dynamic controller provisioning in software defined networks," in Proceedings of the 9th International Conference on Network and Service Management (CNSM '13), pp. 18–25, Zürich, Switzerland, October 2013.

[8] Yao, Jun Bi et al., "On the Capacitated Controller Placement Problem in Software Defined Networks", *IEEE Communication Letter*, 2014.

[9] F. A. Özsoy and M. Ç. Pınar, "An exact algorithm for the capacitated vertex p-center problem," Computers & Operations Research, vol. 33, no. 5, pp. 1420–1436, 2006.

[10] L. Yao, P. Hong, W. Zhang, J. Li, and D. Ni, "Controller placement and flow based dynamic management problem towards SDN," in Proceedings of the IEEE International Conference on Communication Workshop (ICCW '15), pp. 363–368, IEEE, London, UK, June 2015.

[11] F. J. Ros and P. M. Ruiz, "On reliable controller placements in Software-Defined Networks," Computer Communications, vol. 77, pp. 41–51, 2016.

[12] T. Erlebach, A. Hall, L. Moonen, A. Panconesi, F. Spieksma, and D. Vukadinovi, "Robustness of the internet at the topology and routing level," Access and Download Statistics, vol. 4028, pp. 260–274, 2006.

[13] M. Guo and P. Bhattacharya, "Controller placement for improving resilience of software-defined networks," in Proceedings of the 4th IEEE International Conference on Networking and Distributed Computing (ICNDC '13), pp. 23–27, IEEE, Los Angeles, Calif, USA, December 2013.

[14] A. Clauset, M. E. Newman, and C. Moore, "Finding community structure in very large networks," Physical Review E Statistical Nonlinear and Soft Matter Physics, vol. 70, no. 6, pp. 264–277, 2004.

[15] S. Guo, S. Yang, Q. Li, and Y. Jiang, "Towards controller placement for robust software-defined networks," in Proceedings of the IEEE 34th International Performance Computing and Communications Conference (IPCCC '15), pp. 1–8, Nanjing, China, December 2015.

[16] Y. Hu, W. Wang, X. Gong, X. Que, and S. Cheng, "Reliability-aware controller placement for software-defined networks," Wireless Communication Over Zigbee for Automotive Inclination Measurement China Communications, vol. 11, no. 2, pp. 672–675, 2013.

[17] Zhao Z, Wu B. "Scalable SDN architecture with distributed placement of controllers for WAN." Concurrency Computat: Pract Exper. 2017.

[18] Liu, J., Liu, J., Xie, R.: Reliability-Based Controller Placement Algorithm in Software Defined Networking. Computer Science and Information Systems, Vol. 13, No. 2, 547–560. (2016).

[19] M. Yu, J. Rexford, M. J. Freedman, and J. Wang, "Scalable flow-based networking with DIFANE," in Proceedings of the ACM SIGCOMM 2010 conference (SIGCOMM '10), pp. 351–362, New Delhi, India, September 2010.

[20] A. R. Curtis, J. C. Mogul, J. Tourrilhes, P. Yalagandula, P. Sharma, and S. Banerjee, "DevoFlow: scaling flow management for high-performance networks," ACM SIGCOMM Computer Communication Review, vol. 41, no. 4, pp. 254–265, 2011.