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A Survey of Network Measurement in Software-Defined Networking

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Abstract. The huge size of network and diversified business characteristics make network traffic difficult to predict and manage. Network measurement is an effective way which can ensure QoS (Quality of Service) and network optimization. However, due to the differences in the implementation rules of equipment (such as switches, routers etc.), it is difficult to achieve accurate and timely network measurement in traditional networks. Recently emerging software defined network (SDN) separates the network control plane from the data forwarding plane and manages the whole network through the centralized controller platform which improves the efficiency of the network management. The new network model adopting unified south bound(SB) interface protocols (OpenFlow is the commonly SB protocols) to access network equipment which shields the different implementation details of the underlying network equipment. The SDN solves the problems that the heterogeneous devices statistical information which is difficult to obtain and greatly simplifies the complexity of network measurement. On the basis of extensive research, this paper introduces the network measurement methods commonly used in Sandwich including sampling method, link latency measurement and link packet loss measurement method. We believe that the network measurement technology in SDN will greatly optimize the performance and accuracy of network measurement and can provide better guarantee for network quality.

Key words: SDN; QoS; SB; network optimization.; control plane; interface protocols; centralized controller.

INTRODUCTION

With the swelling of the network scale and the emergence of a variety of applications, as an important part of the social infrastructure, the network architecture has more complexity [1]. There huge size and complexity of network have created some troubles. First, the network operators are unable to timely and accurately get network status information's and emergencies. Second, it is difficult to obtain different granularity of measurement information based on application types. Last, the network managers cannot effectively improve network utilization. Therefore, network measurement has become a crucial task, which can ensure Quality of Service(QoS) and optimize the network. Now, the commonly measurement method can have divided into two categories, one is active method, the other is passive method. The active method injects detection packets into the network and monitor the network characteristics by calculating and observing the behavior of packets. The passive method attaches the dedicated devices on network and analyze the network by the data captured by these equipment's. In the traditional network architecture, there are various vendor's equipment's, and each vendor's equipment adopts its own proprietary protocol, it is impossible to obtain the state data of the device through uniform interfaces. This makes the management of large-scale heterogeneous network difficult to realize. So, both the active and passive methods are difficult to monitor and measure the network under the traditional network.

Recently emerging Software-Defined Network (SDN) separates the network control plane from the data forwarding plane and manages the whole network through the centralized controller platform which can collect statistics from the network elements by using SouthBound(SB) protocols. The southbound(SB) protocols shield the

different implementation details of the underlying network equipment and provide a unified interface to access these devices. Currently, the OpenFlow [2] protocol is the most commonly used protocol for the southBound interface, which has become the standard of the SouthBound protocol. The SDN and openflow solve the problems that the heterogeneous devices statistical information which is difficult to obtain and greatly simplifies the complexity of network measurement. Furthermore, network measurement in SDN can be used to obtain several characteristics that cannot be measured in traditional large networks by a direct, non-intrusive and flexible ways. In this paper, we present a survey of monitoring in Software-Defined networks.

TYPICAL SDN ARCHITECTURE AND OPENFLOW PROTOCOLS

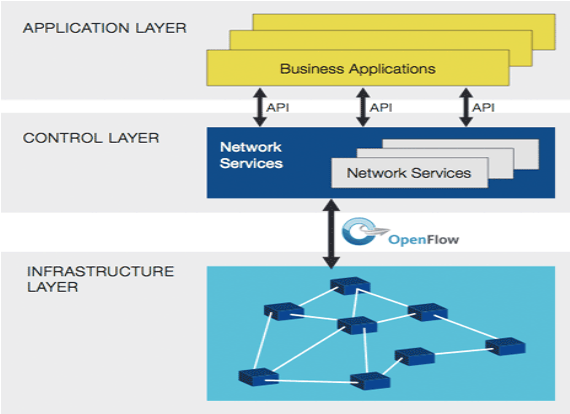

FIGURE 1. SDN Architecture

In 2008, professor McKeown of Stanford published the results of research on OpenFlow in ACM SIGCOMM, which is a top international conference. Based on the programmable characteristics of OpenFlow, professor McKeown further proposed the concept of Software Defined Network (SDN). In 2011, the Open Network Foundation(ONF), an international organization, was established to focus on the standardization and commercialization of SDN. ONF proposes a three-layer SDN architecture [3], as shown in figure 1, which is divided into three levels: the infrastructure layer, the control layer and the application layer. The infrastructure layer represents the underlying forwarding device of the network, which support the OpenFlow protocol; The control layer include OpenFlow controller and network operating system, it focus on the maintenance of the network status, getting the infrastructure information's through Southbound protocols and provide scalable northbound interface to the application layer.; The application layer is composed of applications and provides corresponding control algorithms for specific applications (such as load balancing, etc.).In terms of current influence, the three-tier SDN architecture proposed by ONF is more widely concerned.

The most important protocol in the SDN architecture is the southbound protocol, which is responsible for the information exchange between the controller and the devices. One of the most popular southbound protocol standards is Openflow. The openflow protocol is first proposed by Stanford. The reference implementation of the OpenFlow includes three main parts, controller, openflow switch, and OpenFlow message.

openflow switch: Includes flow tables and dedicated channels. A dedicated channel is used to establish secure connections, exchange commands and transmit packets between openflow switches and controller. A flow table is a collection of table entries which contains a number of matching fields and an action on packets. There are three typical operations, forwarding packets to a specific port, encapsulating packets to the controller and dropping packets.

controller: A controller is usually a software module that be used to manage multiple openflow switches. The controller can push, delete and update flow entries on the switch by using openflow protocols.

openflow messages: The openflow protocol defines three types of messages, which are controller to switch message, asynchronous messages, and symmetric messages.

The interaction between the openflow switch and the controller is shown as the figure below:

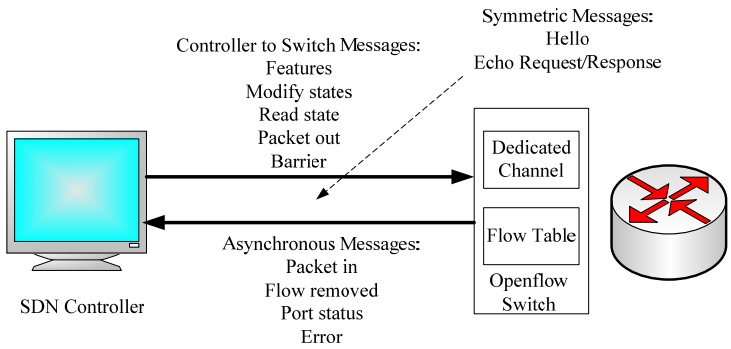

FIGURE 2. Interaction between controller and switch

Initially, the openflow switch is connected to the controller via port 6633/6653. The controller acquires the state of the switch by the Echo message and obtains the capability of the devices through the feature message. In switch, the flow table is empty. The table can be modified by the incoming packet. When a new packet arrives, if there is no matching flow entry, the packet is encapsulated in a packet-out message and forwarded to the controller. By analyzing the global topology, the controller obtains the data path of the packet and push the flow entry into the underlying switch. With continuous additions, deletions, and updates operations, the flow table items in the openflow switch are constantly changing, thus the forwarding of packets is achieved. Openflow and SDN allow network measurement to quickly and flexibly get the statistics of the openflow switch by an unified interface,so they brings a new opportunities for network monitoring.

NETWORK MEASUREMENT IN SDN

Sampling method, link latency measurement and link loss measurement are three important research isuues in network monitoring and measurement. We will discuss these three aspects of the research work.

Sampling Method

The commonly used sampling methods are periodical sampling and adaptive sampling. The former adopts fixed time as the sampling interval,such as[4], which cannot deal with the sensitive changes of the flow. Moreover, when the flow is relatively stable, this method will produce a higher overload. By adjusting the sampling interval time through comparing the differences of some network indexes, the latter can effectively improve the accuracy of sampling and reduce the load of the monitoring, which has become the emphasis in current research. Pangwei Tsai et al. [5] presents a method of polling frequency adjustment based on grouping. First, the system divides some groups which have difference sampling interval. Then each active flow is assigned to these groups. Every group is given a timer to trigger the polling operation.When a round of polling operation is completed, the group of different flow is dynamically adjusted by comparing the change in flow with a specific threshold. This realizes the adjustment of different flow monitoring frequency.The experiments show that this method can effectively balance efficiency and accuracy. He Qiang and Shengbao Wang [6] proposes a method of sampling frequency adjustment based on flow rate.The core idea of this method is: the more the traffic varies, the smaller the polling interval is. Firstly, the low-pass filter function was defined, and then the function was optimized by using proportional linear prediction (PLP) with weighted linear prediction (WLP) method. Finally, the changes of flow rate were obtained. After obtaining the flow rate, the paper achieves the adjustment of sampling frequency of three different situations by comparing the change of flow rate with the pre-setted threshold. An adaptive sampling interval adjustment method based on throughput is proposed in [4]. The method first calculates the changes of throughput in two sampling intervals. It will increase the sampling interval when the throughput change value less than α*prev_throughput(α is a adjustment constant). It will reduce the sampling interval when the throughput change value greater than β*prev_throughput(β is a adjustment constant). When fluctuation does not belong to above two situations, it will increase the small sampling interval. For the sampling method, the exsiting method mainly adjusts the sampling time by the fluctuation of a sepcific network characteristic

Link Latency

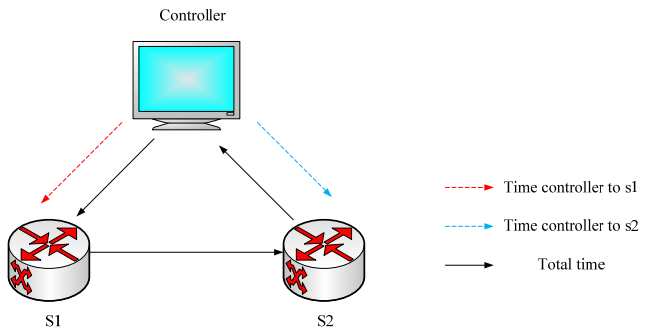

FIGURE 3. The link latency can estimate as follow

Phemius and Bouet [7] propose a latency measurement method. The solution use four types openflow message, there are:STATISTICS_REQUEST,STATISTICS_REPLY,PACKET_OUT,PACKET_IN.The method first created a basic Ethernet frame using the broadcast address as a destination and the hardware address of the port which will be used to send the packet as a source.The controller send this packet to S1 by using packet_out message, when s1 forword the packet to s2,s2 will not find an entry about this packet, then s2 sent the packet back to controller by packet_in message. The controller then retrieve the packet and calculate the total time for this process by using the received time and the packet's Time-stamp. Furthermore, method can get the the Round-Trip Time (RTT) between the controller to s1 and controller to s2 throught the STATISTICS REQUEST and STATISTICS REPLY messages. Now, we get three varibles: T_{total},T_{s1},T_{s2},then the link latency can estimate as follow:

$$\text{Latency}(S1, S2) = T_{total} - \frac{T_{s1}}{2} - \frac{T_{s2}}{2} - c$$

C variable in the equation corresponds to the calibration value of the controller. This is the most commonly used method in link delay measurement. Most measurements are based on this method.

Link Packet Loss

Adrichem and Doerr[8] introduce the OpenNetMon,a tools to monitor network metrics, especially packet loss in software defined netwroks. Opennetmon calculates the packet loss rate of the link by polling the flow statistics of the source switch and the target switch.The packet loss rate is calculated by calculating the difference between the number of bytes sent by the source node and the number of bytes received by the target node Santos[9] introduce a similar packet losss measurement approach for an individual link and discussed the cost of measuring the packet losss of a path based on an individual link loss measurement. Chunyan and wolfgang [10] realizes low load and automated packet loss detection by extending the openflow protocol. EPLE defines the microflow identifier and measurement strategy associated with the microflow in the controller. When ingress switch identifies the microflow according to the policies delegated by the controller, it will inform controller to selected the monitor path. The controller then installs the same microflow descriptors on all the other switches in the measurement path. When the micro flow in the path is expire, the flow statistics is reported to the controller, and the controller can obtain the packet loss by calculating the difference of the flow in the interval. All the above methods are to measure the loss rate of one-way link. Xinchang[11] proposed a method to measure two-way link packet loss based on graph theory. The method first divides the network topology into several connected subgraphs, and then homogenizes the connected subgraph which make the size of the subgraph similar. When the subgraph is homogenized, the symmetric two-way link of the subgraph is obtained by using euler circuit method. For the two-way link, the previous flow statistics method is used to calculate the link loss.

CONCLUSION

In this paper, we review the main architecture of SDN, and introduce the network measurement techniques in SDN, including sampling method, link latency measurement and the link packet loss monitoring in SDN. In SDN, the controller has a global view, and can obtain the switch statistical informations flexibly through the unified Southbound interface protocols. Therefore, we believe that the monitoring techniques in SDN has better potential performance than that in traditional network.

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REFERENCES

1. A Yassine,H Rahimi,S Shirmohammadi. Software Defined Network Traffic Measurement: Current Trends and Challenges. IEEE Instrumentation & Measurement Magazine , 2015,18 (2) , pp 42-50.
2. N. McKeown, T. Anderson, H. Balakrishnan, G. Parulkar, L.Peterson, J.Rexford, S. Shenker, and J. Turner. Openflow: Enabling Innovation in Campus Networks. ACM SIGCOMM Computer Communication Review.2008,38(2), pp 69–74.
3. Open Networking Foundation. http://www.opennetworking.org.
4. Z. Su, T. Wang, Y. Xia, and M. Hamdi. CeMon: A cost-effective flow monitoring system in software defined networks. Computer Networks,2015, 92, pp101-115.
5. Pangwei Tsai, Chunyu Hsu, Monyen Luo, Chusing Yang. On the Implementation of Adaptive Flow Measurement in the SDN-enabled Network: A Prototype.Proceedings of the Asia-Pacific Advanced Network 40 (2015): 7-13.
6. He Qiang, and Shengbao Wang. A Low-Cost Measurement Framework in Software Defined Networks International Journal of Communications, Network and System Sciences 2017 10 (5): pp 54-66.
7. K Phemius ,M Bouet. Monitoring latency with OpenFlow Network and Service Management (CNSM), 2013 9th International Conference on,pp122-125.
8. N. L. M. van Adrichem, C. Doerr, and F. A. Kuipers.OpenNetMon: network monitoring in openflow softwaredefined networks. in Proc. IEEE Network Operations and Management Symposium (NOMS). 2014. 1-8.
9. Renato B Santos, Thiago R Ribeiro, Cecilia De A Castro Cesar. A Network Monitor and Controller using Only OpenFlow. Latin American Network Operations and Management Symposium.2015.9-16.
10. Chunyan Fu, Wolfgang John, Catalin Meirosu. EPLE: an Efficient Passive Lightweight Estimator for SDN Packet Loss Measurement. IEEE Conference on Network Function Virtualization and Software Defined Networks. 2016 .192-198.
11. Xinchang Zhang, Yinglong Wang, Jianwei Zhang, Lu Wang, Yanling Zhao.A two-way link loss measurement approach for software-defined networks. IEEE/ACM IWQoS.2017. 1-10.