WE-Bridge: West-East Bridge for SDN Inter-domain Network Peering

Pingping Lin Jun Bi* Ze Chen Yangyang Wang Hongyu Hu Anmin Xu

Institute for Network Sciences and Cyberspace, Tsinghua University
Tsinghua National Laboratory for Information Science and Technology
Beijing, 100084, China

***Index Terms*— Software Defined Networking, Peering, West-East Bridge, Network View Virtualization, Route Translation.**

I. INTRODUCTION

Software defined networking (SDN) [1] works as a centralized control model. However, the Internet is managed by owners of different domains, which makes the centralized control does not work for inter-domain. Controlling the flow of data packets in a global network requires each NOS (Network Operating System) to have a relative global network view to determine the next NOS hop. Hence, NOSes are required to exchange reachability and topology information between the inter-domain networks. How such information is efficiently exchanged has not been well addressed so far. Thus, this demo proposes a West-East Bridge (WE-Bridge) mechanism for different SDN administrative domains to peer and cooperate with each other: (1) we design a peer-to-peer based high performance network information exchange mechanism. We define what network information should be exchanged and how such information is efficiently exchanged among inter-domain SDN peers. (2) To achieve a resilient peer-to-peer control plane of heterogeneous NOSes, we propose a 'maximum connection degree' based connection algorithm [4]. (3) Considering the privacy, we propose to virtualize the SDN network view, and only exchange the virtualized network view to construct the relative global network view. Applications above WE-Bridge carry out the route translation, calculation, and installation.

We deployed WE-Bridge together with two use cases to four SDN networks CERNET (China Education and Research Network), Internet2 in USA, CSTNET (China Science and Technology Network), and SURFNET (the national research and education network of Netherlands).

II. WE-BRIDGE

All the SDN network controllers/peers are equivalent to each other, and connected as an unstructured network with our proposed 'maximum connection degree' algorithm. Firstly, WE-Bridge in each SDN network virtualizes the local physical network. Then all WE-Bridges from different SDN networks exchange the basic reachability (route) and virtual network information in JSON (JavaScript Object Notation) format, construct the relative global network view, and provide such information to the applications above. Then applications in different domains translate all the routes into OpenFlow [2] flow paths and cooperate with each other to setup cross-domain routing paths.

* Jun Bi is the corresponding author: junbi@tsinghua.edu.cn
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The network view refers to topology, entities (OpenFlow switches, links, and hosts), network abilities and status. SDN domain in this demo refers to administrative SDN domain.

A. Network View Virtualization for Privacy

Each SDN domain may be only willing to expose part of its network to its peers due to privacy concerns. WE-Bridge supports to abstract physical networks to virtual networks with two types and only exchange virtual network information: (1) Abstract a physical network into a virtual network with only edge switch pairs, like network 1 in Figure 1. Route path segments (like VP 1, VP 2, VP 3) in the virtual network can have SLA (Service Level Agreement)-level path attributes such as time latency, reliability, bandwidth, packet loss rate. (2) Abstract a physical network into a virtual node, like network2. The virtual node only retains three physical inter-domain (cross-domain) links: link2, link3, link4.

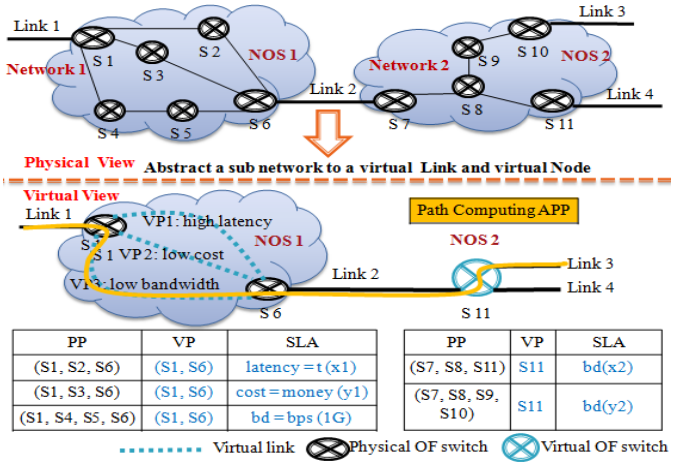

Fig. 1. Network View Virtualization (PP: Physical Path; VP: Virtual Path; OF: OpenFlow; S: Switch; bd: bandwidth; t: time; bps: bits per second)

B. Reachability and Virtual Network View Transfer Format

We adopt JSON (JavaScript Object Notation) for network view and reachability information transfer among different domains, since it is an application-independent language (which enables peering between heterogeneous NOSes). Other alternatives are XML (eXtensible Markup Language), YANG (RFC 6020), and YAML (YAML Ain't Markup Language).

C. Route Translation, Flow Path Calculation and Installation

After exchanging virtual network views and reachability information, each network can construct a relative global network view and provide it to network applications above. We have tried applying the BGP (Border Gateway Protocol

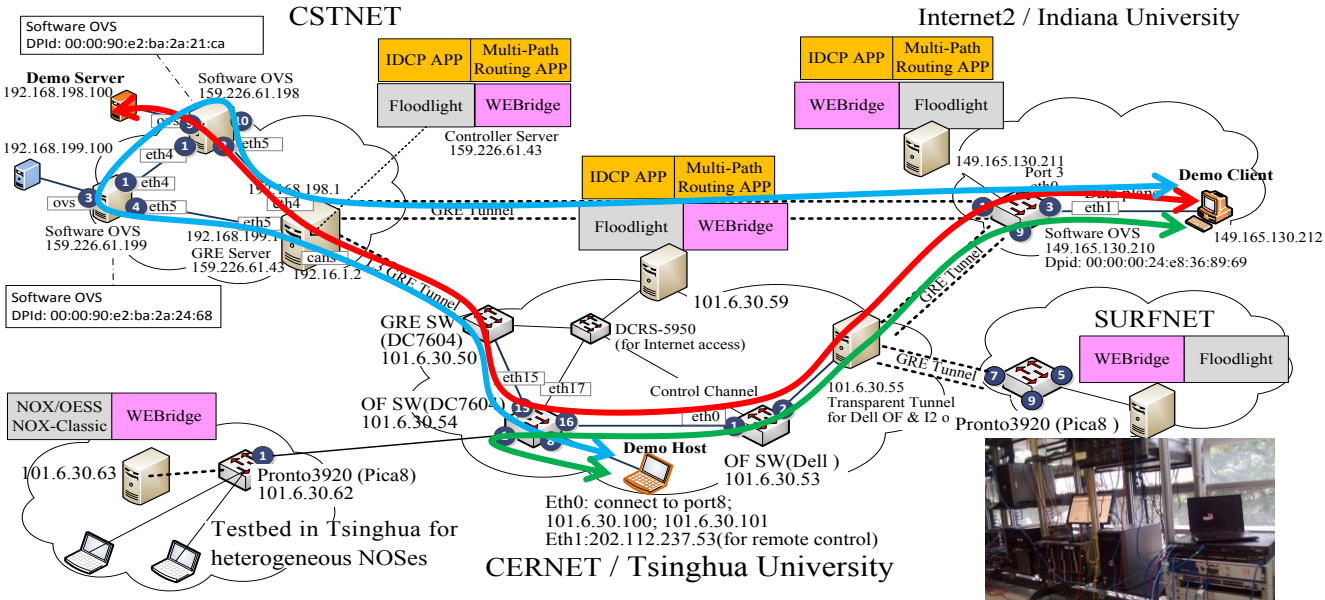

Fig.2. WE-Bridge Federal Deployment: CERNET, CSTNET, Internet2, SURFNET
GRE: Generic Routing Encapsulation; SW: Switch; OVS: Open vSwitch; APP: Application; n : Port

version 4) between SDN domain and other domains [3]. This time, we want to go further on the SDN inter-domain routing. We implement an Inter-domain Path Computation (IDPC) application and a Source-address based Multi-path Routing (SMR) application. Each time, WE-Bridge receives a route; the SMR application will translate it into transit flow paths (from the other edge switch ports to the incoming one which receives the route) with flow entries and proactively install them into OpenFlow switches in its domain. In addition, each time there is a new packet coming to controller, the IDPC application will check the location of destination IP. If the destination IP is in intra-domain, it will carry out re-active flow calculation and installation. Otherwise, it will compute an end-to-end path, and negotiate with other IDPC applications along the path with path segment request: (*ingress switch and port, egress switch and port, matching fields, path attributes*).Then each IDPC application translates the corresponding path segment request into flow entries and installs them to the OpenFlow switches. Thus, all kinds of routing paths can be set up.

III. Demo Implementation and Deployment

WE-Bridge Mechanism: We implemented the WE-Bridge and successfully deployed it to four SDN networks (CERNET, Internet2, CSTNET, SURFNET) with two use cases shown in Figure 2. The demo shows how WE-Bridge connects the four SDN networks, and how WE-Bridges from different SDN networks dynamically exchange reachability and virtual topology together with the bandwidth information.

Use Case1: Inter-domain Path Computation (IDPC): The IDPC application runs on top of WE-Bridge. It reads the global reachability and virtual topology information from WE-Bridge, and corporates with other IDPC applications in other domains to setup a cross-domain path. Both of the bandwidths between Tsinghua and Interent2 and between CSTNET and Tsinghua are larger than that between CSTNET and Internet2. Therefore, the flow path is setup automatically by IDPC applications as follows: CSTNET - Tsinghua - Internet2 shown in Figure 2 as in the red traffic line. Then, we deliver 1 Terabytes FTP (File Transfer Protocol) traffic on this path from server in CSTNET to client in Internet2.

Use Case2: Source-address based Multi-path Routing (SMR): This is also policy routing. Internet2 announces different routes to different peers: (src: 101.6.30.100, dst: 149.165.120.212/32) to CSTNET, (src: 101.6.30.101, dst: 149.165.120.212/32) to CERNET. Tsinghua announces (dst: 101.6.30.100/30) to all peers. Then host in Tsinghua uses different IP addresses to access a same destination IP address of host in Internet2, there will be multiple paths shown in green traffic line and blue traffic line, which could not be achieved in the current Internet.

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References

[1] Nick McKeown. “Keynote talk: Software-defined networking”. In Proceedings of IEEE INFOCOM 2009.

[2] Nick McKeown, Tom Anderson, Hari Balakrishnan, Guru Parulkar, Larry Peterson, Jennifer Rexford, Scott Shenker, and Jonathan Turner. “OpenFlow: enabling innovation in campus networks”. ACM SIGCOMM Computer Communication Review, 38(2), 2008.

[3] Pingping Lin, Jonathan Hart, Masayoshi Kobayashi, Umesh Krishnaswamy, Tetsuya Murakami, Kuang-Ching Wang, Ali Al-Shabibi, Jun Bi, “Seamless Interworking of SDN and IP”. In Proceedings of ACM SIGCOMM 2013.

[4] Pingping Lin, Jun Bi, Yangyang Wang. Whitepaper: “SDN Inter-domain Network Peering”, http://netarchlab.tsinghua.edu.cn/~junbi/THU-NetArchLab-SDN-TR-WEBridge-20131001.pdf.