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P538 Computer Networks: Virtualization Technologies Report

In this report we will discuss network virtualization technologies. Network virtualization is the process of combining physical networks into one virtual software-based network or dividing one physical network into multiple virtual software-based networks. The benefits of network virtualization are: optimize network flow and speed, improve reliability and flexibility, and provide scalability and security. Along with making the job of the network administrator easier because automating tasks can be accomplished. The network virtualization technologies we will look at are: virtual local area networks (VLANs), Virtual Extensible LAN (VXLAN), Network Virtualization using Generic Routing Encapsulation (NVGRE), and Generic Network Virtualization Encapsulation (Geneve).

VLAN is the first technology we'll examine. Its advent came about to solve problems with switched local area networks. Mainly the following three difficulties: lack of network traffic isolation, managing users, and inefficient use of switches. VLAN works on the data link layer (OSI layer 2) to accomplish tasks. Switches modify the ethernet frame by shimming additional data between the "source address" and "type" header fields. This data is referred to the VLAN tag and identifies the VLAN to which the frame belongs to. The VLAN tag is 4-bytes long and consist of two parts, each 2-bytes long. The Tag Protocol Identifier (TPID) is a hexadecimal number in the range of 81-00. The Tag Control Information consists of two parts which are a 12-bit VLAN identifier (VID) field and a 3-bit priority code point (PCP). The PCP field acts similar to the IP datagram TOS field. The remaining 1-bit is used a congestion mechanism. It is called the drop eligible indication (DEI) and indicates if a frame is eligible to be dropped in the presence of congestion. The VLAN tag was introduced in IEEE 802.1Q. In IEEE 802.1ad the concept of double tagging was introduced. This allowed the ability to place a VLAN tag in front of another VLAN tag. This allowed the possibility of carrying traffic in a VLAN that was already VLAN tagged from another VLAN.

VXLAN is similar to VLAN but the main purpose it was created for was to address the scalability issues that VLAN has. These issues arise when large cloud computing deployments use VLANs. With that said, the main difference between VXLAN and VLAN is how the virtual data is handled and scope of network the data enables. VLAN shims the VLAN tag between the two header fields in the ethernet frame. VXLAN completely encapsulates the layer 2 frame along with the VXLAN header inside a UDP datagram. So, the VXLAN header is added to the original layer 2 frame and then it is placed in an UDP-IP packet. The VXLAN header is 8-bytes compared to VLAN's 4-bytes. The VXLAN Network Identifier (VNID), which is analogous to VLAN's VID, is 24-bits. This increases the virtual space from 4,096 to 16 million! The VNID is used to identify layer 2 segments and maintain layer 2 isolation between segments. The remaining bits of the header are reserved. Now, because the original layer 2 frame is encapsulated in the UDP datagram tunneling is used which is something VLAN does not do. This allows layer 2 packets to transmit across layer 3 networks. A VXLAN tunnel endpoint (VTEPs) terminate the VXLAN tunnel and unpack the original layer 2 frame. VTEPs can be virtual or physical switch ports. Port 4789 is the IANA-assigned destination UDP port number for VXLAN.

NVGRE is similar both to VXLAN and VLAN but is more closely related to VXLAN. It's main purpose, like VXLAN, is to alleviate scalability problems that occur in large cloud computing deployments. NVGRE and VXLAN compete with each other for dominance in the large-scale cloud computing VLAN space. Just like VXLAN and unlike VLAN, NVGRE uses encapsulation and tunneling. The main difference between VXLAN and NVGRE is how the encapsulation works. As its name suggest, NVGRE uses Generic Routing Encapsulation (GRE) to tunnel layer 2 packets over layer 3 networks. Now, with that said NVGRE uses the GRE header and encapsulates the layer 2 frame. The lower 24-bits of the GRE header are used as the tenant network identifier (TNI). The rest of the GRE header is unmodified. The TNI is analogous to VXLAN's VNID field and thus is capable of supporting 16 million virtual networks. One major disadvantage NVGRE has, that VXLAN doesn't, is it isn't compatible with traditional load balancers. This is because transmission network needs to use the GRE header which affects the ability of traditional load balancers to do their job. On the other hand, NVGRE supports sharding which VXLAN does not. This allows NVGRE to work on networks that support smaller frame sizes where VXLAN cannot work. The last difference that will be covered is the flooding behavior of these two technologies. VXLAN utilizes multicast in the transport network. This allows VXLAN to simulate flooding behavior for broadcasts, unknown unicast, and multicast in layer 2 segments. This is needed for MAC address learning protocols like ARP to function properly. On the other hand, NVGRE hosts must use multiple IP addresses to load balance traffic. This allows NVGRE to broadcast in a more flexible way and not rely on flooding and broadcasting.

The final virtualization technology I'll review is Generic Network Virtualization Encapsulation (Geneve). Geneve was created by the IETF and is designed to unify the network virtualization encapsulation protocols. Ultimately this would eliminate VXLAN and NVGRE. The main goal of Geneve is to standardize the encapsulation data format. This will decouple any information pertaining to the control plane. The benefit of this is removing specific control plane data which is often different in many ways. Another big difference is the 24-bit identifier fields in VXLAN and NVGRE are fixed. But Geneve will allow this field to be fluid. This gives Geneve more flexibility and extensibility which is highly desired for longevity purposes. Beyond this major change the rest is largely the same. Geneve will use encapsulation and tunneling. The header is fairly similar; there is a field specifying it is a Geneve packet, a field for the length of options, the tunnel identifier, the options field , and a few other fields that aren't drastically important for this discussion.

One last bit of information I want to present is the following. Stateless Transport Tunneling, which was not discussed, deviates from the 24-bit tunnel identifier field and uses a 64-bit field instead.

All in all, network virtualization technologies are very similar sans VLAN. VLAN was the first and with that has been a steppingstone for virtualization technologies that aim to address large-scale problems. VXLAN and NVGRE are very similar and have a few but major differences in their approaches to the large-scale network virtualization problem. Geneve does not deviate too far from VXLAN and NVGRE, but its biggest difference is the fact that it is control plane agnostic and strives to be as flexible and extensible as possible. These two differences make it a great candidate to become the standard for network virtualization.

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