Linux Bridge - Part 1

Posted **Dec 13, 2017** • Updated **Oct 26, 2024**

By **Hechao Li**

13 min read

Overview

In previous post, I described the concept of VXLAN and said it is heavily used in SDN (Software Defined Network). Although SDN is a relatively new concept, the support for virtual networking is not - Linux bridge has made it possible long before. It could be helpful to learn something about this predecessor before diving into SDN.

Linux Bridge is a kernel module that was first introduced in 2.2 kernel, then rewritten by Lennert Buytenhek. The code for bridging has been integrated into 2.4 and 2.6 kernel series. It implements a subset of the ANSI/IEEE 802.1d standard. In the end of the article, we will use a lab to learn the usage of Linux Bridge.

What Is a Bridge?

In the network course I had in school, only hub (Layer 1 device), switch (Layer 2 device) and router (Layer 3 device) are introduced and compared. All I know about bridge is, a bridge is a switch with only two ports. Maybe because nowadays bridges are not as widely used as switches and a switch is more advanced than a bridge, the switch is usually selected as the representative of Layer 2. It kind of makes sense - if iPhone X is available, why buying iPhone 8?

Bridge versus Switch

In some articles, the authors try their best to list differences between a bridge and a switch. For example, this wiki page shows 7 of them. Honestly, I am not quite convinced by those stated differences. My opinion is that people just try hard to make up differences to distinguish these two terms and refuse to admit that they actually have no major differences. This can be supported by the book *Understanding Linux Network Internals* in which the author says:

> **The terms bridge and switch can be used to refer to the same device.** However, nowadays the term bridge is mainly used in the documentation (such as the IEEE specifications) that discusses how a bridge behaves and how the STP works. In contrast, references to the actual devices are usually made with the term switch.

> The only cases where I have seen people referring to a bridge device using the term bridge is when the device is equipped with only two ports (and bridges with two ports are not that common nowadays). This is why I often define a switch informally as a multiport bridge. Unless you are familiar with the official IEEE documentation, you will probably use the term switch. I personally worked on bridging software for years, and as far as I can remember, I used the term bridge only when working on the documentation, never to refer to a device on any network setup.

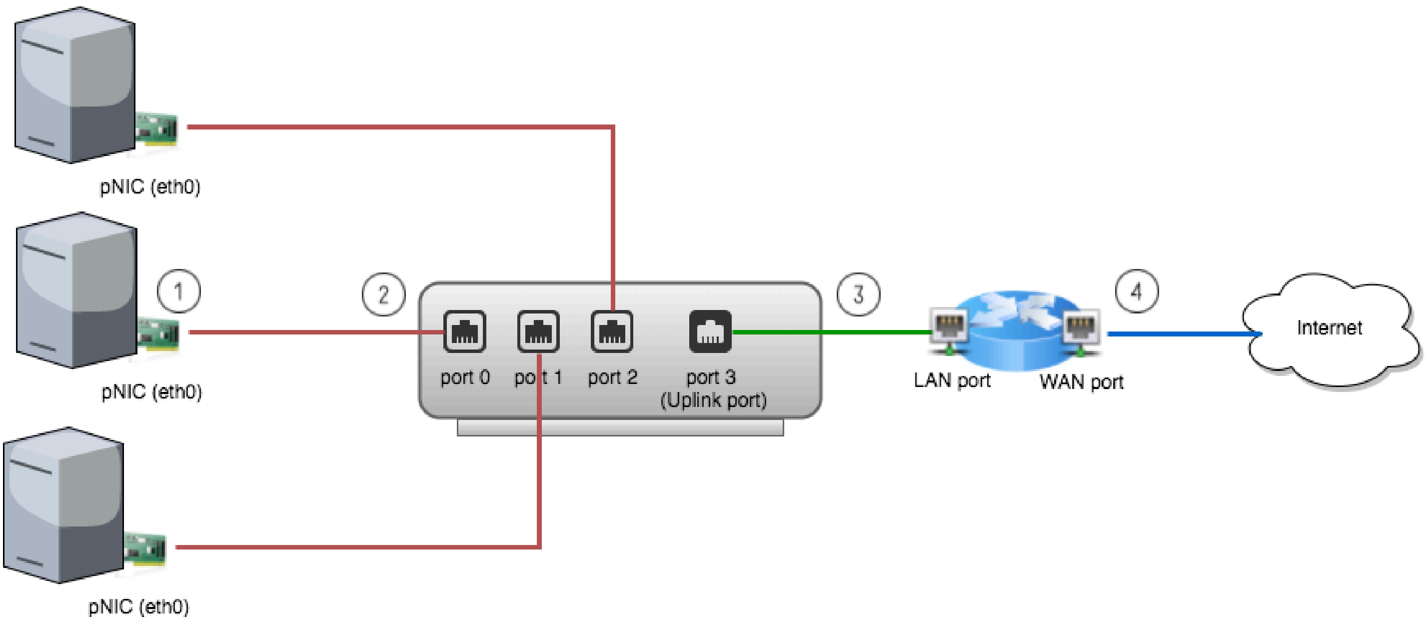
> **Generally speaking, I can say that there is really no difference between a bridge and a switch.**

Bridging VM Network

One use case of Linux bridge is bridging VM network. For example, suppose you have a physical Linux machine running as a KVM hypervisor that hosts some virtual machines. Now all the virtual machines want to access the external network but you have only one physical NIC (Network Interface Card). How can it happen? One solution is to use the Linux bridge. We will discuss how it works later. Before that, let's first see how a bridge is used in the physical network.

Physical Bridge

Suppose in your office there is a small router with 2 ports - one WAN port and one LAN port. If you are the only one in the office then it is sufficient. However, there are two other colleagues also want to access the internet at same time. Thus you need the help of a bridge (or switch if you prefer. I will always use the term bridge hereafter) with at least 4 ports, as shown below:

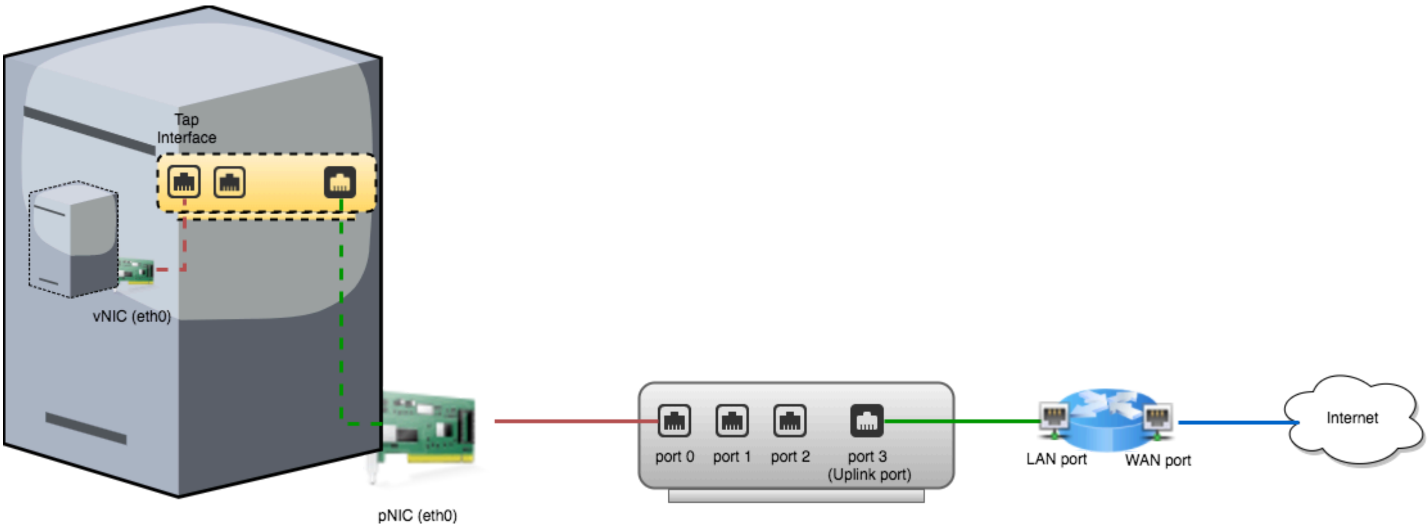


Following is the steps of how data flows from a physical machine to the internet: (Suppose ARP and MAC learning are all done and default gateway IP is set on the physical machines. For details of MAC learning, see previous post)

1. A packet is sent to the pNIC (physical NIC) on the physical machine.
2. The pNIC adds a L2 header to the packet with source address being the pNIC's MAC and destination address being the router's MAC and sends it to the bridge port 0.
3. The bridge forwards the L2 frame received from port 0 to port 3, the uplink port.
4. The router receives the packet and will route it to the final destination.

Linux Bridge (Virtual Bridge)

In the virtual world, nothing is new. All concepts we discuss above still apply. The only difference is, instead of a physical bridge with physical ports that you can see and touch, it now becomes a invisible and untouchable virtual bridge. Suppose in above network, one physical machine is a KVM hypervisor. Let's enlarge it:



Obviously everything looks similar and now the pNIC on the physical machine now becomes the “router” of the virtual world. In order to distinguish between physical and virtual world, we call a NIC on a VM vNIC and call a virtual port on the Linux bridge a tap interface.

Lab

In this lab, I will use a KVM-enabled Linux machine. Honestly it is a virtual machine. But for the purpose of this lab, we just think it as a physical one. If possible, it is always better to use a true physical machine.

Note: If you are using VMWare fusion or VMWare workstation, go to “Settings” -> “Processors & Memory” -> “Advanced options” -> Check “Enable hypervisor applications in this virtual machine” to enable nested virtualization.

Step 1 - Set Up a Bridge

First, we have to create a bridge. There are two ways to do it - one is using distribution-specific scripts; the other is manual configuration. See “Public Bridge” section in this instruction. For simplicity, I will use the first method. However, the second one worth trying since it shows how a bridge is created and how the ports are added to it step by step. Since my hypervisor is an ubuntu machine, I need to modify the `/etc/network/interfaces` file and restart the network:

Plaintext

```
$ cat /etc/network/interfaces
auto lo
iface lo inet loopback

auto br0
```

```
iface br0 inet dhcp
    bridge_ports    ens33
    bridge_stp      off
    bridge_maxwait  0
    bridge_fd       0
$ sudo /etc/init.d/networking restart
```

Note: My pNIC interface name is `ens33`. Typically for a physical machine, it should be `eth0`.

After restart the network, the bridge `br0` should get the IP address (through DHCP) while the physical `ens33` is left without an IP address. As shown below:

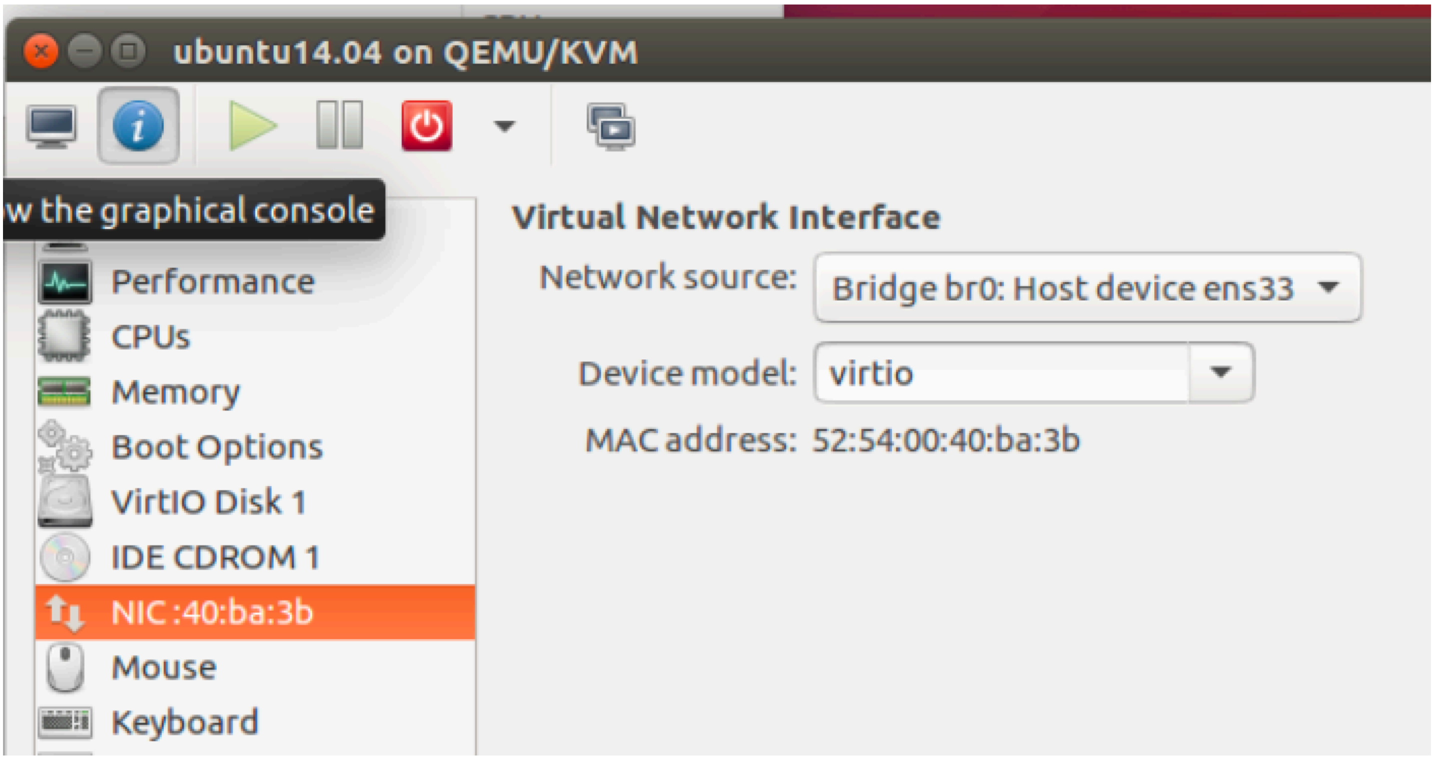
Plaintext

```
$ brctl show
bridge      name bridge id      STP enabled interfaces
br0         8000.000c299e441b   no          ens33

$ ifconfig br0
br0       Link encap:Ethernet  HWaddr 00:0c:29:9e:44:1b
          inet addr:192.168.213.157  Bcast:192.168.213.255  Mask:255.255.255.0
          inet6 addr: fe80::20c:29ff:fe9e:441b/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:484968 errors:0 dropped:0 overruns:0 frame:0
          TX packets:45096 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:678890117 (678.8 MB)  TX bytes:3433367 (3.4 MB)

$ ifconfig ens33
ens33     Link encap:Ethernet  HWaddr 00:0c:29:9e:44:1b
          inet6 addr: fe80::20c:29ff:fe9e:441b/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:528979 errors:0 dropped:0 overruns:0 frame:0
          TX packets:56503 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:730632857 (730.6 MB)  TX bytes:4201577 (4.2 MB)
```

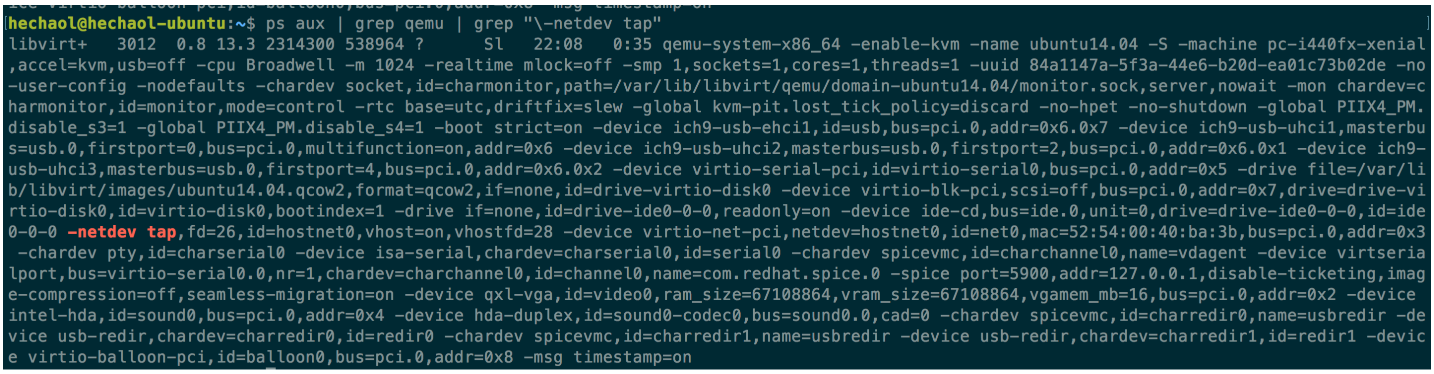
Notice that the interface `br0` and `ens33` have the same MAC address. Because currently `ens33` represents not only the pNIC but also the uplink port of the bridge. This implies the green dot line in above graph.

Step 2 - Connect VMs

Second, start a VM and set it to connect to the bridge `br0`. I am using [Virtual Machine Manager](), which is a GUI application for libvirt. The setting is as follows:



Or if you prefer to start a VM with command line, then just add the parameter `-netdev tap`. This will connect the vNIC to the tap interface on the bridge. For example, the command libvirt uses to start the VM is as follows:



After starting the VM, the bridge should now have two interfaces:

```
$ brctl show
bridge      name bridge id       STP enabled interfaces
br0         8000.000c299e441b    no          ens33
                                             vnet0
```

The interface `vnet0` is a tap interface created by libvirt.

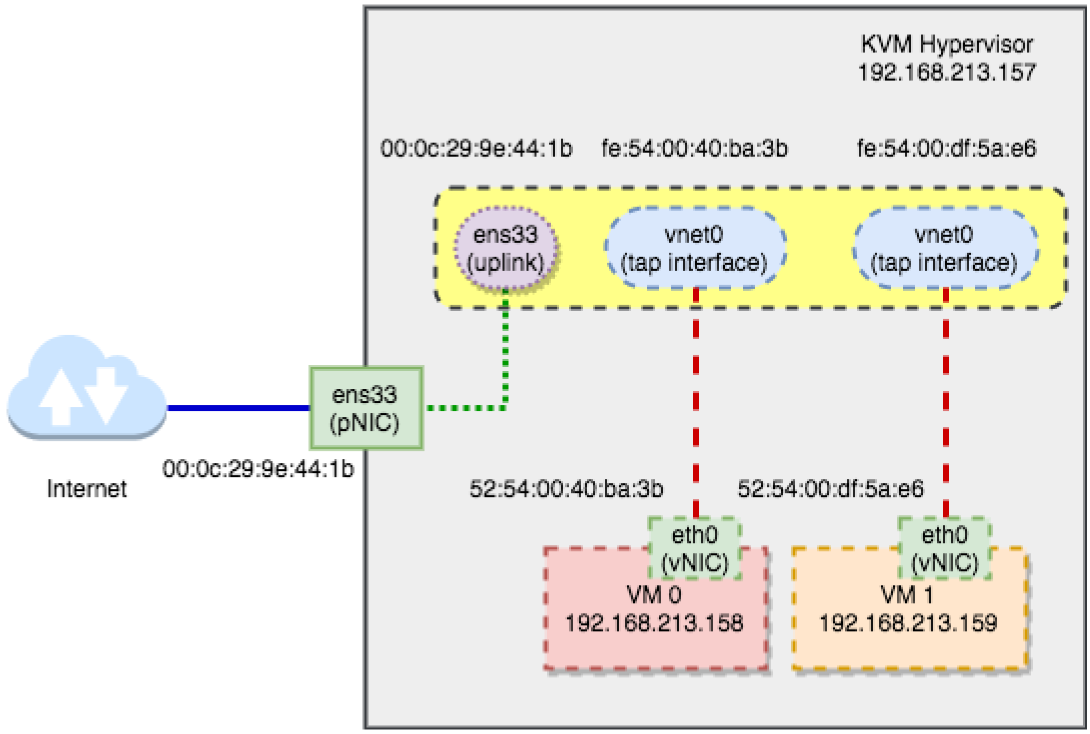
```
$ ifconfig vnet0
vnet0     Link encap:Ethernet  HWaddr fe:54:00:40:ba:3b
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:600 errors:0 dropped:0 overruns:0 frame:0
          TX packets:991 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:43098 (43.0 KB)  TX bytes:1436545 (1.4 MB)
```

Now the VM should be able to connect to the Internet through this bridged network. On the VM, run:

```
$ ifconfig eth0
eth0      Link encap:Ethernet  HWaddr 52:54:00:40:ba:3b
          inet addr:192.168.213.158  Bcast:192.168.213.255  Mask:255.255.255.0
          inet6 addr: fe80::5054:ff:fe40:ba3b/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:982 errors:0 dropped:0 overruns:0 frame:0
          TX packets:591 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1435849 (1.4 MB)  TX bytes:41244 (41.2 KB)
```

The VM gets an IP address in the same subnet of the physical host. Notice that the vNIC's MAC address `52:54:00:40:ba:3b` looks similar to the tap interface's MAC address `fe:54:00:40:ba:3b` - only the first byte is different. I guess this is how KVM represents the connection between vNIC and the tap interface.

I will add another VM before next step. After that, libvirt should create one more tap interface `vnet1`. Now our topology looks like:



Current bridge interfaces:

```
$ brctl show br0
bridge name bridge id           STP enabled interfaces
br0         8000.000c299e441b   no          ens33
                                            vnet0
                                            vnet1
```

Step 3 - Capture Packets

In this step we will use Wireshark to capture packets on each interface. Before that, let's look at the bridge's initial MAC table:

Initial MAC Table

```
$ brctl showmacs br0
port no mac addr              is local?   ageing timer
  1     00:0c:29:9e:44:1b     yes           0.00
  1     00:0c:29:9e:44:1b     yes           0.00
  2     fe:54:00:40:ba:3b     yes           0.00
  2     fe:54:00:40:ba:3b     yes           0.00
  3     fe:54:00:df:5a:e6     yes           0.00
  3     fe:54:00:df:5a:e6     yes           0.00
```

Note: I have no idea why the MAC table shows duplicate entries for each local port. Here somebody said it might be a bug. This person asked same question but was not answered. Please do let me know if you have the answer!

Suppose no duplication exists, then this table shows the initial state of the MAC table before any traffic goes through the bridge. The bridge only has local MAC addresses of its ports. From `ifconfig` results in step 2, we know that port 1 is `br0(ens33)`, port 2 is `vnet0` and port 3 is `vnet1`.

Ping from VM0 to VM1

Next we start Wireshark on the hypervisor and capture packets on `br0`, `ens33`, `vnet0` and `vnet1`. Then let VM0 (192.168.213.158) ping VM1 (192.168.213.159).

```
$ ping -c 1 192.168.213.159
PING 192.168.213.159 (192.168.213.159) 56(84) bytes of data.
64 bytes from 192.168.213.159: icmp_seq=1 ttl=64 time=0.662 ms

--- 192.168.213.159 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.662/0.662/0.662/0.000 ms
```

The result in Wireshark:

No.	Time	Source	Destination	Protocol	Length	Info
→ 1201	287.2966824…	192.168.213.158	192.168.213.159	ICMP	98	Echo (ping) request id=0x053a, seq=1/256, ttl=64 (reply in 1202)
← 1202	287.2970514…	192.168.213.159	192.168.213.158	ICMP	98	Echo (ping) reply id=0x053a, seq=1/256, ttl=64 (request in 1201)
1206	287.2966891…	192.168.213.158	192.168.213.159	ICMP	98	Echo (ping) request id=0x053a, seq=1/256, ttl=64 (no response found!)
1214	287.2966729…	192.168.213.158	192.168.213.159	ICMP	98	Echo (ping) request id=0x053a, seq=1/256, ttl=64 (reply in 1215)
1215	287.2970615…	192.168.213.159	192.168.213.158	ICMP	98	Echo (ping) reply id=0x053a, seq=1/256, ttl=64 (request in 1214)
1223	287.2966729…	192.168.213.158	192.168.213.159	ICMP	98	Echo (ping) request id=0x053a, seq=1/256, ttl=64 (reply in 1224)
1224	287.2970514…	192.168.213.159	192.168.213.158	ICMP	98	Echo (ping) reply id=0x053a, seq=1/256, ttl=64 (request in 1223)

We only sent one ICMP request, why there are so many of them? Let's analyze them packet by packet. We can add one column that shows the interface on which the packet is captured and order the result by time:

No.	Time	interface	Source MAC	Destination MAC	Protocol	Info
→ 1214	287.2966729…	vnet0	52:54:00:40:ba:3b	52:54:00:df:5a:e6	ICMP	Echo (ping) request id=0x053a, seq=1/256, ttl=64 (reply in 1215)
1223	287.2966729…	br0	52:54:00:40:ba:3b	52:54:00:df:5a:e6	ICMP	Echo (ping) request id=0x053a, seq=1/256, ttl=64 (reply in 1224)
1201	287.2966824…	vnet1	52:54:00:40:ba:3b	52:54:00:df:5a:e6	ICMP	Echo (ping) request id=0x053a, seq=1/256, ttl=64 (reply in 1202)
1206	287.2966891…	ens33	52:54:00:40:ba:3b	52:54:00:df:5a:e6	ICMP	Echo (ping) request id=0x053a, seq=1/256, ttl=64 (no response found!)
1202	287.2970514…	vnet1	52:54:00:df:5a:e6	52:54:00:40:ba:3b	ICMP	Echo (ping) reply id=0x053a, seq=1/256, ttl=64 (request in 1201)
1224	287.2970514…	br0	52:54:00:df:5a:e6	52:54:00:40:ba:3b	ICMP	Echo (ping) reply id=0x053a, seq=1/256, ttl=64 (request in 1223)
← 1215	287.2970615…	vnet0	52:54:00:df:5a:e6	52:54:00:40:ba:3b	ICMP	Echo (ping) reply id=0x053a, seq=1/256, ttl=64 (request in 1214)

1. The first packet goes from `vNIC0` to bridge tap interface `vnet0`.
2. The bridge interface `br0` receives the packet and adds an entry to the MAC table with port 1, MAC address `52:54:00:40:ba:3b` and "is local" no. This is called source MAC learning. (We can

see this packet only because the Linux bridge exists as an interface `br0`. For a physical bridge, there is no such packet that can be captured). Since the bridge currently does not have the port mapping of the destination MAC address, it has no idea where to forward the packet. Thus it forwards it to every port except for the source port `vnet0`.

3. Port `vnet1` receives the packet and will forward it to `vNIC1`.
4. Port `ens33` receives the packet and will ignore it because the destination MAC address doesn't match its own MAC. In Wireshark it also shows "no response found!". If there are more VMs in this network, we should be able to see more requests with no response.
5. `vNIC1` receives the packet and replies to `vnet1`, which will forward it to the bridge interface `br0`.
6. The bridge interface `br0` receives the reply packet. This time it knows the destination MAC is mapped to `vnet0` so it will just forward the packet there.
7. Port `vnet0` receives the reply and will forward it to `vNIC0`.

Now let's see the MAC table (Duplication removed):

```
$ brctl showmacs br0
port no mac addr          is local?   ageing timer
  1 00:0c:29:9e:44:1b    yes          0.00
  2 52:54:00:40:ba:3b    no         183.20
  3 52:54:00:df:5a:e6    no         183.20
  2 fe:54:00:40:ba:3b    yes          0.00
  3 fe:54:00:df:5a:e6    yes          0.00
```

We can see that two MAC entires are added and both of them are remote MACs. Port 2 (`vnet0`) is associated with `52:54:00:40:ba:3b` (VM0) and Port 3 (`vnet1`) is associated with `52:54:00:df:5a:e6` (VM1). That means any packet sent to VM0 will be forwarded to port 2 and any packet sent to VM1 will be forwarded to port

1. If we ping again, we should only see 6 packets instead of 7 - the packet sent to `ens33` should not appear any more. Shown as follows:

No.	Time	interface	Source MAC	Destination MAC	Protocol	Info
→ 11	0.713179149	vnet0	52:54:00:40:ba:3b	52:54:00:df:5a:e6	ICMP	Echo (ping) request id=0x0619, seq=1/256, ttl=64 (reply in 12)
25	0.713179149	br0	52:54:00:40:ba:3b	52:54:00:df:5a:e6	ICMP	Echo (ping) request id=0x0619, seq=1/256, ttl=64 (reply in 26)
17	0.713189961	vnet1	52:54:00:40:ba:3b	52:54:00:df:5a:e6	ICMP	Echo (ping) request id=0x0619, seq=1/256, ttl=64 (reply in 18)
18	0.713302230	vnet1	52:54:00:df:5a:e6	52:54:00:40:ba:3b	ICMP	Echo (ping) reply id=0x0619, seq=1/256, ttl=64 (request in 17)
26	0.713302230	br0	52:54:00:df:5a:e6	52:54:00:40:ba:3b	ICMP	Echo (ping) reply id=0x0619, seq=1/256, ttl=64 (request in 25)
← 12	0.713305118	vnet0	52:54:00:df:5a:e6	52:54:00:40:ba:3b	ICMP	Echo (ping) reply id=0x0619, seq=1/256, ttl=64 (request in 11)

Ping from a VM to the Internet

This time we ping from a VM to the Internet and again use Wireshark to capture the packets.

```
$ ping -c 1 hechao.li
PING hechao.li (192.30.252.153) 56(84) bytes of data.
64 bytes from lb-192-30-252-153-iad.github.com (192.30.252.153): icmp_seq=1
ttl=128 time=444 ms

--- hechao.li ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 444.605/444.605/444.605/0.000 ms
```

No.	Time	interface	Source MAC	Destination MAC	Source IP	Destination IP	Protocol	Info
327	377.547502540	vnet0	52:54:00:40:ba:3b	00:50:56:ea:2b:10	192.168.213.158	192.30.252.153	ICMP	Echo (ping) request id=0x065b, seq=1/256, ttl=64 (no response found!)
→ 335	377.547502540	br0	52:54:00:40:ba:3b	00:50:56:ea:2b:10	192.168.213.158	192.30.252.153	ICMP	Echo (ping) request id=0x065b, seq=1/256, ttl=64 (reply in 336)
319	377.547504689	ens33	52:54:00:40:ba:3b	00:50:56:ea:2b:10	192.168.213.158	192.30.252.153	ICMP	Echo (ping) request id=0x065b, seq=1/256, ttl=64 (no response found!)
← 336	377.991898519	br0	00:50:56:ea:2b:10	52:54:00:40:ba:3b	192.30.252.153	192.168.213.158	ICMP	Echo (ping) reply id=0x065b, seq=1/256, ttl=128 (request in 335)
340	377.991898519	ens33	00:50:56:ea:2b:10	52:54:00:40:ba:3b	192.30.252.153	192.168.213.158	ICMP	Echo (ping) reply id=0x065b, seq=1/256, ttl=128
338	377.991914520	vnet0	00:50:56:ea:2b:10	52:54:00:40:ba:3b	192.30.252.153	192.168.213.158	ICMP	Echo (ping) reply id=0x065b, seq=1/256, ttl=128

I will leave the analysis to the reader.

Note:

1. ARP and DNS packets are filtered out.
2. Notice that packet 336 and packet 340 are received at the same time so don't be confused by the order shown in Wireshark.
3. Ignore the "no response found!" info. It is a known bug of Wireshark.

Conclusion

In this post, we discussed what is a Linux Bridge and compared it with a physical bridge. We also did an experiment in which Wireshark is used to capture packets in a KVM bridged network. Analysis of the captured packets matches the theory and helps us understand how exactly the bridge works.

Reference

[1] Understanding Linux Network Internals by Christian Benvenuti

[2] Linux Bridge and Virtual Networking

[3] Linux BRIDGE-STP-HOWTO

[4] Tap Interfaces and Linux Bridge

[5] Configuring Guest Networking