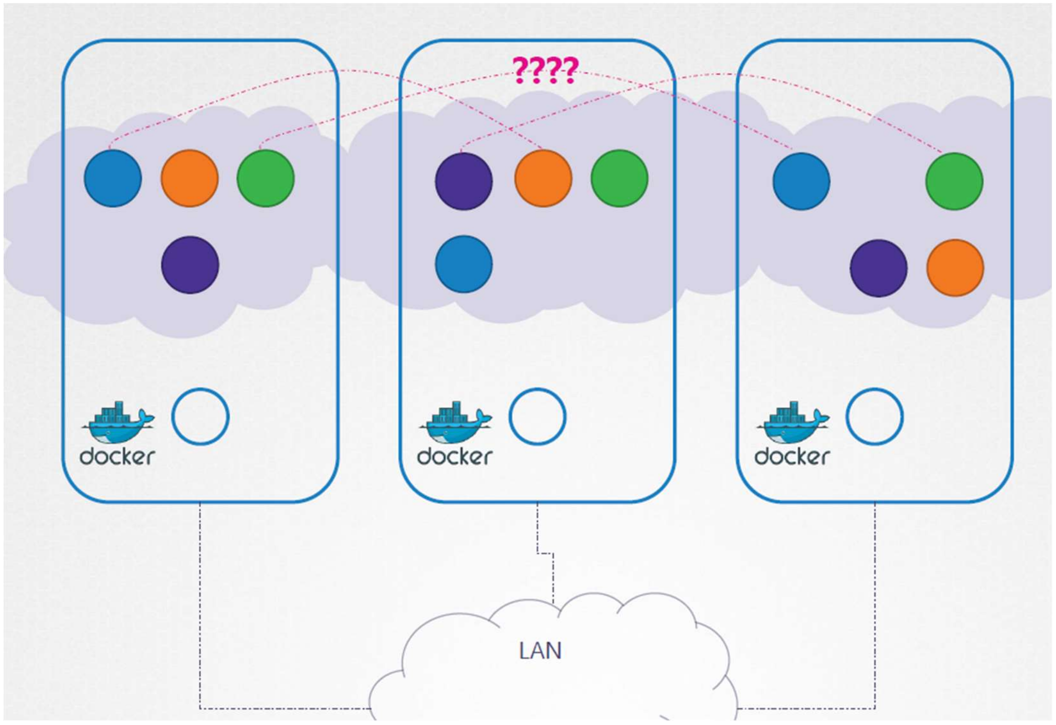
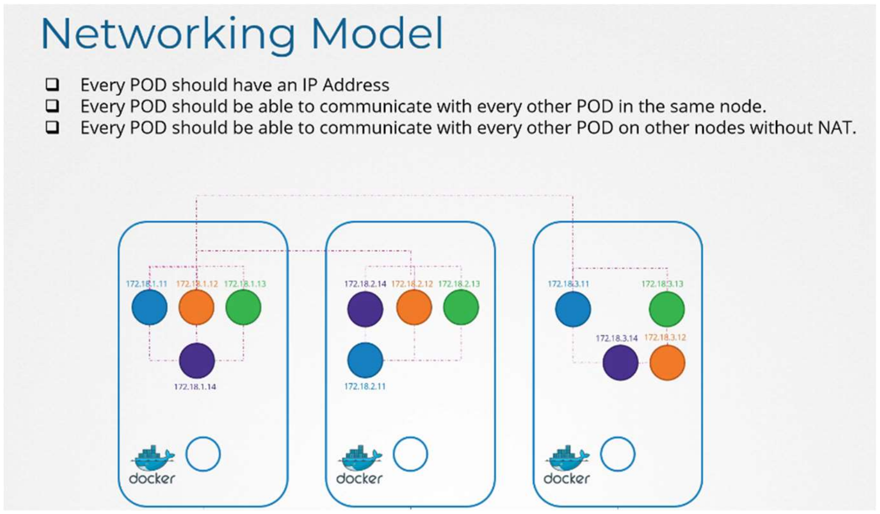
In this lecture we discuss about Pod networking in Kubernetes. So far, we have set up several Kubernetes master and worker nodes, and configured networking between them so they're all on a network that can reach each other. We also made sure the firewall and network security groups are configured correctly, to allow for the Kubernetes control plane components to reach each other. Assume that we have also set up all the Kubernetes control plane components, such as the kube-apiserver, the etcd servers, kubelets, et cetera, and we are finally ready to deploy our applications.

But before we can do that, there's something that we must address. We talked about the network that connects the nodes together, but there's also another layer of networking that is crucial to the clusters functioning, and that is the networking at the Pod layer.

Our Kubernetes cluster is soon going to have a large number of Pods and services running on it. How are the Pods addressed? How do they communicate with each other? How do you access the services running on these Pods internally from within the cluster, as well as externally from outside the cluster? These are challenges that Kubernetes expects you to solve. As of today, Kubernetes does not come with a built-in solution for this. It expects you to implement a networking solution that solves these challenges.



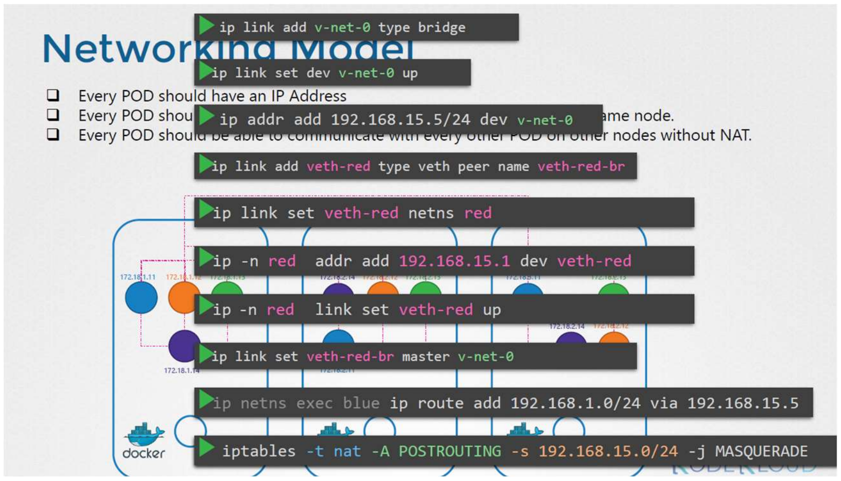
However, Kubernetes have laid out clearly the requirements for Pod networking. Let's take a look at what they are. Kubernetes expects every Pod to get its own unique IP address, and that every Pod should be able to reach every other Pod within the same node using that IP address. And every Pod should be able to reach every other Pod on other nodes as well, using the same IP address. It doesn't care what IP address that is and what range or subnet it belongs to. As long as you can implement a solution that takes care of automatically assigning IP addresses and establish connectivity between the Pods in a node as well as parts on different nodes, you're good, without having to configure any net rules.


Networking Model

- ❑ Every POD should have an IP Address
- ❑ Every POD should be able to communicate with every other POD in the same node.
- ❑ Every POD should be able to communicate with every other POD on other nodes without NAT.

So how do you implement a model that solves these requirements? Now, there are many networking solutions available out there that does these, but we've already learned about networking concepts, routing, IP address management, namespaces, and CNI. So let's try to use that knowledge to solve this problem by ourselves first. This will help in understanding how other solutions work.

I know there is a bit of repetition, but I'm trying to relate the same concept and approach all the way from plain network namespaces on Linux, all the way to Kubernetes.

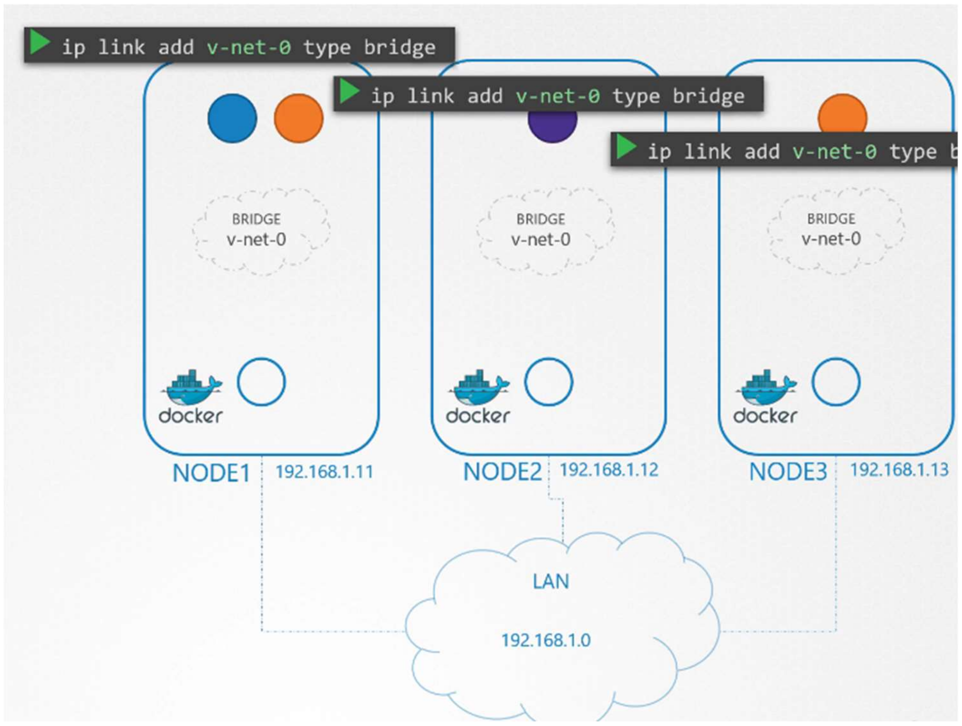

Networking Model

- ❑ Every POD should have an IP Address
- ❑ Every POD shou … ame node.
- ❑ Every POD should … r nodes without NAT.

```
ip link add v-net-0 type bridge
ip link set dev v-net-0 up
ip addr add 192.168.15.5/24 dev v-net-0
ip link add veth-red type veth peer name veth-red-br
ip link set veth-red netns red
ip -n red  addr add 192.168.15.1 dev veth-red
ip -n red  link set veth-red up
ip link set veth-red-br master v-net-0
ip netns exec blue ip route add 192.168.1.0/24 via 192.168.15.5
iptables -t nat -A POSTROUTING -s 192.168.15.0/24 -j MASQUERADE
```

So we have a three node cluster. It doesn't matter which one is master or worker. They all run Pods, either for management or workload purposes. As far as networking is concerned, we're going to consider all of them as the same. So first, let's plan what we are going to do. The nodes are part of an external network, and has IP addresses in the 192.168.1. series. Node one is assigned 11, node two is 12, and node three is 13.

Next step, when containers are created, Kubernetes creates network namespaces for them. To enable communication between them, we attach these namespaces to a network. But what network? We've learned about bridge networks that can be created within nodes to attach namespaces. So we create a bridge network on each node and then bring them up.

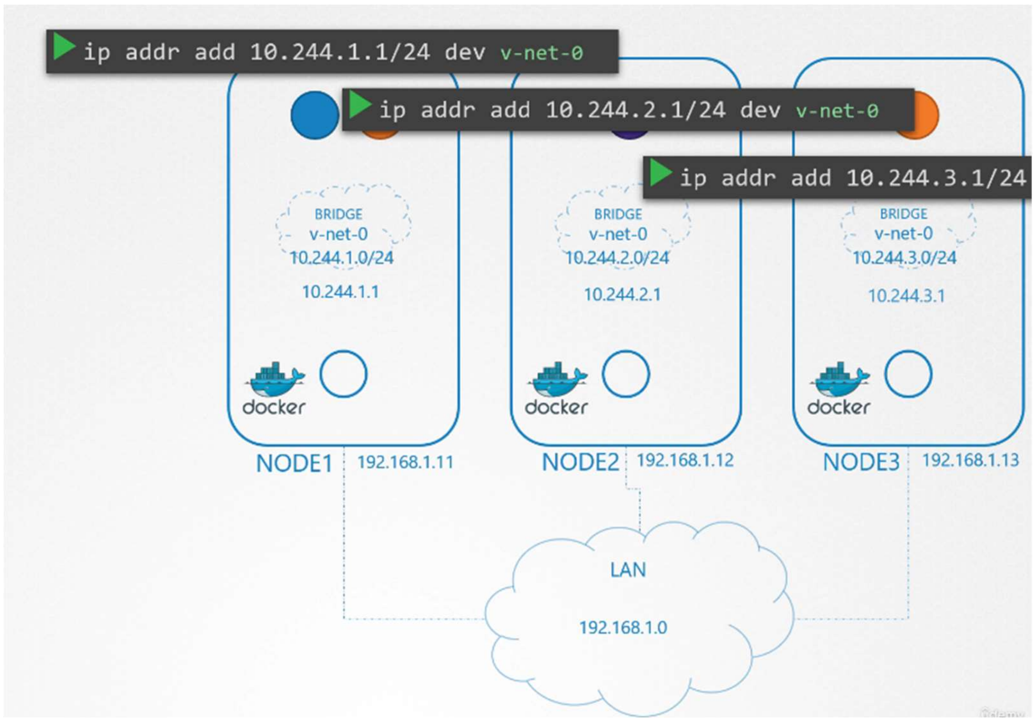


```
ip link add v-net-0 type bridge
```

```
ip link add v-net-0 type bridge
```

```
ip link add v-net-0 type b
```

It's time to assign an IP address to the bridge interfaces, or networks. But what IP address? We decide that each bridge network will be on its own subnet. Choose any private address range, say, 10.244.1, 10.244.2, and 10.244.3. Next, we set the IP address for the bridge interface.



```
ip addr add 10.244.1.1/24 dev v-net-0
```

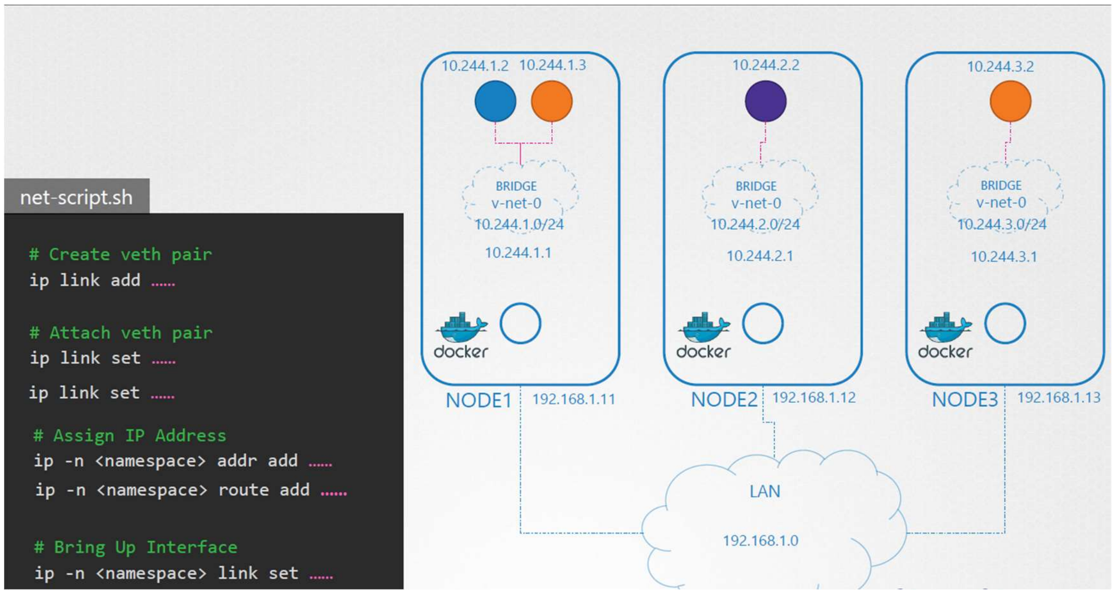
```
ip addr add 10.244.2.1/24 dev v-net-0
```

```
ip addr add 10.244.3.1/24
```

So we have built our base. The remaining steps are to be performed for each container, and every time a new container is created. So we write a script for it.

Now, you don't have to know any kind of complicated scripting. It's just a file that has all commands we will be using, and we can run this multiple times for each container going forward. To attach a container to the network we need a pipe, or virtual network cable. We create that using the ip link add command. Don't focus on the options, as they are similar to what we saw in our previous lectures. Assume that they vary depending on the inputs. We then attach one end to the container, and another end to the bridge using the ip link set command. We then assign IP address using the ip addr command and add a route to the default gateway. But what IP do we add? We either manage that ourselves or store that information in some kind of database. For now, we will assume it is 10.244.1.2, which is a free IP in the subnet. We discuss about IP address management in detail in one of the upcoming lectures. Finally, we bring up the interface. We then run the same script, this time for the second container with its information, and gets the container connected to the network. The two containers can now communicate with each other.

We copy the script to the other nodes and run the script on them to assign IP address and connect those containers to their own internal networks.


net-script.sh

```
# Create veth pair
ip link add ……

# Attach veth pair
ip link set ……
ip link set ……

# Assign IP Address
ip -n <namespace> addr add ……
ip -n <namespace> route add ……

# Bring Up Interface
ip -n <namespace> link set ……
```

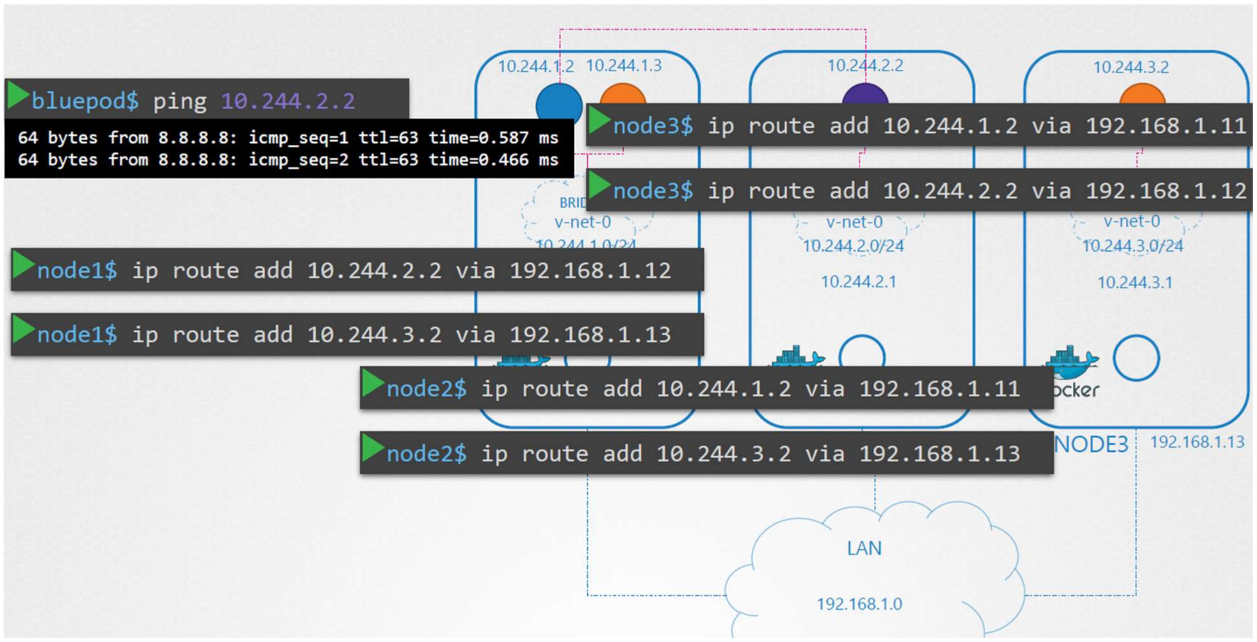
So we have solved the first part of the challenge. The Pods all get their own unique IP address, and are able to communicate with each other on their own nodes.

The next part is to enable them to reach other Pods on other nodes. Say for example, the Pod at 10.244.1.2, on node one, wants to ping Pod 10.244.2.2, on node two.

As of now, the first has no idea where the address 10.244.2.2 is, because it is on a different network than it's own. So it routes to node one's IP, as it is set to be the default gateway. Node one doesn't know either, since 10.244.2.2 is a private network on node two.

Add a route to node one's routing table to route traffic to 10.244.2.2, where the second node's IP at 192.168.1.12. Once the route is added, the blue Pod is able to ping across.

Similarly, we configure route on all hosts to all the other hosts with information regarding the respective networks within them.



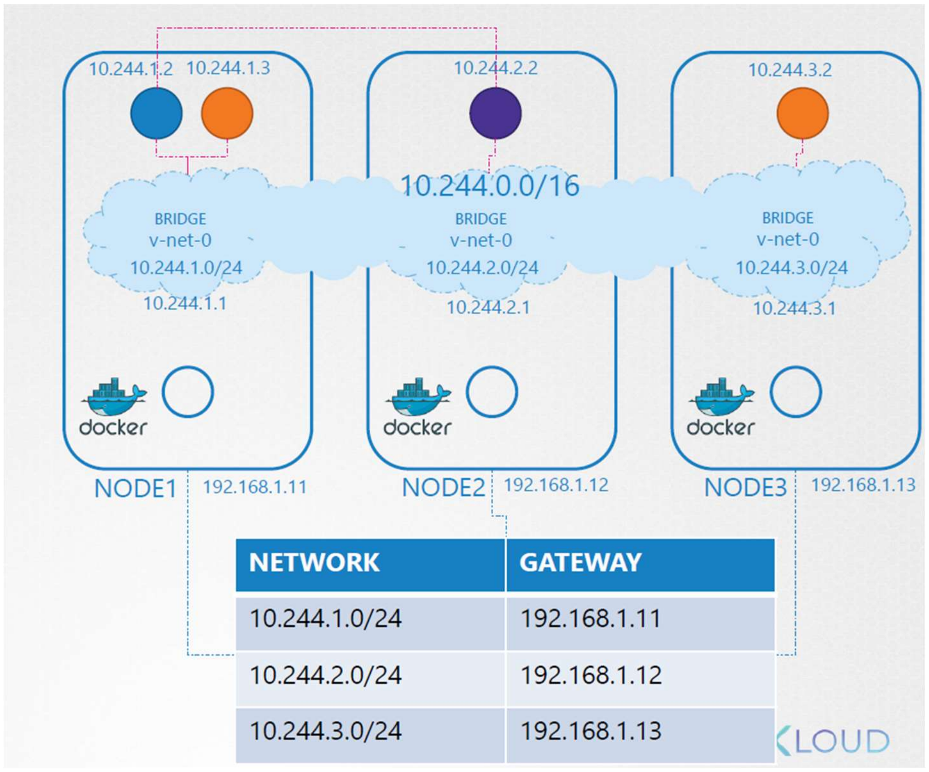
```
bluepod$ ping 10.244.2.2
64 bytes from 8.8.8.8: icmp_seq=1 ttl=63 time=0.587 ms
64 bytes from 8.8.8.8: icmp_seq=2 ttl=63 time=0.466 ms
```

```
node1$ ip route add 10.244.2.2 via 192.168.1.12
node1$ ip route add 10.244.3.2 via 192.168.1.13
node2$ ip route add 10.244.1.2 via 192.168.1.11
node2$ ip route add 10.244.3.2 via 192.168.1.13
node3$ ip route add 10.244.1.2 via 192.168.1.11
node3$ ip route add 10.244.2.2 via 192.168.1.12
```

Now, this works fine in this simple setup, but this will require a lot more configuration as and when your underlying network architecture gets complicated. Instead of having to configure routes on each server a better solution is to do that on a router, if you have one in your network, and point all hosts to use that as the default gateway.

That way you can easily manage routes to all networks in the routing table on the router.

With that, the individual virtual networks we created with the address 10.244.1.0/24 on each node now form a single large network with the address 10.244.0.0/16.



NETWORK	GATEWAY
10.244.1.0/24	192.168.1.11
10.244.2.0/24	192.168.1.12
10.244.3.0/24	192.168.1.13

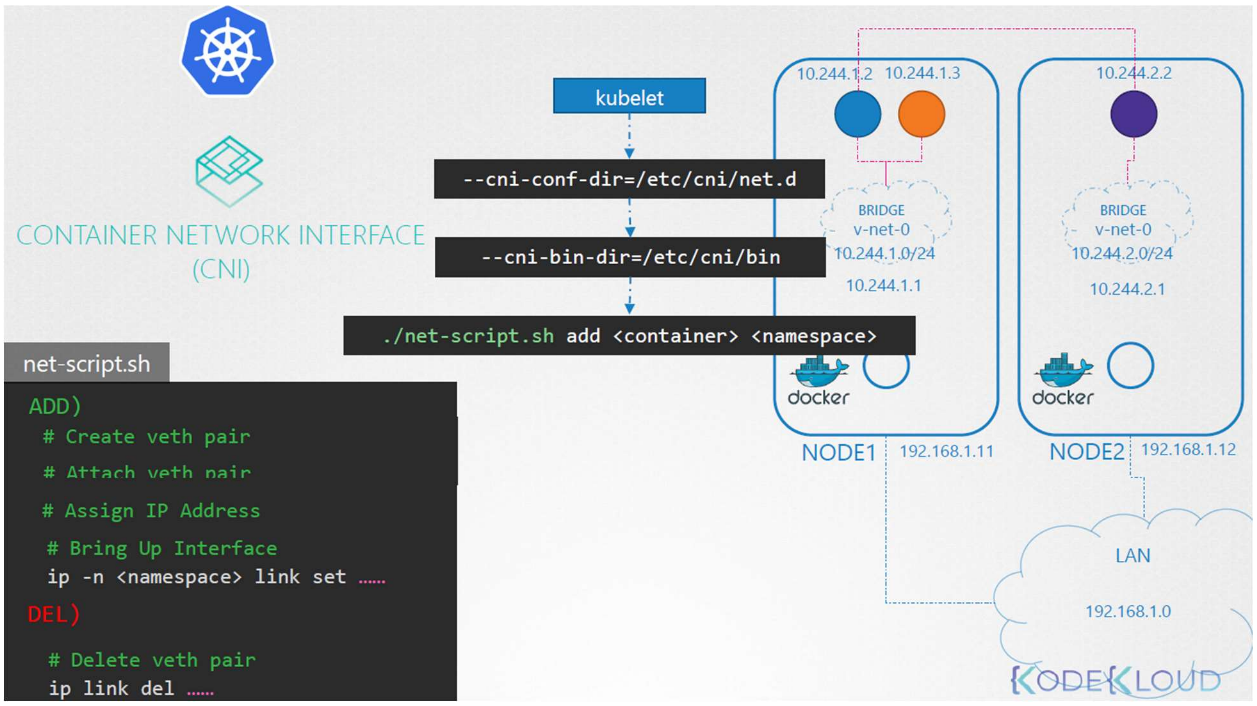
It's time to tie everything together. We performed a number of manual steps to get the environment ready with the bridge networks and routing tables. We then wrote a script that can be run for each container that performs the necessary steps required to connect each container to the network, and we executed the script manually.

Of course, we don't want to do that, as in large environments where thousands of Pods are created every minute.

So how do we run the script automatically when a Pod is created on Kubernetes? That's where CNI comes in, acting as the middleman. CNI tells Kubernetes that this is how you should call a script as soon as you create a container. And CNI tells us this is how your script should look like.

So we need to modify the script a little bit to meet CNI standards. It should have an add section that will take care of adding a container to the network, and a delete section that will take care of deleting container interfaces from the network, and freeing the IP address, et cetera.

The kubelet on each node is responsible for creating containers. Whenever a container is created, the kubelet looks at the CNI configuration, passed as a command line argument when it was run, and identifies our script's name. It then looks in the CNI's bin directory to find our script and then executes the script with the add command and the name and namespace ID of the container. And then our script takes care of the rest.



```
--cni-conf-dir=/etc/cni/net.d
```

```
--cni-bin-dir=/etc/cni/bin
```

```
./net-script.sh add <container> <namespace>
```

net-script.sh

```
ADD)
 # Create veth pair
 # Attach veth pair
 # Assign IP Address
 # Bring Up Interface
 ip -n <namespace> link set ......
DEL)
 # Delete veth pair
 ip link del ......
```