Network Service Mesh

A Narrative Introduction

Frederick Kautz and Kyle Mestery

Sarah

and...

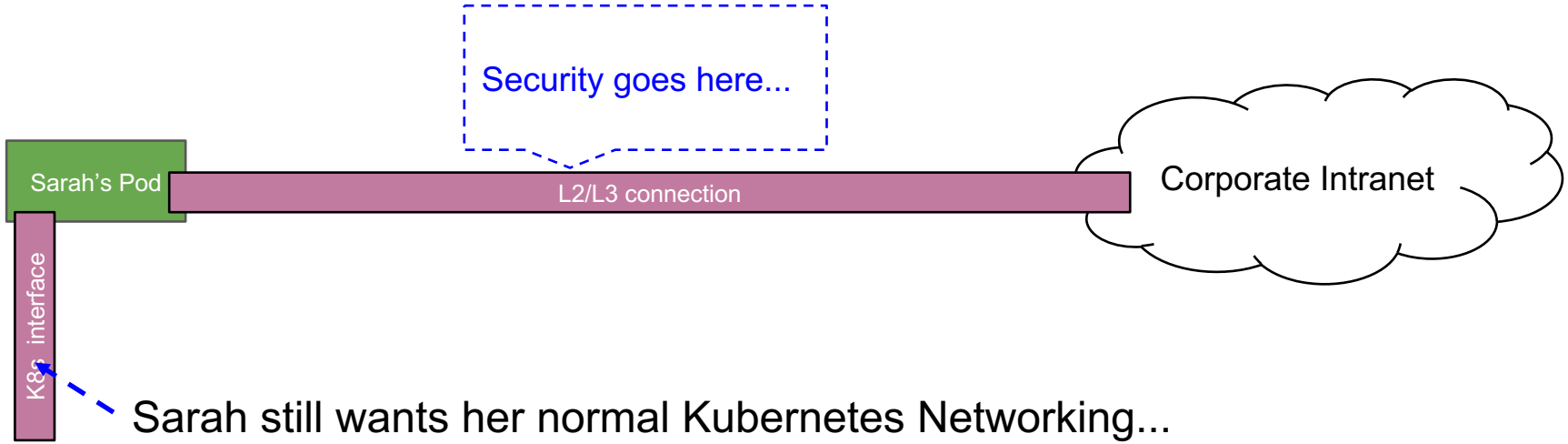
secure-intranet-connectivity

Meet Sarah

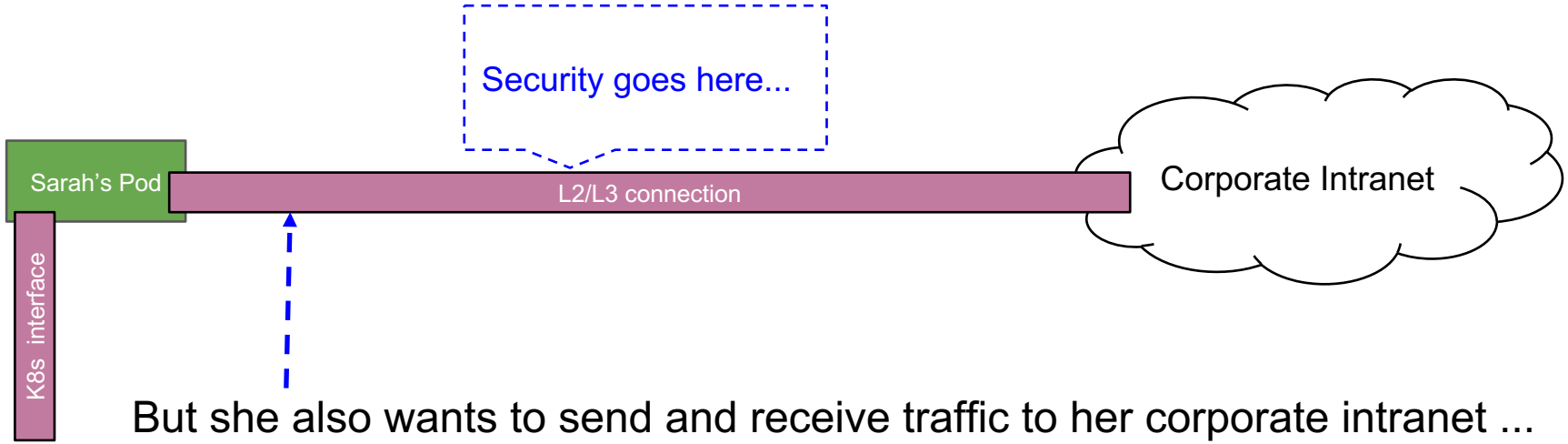
Sarah is writing a Kubernetes app to be deployed in the public cloud

One of the Pods in Sarah’s app needs **secure access to her corporate intranet**

From Sarah's point of view her needs look like this



Sarah still wants her normal Kubernetes Networking...

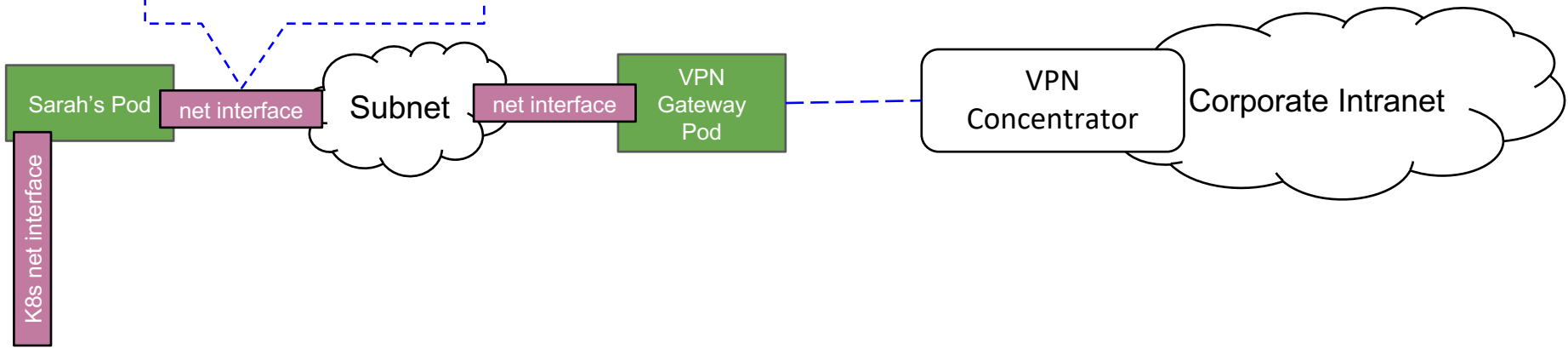


But she also wants to send and receive traffic to her corporate intranet ...

Sarah

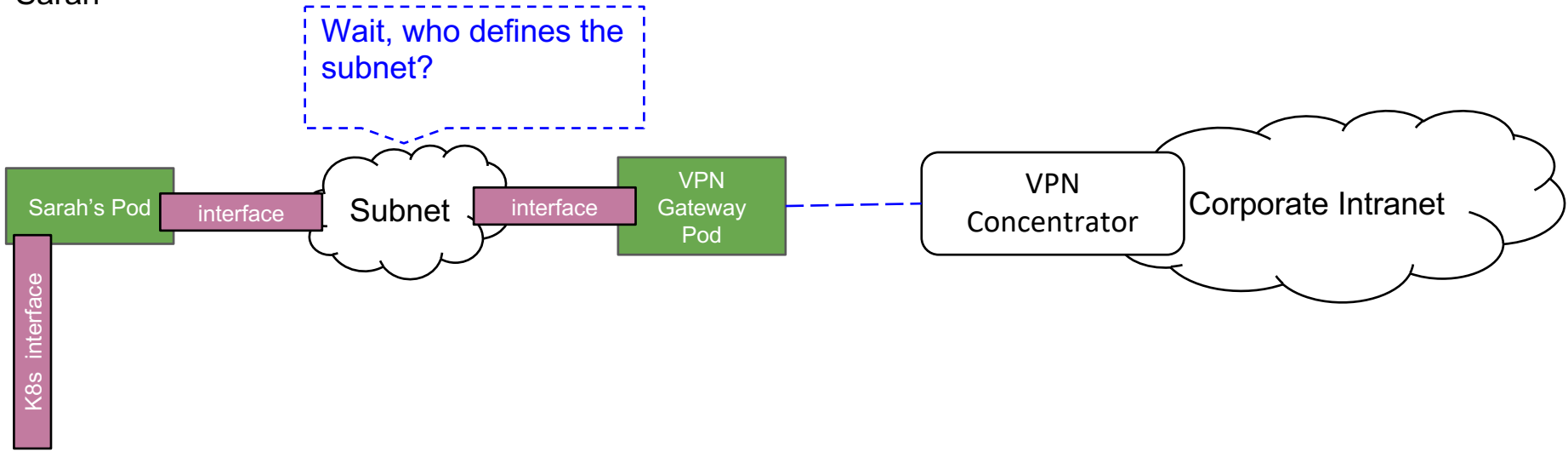
Sarah's definition of hell...

How do I find out what subnet this connects to?



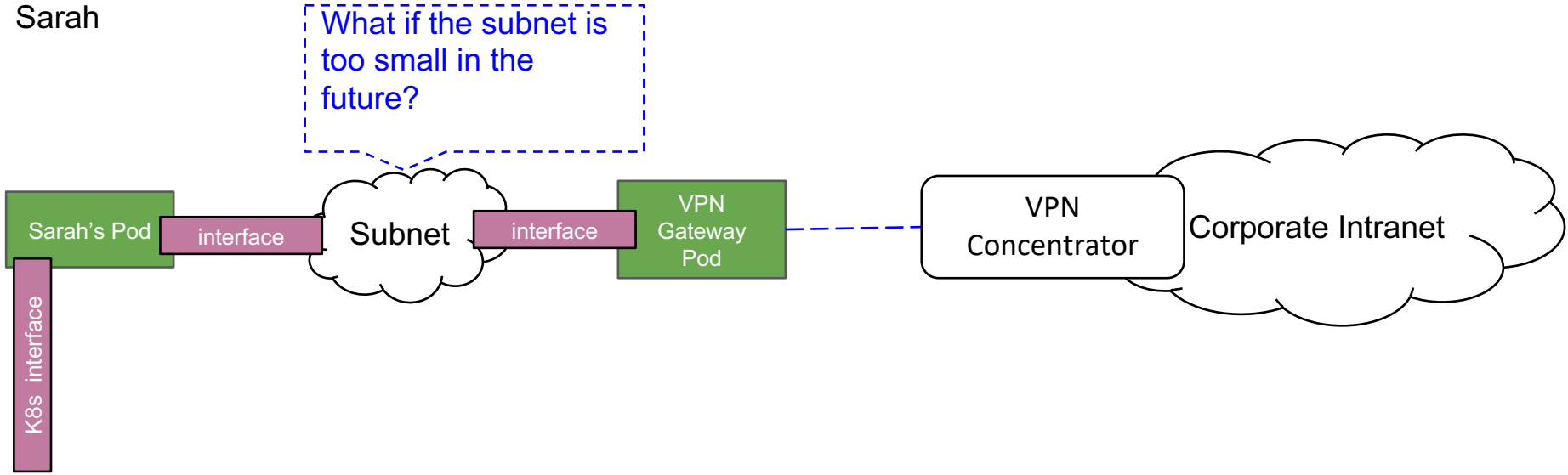
Sarah

Sarah's definition of hell...



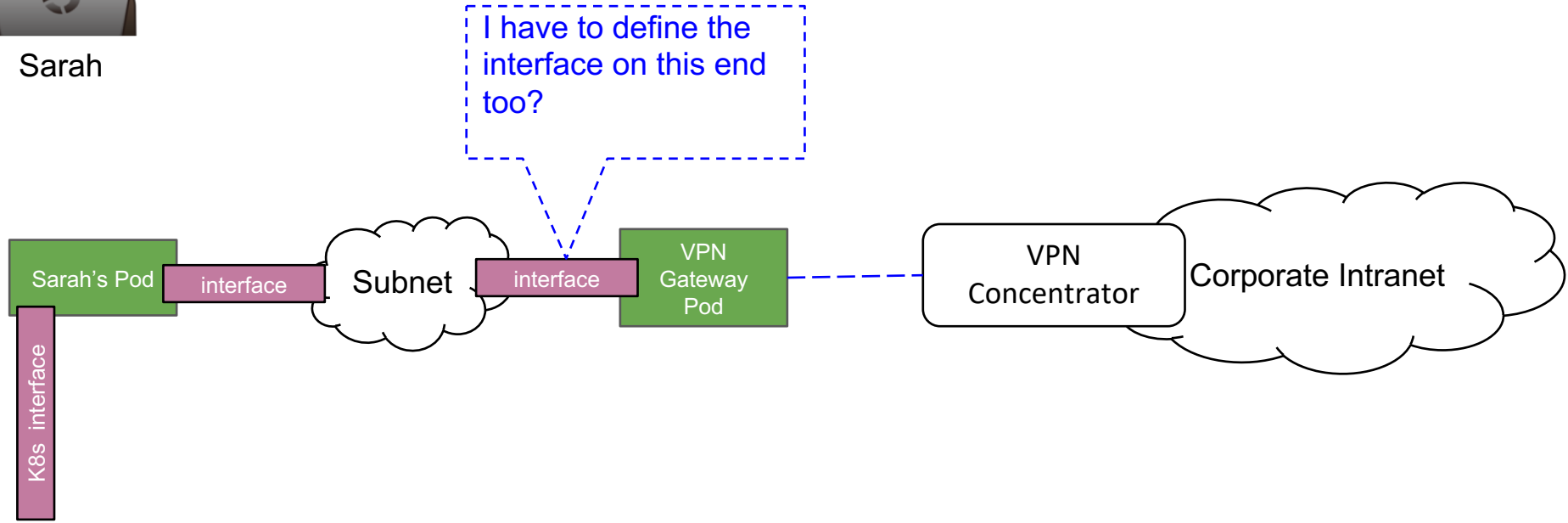
Sarah

Sarah's definition of hell...



Sarah

Sarah's definition of hell...



Sarah's definition of hell...

Sarah

And insert routes for all my corporate IPs into *my* Pod?

Sarah's Pod

interface

Subnet

interface

VPN Gateway Pod

VPN Concentrator

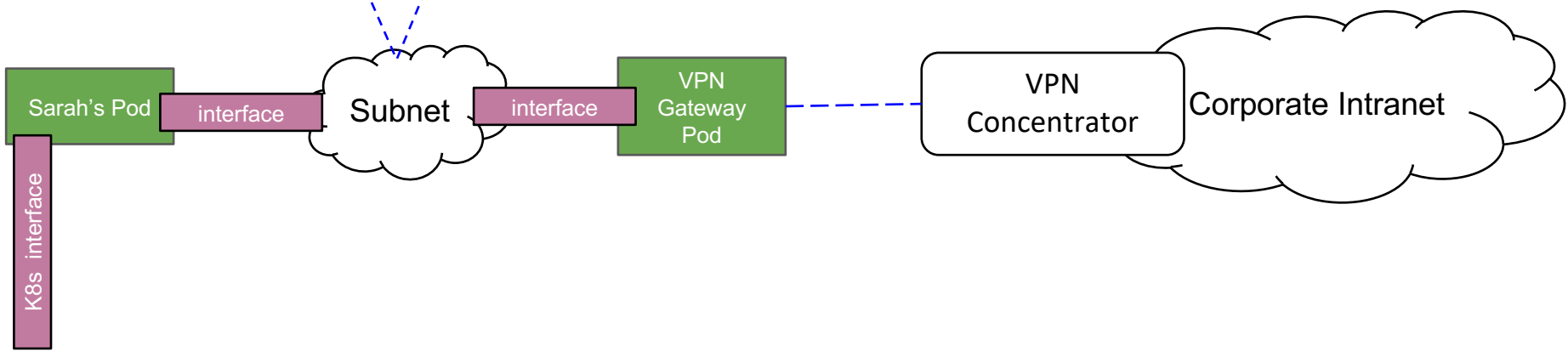
Corporate Intranet

K8s interface

Sarah

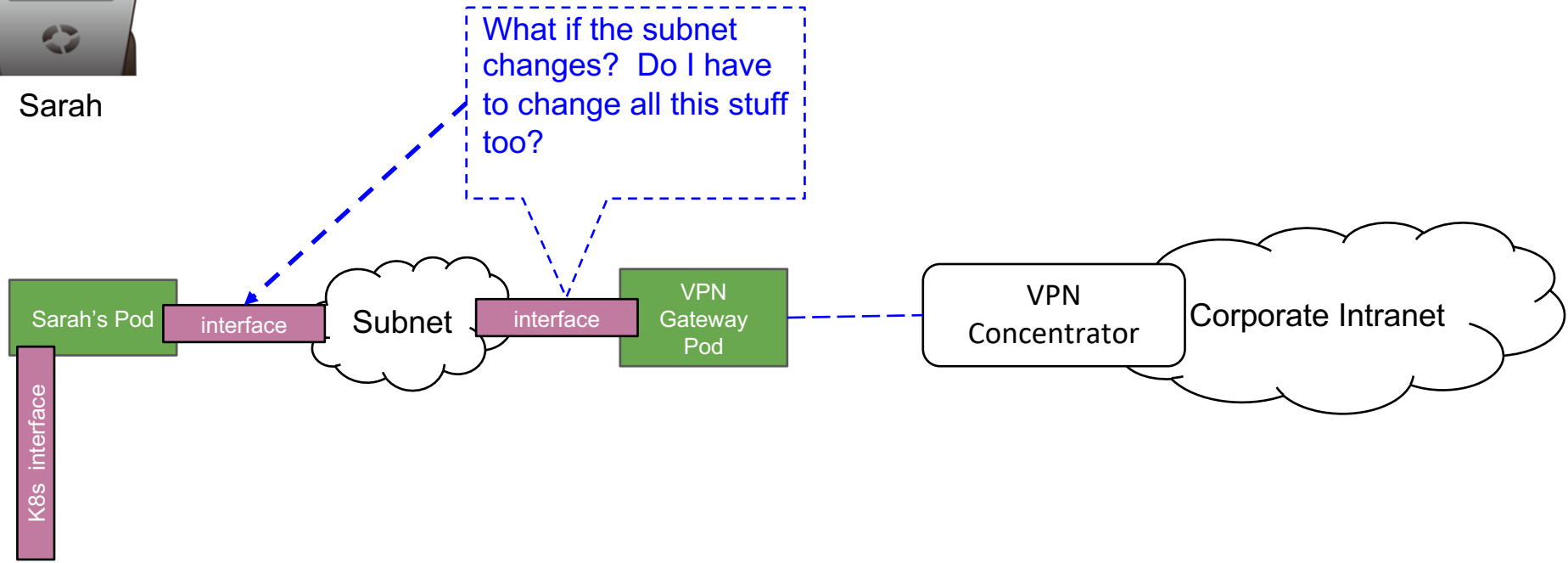
Sarah's definition of hell...

I need more replica's, the subnet is to small now. I have to do this all over again!



Sarah

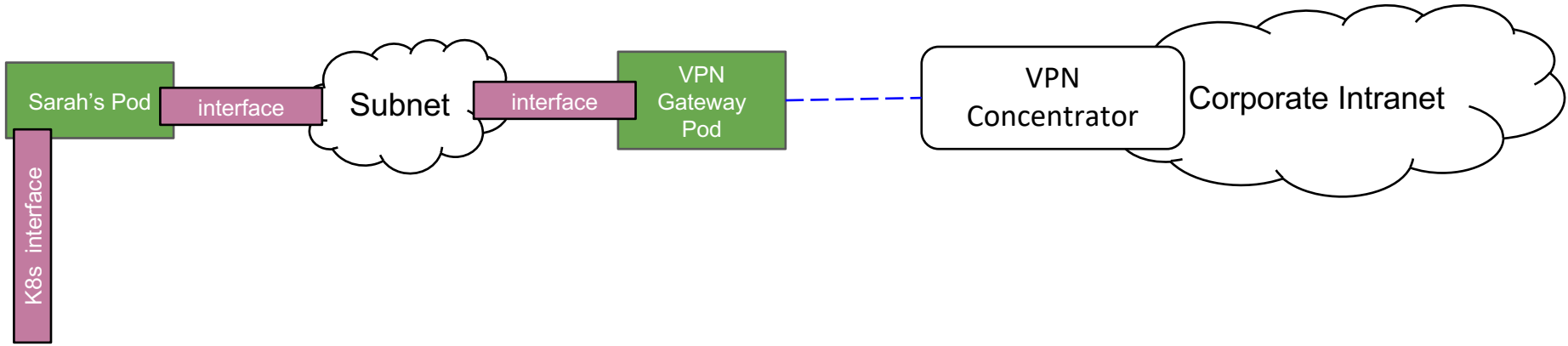
Sarah's definition of hell...



Sarah

Sarah's definition of hell...

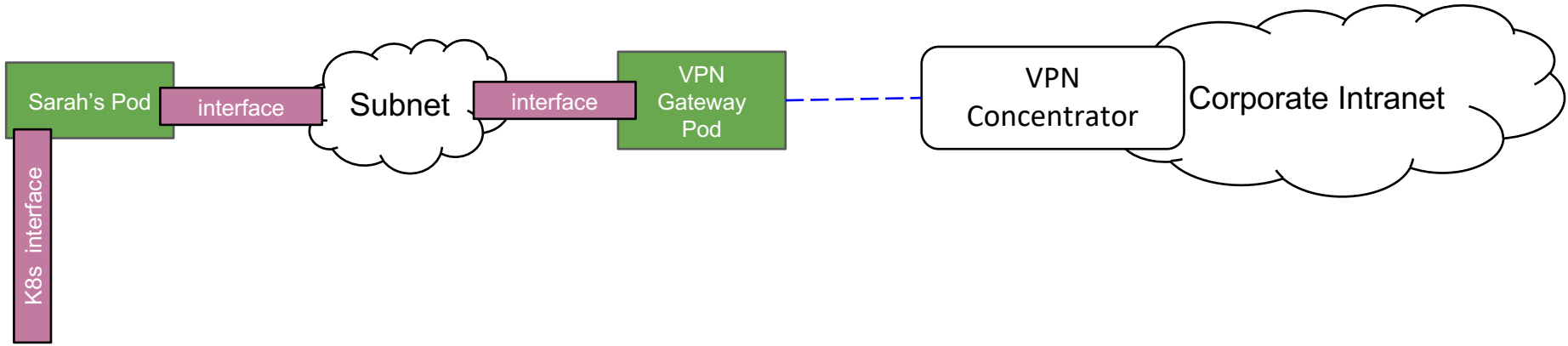
Arrrg… my Enterprise Network guys say I chose a subnet that is incompatible with the corporate intranet. I have to redo all of this again?



Sarah

Sarah's definition of hell...

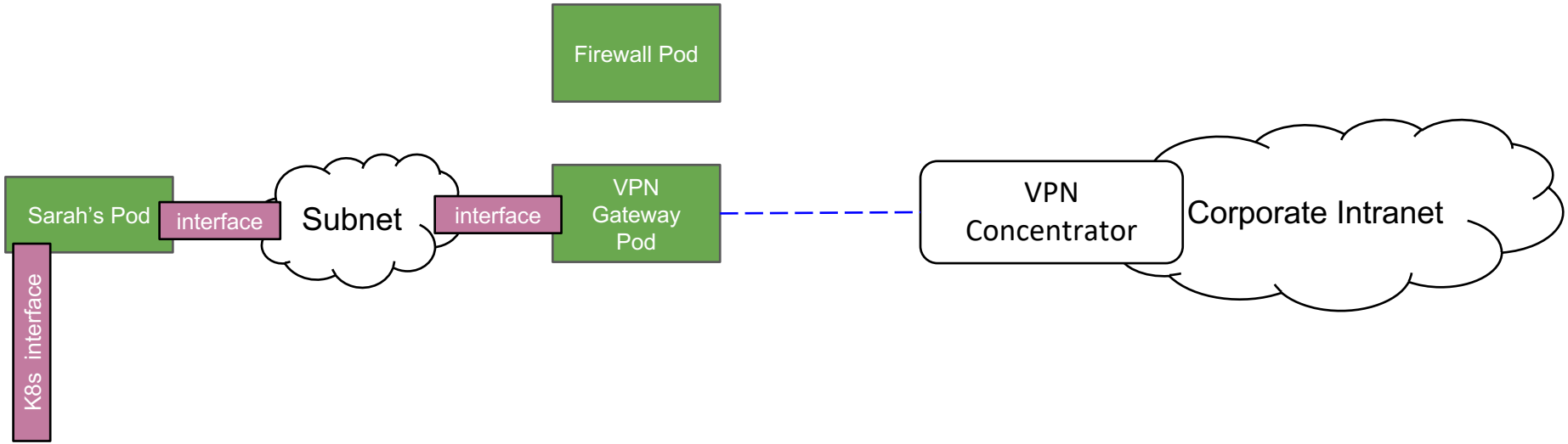
Wait… my network guys re-IPed *something* in the intranet and now my subnet is incompatible again… this is hell!



Sarah

Then Sarah's IT guys decide 'secure' also includes a Firewall Pod

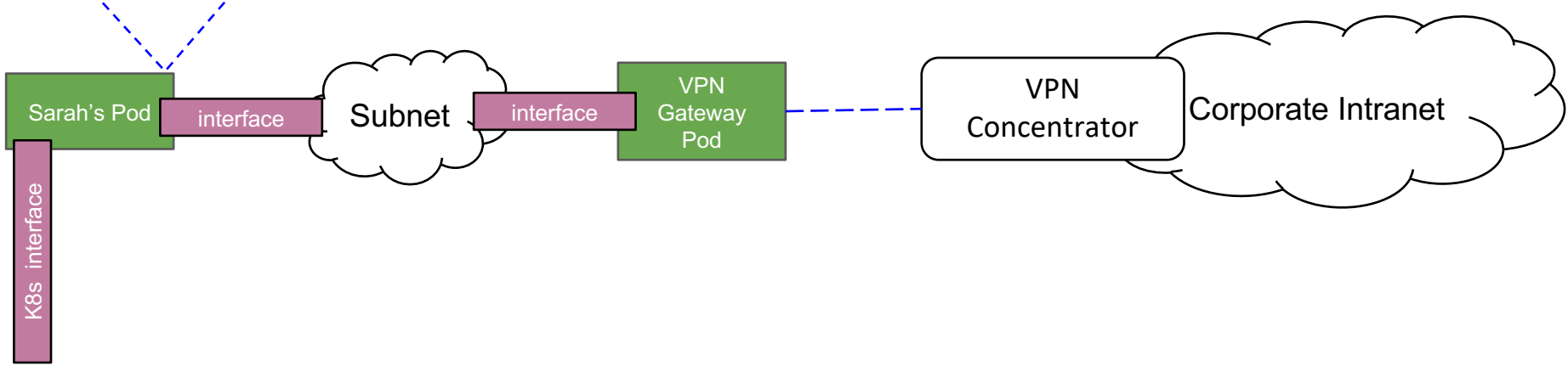
Do I need a new subnet for this? Why am I doing network design with 1990s concepts?



Sarah's definition of hell...

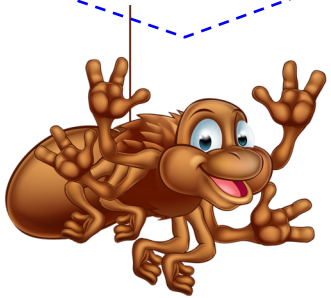
Sarah

Corporate added a new CIDR to the corporate network. Time to update the routes… why God! Why?



Sarah

Maybe I can help?



Who are you?

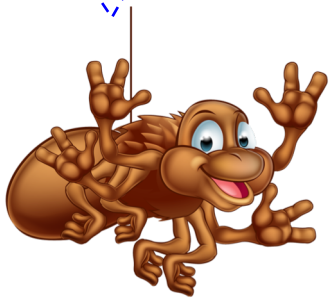
Sarah

I’m the Ariadne the NSM (Network Service Mesh) Spider

What is Network Service Mesh? Is that like Istio?

Sarah

Sort of. You know all the cool things Istio does for you with TCP connections and HTTP?



Yeah, it's awesome!

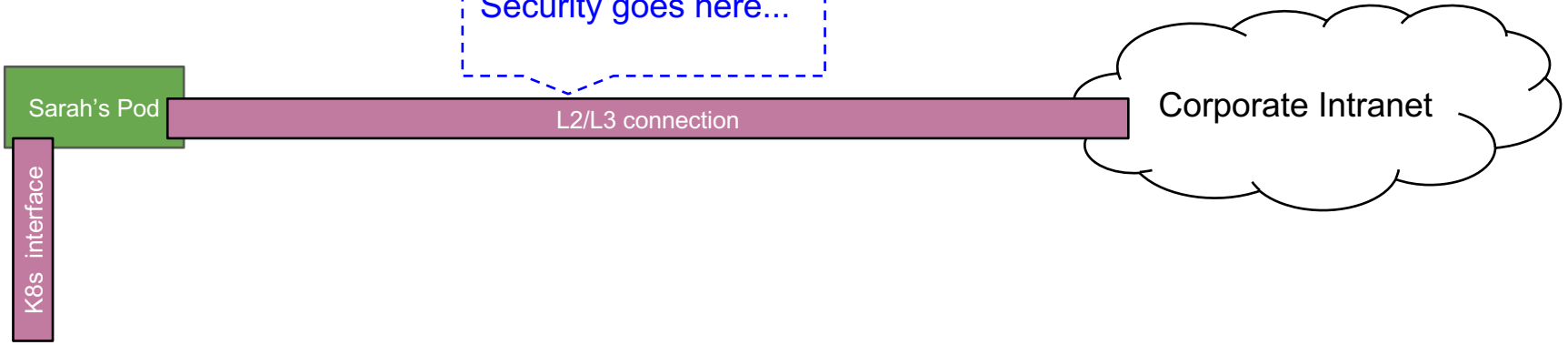
Sarah

I do that for IP, Ethernet, and other L2/L3 protocols. Tell me about your problems.

Sarah

I have a Pod and I just want to securely connect it to my corporate intranet.

Security goes here...



Sarah

```
kind: NetworkService
apiVersion: V1
metadata:
   name: secure-intranet-connectivity
spec:
   selector:
            app: secure-intranet-gateway
            payload: IP
```

Cool, this is how you would do it with NSM.

That looks a lot like a Service Resource in K8s.

Sarah

```
kind: NetworkService
apiVersion: V1
metadata:
   name: secure-intranet-connectivity
spec:
   selector:
            app: secure-intranet-gateway
            payload: IP
```

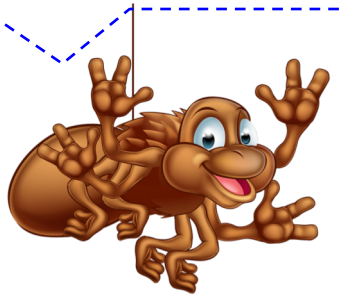
Yep! You use selectors on Pods to find the Pods providing the Network Service, and it exposes ‘payloads’ instead of ports and tcp.

So I just need this and a Deployment for the VPN-GW Pod?

Sarah

```
kind: NetworkService
apiVersion: V1
metadata:
   name: secure-intranet-connectivity
spec:
   selector:
            app: secure-intranet-gateway
            payload: IP
```

Close! You would also want to insert our standard Network Service Mesh init-container and a Config Map telling it what Network Service you want to connect to into your Pod. That's it.

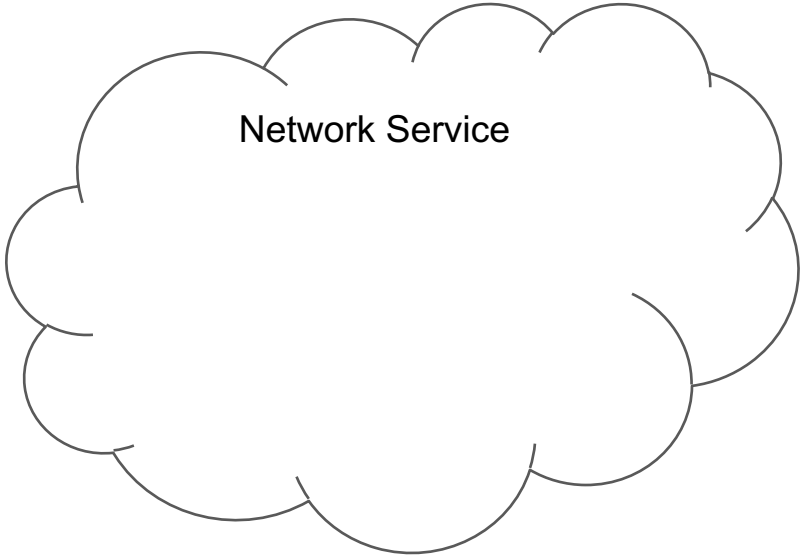


No interfaces? No subnets? No routes? How does all this magic work?

Sarah

```
kind: NetworkService
apiVersion: V1
metadata:
   name: secure-intranet-connectivity
spec:
   selector:
            app: secure-intranet-gateway
            payload: IP
```

Sarah



Network Service Mesh has three basic concepts. You've already met the first: Network Service (NS).

It's something you send L2/L3 payloads to and from and it does something you want.

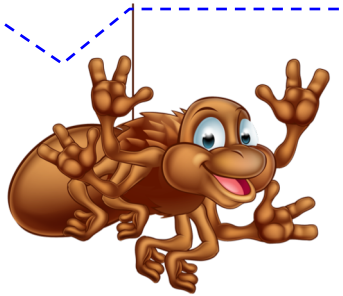
Like giving me secure connectivity to my intranet?

Exactly!

Sarah

Network Service

Example: secure-intranet-connectivity



Sarah

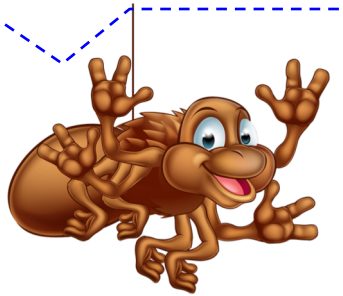
Network Service

Example: secure-intranet-connectivity

Network Service Endpoint

The Second concept is a Network Service Endpoint (NSE).

It's a Pod that is providing the Network Service you want.



Is that like Endpoints for Services?

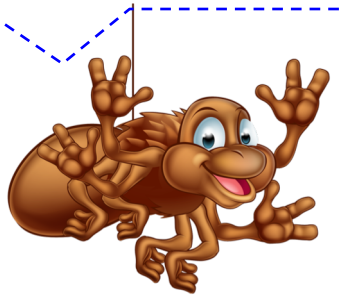
Very much. We tried to use familiar concepts in Network Service Mesh.

Sarah

Network Service

Example: secure-intranet-connectivity

Network Service Endpoint



So the VPN Gateway Pod is a Network Service Endpoint?

You're getting it! :)

Sarah

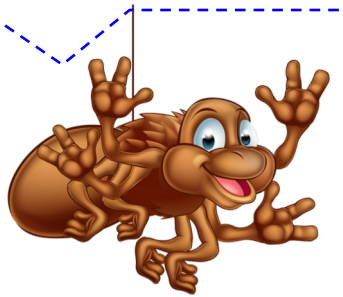
Network Service

Example: secure-intranet-connectivity

Network Service Endpoint
Example: VPN Gateway Pod

The Third concept is the L2/L3 ‘connection’ between your Pod and the NSE.

Sarah



Network Service

Example: secure-intranet-connectivity

Sarah’s Pod

L2/L3 connection

Network Service Endpoint
Example: VPN Gateway Pod

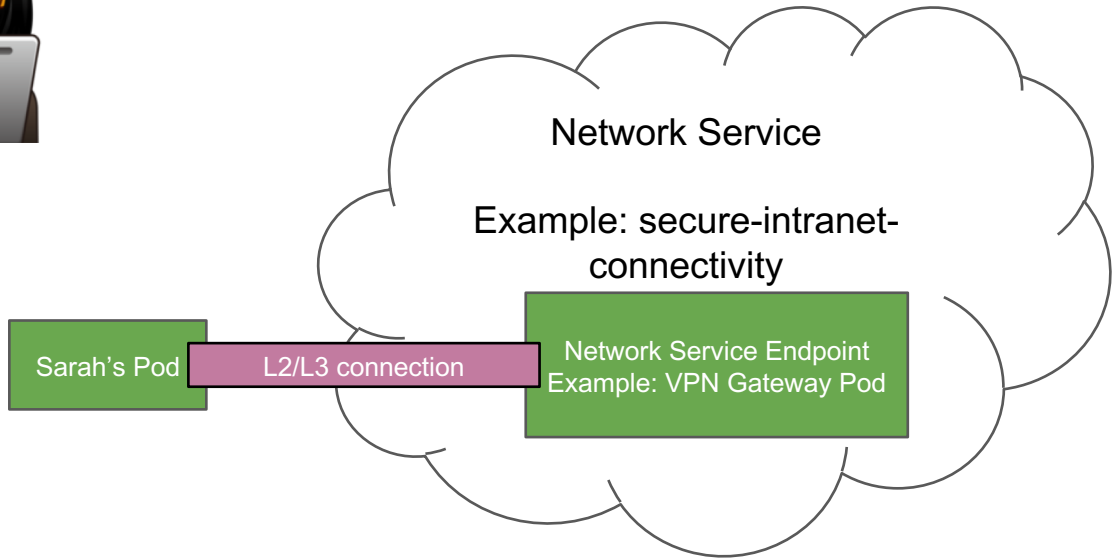
Is that an interface?

Usually it is instantiated as a kernel interface in your Pod.

There are NSM users with more complex use cases who want more exotic things like memif or vhost user, and we can give that to them.

You probably want a kernel interface.

Sarah

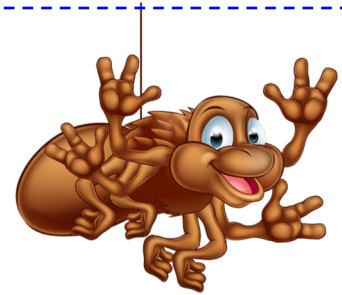


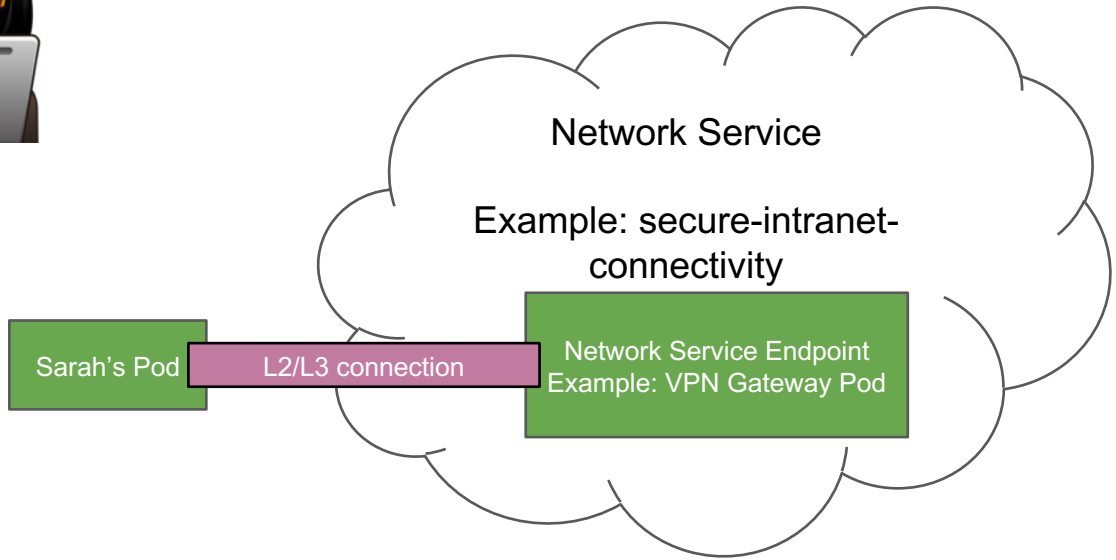
What about subnets?

L2/L3 connections are point to point cross connects between your Pod, and the Network Service you want. You don't have to think about subnets.

If you want a Bridge Domain, that's a Network Service itself.

Sarah



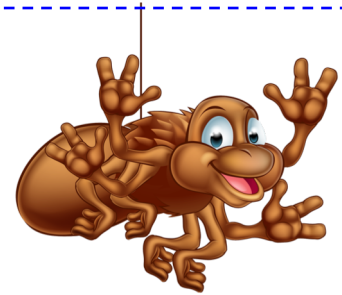


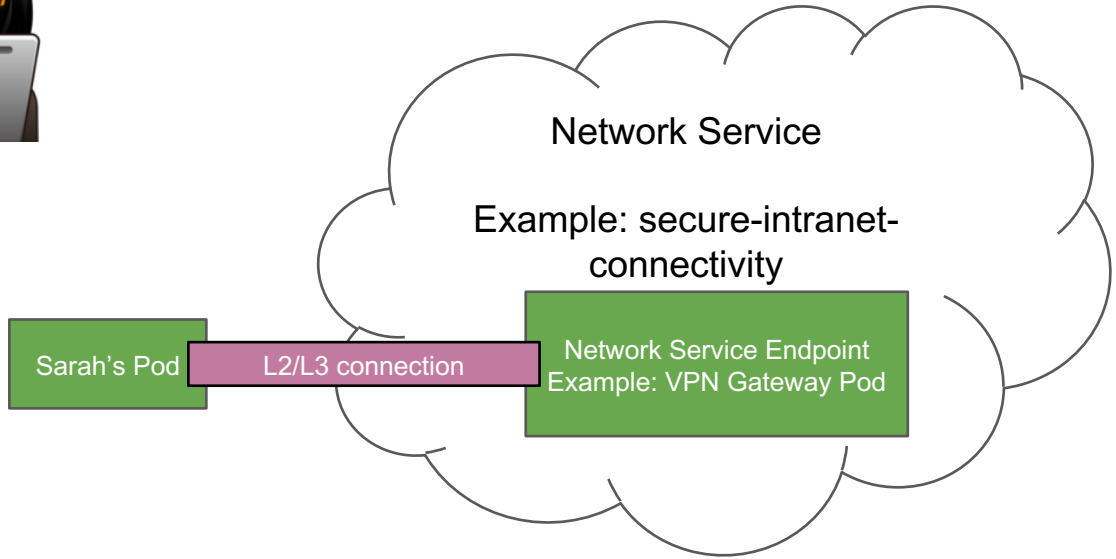
And routes? My network guys added an intranet CIDR last month and I had to update the routes on *all* of my Pods. It sucked!

Generally, **addresses and routes** for an L2/L3 connection come from the **Network Service Endpoint**, like your VPN Gateway. They are in a better position to know what they should be.

Advanced use cases can be done with more flexibility, but that's probably not what you want here.

Sarah





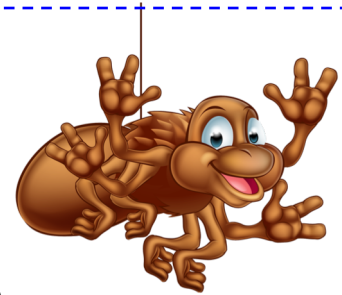
Sarah

What about the new Firewall Pod they want to get traffic before the VPN Gateway Pod?

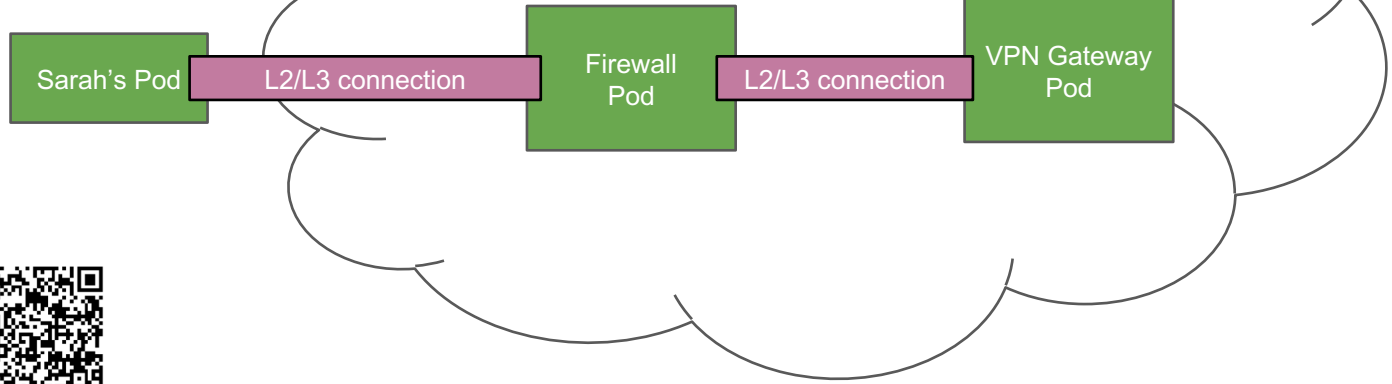
Network Service Mesh is a **Mesh.**

The Firewall Pod and the VPN Gateway Pod work **together** to give you the Network Service you want:

secure-intranet-connectivity



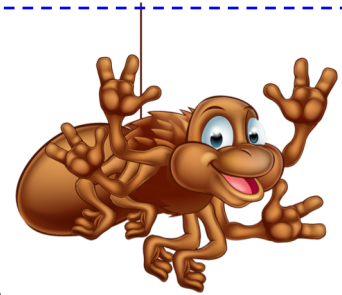
Network Service
secure-intranet-connectivity



Sarah

How does that work?

You know VirtualHosts/RouteRules in Istio?



Network Service
secure-intranet-connectivity

Sarah's Pod

L2/L3 connection

Firewall Pod

L2/L3 connection

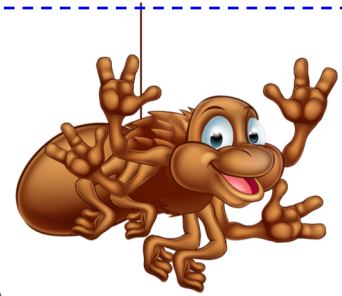
VPN Gateway Pod

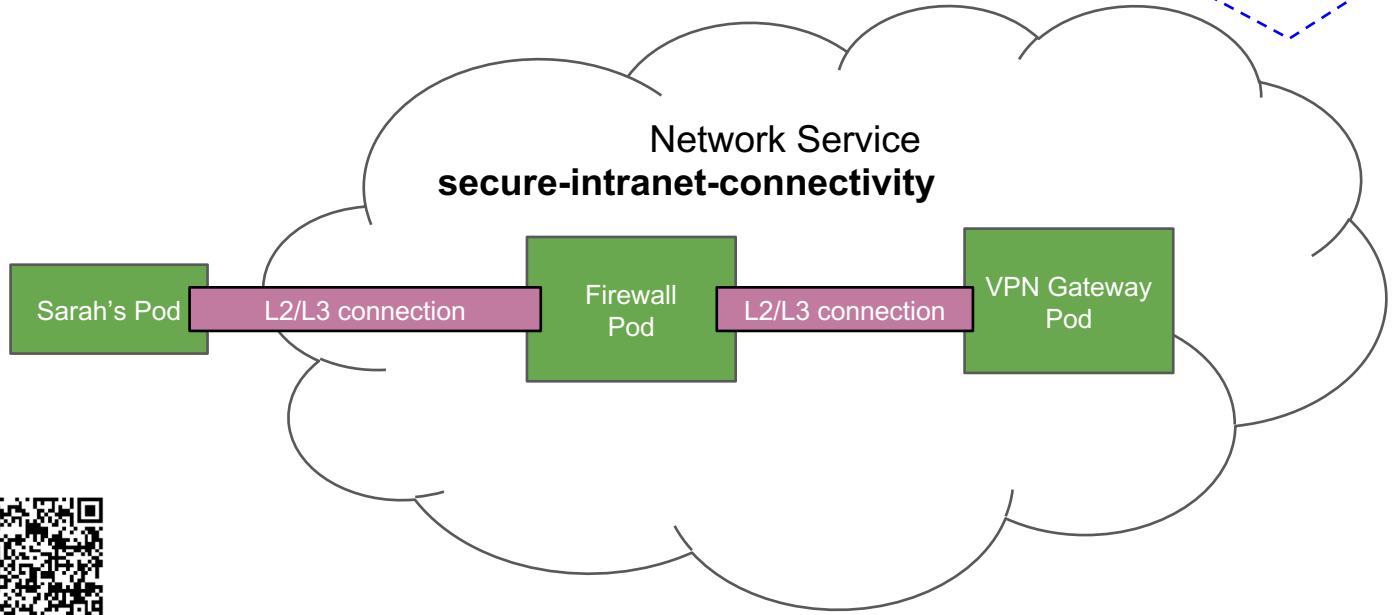
Sarah

Yeah, they are super useful.

Network Service Mesh has an analogous concept, we call them:

Network Service Wirings





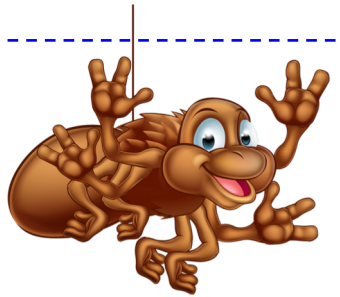
Sarah

```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-1
spec:
   target:
           - secure-intranet-connectivity
    qualifiers:
           source:
           sourceService:
              !secure-intranet-connectivity
    action:
         route:
           -destination:
                      podSelector:
                  firewall=true
```

The ‘secure-intranet-connectivity-wiring-1’ **Network Service Wiring** says:

‘target: secure-intranet-connectivity’

That means it applies to L2/L3 connections trying to reach the secure-intranet-connectivity Network Service.

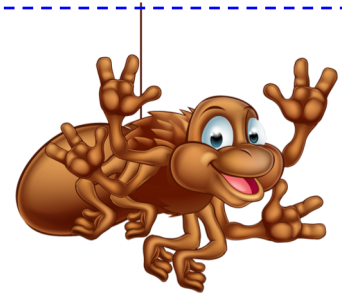


Sarah

```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-1
spec:
   target:
            - secure-intranet-connectivity
    qualifiers:
            source:
            sourceService:
               !secure-intranet-connectivity
    action:
          route:
            -destination:
                        podSelector:
                    firewall=true
```

The ‘secure-intranet-connectivity-wiring-1’ **Network Service Wiring** then has a qualifier that only matches things **not** providing the secure-intranet-connectivity service themselves.

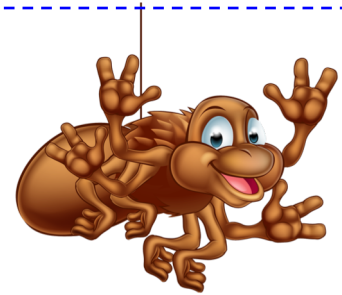
Things like your Pod.



Sarah

```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-1
spec:
   target:
            - secure-intranet-connectivity
    qualifiers:
            source:
            sourceService:
               !secure-intranet-connectivity
    action:
          route:
            -destination:
                        podSelector:
                    firewall=true
```

And it has a ‘route’ that sends those connections to one of the Network Service Endpoints with label ‘firewall=true’... like the Firewall Pod.

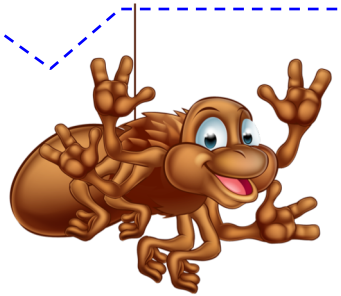


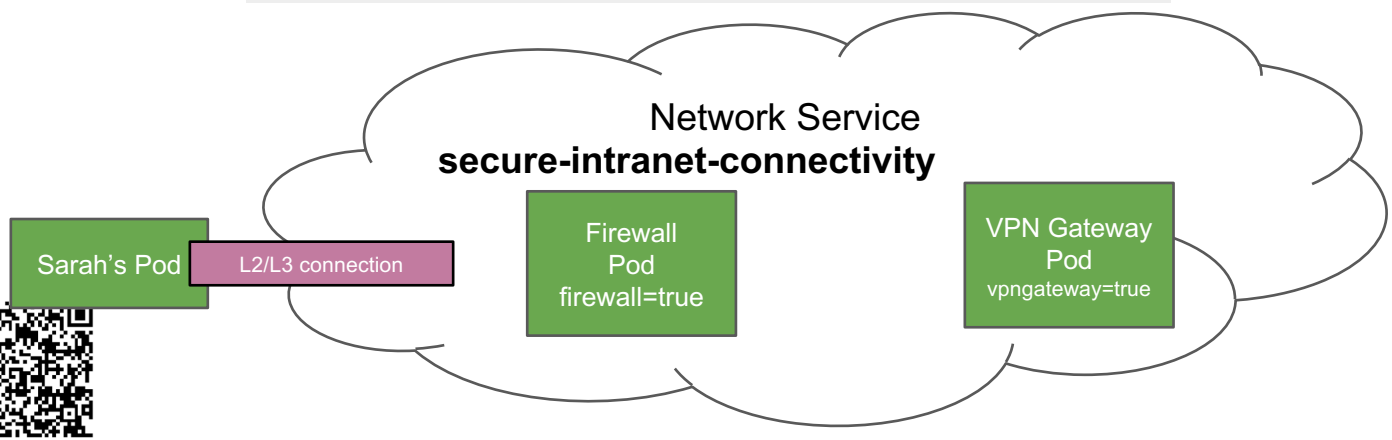
Sarah

```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-1
spec:
   target:
           - secure-intranet-connectivity
    qualifiers:
           source:
           sourceService:
              !secure-intranet-connectivity
    action:
         route:
           -destination:
                      podSelector:
                   firewall=true
```

When your Pod tries to connect to the secure-intranet-connectivity Network Service, it matches the Network Service Wiring:

secure-intranet-connectivity-1





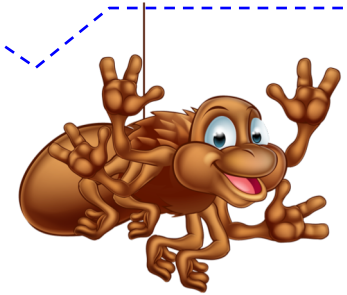
Sarah

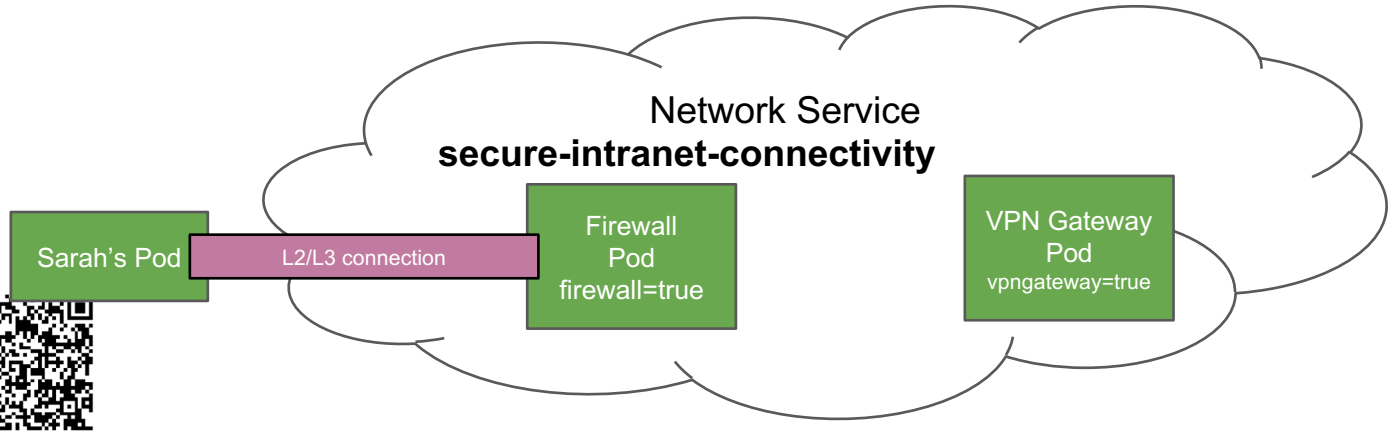
```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-1
spec:
   target:
           - secure-intranet-connectivity
    qualifiers:
           source:
           sourceService:
              !secure-intranet-connectivity
    action:
         route:
           -destination:
                     podSelector:
                  firewall=true
```

Network Service Wiring

secure-intranet-connectivity-wiring-1

Causes your connection to be routed to the Firewall Pod



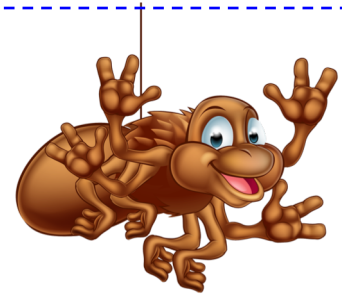


Sarah

OK. How does the Firewall Pod get connected to the VPN Gateway Pod?

You would have a second Network Service Wiring ‘secure-intranet-connectivity-wiring-2’

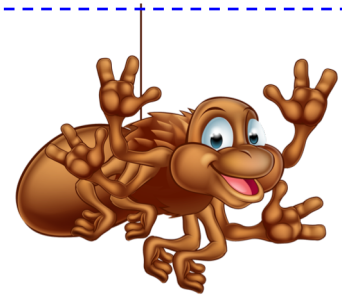
```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-2
spec:
   target:
           - secure-intranet-connectivity
    qualifiers:
            source:
            podSelector:
                firewall=true
    action:
          route:
            -destination:
                       podSelector:
                    vpngateway=true
```



Sarah

```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-2
spec:
   target:
           - secure-intranet-connectivity
    qualifiers:
           source:
           podSelector:
               firewall=true
    action:
         route:
           -destination:
                      podSelector:
                   vpngateway=true
```

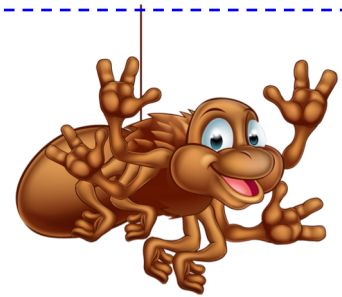
That has a qualifier that matches sources that have label firewall=true



Sarah

```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-2
spec:
   target:
            - secure-intranet-connectivity
    qualifiers:
            source:
            podSelector:
                firewall=true
    action:
          route:
            -destination:
                       podSelector:
                     vpngateway=true
```

And routes them to Pods with vpngateway=true



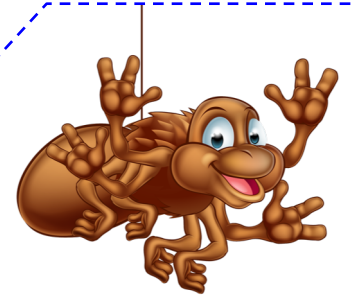
Sarah

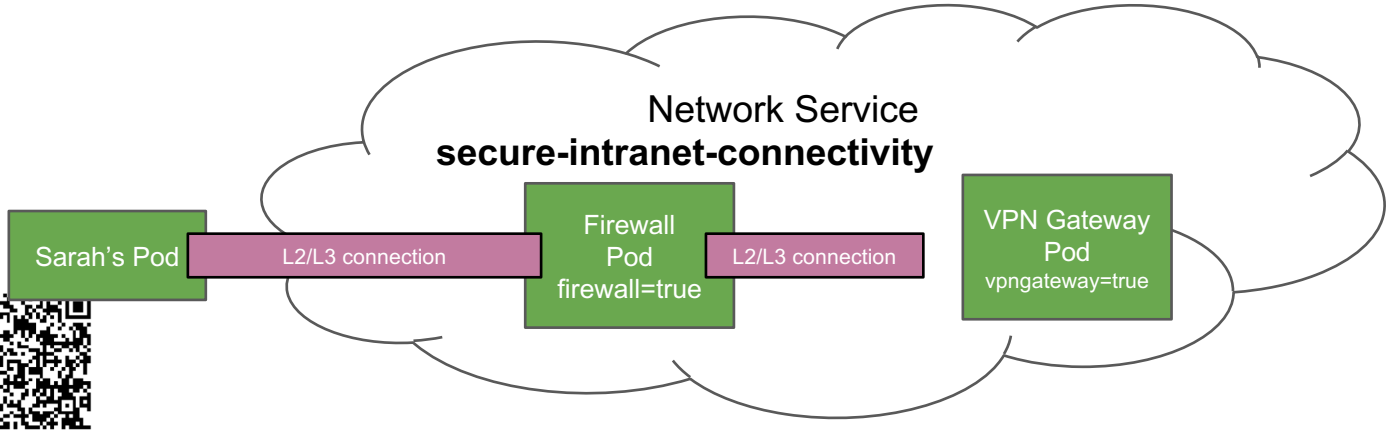
```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-2
spec:
   target:
           - secure-intranet-connectivity
    qualifiers:
           source:
           podSelector:
               firewall=true
    action:
         route:
           -destination:
                      podSelector:
                   vpngateway=true
```

The Firewall Pod does its Firewall thing, but doesn't know anything about how to connect to your intranet. So it opens a connection to secure-intranet-connectivity itself.

The Firewall Pod's connection matches Network Service Wiring:

secure-intranet-connectivity-wiring-2





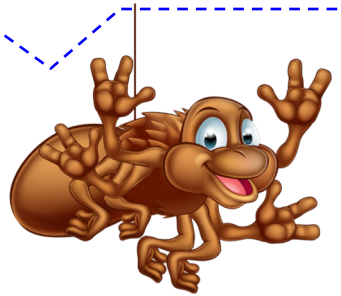
Sarah

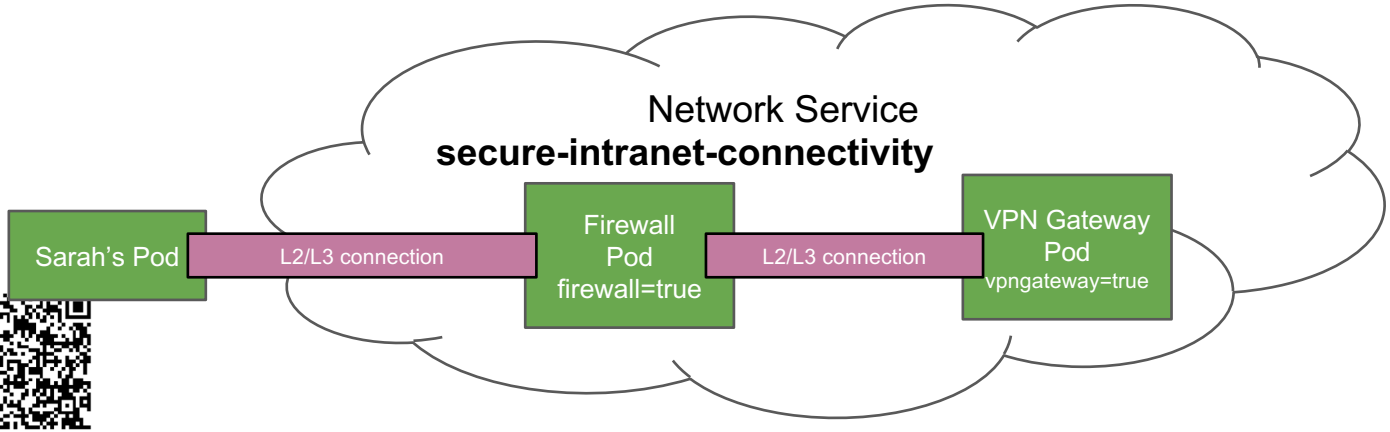
```
kind: NetworkServiceWiring
apiVersion: V1
metadata:
   name: secure-intranet-connectivity-wiring-2
spec:
   target:
           - secure-intranet-connectivity
    qualifiers:
           source:
           podSelector:
               firewall=true
    action:
         route:
           -destination:
                      podSelector:
                    vpngateway=true
```

Network Service Wiring

secure-intranet-connectivity-2

causes the Firewall Pod's connection to be routed to the VPN Gateway Pod

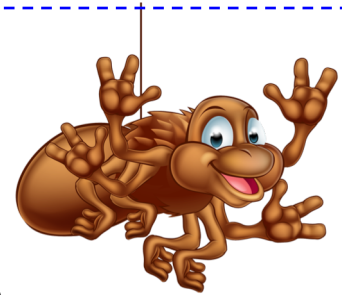




Sarah

So when IT decides to put something else in there for more security, I just add a Deployment for that and a couple of Network Service Wiring Resources?

Yep!



Network Service
secure-intranet-connectivity

Sarah's Pod

L2/L3 connection

Firewall Pod

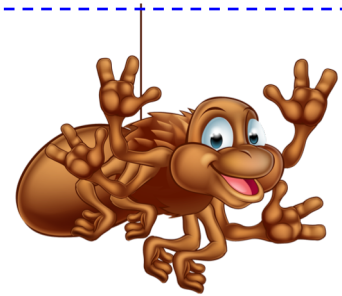
L2/L3 connection

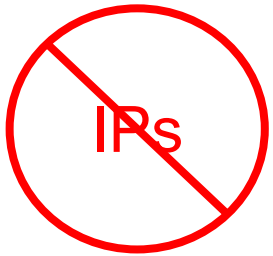
VPN Gateway Pod

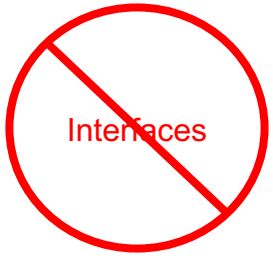
Sarah

No interfaces, no IPs, no subnets, no routes?

Nope!



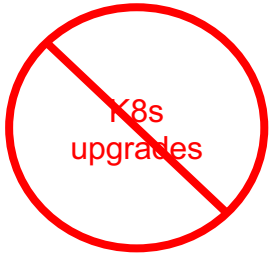


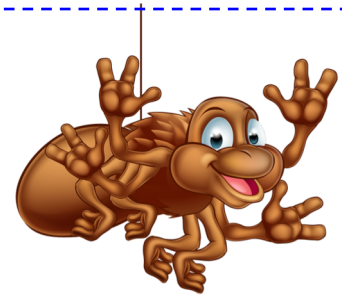


Sarah

Do I need a new version of Kubernetes?
Do I have to use a specific CNI plugin?

Network Service Mesh is completely orthogonal to normal Kubernetes Networking. It doesn't use CNI, and you can use it with your existing Kubernetes and CNI.

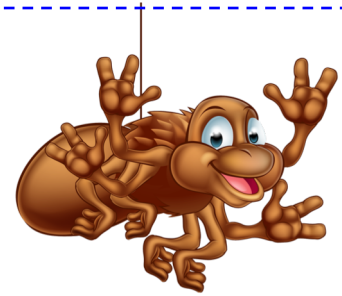


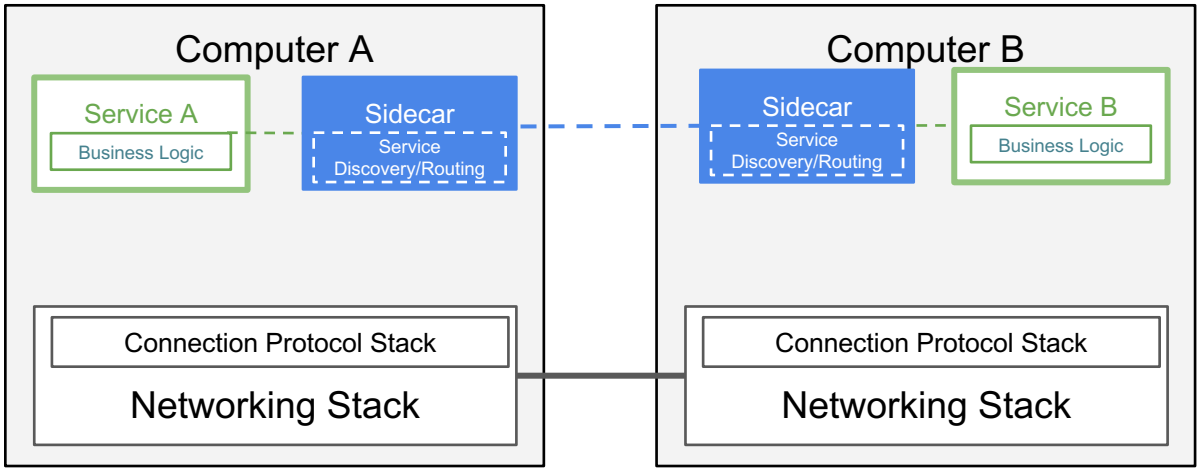


Sarah

That's awesome, how does it work?

You know how Istio Service Mesh's are often described as handling things like Service Routing etc?





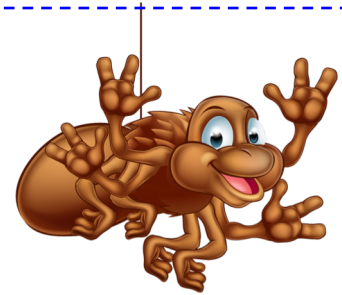
Sarah

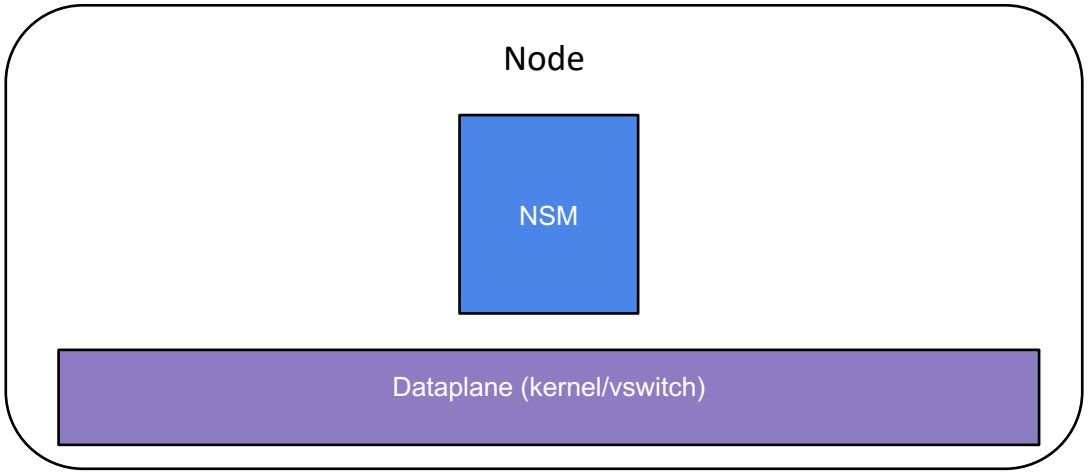
Yep! I've read Phil Calçado 's paper.

Network Service Mesh has something like the Envoy Proxy that does the Service Discovery and Routing too. It's called the:

Network Service Manager (NSM)

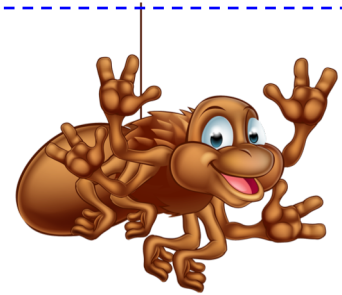
It runs as a DaemonSet so you have one on each Node.

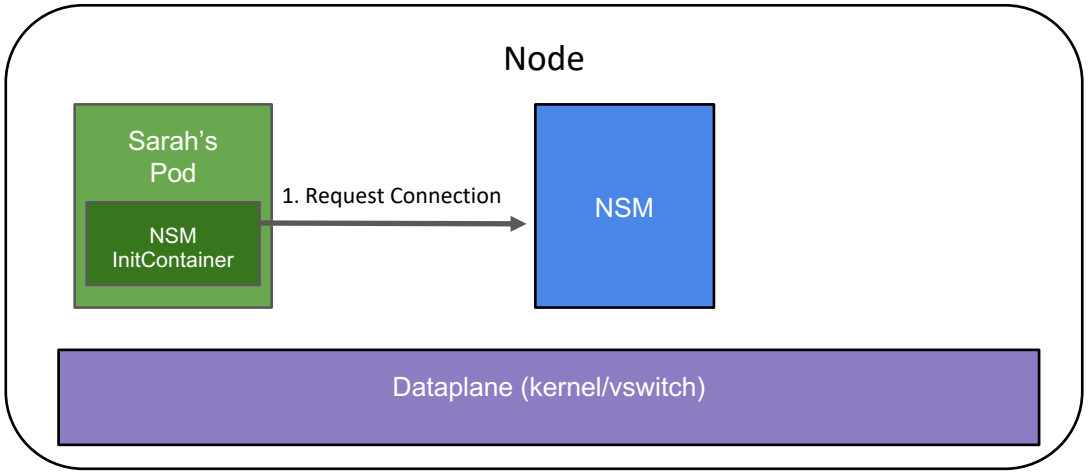




Sarah

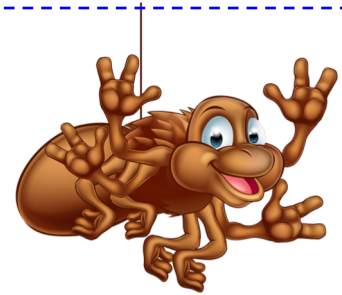
The NSM InitContainer reads your Config Map, and sends a GRPC call across a unix file socket to the NSM to Request an L2/L3 Connection to the secure-intranet-connectivity Network Service.

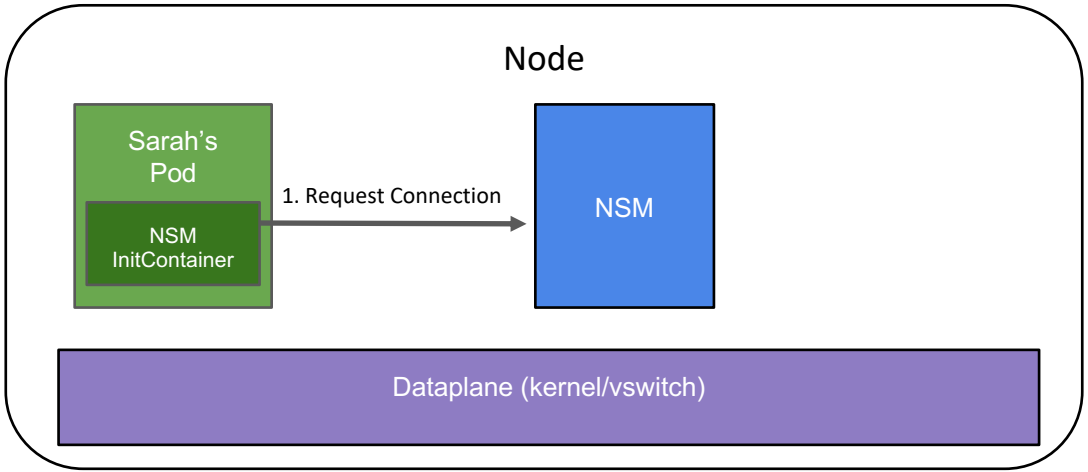




Sarah

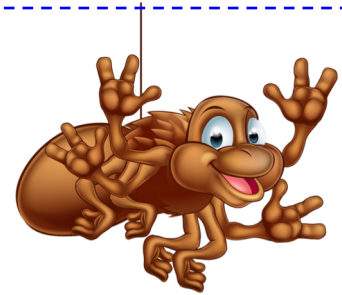
Request Connection has any information needed to be clear about how you want the connection to look to your Pod locally, like that you want it to be a kernel interface, the interface name you'd prefer if you care, etc.

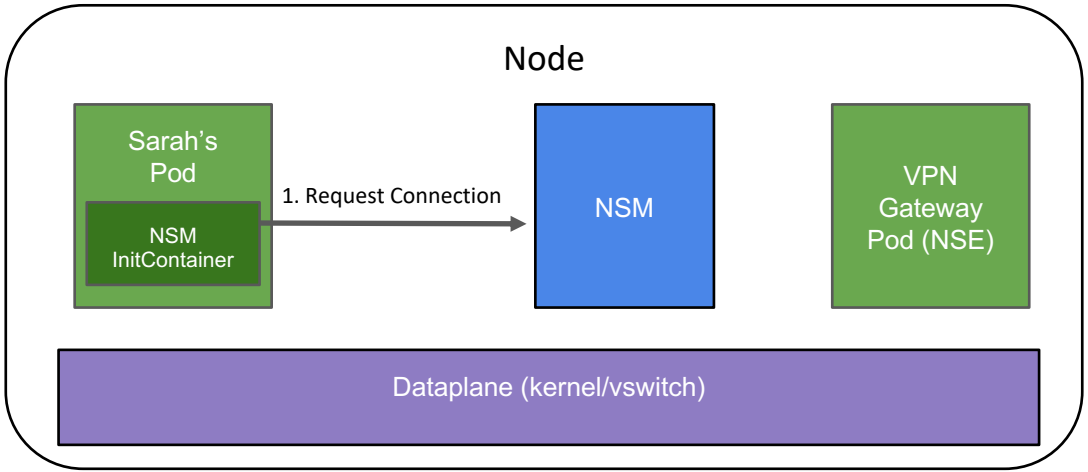




Sarah

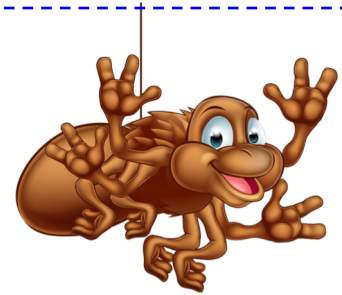
Let’s talk first about the case where your VPN Gateway Pod is on the same Node.

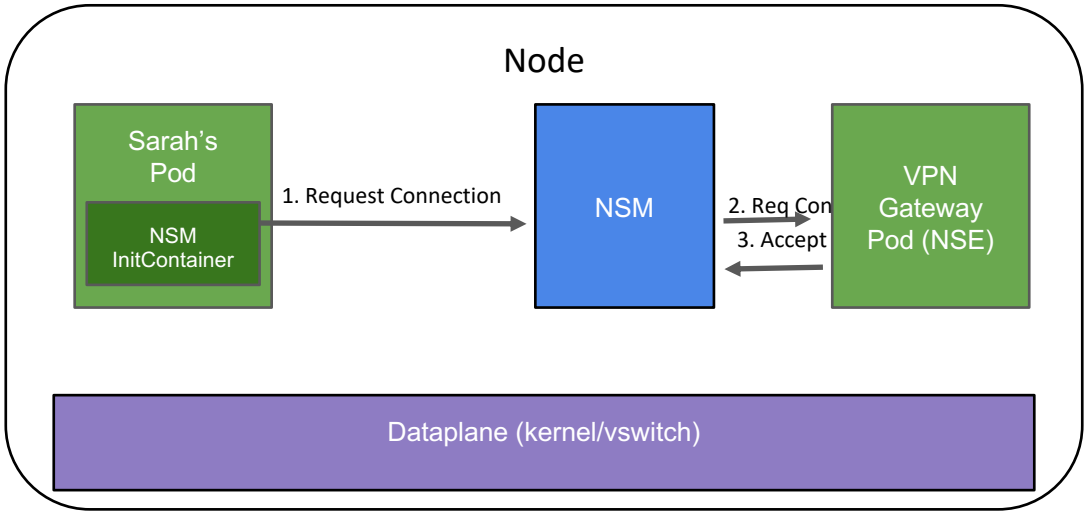




Sarah

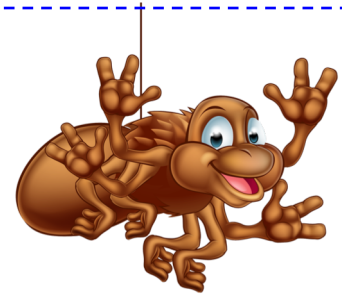
The NSM sends a Request Connection to the VPN Gateway Pod, which sends back an Accept.

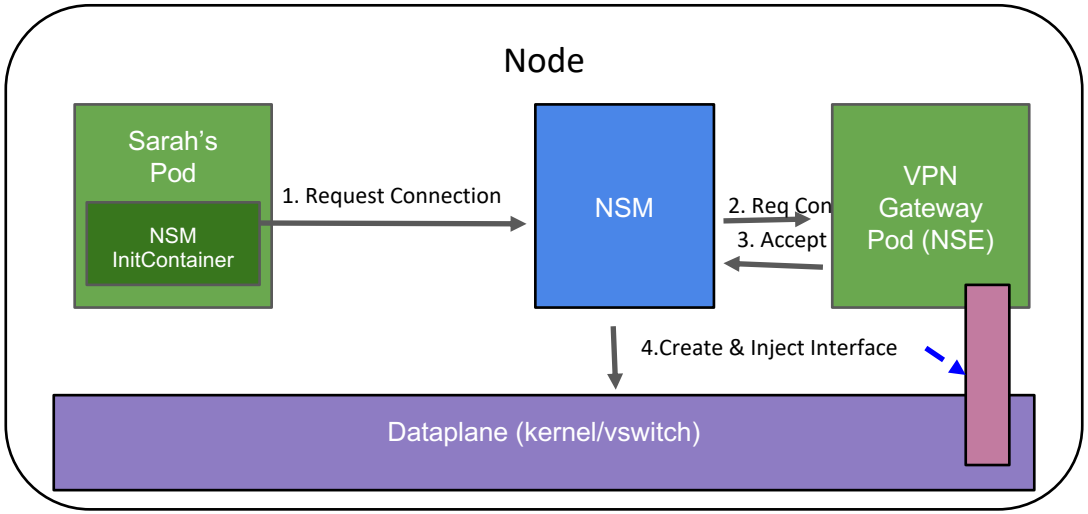




Sarah

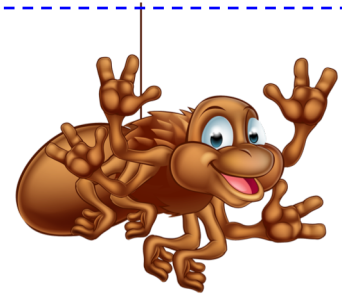
The NSM creates an interface for the connection for the VPN Gateway and injects it into the VPN Gateway Pod.

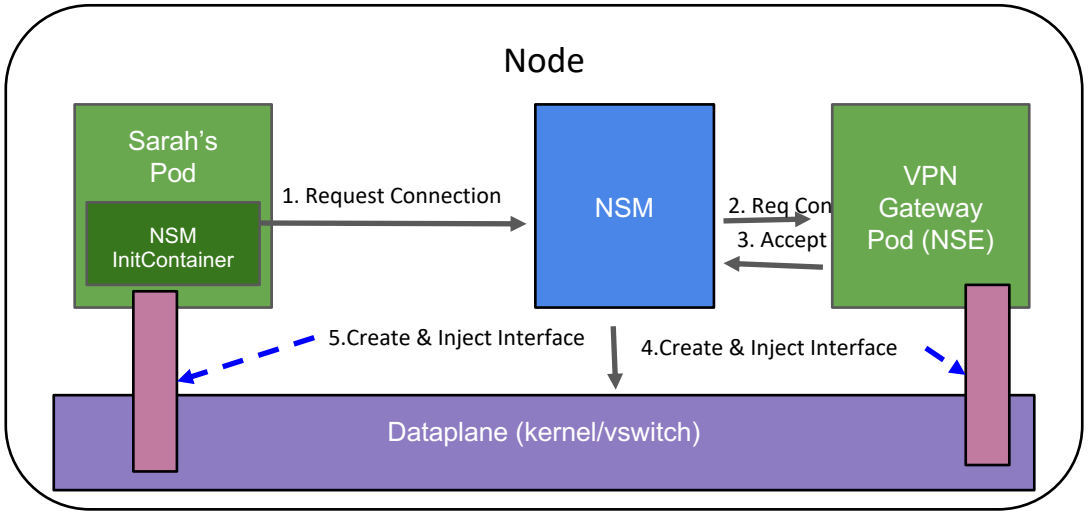




Sarah

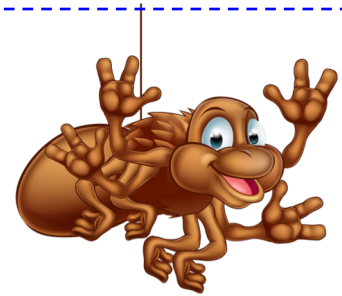
The NSM creates and injects an interface into Sarah's Pod

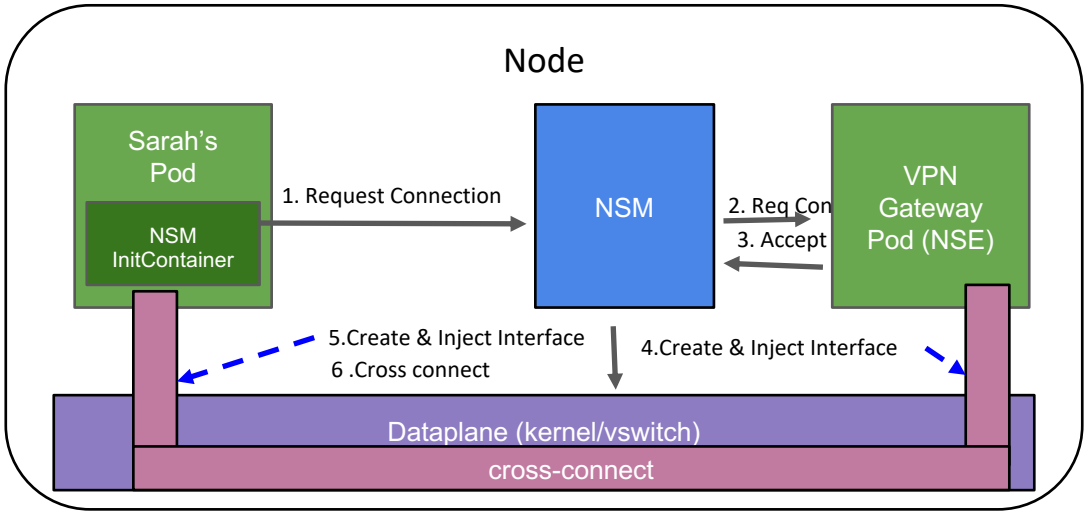




Sarah

The NSM then cross connects the two interfaces in the dataplane.

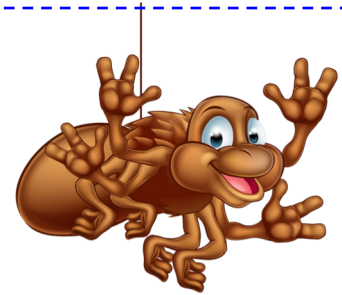


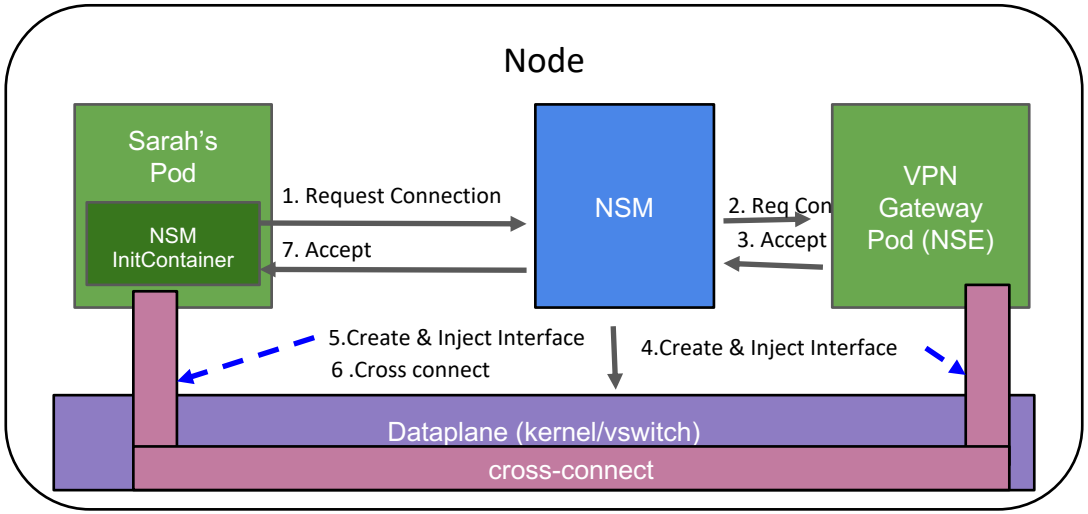


Sarah

Finally the NSM responds to your Pod's NSMInitContainer with an Accept.

Then you are ready to go.



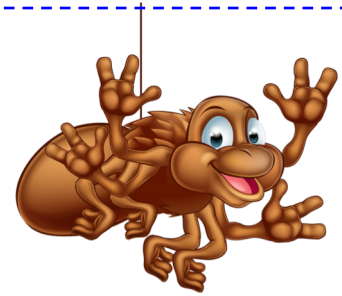


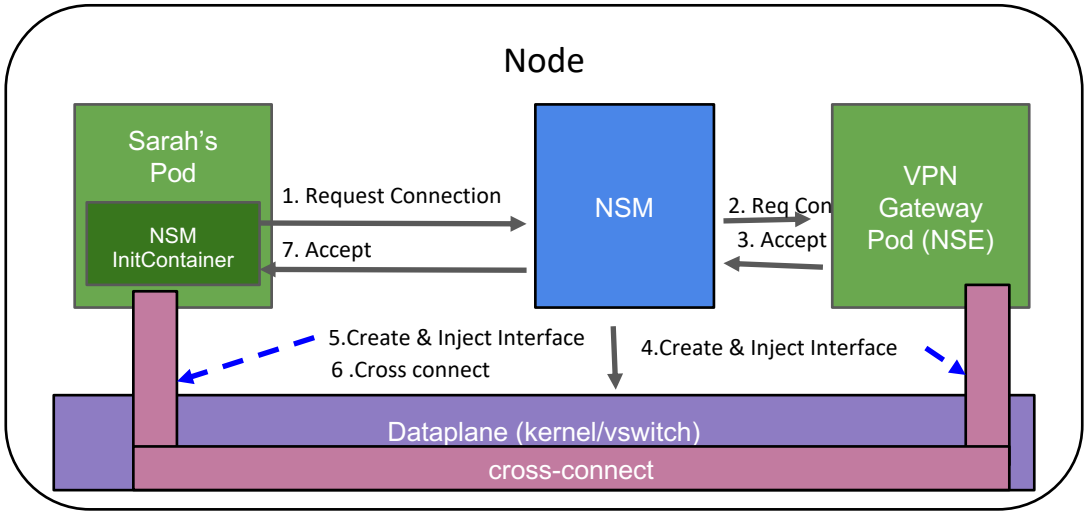
Sarah

So the NSM does Service Discovery **and** sets up the connection?

Yep.

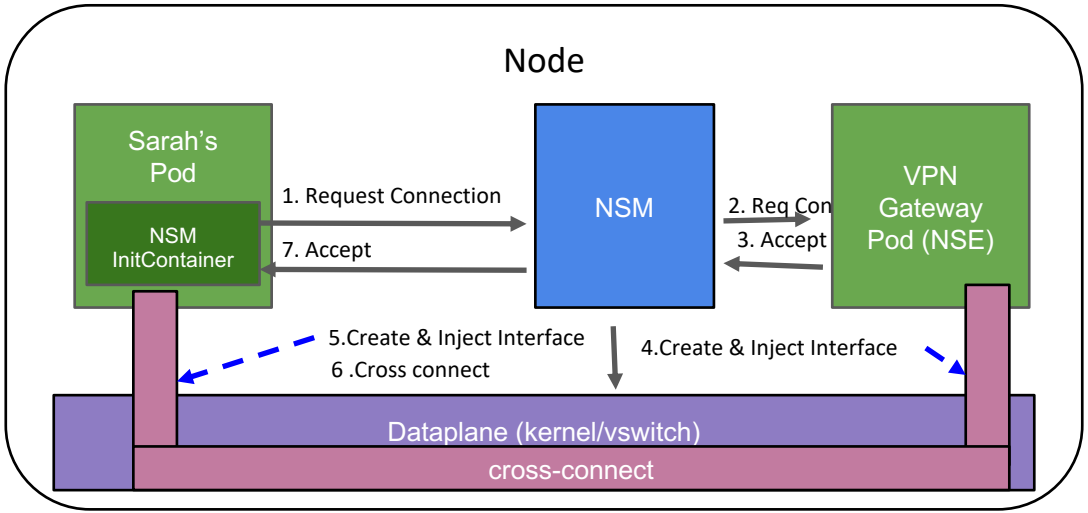
For L2/L3 connections we don't have a universal mechanism like TCP in the kernel, so we have the NSM do it.





Sarah

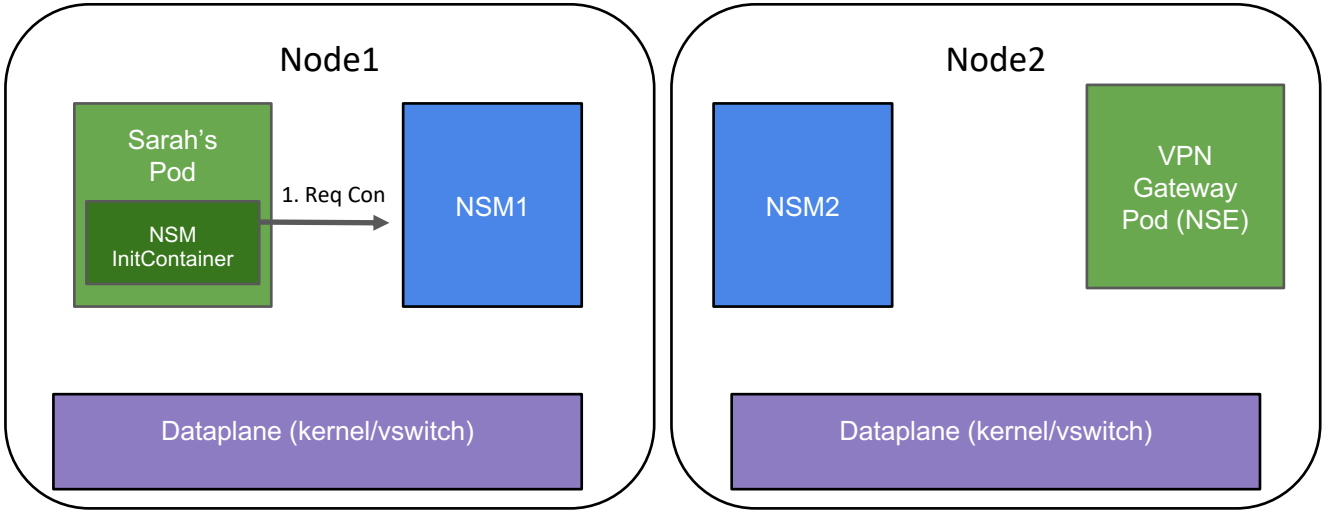
What if the VPN Gateway Pod is on a different Node.



Sarah

If the VPN Gateway Pod is on a different Node, it looks exactly the same to your Pod.

You send a Request Connection request to NSM using GRPC over a unix file socket.

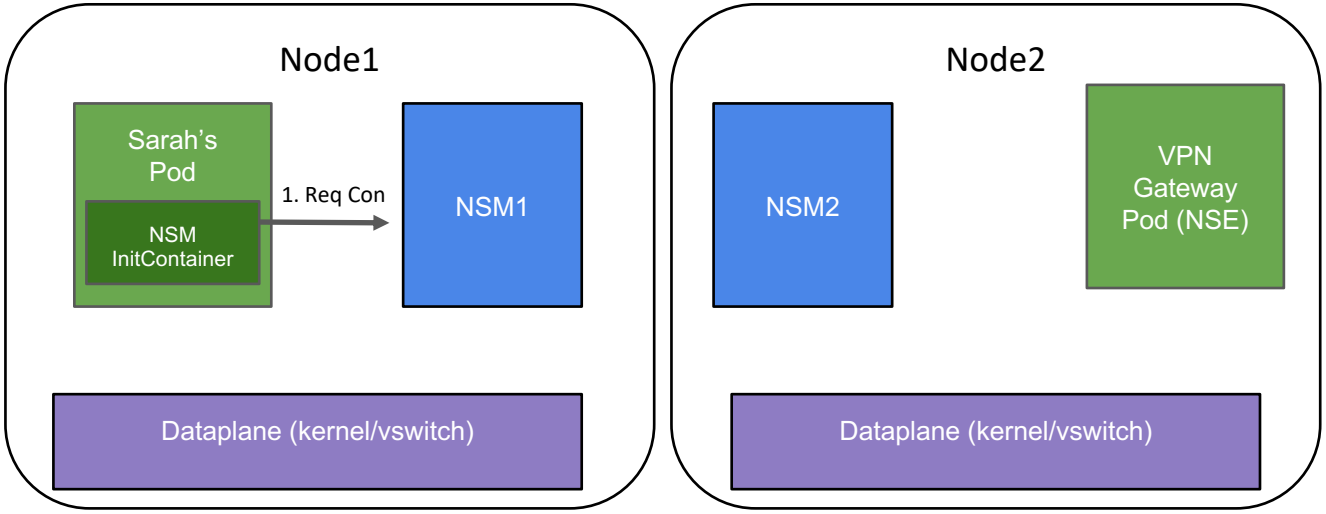


Sarah

If the VPN Gateway Pod is on a different Node, it looks exactly the same to your Pod.

You send a Request Connection request to NSM using GRPC over a unix file socket.

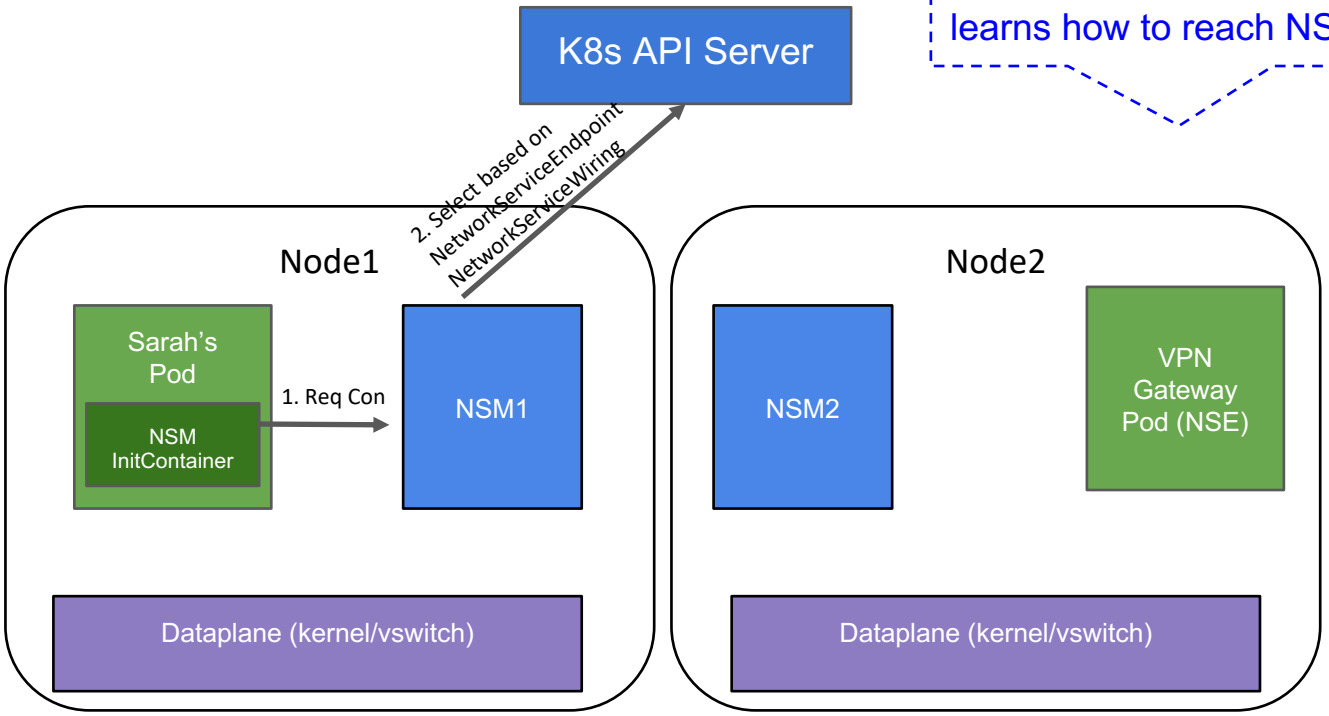
K8s API Server



Sarah

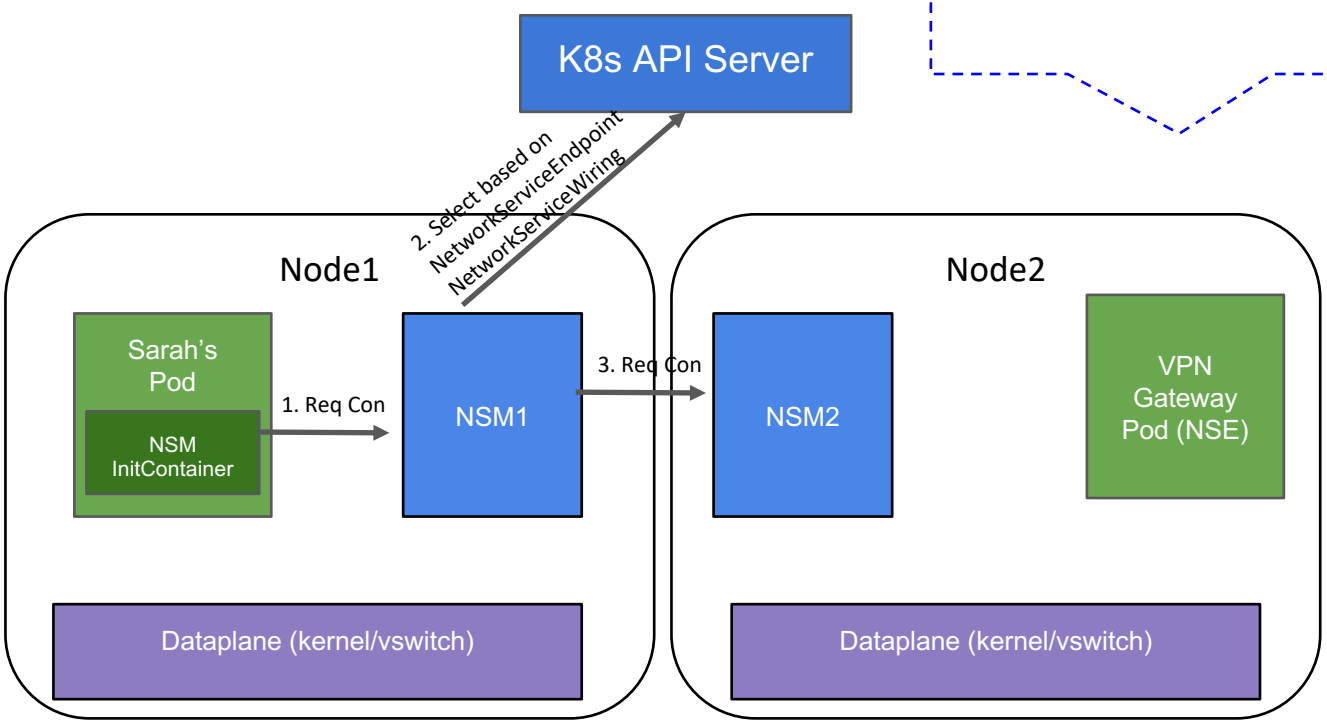
NSM1 then looks up (or more likely caches) NetworkServiceEndpoints and NetworkServiceWiring from the K8s API Server and selects a Network Service Endpoint for the secure-intranet-connectivity Network Service.

From that NetworkServiceEndpoint resource it learns how to reach NSM2.



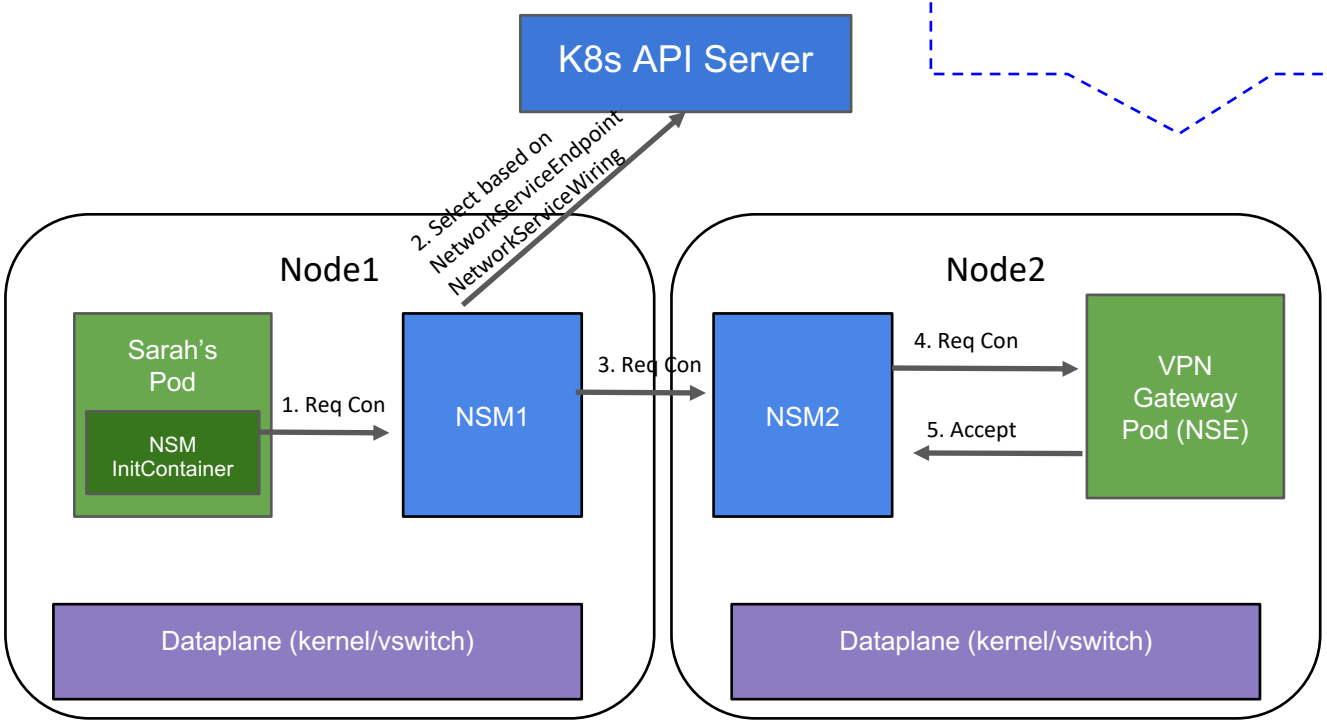
Sarah

NSM1 sends a Request Connection GRPC call to NSM2, listing out what its preferences are for tunnel mechanism (VXLAN, GRE, etc) and its preferences for parameters (VNI, etc.)



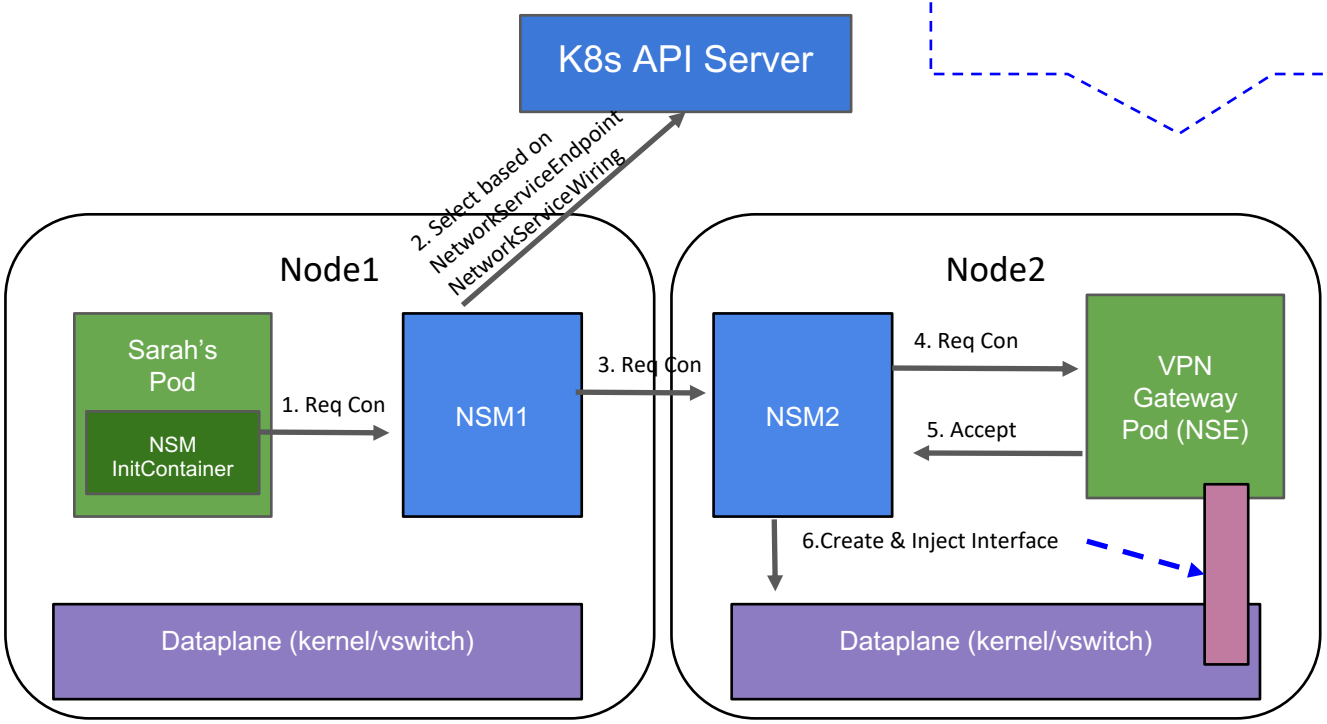
Sarah

NSM2 sends a Request Connection to the VPN Gateway which sends back an Accept.



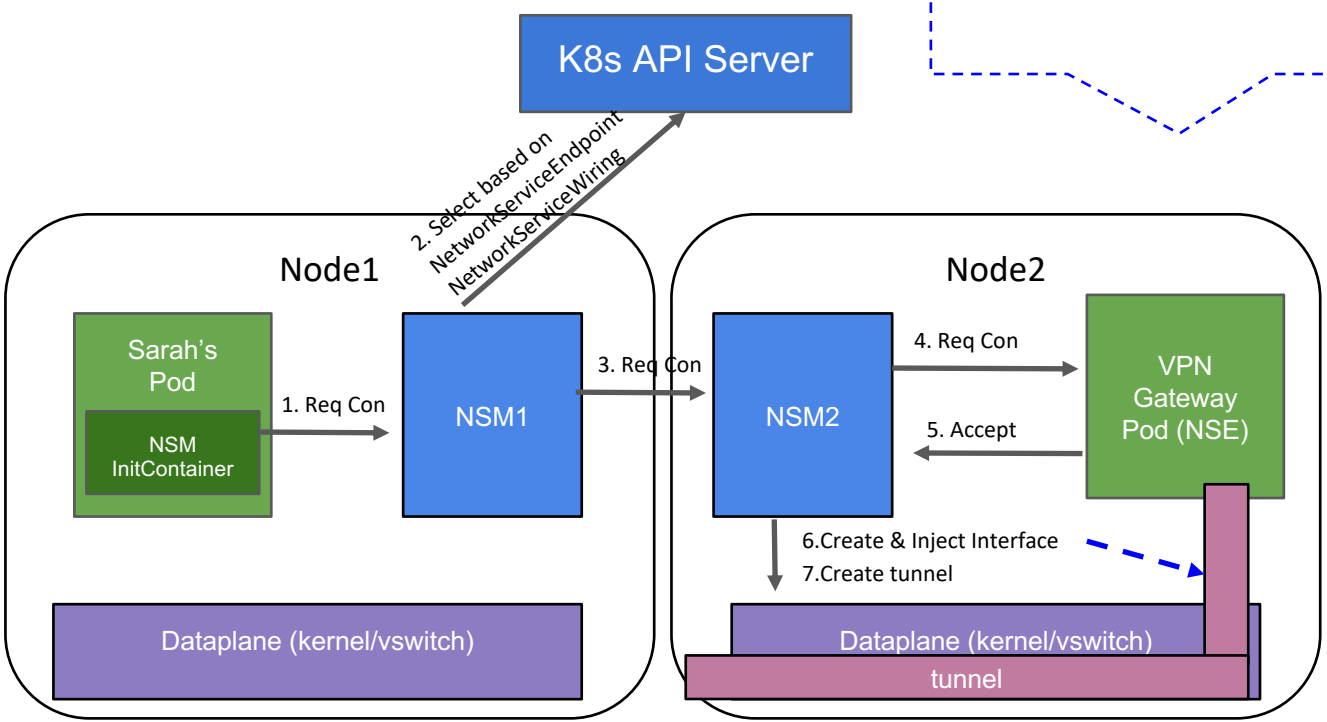
Sarah

NSM2 creates and injects an interface into the VPN Gateway Pod for the connection.



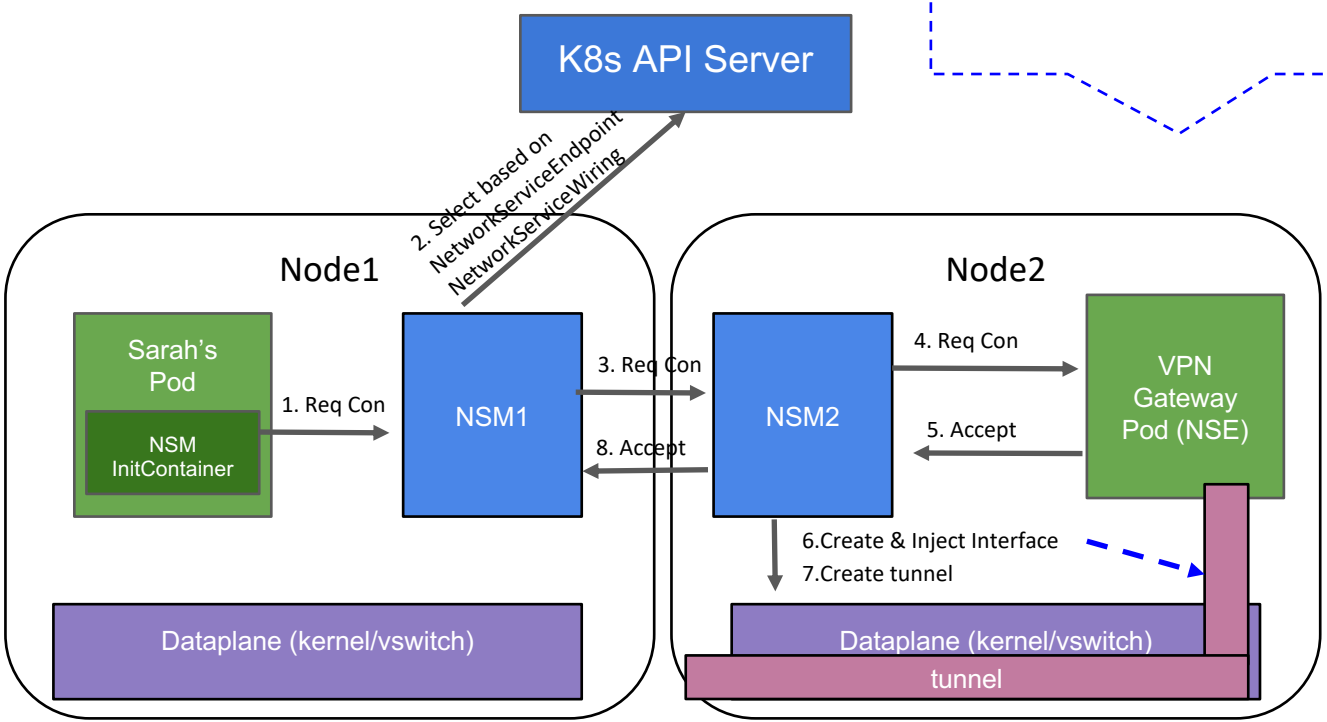
Sarah

NSM2 sets up its end of the tunnel.



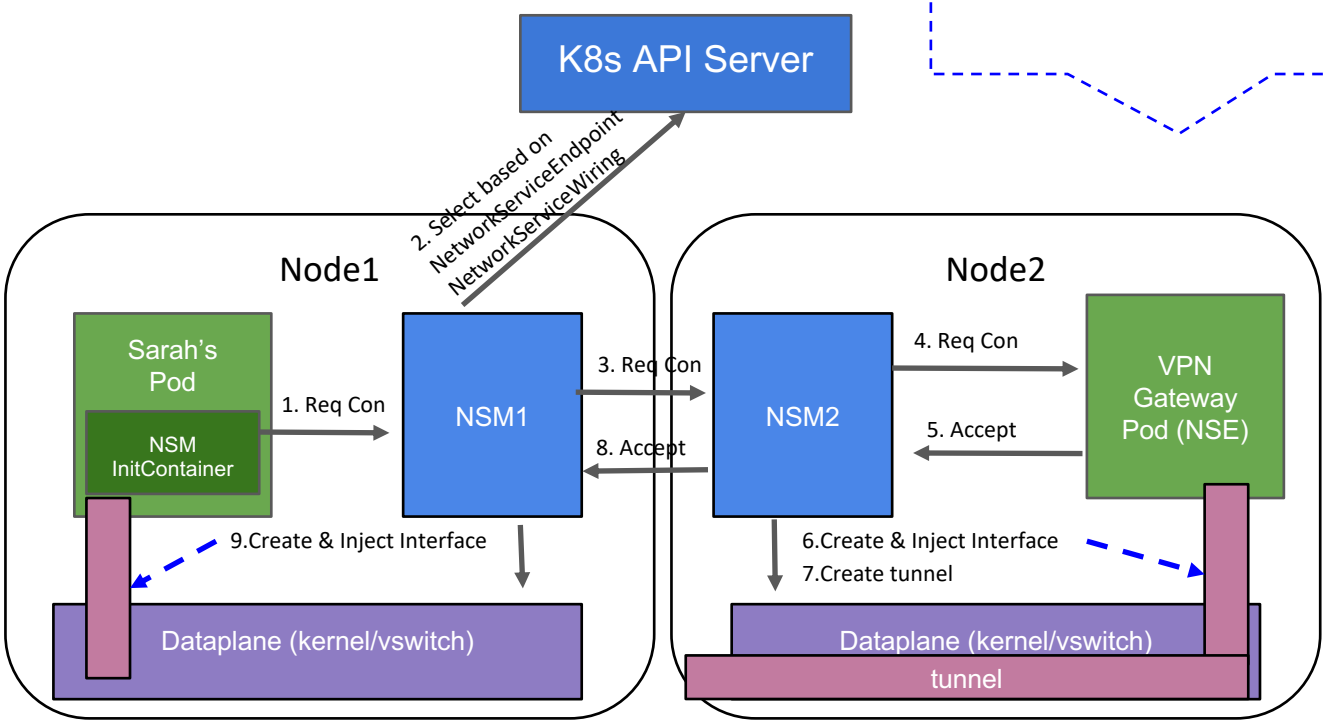
Sarah

NSM2 send an Accept back to NSM1 with the selected tunnel mechanism and tunnel parameters.



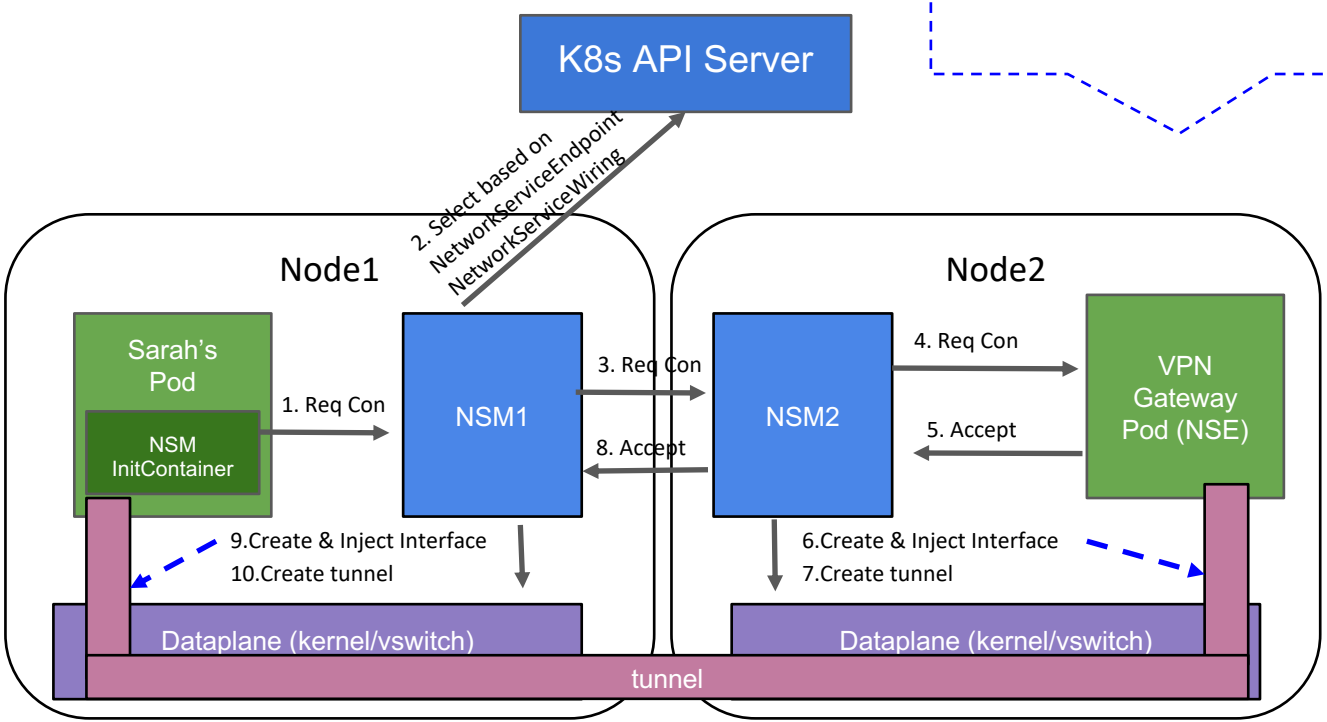
Sarah

NSM1 creates and injects an interface for the connection into Sarah's Pod.



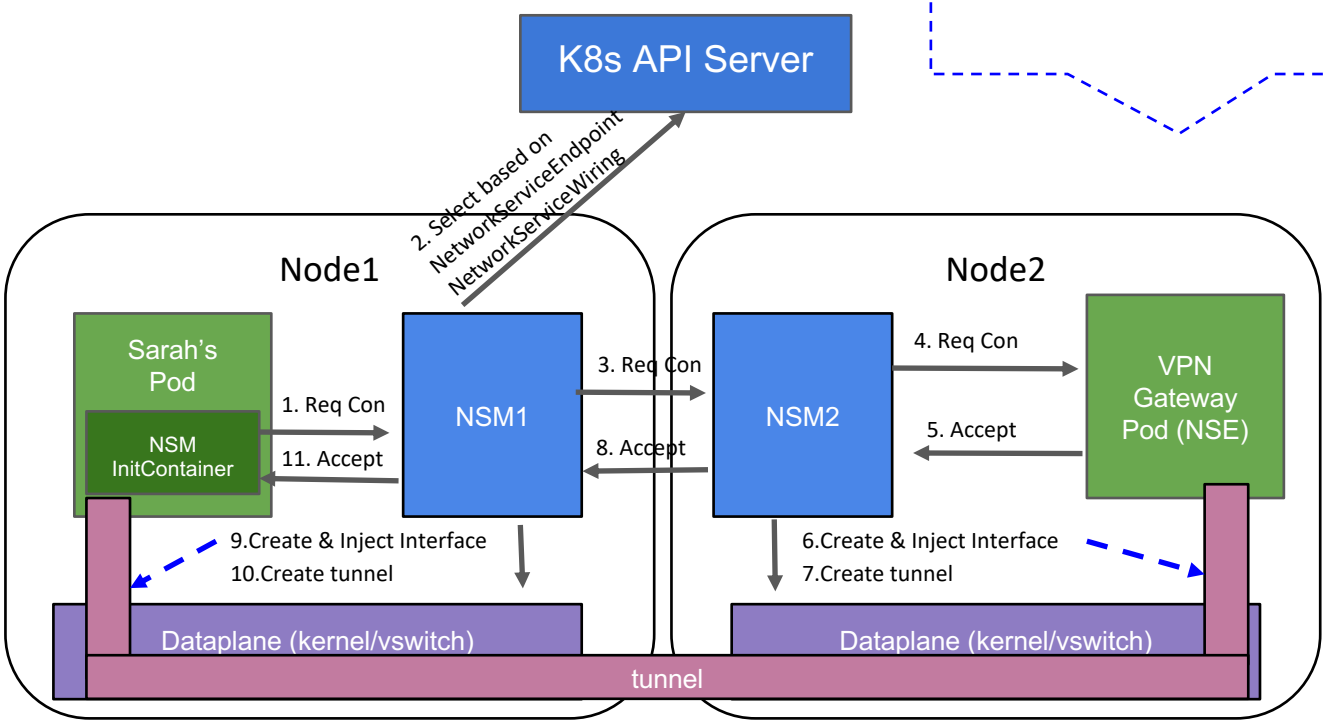
Sarah

NSM1 creates its end of the tunnel and completes the cross connect.



Sarah

Finally NSM1 sends an Accept back to the InitContainer your Pod.



Sarah

How do the NetworkEndpoint Resources get into the API Server? Do I have to put them there?

Nope, let's talk through that.

Sarah

When the VPN Gateway Pod comes up, it Exposes to the NSM1 that it has a secure-intranet-connectivity Network Service willing to accept connections.

K8s API Server

Node1

Sarah's Pod

NSM InitContainer

NSM1

Dataplane (kernel/vswitch)

Node2

NSM2

1. Expose Service

VPN Gateway Pod (NSE)

Dataplane (kernel/vswitch)

Sarah

Then the NSM creates a NetworkServiceEndpoint CRD for it in the K8s API server.

K8s API Server

2. Create NetworkServiceEndpoint

Node1

Sarah's Pod

NSM InitContainer

NSM1

Dataplane (kernel/vswitch)

Node2

NSM2

1. Expose Service

VPN Gateway Pod (NSE)

Dataplane (kernel/vswitch)

Sarah

Cool! This looks so much easier than trying to manually string together interfaces and subnets myself! Thank you!

You are welcome! Have fun!

Thank you!