Our Experiences deploying Kubernetes with IPv6

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Software Engineer  
Covalent IO
What to expect from this talk?

• Quick history of IPv6
• IPv6 in Kubernetes
  – Can I run it?
• Step by step tutorial + Demo
IPv6 history

- IPv4 is not enough? (IETF - ROAD, November 1991)
- IPv6 was (re)born (RFC 2460, December 1998)
- No more IPv4 available! (Let's do NAT over NAT over NAT!, >2008)
- IPv6 in Linux 2.1.8 (Alpha), ~1996
- IPv6 in Linux 2.6.12 (Stable), ~2005
- IPng was born (RFC 1883, December 1995)
- IPv6 - Standard 86! (RFC 8200, July 2017)
- Containers! (Let's do IPv4, what could go wrong?, 2014)
- 20 Years of IPv6 (The year of IPv6?, December 2018)
A Kubernetes cluster on IPv6

- Is it really worth it?
- Infrastructure?
- Kubernetes itself
  - Does it run?
  - Pods, Services and Ingress?
- Does my app / service work?
Is there any benefit to using IPv6 on my home network?

I know that IPv6 is the future because there is only 4 billion IPv4 address, but on a home network, you are not going to have 4 billion users. So are there any other benefits that would make IPv6 on a home network better than using IPv4?

But with IPv4 you can't give all of your kitchen appliances billions of IP addresses! – Phoshi Oct 19 '09 at 15:36

'cause my fridge has a twitter habit and gets very very upset if it can't tweet to all the neighbor fridges... – quack quixote Dec 13 '09 at 22:07
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No, there is not any benefit to using IPv6 at home.

Here is a relevant question: What interesting uses for IPv6 are out there?

But with IPv4 you can't give all of your kitchen appliances billions of IP addresses! – Phoshi Oct 15 '13 at 15:36

Because my fridge has a twitter habit and gets very very upset if it can't tweet to all the neighbors. – quack quixote Dec 13 '09 at 22:07

Not true for all systems. Windows 7 Homegroups uses it (as mentioned in the link). – jdh Jan 5 '13 at 15:12
Is there any benefit to using IPv6 on my home network?

I know that IPv6 is the future because there is only 4 billion IPv4 address, but on a home network, you are not going to have 4 billion users. So are there any other benefits that would make a home network better than using IPv4?

No, there is not any benefit to using IPv6 at home.

Yes, there is a benefit to using IPv6 at home. The main one is education, i.e. you will gain experience at administering an IPv6 network that you can put on your resume. In about two years from now, sometime in 2011, the world will run out of IPv4 addresses and there will be a surge in demand for IPv6 networking, and that includes a demand for people experienced in administering IPv6.
Your house is not a datacenter*

*unless it’s a start up
Your house is not a datacenter*

*unless it’s a start up
Your house is not a datacenter*

*unless it’s a start up
Pets vs Cattle (again…)  

Your house has pets  

- Frog - 192.168.0.1/24  
- Turtle - 192.168.0.2/24  
- Scared Rabbit - 192.168.0.3/24  
- Happy Dog - 192.168.0.4/24  
- Apathetic Cat - 192.168.0.5/24  
- Serious hamster - 192.168.0.6/24  
- Hypnotoad - 192.168.0.7/24
Pets vs Cattle (again…)

Your house has pets

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- Apathetic Cat - 192.168.0.5/24
- Serious hamster - 192.168.0.6/24
- Hypno-toad - 192.168.0.7/24

Your datacenter has cattle

- Cows - 10.0.0.0/8
  - Black cows - 10.1.0.0/16
  - Brown cows - 10.2.0.0/16
  - White cows - 10.3.0.0/16
- Sheeps - 172.16.0.0/12
  - Excited Sheeps - 172.16.0.0/16
  - Sleepy Sheeps - 172.17.0.0/16

Kubernetes cluster Is it really worth it? Infrastructure
Pets vs Cattle (again…)

Your house has pets

- Frog - 192.168.0.1/24
- Turtle - 192.168.0.2/24
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- Happy Dog - 192.168.0.4/24
- Apathetic Cat - 192.168.0.5/24
- Serious hamster - 192.168.0.6/24
- Hypnotoad - 192.168.0.7/24

Your datacenter has cattle containers

- Containers - 10.0.0.0/8
  - Yellow - 10.1.0.0/16
  - Orange - 10.2.0.0/16
  - Red - 10.3.0.0/16
  - Bordeaux - 10.4.0.0/16

---

Kubernetes cluster | Is it really worth it? | Infrastructure
Pets vs Cattle (again…)  

Your house has pets

- Frog - 192.168.0.1/24
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- Apathetic Cat - 192.168.0.5/24
- Serious hamster - 192.168.0.6/24
- Hypnotoad - 192.168.0.7/24

Your datacenter has cattle lots of containers

- Containers - 10.0.0.0/8
  - Yellow - 10.1.0.0/16
  - Orange - 10.2.0.0/16
  - Red - 10.3.0.0/16
  - Bordeaux - 10.4.0.0/16
  - Yellow 2 - 10.5.0.0/16
Pets vs Cattle (again…) 

Your house has pets

- Serious hamster - 192.168.0.6/24
- Hypnotoad - 192.168.0.7/24

Your datacenter has cattle lots of more containers

- Containers - 10.0.0.0/8
  - Yellow - 10.1.0.0/16
  - Orange - 10.2.0.0/16
  - Red - 10.3.0.0/16
  - Bordeaux - 10.4.0.0/16
  - Yellow 2 - 10.5.0.0/16
  - Orange 2 - 10.6.0.0/16
  - Blue 16 - 10.20.0.0/16
Pets vs Cattle (again…)

Your house has pets:

- Serious hamster - 192.168.0.6/24
- Hypnotoad - 192.168.0.7/24

Your datacenter has cattle lots of more and more containers:

- Containers - 10.0.0.0/8
  - Yellow - 10.1.0.0/16
  - Orange - 10.2.0.0/16
  - Red - 10.3.0.0/16
  - Bordeaux - 10.4.0.0/16
  - Yellow 2 - 10.5.0.0/16
  - Orange 2 - 10.6.0.0/16
  - Blue 16 - 10.20.0.0/16

Kubernetes cluster

Is it really worth it?

Infrastructure
Pets vs Cattle (again…)

Your house has pets

- Frog - 192.168.0.1/24
- Turtle - 192.168.0.2/24
- Scared Rabbit - 192.168.0.3/24
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Your datacenter has cattle lots of more and more containers

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  - Red - 10.3.0.0/16
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  - Yellow 2 - 10.5.0.0/16
  - Orange 2 - 10.6.0.0/16
  - Blue 16 - 10.20.0.0/16

ErrNoIPv4
Please help

No more IPv4s?! Let’s do NAT!
Pets vs Cattle (again…)!

Your house has pets

- Frog - 192.168.0.1/24
- Turtle - 192.168.0.2/24
- Scared Rabbit - 192.168.0.3/24
- Happy Dog - 192.168.0.4/24
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  - Yellow 2 - 10.5.0.0/16
  - Orange 2 - 10.6.0.0/16
  - Blue 16 - 10.20.0.0/16

No more IPv4s?! Let’s do NAT!
Let’s assemble our cluster

<table>
<thead>
<tr>
<th>On premises</th>
<th>Cloud</th>
</tr>
</thead>
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1. Does my OS support IPv6?...
Let’s assemble our cluster

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1. Does my OS support IPv6?...

2. Do my servers support IPv6?...

2. Do cloud providers support IPv6?
   - AWS
   - GCE
Let’s assemble our cluster

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1. Does my OS support IPv6?...

2. Do my servers support IPv6?...  
   2.1. Do cloud providers support IPv6?  
      - AWS  
      - GCE

3. Can and will my users use IPv6?
Let’s assemble our cluster

Cloud

- Do cloud providers support IPv6?
  - AWS
  - GCE
- Is use IPv6?
Let’s assemble our cluster

1. Does my OS support IPv6?...

2. Do my servers support IPv6?...

3. Can and will my users use IPv6?

2. Do cloud providers support IPv6?
   - AWS
   - GCE

Is it really worth it?

Infrastructure

Kubernetes - Does it run?
Let's assemble our cluster

1. Does my OS support IPv6?
2. Do my servers support IPv6?
3. Can and will my users use IPv6?

2. Do cloud providers support IPv6?
   - AWS
   - GCE

On premises, 1 in 5!
Let’s go deep dive!
Is it really worth it?

Infrastructure

Kubernetes - Does it run?

Kubernetes cheat sheet

- controller-manager
- kube-apiserver
- kube-scheduler

---

- etcd
  - master

- kubelet
- kube-proxy
  - (cni plugin)

- worker

---

- docker
1 - etcd

- 53 CLI options (etcd not etcdctl)
Is it really worth it? Infrastructure Kubernetes - Does it run?

1 - etcd

- 53 CLI options (etcd not etcdctl)
  - 5 relevant for IPv6
    - --advertise-client-urls 'http://localhost:2379'
    - --initial-advertise-peer-urls 'http://localhost:2380'
    - --initial-cluster 'default=http://localhost:2380'
    - --listen-client-urls 'http://localhost:2379'
    - --listen-peer-urls 'http://localhost:2380'
1 - etcd

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- Solution:
  - “http://localhost:2380” -> “http://[::1]:2380”
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- Solution:
  - “http://localhost:2380” -> “http://[::1]:2380”
- Is that simple? (Yes)
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- Is that simple? (Yes)

- What about https? (L4 != L3)
1 - etcd

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- Solution:
  - "http://localhost:2380" -> "http://[::1]:2380"

- Is that simple? (Yes)

- What about https? (L4 != L3)

- I meant the certificates! (Yes they are IPv6 aware)
2 - kube-scheduler

- 32 CLI options
2 - kube-scheduler

- 32 CLI options
  - ~3 relevant for IPv6
    - --address '0.0.0.0'
    - --master 'http://127.0.0.1:8080'
    - (--kubeconfig)
Is it really worth it?

Infrastructure

Kubernetes - Does it run?

2 - kube-scheduler

- 32 CLI options
  - ~3 relevant for IPv6
    - --address '0.0.0.0'
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- Solution:
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- “Simple” component
3 - kube-apiserver

- 120 CLI options!
3 - kube-apiserver

- 120 CLI options!
  - ~5 relevant for IPv6
    - --advertise-address ip
    - --bind-address '0.0.0.0'
    - --etcd-servers 'stringSlice'
    - --insecure-bind-address '0.0.0.0'
    - --service-cluster-ip-range ipNet
- 120 CLI options!
  - ~5 relevant for IPv6
    - --advertise-address ip
    - --bind-address '0.0.0.0'
    - --etcd-servers 'stringSlice'
    - --insecure-bind-address '0.0.0.0'
    - --service-cluster-ip-range ipNet
  - Solution:
    - "http://localhost:8080" -> "http://[::1]:8080"
  - --service-cluster-ip-range fd03::/112
    fd03::0000:0000:0000:0000:0000:0000:0000:0000/112
Is it really worth it?

Infrastructure

Kubernetes - Does it run?

3 - kube-apiserver

- 120 CLI options!
  - ~5 relevant for IPv6
    - --advertise-address ip
    - --bind-address '0.0.0.0'
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    - --insecure-bind-address '0.0.0.0'
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- Solution:
  - "http://localhost:8080" -> "http://[::1]:8080"

- --service-cluster-ip-range fd03::/112
  fd03::0000:0000:0000:0000:0000:0000:0000:0000/112

  frontend -> fd03::acde
  backend -> fd03::f00d
  kube-dns -> fd03::a (assigned by us)
3 - kube-apiserver

- 120 CLI options!
  - ~5 relevant for IPv6
    - --advertise-address ip
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    - --etcd-servers 'stringSlice'
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Do not try this at home with kubernetes < 1.8.0
https://github.com/kubernetes/kubernetes/pull/43586
4 - controller-manager

- 87 CLI options

controller-manager
kube-apiserver
kube-scheduler
master

kubelet
kube-proxy (cni plugin)
docker
worker 1

kubelet
kube-proxy (cni plugin)
docker
worker 2
4 - controller-manager

- 87 CLI options
  - ~5 relevant for IPv6
  - --address '(0.0.0.0)'
  - --allocate-node-cidrs 'true' (default: false)
  - --cluster-cidr 'fd02::/80'
  - --node-cidr-mask-size '96'
  - --service-cluster-ip-range 'fd03::/112'

controller-manager

VM network subnet - fd00::/16

master - fd00::b/16

worker 1 - fd00::c/16

worker 2 - fd00::d/16

Is it really worth it? Infrastructure Kubernetes - Does it run?
4 - controller-manager

controller-manager

master - fd00::b/16

worker 1 - fd00::c/16

worker 2 - fd00::d/16

physical cluster - fd00::/16

- 87 CLI options
  - ~5 relevant for IPv6
    - --address '(0.0.0.0)'
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    - --cluster-cidr 'fd02::/80'
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services- fd03::/112
Is it really worth it?

4 - controller-manager

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  - --cluster-cidr 'fd02::/80'
  - --node-cidr-mask-size '96'
  - --service-cluster-ip-range 'fd03::/112'

controller-manager

master - fd00::b/16

physical cluster - fd00::/16

worker 1 - fd00::c/16

worker 2 - fd00::d/16

services - fd03::/112

pods (containers) - fd02::/80
Is it really worth it?

Infrastructure

Kubernetes - Does it run?

4 - controller-manager

Cluster CIDR
fd02::/80

physical cluster - fd00::/16

- 87 CLI options
  - ~5 relevant for IPv6
    - --address '(0.0.0.0)'
    - --allocate-node-cidrs 'true' (default: false)
    - --cluster-cidr 'fd02::/80'
    - --node-cidr-mask-size '96'
    - --service-cluster-ip-range 'fd03::/112'

Services - fd03::/112

Pods (containers) - fd02::/80

Worker 1 - fd00::c/16

Worker 2 - fd00::d/16
4 - controller-manager

Cluster CIDR
fd02::0:0:0:0:0:0:0/80

Pod CIDR - 1st node
fd02::0:0:0:0:0:0:0:0/96

- 87 CLI options
  - ~5 relevant for IPv6
    - --address '(0.0.0.0)'
    - --allocate-node-cidrs 'true' (default: false)
    - --cluster-cidr 'fd02::/80'
    - --node-cidr-mask-size '96'
    - --service-cluster-ip-range 'fd03::/112'

physical cluster - fd00::/16

worker 1 - fd00::c/16
worker 2 - fd00::d/16

services- fd03::/112
pods (containers) - fd02::/80
Is it really worth it?

Infrastructure

Kubernetes - Does it run?

4 - controller-manager

Cluster CIDR
fd02:0:0:0:0:0:0:0/80

Pod CIDR - 1st node
fd02:0:0:0:0:0:0:0/96

Physical cluster - fd00::/16

- 87 CLI options
  - ~5 relevant for IPv6
    - --address '0.0.0.0'
    - --allocate-node-cidrs 'true' (default: false)
    - --cluster-cidr 'fd02::/80'
    - --node-cidr-mask-size '96'
    - --service-cluster-ip-range 'fd03::/112'

services - fd03::/112

pods (containers) - fd02::/80

worker 1 - fd00::c/16
worker 2 - fd00::d/16
Is it really worth it?

Infrastructure

Kubernetes - Does it run?

**4 - controller-manager**

Cluster CIDR

```
fd02:0:0:0:0:0:0:0/80
```

Pod CIDR - 1st node

```
fd02:0:0:0:0:0:0:0/96
```

Pod CIDR - 2nd node

```
fd02:0:0:0:0:1:0:0/96
```

physical cluster - fd00::/16

- 87 CLI options
  - ~5 relevant for IPv6
    - `--address '(0.0.0.0)'`
    - `--allocate-node-cidrs 'true'` (default: false)
    - `--cluster-cidr 'fd02::/80'`
    - `--node-cidr-mask-size '96'`
    - `--service-cluster-ip-range 'fd03::/112'`

services- fd03::/112

pods (containers) - fd02::/80

```
fd02::/96
```

```
fd02:0:0:0:0:1::/96
```

worker 1 - fd00::c/16

worker 2 - fd00::d/16
Is it really worth it?

Infrastructure

Kubernetes - Does it run?
Is it really worth it?

Infrastructure

Kubernetes - Does it run?

### What If I Told You

**Don’t need to care about IP addresses.**

Cluster CIDR
- `fd02:0:0:0:0:0:0:80` (default)

Pod CIDR - 1st node
- `fd02:0:0:0:0:0:0:96`

Pod CIDR - 2nd node
- `fd02:0:0:0:0:1:0:0:96`

Pod CIDR - 65536th node
- `fd02:0:0:0:0:ffff:0:0:96`

- 87 CLI options
  - ~5 relevant for IPv6
  - `--address '(0.0.0.0)'`
  - `--allocate-node-cidrs 'true'` (default: false)
  - `--cluster-cidr 'fd02::/80'`
  - `--node-cidr-mask-size '96'`
  - `--service-cluster-ip-range 'fd03::/112'`
Is it really worth it?

Infrastructure

Kubernetes - Does it run?

5 - docker

- a runtime container
- network plumbing made by:
  - libnetwork (IPv6 only with IPv4)
  - CNI
    blog.kubernetes.io/2016/01/why-Kubernetes-doesnt-use-libnetwork.html
Is it really worth it?

Infrastructure

Kubernetes - Does it run?

- choose your own flavour
  - cilium (IPv6 as a first-class citizen)
- Pod addressing
  - `--allocate-node-cidrs=true`
  - `--cluster-cidr fd02::/80`
  - `--node-cidr-mask-size '96'`
- Service routing

6 - cni plugin

Kubernetes - Does it run?

worker 1

worker 2

master

docker

docker

kubelet

kube-proxy

(cni plugin)
7 - kube-proxy

- No relevant options regarding IPv6
- Some CNI plugins rely on kube-proxy (not cilium)
8 - kubelet

- 160 CLI options (winner!)
  - ~3 relevant for IPv6
    - --address ('0.0.0.0')
    - --cluster-dns ('fd03::a')
    - --node-ip ('fd00::c')

- K8s PR #45551
Is it really worth it?

Infrastructure

Kubernetes - Does it run?
Where’s kube-dns?

- DNS for the k8s cluster
- Serves all DNS requests
Where's kube-dns?

- DNS for the k8s cluster
- Serves all DNS requests
- Deployment k8s spec file
- Service k8s spec file
- 1 Change in Deployment file
  - probe for AAAA instead of A

```bash
--probe=kubedns,[:1]:10053,kubernetes.default.svc.cluster.local,5,AAAA
--probe=dnsmasq,[:1]:53,kubernetes.default.svc.cluster.local,5,AAAA
```
Where's kube-dns?

controller-manager
kube-apiserver
kube-scheduler

etcd
master

kubelet
kube-proxy
(cni plugin)

(kube-dns)

Is it really worth it?

Infrastructure

Kubernetes - Does it run?
Where's ingress?

- NGinx Ingress controller
- Exposes your pods to the outside
- Deployment k8s spec file
- Service k8s spec file
- No changes needed
Where's ingress?

- **controller-manager**
- **kube-apiserver**
- **kube-scheduler**

**etcd**

**master**

**kubelet**
**kube-proxy**

(cni plugin)

**docker**

**worker 1**

**kubelet**
**kube-proxy**

(kube-dns)

**docker**

**worker 2**
Kubernetes cluster - demo!

worker 1
- kube-dns
- redis-slave
- docker
- cilium

worker 2
- guestbook
- redis-master
- docker
- cilium

Kubernetes - Does it run? Demo Final thoughts
Kubernetes cluster - demo!

Kubernetes cluster - demo!

kube-dns

redis-slave

guestbook

redis-master

docker
cilium

docker
cilium

worker 1

worker 2

Kubernetes - Does it run?  Demo  Final thoughts
Kubernetes cluster - demo!

Worker 1:
- kube-dns
- redis-slave
- docker
- cilium

Worker 2:
- guestbook
- redis-master
- docker
- cilium

Kubernetes - Does it run?  Demo  Final thoughts
Kubernetes cluster - demo!

 worker 1

 worker 2

 kube-dns

 guestbook

 redis-slave

 redis-master

 docker

 cilium

 docker

 cilium

 Kubernetes - Does it run?  Demo  Final thoughts
Kubernetes cluster - demo!

Kubernetes cluster - demo!
Kubernetes cluster - demo!

- kube-dns
- guestbook
- redis-slave
- redis-master
- worker 1: docker, cilium
- worker 2: docker, cilium

Kubernetes - Does it run?  Demo  Final thoughts
Kubernetes cluster - demo!

Worker 1:
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- redis-slave
- docker
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Kubernetes - Does it run?  Demo  Final thoughts
Kubernetes cluster - demo!

worker 1
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- redis-slave
- docker
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Kubernetes - Does it run? Demo Final thoughts
Kubernetes cluster - demo!
Final thoughts

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    - Dual stack! - GH #27398
    - Kubelet’s node IP option with IPv6 - PR #45551
    - Waive IPv6 prefix size limit for cluster CIDR - PR #52033
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Final thoughts

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- Unless you try it you’ll never find out.
Thank You!

Q & A

Coming next… @ 2:50 pm in Diamond Ballroom 6 (this room)

Cilium - Container Security and Networking Using BPF and XDP
By Thomas Graf, Covalent

We are on Booth 501
https://www.cilium.io

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