



netlab

Bringing the joy back to virtual networking labs

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Who is Ivan Pepelnjak (@ioshints)

Past

- Kernel programmer, network OS, and web developer
- Sysadmin, database admin, network engineer, CCIE
- Trainer, course developer, curriculum architect
- Team lead, CTO, business owner

Present

- Network architect, consultant, blogger, webinar, and book author

Focus

- SDN and network automation
- Large-scale data centers, clouds, and network virtualization
- Scalable application design
- Core IP routing/MPLS, IPv6, VPN



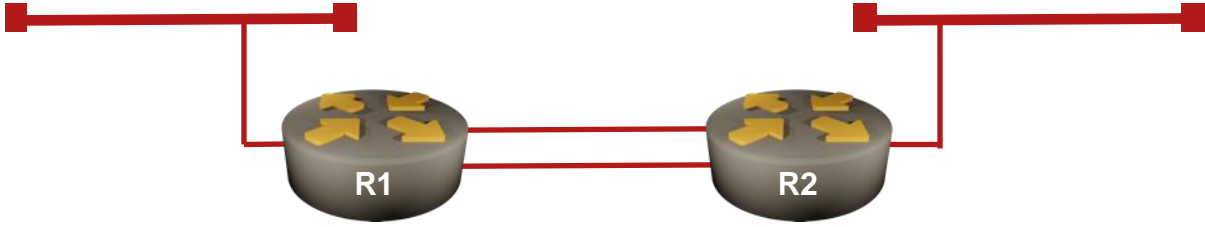
Also: I built too many labs for one lifetime, and hated that with passion

Based on a True Story

Pär Stolpe 01 September 2023 12:06

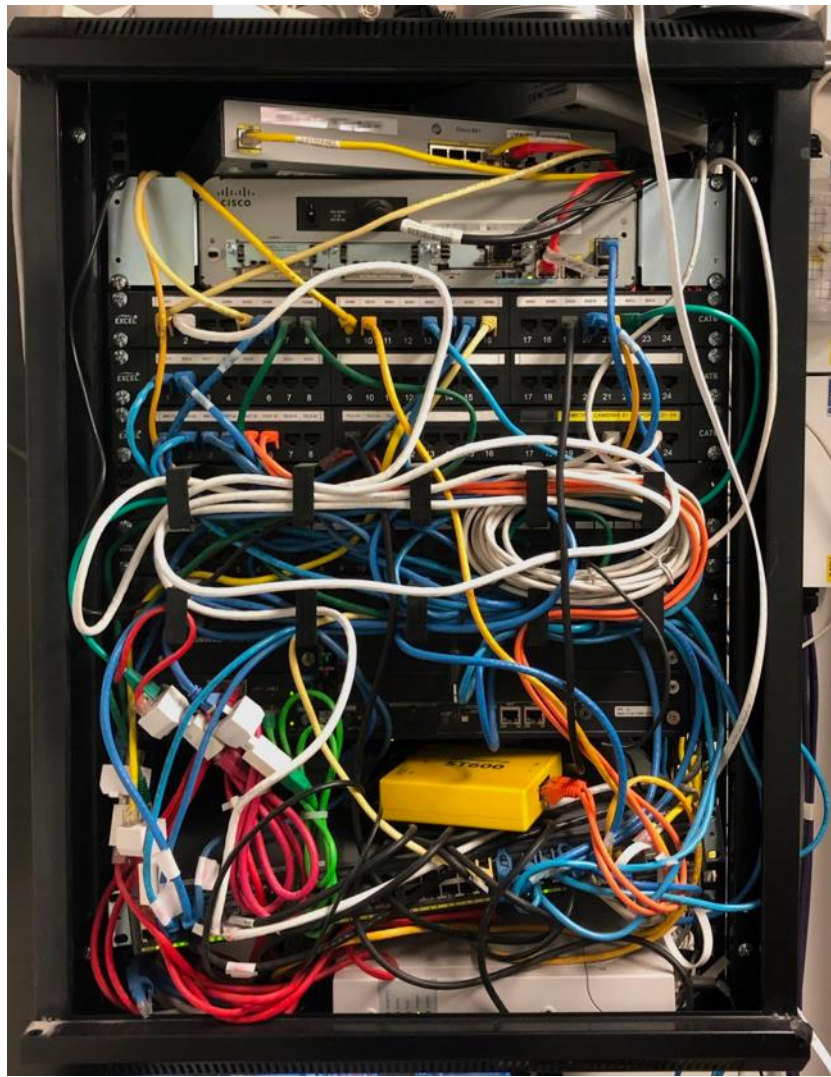
Beware of the fact that having more than one ospf link in between the same two nodes, together with unnumbered interfaces for multipathing purposes would most likely cause troubles. I don't know if any vendor have solved it or if they just recommend using link aggregation instead.

 **reply**



That should be trivial to test in a lab... However, someone has to build that lab...

The Reality Intervenes...



VM Maestro

Projects: My Topologies (routegen.virl, routeserver.virl, SpringBoard.virl)

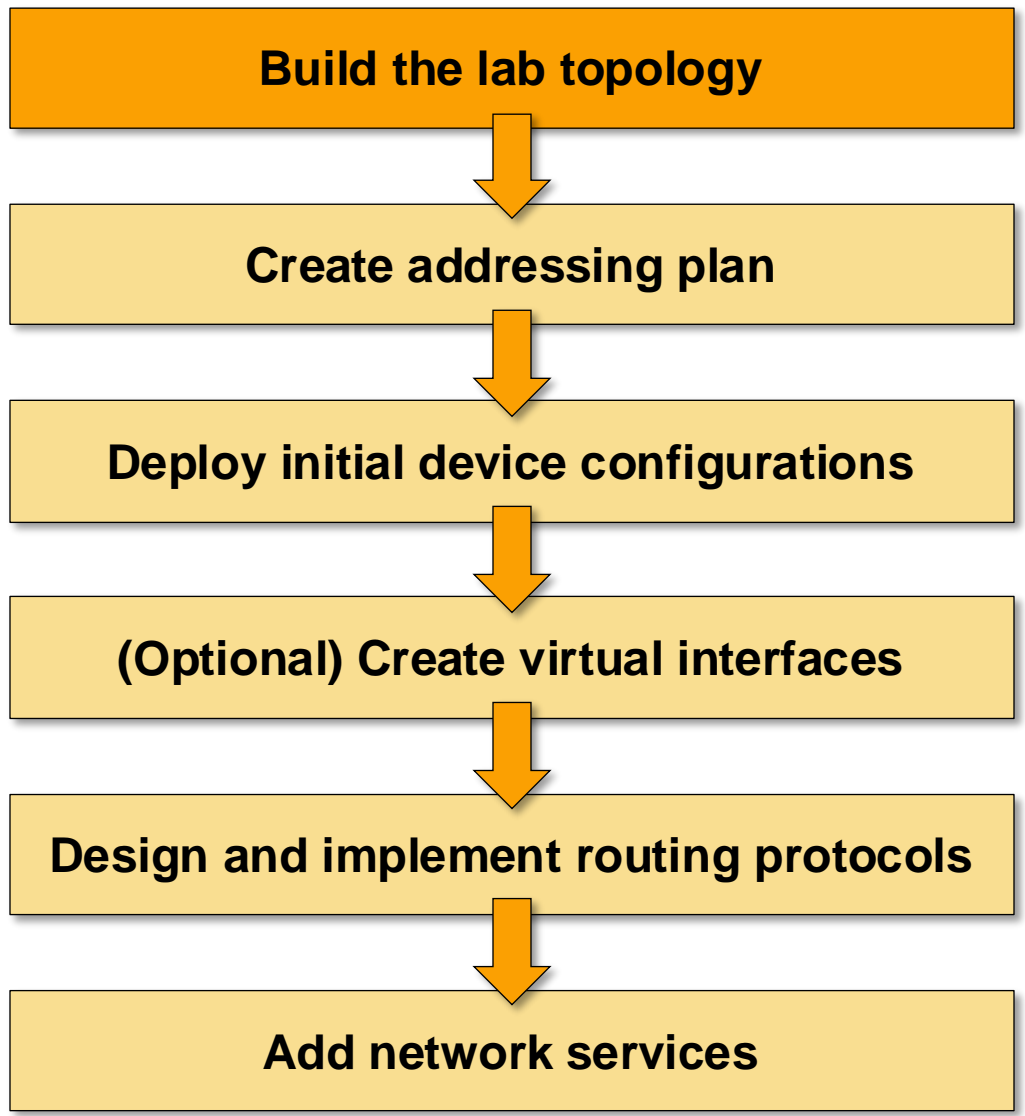
Thbbft! virl:topology

Simulations: Thbbft! (Last updated: Sun Jul 10 10:40:35 PDT 2016)

- guest
 - Thbbft!
 - Atlanta [ACTIVE]
 - Berlin [ACTIVE]
 - Boston [ACTIVE]
 - Dallas [ABSENT]
 - Denver [ACTIVE]
 - London [ACTIVE]
 - Milan [ACTIVE]
 - Paris [ACTIVE]
 - Seattle [ACTIVE]
 - Vienna [ACTIVE]
 - ~lxc-flat
 - External Address [172.16.1.51]
 - Forwarding Port on Server [10000]
 - ~mgmt-lxc interface [eth0]
 - ~mgmt-lxc [ACTIVE]

Console: Unknown simulation Thbbft!
(INFO) [Jul/10/2016 16:46:30] Starting node "~mgmt-lxc"
(INFO) [Jul/10/2016 16:46:45] Node "Berlin" state changed from BUILDING to ACTIVE
(INFO) [Jul/10/2016 16:46:45] Node "Boston" state changed from BUILDING to ACTIVE
(INFO) [Jul/10/2016 17:39:47] Stopping node "Dallas"
(INFO) [Jul/10/2016 17:40:03] Node "Dallas" state changed from ACTIVE to ABSENT

A Networking Lab Is Much More than Topology





And now for something completely different

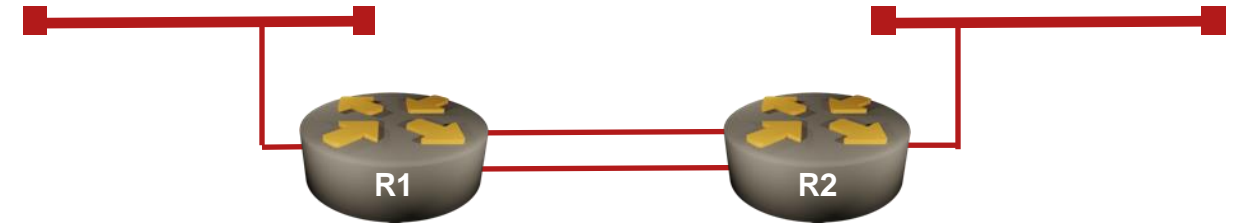
What Do We Need (in Unicorn Land of Infrastructure-as-Code)

Create a high-level description of the network

- Two devices: R1 and R2
- Let's make them Arista EOS containers
- They are running OSPF
- We need four links (two of them stub LANs)
- Oh, we're running unnumbered links...

Next

- Save the file
- Execute **netlab up** and you'll get a running network (including IP addressing and OSPF)



topology.yml

```
nodes: [ r1, r2 ]

defaults.device: eos
provider: clab

module: [ ospf ]

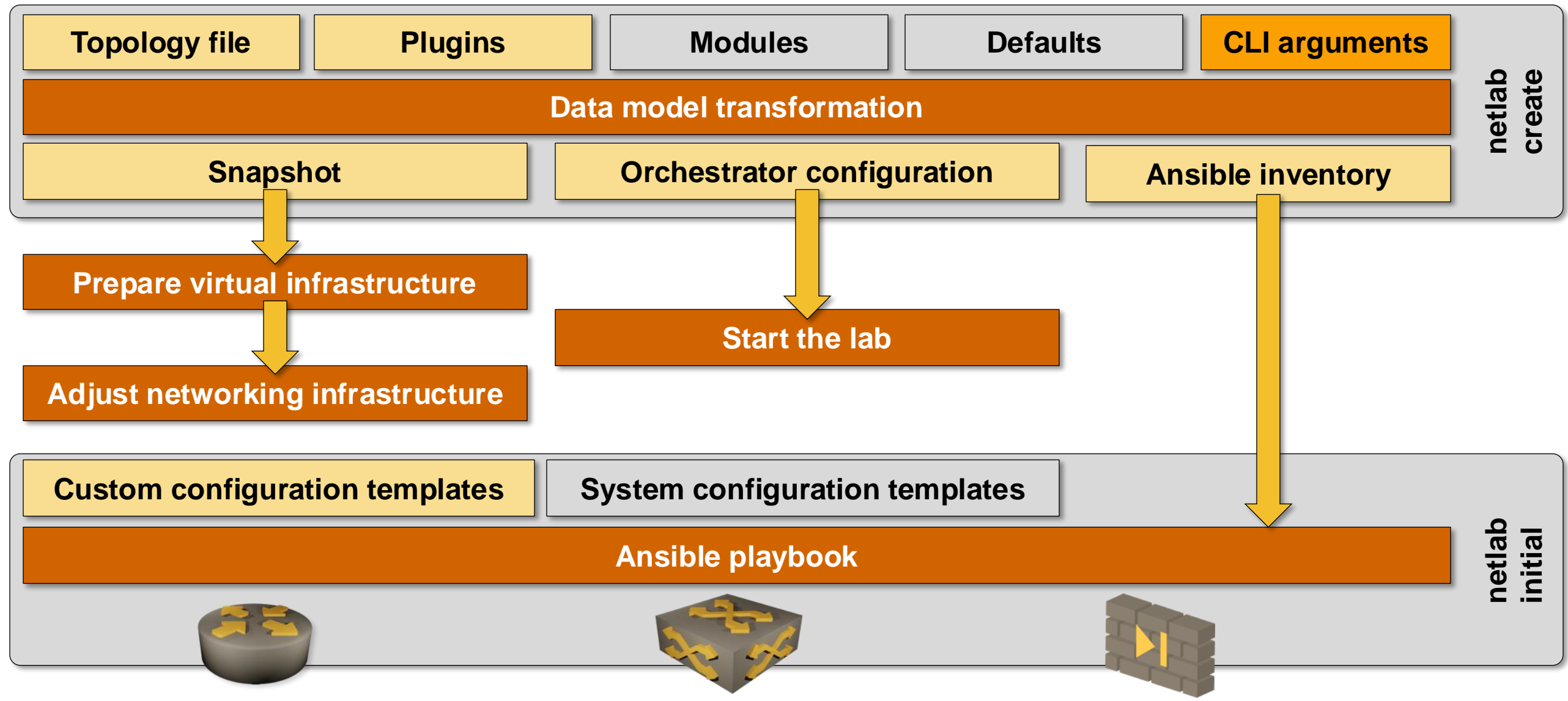
links: [ r1, r2, r1-r2, r1-r2 ]

addressing.p2p.ipv4: True
```

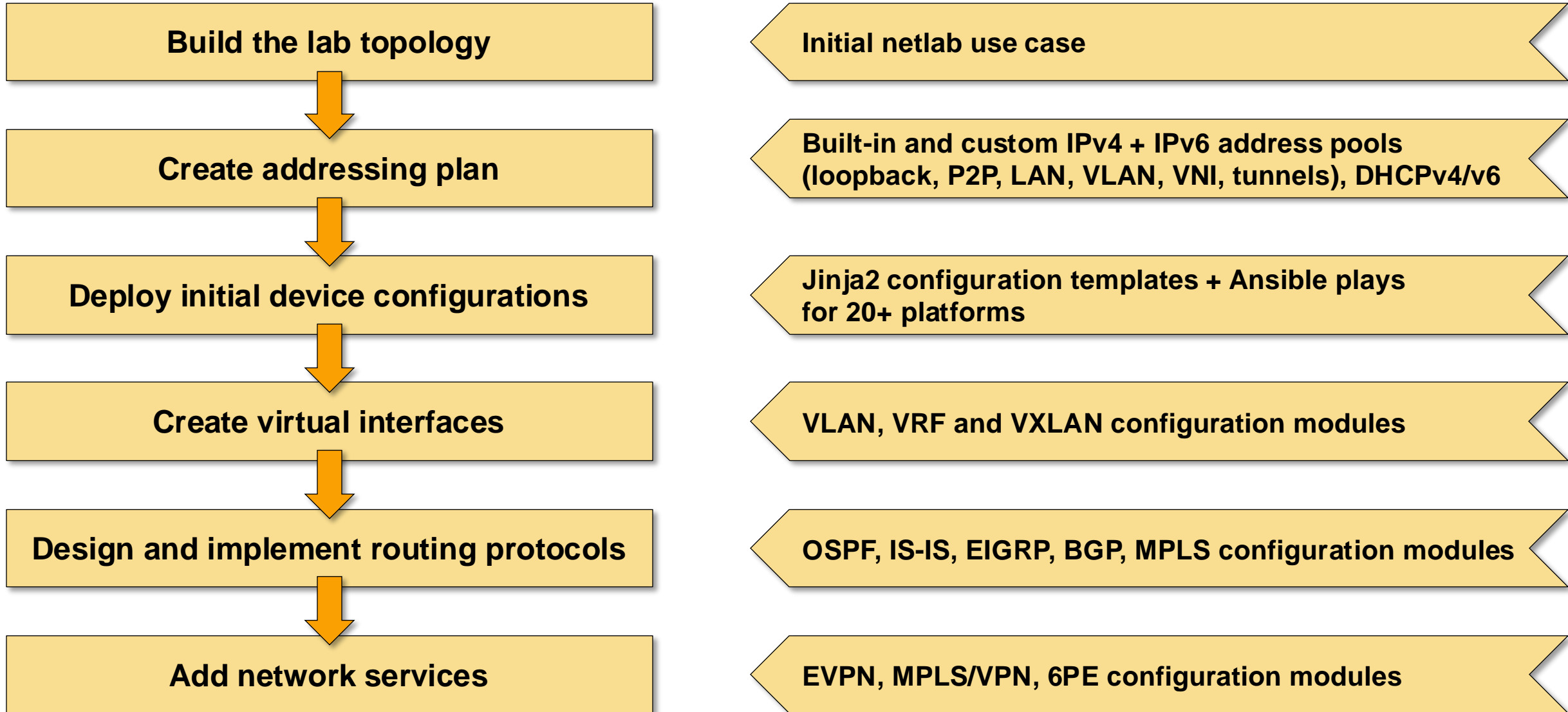
```
$ netlab up -p clab -d eos parallel.yml █
```

- Create configuration files
- Start the containers
- Start an Ansible playbook
- Initial device configuration
- Configuring OSPF
- Connect to the device
- ... and we have the answer!

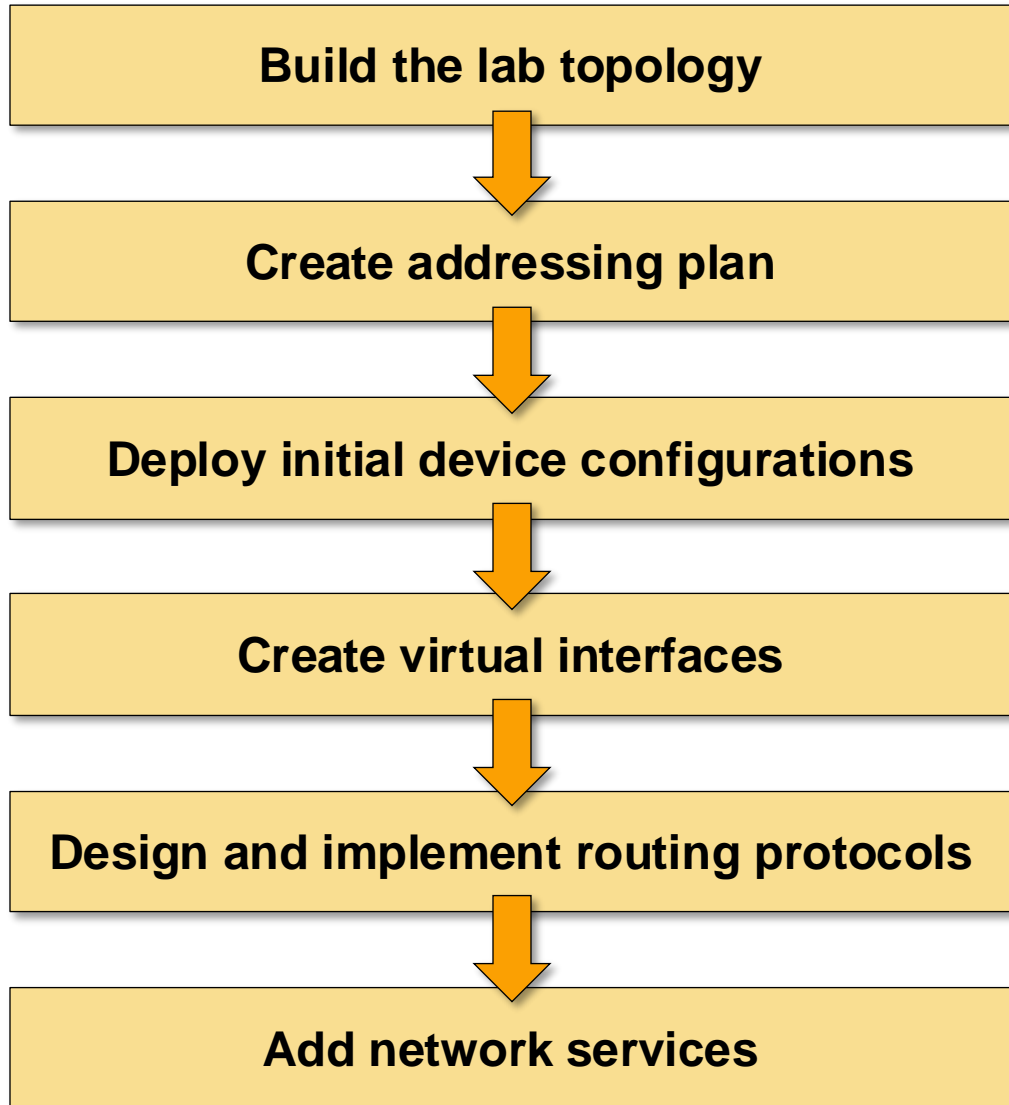
Wait, What Just Happened? netlab up Behind the Scenes



Building a Networking Lab with netlab



Every Lab Is Special



Add custom configuration

- Static configuration templates
- Configuration templates modifying built-in configurations
- Multi-vendor and multi-platform support

Modify data transformation with plugins

- Modify the built-in transformation rules
- Add new functionality (example: IP anycast)
- Add new attributes or functionality to existing configuration modules (example: BGP allowas-in)

Current State of netlab (October 2024)

Network devices

- Arista vEOS/cEOS
- Aruba CX
- Cisco ASAv, IOSv, IOSvL2, IOL, IOLL2, CSR 1000v, Catalyst 8000v, Nexus OS (9300v), IOS XR/XRd
- Cumulus Linux 4.x and 5.x (NVUE)
- Dell OS10
- Fortinet
- FRR
- Juniper vSRX 3.0, vMX, vPTX (vEVO), vJunos-switch
- Mikrotik RouterOS 6 and 7
- Nokia SR Linux and SR OS
- Sonic
- VyOS 1.4 and 1.5

Hosts and daemons

- Generic Linux host or container
- BIRD
- dnsmasq

Virtualization providers

- KVM with libvirt (Vagrant)
- Docker (containerlab)
- Hardware labs (requires extra interface information)
- VirtualBox (Vagrant) (deprecated)

Multi-provider topologies

- Combine containers and virtual machines in the same lab
- Connect external devices with the virtual lab

Current State of netlab (October 2024)

Addressing

- IPv4 + IPv6
- Address pools + static prefixes
- VLAN-wide subnets
- Static interface addresses
- Unnumbered IPv4 and IPv6 (LLA) interfaces
- Layer-2-only interfaces
- DHCP (clients, servers, relays)

Data Plane

- VLANs and VRFs
- VXLAN (static ingress replication or EVPN)
- MPLS including SR-MPLS
- SRv6
- Tunnel interfaces

Routing and Routing Protocols

- OSPFv2, OSPFv3, IS-IS, RIP, EIGRP
- BGP
- BFD
- Routing policies
- Route redistribution and default routes
- Prefix filters, AS-path filters, BGP community filters
- VRRP and anycast gateways

MPLS Control Plane

- LDP, BGP-LU, SR-MPLS (IS-IS)

Network Virtualization

- MPLS L3VPN and 6PE
- EVPN (bridging, VLAN bundles, asymmetric and symmetric IRB, most combinations of IGP and BGP)

Sample Platform Support

Operating system	Hostname	IPv4 hosts	LLDP	Loopback IPv4 address	Loopback IPv6 address
Arista EOS	✓	✓	✓	✓	✓
Aruba AOS-CX	✓	✗	✓	✓	✓
Cisco ASA v	✓	✓	✗	✗	✗
Cisco IOS/IOS XE	✓	✓	✓	✓	✓
Cisco IOS XRv	✓	✓	✓	✓	✓
Cisco Nexus OS	✓	✓	✓	✓	✓
Cumulus Linux	✓	✓	✓	✓	✓
Cumulus Linux 5.0 (NVUE)	✓	✓	✓	✓	✓
Dell OS10	✓	✓	✓	✓	✓
Fortinet FortiOS	✓	✗	✓	✓	✓
FRR	✓	✓	✗	✓	✓
Generic Linux	✓	✓	✓!	✓	✓
Juniper vMX	✓	✗	✓	✓	✓
Juniper vPTX	✓	✗	✓	✓	✓
Juniper vSRX 3.0	✓	✗	✓	✓	✓
Mikrotik RouterOS 6	✓	✓	✓!	✓	✓
Mikrotik RouterOS 7	✓	✓	✓!	✓	✓
Nokia SR Linux	✓	✓	✓	✓	✓
Nokia SR OS	✓	✓	✓	✓	✓
VyOS	✓	✓	✓	✓	✓

Operating system	OSPF	IS-IS	EIGRP	BGP	BFD	EVPN	FHRP
Arista EOS	✓	✓	✗	✓	✓	✓	✓
Aruba AOS-CX	✓	✗	✗	✓	✓	✓	✓
Cisco ASA v	✗	✓	✗	✓	✗	✗	✗
Cisco IOSv	✓	✓	✓	✓	✓	✗	✓
Cisco IOS XE	✓	✓	✓	✓	✓	✗	✓
Cisco IOS XRv	✓	✓	✗	✓	✗	✗	✗
Cisco Nexus OS	✓	✓	✓	✓	✓	✓	✓
Cumulus Linux	✓	✗	✗	✓	✗	✓	✓
Cumulus Linux 5.0 (NVUE)	✓	✗	✗	✓	✗	✗	✗
Dell OS10	!	✗	✗	✓	✓	✓	✗
Fortinet FortiOS	!	✗	✗	✗	✗	✗	✗
FRR	✓	✓	✗	✓	✗	✓	✗
Juniper vMX	✓	✓	✗	✓	✓	✗	✗
Juniper vPTX	✓	✓	✗	✓	✓	✗	✗
Juniper vSRX 3.0	✓	✓	✗	✓	✓	✗	✗
Mikrotik RouterOS 6	✓	✗	✗	✓	✓	✗	✗
Mikrotik RouterOS 7	✓	✗	✗	✓	✓	✗	✗
Nokia SR Linux	✓	✓	✗	✓	✓	✓	✓
Nokia SR OS	✓	✓	✗	✓	✓	✓	✓
VyOS	✓	✓	✗	✓	✓	✓	✗

But Wait, There's More

Ease-of-use

- Combining VMs and containers in the same lab
- Graphs (Graphviz or D2)
- Graphite GUI 🍰 🍰 🍰
- Wiring, addressing, OSPF, and BGP reports (text, Markdown, HTML)
- Packet capture on VM and container interfaces
- Automated validation
- Multiple lab instances on a single server
- Restore previous configurations

External Connectivity

- Macvtap libvirt interfaces
- Macvlan container interfaces
- Port forwarding for VMs and containers

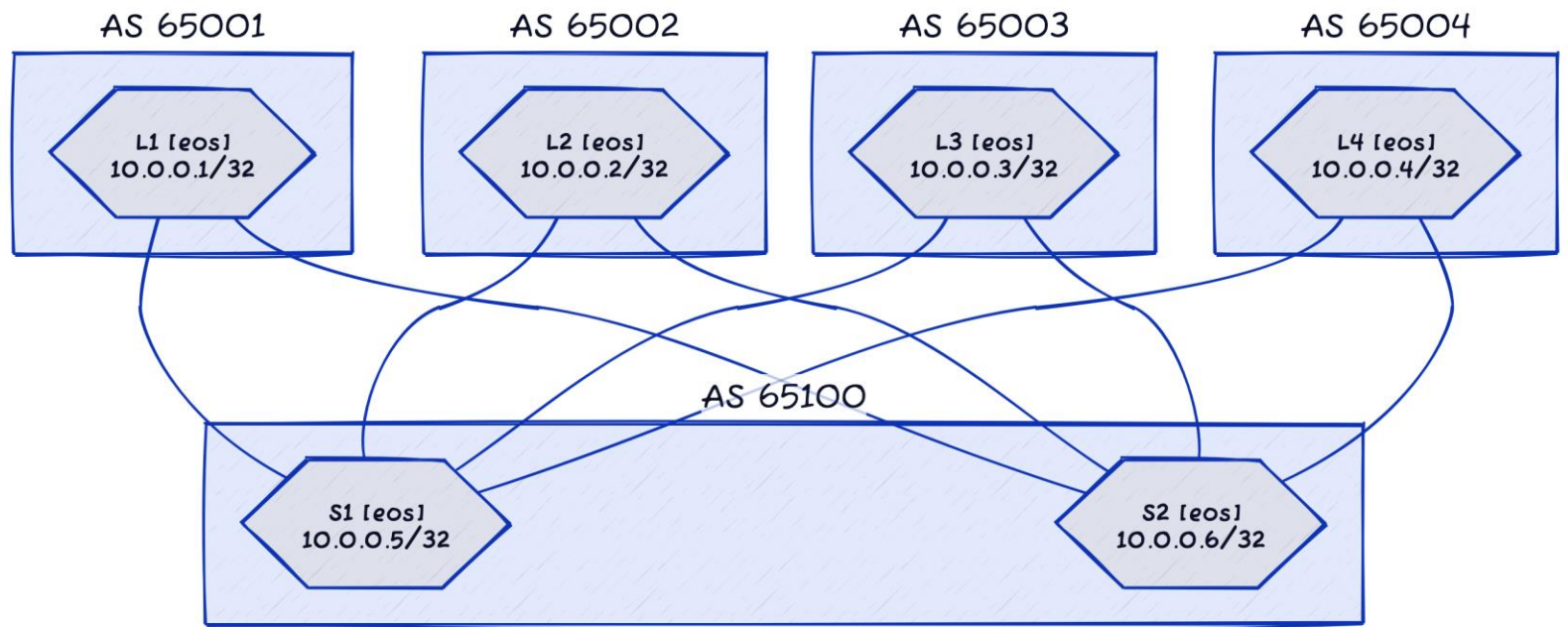
Large topologies

- Topology templates
- Staggered device start
- Link groups

External Tools

- SuzieQ
- Graphite

Example: Graph (D2)



Example: Addressing Report (BGP)

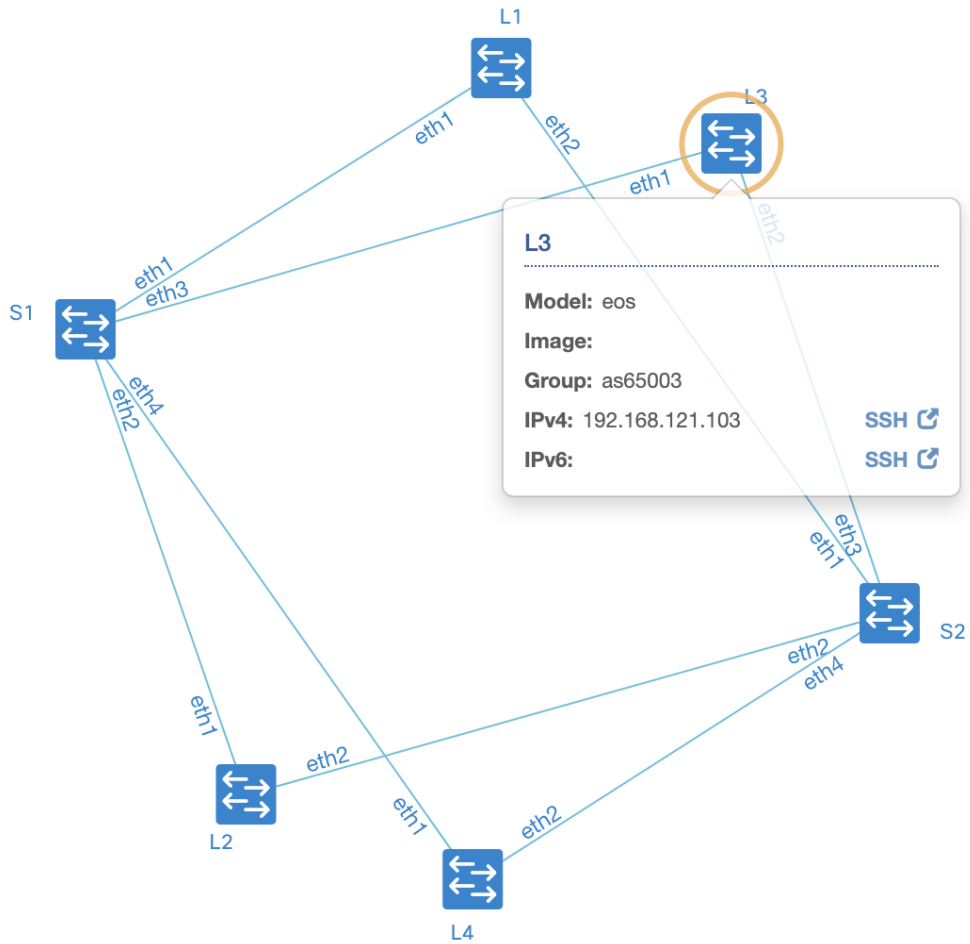
BGP AS Numbers

NODE/ASN	ROUTER ID	ADVERTISED PREFIXES
AS65001		
L1	10.0.0.1	10.0.0.1/32
AS65002		
L2	10.0.0.2	10.0.0.2/32
AS65003		
L3	10.0.0.3	10.0.0.3/32
AS65004		
L4	10.0.0.4	10.0.0.4/32
AS65100		
S1	10.0.0.5	10.0.0.5/32
S2	10.0.0.6	10.0.0.6/32

BGP Neighbors

NODE	NEIGHBOR	NEIGHBOR AS	NEIGHBOR IPV4
L1 (10.0.0.1 / AS 65001)			
	S1	65100	10.1.0.2
	S2	65100	10.1.0.6
L2 (10.0.0.2 / AS 65002)			
	S1	65100	10.1.0.10
	S2	65100	10.1.0.14
L3 (10.0.0.3 / AS 65003)			
	S1	65100	10.1.0.18
	S2	65100	10.1.0.22
L4 (10.0.0.4 / AS 65004)			
	S1	65100	10.1.0.26
	S2	65100	10.1.0.30

Example: Graphite GUI



Example: Network Validation

```
$ netlab validate
[session] Check IPv6 EBGP session with RTR on ISP routers [ node(s): x1,x2 ]
[PASS] Validation succeeded on x1
[PASS] Validation succeeded on x2
[PASS] The IPv6 EBGP session with RTR is in Established state

[pfxcnt] Check whether RTR receives and sends IPv6 prefixes [ node(s): x1,x2 ]
[PASS] Validation succeeded on x1
[PASS] Validation succeeded on x2
[PASS] RTR is advertising IPv6 prefixes to ISP routers

[advroute] Check whether RTR advertises 2001:db8:1::/48 [ node(s): x1,x2 ]
[PASS] Validation succeeded on x1
[PASS] Validation succeeded on x2
[PASS] RTR is advertising 2001:db8:1::/48 to ISP routers

[SUCCESS] Tests passed: 6
$ █
```

Deployment Scenarios

**Open-Source BGP
Configuration Labs**

[Deploy BGP in Your Network](#)

[BGP Routing Policies](#)

[Challenge Labs](#)

[Recent Labs](#)

Open-Source BGP Configuration Labs

This series of BGP hands-on labs will help you master numerous aspects of EBGP, IBGP, and BGP routing policy configuration on a [platform of your choice](#)¹, including:

- Arista EOS
- Aruba AOS-CX
- Cisco ASAv, IOSv, IOS XE, IOS XR and Nexus OS
- Cumulus Linux and FRR
- Dell OS10
- Juniper vSRX, vMX and vPTX
- Mikrotik RouterOS
- Nokia SR OS and SR Linux
- Vyatta VyOS

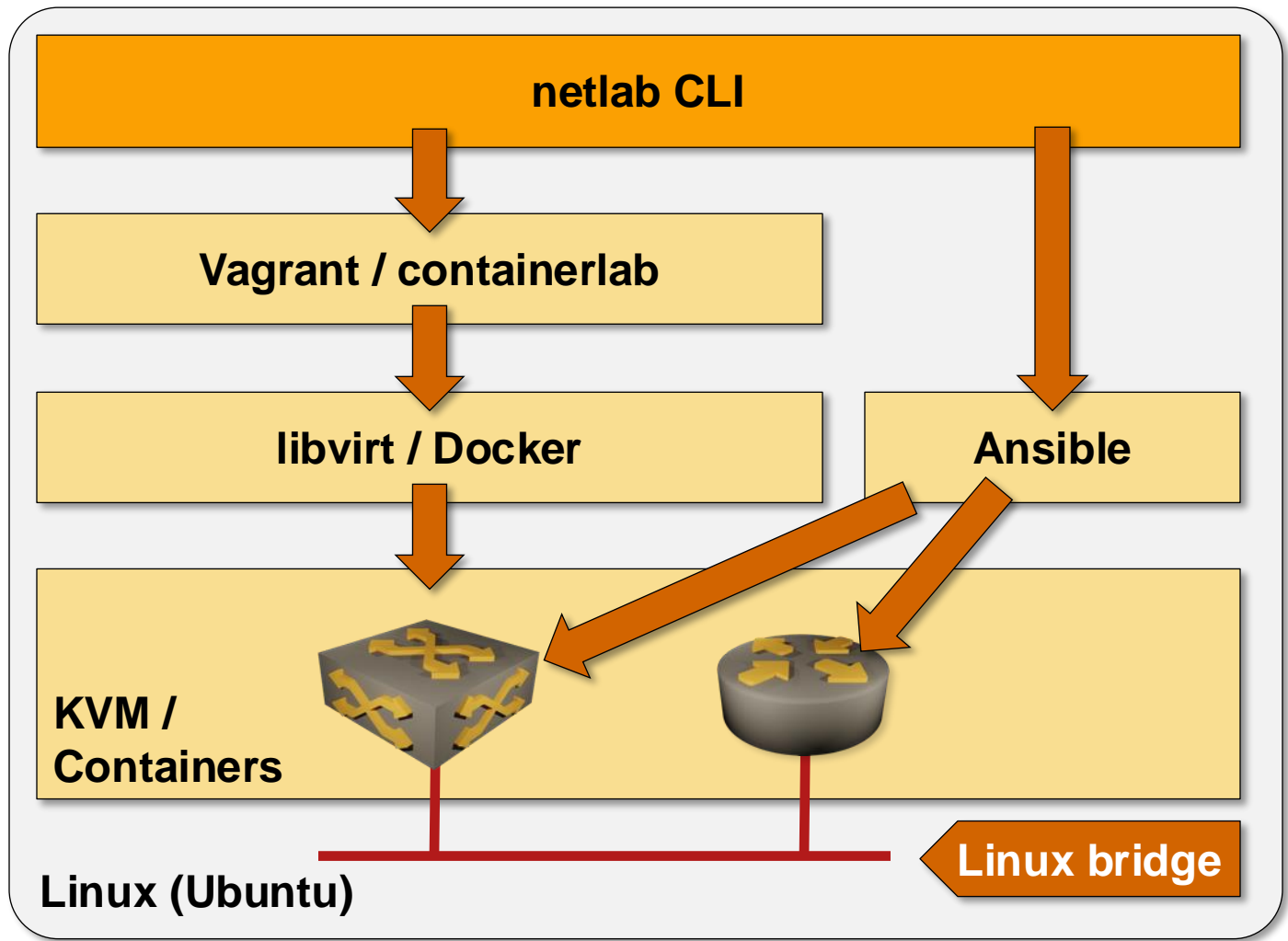
Dozens of labs are already waiting for you (with more [coming soon](#)), but if this is your first visit to this site, you should start with the [Installation and Setup](#) documentation or [run BGP labs in GitHub codespaces](#).

Deploy BGP in Your Network

In the first set of the BGP labs, you'll master these skills:

- [Configure and monitor routing daemons on Cumulus Linux and FRRouting](#)
- [Configure BGP sessions and advertise IPv4 and IPv6 prefixes](#)
- [Protect BGP sessions](#)
- [Run BGP in networks with more than one BGP router](#)
- [Manipulate BGP AS numbers or AS paths](#) with nerd knobs like **as-override** and **local-as**

Recommended: Ubuntu, KVM, libvirt, Docker



- Install Python3 and Pip
- Install netlab package
- Run netlab installation scripts

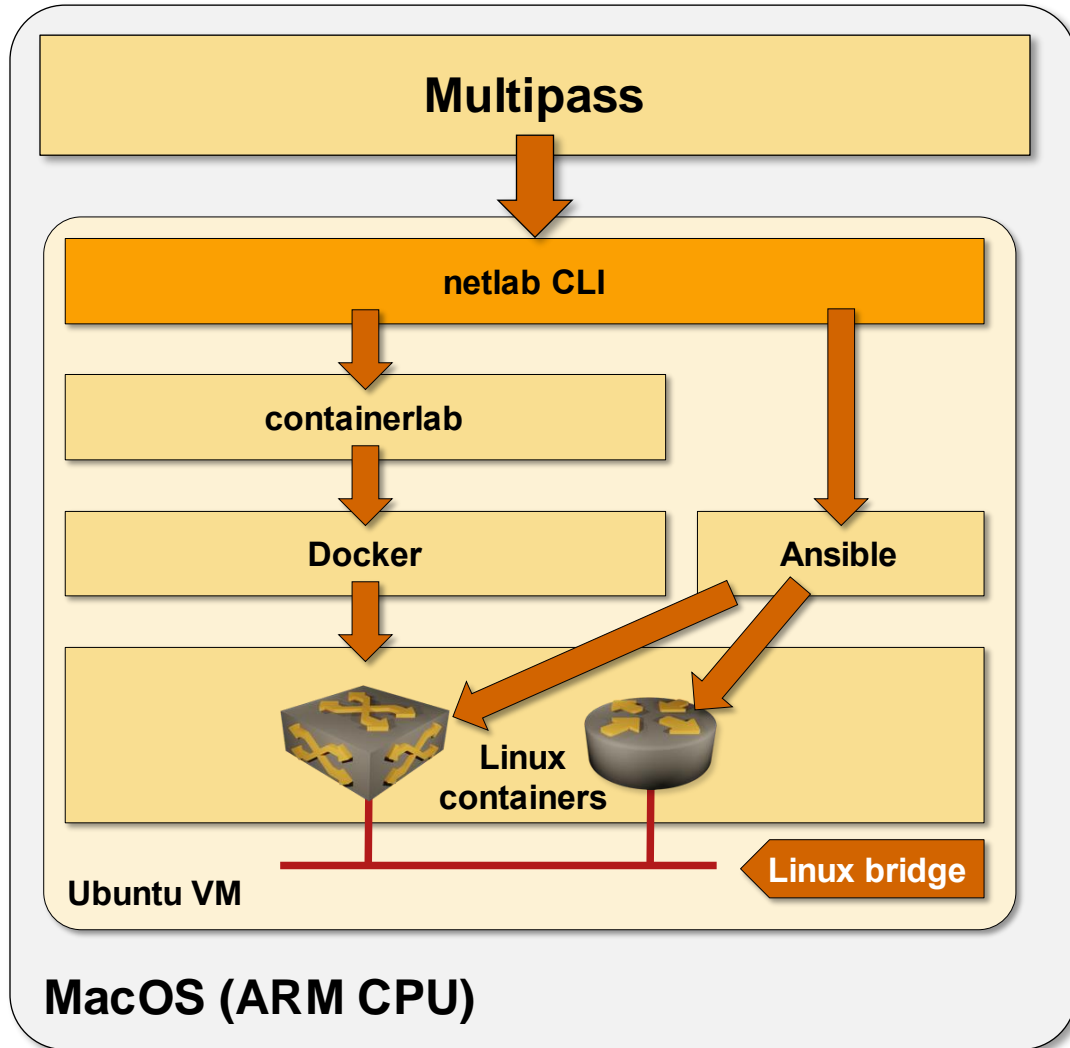
Netlab installation scripts

- Ubuntu utilities
- KVM, libvirt, vagrant (VMs)
- Docker and containerlab (containers)
- Ansible

Other Linux distros

- You're on your own
- WSL, AlmaLinux/RHEL, Suse, Nixos...

Ubuntu VM on Apple Silicon



- **multipass** starts an Ubuntu VM on an ARM CPU
- Nested virtualization is not supported → containers only
- Container images must be built for the ARM CPU → FRRouting and SR Linux (at the moment)

Interesting use cases

- Run BGP, VXLAN, or EVPN labs on your Apple laptop
- FRRouting control-plane configuration syntax is pretty close to the *industry standard CLI*



Is It Worth It? What Others Are Saying...



Lou D. • 2nd 4h (edited) ...
Network Security Engineer | Network Automation

I fully agree with Ivan's point on the show about being exhausted building labs . Netlab is really one the best tools to help me build fairly complex network designs quick and also cheap ! I don't need so much resource provisioning to get something started a tiny aws Ubuntu box will build an decent amount of nodes .

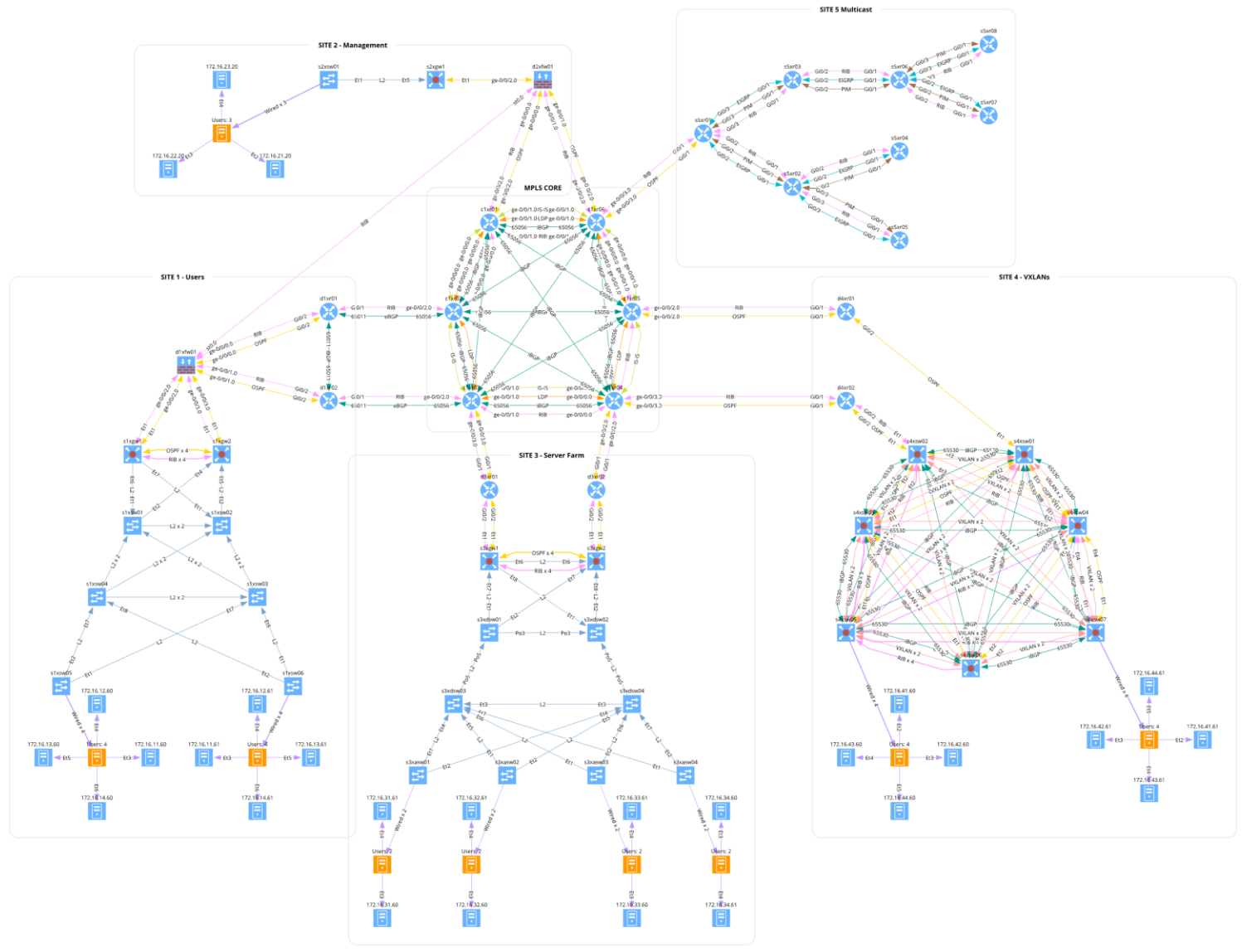
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Ethan Banks • 1st ...
IT Podcast Host & Industry Analyst
1mo ·

If you work with networking labs but haven't worked with the netlab project, you need to. YAML-defined labbing, essentially. So much of the tedious work is just done for you. You don't have to drag icons around on a canvas and make links and setup IP addressing and configure routing and and and. Just tell netlab what you want it to build in the YAML file. Then "netlab up".

What Others Are Building with netlab



How Can You Help?

- Spread the word ;)
- Use the tool to build your labs
- Ask questions and report bugs

Want to contribute?

- Fix documentation
- Fix bugs
- Add new functionality to existing devices (example: VXLAN on IOS XR or vPTX)
- Add new devices

Still not enough?

- Develop new plugins (hint: OSPF interface parameters)
- Develop new modules (IP multicast, Babel...)



Questions?

Netlab resources

- Documentation: [netlab.tools](#)
- Blog posts: blog.ipSpace.net/tag/netlab
- Source code: github.com/ipSpace/netlab
- Examples: github.com/ipSpace/netlab-examples
- Sample projects: bgplabs.net
isis.bgplabs.net

To reach me

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