Building a Test-Driven Network Infrastructure

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Introductions

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Disclaimer

This presentation does not reflect the views or opinions of my employer or anyone else. They're mine. They're probably wrong.

Who am I?

- Network Architect
  - I make *some* decisions
    - Hardware
    - Logical and physical designs
- Aspiring Pythonista
- Lover of Regular Expressions

Where am I?

- Twitter: @supertylerc
- GitHub: @supertylerc
- GitLab: @supertylerc

Who are *you*?

- Network engineers/administrators/technicians?
- Linux engineers/administrators/technicians?
- Software engineers/developers?

What Isn't This?

- How to Install <software>
- How to Configure <protocol>
- How to Design <system>
- How to […]

What Is This?

- An Exploration of Problems and Potential Solutions
- An Introduction to CI/CD Practices in Networking

Misalignment

Business vs. Network

- Networks are:
  - Frequently Complex
  - Generally Slow to Adapt
  - Often 100% Production
    - "Everybody has a testing environment. Some people are lucky enough to have a totally separate environment to run production in."

Business vs. Network

- Businesses Need:
  - Transport of Services
  - Rapid Response and Agility
  - Reliability and Stability

Networking is a Little Behind

- Minimal Virtualization of Networks
  - RAM Gluttons: 8-16GB RAM for one VM
  - Limited Data Plane: ASICs
- Limited Automation Tooling
  - Ansible
  - SaltStack

Networking is a Little Behind

- Less Familiarity with Software Engineering
  - Python is Gaining Ground
  - CI/CD are Nearly Foreign
- View of Networks is Skewed
  - Protocols: General view of network professionals
  - Services: This is what we really enable

Aligning Networking

Networks Transport Services

- View Configuration as Services
  - Not per device
  - Full configuration to support a service over the base of the underlying network

Software Engineering Principles are Critical

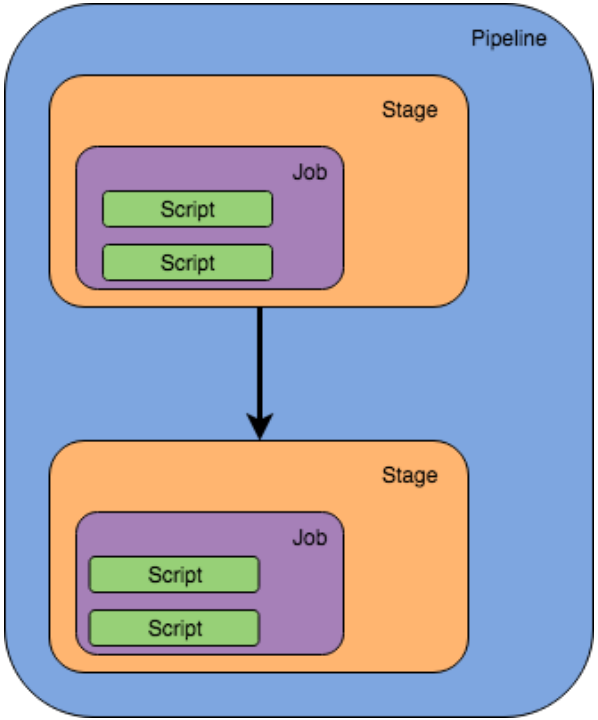
- The basics of variables and flow control are necessities
- Modularity is your friend
- Pipelines are the foundation of this entire talk

Pipelines

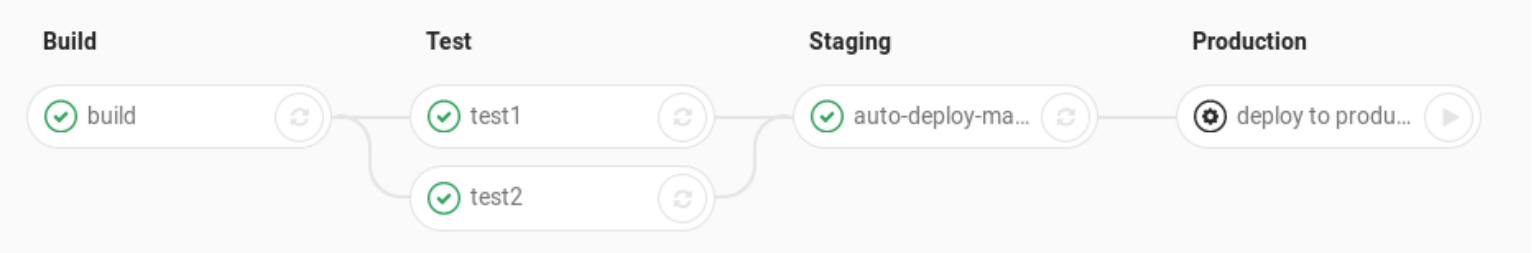
Definitions

- Job: a series of instructions
  - Sequential
- Stage: a collection of jobs
  - Nonsequential
- Pipeline: a collection of stages
  - (Usually) Sequential

Pipeline Hierarchy



Example Pipeline

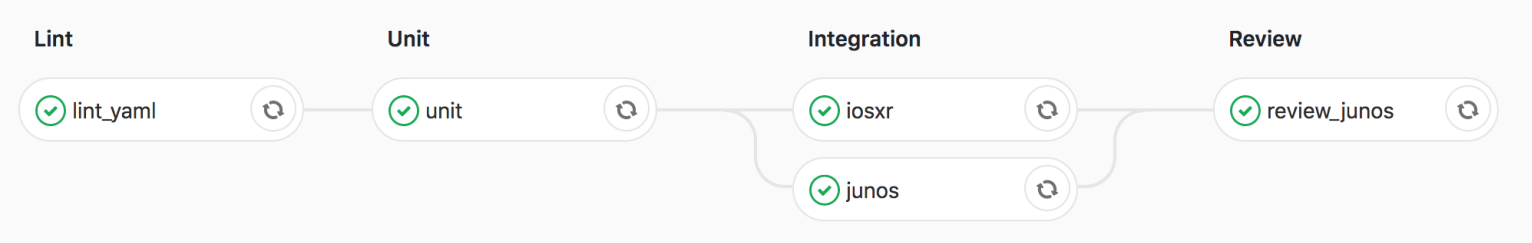


Source: https://docs.gitlab.com/ee/ci/pipelines.html

Network Pipelines

- Same as Software Pipelines
  - Use a combination of tools to orchestrate the pipeline
    - GitLab
    - Vagrant
    - Python
    - SaltStack
      - or Ansible or any other "config management" system)

Example Network Pipeline



GitLab CI Configuration Example

```
---

stages:
  - lint
  - unit
  - integration
  - review

.job: &job
  stage: integration
  tags: ['kitchen']
  before_script:
    - python --version
  script: './test/scripts/integration.sh'

junos:
  <<: *job
  variables:
    VENDOR: junos

iosxr:
  <<: *job
  variables:
    VENDOR: iosxr
```

```
unit:
  <<: *job
  tags: ['docker']
  stage: unit
  image: supertylerc/salt-masterless-test
  script: './test/scripts/unit.sh'

lint_yaml:
  <<: *job
  stage: lint
  tags: ['docker']
  image:
    name: boiyaa/yamllint
    # This entrypoint can be blank in 10.x
    entrypoint: ['/bin/sh', '-c']
  script: './test/scripts/lint.sh'
```

GitLab CI Configuration Example

```
junos_review:
  <<: *job
  stage: review
  environment:
    name: review/$CI_COMMIT_REF_NAME
    on_stop: stop_junos_review
  only:
    - branches
  except:
    - master
  variables:
    VENDOR: junos
    REVIEW: 'true'

stop_junos_review:
  <<: *job
  stage: review
  environment:
    name: review/$CI_COMMIT_REF_NAME
    action: stop
  variables:
    GIT_STRATEGY: none
  script:
    - cd test; vagrant destroy -f salt junos
  when: manual
```

Linting

- Validate Syntax and Models
  - Syntax: yamllint, xmllint, jsonlint, etc.
    - Don't go further if something breaks the rules!
  - Models/schemas: yamale, xsd, kwalify, jsonschema, etc.
    - Stop if incorrect data is entered!
      - example: customer VLAN ranges are over 3000, but someone entered a VLAN id of 1003

Unit Tests

- Test Discrete Features
  - Use mock or fake data
    - Expected configuration output vs. actual configuration output
  - Tests should be fast and have a high confidence of success
    - Don't bring up a virtual router during this stage
    - Ensure your tests are relevant to the changes being made

Unit Tests

- Tests written in Python using pytest and testinfra
  - Take advantage of testinfra's salt capabilities
  - Since it's a container or Linux VM, fake the host's OS to get the correct configuration for a network device

Unit Tests

```python
import json
import re

import pytest


@pytest.mark.parametrize("router", [
    'junos',
    'nxos',
    'iosxr'
])
def test_lint_ntp_state(host, router):
    host.salt('grains.set', ['os', router], local=True)
    assert host.salt('state.show_sls', ['ntp.test_netconfig'], local=True)


@pytest.mark.parametrize("router", [
    'junos',
    'nxos',
    'iosxr'
])
def test_ntp_state_test(host, router):
    host.salt('grains.set', ['os', router], local=True)
    assert host.salt('state.apply', ['ntp.test_netconfig', 'test=true'], local=True)
```

Unit Tests

```
@pytest.mark.parametrize("router", [
    'junos',
    'nxos',
    'iosxr'
])
def test_state(host, router):
    host.salt('grains.set', ['os', router], local=True)
    host.salt('saltutil.refresh_pillar', local=True)
    host.salt('state.apply', ['ntp.test_netconfig', "exclude=[{'id': 'file.remove'}]"], local=True)
    expected = [x.rstrip() for x in host.file('/tmp/mock/%s_unit_ntp.mock' % router).content_string.strip().split('\n')]
    actual = [x.rstrip() for x in host.file('/tmp/__salt_ntp_salt.example.com.txt').content_string.strip().split('\n')]
    assert expected == actual
    host.salt(
        'state.apply',
        ['ntp.test_netconfig', "exclude=[{'id': 'file.read'}, {'id':'oc_ntp_netconfig_test'}]"],
        local=True
    )
```

Integration Tests

- Apply changes to virtual routers
  - Be prepared for longer test times!
  - Test as close to your production software version(s) as possible
  - You can have many of these running in parallel as long as you have the resources
- Validate changes to virtual routers

Integration Tests

- Vagrant controls the VMs
- pytest and testinfra provide the testing framework
- Mocks of configurations and states ensure live network device VM data matches expectations
- A bash script ties them together

Integration Tests

```python
import json
import re

import pytest

@pytest.mark.parametrize("router", [
    pytest.param('junos', marks=pytest.mark.junos),
    pytest.param('iosxr', marks=pytest.mark.iosxr)
])
def test_ntp_state(host, router):
    output = None
    with host.sudo():
        output = host.check_output('salt %s state.apply' % router)
    assert re.search(r'Failed:\s+0\n', output)
    assert re.search(r'Succeeded:\s+1\s+\(changed=1\)\n', output)
    assert re.search(r'Comment:\s+Configuration changed!\n', output)
    # can probably be replaced with getattr
    _test_ntp_map(router)(output)


def _test_ntp_map(router):
    return {
        'junos': _test_junos_ntp,
        'iosxr': _test_iosxr_ntp
    }[router]


def _test_junos_ntp(output):
    assert re.search(r'\s+peer 172.17.19.2;\n', output)
    assert re.search(r'\s+server 172.17.19.1 prefer;\n', output)
```

Integration Tests

```
def _test_iosxr_ntp(output):
    assert re.search(r'\s+peer 172.17.19.2\n', output)
    assert re.search(r'\s+server 172.17.19.1 prefer\n', output)


@pytest.mark.parametrize("router", [
    pytest.param('junos', marks=pytest.mark.junos),
    pytest.param('iosxr', marks=pytest.mark.iosxr)
])
def test_ntp_is_applied(host, router):
    with host.sudo():
        output = host.check_output('salt %s state.apply' % router)
        assert re.search(r'Succeeded:\s+1\n', output)
        assert re.search(r'Failed:\s+0\n', output)
        assert re.search(r'Comment:\s+Already configured.\n', output)


def _router_ntp_config_command(router):
    return {
        'junos': 'sh conf system ntp',
        'iosxr': 'sh run ntp'
    }[router]
```

Integration Tests

```
@pytest.mark.parametrize("router", [
    pytest.param('junos', marks=pytest.mark.junos),
    pytest.param('iosxr', marks=pytest.mark.iosxr)
])
def test_state(host, router):
    cmd = _router_ntp_config_command(router)
    output = None
    with host.sudo():
        output = json.loads(host.check_output('salt --output=json %s net.cli "%s"' % (router, cmd)))
    output = output[router]['out'][cmd].strip()
    assert output == host.file('/vagrant/mock/%s_ntp.mock' % router).content_string.strip()
```

Integration Tests

```
@pytest.mark.parametrize("router", [
    pytest.param('junos', marks=pytest.mark.junos),
    pytest.param('iosxr', marks=pytest.mark.iosxr)
])
def test_state(host, router):
    cmd = _router_ntp_config_command(router)
    output = None
    with host.sudo():
        output = json.loads(host.check_output('salt --output=json %s net.cli "%s"' % (router, cmd)))
    output = output[router]['out'][cmd].strip()
    assert output == host.file('/vagrant/mock/%s_ntp.mock' % router).content_string.strip()
```

Integration Tests - Vagrant

- vagrant-triggers plugin is useful for network devices that can't use provision during the normal Vagrant cyle
- An extra network is used on all VMs to put the Salt Proxy Minions on the same management network as the network VMs
- Additional shell scripts set up base network connectivity from the Salt infrastructure to the network devices

Review Environment

- Bring up the exact same environment as was used for the Integration Tests
- As a final gate before something is released, allow an engineer to log into the virtual environment and inspect its behavior for any additional oddities
  - Ideally anything not caught by integration tests is noted during this stage and added to integration tests

More Complex Topologies

- Vagrant isn't the only way to control VMs
- GNS3 and other simulation/emulation tools have APIs to bring complex and resource-intensive topologies to life

Gating

Branching Strategy

- Have a branch for development, staging, and production
- Only allow changes to flow from development to staging to production
- Do not allow direct changes to the staging or production branches

Development Branch

- This is really just a feature branch
- Short-lived and concerned only with the changes being made in a specific pull request

Staging Branch

- This is the branch into which the development branches get merged
- This longer-lived branch is concerned with combining multiple development features into a single point-in-time state
- Tag it before you want to release it to production

Staging Environment

- The staging environment should consist of a tagged version of the staging branches of all features (repositories)
- A suite of automated tests should exist that are designed to validate the staging environment end-to-end across many features

Staging Environment

- The staging environment can be physical or virtual
  - If virtual, ensure you're taking advantage of APIs of your systems to speed up provisioning and decommissioning of the environment
- Always start from scratch!

Production Branch

- Once the staging environment has been thoroughly tested by automated systems and human review, merge the branch from staging to the production branch
- From this point, an automated system could deploy the changes from the production branch directly to your network devices

Production Deploy

- SaltStack has schedules
- Run high states on a schedule to always deploy the production branch
  - Temporarily disable schedules when implementing workarounds or emergency fixes until they make their way back into configuration management
- Run post-production deploy automated tests to validate your production network

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  - Second level
    - Third level
      - Fourth level
        - Fifth level

Summary

Tools

- Python
- SaltStack
- Jinja2
- YAML
- GitLab
- Vagrant
- GNS3
- EVE-NG
- VIRL
- OpenStack

Pipelines

- Series of tests
- Start with short, high value tests
- Progress to increasingly complex and longer tests in new stages
- Fail early, fail fast!
- Spin up review environments!

Branching

- Protect production
  - Don't allow changes not originating from your config management
    - Automatically revert them to the correct state according to your config management system
  - Don't allow changes directly to the production branch of your config management system
    - Gate them through development and staging first!

Questions?

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