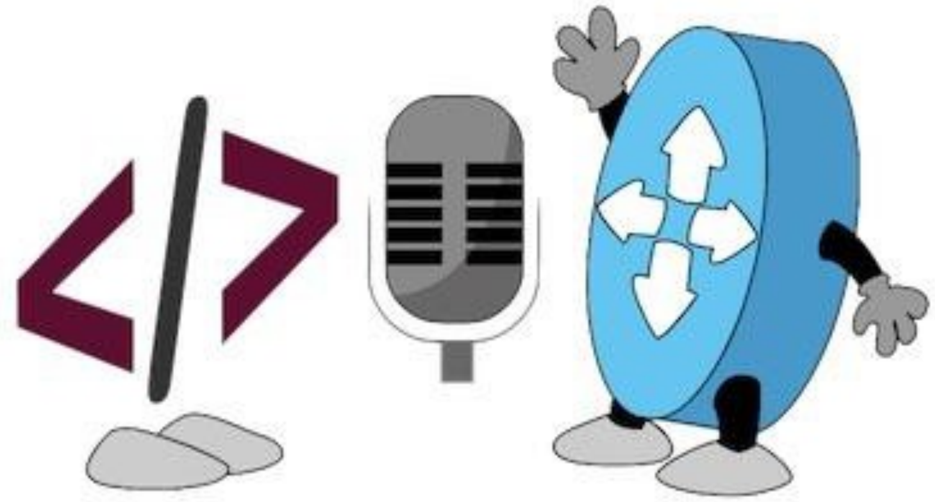
Useful Python Libraries for Network Engineers

Slides adapted from Cisco Devnet

What are we going to talk about?

- Libraries to Work with Data
- API Libraries
- Configuration Management Tools and Libraries
- Some Other Cool Python Stuff



Libraries to Work with Data

Manipulating Data of All Formats

- XML - xmltodict
  - `pip install xmltodict`
    `import xmltodict`
- JSON
  - import json
- YAML - PyYAML
  - `pip install PyYAML`
    `import yaml`
- CSV
  - `import csv`
- YANG - pyang
  - `import pyang`

Treat XML like Python Dictionaries with xmltodict

- Easily work with XML data
- Convert from XML -> Dict* and back
  - xmltodict.parse(xml_data)
  - xmltodict.unparse(dict)
- Python includes a native Markup (html/xml) interfaces as well
  - More powerful, but also more complex

** Technically to an OrderedDict*

https://pypi.python.org/pypi/xmltodict

```
# Import the xmltodict library
import xmltodict

# Open the sample xml file and read it into variable
with open("xml_example.xml") as f:
    xml_example = f.read()

# Print the raw XML data
print(xml_example)

# Parse the XML into a Python dictionary
xml_dict = xmltodict.parse(xml_example)

# Save the interface name into a variable using XML nodes as
keys
int_name = xml_dict["interface"]["name"]

# Print the interface name
print(int_name)

# Change the IP address of the interface
xml_dict["interface"]["ipv4"]["address"]["ip"] = "192.168.0.2"

# Revert to the XML string version of the dictionary
print(xmltodict.unparse(xml_dict))
```

data_manipulation/xml/xml_example.py

To JSON and back again with json

- JSON and Python go together like peanut butter and jelly
  - `json.loads(`**`json_data`**`)`
  - `json.dumps(`**`object`**`)`
- JSON Objects convert to Dictionaries
- JSON Arrays convert to Lists

https://docs.python.org/3/library/json.html

```python
# Import the jsontodict library
import json

# Open the sample json file and read it into variable
with open("json_example.json") as
    f:  json_example = f.read()

# Print the raw json data
print(json_example)

# Parse the json into a Python dictionary
json_dict = json.loads(json_example)

# Save the interface name into a variable
int_name = json_dict["interface"]["name"]

# Print the interface name
print(int_name)

# Change the IP address of the interface
json_dict["interface"]["ipv4"]["address"][0]["ip"]
   = \  "192.168.0.2"

# Revert to the json string version of the dictionary
print(json.dumps(json_dict))
```

data_manipulation/json/json_example.py

YAML? Yep, Python Can Do That Too!

- Easily convert a YAML file to a Python Object
  - `yaml.load(`**`yaml_data`**`)`
  - `yaml.dump(`**`object`**`)`
- YAML Objects become Dictionaries
- YAML Lists become Lists

https://pypi.python.org/pypi/PyYAML/3.12

```python
# Import the yamltodict library
import yaml

# Open the sample yaml file and read it into variable
with open("yaml_example.yaml") as f:
    yaml_example = f.read()

# Print the raw yaml data
print(yaml_example)

# Parse the yaml into a Python dictionary
yaml_dict = yaml.load(yaml_example)

# Save the interface name into a variable
int_name = yaml_dict["interface"]["name"]

# Print the interface name
print(int_name)

# Change the IP address of the interface
yaml_dict["interface"]["ipv4"]["address"][0]["ip"] = \
   "192.168.0.2"

# Revert to the yaml string version of the dictionary
print(yaml.dump(yaml_dict, default_flow_style=False))
```

data_manipulation/yaml/yaml_example.py

Import Spreadsheets and Data with csv

- Treat CSV data as lists
  `csv.reader(`**`file_object`**`)`
- Efficiently processes large files without memory issues
- Options for header rows and different formats

https://docs.python.org/3/library/csv.html

```
# Import the csv library
import csv

# Open the sample csv file and print it to screen
with open("csv_example.csv") as f:
    print(f.read())

# Open the sample csv file, and create a csv.reader
object
with open("csv_example.csv") as f:
    csv_python = csv.reader(f)

    # Loop over each row in csv and leverage the data
    # in code
    for row in csv_python:
        print("{device} is in {location} " \
              "and has IP {ip}.".format(
                  device = row[0],
                  location = row[2],
                  ip = row[1]
                  )
              )
```

data_manipulation/csv/csv_example.py

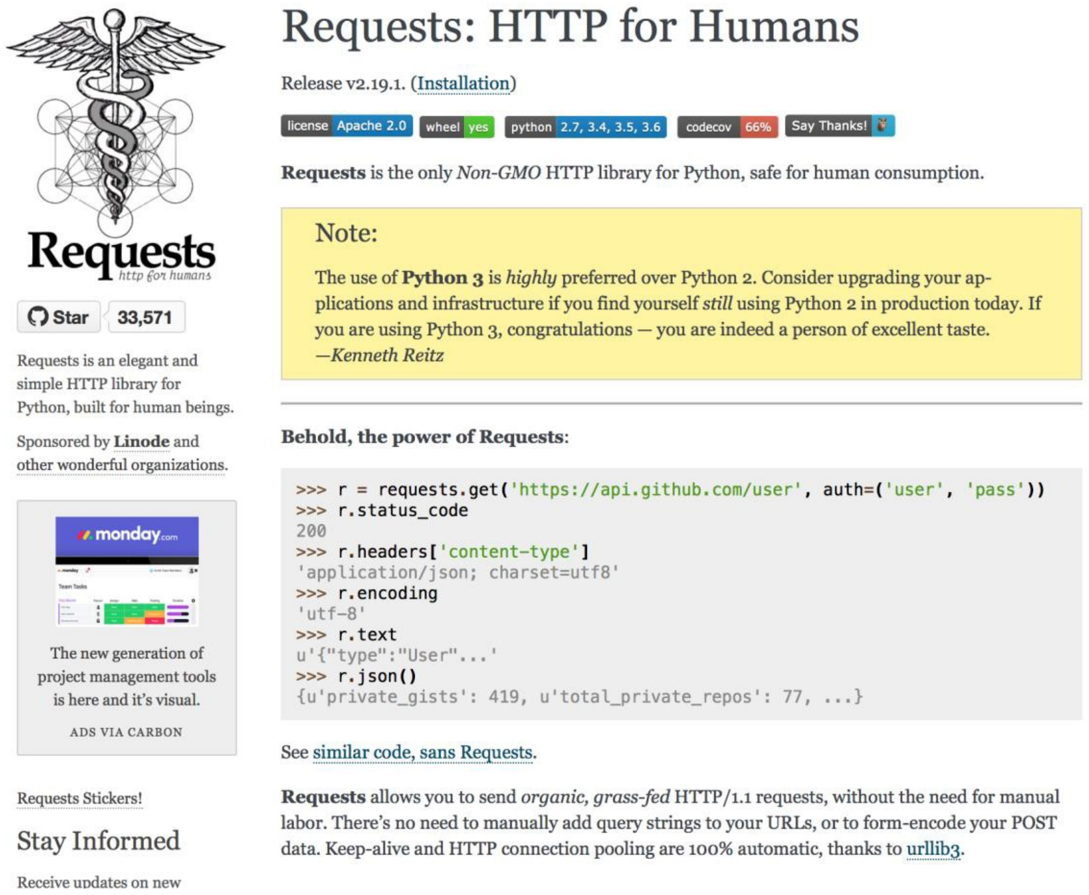
API Libraries

Access Different APIs Easily

- REST APIs – requests
  - `pip install requests`
    `import requests`
- NETCONF – ncclient
  - `pip install ncclient`
    `import ncclient`
- Network CLI – netmiko
  - `pip install netmiko`
    `import netmiko`
- SNMP – PySNMP
  - `pip install pysnmp`
    `import pysnmp`

Make HTTP Calls with Ease using “requests”

- Full HTTP Client
- Simplifies authentication, headers, and response tracking
- Great for REST API calls, or any HTTP request
- Network uses include RESTCONF, native REST APIs, JSON-RPC



Requests is an elegant and simple HTTP library for Python, built for human beings.

Sponsored by **Linode** and other wonderful organizations.

Requests Stickers!

Stay Informed

Receive updates on new

Requests: HTTP for Humans

Release v2.19.1. (Installation)

Requests is the only *Non-GMO* HTTP library for Python, safe for human consumption.

> Note:
>
> The use of **Python 3** is *highly* preferred over Python 2. Consider upgrading your applications and infrastructure if you find yourself *still* using Python 2 in production today. If you are using Python 3, congratulations — you are indeed a person of excellent taste.
> —*Kenneth Reitz*

Behold, the power of Requests:

```
>>> r = requests.get('https://api.github.com/user', auth=('user', 'pass'))
>>> r.status_code
200
>>> r.headers['content-type']
'application/json; charset=utf8'
>>> r.encoding
'utf-8'
>>> r.text
u'{"type":"User"...'
>>> r.json()
{u'private_gists': 419, u'total_private_repos': 77, ...}
```

See similar code, sans Requests.

Requests allows you to send *organic, grass-fed* HTTP/1.1 requests, without the need for manual labor. There’s no need to manually add query strings to your URLs, or to form-encode your POST data. Keep-alive and HTTP connection pooling are 100% automatic, thanks to urllib3.

http://docs.python-requests.org

Example: Retrieving Configuration Details with RESTCONF

RESTCONF: Basic Request for Device Data 1/2

```python
# Import libraries
import requests, urllib3
import sys

# Add parent directory to path to allow importing common vars
sys.path.append("..") # noqa
from device_info import ios_xe1 as device # noqa

# Disable Self-Signed Cert warning for demo
urllib3.disable_warnings(urllib3.exceptions.InsecureRequestWarning)

# Setup base variable for request
restconf_headers = {"Accept": "application/yang-data+json"}
restconf_base = "https://{ip}:{port}/restconf/data"
interface_url = restconf_base + "/ietf-interfaces:interfaces/interface={int_name}"
```

device_apis/rest/restconf_example1.py

RESTCONF: Basic Request for Device Data 2/2

```
# Create URL and send RESTCONF request to core1 for GigE2 Config
url = interface_url.format(ip = device["address"], port = device["restconf_port"],
                           int_name = "GigabitEthernet2"
                          )
r = requests.get(url,
        headers = restconf_headers,
        auth=(device["username"], device["password"]),
        verify=False)

# Print returned data
print(r.text)

# Process JSON data into Python Dictionary and use
interface = r.json()["ietf-interfaces:interface"]
print("The interface {name} has ip address {ip}/{mask}".format(
      name = interface["name"],
      ip = interface["ietf-ip:ipv4"]["address"][0]["ip"],
      mask = interface["ietf-ip:ipv4"]["address"][0]["netmask"],
      )
)
```

device_apis/rest/restconf_example1.py

Example: Updating Configuration with RESTCONF

RESTCONF: Creating a New Loopback 1/2

```
# Setup base variable for request
restconf_headers["Content-Type"] = "application/yang-data+json"
# New Loopback Details
loopback = {"name": "Loopback101",
            "description": "Demo interface by RESTCONF",
            "ip": "192.168.101.1",
            "netmask": "255.255.255.0"}
# Setup data body to create new loopback interface
data = {
    "ietf-interfaces:interface": {
        "name": loopback["name"],
        "description": loopback["description"],
        "type": "iana-if-type:softwareLoopback",
        "enabled": True,
        "ietf-ip:ipv4": {
            "address": [
                {"ip": loopback["ip"],
                 "netmask": loopback["netmask"]}
            ] } } }
```

device_apis/rest/restconf_example2.py

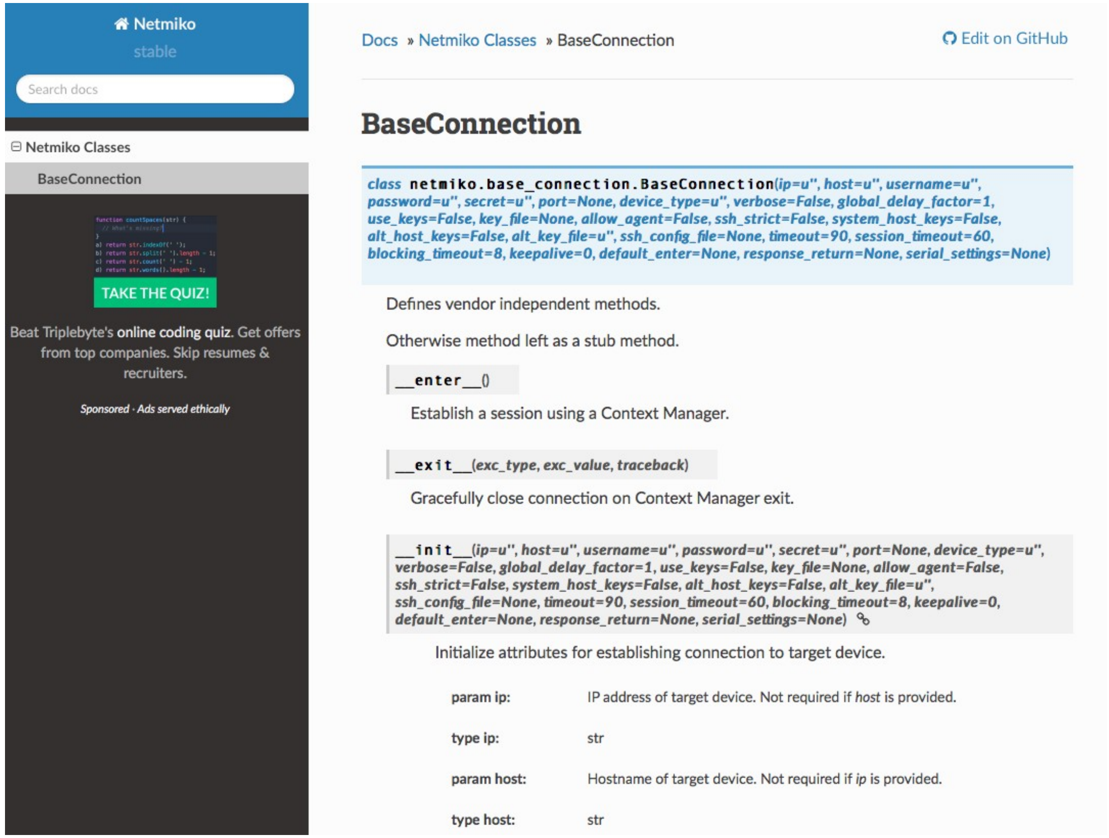
RESTCONF: Creating a New Loopback 2/2

```
# Create URL and send RESTCONF request to core1 for GigE2 Config
url = interface_url.format(ip = core1_ip, int_name = loopback["name"])
r = requests.put(url,
        headers = restconf_headers,
        auth=(username, password),
        json = data,
        verify=False)


# Print returned data
print("Request Status Code: {}".format(r.status_code))
```

device_apis/rest/restconf_example2.py

For When CLI is the Only Option – netmiko

- If no other API is available…
- Builds on paramiko library for SSH connectivity
- Support for a range of vendors network devices and operating systems
- Send and receive clear text
    - Post processing of data will be key



BaseConnection

```
class netmiko.base_connection.BaseConnection(ip=u'', host=u'', username=u'', password=u'', secret=u'', port=None, device_type=u'', verbose=False, global_delay_factor=1, use_keys=False, key_file=None, allow_agent=False, ssh_strict=False, system_host_keys=False, alt_host_keys=False, alt_key_file=u'', ssh_config_file=None, timeout=90, session_timeout=60, blocking_timeout=8, keepalive=0, default_enter=None, response_return=None, serial_settings=None)
```

Defines vendor independent methods.

Otherwise method left as a stub method.

```
__enter__()
```

Establish a session using a Context Manager.

```
__exit__(exc_type, exc_value, traceback)
```

Gracefully close connection on Context Manager exit.

```
__init__(ip=u'', host=u'', username=u'', password=u'', secret=u'', port=None, device_type=u'', verbose=False, global_delay_factor=1, use_keys=False, key_file=None, allow_agent=False, ssh_strict=False, system_host_keys=False, alt_host_keys=False, alt_key_file=u'', ssh_config_file=None, timeout=90, session_timeout=60, blocking_timeout=8, keepalive=0, default_enter=None, response_return=None, serial_settings=None)
```

Initialize attributes for establishing connection to target device.

param ip:	IP address of target device. Not required if *host* is provided.
type ip:	str
param host:	Hostname of target device. Not required if *ip* is provided.
type host:	str

https://github.com/ktbyers/netmiko

Example: Retrieving Configuration Details with CLI

CLI: Basic Request for Device Data 1/3

```
# Import libraries
from netmiko import ConnectHandler
import re
import sys

# Add parent directory to path to allow importing common vars
sys.path.append("..") # noqa
from device_info import ios_xe1 as device # noqa

# Set device_type for netmiko
device["device_type"] = "cisco_ios"

# Create a CLI command template
show_interface_config_temp = "show running-config interface {}"
```

device_apis/cli/netmiko_example1.py

CLI: Basic Request for Device Data 2/3

```python
# Open CLI connection to device
with ConnectHandler(ip = device["address"],
                    port = device["ssh_port"],
                    username = device["username"],
                    password = device["password"],
                    device_type = device["device_type"]) as ch:


    # Create desired CLI command and send to device
    command = show_interface_config_temp.format("GigabitEthernet2")
    interface = ch.send_command(command)

    # Print the raw command output to the screen
    print(interface)
```

device_apis/cli/netmiko_example1.py

CLI: Basic Request for Device Data 3/3

```
# Use regular expressions to parse the output for desired data
name = re.search(r'interface (.*)', interface).group(1)
description = re.search(r'description (.*)', interface).group(1)
ip_info = re.search(r'ip address (.*) (.*)', interface)
ip = ip_info.group(1)
netmask = ip_info.group(2)

# Print the info to the screen
print("The interface {name} has ip address {ip}/{mask}".format(
        name = name,
        ip = ip,
        mask = netmask,
        )
    )
```

device_apis/cli/netmiko_example1.py

Example: Updating Configuration with CLI

CLI: Creating a New Loopback

```
# New Loopback Details
loopback = {"int_name": "Loopback103",
            "description": "Demo interface by CLI and netmiko",
            "ip": "192.168.103.1",
            "netmask": "255.255.255.0"}
# Create a CLI configuration
interface_config = [
    "interface {}".format(loopback["int_name"]),
    "description {}".format(loopback["description"]),
    "ip address {} {}".format(loopback["ip"], loopback["netmask"]),
    "no shut"]

# Open CLI connection to device
with ConnectHandler(ip=core1["ip"],
                    username=username,
                    password=password,
                    device_type=core1["device_type"]) as ch:

    # Send configuration to device
    output = ch.send_config_set(interface_config)
```

device_apis/cli/netmiko_example2.py

Configuration Management Tools and Libraries

Open Source Python projects for full network config management

Designed for Network Automation

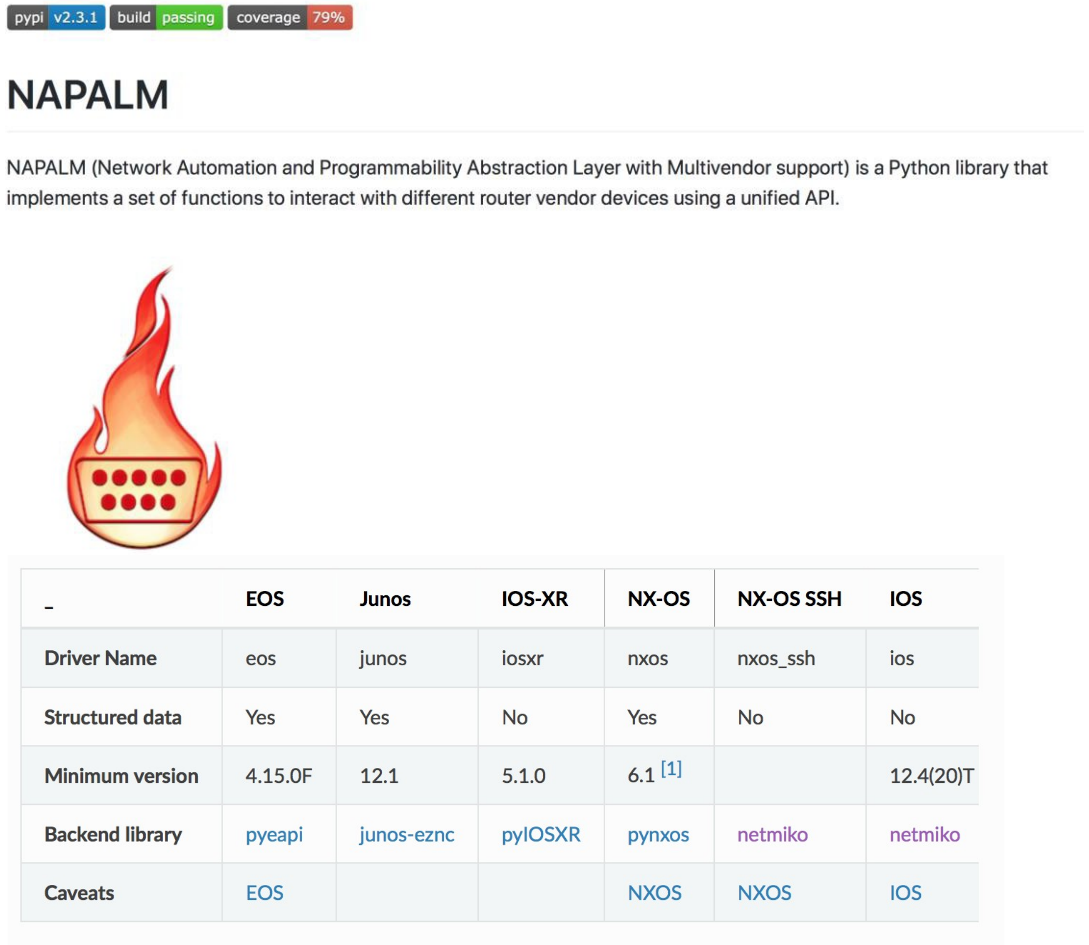
- NAPALM
  - Library providing a standard set of functions for working with different network OS's
- Nornir
  - New automation framework focused on being Python native. Can leverage other tools like NAPALM.

Designed for Server Automation

- Ansible
  - Declarative, agent-less automation framework for managing configuration. Robust support for network platforms
- Salt
  - Configuration management and remote code execution engine. Network automation options in development.

NAPALM – Mature Python Library for Multi-Vendor Interactions

- Robust configuration management options
  - Replace, Merge, Compare, Commit, Discard, Rollback
- Builds on available backend libraries and interfaces (CLI, NX-API, NETCONF, etc)
- Can be used and integrated into other tools (ie Ansible, Nornir)



pypi v2.3.1 build passing coverage 79%

NAPALM

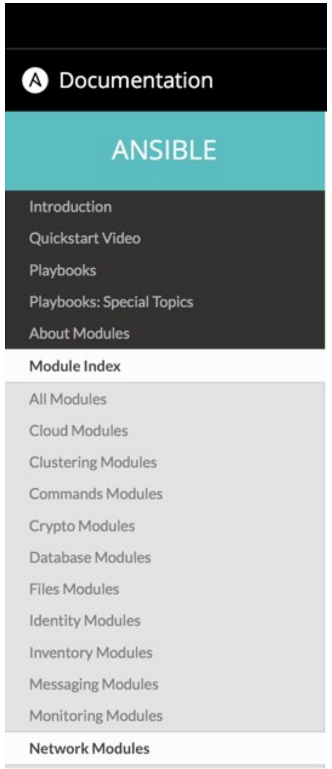
NAPALM (Network Automation and Programmability Abstraction Layer with Multivendor support) is a Python library that implements a set of functions to interact with different router vendor devices using a unified API.

_	EOS	Junos	IOS-XR	NX-OS	NX-OS SSH	IOS
Driver Name	eos	junos	iosxr	nxos	nxos_ssh	ios
Structured data	Yes	Yes	No	Yes	No	No
Minimum version	4.15.0F	12.1	5.1.0	6.1 [1]		12.4(20)T
Backend library	pyeapi	junos-eznc	pyIOSXR	pynxos	netmiko	netmiko
Caveats	EOS			NXOS	NXOS	IOS

https://github.com/napalm-automation/napalm
https://napalm.readthedocs.io

Ansible – Leading DevOps Tool for Network Configuration Management

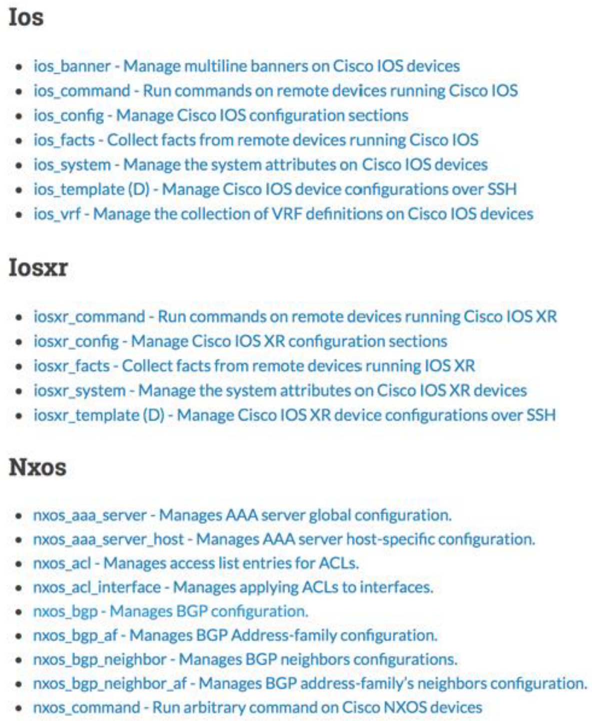
- Agentless – no edge software installation needed
- Support for both old and new platforms and interfaces (ie CLI & NETCONF)
- Robust and growing library of network modules



Documentation

ANSIBLE

Introduction
Quickstart Video
Playbooks
Playbooks: Special Topics
About Modules
Module Index
All Modules
Cloud Modules
Clustering Modules
Commands Modules
Crypto Modules
Database Modules
Files Modules
Identity Modules
Inventory Modules
Messaging Modules
Monitoring Modules
Network Modules



Ios

- ios_banner - Manage multiline banners on Cisco IOS devices
- ios_command - Run commands on remote devices running Cisco IOS
- ios_config - Manage Cisco IOS configuration sections
- ios_facts - Collect facts from remote devices running Cisco IOS
- ios_system - Manage the system attributes on Cisco IOS devices
- ios_template (D) - Manage Cisco IOS device configurations over SSH
- ios_vrf - Manage the collection of VRF definitions on Cisco IOS devices

Iosxr

- iosxr_command - Run commands on remote devices running Cisco IOS XR
- iosxr_config - Manage Cisco IOS XR configuration sections
- iosxr_facts - Collect facts from remote devices running IOS XR
- iosxr_system - Manage the system attributes on Cisco IOS XR devices
- iosxr_template (D) - Manage Cisco IOS XR device configurations over SSH

Nxos

- nxos_aaa_server - Manages AAA server global configuration.
- nxos_aaa_server_host - Manages AAA server host-specific configuration.
- nxos_acl - Manages access list entries for ACLs.
- nxos_acl_interface - Manages applying ACLs to interfaces.
- nxos_bgp - Manages BGP configuration.
- nxos_bgp_af - Manages BGP Address-family configuration.
- nxos_bgp_neighbor - Manages BGP neighbors configurations.
- nxos_bgp_neighbor_af - Manages BGP address-family's neighbors configuration.
- nxos_command - Run arbitrary command on Cisco NXOS devices

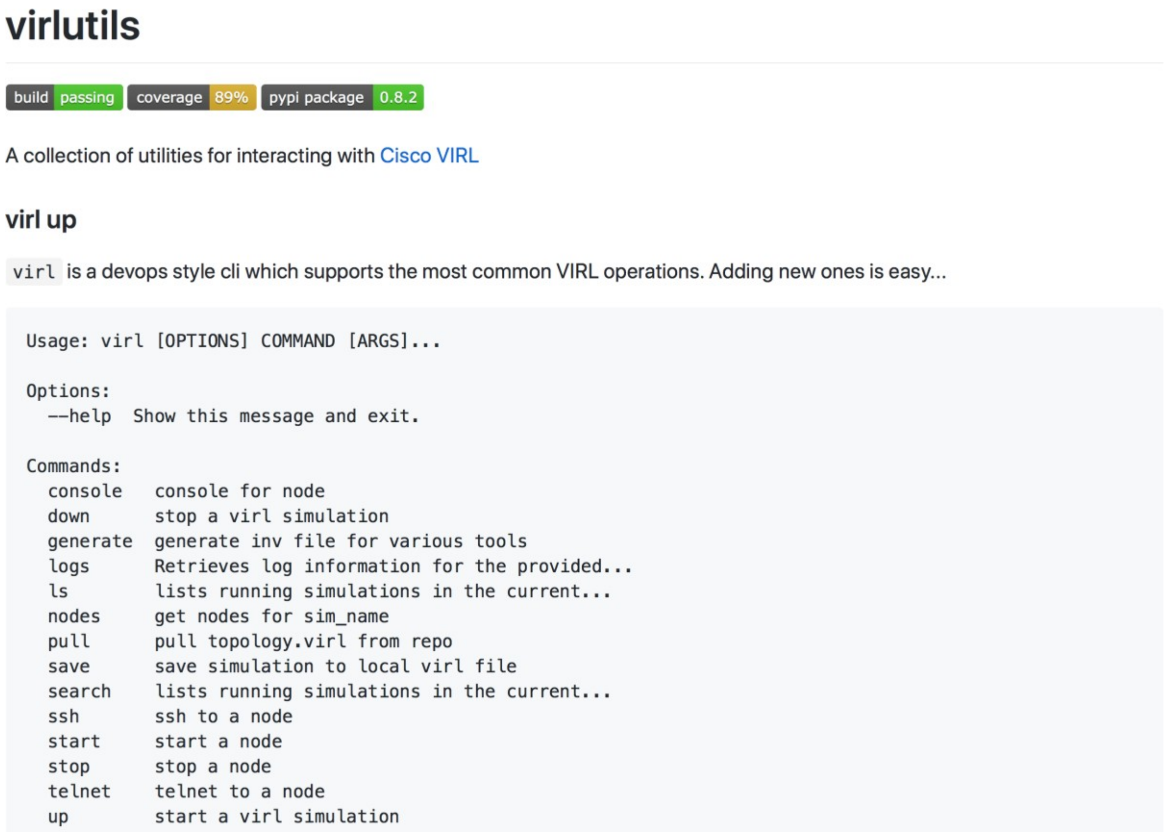
Screenshot edited to include IOS, IOS-XR and NX-OS Content

https://www.ansible.com/overview/networking
https://docs.ansible.com/ansible/latest/modules/list_of_network_modules.html

Some Other Cool Python Stuff

virlutils – It’s like “vagrant up” but for the Network!

- Open Source command line utility for managing simulations with Cisco VIRL/CML
- Designed for NetDevOps workflows
  - Development environments
  - Test networks within CICD pipelines



virlutils

A collection of utilities for interacting with Cisco VIRL

virl up

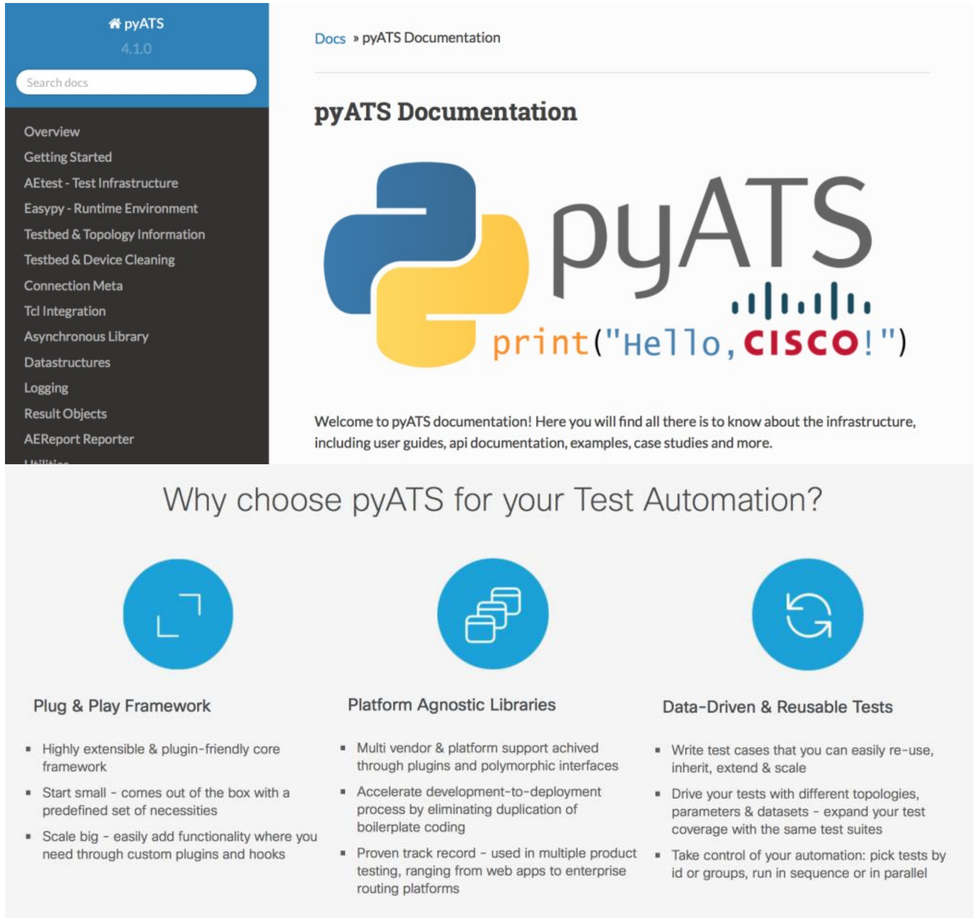
`virl` is a devops style cli which supports the most common VIRL operations. Adding new ones is easy...

```
Usage: virl [OPTIONS] COMMAND [ARGS]...

Options:
  --help  Show this message and exit.

Commands:
  console   console for node
  down      stop a virl simulation
  generate  generate inv file for various tools
  logs      Retrieves log information for the provided...
  ls        lists running simulations in the current...
  nodes     get nodes for sim_name
  pull      pull topology.virl from repo
  save      save simulation to local virl file
  search    lists running simulations in the current...
  ssh       ssh to a node
  start     start a node
  stop      stop a node
  telnet    telnet to a node
  up        start a virl simulation
```

https://github.com/CiscoDevNet/virlutils
https://learningnetworkstore.cisco.com/virlfaq/aboutVirl

pyATS – Profile and Test Your Network Before, During, and After Changes

- No longer is “ping” the best network test tool available
- PyATS is built to work like software test suites, and uses common frameworks (ie robot)
- Profile the network to get a baseline for interfaces, routing protocols, and platform details – verify at anytime.



pyATS Documentation

Welcome to pyATS documentation! Here you will find all there is to know about the infrastructure, including user guides, api documentation, examples, case studies and more.

Why choose pyATS for your Test Automation?

Plug & Play Framework

- Highly extensible & plugin-friendly core framework
- Start small - comes out of the box with a predefined set of necessities
- Scale big - easily add functionality where you need through custom plugins and hooks

Platform Agnostic Libraries

- Multi vendor & platform support achived through plugins and polymorphic interfaces
- Accelerate development-to-deployment process by eliminating duplication of boilerplate coding
- Proven track record - used in multiple product testing, ranging from web apps to enterprise routing platforms

Data-Driven & Reusable Tests

- Write test cases that you can easily re-use, inherit, extend & scale
- Drive your tests with different topologies, parameters & datasets - expand your test coverage with the same test suites
- Take control of your automation: pick tests by id or groups, run in sequence or in parallel

https://developer.cisco.com/site/pyats/
https://developer.cisco.com/docs/pyats/

APIs and RESTful APIs

Application Programming Interface (API)

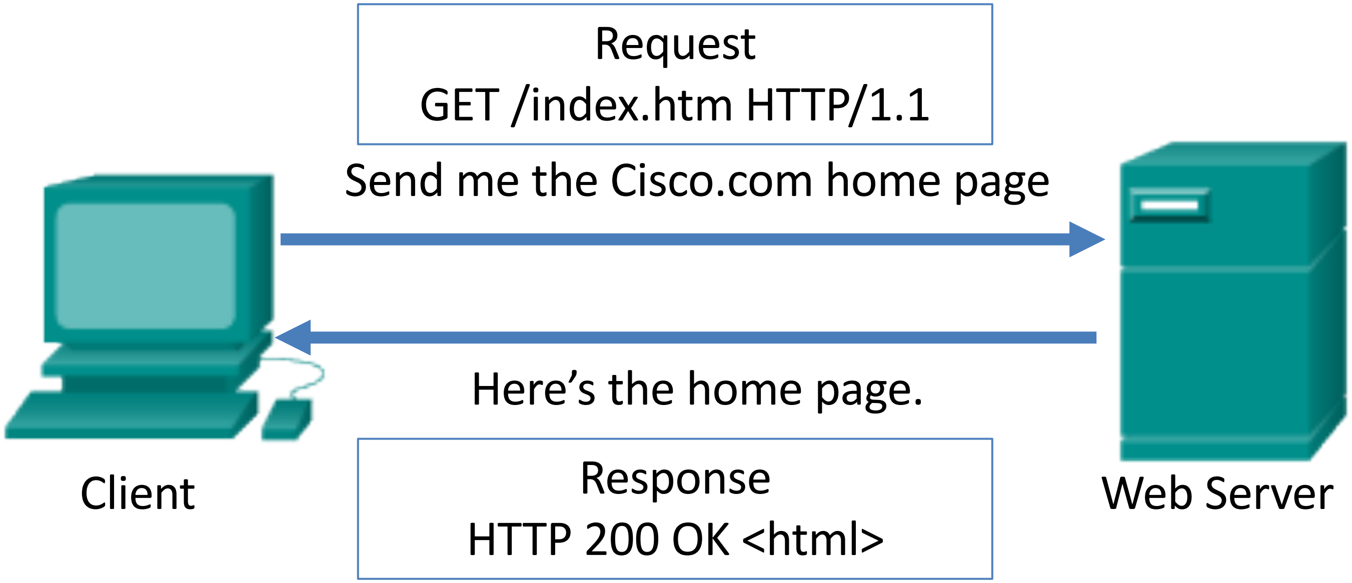
- An API allows one piece of software talk to another.
- An API is analogous to a power outlet.
- Without a power outlet, what would you have to do to power your laptop?
  - Open the wall
  - Unsheath wires
  - Splice wires together
  - Understand all the wires in the wall
- An API defines how a programmer can write a piece of software to extend an existing application's features or even build entirely new applications.

API Example

- Restaurant Recommendation App
  - Returns a list of relevant restaurants in the area
  - Integrates a third-party API to provide map functionality
  - The map API enforces a specification of an interface

Web Services Interface using HTTP

- Web browsers use Hypertext Transfer Protocol (HTTP) to request (GET) a web page.
- If successfully requested (HTTP status code 200), web servers respond to GET requests with a Hypertext Markup Language (HTML) coded web page.



Request
GET /index.htm HTTP/1.1

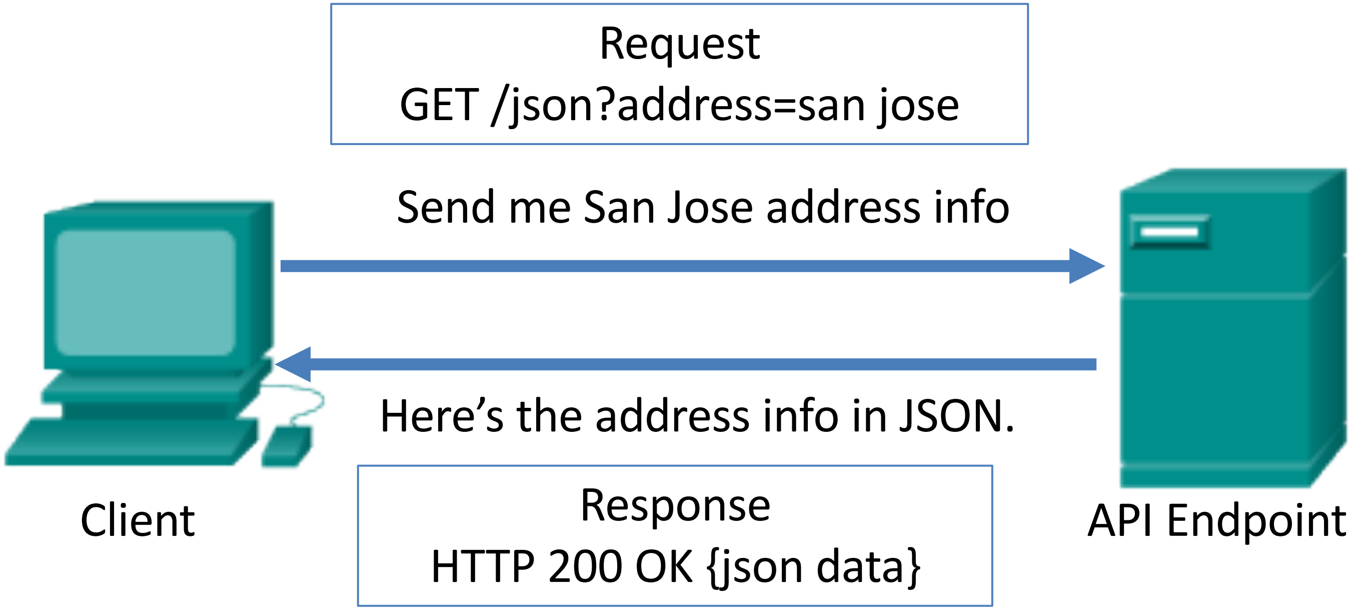
Send me the Cisco.com home page

Here’s the home page.

Response
HTTP 200 OK <html>

RESTful API using HTTP

- Representation State Transfer (REST) APIs use HTTP to interface with RESTful services.
- The HTTP request asks for JavaScript Object Notation (JSON) formatted data.
- If successfully formatted according to the API documentation, the server will respond with JSON data.



Request
GET /json?address=san jose

Send me San Jose address info

Here's the address info in JSON.

Response
HTTP 200 OK {json data}

RESTful API using HTTP

- Representation State Transfer (REST) APIs use HTTP to interface with RESTful services.
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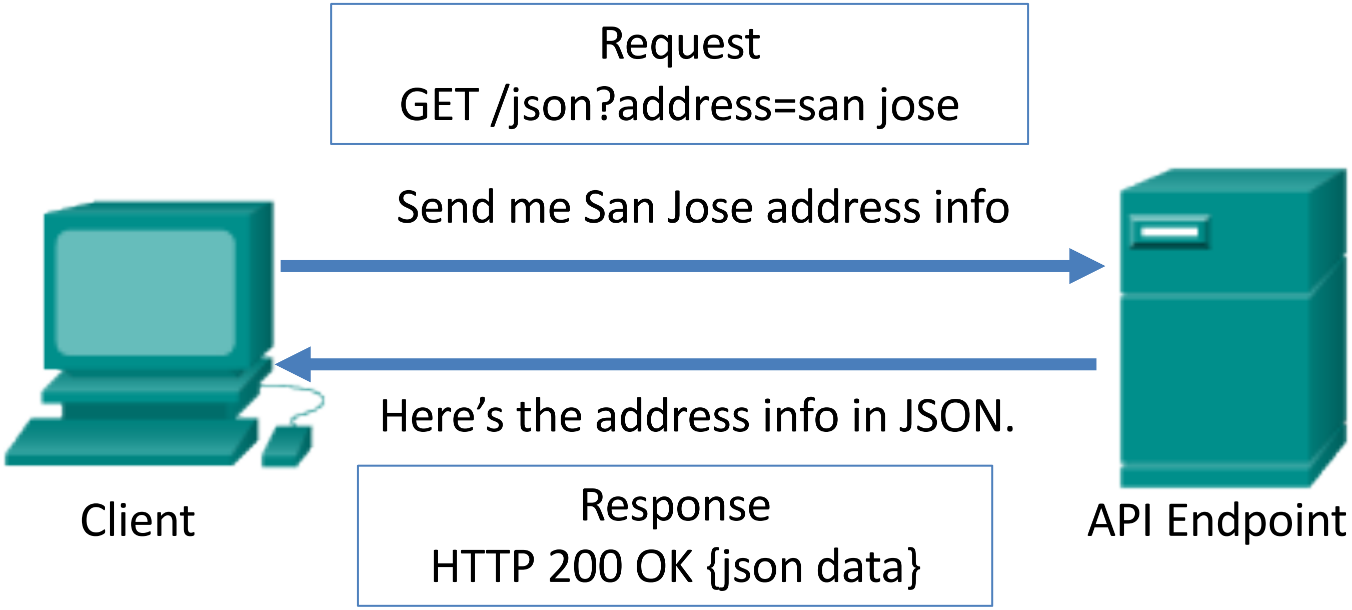


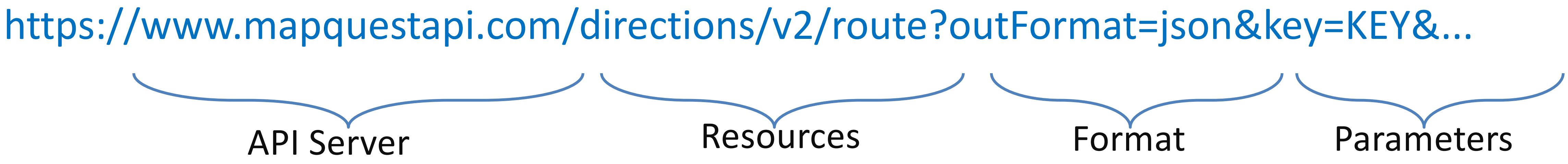
Request
GET /json?address=san jose

Send me San Jose address info

Here's the address info in JSON.

Response
HTTP 200 OK {json data}

Anatomy of a RESTful Request

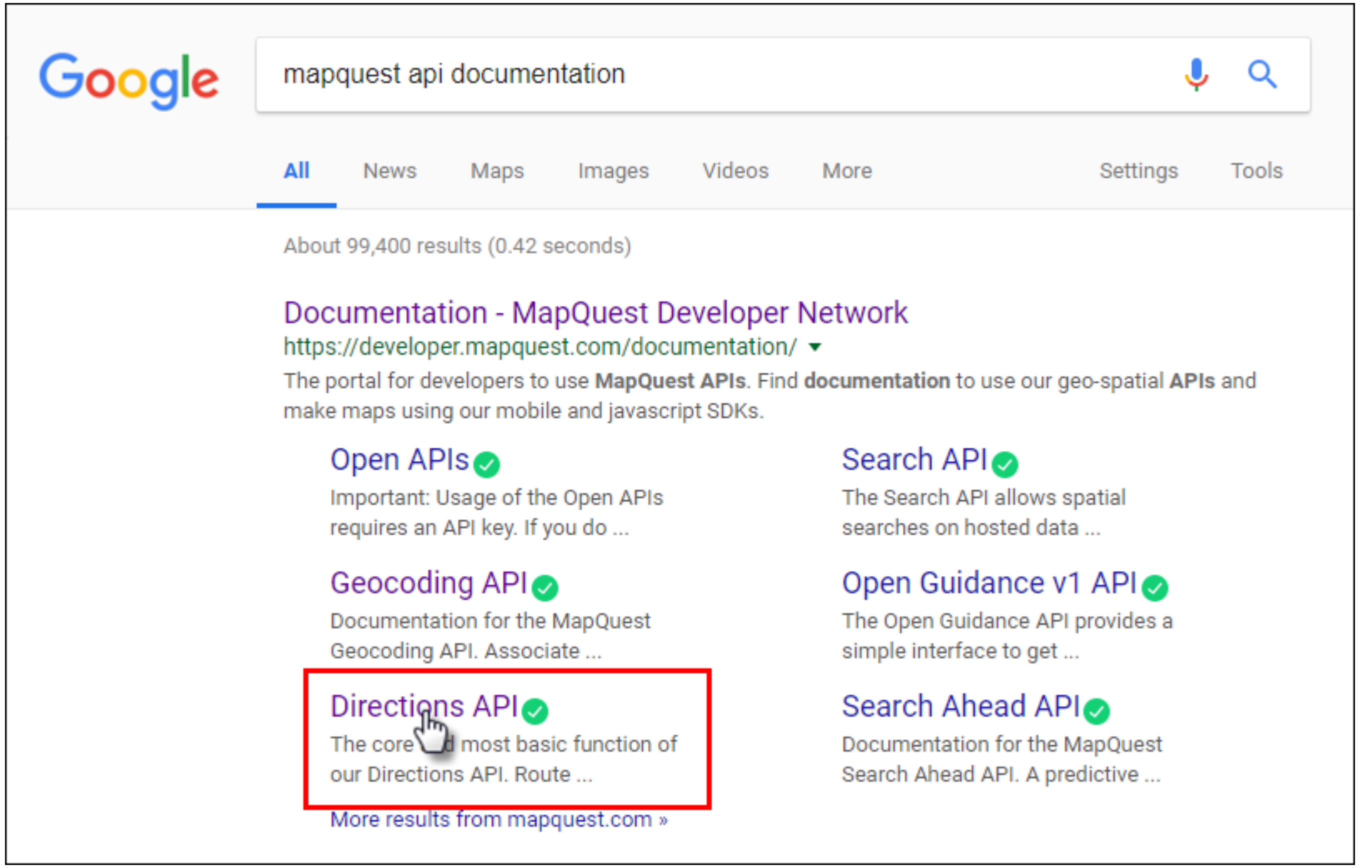


https://www.mapquestapi.com/directions/v2/route?outFormat=json&key=KEY&...

- API Server: The URL for the server that answers REST requests
- Resources: Specifies the API that is being requested.
- Format: Usually JSON or XML
- Parameters: Specifies what data is being requested

API Documentation

- Use an Internet search to find documentation for an API.



mapquest api documentation

About 99,400 results (0.42 seconds)

Documentation - MapQuest Developer Network
https://developer.mapquest.com/documentation/
The portal for developers to use **MapQuest APIs**. Find **documentation** to use our geo-spatial **APIs** and make maps using our mobile and javascript SDKs.

Open APIs ✓
Important: Usage of the Open APIs requires an API key. If you do ...

Search API ✓
The Search API allows spatial searches on hosted data ...

Geocoding API ✓
Documentation for the MapQuest Geocoding API. Associate ...

Open Guidance v1 API ✓
The Open Guidance API provides a simple interface to get ...

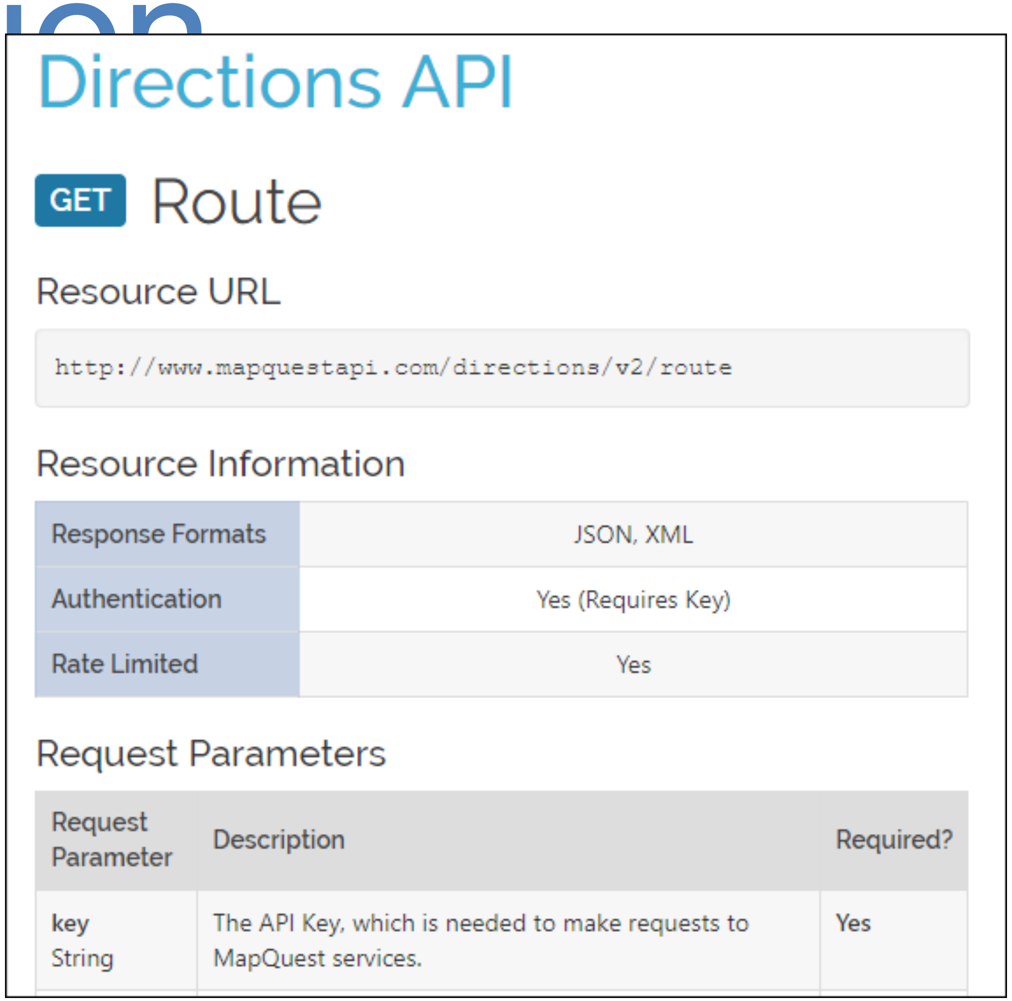
Directions API ✓
The core and most basic function of our Directions API. Route ...

Search Ahead API ✓
Documentation for the MapQuest Search Ahead API. A predictive ...

More results from mapquest.com »

API Documentation

- The API documentation will specify...
  - The request format (JSON, XML, or text)
  - The request parameters
  - The response fields



Directions API

GET Route

Resource URL

```
http://www.mapquestapi.com/directions/v2/route
```

Resource Information

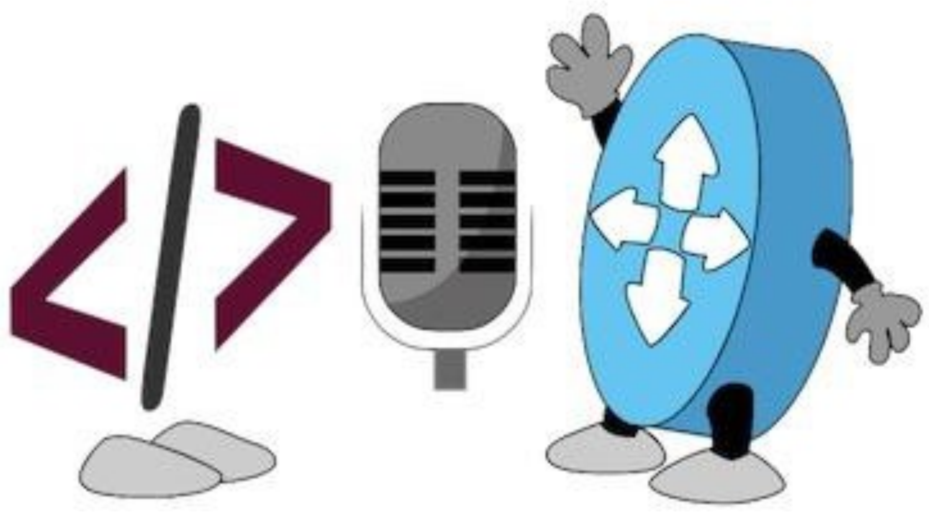
Response Formats	JSON, XML
Authentication	Yes (Requires Key)
Rate Limited	Yes

Request Parameters

Request Parameter	Description	Required?
key String	The API Key, which is needed to make requests to MapQuest services.	Yes

What did we talk about?

- Libraries to Work with Data
  - xmltodict, json, PyYAML, csv, pyang
- API Libraries
  - requests, ncclient, netmiko, pysnmp
- Configuration Management
  - NAPALM, Ansible, Salt, Nornir
- Some Other Cool Python Stuff
  - virlutils, pyATS



Resource List

- Docs and Links
  - https://developer.cisco.com/python
- Learning Labs
  - Laptop Setup http://cs.co/lab-dev-setup
  - Coding Fundamentals http://cs.co/lab-coding-fundamentals
  - Model Driven Programmability http://cs.co/lab-mdp
- DevNet Sandboxes
  - IOS Always On http://cs.co/sbx-iosxe
  - NX-OS Always On http://cs.co/sbx-nxos

Summing up