CGR

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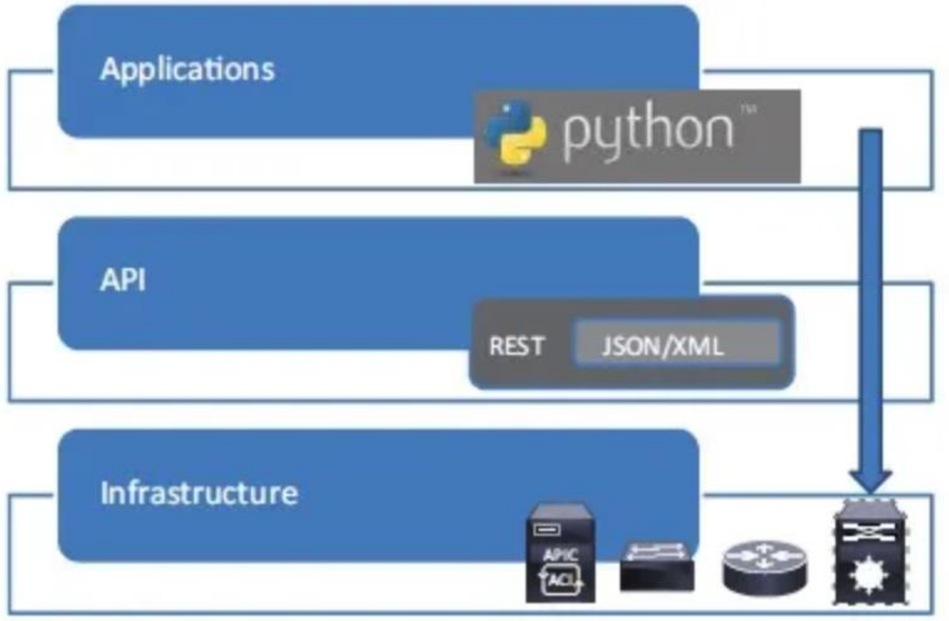
CIÊNCIAS E TECNOLOGIA

Network Programmability

- Definition: Network programmability is the use of software to deploy, manage, and troubleshoot network devices and services. This approach moves away from traditional manual configuration methods towards more automated, software-driven techniques.

Allows:

- Quicker deployments of new network configurations or services.
- More efficient managing of existing network infrastructure.
- Troubleshooting issues using programmatic tools



Instead of logging into each device individually to make changes, network programmability allows for centralized control and automation of these tasks.

Network Programmability

Key Components:

APIs (Application Programming Interfaces):

- Sets of protocols, routines, and tools for building software applications.
- Allow direct interaction with network devices.

Examples: Cisco's NX-API , Juniper's Junos XML API or REST APIs like RESTCONF and the NVDUE API.

Protocols

NETCONF (Network Configuration Protocol): developed by the IETF for installing, manipulating, and deleting network device configurations.

- Uses XML for data encoding and operates over a secure transport (typically SSH).

RESTCONF REST-like protocol that provides a programmatic interface for accessing data defined in YANG, using datastores defined in NETCONF.

- Uses HTTP/HTTPS for transport and JSON or XML for data encoding.

Programming Languages:

Python: popular choice for network automation. Libraries like Netmiko or NAPALM are widely used for network automation tasks.

YANG: data modelling language used to model configuration and state data manipulated by network protocols like NETCONF and RESTCONF.

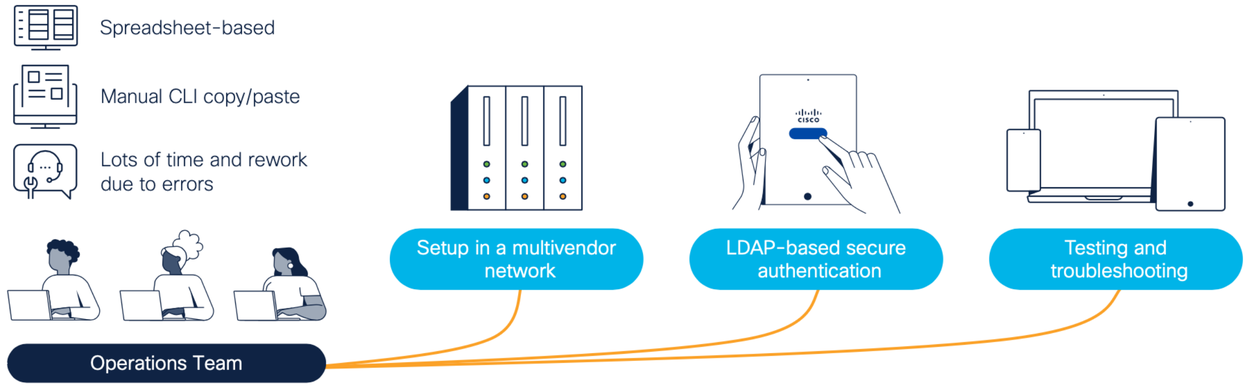
It describes what data is available, but not how it is stored or accessed.

Network Programmability

SHIFT IN APPROACH:

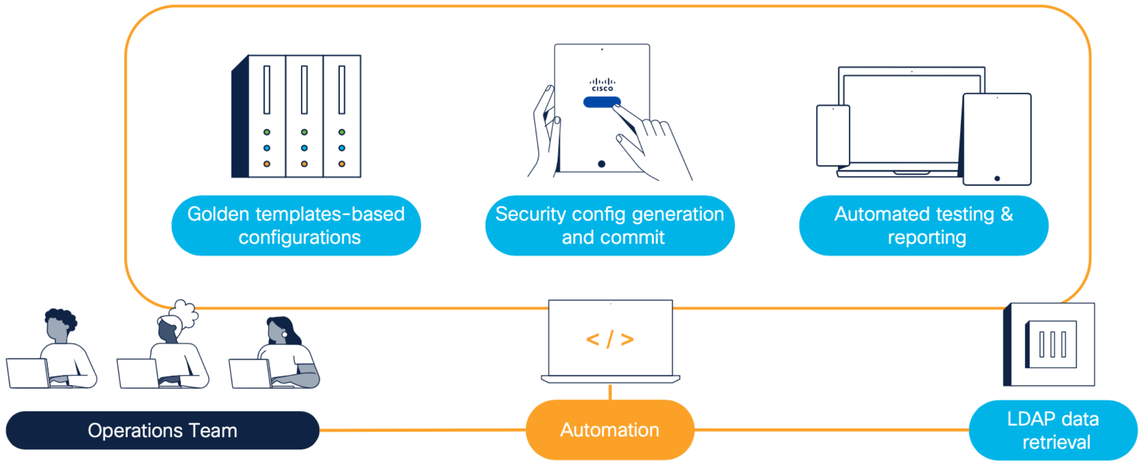
Traditional method: Manual, device-by-device configuration:

- Network engineers would log into each device separately.
- Use Command Line Interface (CLI) to make changes.
- Time-consuming and prone to human error, especially in large networks



New programmable method: Automated, programmatic control:

- Write scripts or use automation tools to manage multiple devices simultaneously.
- Changes can be version-controlled and tested before deployment.
- Enables consistency across the network and reduces the chance of human error.
- Allows for rapid deployment of changes and easier scaling of network management.



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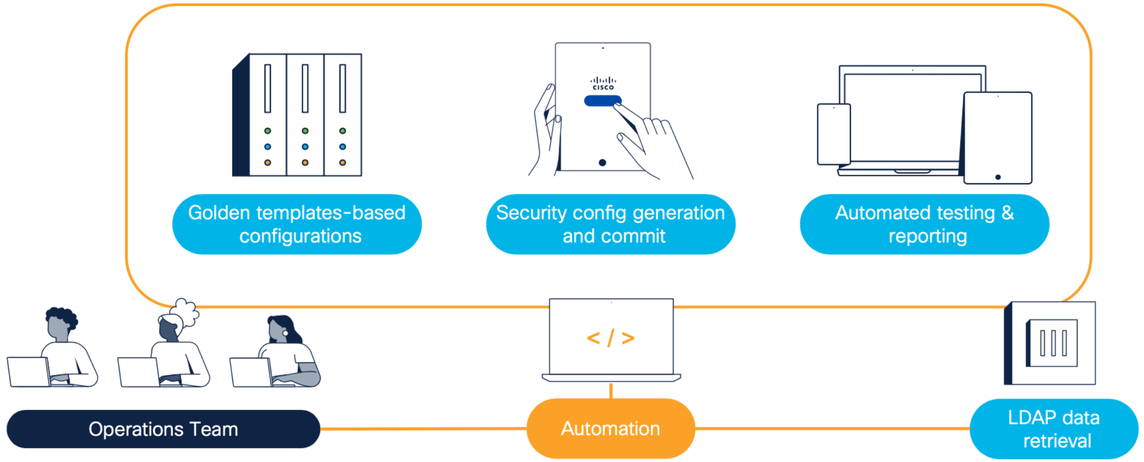

Examples:

- Configuration backups: Automatically backing up device configs daily.
- Compliance checks: Ensuring all devices meet security standards.
- Troubleshooting: Automated collection of diagnostic information.

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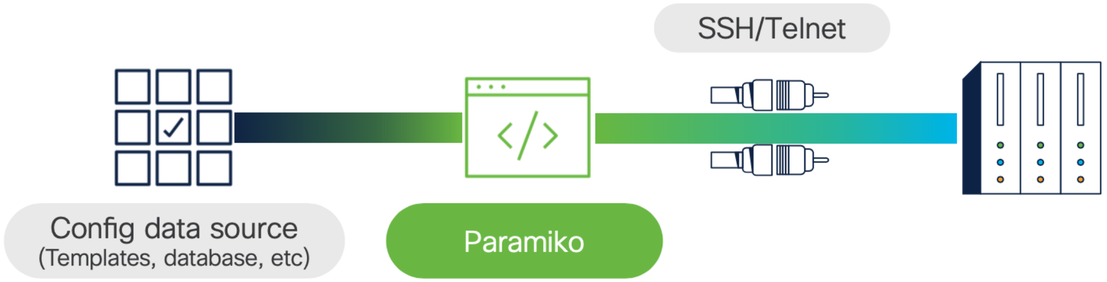
COMMON AUTOMATION TOOLS AND FRAMEWORKS

Network automation frameworks:

- Paramiko: Python library for connecting to network devices via SSH
- NAPALM (Network Automation and Programmability Abstraction Layer with Multivendor support): Provides a unified API to interact with different network device Operating Systems



Still SSH based (manual CLI mimicking)

Configuration management tools:

- Ansible: Agentless automation tool, uses YAML for playbooks
- Puppet: Uses its own declarative language, good for large-scale deployments
- Chef: Ruby-based, focuses on infrastructure as code

Network Programmability

KEY CONCEPTS AND BENEFITS

Automation

Examples:

- Configuration backups: Automatically backing up device configs daily.
- Compliance checks: Ensuring all devices meet security standards.
- Troubleshooting: Automated collection of diagnostic information.

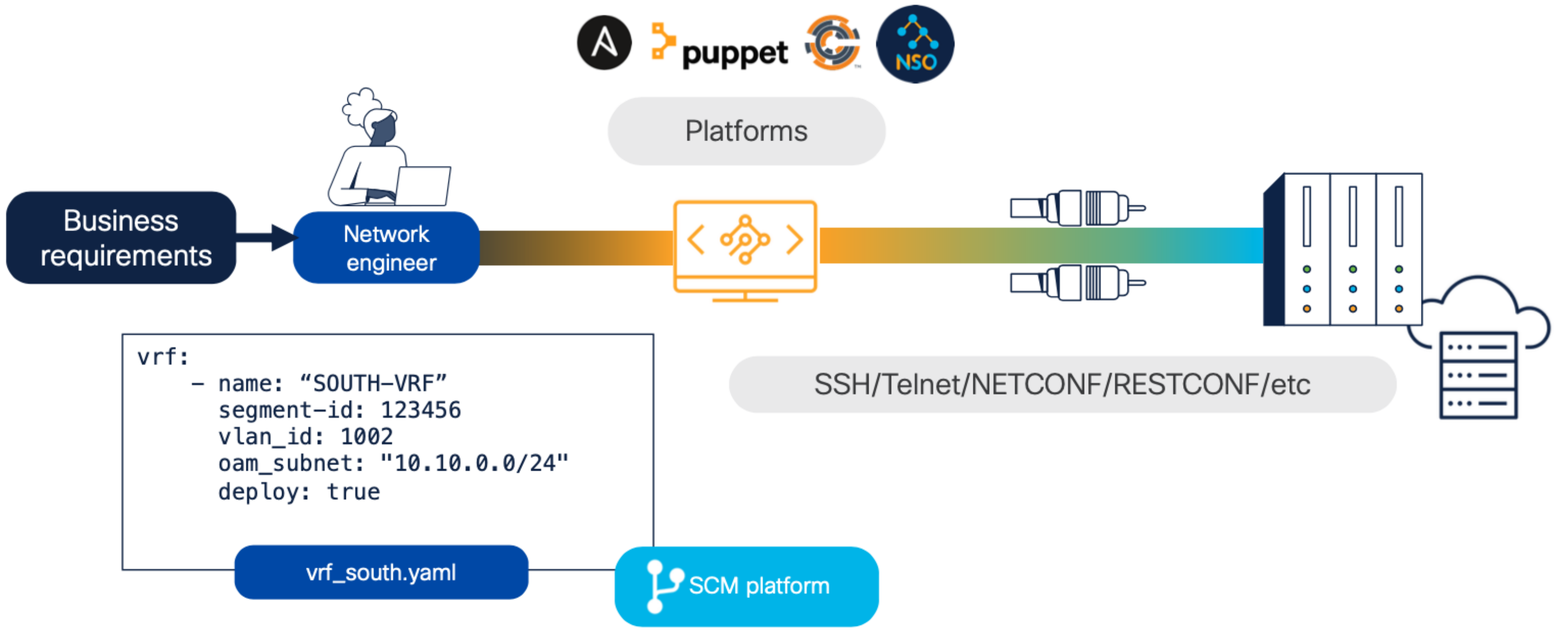
IaC (Infrastructure as Code)

Treating network configurations as software code

Benifits:

- Version control, reproducibility, easier testing and rollback.

- Defining the desired state of a network using simple text files
- IaC platforms for diferente purposes
- Vendor plugins specific for their network devices



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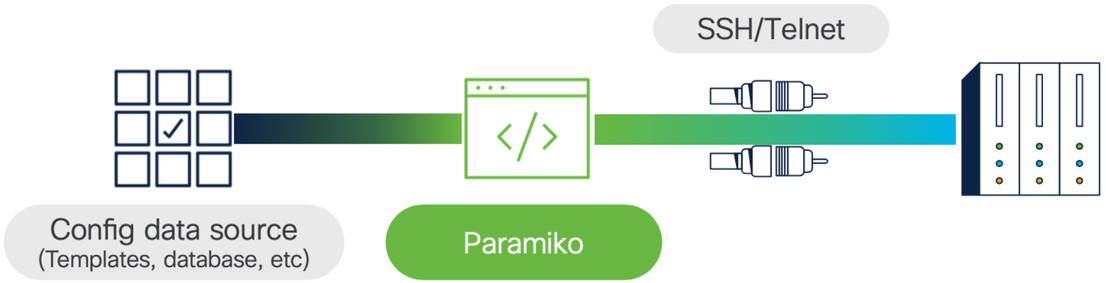

Still SSH based (manula CLI mimicking)

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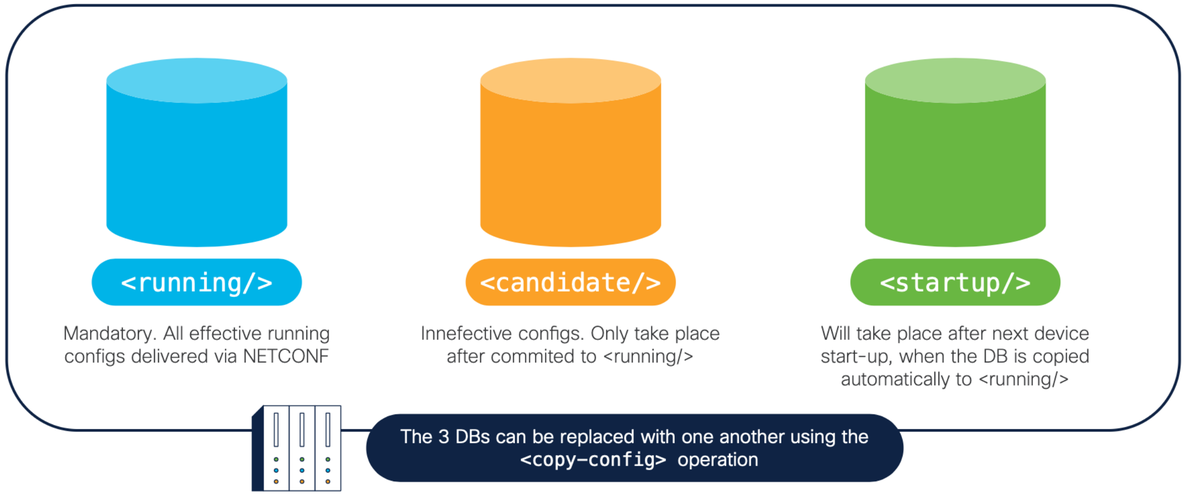
COMMON AUTOMATION TOOLS AND FRAMEWORKS

APIs and Protocols

NETCONF (Network Configuration Protocol):

- RFC 6241
- Uses XML encoding
- Provides a set of operations to manage device configurations
- Runs over SSH, port 830 as default.
- Yang Models are used to model the device's config.



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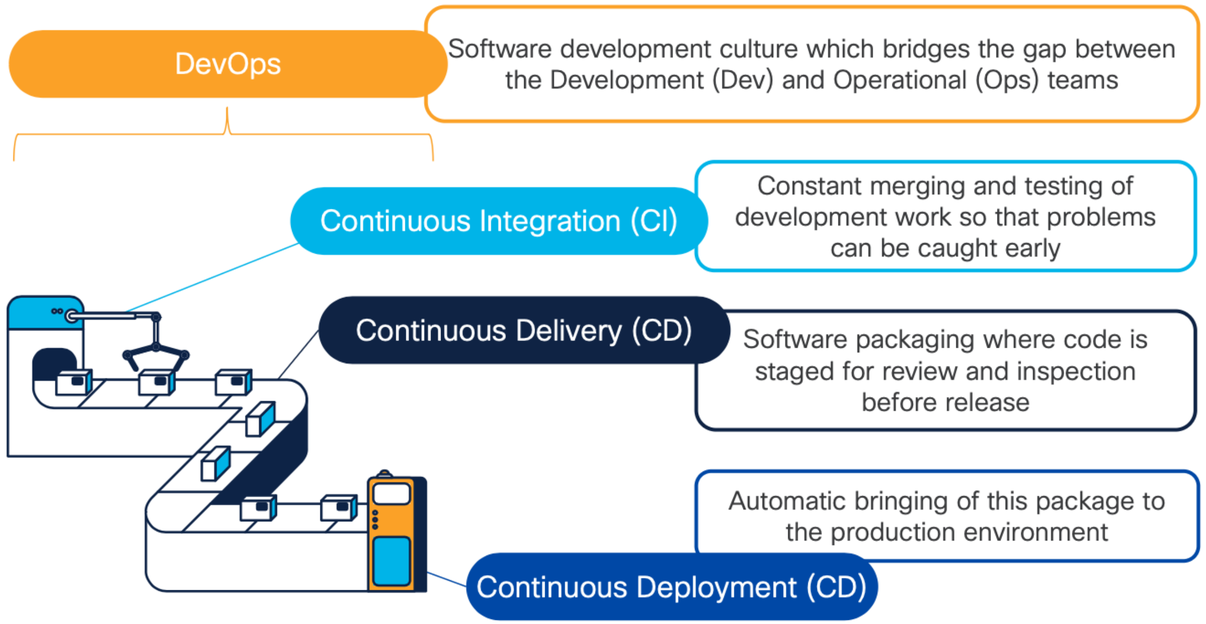
CONFIGURATION AS CODE PRINCIPLES

- Defining network configurations in a declarative manner (models, automation scripts)
- Version control for network configurations (for example using git for change tracking and rollbacks)
- Treating network changes like software development (code reviews, testing)



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EXAMPLE: AUTOMATING VLAN CONFIGURATION WITH ANSIBLE

Scenario: Configuring VLANs across multiple switches using Ansible to orchestrate and automate CLI configuration.

Step-by-step walkthrough:

- a. Define the desired VLAN configuration in YAML (vlan_config.yml):

```yaml
vlans:
  - id: 10
    name: "Data"
  - id: 20
    name: "Voice"
  - id: 30
    name: "Guest"
```

Network Programmability

EXAMPLE: AUTOMATING VLAN CONFIGURATION WITH ANSIBLE

Step-by-step walkthrough:

- b. Create an Ansible playbook to apply the VLAN configuration (configure_vlans.yml):

Ansible translates the configuration specified in the cisco.ios.ios_vlans module into the corresponding CLI commands, which it then sends to the device over SSH.

```yaml
- name: Configure VLANs on switches
  hosts: switches
  gather_facts: no

  vars_files:
    - vlan_config.yml

  tasks:
    - name: Configure VLANs
      cisco.ios.ios_vlans:
        config:
          - name: "{{ item.name }}"
            vlan_id: "{{ item.id }}"
            state: merged
      loop: "{{ vlans }}"

    - name: Save running config to startup config
      cisco.ios.ios_config:
        save_when: always

    - name: Verify VLAN configuration
      cisco.ios.ios_command:
        commands:
          - show vlan brief
      register: vlan_output

    - name: Display VLAN configuration
      debug:
        var: vlan_output.stdout_lines
```

- c. Run the playbook and verify the results :

ansible-playbook -i inventory.yml configure_vlans.yml

Network Programmability

EXAMPLE: AUTOMATING VLAN CONFIGURATION WITH ANSIBLE

Step-by-step walkthrough:

- b. Run the playbook and verify the results):

ansible-playbook -i inventory.yml configure_vlans.yml

inventory.yml file list all the hosts that we want to configure:

```
switches:
  hosts:
    switch1:
      ansible_host: 192.168.1.10
      ansible_user: admin
      ansible_password: your_password
      ansible_network_os: ios
    switch2:
      ansible_host: 192.168.1.11
      ansible_user: admin
      ansible_password: your_password
      ansible_network_os: ios
```

Network Programmability

EXAMPLE: AUTOMATING VLAN CONFIGURATION WITH ANSIBLE

Benefits:

- Consistency across devices.
- Easy to modify and extend.
- Version controlled.
- Idempotent (can be run multiple times safely).
- Includes verification step.
- Separates data (VLAN definitions) from logic (automation steps).

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RESTCONF

RESTCONF is an API :

- Used instead of CLI.
- Orchestration tools like Ansible can use RESTCONF modules and orchestrate configurations via RESTCONF and other APIs.

RESTCONF vs NETCONF:

- NETCONF uses XML for data encoding and typically runs over SSH.
- RESTCONF uses HTTP/HTTPS and supports both XML and JSON.
- NETCONF provides a more extensive set of operations but can be more complex to implement.
- RESTCONF aligns more closely with RESTful design principles.

Key benefits: simplicity, HTTP-based, JSON support

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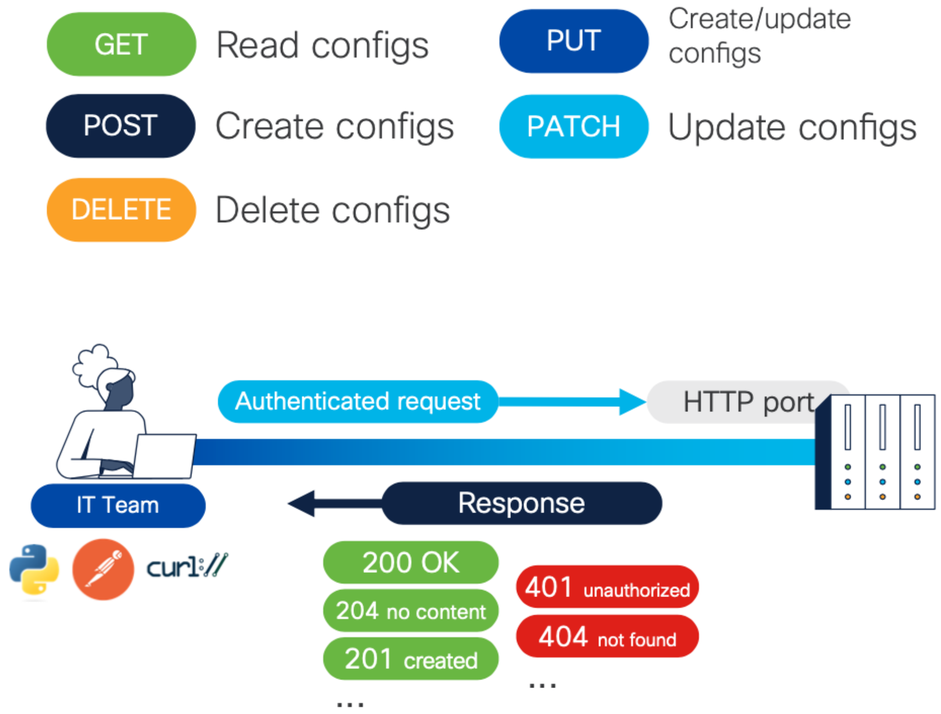
RESTCONF ARCHITECTURE

REST API :

- HTTPS-based communications.
- Stateless
- RESTful API interface for operations
- Verbs for CRUD actions
- Standarized response codes



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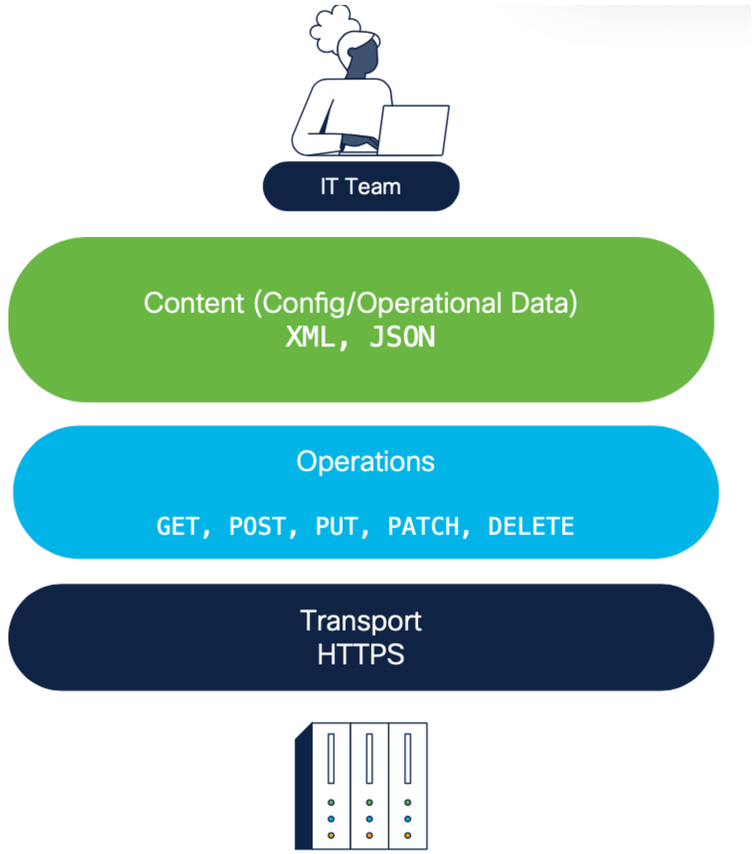
RESTCONF ARCHITECTURE

RESTCONF protocol:

- RFC 8040.
- Based on XML or JSON for data encoding
- Using YANG data models



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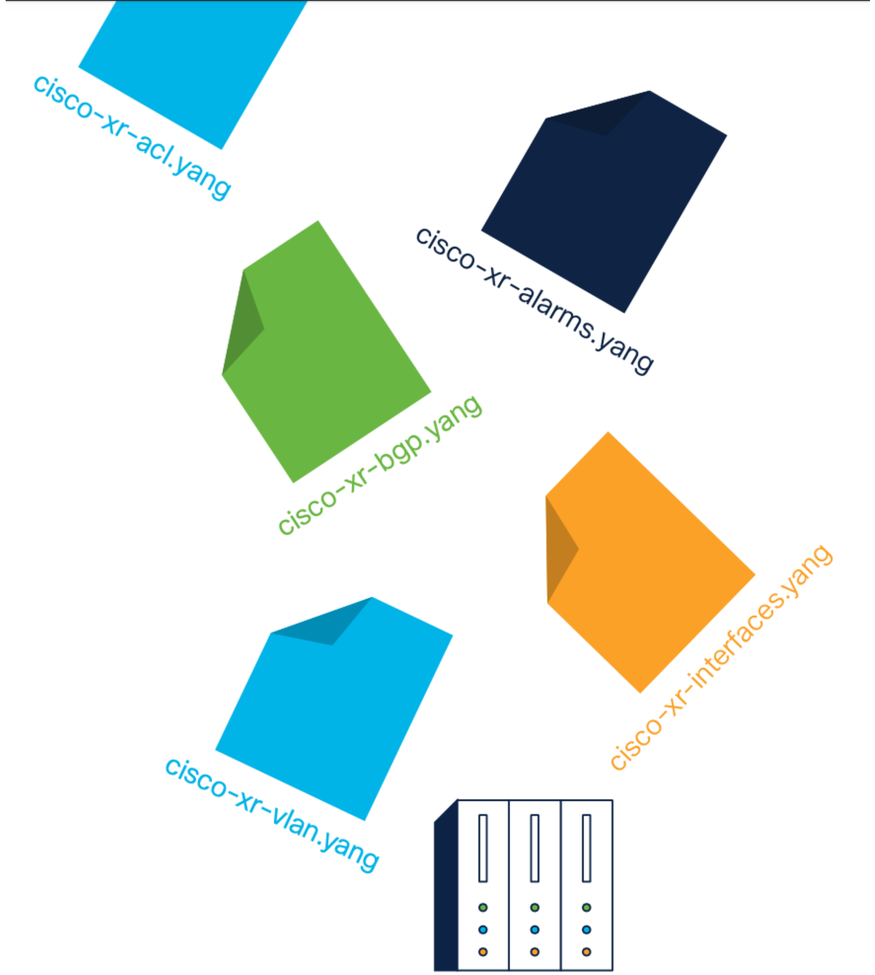
RESTCONF ARCHITECTURE

YANG data models

- RFC 6020.
- Data modeling language
- Models configurations and state of a data of a device or service
- Organized in nodes
- Several node and data types
- Device Data Models (Interface, VLAN, etc)
- Service Data Models (L3VPN, VRF, etc)
- Industry Santard vs. Vendor Specific



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YANG DATA MODELS

Leaf

```
leaf host-name {
    type string;
    description "Hostname for this system";
}
```

Simple data like integer or string. It holds exactly one value of a type, and has no children

Leaf-list

```
leaf-list domain-search {
    type string;
    description "List of domain names to search”;
}
```

Sequence of leaf nodes with exactly one value of a particular type per leaf

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YANG DATA MODELS

Container 📦

```
container login {
    leaf message {
        type string;
        description
           "Message given at start of login session";
         }
    }
```

Grouping of related nodes in a subtree. It has only child nodes and no value.
May contain any number of child nodes of any type

List 📋

```
list interface {
     tailf:info "Assign interface as port0";
     key name;
     leaf name {
          type string {
          tailf:info "Interface Name";
}
. . .
```

Sequence of entries uniquely identified by the value on their key leaf.
A list can define multiple keys and may contain any number of child nodes of any type

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RESTCONF EXAMPLE

1. Creating a new VLAN (POST request)

- Import the necessary libraries (requests and json).
- Disable SSL warnings for sandbox enviroments.
- Define the base URL for RESTCONF on Cisco NX-OS (sandbox environment)
- Set headers to indicate the content type and format (YANG)
- Provide authentication details

```
import requests
import json

# Disable SSL verification warnings (for sandbox environment)
requests.packages.urllib3.disable_warnings()

# DevNet Always-On NX-OS Sandbox details
url_base = "https://sandbox-nxos-1.cisco.com/restconf"
headers = {
    "Accept": "application/yang-data+json",
    "Content-Type": "application/yang-data+json"
}
auth = ("admin", "Admin_1234!")
```

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RESTCONF EXAMPLE

2. Retrieving interface information (GET request)

- Construct the URL to get interface information
- Send GET request to retrieve interface data.
- Check the response status and print the interfaces in a readable format if successful

```
# Get all interfaces
url = f"{url_base}/data/Cisco-NX-OS-device:System/intf-items"
response = requests.get(url, headers=headers, auth=auth, verify=False)

if response.status_code == 200:
    interfaces = response.json()
    print(json.dumps(interfaces, indent=2))
else:
    print(f"Error: {response.status_code} - {response.text}")
```

Network Programmability

RESTCONF EXAMPLE

- **Container** (System): The top-level container for system-level configurations.
- **Container** (intf-items): Contains all interface-related configurations.
- **Container** (phys-items): Specifically for physical interfaces
- **List (**PhysIf): List of physical interfaces. Each interface is an entry in the list.
  - **Leaf** id: Identifier for the interface.
  - **Leaf** descr: Description of the interface.
  - **Leaf** adminSt: Administrative state of the interface (e.g., up or d own)

Interface YANG Model Example

Json

```
{
  "Cisco-NX-OS-device:System": {
    "intf-items": {
      "phys-items": {
        "PhysIf": [
          {
            "id": "eth1/1",
            "descr": "Initial description",
            "adminSt": "up"
          }
        ]
      }
    }
  }
}
```

Network Programmability

RESTCONF EXAMPLE

3. Modifying interface description (PATCH request)

- Define the Interface to be updated
- Create a payload with the new description
- Send a PATCH request to update the interface description
- Check the response status confirm the update

```python
# Update description for Ethernet1/1
interface_name = "eth1/1"
url = f"{url_base}/data/Cisco-NX-OS-device:System/intf-items/phys-items/PhysIf={interface_name}"

payload = {
    "Cisco-NX-OS-device:PhysIf": {
        "descr": "Updated via RESTCONF"
    }
}

response = requests.patch(url, headers=headers, auth=auth, data=json.dumps(payload), verify=False)

if response.status_code == 204:
    print(f"Interface {interface_name} description updated successfully")
else:
    print(f"Error: {response.status_code} - {response.text}")
```

Network Programmability

RESTCONF EXAMPLE

4. Creating a new VLAN (POST request)

- Construct the URL to create a new VLAN
- Create a payload with the VLAN details
- Send a POST request to create the VLAN
- Check the response status and confirm the creation

```python
# Create VLAN 100
url = f"{url_base}/data/Cisco-NX-OS-device:System/bd-items/bd-items"

payload = {
    "Cisco-NX-OS-device:bd-items": {
        "BD-list": [
            {
                "fabEncap": "vlan-100",
                "name": "VLAN100_via_RESTCONF"
            }
        ]
    }
}

response = requests.post(url, headers=headers, auth=auth, data=json.dumps(payload), verify=False)

if response.status_code == 201:
    print("VLAN 100 created successfully")
else:
    print(f"Error: {response.status_code} - {response.text}")
```

Network Programmability

RESTCONF EXAMPLE

VLAN YANG Model Example

- **Container** (System): The top-level container for system-level configurations.
- **Container** (bd-items): Contains all bridge domain (VLAN) related configurations.
- **List** (PhysIf): List of bridge domains (VLANs). Each VLAN is an entry in the list.
  - **Leaf** fabEncap: Encapsulation method, including the VLANN ID.
  - **Leaf** name: Name of the VLAN.

```
{
  "Cisco-NX-OS-device:System": {
    "bd-items": {
      "BD-list": [
        {
          "fabEncap": "vlan-100",
          "name": "VLAN100_via_RESTCONF"
        }
      ]
    }
  }
}
```

Network Programmability

RESTCONF EXAMPLE

4. Retrieving routing information (GET request)

- Construct the URL to get IPv4 routing information
- Send a GET request to retrieve routing data
- Send a POST request to create the VLAN
- Check the response status and print the routes in a readable format if successful

```
# Get IPv4 routing table
url = f"{url_base}/data/Cisco-NX-OS-device:System/ipv4-items/inst-items/dom-items/Dom-list=default/rt-items"
response = requests.get(url, headers=headers, auth=auth, verify=False)

if response.status_code == 200:
    routes = response.json()
    print(json.dumps(routes, indent=2))
else:
    print(f"Error: {response.status_code} - {response.text}")

Explanation:

Construct the URL to get IPv4 routing information.

Send a GET request to retrieve routing data.

Check the response status and print the routes in a readable format if successful.
```

Network Programmability

RESTCONF EXAMPLE

VLAN YANG Model Example

- **Container** (System): The top-level container for system-level configurations.
- **Container** (ipv4-items): Contains all IPv4-related configurations.
- **Container** (inst-items): Instance-level configurations for IPv4.
- **Container** (dom-items): Domain-related configurations.
- **List** (Dom-list): List of domains. Each domain is an entry in the list.
  - **Leaf** (name): Name of the domain (e.g., default).
- **Container** (rt-items): Contains routing table entries
- **List** (Route-list): List of routes. Each route is an entry in the list.
  - **Leaf** (prefix): Prefix of the route.
  - **Leaf** (nextHop): Next-hop address for the route.


```
{
  "Cisco-NX-OS-device:System": {
    "ipv4-items": {
      "inst-items": {
        "dom-items": {
          "Dom-list": [
            {
              "name": "default",
              "rt-items": {
                "Route-list": [
                  {
                    "prefix": "10.0.0.0/24",
                    "nextHop": "192.168.0.1"
                  }
                ]
              }
            }
          ]
        }
      }
    }
  }
}
```