Automating Internet2's Nationwide Network with Cisco NSO

Karl Newell

Network Software Architect, Internet2

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Agenda

- Background
- Some History
- Migration
- Modern Times
- Keys to Success

Background

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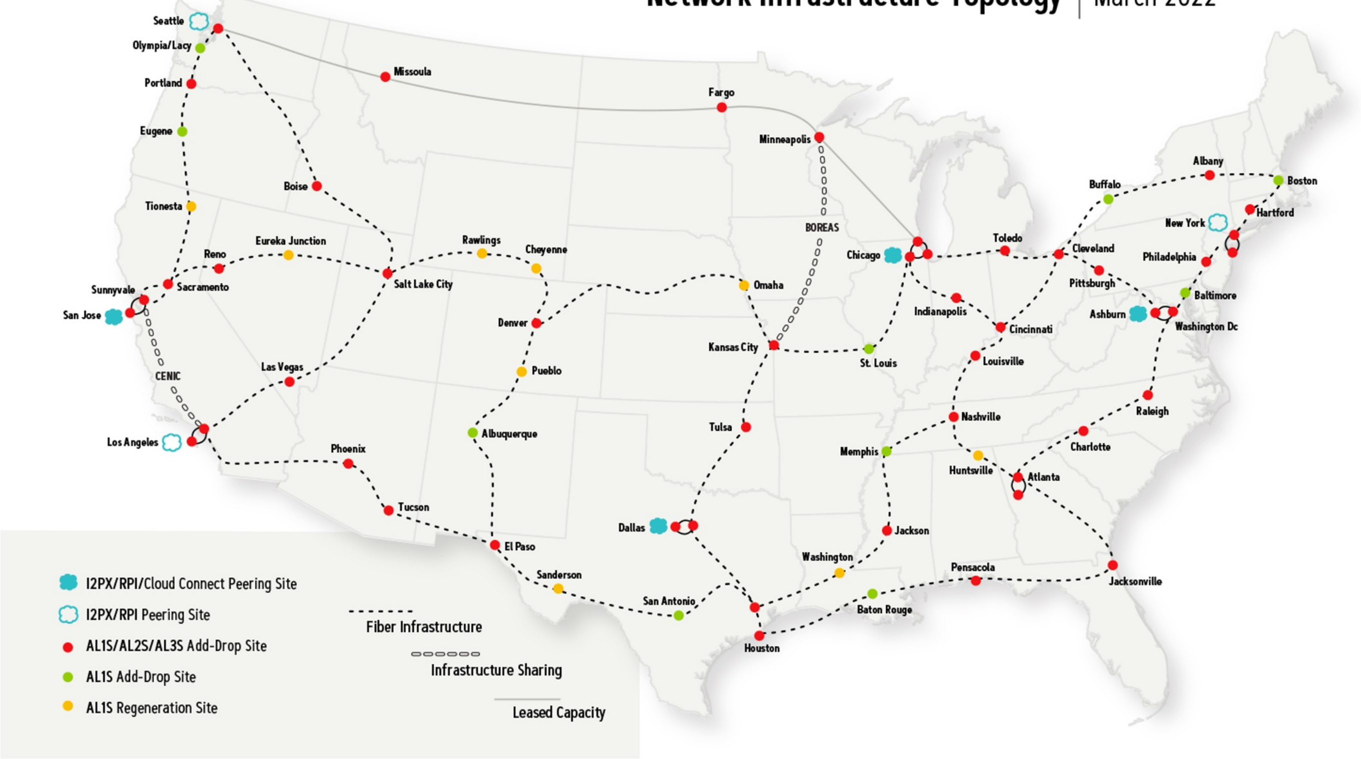
Network Infrastructure Topology | March 2022



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BY THE NUMBERS

320+
HIGHER EDUCATION MEMBERS

350+
NET+ SUBSCRIBERS

100+
COUNTRIES & RESEARCH NETWORKS CONNECTIONS

80,000+
COMMUNITY ANCHOR INSTITUTIONS

1000+
INCOMMON PARTICIPANTS

50+
INDUSTRY MEMBERS

950+
EDUROAM SUBSCRIBERS

750+
NET+ CLOUD CONTRACTS

60
AFFILIATE & GOVERNMENT MEMBERS

800G+
WAVELENGTHS OF NETWORK CAPABILITY

46
REGIONAL & STATE NETWORKS

32Tbps
CAPACITY PER LINK

Some History

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The Challenge

- Deploy a new nationwide network
  - Double the device count
- Change vendors
- Migrate legacy configuration

The Solution

- Cisco Network Services Orchestrator (NSO)
- Lots of Python
  - pyATS
- Google Sheets and Apps Script
- Amazing Network Engineers and Developers

What NSO Offers

- Configuration Orchestration
  - Multi-vendor support
  - Templates
  - Single config tree includes all devices
- System-wide transactions
- Coexistence with out of band changes
- Graceful evolution over time
- **Command line interface**

How NSO Works

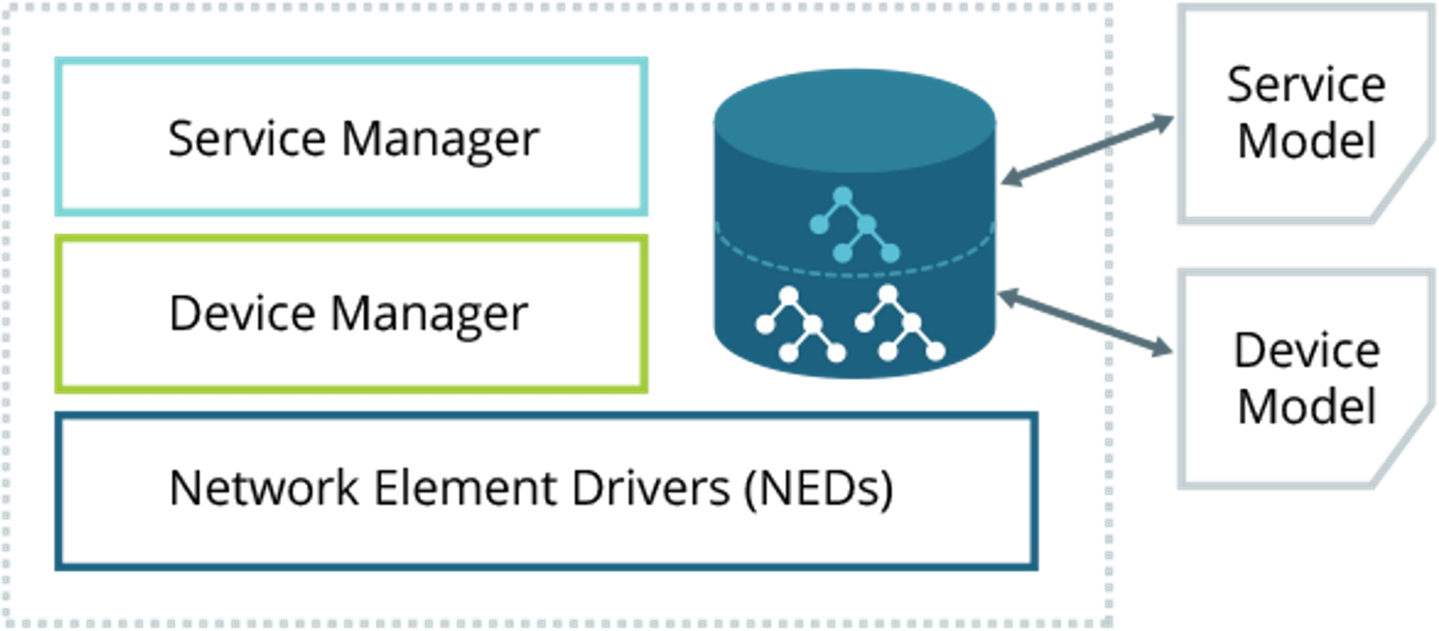
- Service models
  - YANG
  - Vendor neutral
- Templates
  - XML
  - Vendor specific
- Declarative
  - NSO determines the minimal amount of changes needed to configure the device
  - Service instance deletion removes relevant configuration

Example Service Model

```
> show configuration services i2px-cust ALBA-TEST*

i2px-cust ALBA-TEST-1 {
    admin-state  in-service;
    service-id   55668;
    entity       TEST;
    pdp          ALBA-CONN-TEST-1;
    encapsulation {
        dot1q {
            vlan-id 1091;
        }
    }
    address-ipv4 192.0.2.1/30;
    address-ipv6 2001:db8::1/64;
    remote-as    65505;
    neighbor 192.0.2.2 {
        maximum-prefix 20;
    }
    neighbor 2001:db8::2 {
        maximum-prefix 10;
    }
    password-md5 REDACTED;
    select-in {
        prefix 65505-CUST-V4-IN;
        prefix 65505-CUST-V6-IN;
    }
}
```

How NSO Works



Why We Chose NSO

- Vendor agnostic
- Declarative configuration
    - Service deletion removes all related configuration
- System wide commits
    - Problems don't strand broken config
- CLI
- Engineers aren't copying around their version of a configuration template
- Engineers spend less time implementing changes

Migration

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Network Automation and Migration

- NSO service models leveraged for service deployments
  - Minimal, simple parameters needed to produce complex device configuration
  - All changes are atomic across the network
- Layer 3 (BGP) service migrations - Cisco NSO, Google Sheets
  - Imported legacy network/DB data to produce NSO-generated service config
  - Allowed migration of 2000 peerings in ~30 days (up to 150/night)

Network Automation and Migration

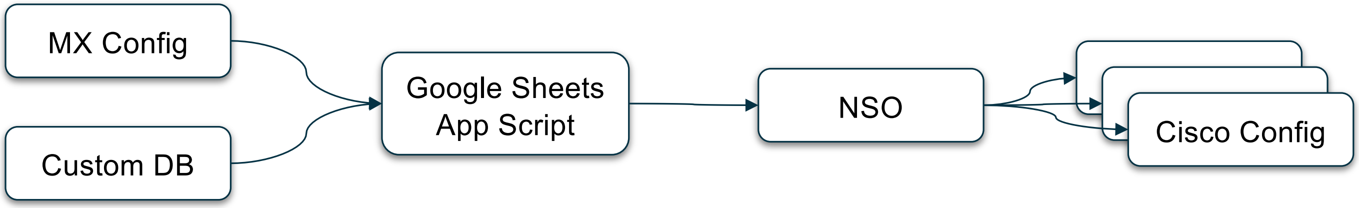
- Validation tooling for quality assurance - Cisco pyATS
  - BGP prefix acceptance/rejection monitoring before and after migration
  - Allowed rapid validation of migrated service
- Test Driven Development - Robot Framework
  - Rapid iteration of NSO service models with testing to deter regression
  - Decrease time needed for new service deployments

Network Automation and Migration

- Configuration control and monitoring
  - Manual changes on device are identified and flagged for reintegration into NSO models
  - Ensures minimal drift

Network Automation and Migration

- Juniper MX to Cisco 8200 (IOS-XR)
- Translate services - legacy to NGI
  - Extract-Transform-Load
    - Scripts to pull config from legacy network and DB
    - Save into Google Sheet
    - Google Apps Script to convert data into NSO config
- Service validation scripts
  - pyATS



Network Automation and Migration

- pyATS validation scripts
  - pre and post migration BGP data (prefixes and counts)
  - diff and report anomalies

```
=== re-participant CHIC-CUST-1 (192.0.2.1) ===
Neighbor migrated: rtsw.chic -> core2.chic


                               [   PRE    ] [   POST  ]
Prefix                         Recv Accept  Recv Accept  INFO/Advice
192.0.0.0/24                      *      *     *         INVESTIGATE - route no longer being accepted
192.0.2.0/24                      *      *     *         INVESTIGATE - route no longer being accepted
192.168.0.0/16                    *      *     *         INVESTIGATE - route no longer being accepted
198.51.100.0/24                   *      *     *         INVESTIGATE - route no longer being accepted
203.0.113.0/24                    *      *     *         INVESTIGATE - route no longer being accepted

 Skipped 14 routes that did not change
```

NSO Stats

- 30 service models (19 edge service models)
- 4,000+ service instances
- 32,047 lines of NSO service config
    - resulting in 250,282 lines of device config
- **7.81 config compression ratio**
- 2,200+ commits
- 632 git merges
- 6,000+ build pipelines

Modern Times

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Service Development

- Rapid iteration with Network Engineering
    - “paper prototypes” - what would an Engineer want to enter on the CLI to define a Service
- Keep Service options to a minimum - don’t need all the knobs
    - Reduces the amount of testing needed
- **We spend a significant amount of time defining what a Service is and what input is needed to differentiate Service instances**

Multi Vendor Support

- Cisco 8200 (IOS-XR)
- Cisco NCS 5500 (IOS-XR)
- Arista 7280R3
- Juniper EX 4600
- Juniper SRX 1500
- Juniper SRX 4100

User-facing Service Provisioning

- Developing the Internet2 Insight Console
  - Layer 2 and 3 circuit provisioning
  - Cloud Connections
  - Routing Intentions (prefix management)
- Looking Glass
- Future
  - Visualization and reporting of all member services
  - Management of all member services

Keys to Success

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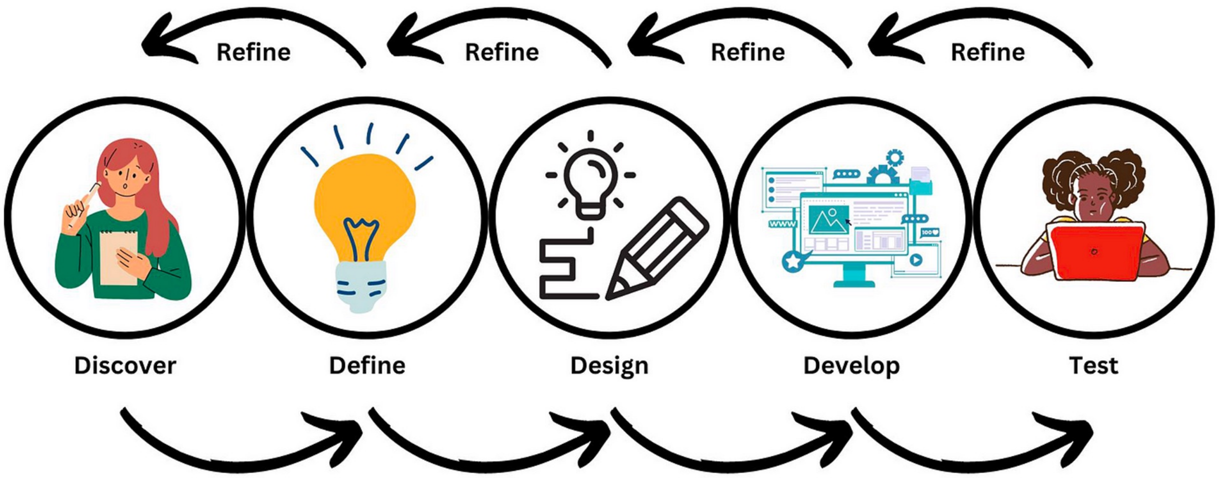
Integrated Team

- Software Development and Network Engineering teams were tightly integrated
  - Met (and continue to meet) weekly
  - Developers and engineers worked together to develop service models and implementation

Iteration

- Don’t be afraid to start over
  - Some of our service models are on their third revision



Right Tools for the Job

- NSO is designed for network automation
- But NSO doesn’t meet all of our needs so we use other tools as well
  - pyATS
  - Nornir
- Spreadsheets work
  - Especially coupled with scripting (Google Apps Script)

Thank you

Karl Newell

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