



The bridge to possible

# Catalyst 9000 IOS-XE Innovations:

Edge Services using App-Hosting, Programmability and Cloud

Sohaib Abid, Customer Success Specialist

# Cisco Webex App

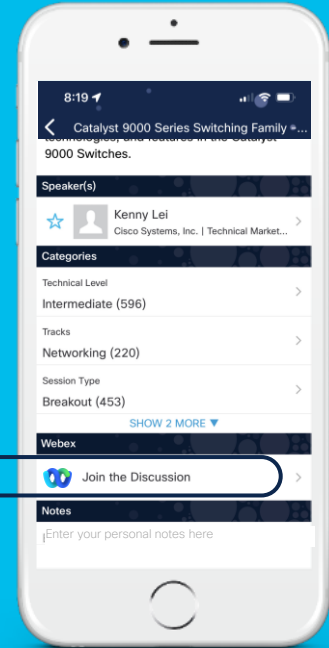
## Questions?

Use Cisco Webex App to chat with the speaker after the session

## How

- 1 Find this session in the Cisco Live Mobile App
- 2 Click “Join the Discussion”
- 3 Install the Webex App or go directly to the Webex space
- 4 Enter messages/questions in the Webex space

Webex spaces will be moderated until February 24, 2023.



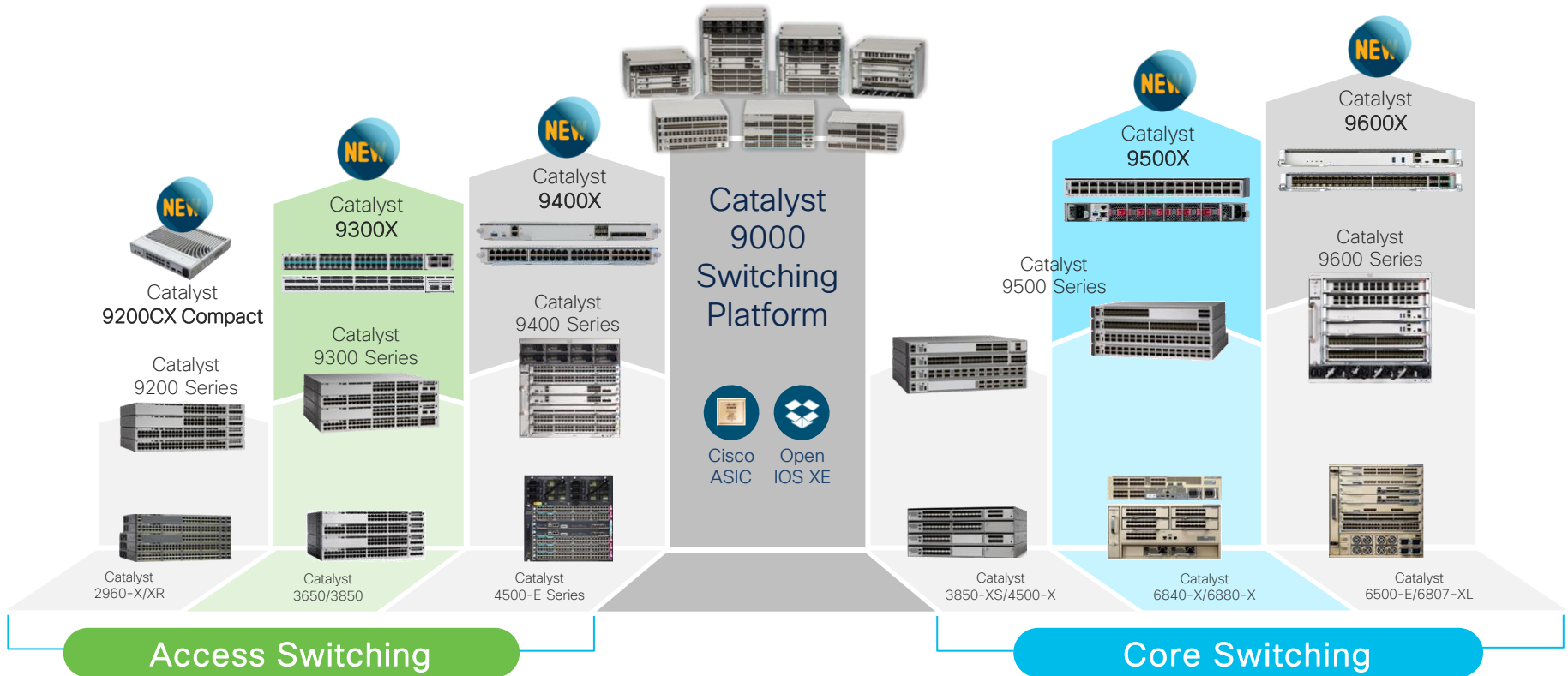


# Agenda

- Catalyst Family and its Evolution
- IOS-XE Programmability
- Device Provisioning / ZTP
- App Hosting Infrastructure & Management
- Cloud Services at the Edge

# Cisco Catalyst 9000 Switching Portfolio

Adding the “X factor” to the industry’s leading switching family



# Catalyst 9000 Series – Common Building Blocks



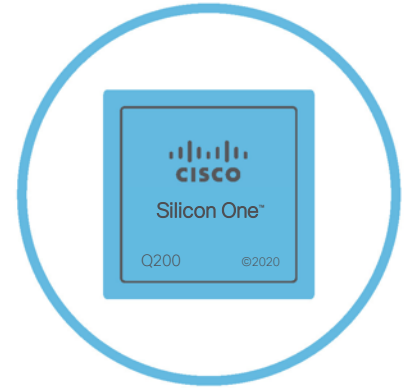
Programmable x86  
Multi-Core CPU

Application Hosting  
Secure Containers



Open IOS XE®  
Polaris

Model-Driven APIs  
Modular Patching

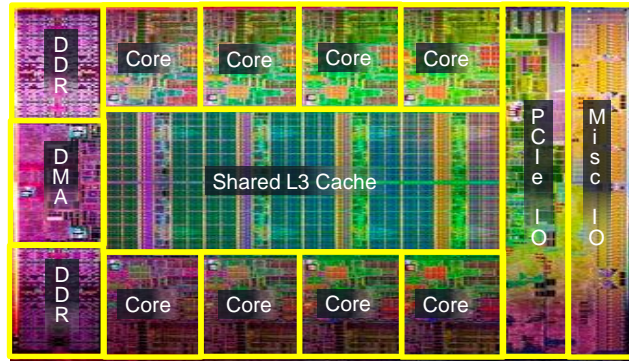


Cisco UADP &  
Silicon One™

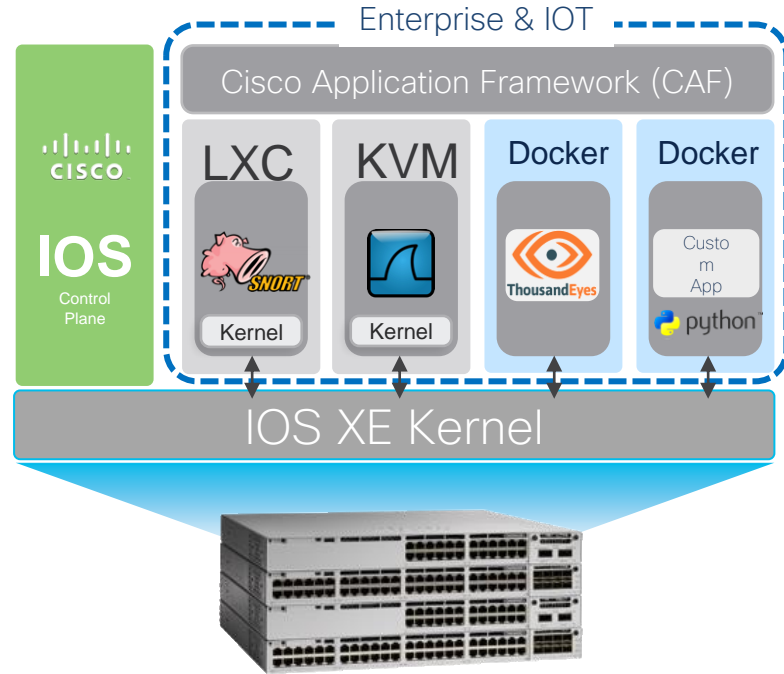
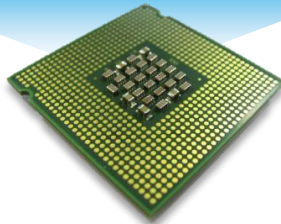
Programmable Pipeline  
Flexible Tables

Same IOS XE image for both UADP and Silicon One C9K platforms

# Multi-Core CPU – Built for App Hosting

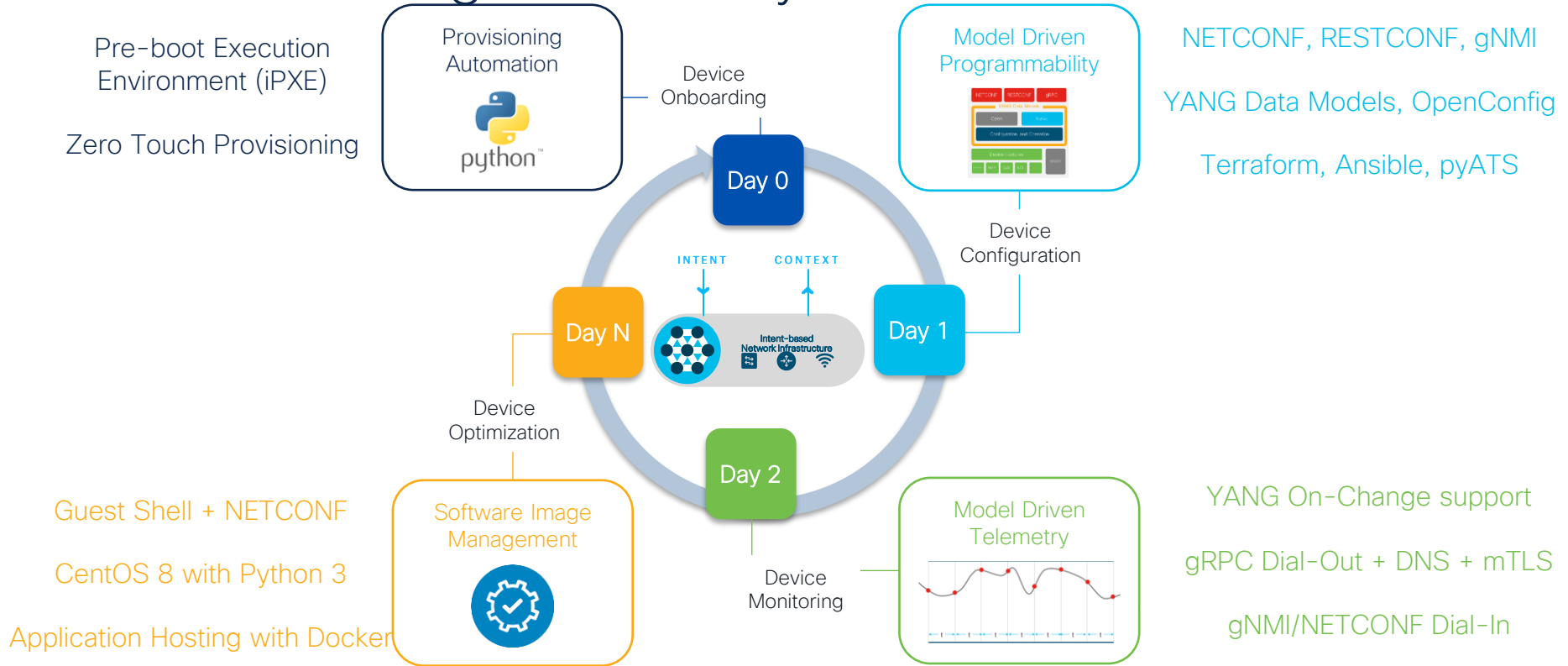


**x86**  
CPU



x86 CPU enables hosting NFV devices, Containers and 3<sup>rd</sup>-party Apps

# IOS XE Programmability & Automation Overview



# New strategic capabilities with App Hosting on C9K Switches

Existing Hardware

Managed via CLI  
or DNA-C

Real Time Processing

Lower Latency

Save Bandwidth



IT Operations and  
Monitoring Tools

Consolidate Physical  
Infrastructure



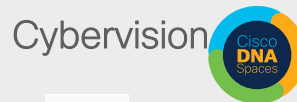
Security Agents  
and Functions

Enhance Visibility &  
Security Enforcement



Cloud Gateways with  
Serverless Edge Compute

Reduce App Latency  
& Optimize App Traffic



Customer Specific  
Applications

3<sup>rd</sup> Party App Hosting

Rich ecosystem  
partnership with 25+  
certified apps and  
200+ active  
customer



# IOS-XE Programmability



# Programmable Interfaces

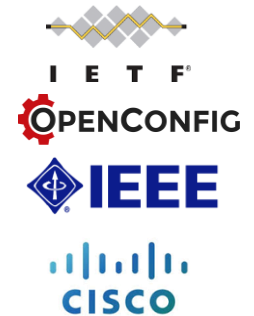
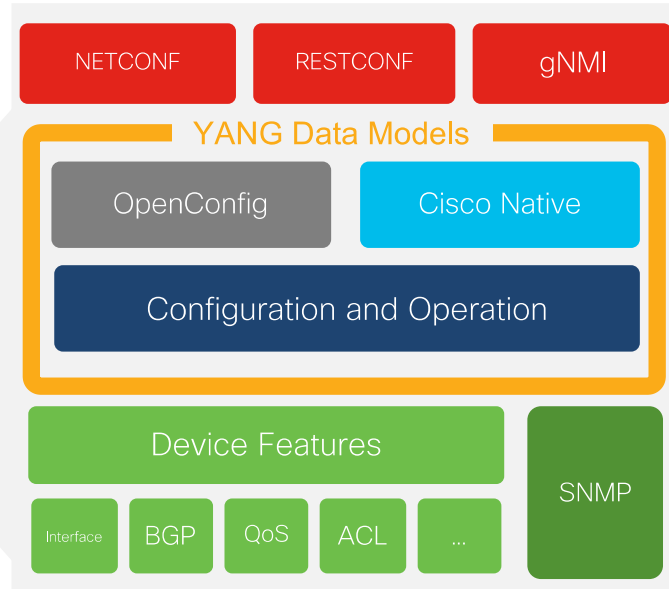
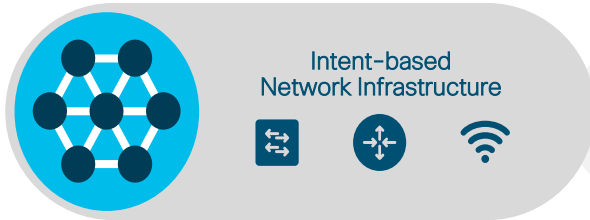
CLI

SNMP

WebUI

The NETCONF, RESTCONF and gNMI are programmatic interfaces that provide additional methods for interfacing with the IOS XE device – Just like the CLI, SNMP, and WebUI

YANG data models define the data that is available for configuration and streaming telemetry



# Cisco YANG Suite



Construct and test YANG based APIs over  
NETCONF, RESTCONF, gRPC and gNMI  
IOS XE / IOS XR / NX OS platforms

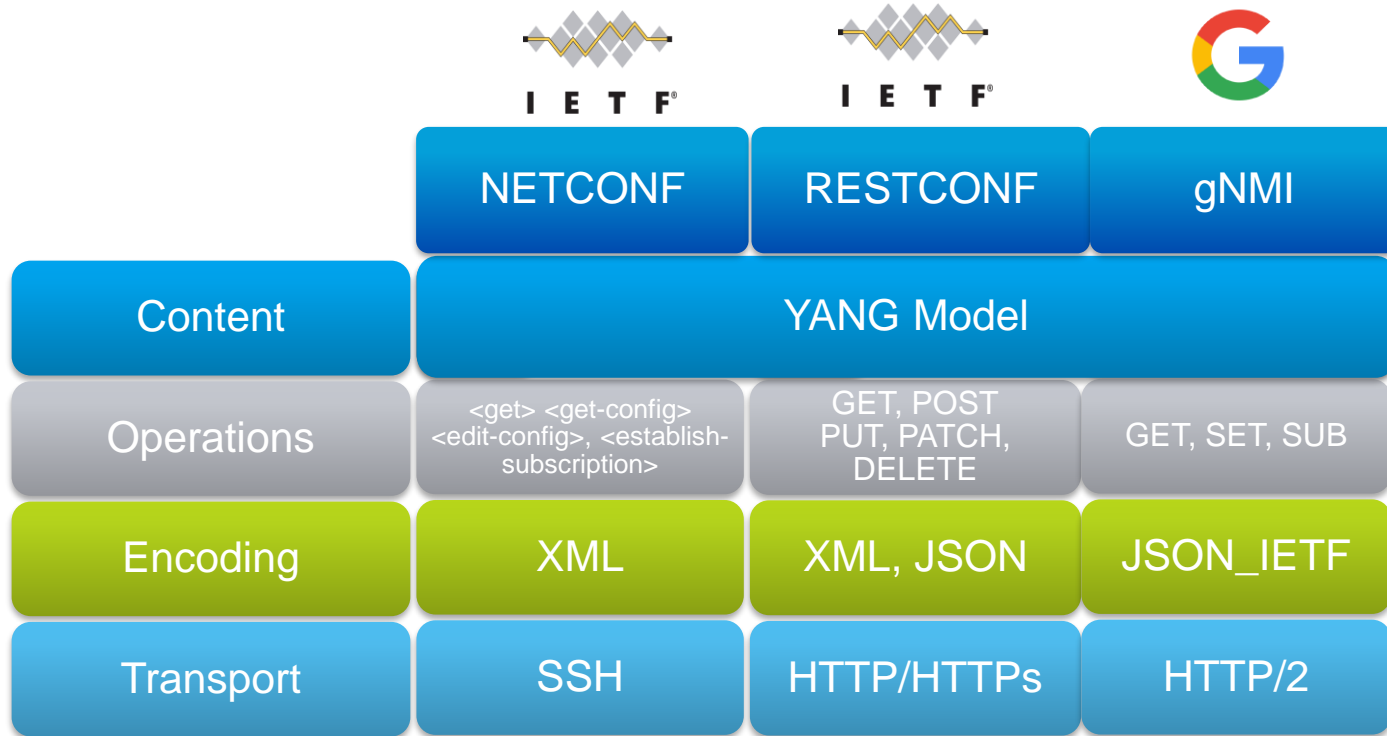
The top screenshot shows the 'Explore YANG Models' view. It features a navigation sidebar on the left with options like Admin, Setup, Explore, Protocols, and Help. The main area displays the selected YANG set (C9300) and module (Cisco-IOS-XE-interfaces-oper). A tree view shows the module's structure, including 'interfaces' and 'interface' nodes. A 'Node Properties' table is visible on the right, listing details such as Name, Nodetype, Description, Module, Revision, Xpath, Prefix, and Namespace.

The bottom screenshot shows the 'NETCONF' view. It includes a 'YANG Set' dropdown (C9300), a 'Module(s)' dropdown (Cisco-IOS-XE-interfaces-oper), and a 'Load Module(s)' button. Below this, there are controls for 'NETCONF Operation' (get), 'Device' (JCOHOE-DMZ-C9300), and buttons for 'Edit Device', 'Open Device Window', 'Run RPC(s)', and 'Clear RPC(s)'. A 'Build RPC' button is also present. The main area is split into two panes: a tree view on the left showing the YANG model structure, and an XML payload on the right. The XML payload is an RPC message for the 'get' operation on the 'Cisco-IOS-XE-interfaces-oper' module.

[developer.cisco.com/yangsuite](https://developer.cisco.com/yangsuite)

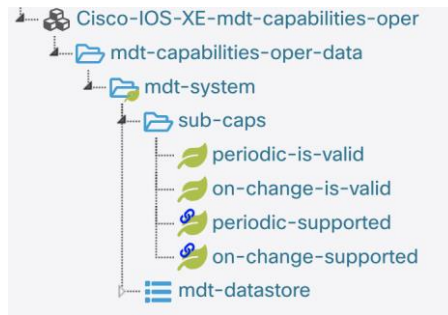
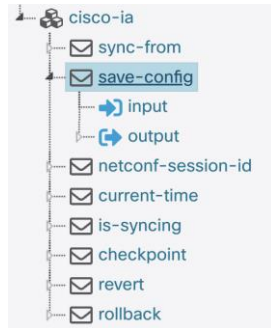
[github.com/CiscoDevNet/yangsuite](https://github.com/CiscoDevNet/yangsuite)

# API Interfaces



# Notable YANG models

YANG Module	Description
Cisco-IOS-XE-native.YANG	Running-configuration
Cisco-IOS-XE-{feature}-oper.YANG	Feature specific operational data
Cisco-IOS-XE-{feature}-cfg.YANG	Feature specific configuration
Cisco-IOS-XE-RPC, cisco-ia	Actions for DHCP Renew, Save config
Cisco-IOS-XE-events-oper.yang	Event based telemetry notifications
Cisco-IOS-XE-mdt-capabilities-oper.yang	Telemetry capabilities



<https://github.com/YangModels/yang/tree/master/vendor/cisco/xe>

# CLI to YANG

- This new CLI addition to “show run | format” brings additional visibility into the YANG modelled configuration, either for NETCONF with XML or JSON with RESTCONF
- Easily convert CLI into YANG to re-use in tooling, scripts, and automation and orchestration systems

```
show run | format netconf-xml
```

```
show run | format restconf-json
```

```
C9300#show run | format netconf-xml
<config xmlns="http://tail-f.com/ns/config/1.0">
  <native xmlns="http://cisco.com/ns/yang/Cisco-IOS-XE-native">
    <version>17.7</version>
    <memory>
      <free>
        <low-watermark>
          <processor>131752</processor>
        </low-watermark>
      </free>
    </memory>
  </native>
</config>
```

```
C9300#show run | format restconf-json
{
  "data": {
    "Cisco-IOS-XE-native:native": {
      "version": "17.7",
      "memory": {
        "free": {
          "low-watermark": {
            "processor": 131923
          }
        }
      }
    }
  }
}
```

```
C9300#
C9300#show run | i netconf-yang
netconf-yang
C9300#
```

Requires netconf-yang Data Model Interfaces to be enabled  
CLIs with corresponding native YANG and modeled in show run are returned

# Model Driven Telemetry Interfaces

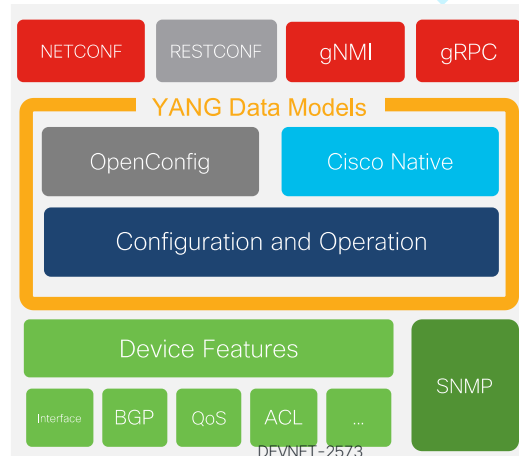


Dial In: Collector establishes a connection to the device then subscribes to telemetry (pub/sub)



Dial Out: Telemetry is pushed from the device to the collector based off configuration (push)

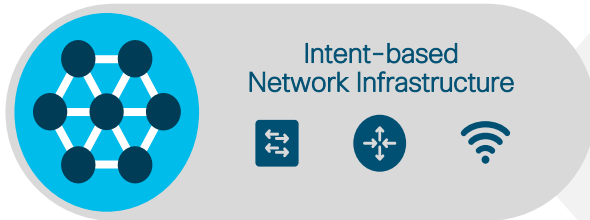
## Publication / Subscription



XML, JSON encoding

Consistent YANG data models between interfaces

On-change event and time-based publication options



Intent-based Network Infrastructure

# Model Driven Telemetry Interface Comparison

	NETCONF	gRPC	gNMI
Minimum IOS XE Version	16.6	16.10	16.12
Telemetry Direction	Dial-In, IOS XE is server	Dial-Out IOS XE is client	Dial-In IOS XE is server
Configuration	Dynamic per session	Static per configuration	Dynamic per session
Telemetry Collector	Client	Server	Client
Encoding	XML	KV GPB	JSON_IETF
Security	SSH + PKI certificate or password	TLS or plain-text	TLS certificate with user authentication
Transport Protocol	SSH	HTTP2	HTTP2
Data Models	YANG	YANG	YANG



# Model Driven Telemetry: usage comparison

60-minute collection sample with 60-second update interval

Interface	CPU Impact	PCAP file size/data size (MB)	Data byte Rate	Data bit rate	Average Packet Rate (sec)	Average Packet Size (bytes)
gNMI	+3%	23 MB	6 kBps	53 kbps	5	1180
gRPC	+3%	69 MB	19 kBps	155 kbps	58	333
NETCONF	+2%	83 MB	23 kBps	185 kbps	29	780
RESTCONF	+4%	200 MB	35 kBps	281 kbps	37	945
SNMP *	+6%	120 / 87	24 kBps	197 kbps	90	273

17 xpaths collected at 60 second update interval

- /arp-ios-xe-oper:arp-data
- /cdp-ios-xe-oper:cdp-neighbor-details
- /environment-ios-xe-oper:environment-sensors
- /if:interfaces-state
- /interfaces-ios-xe-oper:interfaces/interface
- /ios:native
- /lldp-ios-xe-oper:lldp-entries
- /matm-ios-xe-oper:matm-oper-data
- /mdt-oper:mdt-oper-data/mdt-subscriptions
- /memory-ios-xe-oper:memory-statistics/memory-statistic
- /oc-if:interfaces/interface/state/counters
- /oc-platform:components
- /oc-sys:system
- /platform-ios-xe-oper:components
- /poe-ios-xe-oper:poe-oper-data/poe-switch
- /process-cpu-ios-xe-oper:cpu-usage/cpu-utilization
- /process-memory-ios-xe-oper:memory-usage-processes

\* SNMP collection of interfaces (IF-MIB) only



# Device Provisioning / ZTP



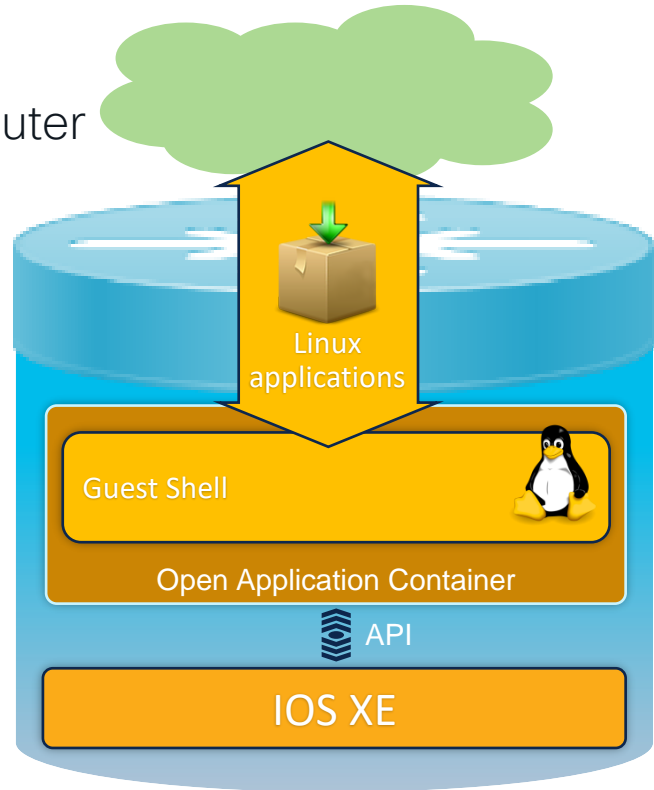
# ZTP Overview

1. When an IOS XE device boots and no configuration is present, the device will issue a DHCP request on the management port and on the front panel port.
2. If the DHCP response contains option 67 then ZTP is initiated, and the device will retrieve and execute the python script from within the Guest Shell
3. Guest Shell is started, and networking is automatically configured

# Guest Shell Application

## Linux Shell Environment On Your Switch or Router

- Maintain IOS-XE system integrity
  - Isolated User Space
  - Fault Isolation
  - Resource Isolation
- On-box rapid prototyping
  - Device-level API Integration
  - Scripting (Python)
  - Linux Commands
- Application Hosting
- Integrate into your Linux workflow
- Integrated with IOS-XE



# Guest Shell High Availability

- Improvements to Guest Shell storage and file handling means there is now a dedicated folder within the flash that is shared with the Guest Shell: “guest-share” folder
- The Guest Shell state is maintained during a High Availability switchover

```
C9300-Stack#show iox-service

IOx Infrastructure Summary:
-----
IOx service (CAF)           : Running
IOx service (HA)           : Running
IOx service (IOxman)       : Running
IOx service (Sec storage)   : Running
Libvirt 5.5.0              : Running
Dockerd v19.03.13-ce       : Running
Redundancy Status          : Ready
Sync status                 : Successful
Last application sync time  : 2022-03-21 22:20:17.141802
```

The Guest-Share files are maintained during HA switchover when HA mode is used and the files are < 50MB.

When a failover event occurs the data in /bootflash/guest-share is available on the Standby switch.

# ZTP customer use case - workflow

- How can we reduce the manual work that takes time when deploying networks at various locations globally ?
- Zero Touch Provisioning and automated onboarding solution for multiple devices in multiple locations.
- DHCP connectivity required, and new devices are upgraded, configured, and available for management without any manual interaction



Option 67 for ZTP python script

Python3 script + Guest Shell  
Software upgrade + EEM  
Download and apply pre-generated config

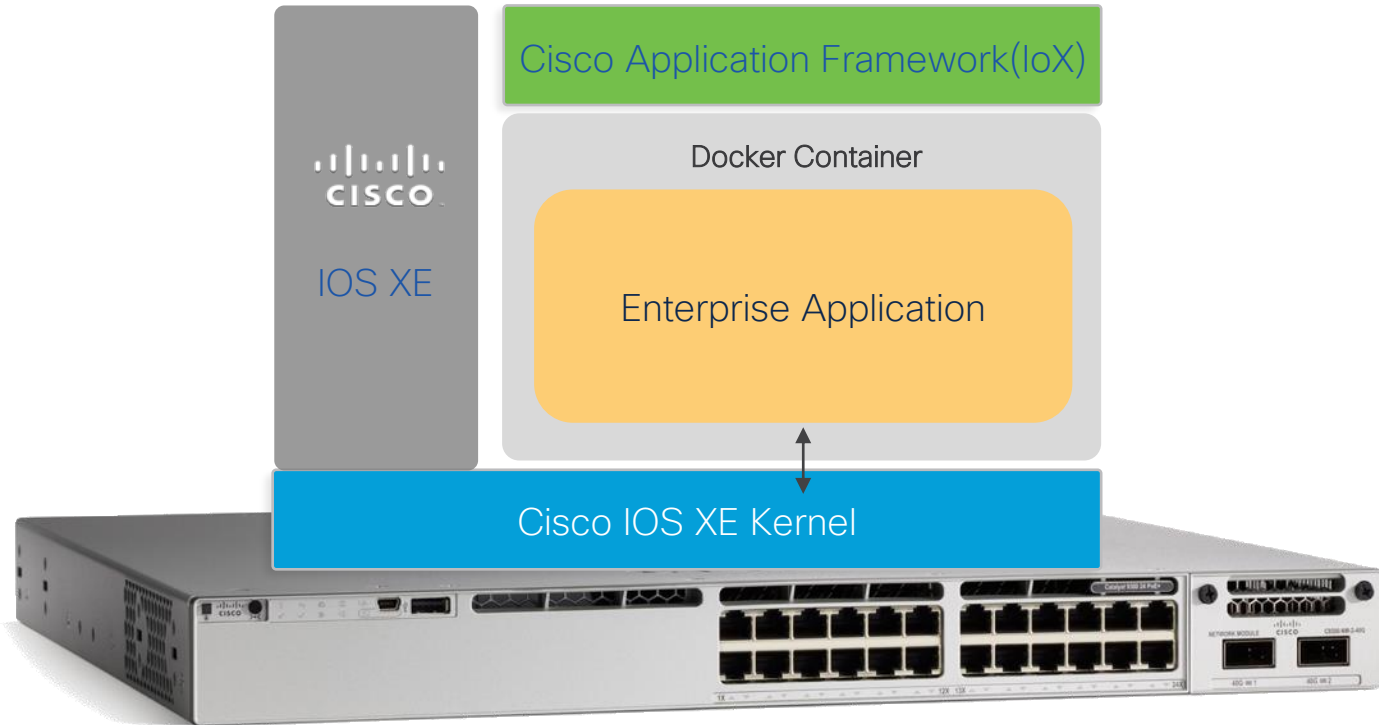
Option 150 for AutoInstall CLI config

Auto Install CLI config  
Set basic device config

# App Hosting Infrastructure & Management



# Catalyst 9000 Application Hosting Infra





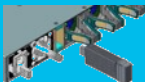
# HW resources for App Hosting

	Resource type	Catalyst 9300	Catalyst 9300-X	Catalyst 9400	Catalyst 9400-X	Catalyst 9500	Catalyst 9500-X	Catalyst 9600	Catalyst 9600-X
Networking	AppGig Port	1x1G	2x10G	1x1G	2x10G	Mgmt Port*	2x10G	Mgmt Port*	Mgmt Port* (2x10G CPU ports)
Resources	Memory	2GB	8GB	8GB	8GB	8GB	8GB	8GB	8GB
	CPU	1 core	2 core	1 core	1 core	1 core	1 core	1 core	1 core
	Storage	240GB (USB3.0/SSD)	240GB (USB3.0/SSD)	480-960GB (SATA)	480-960GB (SATA)	480-960GB (SATA)	480-960GB (SATA)	480-960GB (SATA)	480-960GB (SATA)

\* Using loopback with any external ports

**Catalyst 9300-X**

USB 3.0  
240GB




Back panel



**Catalyst 9400-X**

M2 SATA  
480/960GB




Plug into removable SUP



**Catalyst 9500-X**

M2 SATA  
480/960GB

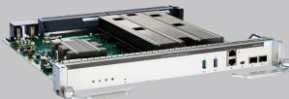


Back panel



**Catalyst 9600-X**

M2 SATA  
480/960GB



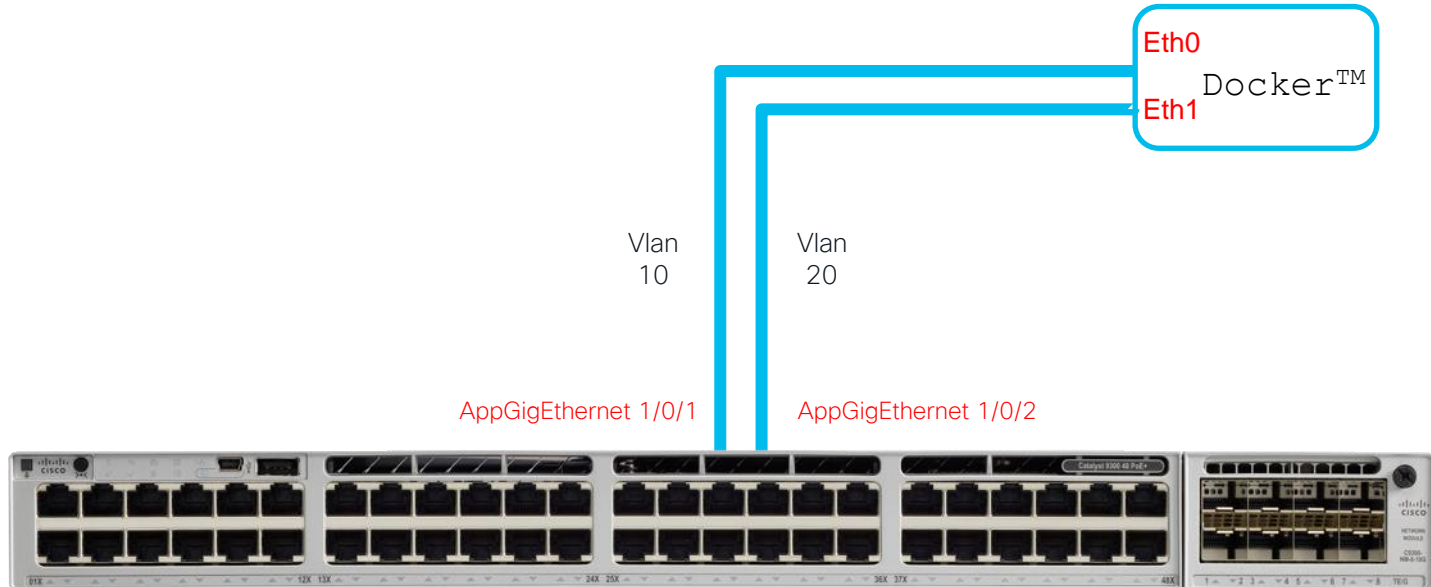
Plug into removable SUP



# AppGigEthernet Port

## What is AppGigEthernet Port ?

An internal hardware data port which is hardware-switched to the front-panel data ports.

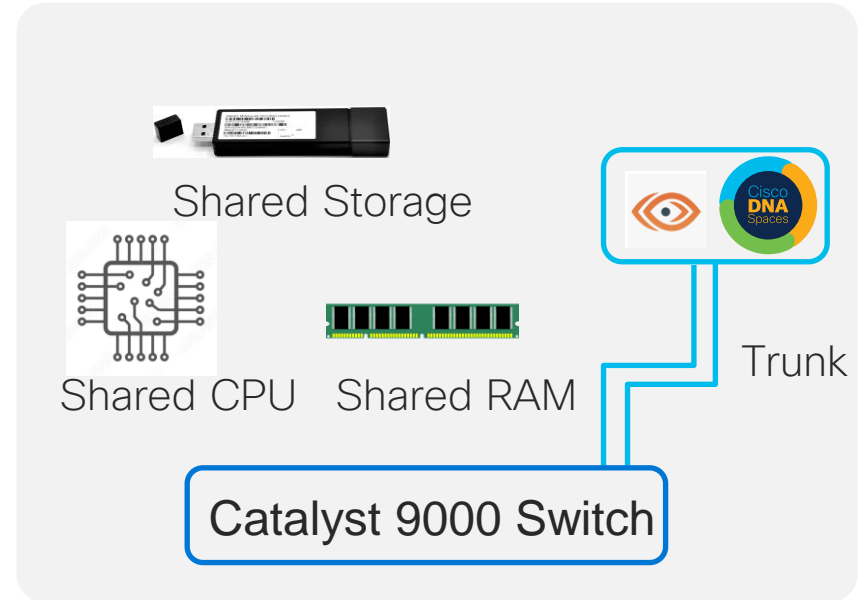


# Multiple Applications Support on Catalyst 9K

17.5.1

## Requirements :

- Cisco Signed Applications Only  
(ex. ThousandEyes, IoT Gateway)
- Customer Apps must use SSD Storage
- HW resources should be available
- AppGigabitEthernet ports config must not create a conflict between the apps



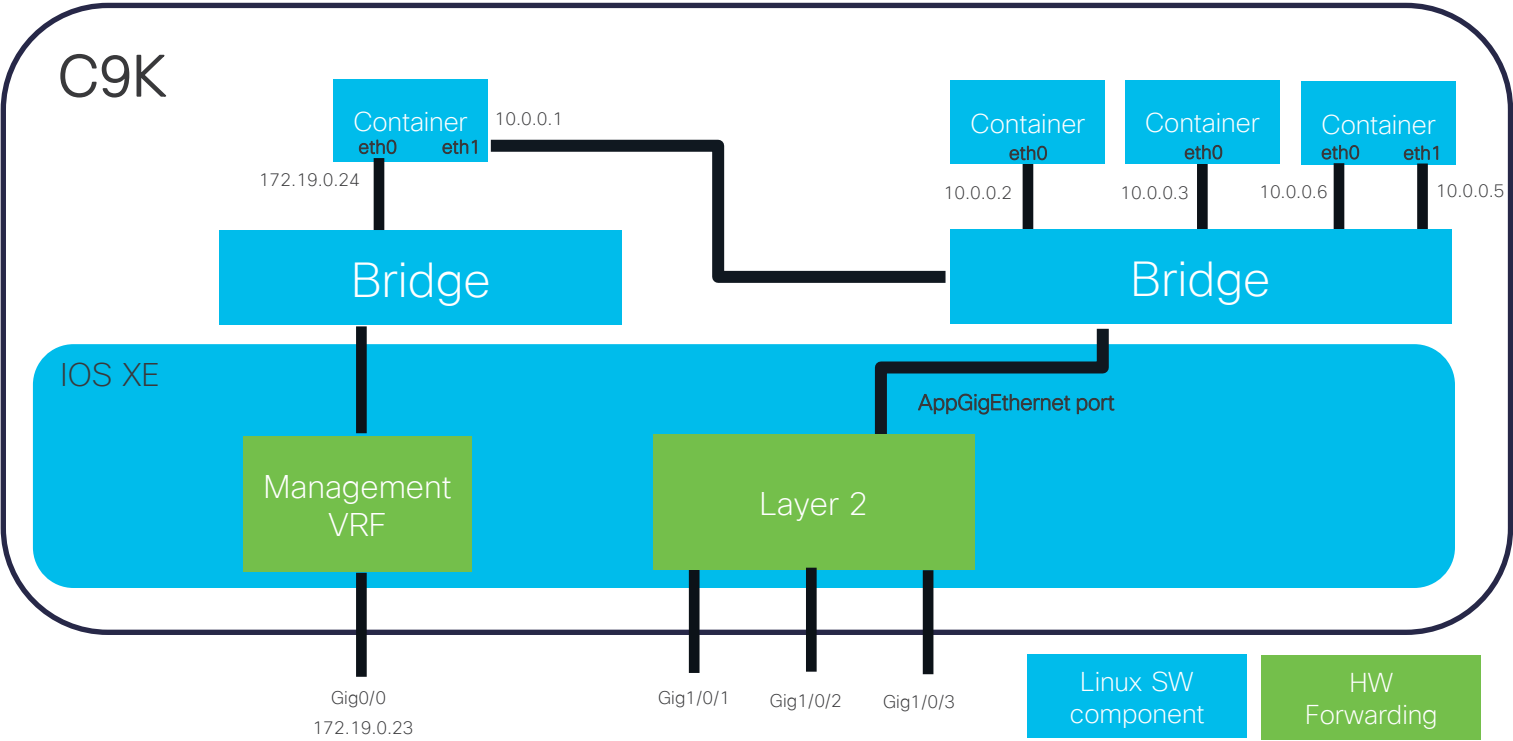
HW resource can be customized via DNA-C and CLI

# IOS XE performance and security protection

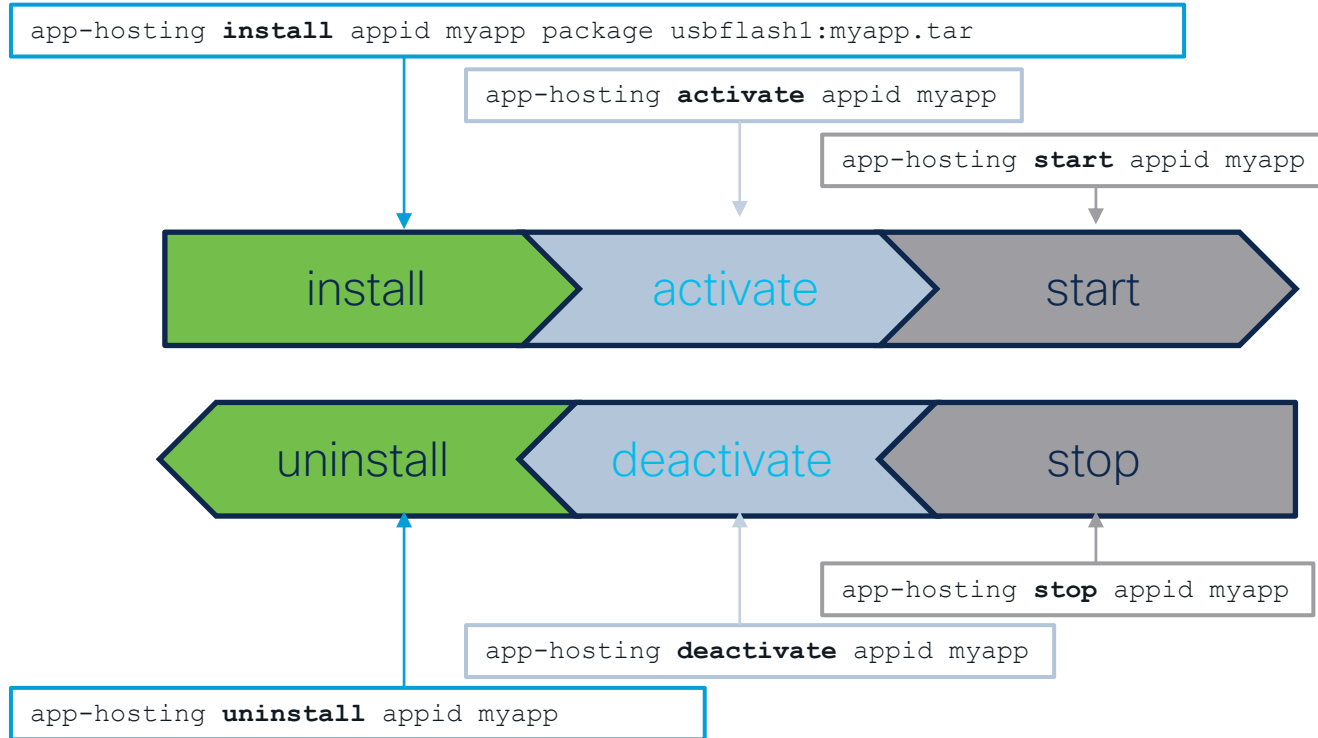


- Memory and CPU usage for Apps are bounded using Control groups (cgroups).
- Process and files access for Apps are isolated and restricted (using user namespace).
- Disk usage is isolated using separate storage.

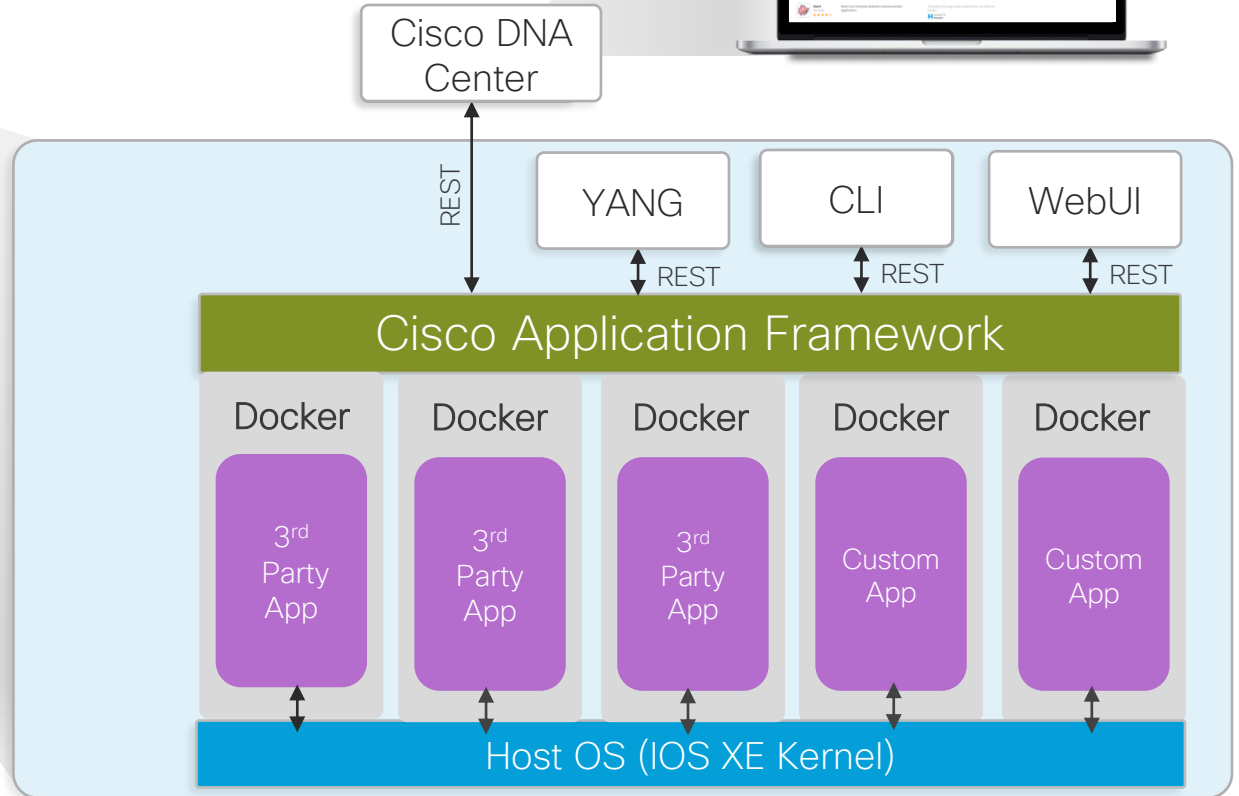
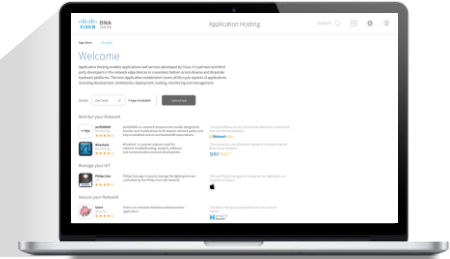
# Catalyst 9000 Containers Networking



# App Lifecycle Management – State Transitions



# Application Management



# Application Management using Cisco DNA

DNA Center Enable Apps on Switches

## Select Switches


Select switches where you want to enable **thousandeyes/enterprise-agent**.

Switches (2) 0 Selected

Search Table

<input type="checkbox"/>	Device Name	Site	IP Address	Serial Number
<input type="checkbox"/>	197-CAT-DOG.cisco.com	.../BLR-18/FLR-1	10.78.106.197	FCW2221G0HJ
<input type="checkbox"/>	198-CAT.cisco.com	.../BLR-18/FLR-1	10.78.106.198	FOC2221Z072

2 Records



Cisco DNA Center Enable Apps on Switches

## Configure App

Configure app specific settings to bootstrap **thousandeyes/enterprise-agent**.

**Add Application Vlan**

Network Settings

Interface Name: eth0  
VLAN: VLAN0299  
Address Type: Dynamic

App Resources

App Data

Docker Runtime Options

If the app requires docker runtime options add/edit them here.

```
-e TEAGENT_ACCOUNT_TOKEN=ADD_DATA --hostname=$(SYSTEM_NAME) --cap-add=NET_ADMIN --mount type=tmpfs,destination=/var/roq/agent,tmpfs-size=1kum --mount type=tmpfs,destination=/var/lib/te-agent/data,tmpfs-size=200m -v $(APP_DATA)/data:/var/lib/te-agent -e TEAGENT_PROXY_TYPE=DIRECT -e TEAGENT_PROXY_LOCATION= -e
```

**Add Account Token from ThousandEyes Account**

The app will be started by default. Deselect this option only if you do not want the app to be started after installation.

Start app on installation



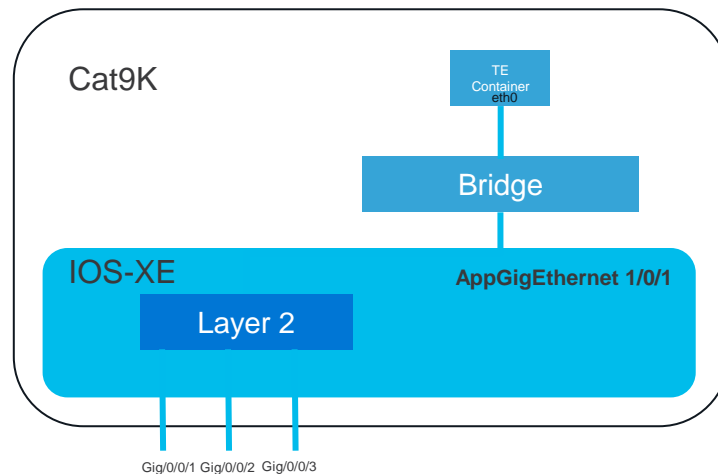
# Application Management using CLI

## New Deployment

- Image will be copied in **flash:Apps** directory by Manufacturing
- `app-hosting install appid <app-name> package flash:/Apps/<embedded-thousand-eyes-image>`

## Existing Deployment

- Download image from ThousandEyes portal
- `app-hosting install appid <app-name> package <https-url-of-thousand-eyes-image>`



### Enable IOX :

```
conf t
iox
```

### AppGigEthernet Configuration :

```
interface AppGigabitEthernet1/0/1
  switchport trunk allowed vlan <vlan-id>
  switchport mode trunk
```

# Application Management using CLI

## App Configuration :

```
app-hosting appid <app-name>
  app-vnic AppGigabitEthernet trunk
  vlan <vlan-id> guest-interface 0 ← refer to eth 0
  guest-ipaddress <app-ip> netmask <mask>
  app-default-gateway <gateway-ip> guest-interface 0

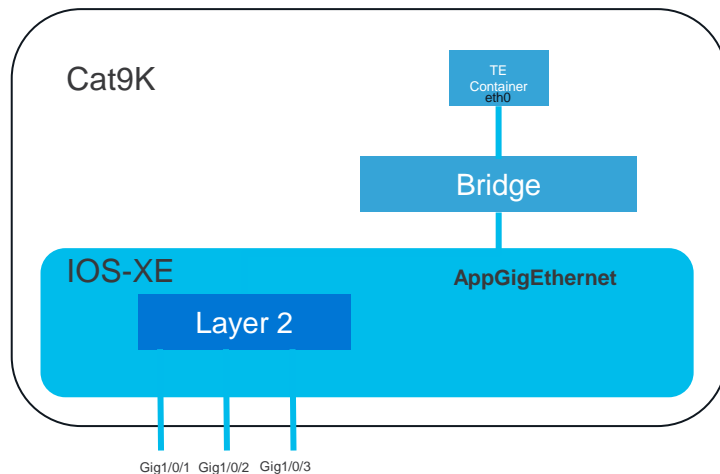
app-resource docker
  run-opts 1 "-e TEAGENT_ACCOUNT_TOKEN=<token-id>*"
  prepend-package-opts
```

## Run TE App:

```
app-hosting activate appid <app-name>
app-hosting start appid <app-name>
```

## Verify TE App:

```
Show app-hosting list
```



Virtual NIC inside containers are seen as standard Ethernet interfaces (“eth#”)

\* <token-id> is available in ThousandEyes Account

# ThousandEyes dashboard

Step 3

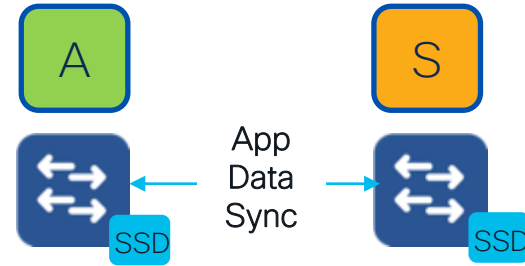
The screenshot shows the ThousandEyes dashboard interface. On the left is a dark sidebar with navigation options: Cloud & Enterprise Agents (highlighted with an orange box), Views, Test Settings, Agent Settings, BGP Monitors, Endpoint Agents, Devices, Internet Insights, Dashboards, Alerts, Reports, Sharing, and Account Settings. The main content area displays the 'AGENT STATUS' section with a map of North America. A legend indicates 5 Online and 1 Offline agents. Two green circles on the map are labeled with '5' and '4'. Below the map is a table of agents.

Agent Name	Hostname	Utilization	Status/Last Contact
London (Cat9k agent)	ip-12-0-0-85	General 1%	1 minute ago
Target Agent- S2S	C93CSR-Client02	General 1%	1 minute ago
CSK	CSK	General 1%	1 minute ago
<b>CSK-Demo</b>	CSK-Demo	General 1%	<b>Just now</b>
CSK-CL_Demo	CSK-Demo	General 1%	1 minute ago
teye_pod10	teye_pod10	N/A	Yesterday

Agent registered with  
Thousand Account

# App Hosting High Availability with Auto-Restart

- Provides cold restartability of application and the underlying app hosting framework
- Retain the last configured operational state of app in the event of system switchover or restart
- 1+1 redundancy mode
- Same storage type (Flash\* or SSD) required on both Active and Standby
- Enabled by default



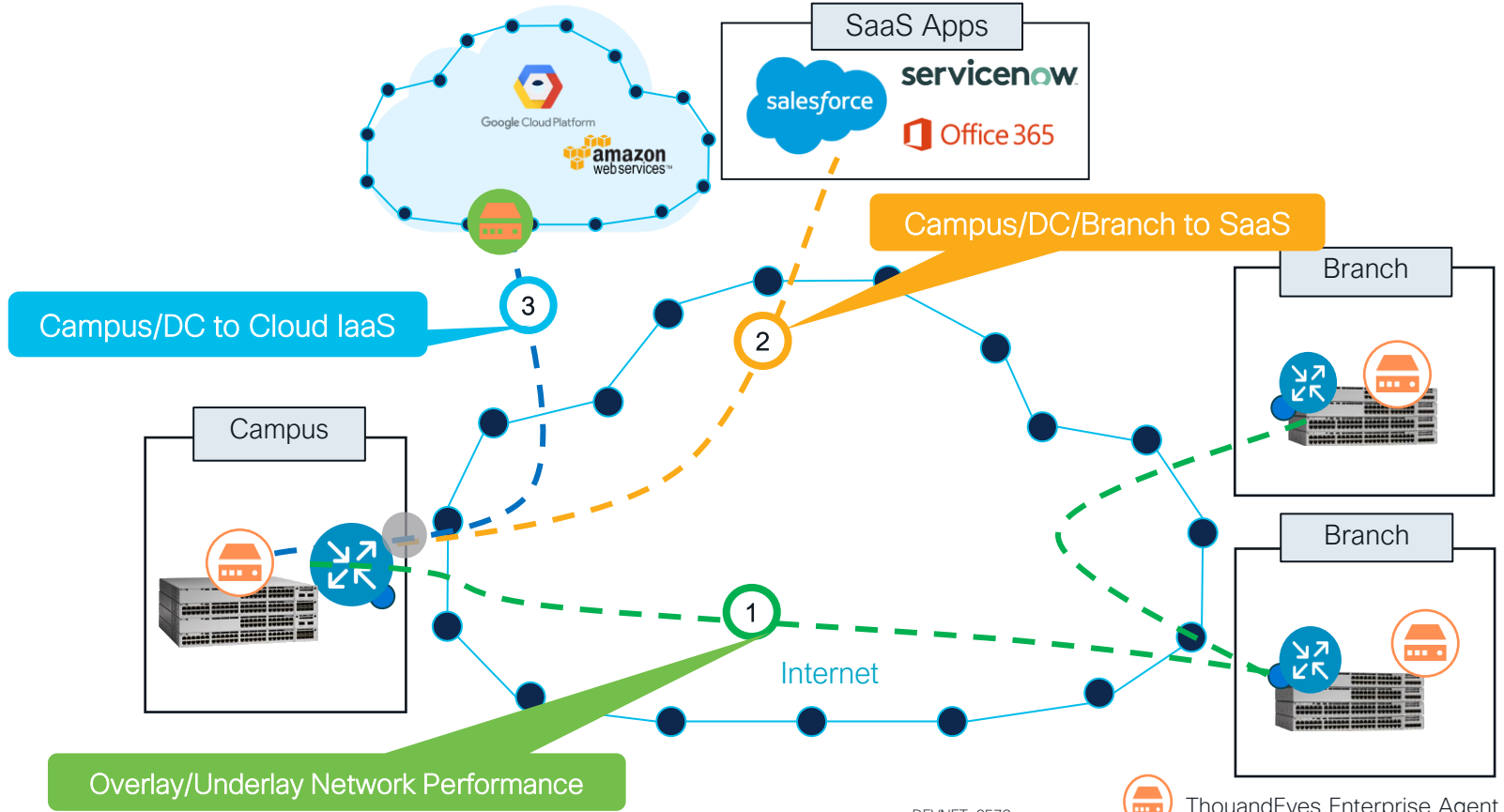
Supported Platforms	Release
9300 StackWise (1+1 mode only)	17.2.1
9400 Dual Sup (Single Chassis & StackWise Virtual)	17.5.1
9500/H StackWise Virtual	17.5.1
9600 Dual Sup (Single Chassis & StackWise Virtual)	17.5.1

\* Flash is only for Cisco Singed app

# Cloud Services at the Edge



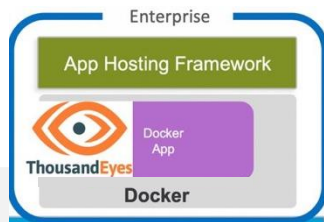
# Service Assurance with ThousandEyes



# ThousandEyes now included with Cisco DNA licenses

New and existing Catalyst 9000 switches now include ThousandEyes service assurance

App hosting: no extra hardware



- Run ThousandEyes agent natively on flash of 9300/9400 switches
- Out of the box access to ThousandEyes for new switches

DNA subscription benefits



DNA Essentials

DNA Advantage 

DNA Premier 

- Includes 22 x ThousandEyes Units for a month
- Pool entitled test capacity to deploy anywhere within your network

Data Visualization



- License to ThousandEyes SaaS-based management platform
- Access to Dashboards, alerts and reporting tools



Campus connectivity



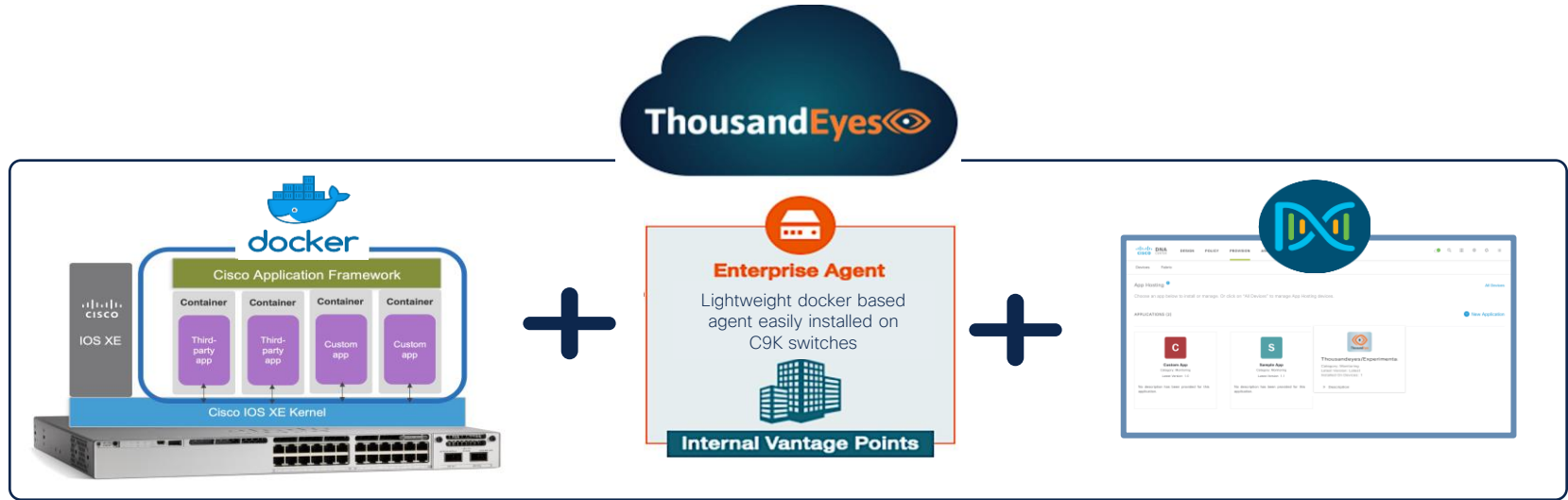
Modern WAN



Application experience

\*Choose from a menu of several networking, web and voice tests  
Browser-based tests need the use of SSD and consume more ThousandEyes units

# Service Assurance from Catalyst 9000



ThousandEyes  
Enterprise Agent

Agent installed in Flash

Test Included:

- **Web** - HTTP Server, FTP Server
- **DNS** - DNS Server, DNS Trace, DNSSEC
- **Network** - Agent to Agent, Agent to Server
- **Voice** - SIP Server, RTP Stream, Voice Call

Agent installed in SSD

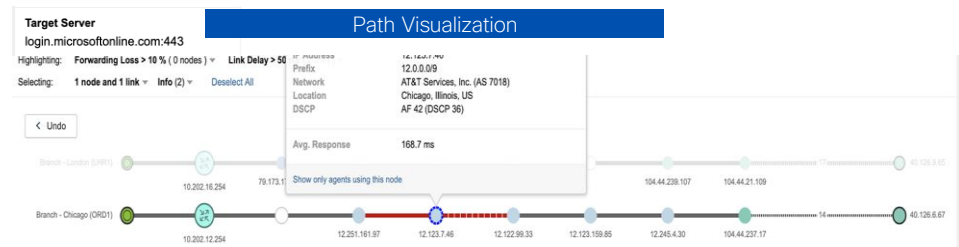
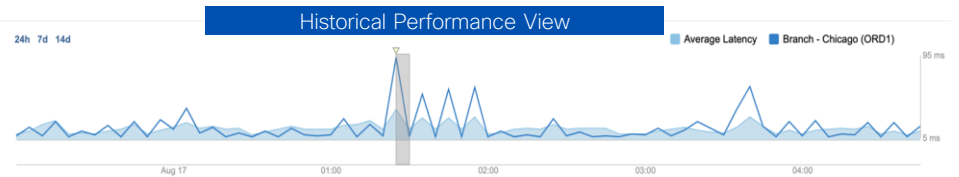
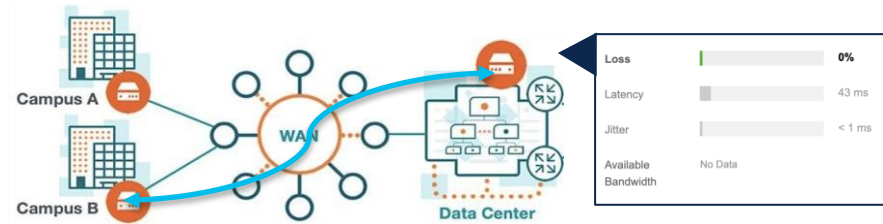
Test Included:

- **Web** - HTTP Server, FTP Server
- **DNS** - DNS Server, DNS Trace, DNSSEC
- **Network** - Agent to Agent, Agent to Server
- **Voice** - SIP Server, RTP Stream, Voice Call
- **BrowserBot** - Page load & Transaction



# Troubleshooting SaaS & monitoring campus

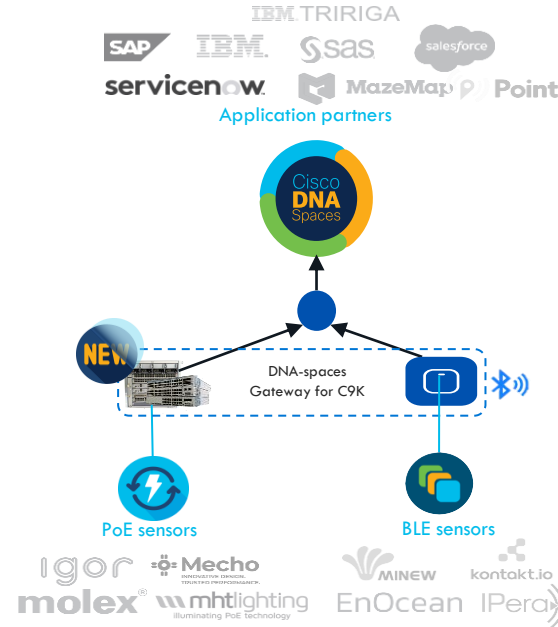
- Identifying **poor user experience**
- Did traffic handoff to SaaS app optimally?
- Was there an outage within Enterprise, WAN or SaaS backbone?
- **Full path visibility** to identify and resolve issues
- Active monitoring for **Latency, Loss, Bandwidth, Jitter**



Hop-by-hop view of network paths and performance with Proactive Customizable Alerts

# Catalyst 9K expands value for Smart buildings

Next: DNA-spaces gateway for Catalyst 9K will expand outcomes



## New use cases

- o Sustainable buildings
- o Employee health & Safety
- o Productivity Improvement
- o Building Analytics

## Unified Marketplace

- o Largest choice of IoT devices
- o Unmatched solution scale
- o Cisco validated

## Lower TCO

- o Automated workflows
- o No vendor lock-ins
- o Cloud based as-a-service

\*Source: Cisco Smart building TCO calculator



# Use Cases

User Experience

Safety & Compliance

Real Estate Utilization

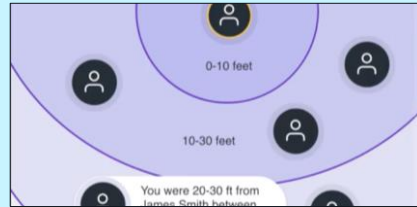
Automation & Optimization

Conference Room Booking

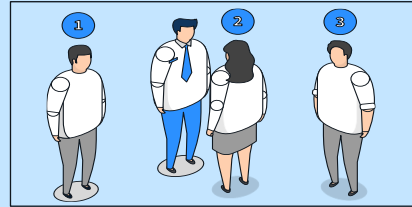
GA



Density Triggers



Device/People Counting



Environmental Monitoring & Asset location



Cisco Catalyst 9K



Cisco DNA Spaces



PoE lights & Sensors



Cisco Catalyst Wireless LAN Controller



Cisco Catalyst Wireless LAN Controller



POE sensors / HVAC

# Indoor IoT Services – Overview

## DNA Spaces cloud

- IoT Market place and Partner Apps.
- Firehose API

## DNA Spaces Connector

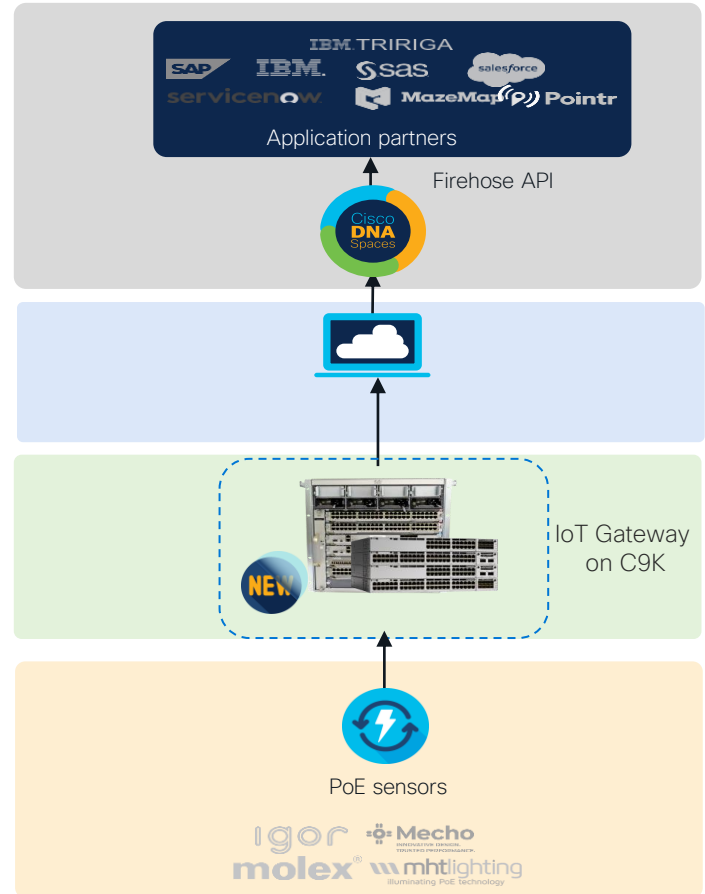
- Interfaces between DNA Spaces Cloud & on prem devices
- Collects sensor data

## Catalyst 9300/9400

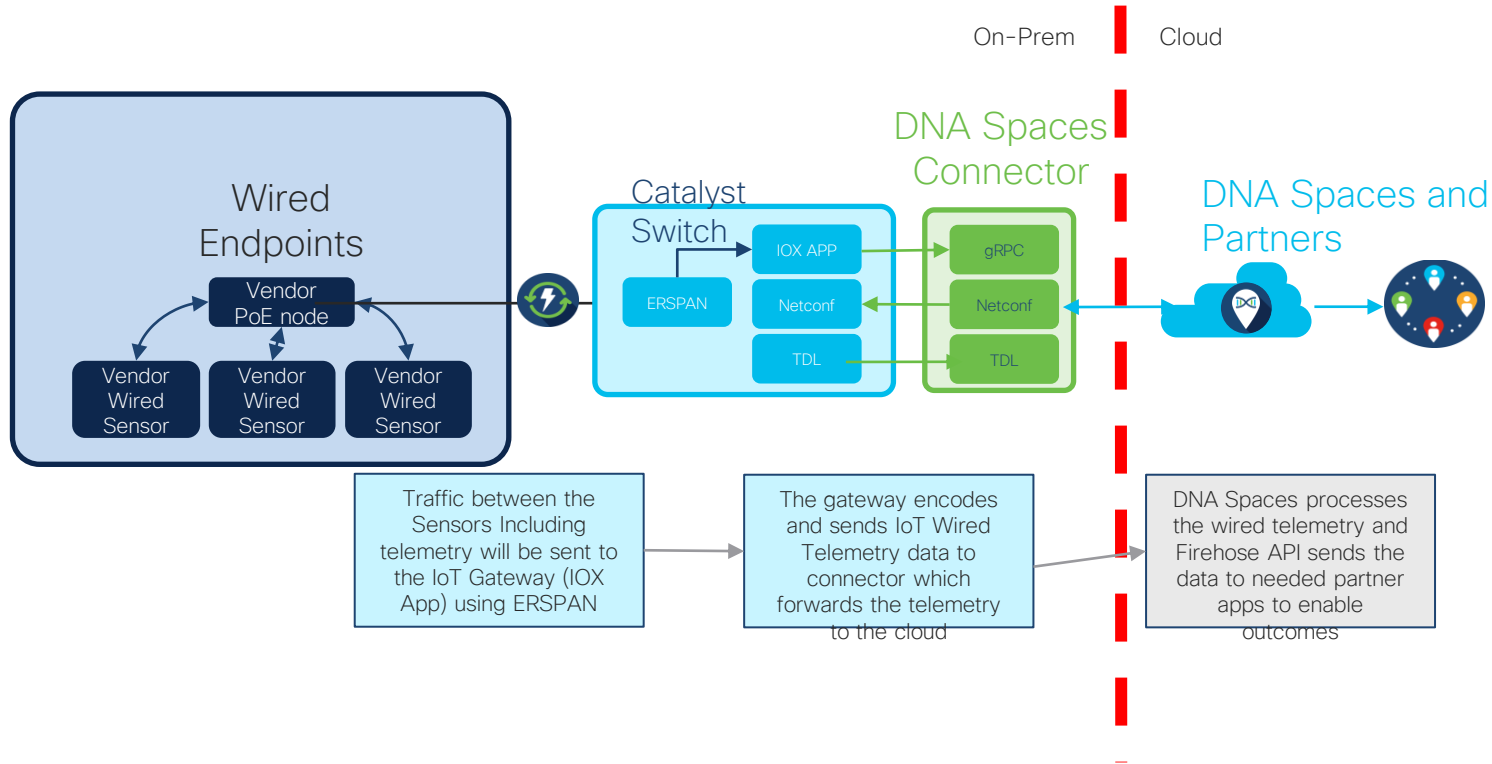
- UPOE/UPOE+ Connectivity
- IoT GW App

## PoE Sensors

- Wired PoE Sensors
- Powered by UPOE/UPOE+ port on the switch



# Indoor IoT Services with IoT Gateway App



# More on - Cisco IOS XE Programmability

<http://cs.co/programmabilitybook>

<https://developer.cisco.com/site/ios-xe>



# Complete your Session Survey

- Please complete your session survey after each session. Your feedback is very important.
- Complete a minimum of 4 session surveys and the Overall Conference survey (open from Thursday) to receive your Cisco Live t-shirt.
- All surveys can be taken in the Cisco Events Mobile App or by logging in to the Session Catalog and clicking the "Attendee Dashboard" at <https://www.ciscolive.com/emea/learn/sessions/session-catalog.html>



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Book your one-on-one Meet the Engineer meeting.



Attend any of the related sessions at the DevNet, Capture the Flag, and Walk-in Labs zones.



Visit the On-Demand Library for more sessions at [ciscolive.com/on-demand](https://ciscolive.com/on-demand).





The bridge to possible

Thank you

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CISCO *Live!*

ALL IN