TOMORROW starts here.
Cloud Enablement Architecture and NFV Services Delivery

BRKSPG-3864

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Distinguished Engineer, CAO
Key SP Challenges and Path Forward

- Traffic Growth
- Competitive Pressure
- Network Cost and Complexity
- Time to Market
- Slow Innovation

TRADITIONAL SP

Lean SP + Rapid Innovation
Evolved Services Platform

Transformation To Carrier as a Service

Traditional SP + NFv + SDN & Physical E2E Service Orchestration + Self Service + Carrier Class = Lean SP

Carrier As A Service
Evolved Services Platform

... an open, standards-based, modular architecture and platform for services orchestration

... manages the physical & virtual network, as well as the compute & storage infrastructure to deliver carrier-class services

... which range from VPC to NFV services
ESP - End to End Architecture for Service Orchestration

Evolved Services Platform (ESP)

Service Catalog
“Business Intent” catalogs

Routing / VPN  Transport  Security  Virtual Private Cloud  Mobility  Video/ Content  Managed Services

Cross Domain Orchestration

Service Provisioning (Physical & Virtual Services)
- Provision WAN services
- Provision NFV in DC

Network Orchestration
- DC SDN
- WAN Orchestration & Optimisation

Compute & Storage Control
- Elastic Services Control
- Service Lifecycle management

Orchestration Engine
“Execution” configuration, workflow, automation, provisioning

Physical & Virtual Network, Compute & Storage

End-to-End Carrier Class Service Orchestration

Provision WAN/VPN Services & SLA

Admit Bandwidth Optimise WAN

Activate & Place Cloud/NFV services

SP WAN / VPN

SP Core

SP DC
ESP – Evolved Services Platform

“A flexible multi-tenanted cloud services orchestration platform for the virtualised data centre”

WHAT CAN BE VIRTUALISED?

ENTERPRISE APPS
3-tier Apps, Web Servers, DB Servers, Hadoop Clusters, Distributed Storage

TRANSIT NFV
DPI, Firewall, NAT, Load Balancers, WaaS, GI-LAN Applications

TERMINATE NFV
IPSec Gateways, SSL VPNs, vEPC Applications

NETWORK SERVICES
DNS, Routing, BRAS, NTP

NETWORK AND APPLICATION CONNECTIVITY MODELS

SP-WAN
VPC

SaaS Cloud
SP-WAN
Transit-NFv

SP-WAN
R-a-a-S

vBRAS
Legacy Services

Cisco Public
Transit NFv Examples

**NFV – Internet FW – 1A**

- Provide internet connectivity for VPN customers and apply NAT and Firewall policies per customer.
- VNF = CSR per customer VRF instance
- Provide remote branch of an enterprise with ability to access headquarters over a secure tunnel using IPSec
- Map IPSec tunnel to a enterprise VRF
- VNF = CSR per customer VRF instance
- Provide connectivity between 2 different enterprise VPNs. Apply firewall policies and translate addresses.
- VNF = CSR per customer VRF instance
- Use case based on many tier 1 SP customer requirements

**NFV – Remote Access – 1B**

**NFV – Inter-VPN Firewall – 1C**
Data Centre Evolution

Legacy DC

ESP DC

Virtualised Compute and DC overlay

Agility (Create/Delete), Scale, Flexible Topologies, BYOD, Elasticity, Utility Based Pricing

Cisco Public
ESP – Automated Cloud Services Delivery

TRANSFORMATION

Service provisioning from days to minutes

From Cabling to Service Chaining

Simple Logistics & Common Sparing

Dynamic & Elastic Scale

Seamless Integration with IP NGN
What are the Use Cases for SP Virtualisation

Virtualisation of SP Infrastructure
Virtualisation of foundation SP infra such as routing and mobility packet core.

Routing Infra Virtualisation
- Virtual Route Reflector
- Virtual PE Router
- Virtual BNG

Mobile Infra Virtualisation
- Virtual EPC
- Virtual GiLAN

NFV for Enterprise Managed Services
Virtualisation of Network Services that can be delivered as managed services for enterprise

SP Cloud Services Platform
- User Portal / Catalog / NB REST API
- Orchestration
  - Network Control
  - Compute Control
  - Storage Control
  - SDN Overlay Network
  - Service Chaining
  - L3VPN/Internet integration

Security-as-a-Service (Virtual Firewall)
Routing-as-a-Service (Virtual CE)
Virtual Private Cloud (VPC)
# Cloud and Data Centre Requirements

## Scale
- Data centres of varying sizes
- Large number of servers/VMs
- Multi-tenancy
- High bisectional bandwidth within DC

## Services
- Network Virtualisation, instant Insertion of network services
- Service Chaining, Services networking
- Robust network availability and redundancy
- Seamless integration with WAN, DCI

## Flexibility
- DC Underlay network agnostic
- Add network capacity and load incrementally
- Workload and VM mobility
- Variety of server, access connectivity options, multi-homing

## Manageability
- Network orchestration and operations at scale
- Simplified network, service provisioning for tenants
- Ease of data collection and troubleshooting
- Support for OAM and proactive monitoring

## Openness
- Yang Models
- REST, RESTConf
- BGP
- MPLS-over-GRE, VXLAN,
- MPLS-over-UDP, L2TPv3
- OVF, VMDK
- Linux/Ubuntu
- Openstack
- KVM
- Ganglia
- Puppet & Cobbler

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Architectural Goals

ESP Architecture

NG-SP-DC Requirements (Constants)

Deployments (Variables)

Open Systems Design (Inclusive)

Customer Experience (Agility, Opex)
Architectural Goals

ESP Architecture

- NG-SP-DC Requirements (Constants)
- Deployments (Variables)
- Open Systems Design (Inclusive)
- Customer Experience (Agility, Opex)

- LARGE NUMBER OF SERVERS AND VMs
- MULTI-TENANCY
- HIGH BISECTIONAL BANDWIDTH
- OPTIMAL L2 and L3 FORWARDING
- NETWORK VIRTUALISATION
- SLA ASSURANCE
- AVAILABILITY AND RELIABILITY
- SEAMLESS DCI INTEGRATION
- NETWORK SERVICES
- ELASTIC SCALING
- WORKLOAD MOBILITY
- MULTIPLE CONNECTIVITY OPTIONS
- PHYSICAL DEVICE INTEGRATION
Architectural Goals

ESP Architecture

- NG-SP-DC Requirements (Constants)
- Deployments (Variables)
- Open Systems Design (Inclusive)
- Customer Experience (Agility, Opex)

THIRD PARTY SWITCHES, SERVERS AND DCI
DIFFERENT PHYSICAL UNDERLAY CONNECTIVITY
OPENSTACK & VMWARE SUPPORT
CEPH & NETAPP SUPPORT
BARE METAL INTEGRATION

3RD PARTY NFVS
L2 VPN, L3VPN, INTERNET FOR WAN ACCESS
ENCAPSULATIONS (VXLAN, MPLS-O-GRE, L2TPV3)
SERVICE TOPOLOGIES
TENANT APPLICATIONS

IDENTITY MANAGEMENT
ADMINISTRATIVE SEPARATION
OSS DIFFERENCES
BROWN FIELD DEPLOYMENTS
Architectural Goals

ESP Architecture

NG-SP-DC Requirements (Constants)

Deployments (Variables)

Open Systems Design (Inclusive)

Customer Experience (Agility, Opex)

YANG MODELS
REST, HTTP, RESTCONF
BGP, IGP
ETHERNET/IP
MPLS-OVER-GRE, VXLAN, MPLS-OVER-UDP, L2TPV3
L3VPN & L2VPN INTEGRATION
OVF, QCOW2, VMDK

LINUX/UBUNTU
OPENSTACK/KVM
NAGIOS
MYSQL
GANGLIA
PUPPET & COBBLER

JUNIPER AND ALU DCI
PLUGGABLE DHCP AND DNS
AGENTLESS NFv
3RD PARTY SERVERS AND NICS
Architectural Goals

ESP Architecture

- NG-SP-DC Requirements (Constants)
- Deployments (Variables)
- Open Systems Design (Inclusive)
- Customer Experience (Agility, Opex)

AUTOMATED INSTALLER
AUTOMATED UPDATES
ISSU
SCALE OUT
MODULAR POD
APPLICATION CENTRIC PODS

ZERO TOUCH PROVISIONING OF SERVERS AND DCI
CENTRAL TRACING OF SYSTEM EVENTS
APPLICATION ORIENTED SERVICE PROVISIONING

CONTROL HA
PHYSICAL NODE HA
DCI HA
GEO-REDUNDANCY FOR SERVICE TOPOLOGIES
AUTOMATIC RESTART OF FAILED PROCESSES
OVERLAY NETWORK OAM
The Data Centre Infrastructure
Building an Overlay
Connecting VMs to VPNs
Connecting VMs to VPNs
Data Centre Fabric – The Underlay Network

- Many Options for building the underlay
- Provides Fast Reliable Network Connectivity
- Should support P2P and P2MP Capabilities
- Hardware optimised for cost and efficiency

SP WAN (L3VPN, L2VPN, IPv4/v6, Internet)

Folded Clos

Single Tier Access Aggregation Type

Three Tier Fat Tree

Single Tier Full-Mesh Computer Cluster

Data Centre

SP WAN
(L3VPN, L2VPN, IPv4/v6, Internet)

Server-1

Server-2

Server-3

Server-4
L2 Segment and Forwarding

- Each vPE-f has VRF L2 tables
- vPE-f populated with MAC entries
- VMs see each other in an L2 segment
- MT traffic encapsulated in single transport tunnel
- Only a small class of applications need strict L2 connectivity
L2 Segment and DCI

- Each vPE-f has VRF L2 tables
- vPE-f populated with MAC entries
- VMs see each other in an L2 segment
- MT traffic encapsulated in single transport tunnel
- Only a small class of applications need strict L2 connectivity

Virtual Topology

VM1 GE-DB

VM2 GE-WEB

Data Centre

L2 Segment Attached to L3VPNs or L2VPNs

Folded Clos

Three Tier Fat Tree

L2 Segment Attached to L3VPNs or L2VPNs

Single Tier Access Aggregation Type

Single Tier Full-Mesh Computer Cluster

Data Centre

VM WALMAR T

VM GE-DB

SP WAN (L3VPN, L2VPN, IPv4/v6, Internet)

VM GE-WEB

VM WALMAR T

VM GE-DB

Server-1

Server-2

Server-3

Server-4

Ciscolive!
IP Forwarding

- Each vPE-f has VRF L3 tables
- vPE-f populated with L3 /32 or /128 entries
- vPE-f is first hop router/DHCP Relay
- VMs can reach each other in L3 network
- MT traffic encapsulated in single transport tunnel

Three Tier Fat Tree

Virtual Topology

SP WAN (L3VPN, L2VPN, IPv4/v6, Internet)

Data Centre

Server-1

Server-2

Server-3

Server-4

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Network Function Virtualisation

- Network Services could be bump-in-the-wire services or termination services
- Using L2/L3 entries in tables an arbitrary services topology can be created
- No hair-pinning of traffic as it moves from service to service
- Control Plane responsible for computation of paths and optimal routing of traffic
- Bring-your-own-Service or choose from Cisco service catalog

SP WAN (L3VPN, L2VPN, IPv4/v6, Internet)

**Virtual Topology**

- **VM1**
  - GE-DB
- **VM2**
  - GE-FW
- **VM3**
  - GE-FW
- **VM4**
  - GE-FW

**Single Tier Access Aggregation Type**

**Three Tier Fat Tree**

**Folded Clos**

**Single Tier Full-Mesh Computer Cluster**

**MPLS-over-GRE (or) VXLAN Tunnels**

**Server-1**
- WALMART
- GE-DB
- VM
- L3
- VRF FIB
- vPE

**Server-2**
- WALMART
- GE-FW
- VM
- L3
- VRF FIB
- vPE

**Server-3**
- WALMART
- GE-FW
- VM
- L3
- VRF FIB
- vPE

**Server-4**
- L3
- VRF FIB
- vPE

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L3VPN, L2VPN & Internet Access

- DCI can be either by injecting /32 or aggregates in SP-WAN MP-BGP
- All VMs default route to DCI for unknown destinations

Virtual Topology

Three Tier Fat Tree

SP WAN (L3VPN, L2VPN, IPv4/v6, Internet)

Single Tier Access Aggregation Type

Folded Clos

Single Tier Full-Mesh Computer Cluster

MPLS-over-GRE (or) VXLAN Tunnels

Virtual Topology
ESP Service Chains

Network Services can be daisy chained
No restriction on the number of services in a chain
Services can be dynamically inserted in the chain

Virtual Topology

Three Tier Fat Tree

Data Centre

SP WAN (L3VPN, L2VPN, IPv4/v6, Internet)

DOIs

Data Centre
NFv Horizontal Scale, Stateful Load Balancing, Elasticity & Flow Stickiness
Virtual Packet Edge Forwarder (vPE-F)

- Light weight, high performance software forwarding plane
- Provides highly optimised forwarding in x86 environment
- Runs once on each server
- Contains a unique forwarding context per tenant
- Provides per-tenant L3, L2 and PBR forwarding for service chaining
- Provides IP routed and L2 P2P transport
- Provides DHCP relay, ARP function
- Programmed by vSOC Controller using YANG over RESTConf
  All forwarding controlled centrally
  Granular L3 and L2 forwarding entries
  N-tuple match
The patch panel provides a virtual point-to-point connection from the tenant VMs to the vPE-f dataplane.

Patch panel is a L2 switch running as host kernel module configured for Point-to-point connectivity without Mac learning.

VM deployment model: easy portable, high performance.
VPE-Forwarder Capabilities

- **L3 IP stack and Forwarding**
  - IPv6
  - IPv4 (ARP, ICMP, etc.)
  - VRF aware FIBs for all address families
  - un-equal-cost multipath forwarding
  - ARP/ND Proxy
  - DHCPv6 Relay

- **L2 Forwarding**
  - VLAN crossconnect
  - L2 P2P
  - L2 Bridging

- **Load-Balancing**
  - Sticky load balancing onto stateful services (e.g. firewall)

- **Tenant Encapsulation**
  - Ethernet
  - 802.1q (single-tag) VLAN sub-interfaces

- **Network Encapsulation**
  - Routed: GREoIPv4, MPLS-o-GREoIPv4
  - L2 Forwarded: L2tpv3 L2 cross-connect
vSOC – Virtual Systems Operations Centre

- **Orchestration**
  - Exposes a North Bound ReST API that allows provisioning of services
  - Implements model driven workflows to realise the services
  - Secure REST NB API with RBAC support
  - Implements service templates for easy OSS integration

- **Compute/Storage Control**
  - Service VM Lifecycle management
  - VM Monitoring & VM Recovery
  - Scale up/down of VM based on elasticity criteria
  - Integrates with NAS, SAN systems (CEPH, NetAPP)

- **Network Control**
  - Controls forwarding entries in vPE-forwarder
  - Controls routing to DCI through XRvR

- **Service Provisioning**
  - Configures DHCP Server
  - Configures Service VMs e.g. ACL, Firewall, etc. on CSR
  - Configures DCI router for L3VPN VRF & MPLSoGRE tunnel for connection to vPE-f
  - Configures remote PE and CPE’s.

- **System Management**
  - Auto Installation of the system
  - vSOC HA Control
  - ISSU Control
  - Packaging
ESP High Availability

vSOC - ACTIVE

vSOC - BACKUP

• vSOC is not required in steady state
• vSOC supports Active-Standby HA

Service Routing

VM Management (ESG)

Address Management

Routing Control

Admin Interface

Policy Database

Monitoring

vSOC Cluster Controller

BSS/ OSS Integration

vSOC Infrastructure (Orchestration, Event Notification/Messaging)

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vSOC Infrastructure (Orchestratio
vSOC Elastic Services Control

Elastic Services Controller

Provisioning
Configuration
Monitoring

Service Catalog Entry

Provisioning Recipe
Configuration Recipe
Monitoring Recipe

Provisioning
- VM Disk Images - can be several images in a topology
- Virtual CPUs, MEMORY – resource requirements for service
- Network – NIC interface type & network topology/configuration (basic or complex)
- Hypervisor - supported hypervisors for this service

Configuration
- Puppet/Chef - Service has a puppet/chef agent that allows it to have its configuration pushed to the VM after boot-up
- Inject – Orchestration system can inject the configuration into the VM image file-system at provision time

Monitoring
- SNMP - service has an SNMP agent & metrics that can be monitored
- Ganglia - service has a ganglia agent & metrics that can be monitored
- PING – service has no monitoring support so is deemed to be alive when VM responds to pings
vSOC - System Management Overview

Cluster Installation
- Packaging
- Zero Touch Install
- Policy Based Declarative Install
- System Underlay Inventory
- Software Versioning
- ISSU

Cluster Monitoring
- Server Monitoring
- Control Plane VM Monitoring
- NIC Monitoring
- Storage Monitoring
- Process Monitoring
- DCI Monitoring

Cluster High Availability
- Fault Detection
- NIC Failure Detection & Recovery
- Server/VM Failure recovery
- Control VM Switch over
- NIC Teaming, bonding and Redundancy
- DCI Redundancy
- Storage HA
- Service Assurance

Cluster Admin Functions
- System Log Management
- Time synchronisation
- Name Resolution
- License Management
- Crypto Key Management
- Backup and Restore
- Storage Management
Provisioning the ESP System

MODEL BASED – DECLARATIVE SERVICE DEFINITION

REST BASED API

TENANT & ORGANISATION DEFINITION
Tenant Identifier, Tenant Specific VPN Identifier, L3VPN & L2VPN Extended Communities, Organisation Definition, Global Tenant Specific IP Address Pools

NETWORK & TOPOLOGY DEFINITION
Network Zones, Zone Connectivity, External Zones, Managed Zones, Transit NFv Appliances, Terminate NFv Appliances, Service Topology Definition, Service Chain Definition, Multi-Path Requirements

COMPUTE & STORAGE DEFINITION
Define CPU, Memory, Network Interfaces, Horizontal Scale Factor, Elasticity, Disk Storage, Persistency Requirements, Service Configuration
ESP Models Example: Mobility (vEPC + Gi-LAN)
Customer Experience - GUI

- Single portal for customers to login and provision their network and application VMs
- Each customer can create multiple topologies
- Traffic for a topology could come from Internet, existing L3VPN network, L2VPN network
- Topology composed of multiple zones
- Inter zonal traffic subjected to one or more services (FW, NAT, DPI, Load Balancer)
- Ability to provide pre-packaged end application services such as Web Server, Video Server, Mail Server, Database Servers, Hadoop Cluster, etc
- Design template library and custom network topology templates for provisioning ease.
- BYOS – Ability for customers to bring their own service appliances
Customer Experience - GUI

Cisco virtual Systems Operations Center

Manage My Dashboards
(Coming soon)

Manage My Stuff
Review your services, track open orders for services, access your order history, get analytics on currently active services, and take action to maintain or upgrade your services.

Tenant and User Management

Topology Management

Tenant Management
Organization Management
User Management
Network Management
Zone Management
ESP GUI: Designing The Mobility Service
ESP PODs & Satellite PODs

- ESP PODs
  - Scale
  - Modular Construction
  - Fault Containment
  - Application Centricity
  - High Availability
  - and Admin Separation

- Satellite POD
  - (# Servers = 1)

- Legacy CPE

- Metro Data Centre

- Virtualised CPE
ESP PODs

- Scale
- Modular Construction
- Fault Containment
- Application Centricity
- High Availability
- and
- Admin Separation

Data Centre
ESP SLA Aware End-to-End Service Provisioning

Cross Domain Orchestration

Provision network connectivity in WAN
Multi-layer visibility and SLA assurance
Provision Cloud/NFV services

REST APIs for End-to-End Design and Performance Monitoring

Data Centre 1

Data Centre 2

Provisioning ESP SLA Aware End-to-End Service Provisioning
ESP Geo-Redundancy

Cross Domain Orchestration

REST APIs for End-to-End Design and Performance Monitoring

OSS

SERVICE PORTAL

EMS

WAN OPTIMISER

CLOUD SERVICES

Provision Cloud/NFV services

Data Centre 1

vSOC

vSOC

vSOC

vSOC

Mount POC

Mount POC

Mount POC

Mount POC

Data Centre 2

vSOC

vSOC

vSOC

vSOC

Mount POC

Mount POC

Mount POC

Mount POC

SP WAN/MAN

CUSTOMER NETWORK

Customer requests service

Data Centre 1

SP WAN/MAN

Data Centre 2

IP OPTICAL NETWORK

BGP ROUTES

MPLS TE

OPTICA

End-to-End Design and Performance Monitoring
Key Solution Highlights

- **End to end Solution offering**
- **Based on Open, standards-based interfaces**
- **Highest performance virtual forwarder**
- **Virtual forwarder in a VM isolates network failure domain from compute**
- **Overlay architecture independent of underlying fabric**
- **Self Service model and automated network config enables zero touch provisioning**
- **Service configuration integrated with Solution**
- **Elastic Service management**
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