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Policy Architecture and Framework for NFV Infrastructures  
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Abstract

A policy architecture and framework is discussed to support NFV environments, where policies are used to enforce business rules and to specify resource constraints in a number of subsystems. This document approaches the policy framework and architecture from the perspective of overall orchestration requirements for services involving multiple subsystems. The framework extends beyond common orchestration constraints across compute, network, and storage subsystems to include energy conservation. This document also analyses policy scope, global versus local policies, policy actions and translations, policy conflict detection and resolution, interactions among policies engines, and a hierarchical policy architecture/framework to address the demanding and growing requirements of NFV environments, that could also be applicable to cloud infrastructures in general.

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The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

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## 1. Introduction

This document discusses the policy architecture and framework to support Network Function Virtualization (NFV) [3] infrastructures. In these environments, policies are used to enforce business rules and to specify resource constraints, e.g., energy constraints, in a number of subsystems, e.g., compute, storage, network, and etc., and across subsystems. These subsystems correspond to the different "infrastructure domains" identified by the NFV ISG Infrastructure Working Group [6][7].

The current work in the area of policy for NFV is mostly considered in the framework of general cloud services, and typically focused on individual subsystems and addressing very specific use cases or environments. For example, [3] addresses network subsystem policy for network virtualization, [14] and [15] are open source projects in the area of network policy as part of the OpenDaylight [16] software define networking (SDN) controller framework, [13] specifies an information model for network policy, [9] focuses on placement and migration policies for distributed virtual computing, [18] is an open source project proposal in OpenStack [17] to address policy for general cloud environments.

This document approaches policy, policy framework, and policy architecture for NFV services from the perspective of overall orchestration requirements for services involving multiple subsystems, and can be applied to the general case of any cloud-based service. The analysis extends beyond common orchestration constraints across compute, network, and storage subsystems to also include energy conservation constraints applicable to NFV and other environments. The analysis in this document also extends beyond a single virtual Point of Presence (vPoP) or administrative domain to include multiple data centers and networks forming hierarchical domain architectures [8]. The focus of this document is not general policy theory, which has already been intensively studied and documented on numerous publications over the past 10 to 15 years (see [13], [21], [12], [22], and [1] to name a few). This document's purpose is to discuss and document a policy architecture that uses known policy concepts and theories to address the unique requirements of NFV services including multiple vPoPs and networks forming hierarchical domain architectures [8].

With the above goals, this document analyses policy scope, global versus local policies, policy actions and translations of actions, policy conflict detection and resolution, the interactions among policies engines from the different vPoPs and network subsystems, demanding and growing requirements of NFV environments.

## 2. Policy Intent Statement versus Subsystem Actions and Configurations

Policies define which states of deployment are in compliance, and, by logic negation, which ones are not. The compliance statement in a policy may define specific actions, e.g., "a given customer is [not allowed to deploy VNF X]", where VNF refers to a Virtual Network Function, or quasi-specific actions, e.g., "a given customer [must be given platinum treatment]." Quasi-specific actions differ from the specific ones in that the former requires an additional level of translation or interpretation, which will depend on the subsystems where the policy is being evaluated, while the latter does not require further translation or interpretation.

In the previous examples, "VNF X" defines a specific VNF type, i.e., "X" in this case, while "platinum treatment" could be translated to an appropriate resource type depending on the subsystem. For example, in the compute subsystem this could be translated to servers of a defined minimum performance specification, while in the network subsystem this could be translated to a specific Quality of Service (QoS) level treatment.

The actions defined in a policy may be translated to subsystem configurations. For example, when "platinum treatment" is translated to a specific QoS level treatment in a networking subsystem, one of the outcomes (there can be multiple ones) of the policy could be the configuration of network elements (physical or virtual) to mark that customer's traffic to a certain DSCP (DiffServ Code Point) level (Figure 1). Some may refer to the QoS configuration above as a policy in itself, e.g., [21], [22], [2], and [12]. In this document, such domain configurations are called policy enforcement technologies to set them apart from the actual policy intent, e.g., "a given customer must be given platinum treatment" as in the above example.

Describing intent using a high-level policy language instead of directly describing configuration details allows for the decoupling of the desired intent from the actual configurations, which are subsystem dependent, as shown in the previous example (Figure 1). The translation of a policy into appropriate subsystem configurations requires additional information that is usually subsystem and technology dependent. Therefore, policies should not be written in terms of policy enforcement technologies. Policies should be translated at the subsystems using the appropriate policy provides a few examples where the policy "a given customer must be given platinum treatment" is translated to appropriate configurations at the respective subsystems.

The above may sound like a discussion about "declarative" versus "imperative" policies. We are actually postulating that "imperative

policy" is just a derived subsystem configuration using an appropriate policy enforcement technology to support an actually intended policy.

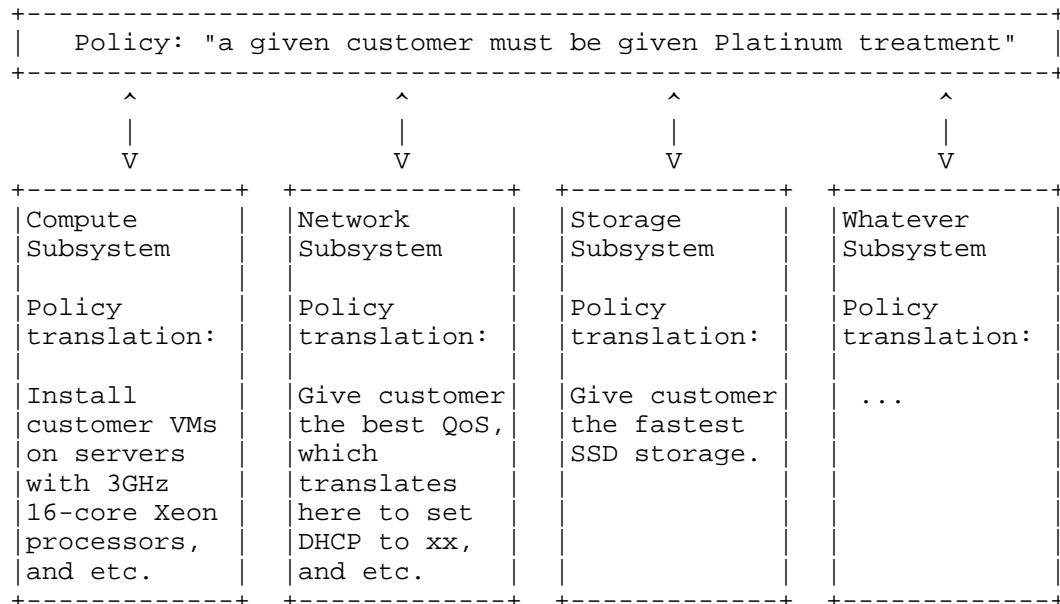


Figure 1: Example of Subsystem Translations of Policy Actions

### 3. Global vs Local Policies

Some policies may be subsystem specific in scope, while others may have broader scope and interact with multiple subsystems. For example, a policy constraining certain customer types (or specific customers) to only use certain server types for VNF or Virtual Machine (VM) deployment would be within the scope of the compute subsystem. A policy dictating that a given customer type (or different implications on different subsystems. As shown in Figure 1, that "platinum treatment" could be translated to servers of a given performance specification in a compute subsystem and storage of a given performance specification in a storage subsystem.

Policies with broader scope, or global policies, would be defined outside affected subsystems and enforced by a global policy engine (Figure 2), while subsystem-specific policies or local policies, would be defined and enforced at the local policy engines of the respective subsystems.

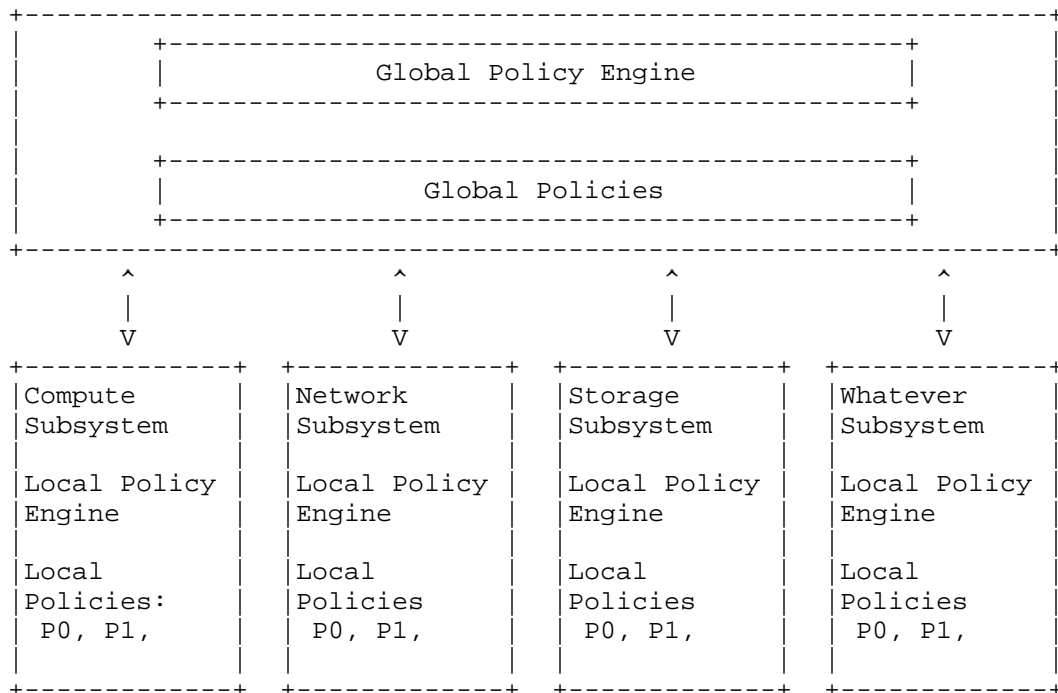


Figure 2: Global versus Local Policy Engines

So far, we have referenced compute, network, and storage as subsystems examples. However, the following subsystems may also support policy engines and subsystem specific policies:

- SDN Controllers, e.g., OpenDaylight [16].
- OpenStack [17] components such as, Neutron, Cinder, Nova, and etc.
- Directories, e.g., LDAP, ActiveDirectory, and etc.
- Applications in general, e.g., standalone or on top of OpenDaylight or OpenStack.
- Physical and virtual network elements, e.g., routers, firewalls, application delivery controllers (ADCs), and etc.
- Energy subsystems, e.g., OpenStack Neat [19].

Therefore, a policy framework may involve a multitude of subsystems. Subsystems may include other lower level subsystems, e.g., Neutron [20] would be a lower level subsystem in the OpenStack subsystem. In other words, the policy framework is hierarchical in nature, where the policy engine of a subsystem may be viewed as a higher level policy engine by lower level subsystems. In fact, the global policy

engine in Figure 2 could be the policy engine of a Data Center subsystem and multiple Data Center subsystems could be grouped in a region containing a region global policy engine. In addition, one could define regions inside regions, hierarchically, as shown in Figure 3.

Metro and wide-area network (WAN) used to interconnect data centers would also be independent subsystems with their own policy engines.

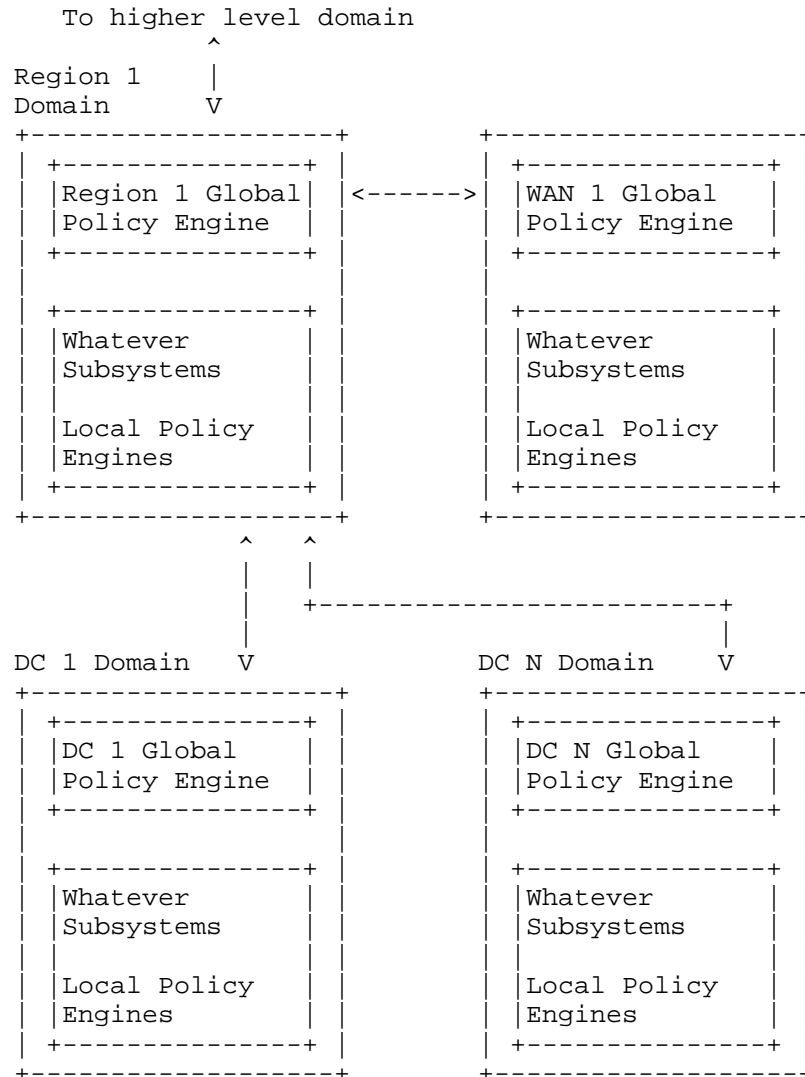


Figure 3: A Hierarchical Policy Framework

## 5. Policy Conflicts and Resolution

Policies should be stored in databases accessible by the policy engines. For example, the local policies defined for the Compute subsystem in Figure 2 would be stored in a database accessible by the local policy engine in that subsystem.

As a new policy is added to a subsystem, the subsystem's policy engine should perform conflict checks. For example, a simple conflict would be created if a new policy states that "customer A must not be allowed to use VNF X", while an already existing policy states that "customer A is allowed to use VNF X". In this case, the conflict should be detected and an appropriate policy conflict resolution mechanism should be initiated.

The nature of the policy conflict resolution mechanism would depend on how the new policy is being entered into the database. If an administrator is manually attempting to enter that policy, the conflict resolution could entail a warning message and rejection of the new policy. The administrator would then decide whether or not to replace the existing policy with the new one.

When policies are batched for later inclusion in the database, the administrator should run a preemptive conflict resolution check on those policies before committing to include them in the database at a future time. However, running a preemptive conflict resolution check does not guarantee that there will be no conflicts at the time the batched policies are actually included in the database, since other policies could have been added in the interim that cause conflicts with those batched policies.

To avoid conflicts between batched policies waiting for later inclusion in the database and new policies being immediately added to the database, one could run a preemptive conflict resolution check against database policies and also batched policies every time new policies are added to the database. However, this may not be sufficient in case of separate administrative domains. A region administration could define batched policies to be pushed to the Compute subsystem of a Data Center at a later time. However, the Compute subsystem may be a separate administrative domain from that of the region administrative domain. In this case, the Compute subsystem may not be allowed to run preemptive policy conflict checks against the batched policies defined at the region administrative domain. Thus, there is a need for a reactive policy conflict resolution mechanism besides preemptive techniques.

The above discussions implicitly assumed that policies are individually evaluated for conflicts and individually committed



without regard to other policies. However, a set of policies could be labeled as part of a same "Commit Group", where the whole set of policies in the Commit Group must be committed for a desired result to be obtained. In this case, the conflict resolution mechanism would need to verify that none of the policies in the Commit Group conflicts with currently committed policies before the Commit Group is added (in other words, committed) to the policy database.

The Commit Group conflict detection mechanism and subsequent addition to the database should be implemented as an atomic process, i.e., no changes to the policy database should be allowed by other processes until either the whole Commit Group is checked and committed or a conflict is detected and the process stopped, to avoid multiple writers issues.

The above described atomic Commit Group conflict detection and policy commit mechanism would eliminate the need for Commit Group rollback. A rollback could be required if policies in a Commit Group were to be checked for conflicts and committed one by one, since the detection of a subsequent policy conflict in the Commit Group would require the rollback of previously committed policies in that group.

## 6. Policy Pub/Sub Bus

In the previous section, we considered policy conflicts within a same level subsystem. For example, new local policies added to the Compute subsystem conflicting with existing local policies at that subsystem. However, more subtle conflicts are possible between global and local policies.

A global policy may conflict with subsystems' local policies. Consider the following Compute subsystem local policy: "Platinum treatment must be provided using server of type A."

The addition of the Global policy "Platinum treatment must be provided using server subtype A-1" would intrude into the Compute subsystem by redefining the type of server to be used for a particular service treatment. While one could argue that such global policy should not be permitted, this is an event that requires detection and proper resolution. A possible resolution is for the Compute subsystem to import the more restrictive policy into its local database. The original local policy would remain in the database as is along with the new restrictive policy. The local policy engine would then enforce the more restricted form of the policy after this policy change, which could make already existing resource allocations non-compliant and requiring corrective actions, e.g., Platinum treatment being currently provided by a server of type A instead of a server of type A-1.

If the new Global policy read "Platinum treatment must be provided using server of types A or B" instead, the Compute subsystem would not need to do anything different, since the Compute subsystem has a more restrictive local policy in place, i.e., "Platinum treatment must be provided using server of type A."

The above examples demonstrate the need for subsystems to subscribe to policy updates at the Global policy level. A policy publication/subscription (pub/sub) bus would be required as shown in Figure 4.

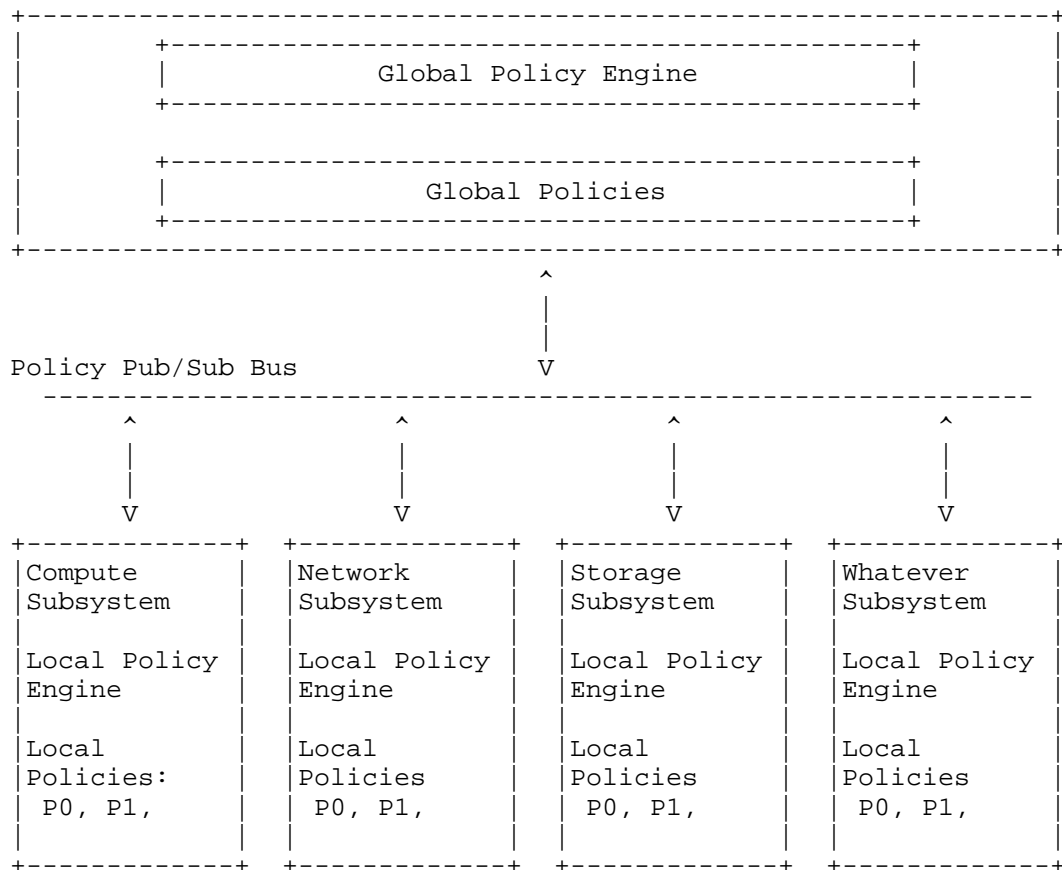


Figure 4: A Policy Pub/Sub Bus

A policy conflict may force policies to change scope. Consider the following existing policies in a Data Center:

Compute subsystem policy: "Platinum treatment requires a server of

type A or B."

Storage subsystem policy: "Platinum treatment requires a server storage of type X or Y."

Now consider the outcome of adding the following new Global policy: "Platinum treatment requires a server of type A when storage of type X is used or a server of type B when storage of type Y is used."

This new Global policy intrudes into the Compute and Storage subsystems. Again, one could argue that such global policy should not be permitted. Nevertheless, this is an event that would require detection and proper resolution. This Global policy causes a conflict because the Compute and Storage subsystems can no longer independently define whether to use a server of type A or B or storage of type X or Y, respectively. If the Compute subsystem selects server of type A for a customer and the Storage subsystem selects storage of type Y for that same customer service the Global policy is violated. In conclusion, if such global policy is permitted, the Compute and Storage subsystems can no longer make such selections. A possible conflict resolution is for the Compute and Storage subsystems to relegate policy enforcement for such resources to the Global policy engine. In this example, the Global Policy engine would need to coordinate with the Compute and Storage subsystems the selection of appropriate resource types to satisfy that policy.

That suggests that the policy pub/sub bus should in fact be an integral part of the northbound service interfaces (NBI) of the subsystems in the hierarchy. Such issue was analyzed in [8], where the concepts of service capability, service availability, and service instantiation were introduced to enable a higher-level subsystem to properly select services and resources from lower-level subsystems to satisfy existing policies.

The above example demonstrates again the need for subsystems to subscribe to policy updates at the higher policy level (the Global policy level in this example) as shown in Figure 4.

If, as demonstrated, a Global policy may "hijack" or "nullify" local policies of subsystems, what exactly makes the scope of a policy local versus global then?

Proposition: A Local Policy does not affect the compliance state imposed by global Policies or the local policies of other subsystems.

The above non-exhaustive examples demonstrate that global and local policies may conflict in subtle ways. Policy conflicts will also

policy framework requires a policy pub/sub bus between all levels to allow for conflict detection, conflict information propagation, and conflict resolution (Figure 5).

Pub/Sub bus to higher level

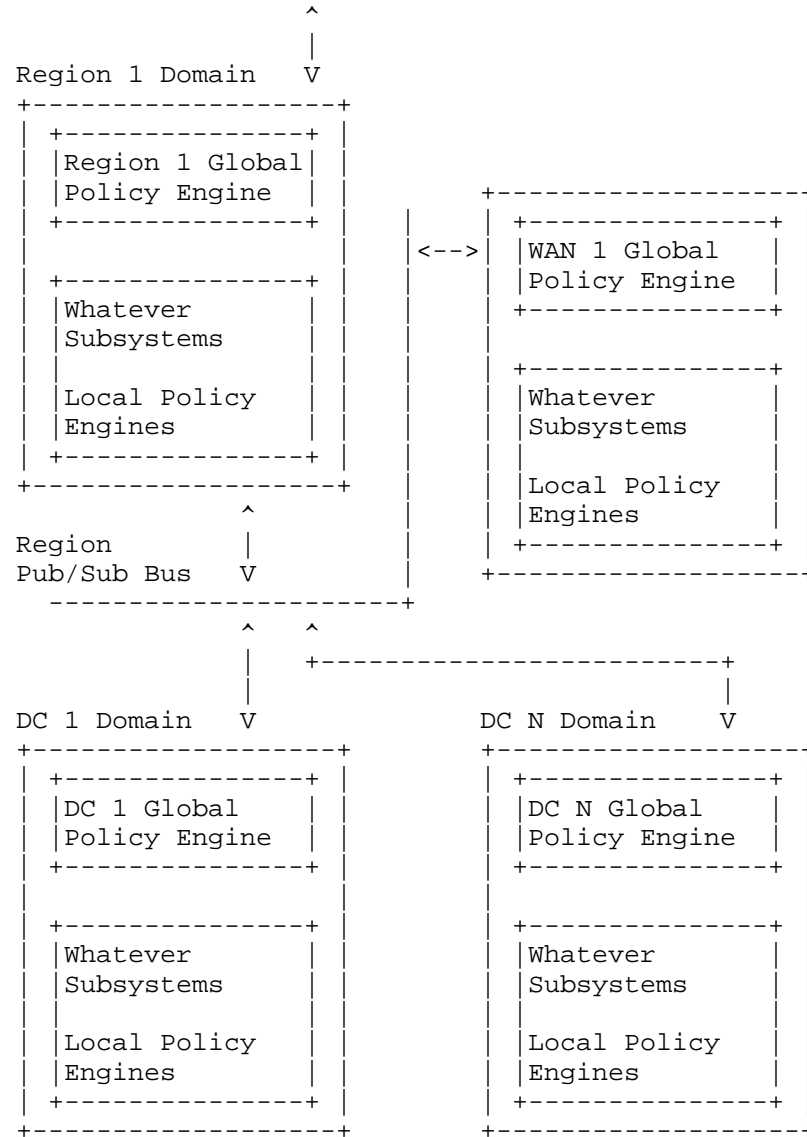


Figure 5: Pub/Sub Bus - Hierarchical Policy Framework

## 7. Examples

### 7.1 Establishment of a Multipoint Ethernet Service

Consider a service provider with an NFV infrastructure (NFVI) with multiple vPoPs, where each vPoP is a separate administrative domain. A customer "Z" requests the creation of a "multipoint Silver Ethernet service" between three of its sites, which are connected to service provider's vPoPs A, B, and C. The customer request is carried out using a service provider self-service web portal, which offers customers multiple service type options, e.g., point-to-point and multipoint Ethernet services, and multiple service levels per service type, e.g., Platinum, Gold, and Silver Ethernet services, where the different service levels may represent different service specifications in terms of QoS, latency, and etc. The web portal relays the request to a service provider's OSS/BSS. The service request is stored as a service policy that reads as: "multipoint Silver Ethernet service between vPoPs A, B, and C for customer Z".

The OSS/BSS subsystem communicates the service request and requirements as a policy to a global NFV Orchestrator (NFVO) subsystem. The service provider's vPoP NFV infrastructure architecture may vary depending on the size of each vPoP and other specific needs of the service provider. For example, a vPoP may have a local NFVO subsystem and one or more local Virtual Infrastructure Manager (VIM) subsystems or it may simply have a VIM, but no local NFVO subsystem. For simplicity of exposition, assume that the service provider has a VIM and no NFVO per vPoP (as in Figure 6). In this case, the global NFVO subsystem communicates the service request and requirements as a policy to the VIMs of vPoPs A, B, and C.

At each vPoP, the local VIM will carry out the requested service policy based on the local configuration of respective subsystems and current availability of resources. For example, Silver service type, as specified in the policy, may translate in vPoP A to use a specific vCPE VNF type, say vCPE\_X, while Silver service type in vPoP B may translate to a different vCPE VNF type, say vCPE\_Y, due to local subsystem configurations (refer to Section 2 for a discussion on subsystem actions and configurations). Similarly, the local VIM interaction with the vPoP's compute, network, and storage subsystems may lead to local configurations of these subsystems driven by the translation of the policy by the respective subsystems (see Section 3 for a discussion on global versus local policies).

The global NFVO subsystem would potentially communicate the service policy to a WAN infrastructure management (WIM) subsystem (not shown in Figure 6), to provision a multipoint Silver Ethernet service between vPoPs A, B, and C. The WIM subsystem could oversee a

hierarchy of other subsystems, e.g., SDN multi-domain architecture of controllers deployed as a hierarchy of network regions (see [8]). Network subsystems would translate the Silver type requirement to a local configuration (again, refer to Section 2 for a discussion on subsystem actions and configurations).

As depicted in Figure 6, service policy communications should employ a policy pub/sub bus between the subsystems' policy engines in the policy hierarchy (see Section 6 for a discussion on policy pub/sub bus). The global NFVO subsystem should have visibility into the policies defined locally at each vPoP to be able to detect any potential global policy conflicts, e.g., a local vPoP administrator could add a local policy that violates or conflicts with a global policy. In addition, the global NFVO subsystem would benefit from being able to import the currently configured services at each vPoP. For example, each vPoP could publish a table of currently configured services. The global NFVO would use such information to monitor global policy conformance and also to facilitate detection of policy violations when new global policies are created, e.g., a global level administrator is about to add a new global policy that, if committed, would make certain already configured services a violation of the policy. The publication of subsystem service tables for consumption by a global policy engine is a concept used in the Congress [18] OpenStack [17] project.

In the hierarchical policy framework described in this document, a subsystem's currently configured services table could be published to higher tier policy engines using the policy pub/sub bus. The subsystem's currently configured services table would describe configured services based on the configured policy name space for the respective policy pub/sub bus. The name space of a policy pub/sub bus refers to the name space available to communicate policies between the subsystems connected to the particular policy pub/sub bus. In this example, Ethernet services use the name space "Platinum", "Gold", and "Silver". A policy can then specify Silver Ethernet service. The policy name space would be an attribute associated with a particular policy pub/sub bus and should be pre-defined/pre-configured in the respective subsystems for each policy pub/sub bus.

Note that in a hierarchical policy framework a policy engine may use more than one policy pub/sub bus, e.g., a policy pub/sub bus to communicate with higher tier policy engines and another policy pub/sub bus to communicate with lower tier policy engines. For example, Figure 6 shows a policy pub/sub bus between the global NFVO subsystem and the vPoPs. Each vPoP could have an internal hierarchy of policy engines, e.g., VIM policy engine communicating with network (e.g., SDN controller), compute (VM orchestration), and storage subsystems' policy engines.

The amount of information that would be reported by a subsystem's currently configured services table would then depend on the pre-defined name space of a particular policy pub/sub bus. In this example, the vPoPs would communicate that customer Z is assigned/configured a vCPE VNF of type Silver.

Note that the described policy framework does not mandate or preclude use of detailed name spaces. However, to promote scalability and limit complexity, one should preferably use a name space hierarchy where the name spaces used by higher tier policy engines would be limited to higher level details. For example, suppose that vPoP A supports VNF types Silver.vCPE\_X1 and Silver.vCPE\_X2, that is, vCPE\_X1 and vCPE\_X2 are VNFs that were configured at vPoP A as supporting Silver services. Local policies in vPoP A would be used for the selection of vCPE\_X1 or vCPE\_X2 VNF when a service request requires a Silver vCPE VNF. vPoP A would report customer Z as using Silver.vCPE\_X1 vCPE VNF (instead of simply Silver vCPE VNF) only when the name space between vPoP A and the global NFVO defines this granularity of Ethernet services. Note that one would want to define Silver.vCPE\_X1 and Silver.vCPE\_X2 as part of the policy name space between vPoP A and the global NFVO if the capability to specify such policy specificity is desired at the global level. However, the higher the degree of specificity allowed at the higher tiers of the policy hierarchy the higher the operational complexity.

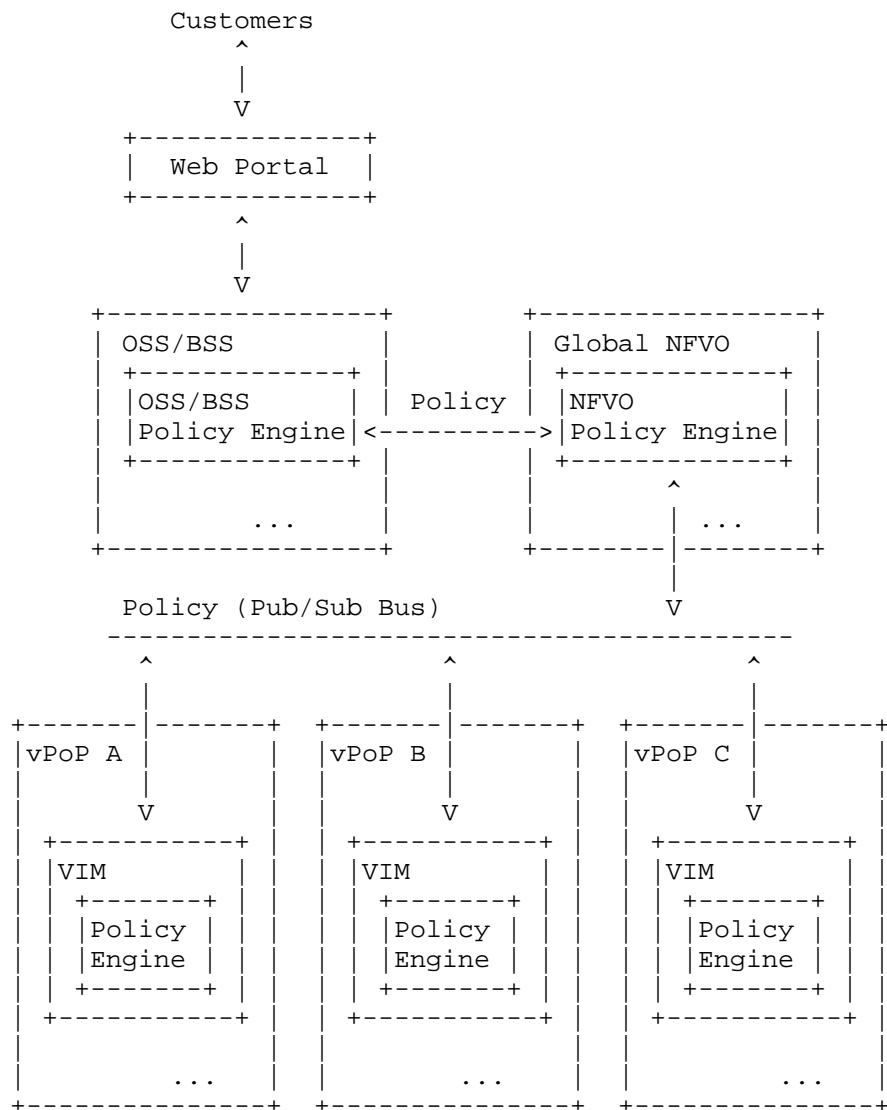


Figure 6: Simplified view of a service provider's NFV Architecture:  
Multipoint Ethernet Service Example



## 7.2 Policy-Based NFV Placement

IRTF draft [10] describes a detailed example of a global policy written in Datalog [1] applicable to compute to promote energy conservation for the NFVIaaS use case [4] in an OpenStack framework. The goal of that policy is to address the energy efficiency requirements described in the ETSI NFV Virtualization Requirements [5].

Related to the above, energy efficiency using analytics-driven policies in the context of OpenStack Congress [18] policy as a service was presented and demonstrated at the Vancouver OpenStack summit [11], where the Congress policy engine delegates VM placement to a VM placement engine that migrates under-utilized VMs to save energy.

## 8. Summary

This document approached the policy framework and architecture from the perspective of overall orchestration requirements for services involving multiple subsystems. The analysis extended beyond common orchestration for compute, network, and storage subsystems to also include energy conservation constraints. This document also analyzed policy scope, global versus local policies, policy actions and translations, policy conflict detection and resolution, interactions among policies engines, and a hierarchical policy architecture/framework to address the demanding and growing requirements of NFV environments, applicable as well to general cloud infrastructures.

The concept of NFV and the proposed policy architecture is applicable to service providers and also enterprises. For example, an enterprise branch office could have capacity and energy constraints similar to that of many service provider NFV vPoPs in constrained environments. This is an aspect that would be worth examining in detail in future work.

## 9. IANA Considerations

This draft does not have any IANA considerations.

## 10. Security Considerations

Security issues due to exchanging policies across different administrative domains are an aspect for further study.

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