

MIF Working Group  
Internet-Draft  
Intended status: Informational  
Expires: August 04, 2014

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February 02, 2014

Multiple Provisioning Domain Architecture  
draft-ietf-mif-mpvd-arch-00

## Abstract

This document is a product of the work of MIF architecture design team. It outlines a solution framework for some of the issues, experienced by nodes that can be attached to multiple networks. The framework defines the notion of a Provisioning Domain (PVD) - a consistent set of network configuration information, and PVD-aware nodes - nodes which learn PVDs from the attached network(s) and/or other sources and manage and use multiple PVDs for connectivity separately and consistently.

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## [1.](#) Introduction

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Nodes attached to multiple networks may encounter problems due to conflict of the networks configuration and/or simultaneous use of the multiple available networks. While existing implementations apply various techniques ([\[RFC6419\]](#)) to tackle such problems, in many cases the issues may still appear. The MIF problem statement document [\[RFC6418\]](#) describes the general landscape as well as discusses many specific issues and scenarios details.

Problems, enumerated in [\[RFC6418\]](#), can be grouped into 3 categories:

1. Lack of consistent and distinctive management of configuration elements, associated with different networks.
2. Inappropriate mixed use of configuration elements, associated with different networks, in the course of a particular network activity / connection.
3. Use of a particular network, not consistent with the intent of the scenario / involved parties, leading to connectivity failure and / or other undesired consequences.

An example of (1) is a single node-scoped list of DNS server IP addresses, learned from different networks, leading to failures or delays in resolution of names from particular namespaces; an example of (2) is use of an attempt to resolve a name of a HTTP proxy server, learned from a network A, with a DNS server, learned from a network B, that is likely to fail; an example of (3) is use of an employer-sponsored VPN connection for peer-to-peer connectivity, unrelated to employment activities.

This architecture describes a solution to these categories of

problems, respectively, by:

1. Introducing a formal notion of the PVD, including PVD identity, and ways for nodes to learn the intended associations among acquired network configuration information elements.
2. Introducing a reference model for a PVD-aware node, preventing inadvertent mixed use of the configuration information, which may belong to different PVDs.
3. Providing recommendations on PVD selection based on PVD identity and connectivity tests for common scenarios.

### 1.1. Requirements Language

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](#) [[RFC2119](#)].

## 2. Definitions and types of PVDs

**Provisioning Domain:** a consistent set of network configuration information. Classically, the entire set available on a single interface is provided by a single source, such as network administrator, and can therefore be treated as a single provisioning domain. In modern IPv6 networks, multihoming can result in more than one provisioning domain being present on a single link. In some scenarios, it is also possible for elements of the same domain to be present on multiple links.

Typical examples of information in a provisioning domain, learned from the network, are: source address prefixes that can be used by connections within the provisioning domain, IP address of DNS server, name of HTTP proxy server if available, DNS suffixes associated with the network etc.

**PVD-aware node:** a node that supports association of network configuration information into PVDs, and using these PVDs to serve requests for network connections in ways, consistent with recommendations of this architecture.

## [2.1.](#) Explicit PVDs

A node may receive explicit information from the network and/or other sources, about presence of PVDs and association of particular network information with a particular PVD. PVDs, constructed based on such information, are referred to in this document as "explicit".

Protocol changes/extensions will likely be required to support the explicit PVDs by IETF-defined mechanisms. As an example, one could think of one or several DHCP options, carrying PVD identity and / or its elements. A different approach could be to introduce a DHCP option, which only carries identity of a PVD, while the association of network information elements with that identity, is implemented by the respective protocols - such as e.g., with a Router Discovery [[RFC4861](#)] option associating an address range with a PVD.

Specific, existing or new, features of networking protocols to enable delivery of PVD identity and association with various network information elements will be defined in companion design documents.

Link-specific and/or vendor-proprietary mechanisms for discovery of PVD information, different from the IETF-defined mechanisms, can be used by the nodes separately from or together with IETF-defined mechanisms, as long as they allow to discover necessary elements of the PVD(s). Another example of a delivery mechanism for PVDs are key exchange or tunneling protocols, such as IKEv2 [[RFC5996](#)] that allow transporting host configuration information. In all cases, by default nodes must ensure that the lifetime of all dynamically

discovered PVD configuration is appropriately limited by the relevant events - for example, if an interface media state change was indicated, the previously discovered information may no longer be valid and needs to be re-discovered or confirmed.

It shall be possible for sources of PVD information to communicate that some of their configuration elements could be used within a context of other networks/PVDs. PVD-aware nodes, based on such declaration and their policies, may choose to inject such elements into some or all other PVDs they connect to.

In some network topologies, the network infrastructure elements may

need to advertise multiple PVDs. The details of how this is done generally will be defined in the individual companion design documents. However, where different design choices are possible, the choice that requires smaller number of packets shall be preferred for efficiency.

## [2.2.](#) Implicit PVDs and incremental adoption of the explicit PVDs

It is likely that for a long time there may be networks which do not advertise explicit PVD information, since deployment of any new features in networking protocols is a relatively slow process.

When connected to networks, which don't advertise explicit PVD information, PVD-aware node shall automatically create separate PVDs for configuration received on multiple interfaces. Such PVDs are referred to in this document as "implicit".

With implicit PVDs, PVD-aware nodes may still provide benefits to their users as compared to non-PVD aware nodes, by using network information from different interfaces separately and consistently to serve network connection requests, following best practices described in [Section 5](#).

In the mixed mode, where e.g., multiple networks are available on the link the interface is attached to, and only some of the networks advertise PVD information, the PVD-aware node shall create explicit PVDs based on explicitly learned PVD information, and associate the rest of the configuration with an implicit PVD created for that interface.

## [2.3.](#) Relationship between PVDs and interfaces

Implicit PVDs are limited to network configuration information received on a single interface. Explicit PVDs, in practice will often also be scoped to a configuration related to a particular interface, however per this architecture there is no such requirement or limitation and as defined in this architecture, explicit PVDs may include information related to more than one interfaces, if the node learns presence of the same PVD on those interfaces and the

authentication of the PVD ID meets the level required by the node policy.

It is an intent of this architecture to support such scenarios among others. Hence, it shall be noted that no hierarchical relationship exists between interfaces and PVDs: it is possible for multiple PVDs to be simultaneously accessible over one interface, as well as single PVD to be simultaneously accessible over multiple interfaces.

#### [2.4.](#) PVD identity/naming

For explicit PVDs, PVD ID (globally unique ID, that possibly is human-readable) is received as part of that information. For implicit PVDs, the node assigns a locally generated globally unique ID to each implicit PVD.

PVD-aware node may use these IDs to choose a PVD with matching ID for special-purpose connection requests, in accordance with node policy or choice by advanced applications, and/or to present human-readable representation of the IDs to the end-user for selection of Internet-connected PVDs.

A single network provider may operate multiple networks, including networks at different locations. In such cases, the provider may chose whether to advertise single or multiple PVD identities at all or some of those networks, as it suits their business needs. This architecture doesn't impose specific requirements in this regard.

When multiple nodes are connected to the same link, where one or more explicit PVDs are available, this architecture assumes that the information about all available PVDs is advertized by the networks to all the connected nodes. At the same time, the connected nodes may have different heuristics, policies and/or other settings, including configured set of their trusted PVDs, which may lead to different PVDs actually being used by different nodes for their connections.

Possible extensions, where different sets of PVDs may be advertised by the networks to different connected nodes, are out of scope of this document.

#### [2.5.](#) Relationship to dual-stack networks

When applied to dual-stack networks, the PVD definition allows for multiple PVDs to be created, where each PVD contain information for only one address family, or for a single PVD that contains information about multiple address families. This architecture requires that accompanying design documents for the PVD-related protocol changes must support PVDs containing information from

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multiple address families. PVD-aware nodes must be capable of dealing with both single-family and multi-family PVDs.

For explicit PVDs, the choice of either of the approaches is a policy decision of a network administrator and/or node user/administrator. Since some of the IP configuration information that can be learned from the network can be applicable to multiple address families (for instance DHCP address selection option [[RFC7078](#)]), it is likely that dual-stack networks will deploy single PVDs for both address families.

For implicit PVDs, by default PVD-aware nodes shall including multiple IP families into single implicit PVD created for an interface. At the time of writing of this document in dual-stack networks it appears to be a common practice for configuration of both address families to be provided by a single source.

A PVD-aware node that provides API to use / enumerate / inspect PVDs and/or their properties shall provide ability to filter PVDs and/or their properties by address family.

## [2.6.](#) Elements of PVD

## [3.](#) Conveying PVD information using DHCPv6 and Router Advertisements

DHCPv6 and Router Advertisements are the two most common methods of configuring hosts and they would need to be extended to convey explicit PVD information. There are several things that need to be considered before finalizing a mechanism to augment DHCPv6 and RAs with Pvd information.

### [3.1.](#) Separate messages or one message

When information from several PVDs is available at the same configuration source, there are two possibilities regarding how to send these out. One way is to send information from different provisioning domains in separate messages. The other is to combine information from several PVDs onto one message. The latter method has the advantage of being more efficient but could have issues due to authentication and authorization issues as well as potential issues with accommodating common information and information not tagged with any PVD information.



### [3.2.](#) Securing the PVD information

DHCPv6 and RAs both provide some form of authentication that ensures the identity of the source as well as the integrity of the contents that have been secured. While this is useful, the authenticity of the information provides no information whether the configuration source is actually allowed to provide information from a given PVD. In order to do be able to do this, there must be a mechanism for the

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owner of the PVD to attach some form of authorization token to the configuration information that is delivered.

### [3.3.](#) Backward compatibility

The extensions to RAs and DHCPv6 should be defined in such a manner than unmodified hosts (i.e. hosts not aware of PVDs) will continue to function as well as they did before the PVD information got added. This could imply that some information may need to be duplicated in order to be conveyed to legacy hosts. Similarly PVD aware hosts need to be able to handle legacy configuration sources which do not provide PVD information. There are also several initiatives ongoing that are aimed at adding some form of additional information to prefixes [refs to [draft-bhandari](#) and [draft-korhonen](#)] and any new mechanism should try to consider co-existence with these existing mechanisms.

### [3.4.](#) Selective propagation

When a configuration source has information regarding several PVDs it is not clear whether it should provide information about all of them to any host that requests info from it. While it may be reasonable in some cases, this might become an unreasonable burden once the number of PVDs starts increasing. One way to restrict the propagation of useless information is for the host to select the PVD information they desire in their request to the configuration source. One way this could be accomplished is by using an ORO with the PVDs that are of interest. The configuration source can then respond with only the requested information.

By default, a configuration source SHOULD provide information related to all provisioning domains without expecting the client to select the PVD(s) it requires. This is necessary to ensure that hosts that

do not support requesting selective PvD information will continue to work. Also note that IPv6 neighbor discovery does not provide any functionality analogous to the DHCPv6 OR0.

In this case, when a host receives PvD information it does not require, the information can simply be discarded. Also, in constrained networks such as LLNs, the amount of configuration information needs to be restricted to ensure that the load on the hosts is bearable while keeping the information identical across all the hosts.

In case selective propagation is required, some form of PvD discovery mechanism needs to be specified so that hosts/applications can be pre-provisioned to request a specific PvD. Alternately, the set of

PvDs that the network can provide to the host can be propagated to the host using RAs or stateless DHCPv6. The discovery mechanism may potentially support the discovery of available PvDs on a per-host basis.

### [3.5.](#) Retracting/updating PvD information

After the PvD information is provided to the host it may be outdated or updated with newer information before the hosts would normally request updates. This would require the mechanism to be able to update and/or withdraw all (or some subset) of information related to a given PvD. For efficiency reasons, there should be a way to specify that all the information from the PvD needs to be reconfigured instead of individually updating each item associated with the PvD.

### [3.6.](#) Conveying configuration information using IKEv2

Internet Key Exchange protocol version 2 (IKEv2) [[RFC5996](#)] [[RFC5739](#)] is another widely used and a popular method of configuring IP information in a host. In the case of IKEv2 the provisioning domain could actually be implicitly learnt from the Identification - Responder (IDr) payloads the IKEv2 initiator and the responder inject during the IKEv2 exchange. The IP configuration may depend on the

named IDr. Another possibility could be adding specific provisioning domain identifying payload extensions to IKEv2. All of the considerations listed above for DHCPv6 and RAs potentially apply to IKEv2 as well.

#### 4. Example network configurations and number of PVDs

#### 5. Reference model of PVD-aware node

##### 5.1. Constructions and maintenance of separate PVDs

It is assumed that normally, configuration information contained in a single PVD, shall be sufficient for a node to fulfill a network connection request by an application, and hence there should be no need to attempt to merge information across different PVDs.

Nevertheless, even when a PVD lack some parts of the configuration, merging of information from different PVD(s) shall not be done automatically, since typically it would lead to issues described in [\[RFC6418\]](#).

A node may use other sources, such as e.g., node local policy, user input or other mechanisms, not defined by IETF, to either construct a PVD entirely (analogously to static IP configuration of an interface), or supplement with particular elements all or some PVDs learned from the network, or potentially merge information from different PVDs, if such merge is known to the node to be safe, based on explicit policies.

As an example, node administrator could inject a not ISP-specific DNS server into PVDs for any of the networks the node could become attached to. Such creation / augmentation of PVD(s) could be static or dynamic. The particular implementation mechanisms are outside of the scope of this document.

##### 5.2. Consistent use of PVDs for network connections

PVDs enable PVD-aware nodes to use consistently a correct set of configuration elements to serve the specific network requests from beginning to end. This section describes specific examples of such consistent use.

### [5.2.1.](#) Name resolution

When PVD-aware node needs to resolve a name of the destination used by a connection request, the node could decide to use one, or multiple PVDs for a given name lookup.

The node shall chose one PVD, if e.g., the node policy required to use a particular PVD for a particular purpose (e.g. to download an MMS using a specific APN over a cellular connection). To make the choice, the node could use a match of the PVD DNS suffix or other form of PVD ID, as determined by the node policy.

The node may pick multiple PVDs, if e.g., they are general purpose PVDs providing connectivity to the Internet, and the node desires to maximize chances for connectivity in Happy Eyeballs style. In this case, the node could do the lookups in parallel, or in sequence. Alternatively, the node may use for the lookup only one PVD, based on the PVD connectivity properties, user choice of the preferred Internet PVD, etc.

In either case, by default the node uses information obtained in a name service lookup to establish connections only within the same PVD from which the lookup results were obtained.

For simplicity, when we say that name service lookup results were obtained from a PVD, what we mean is that the name service query was issued against a name service the configuration of which is present in a particular PVD. In that sense, the results are "from" that particular PVD.

Some nodes may support transports and/or APIs, which provide an abstraction of a single connection, aggregating multiple underlying connections. MPTCP [[RFC6182](#)] is an example of such transport protocol. For the connections provided by such transports/APIs, a PVD-aware node may use different PVDs for servicing of that logical connection, provided that all operations on the underlying

connections are done consistently within their corresponding PVD(s).

### [5.2.2.](#) Next-hop and source address selection

For the purpose of this discussion, let's assume the preceding name lookup succeeded in a particular PVD. For each obtained destination address, the node shall perform a next-hop lookup among routers, associated with that PVD. As an example, such association could be determined by the node via matching the source address prefixes/ specific routes advertized by the router against known PVDs, or receiving explicit PVD affiliation advertized through a new Router Discovery [[RFC4861](#)] option.

For each destination, once the best next-hop is found, the node selects best source address according to the [[RFC6724](#)] rules, but with a constraint that the source address must belong to a range associated with the used PVD. If needed, the node would use the prefix policy from the same PVD for the best source address selection among multiple candidates.

When destination/source pairs are identified, then they are sorted using the [[RFC6724](#)] destination sorting rules and the prefix policy table from the used PVD.

### [5.3.](#) Connectivity tests

Although some PVDs may appear as valid candidates for PVD selection (e.g. good link quality, consistent connection parameters, etc.), they may provide limited or no connectivity to the desired network or the Internet. For example, some PVDs provide limited IP connectivity (e.g., scoped to the link or to the access network), but require the node to authenticate through a web portal to get full access to the Internet. This may be more likely to happen for PVDs, which are not trusted by the given PVD-aware node.

An attempt to use such PVD may lead to limited network connectivity or connection failures for applications. To prevent the latter, a PVD-aware node may perform connectivity test for the PVD, before using it to serve network connection requests of the applications. In current implementations, some nodes do that, for instance, by trying to reach a dedicated web server (e.g., see [[RFC6419](#)]).

Per [Section 5.2](#), a PVD-aware node shall maintain and use multiple PVDs separately. The PVD-aware node shall perform connectivity test and, only after validation of the PVD, consider using it to serve application connections requests. Ongoing connectivity tests are also required, since during the IP session, the end-to-end connectivity could be disrupted for various reasons (e.g. poor L2,

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IP QoS issues); hence a connectivity monitoring function is needed to check the connectivity status and remove the PVD from the set of usable PVDs if necessary.

There may be cases where a connectivity test for PVD selection may be not appropriate and should be complemented, or replaced, by PVD selection based on other factors. This could be realized e.g., by leveraging some 3GPP and IEEE mechanisms, which would allow to expose some PVD characteristics to the node (e.g. 3GPP Access Network Discovery and Selection Function (ANDSF) [[TS23.402](#)], IEEE 802.11u [[IEEE802.11u](#)]/ANQP).

#### [5.4.](#) Relationship to interface management and connection managers

Current devices such as mobile handsets make use of proprietary mechanisms and custom applications to manage connectivity in environments with multiple interfaces and multiple sets of network configurations. These mechanisms or applications are commonly known as connection managers [[RFC6419](#)].

Connection managers sometimes rely on policy servers to allow the node, connected to multiple networks, perform the network selection. They can also make use of routing guidance from the network (e.g. 3GPP ANDSF [[TS23.402](#)]). Although connection managers solve some connectivity problems, they rarely address the network selection problems in a comprehensive manner. With proprietary solutions, it is challenging to present a coherent behaviour to the end user of the device, as different platforms present different behaviours even when connected to the same network, with the same type of interface, and for the same purpose.

### [6.](#) PVD support in APIs

In all cases changes in available PVDs must be somehow exposed, appropriately for each of the approaches.

#### [6.1.](#) Basic

Applications are not PVD-aware in any manner, and only submit connection requests. The node performs PVD selection implicitly, without any otherwise applications participation, and based purely on node-specific administrative policies and/or choices made by the user in a user interface provided by the operating environment, not by the application.

As an example, such PVD selection can be done at the name service lookup step, by using the relevant configuration elements, such as e.g., those described in [[RFC6731](#)]. As another example, the PVD selection could be done based on application identity or type (i.e., a node could always use a particular PVD for a VOIP application).

## [6.2.](#) Intermediate

Applications indirectly participate in selection of PVD by specifying hard requirements and soft preferences. The node performs PVD selection, based on applications inputs and policies and/or user preferences. Some / all properties of the resultant PVD may be exposed to applications.

## [6.3.](#) Advanced

PVDs are directly exposed to applications, for enumeration and selection. Node policies and/or user choices, may still override the application preferences and limit which PVD(s) can be enumerated and/or used by the application, irrespectively of any preferences which application may have specified. Depending on the implementation, such restrictions, imposed per node policy and/or user choice, may or may not be visible to the application.

## [7.](#) PVD-aware nodes trust to PVDs

### [7.1.](#) Untrusted PVDs

Implicit and explicit PVDs for which no trust relationship exists are considered untrusted. Only PVDs, which meet the requirements in [Section 7.2](#), are trusted; any other PVD is untrusted.

In order to avoid various forms of misinformation that can be asserted when PVDs are untrusted, nodes that implement PVD separation cannot assume that two explicit PVDs with the same identifier are actually the same PVD. A node that did make this assumption would be vulnerable to attacks where for example an open Wifi hotspot might assert that it was part of another PVD, and thereby might draw traffic intended for that PVD onto its own network.

Since implicit PVD identifiers are synthesized by the node, this issue cannot arise with implicit PVDs.

Mechanisms exist (for example, [[RFC6731](#)]) whereby a PVD can provide configuration information that asserts special knowledge about the reachability of resources through that PVD. Such assertions cannot be validated unless the node has a trust relationship with the PVD; assertions of this type therefore must be ignored by nodes that receive them from untrusted PVDs. Failure to ignore such assertions could result in traffic being diverted from legitimate destinations to spoofed destinations.

## [7.2.](#) Trusted PVDs

Trusted PVDs are PVDs for which two conditions apply. First, a trust relationship must exist between the node that is using the PVD configuration and the source that provided that configuration; this is the authorization portion of the trust relationship. Second, there must be some way to validate the trust relationship. This is the authentication portion of the trust relationship. Two mechanisms for validating the trust relationship are defined.

It shall be possible to validate the trust relationship for all advertised elements of a trusted PVD, irrespective of whether the PVD elements are communicated as a whole, e.g. in a single DHCP option, or separately, e.g. in supplementary RA options. Whether or not this is feasible to provide mechanisms to implement trust relationship for all PVD elements, will be determined in the respective companion design documents.

### [7.2.1.](#) Authenticated PVDs

One way to validate the trust relationship between a node and the source of a PVD is through the combination of cryptographic authentication and an identifier configured on the node. In some cases, the two could be the same; for example, if authentication is done with a shared secret, the secret would have to be associated



with the PVD identifier. Without a (PVD Identifier, shared key) tuple, authentication would be impossible, and hence authentication and authorization are combined.

However, if authentication is done using some public key mechanism such as a TLS cert or DANE, authentication by itself isn't enough, since theoretically any PVD could be authenticated in this way. In addition to authentication, the node would need to be configured to trust the identifier being authenticated. Validating the authenticated PVD name against a list of PVD names configured as trusted on the node would constitute the authorization step in this case.

#### [7.2.2.](#) PVDs trusted by attachment

In some cases a trust relationship may be validated by some means other than described in [Section 7.2.1](#), simply by virtue of the connection through which the PVD was obtained. For instance, a handset connected to a mobile network may know through the mobile network infrastructure that it is connected to a trusted PVD, and whatever mechanism was used to validate that connection constitutes the authentication portion of the PVD trust relationship. Presumably such a handset would be configured from the factory, or else through mobile operator or user preference settings, to trust the PVD, and this would constitute the authorization portion of this type of trust relationship.

### [8.](#) Acknowledgements

This document was created as a product of a MIF architecture design team.

### [9.](#) IANA Considerations

This memo includes no request to IANA.

### [10.](#) Security Considerations

There are at least three different form of attacks that can be performed using configuration sources that use multiple provisioning domains.

Tampering with configuration information provided An attacker may attempt to modify the information provided inside the PVD container option. These attacks can easily be prevented by using the message integrity features provided by the underlying protocol used to carry the configuration information. e.g. SEND [[RFC3971](#)] would detect any form of tampering with the RA contents and the DHCPv6 [[RFC3315](#)] AUTH option that would detect any form of tampering with the DHCPv6 message contents. This attack can also be performed by a compromised configuration source by modifying information inside a specific , in which case the mitigations proposed in the next subsection may be helpful.

Rogue configuration source A compromised configuration source such as a router or a DHCPv6 server may advertise information about PVDs that it is not authorized to advertise. e.g. A coffee shop may advertise configuration information purporting to be from an enterprise and may try to attract enterprise related traffic. The only real way to avoid this is that the PVD related configuration container contains embedded authentication and authorization information from the owner of the PVD. Then, this attack can be detected by the client by verifying the authentication and authorization information provided inside the PVD container option after verifying its trust towards the PVD owner (e.g. a certificate with a well-known/common trust anchor).

Replay attacks A compromised configuration source or an on-link attacker may try to capture advertised configuration information and replay it on a different link or at a future point in time. This can be avoided by including some replay protection mechanism such as a timestamp or a nonce inside the PVD container to ensure freshness of the provided information.

## [11.](#) References

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Internet-Draft

MPVD architecture

February 2014

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