Policy Decision Point (PDP) Software Design Document

J. Spagnolo, D. Cayer

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Policy Decision Point (PDP) Software Design Document

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1. Introduction

Policy Based Network Management (PBNM) systems provide an automated means to configure and administer Policy Enforcement Point (PEP) devices such as virtual private network (VPN) gateways, firewalls and routers. The Policy Decision Point (PDP) takes high level policies as input and produces lower level PEP specific policies as output. The PBNM system can process different types of policies. When evaluating policies, the PDP must identify and resolve conflicts within competing policies as well as take into consideration external factors such as the time-of-day and the current threat level.

A PBNM system alleviates the need for network administrators to manually configure numerous network devices in order to implement local policy changes. We also introduce the concept of policy negotiation for inter-domain policies\(^1\) such as inter-domain security policies. Negotiable policies are not complete policy documents and therefore the PDP cannot directly implement them. Instead, the local PDP must exchange policy proposals with a PDP in a remote administrative domain. Policy proposals contain all the negotiation parameters needed by the other party to correctly evaluate the proposed policy against the local policy. A PDP can accept a proposed policy in whole or in part or it can reject the proposed policy. If both parties accept the other party’s proposed policy in whole or in part, each party merges the local and remote policy proposals to form a complete policy document that the PDP can implement. The PBNM system automatically reconfigures network devices as required to implement negotiated policies.

2. Purpose

This document presents a software design for the Policy Decision Point (PDP) component of PBNM system described in the “Policy Based Network Management - System Design Document” [PBNM]. The system facilitates the compilation of policies, the storage of policies, the exchange of policies, the evaluation and negotiation of policies, as well as the implementation and enforcement of policies.

The PDP is implemented in Java. The primary goal of this software design is to create an extensible PDP framework that can support different types of policies without requiring significant modifications to the existing software. Moreover, this software design makes extensive use of Java software interfaces to define the functions of the major system components. This allows for different implementations of the same software component to be substituted into the system without affecting the remainder of the system.

3. Software Architecture

Figure 1 illustrates major software components that comprise software architecture for the PDP. Most software components are defined by a Java interface that describes their intended purpose. This hides the implementation details and allows other objects to interact with the software component using the generic Java interface.

\(^1\) Note that inter-domain policies may also be intra-organizational policies as some “domains” will be identified parts of larger organizations.
The Policy Processing Unit (PPU) forms the core of the PDP and is the only component that possesses knowledge of policy structure, syntax and encoding. The PDP requires the implementation of a distinct PPU class for each type of policy supported by the system. Section Error! Reference source not found., which describes the PPU class in more detail, describes how a specific PPU class is implemented by extending a pair of abstract Java classes.

The PPU class\textsuperscript{2} implements two interfaces. The Policy Info Consumer interface allows the PPU to acquire new policy documents from the Policy Editor via the Policy Info Provider, while the Command Processor interface allows the PPU to accept user commands from the PDP Console via the Main Program.

The PPU makes extensive use of the four infrastructure services. The Policy Repository provides access to an XML based directory where the PPU stores policy objects. The XML Digital

\textsuperscript{2} In reality, PPU inner classes implement these interfaces.
Signature Service applies digital signatures to XML documents and verifies digital signatures on XML documents. The Authorization Service determines which operations an entity (based on the entity’s digital credentials) can perform. The Address Resolution Service maps between administrative domain names and the associated network layer information. In addition to the PPU, other PDP software components make use of these infrastructure services, including the infrastructure services themselves.

The Policy Info Provider interacts with the Policy Editor to acquire new policy documents and submits them to interested consumers. Currently only PPU objects act as Policy Info Consumers. In the future however, other PDP objects will accept policy documents from the Policy Editor and they will also implement the Policy Info Consumer interface.

For inter-domain negotiable policies, the Comm Handler facilitates communication between the various PPU objects within the PDP system and the Policy Negotiation Proxy (PNP) system. The PBNM system supports the simultaneous negotiation of different types of policies.

The Policy Server accepts device level policy documents from the various PPU objects to be implemented within Policy Enforcement Point (PEP) devices. The Policy Server accepts Common Object Policy Service (COPS) for provisioning (COPS-PR) sessions from PEP devices and supplies the relevant portions of device level policy documents as configuration information to PEP devices based on the PEP device’s type or role.

The Main Program provides the entry point for the PDP system. It instantiates all the major software components shown in Figure 1 and provides methods that allow PDP software components to acquire references to other PDP software components. This is how the PPU objects acquire references to the objects that provide infrastructure services, as well as to the Policy Info Provider, the Comm Handler, and the Policy Server. The Main Program also provides a basic command line interface for the PDP system through the PDP Console.

Figure 1 does not show the Status Code Manager, which maps PBNM status codes to informative strings. Like the other major software components, the Status Code Manager is also a Java interface that can realize many different implementations. Internationalization can be easily achieved by creating different implementations of the Status Code Manager interface.

4. Compliance with System Design

The software design described in this document implements the PDP portion of the PBNM system described in [PBNM] – with the following exceptions:

1. The PDP only includes support for negotiable inter-domain policies. Static policies are not yet supported.

2. The communication between the PDP and the PNP as well as the inter-PNP communication is implemented using JGroups [JGROUPS].

3. Due to limitations with JGroups, the PDP/PNP communication channel and the inter-PNP communication channels are not authenticated or secured. The system is easily extensible however and could easily incorporate different communication frameworks (i.e. Transport Layer Security, Session Initiation Protocol).
4. The Policy Editor does not possess the ability to retrieve a policy document from the PDP. As such, policy documents are stored locally on the system housing the Policy Editor.

5. The PDP does not preserve the digital signature of the policy document creator when it applies the PDP digital signature on a newly submitted policy document. The policy documents stored in the directory only contain the PDP’s single digital signature.

6. The PDP system does not currently perform status checks on certificates used to authenticate communication channels and to sign policy objects.

7. The PDP does not currently retrieve policy negotiation artifacts at start-up.

5. Software Design
This section presents a high-level design for each PDP software component. It provides an overview of each component, it lists the requirements for each component, and it outlines the design for each component in terms of processing, thread synchronization and exceptions.

5.1 Base PBNM Objects
This section provides a description of some of the base PBNM software objects referenced in the remainder of this document.

<table>
<thead>
<tr>
<th>Object</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AlertListener</td>
<td>An AlertListener is an interface that a class implements when it wants to be alerted of asynchronous events from objects executing in a different thread. The alert() method accepts a single object of type Object as an argument.</td>
</tr>
<tr>
<td>Reminder</td>
<td>A Reminder is an object that dispatches an alert at a specific time in the future. The recipient of the alert must be an AlertListener.</td>
</tr>
<tr>
<td>NetworkID</td>
<td>A NetworkID contains the information that is needed to communicate with another network entity. This includes network layer (IPv4 or IPv6) addresses and transport port numbers.</td>
</tr>
<tr>
<td>DigitalID</td>
<td>A DigitalID contains a generic certificate that uniquely identifies an entity – an individual, system or process. The system currently supports digital identifiers based on X.509 certificates.</td>
</tr>
<tr>
<td>PBNMKeyStore</td>
<td>A PBNMKeyStore contains generic digital credentials that include both a private key and a public certificate. The system currently supports digital credentials enclosed within PKCS #12 files.</td>
</tr>
<tr>
<td>SynchronizedQueue</td>
<td>A SynchronizedQueue allows two threads to exchange objects/messages in a synchronized fashion.</td>
</tr>
<tr>
<td>Component</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PolicyInfo</td>
<td>A PolicyInfo object carries a policy document between the Policy Editor and the PPU responsible for its processing. A PolicyInfo object includes a header that identifies the type of policy and the type of policy object contained within its payload.</td>
</tr>
<tr>
<td>PNU</td>
<td>A policy negotiation unit (PNU) carries policy negotiation objects between the PNP and the PPU responsible for its processing. A PNU includes a header that identifies the type of policy and the type of policy object contained within its payload.</td>
</tr>
<tr>
<td>Read/Write Lock</td>
<td>A read/write lock synchronizes access to objects – allowing access by single writer when no readers are active or by many concurrent readers when no writers are active.</td>
</tr>
<tr>
<td>LockableDocument</td>
<td>A LockableDocument adds a read/write lock to the org.w3c.dom.Document class. Callers apply and remove read or write locks on the Document prior to accessing it.</td>
</tr>
<tr>
<td>LockableHashtable</td>
<td>A LockableHashtable adds a read/write lock to the java.util.Hashtable class. Callers apply and remove read or write locks on the Hashtable prior to accessing it.</td>
</tr>
</tbody>
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### 5.2 Policy Repository

The Policy Repository stores and retrieves XML documents from a XML database.

Figure 2 shows the UML (Unified Modelling Language) class diagram for the Policy Repository. The XindiceRepository class implements the PolicyRepository interface, which mandates the implementation of the following public methods:

- `retrieve()` Retrieve a specific document from the database.
- `store()` Store a specific XML document in the database.

The `retrieve()` and `store()` methods execute in the context of the caller’s thread. They perform their intended functions with the use of blocking I/O operations and as such they will cause the caller’s thread to block until the I/O operation completes.
5.2.1 Requirements
The *XindiceRepository* must fulfill the following requirements:

1. Register with the database server.
2. Retrieve a specific document from the database.

5.2.2 Design
The *Main Program* creates a single instance of the *XindiceRepository* class. The lone *XindiceRepository* constructor takes a single argument – the Uniform Resource Identifier (URI) of the Apache Xindice database server. Once the *XindiceRepository* constructor registers with the database server, the *XindiceRepository* is ready to perform retrieve and store operations.

5.2.2.1 Synchronization
The *XindiceRepository* class does not concern itself with thread synchronization.

5.2.2.2 Exceptions
The *XindiceRepository* class throws a *RepositoryException* exception if it encounters difficulties registering with the database server, or if a retrieve or store operation results in an error condition.

5.3 XML Digital Signature Service
The *XML Digital Signature Service* provides a XML based digital signature service to other PDP software components.
Figure 3 shows the UML class diagram for the XML Digital Signature Service. The Jsr105XMLDsigService class implements the XMLDsigService interface, which mandates the implementation of the following public methods:

- sign() Apply a signature to the supplied XML document.
- verify() Verify the outer most digital signature on the supplied XML document and optionally remove the digital signature element from the XML document.

The sign() and verify() methods execute in the context of the caller’s thread. They perform their intended functions without the use of blocking I/O operations and as such they will not cause the caller’s thread to block for an extended period of time.

**Figure 3 - XML Digital Signature Service Interface**

### 5.3.1 Requirements

The Jsr105XMLDsigService must fulfill the following requirements:

1. Accept and manage the digital credentials, including the private key.
2. Verify the outer most digital signature on an XML document and optionally remove the digital signature element from the XML document.
3. Apply a digital signature to a XML document.
In the future, the *XML Digital Signature Service* should also accept new digital credentials at run-time.

### 5.3.2 Design

The *Main Program* creates a single instance of the *Jsr105XMLDsigService* class. The lone *Jsr105XMLDsigService* constructor takes two arguments: a reference to the *Main Program*, and a reference to a *PBNMKeyStore* that holds the digital credentials of the local PDP. The constructor stores the reference to the *PBNMKeyStore* for use by the public *sign()* method.

The *Jsr105XMLDsigService* is ready to provide XML based digital signature services once the constructor completes. Both the *sign()* and *verify()* methods take an XML document as an argument. The *sign()* and *verify* methods manipulate the document object directly – no copies are made. Both the *sign()* and *verify* methods return a *DigitalID*, which contains the digital credentials (certificate) of the entity that signed the XML document.

#### 5.3.2.1 Synchronization

The *Jsr105XMLDsigService* class uses class level synchronization to ensure that only a single instance of the class is active within the system.

The public *sign()* and *verify()* methods are fully synchronized although they do not try to alter instance variables. The absence of method synchronization resulted in signature validation failure during concurrent load testing. Additional research is needed to determine why these methods must be synchronized.

In the future, the *Jsr105XMLDsigService* class may accept new digital credentials at run-time. In case method synchronization is removed in the future, the public *sign()* method copies the reference to the current digital credentials into a local variable to ensure that the private key used to sign the document matches the public certificate inserted into the document.

#### 5.3.2.2 Exceptions

The *Jsr105XMLDsigService* class throws the *XMLDsigException* when an attempt to instantiate more than one instance of the class is attempted.

The *Jsr105XMLDsigService* class throws the *XMLDsigSignException* if it encounters difficulties in applying a digital signature to the XML document.

The *Jsr105XMLDsigService* class throws the *XMLDsigVerifyException* if it encounters difficulties verifying the digital signature on the supplied XML document.

### 5.4 Authorization Service

The *Authorization Service* determines whether or not a specific entity is authorized to perform a specific activity. Examples of the type of actions supported by the Simple Authorization Service include:

- Who can establish an SSL session using the Policy Editor
- Who can sign a Policy document
- Who can sign a Policy Negotiation objects
Figure 4 shows the UML class diagram for the Authorization Service. The SimpleAuthorizationService class implements the AuthService interface, which mandates the implementation of the following public method.

```java
checkAuth() Determine if the originator is authorized to perform a specific action.
```

The checkAuth() method executes in the context of the caller’s thread. It performs its intended function without the use of blocking I/O operations and as such it will not cause the caller’s thread to block for an extended period of time.

The SimpleAuthorizationService consults the contents of a XML Trusted Authorities file to determine the trusted certificate authority for a remote administrative domain. 

5.4.1 Requirements

The SimpleAuthorizationService must fulfill the following requirements:

1. Retrieve the latest XML Trusted Authorities file from the policy repository at start up.

2. Verify the integrity, authenticity and authority of the XML Trusted Authorities file. When retrieved from the policy repository, the XML Trusted Authorities file must contain two nested digital signatures. The signature of the entity that created the file as the inner signature and the signature of the entity that validated the file as the outer signature.

NRNS Incorporated, September 2005
3. Store the information contained in the XML Trusted Authorities file in an internal data structure.

4. Provide an authorization check service based on the administrative domain of the originator, the requested action, and the digital identifier of the originator.

In the future, the SimpleAuthorizationService should accept new versions of the XML Trusted Authorities file via the Policy Submit Provider.

5.4.2 Design

The Main Program creates a single instance of the SimpleAuthorizationService class. The lone SimpleAuthorizationService constructor takes two arguments: a reference to the Main Program, and a reference to a DigitalID, which contains the digital identifier of the local certificate authority. The Main Program provides the needed references to the Policy Repository and the XML Digital Signature Service. The SimpleAuthorizationService constructor retrieves the contents of the XML Trusted Authorities file from the policy repository; verifies the integrity and authenticity of the file; ensures that the file was created and validated by authorized entities; and loads the contents of the file into an internal data structure.

The SimpleAuthorizationService is ready to perform authorization checks once the constructor creates the internal trusted authorities data structure. The public checkAuth() method bases its decision on the expected administrative domain of the originator, the requested action as well as the digital identity of the originator. The expected administrative domain is expressed as an administrative domain name or null if the originator is expected to be from the local administrative domain. The SimpleAuthorizationService performs regular expression matches on the common name portion of the subject name encoded within the digital identifier (certificate).

5.4.2.1 Synchronization

The SimpleAuthorizationService class uses class level synchronization to ensure that only a single instance of the class is active within the system.

The private load() method uses object level synchronization to prevent the concurrent loading of the trusted authorities data structure by more than one thread. This synchronization is not needed at this time since only the constructor currently calls the private load() method. In the future however, the SimpleAuthorizationService class could accept new versions of the XML Trusted Authorities file via the Policy Info Provider. For this reason, the checkAuth() method also synchronizes its access to the trusted authorities data structure.

5.4.2.2 Exceptions

The SimpleAuthorizationService class throws the AuthException if it encounters the following difficulties:

- An attempt to instantiate more than one instance of the class.
- It cannot verify the digital signatures on the XML Trusted Authorities file.
- The XML Trusted Authorities file is not signed by an authorized entity.
- The XML Trusted Authorities file contains a structural, syntax or format error.
- The identified originator is not authorized to perform the requested action.
5.5 XML Address Resolution Service

The XML Address Resolution Service translates between administrative domain names and network layer information.

Figure 5 shows the UML class diagram for the XML Address Resolution Service. The XMLAddressResolver class implements the AddrResolveService interface, which mandates the implementation of the following public methods:

- `lookupAddress()` Translate an administrative domain name to network layer information.
- `reverseLookup()` Translate network layer information to an administrative domain name.

The `lookupAddress()` and `reverseLookup()` methods execute in the context of the caller’s thread. They perform their intended functions without the use of blocking I/O operations and as such they will not cause the caller’s thread to block for an extended period of time.

Figure 5 - XML Address Resolution Service UML Diagram

PBNM policies include references to remote administrative domains, but they do not explicitly identify how to communicate with these remote administrative domains. The XMLAddressResolver maintains an XML encoded Address Resolution Mapping file that describes how the local Policy Negotiation Proxy (PNP) communicates with the remote PNP for
the associated administrative domain. The network layer information includes the Internet Protocol (IP) address of the remote PNP, the transport layer port number of the local PNP, and the transport layer port number of the remote PNP. Error! Reference source not found. of this document contains a sample XML Address Resolution Mapping file.

5.5.1 Requirements

The XMLAddressResolver must fulfill the following requirements:

1. Retrieve the latest XML Address Resolution Mapping file from the policy repository at start up.
2. Verify the integrity, authenticity and authority of the XML Address Resolution Mapping file. When retrieved from the policy repository, the XML Address Resolution Mapping file must contain two nested digital signatures. The signature of the entity that created the file as the inner signature and the signature of the entity that validated the file as the outer signature.
3. Store the mapping information contained in the XML Address Resolution Mapping file in internal data structures.
4. Provide a forward translation service that maps an administrative domain name to network layer information.
5. Provide a reverse translation service that maps network layer information to an administrative domain name.

In the future, the XMLAddressResolver should accept new versions of the XML Address Resolution Mapping file via the Policy Submit Provider.

5.5.2 Design

The Main Program creates a single instance of the XMLAddressResolver class. The lone XMLAddressResolver constructor takes a reference to the Main Program as its argument. The Main Program provides the needed references to the Policy Repository, XML Digital Signature Service and the Authorization Service. The XMLAddressResolver constructor retrieves the contents of the XML Address Resolution Mapping file from the policy repository; verifies the integrity and authenticity of the file; ensures that the file was created and validated by authorized entities; and loads the contents of the file into a pair of internal data structures: one for forward lookups and one for reverse lookups.

The XMLAddressResolver is ready to perform address resolution operations once the constructor creates the necessary internal data structures. The public lookupAddress() method takes an administrative domain name as an argument and returns the associated network address information. The public reverseLookup() method takes network address information as an argument and returns the associated administrative domain name. Both methods return null if the lookup fails.

5.5.2.1 Synchronization

The XMLAddressResolver class uses class level synchronization to ensure that only a single instance of the class is active within the system.
The private load() method uses object level synchronization to prevent the concurrent loading of internal data structures by more than one thread. This synchronization is not needed at this time since only the constructor currently calls the private load() method. In the future however, the XMLAddressResolver class could accept new versions of the XML Address Resolution Mapping file via the Policy Info Provider.

Both the lookupAddress() and reverseLookup() methods are fully synchronized to prevent concurrent access to the internal data structures by more than one thread.

5.5.2.2 Exceptions
The XMLAddressResolver class throws the ResolverException if it encounters the following difficulties:

- An attempt to instantiate more than one instance of the class.
- It cannot verify the digital signatures on the XML Address Resolution Mapping file.
- The XML Address Resolution Mapping file is not signed by an authorized entity.
- The XML Address Resolution Mapping file contained a structural, syntax or format error.

5.6 Policy Info Provider
Authorized individuals within the local administrative domains may create or alter policies using the Policy Editor. Once compiled, the Policy Editor applies the security officer’s digital signature to the policy document and submits the policy document to the PDP via a Secure Socket Layer (SSL) secured channel. The Policy Info Provider accepts new policy documents from the Policy Editor and routes them to registered Policy Info Manager objects.

Figure 6 shows the UML class diagram for the Policy Info Provider. The PolicySubmitProvider class implements the PolicyInfoProvider interface, which mandates the implementation of the following public methods:

- register() Register a Policy Information Manager with a specific type of policy document.
- unregister() Unregister a previously registered Policy Information Manager.

The register() and unregister() methods execute in the context of the caller’s thread. They perform their intended functions without the use of blocking I/O operations and as such they will not cause the caller’s thread to block for an extended period of time.
5.6.1 Requirements
The PolicySubmitProvider must meet the following requirements:

1. Accept registration requests from Policy Info Manager objects for specific policy documents.
2. Listen for SSL sessions from the Policy Editor.
3. Accept SSL sessions from the Policy Editor and service many concurrent instances of the Policy Editor.
4. Interact with interested Policy Info Manager objects on behalf of the Policy Editor.

5.6.2 Design
The Main Program creates a single instance of the PolicySubmitProvider class. The PolicySubmitProvider class runs in its own thread and therefore it implements the java.lang.Runnable interface.

The lone PolicySubmitProvider constructor takes three arguments: a reference to the Main Program, a reference to the PBNMKeyStore containing the digital credentials for the local Policy...
Info Provider, and the transport port number to listen on for incoming SSL sessions. The PolicySubmitProvider retrieves a reference to the Authorization Service from the Main Program.

The PolicySubmitProvider accepts registration requests for specific types of policy documents and stores this registration information in an internal data structure. The registration information identifies the Policy Info Manager interested in receiving the specific type of policy document. Currently, only PPU objects register as Policy Info Managers with the PolicySubmitProvider.

The PolicySubmitProvider executes in its own thread where it waits for incoming SSL sessions. The PolicySubmitProvider creates a new instance of an inner class called the PolicySubmitHandler to service each individual SSL session. As well, the PolicySubmitProvider creates a new instance of an inner class called the HandshakeListener for each individual SSL session. Each PolicySubmitHandler executes in its own thread since many instances of the PolicySubmitHandler can execute concurrently. The HandshakeListener waits for the SSL handshake to complete before attempting to obtain the certificate used by the Policy Editor to authenticate the SSL session. When the certificate is available, the HandshakeListener starts the PolicySubmitHandler thread.

5.6.2.1 Handshake Listener

The HandshakeListener class implements the javax.net.ssl.HandshakeCompletedListener interface. This interface requires that the Policy Submit Provider implement the following public method:

   handshakeCompleted() An indication that the SSL handshake completed.

The PolicySubmitProvider provides a reference to the PolicySubmitHandler object and the associated thread by invoking the setHandler() and setThread() methods on the HandshakeListener object. When the SSL handshake completes, the HandshakeListener obtains the certificate used by the Policy Editor to authenticate the SSL session. Once the HandshakeListener obtains all three pieces of information, it provides the certificate to the PolicySubmitHandler by invoking the PolicySubmitHandler setPeerCert() method and calls the start() method of the supplied thread to start the corresponding PolicySubmitHandler thread.

5.6.2.2 Policy Submit Handler

The PolicySubmitHandler runs in its own thread and therefore it implements the java.lang.Runnable interface.

The PolicySubmitHandler requests an authorization check from the AuthorizationService to verify that the SSL session was initiated by an authorized individual. The PolicySubmitHandler retrieves the reference for the registered Policy Info Manager from its internal data structure and relays PolicyInfo objects between the Policy Editor and the Policy Info Manager. The PolicySubmitHandler does not interpret the payload contained within the PolicyInfo objects however. The PolicySubmitHandler continues to relay PolicyInfo objects until a response from the Policy Info Manager indicates an erroneous condition or until the Policy Editor closes the SSL session.

5.6.2.3 Synchronization

The PolicySubmitProvider uses class level synchronization to ensure that only a single instance of the class is active within the system.

---

3 The Policy Editor makes use of the certificate owned by the authorized individual.
The HandshakeListener synchronizes the start of the PolicySubmitHandler thread with the availability of the certificate used to authenticate the SSL session from the Policy Editor. The HandshakeListener object also uses object level synchronization to ensure that it only attempts to start the PolicySubmitHandler thread once.

The register(), unregister() and lookup() methods are fully synchronized to prevent concurrent access to the list of registered Policy Info Managers by more than one thread.

### 5.6.2.4 Exceptions

The PolicySubmitProvider class throws the SubmitException if it encounters the following difficulties:

- An attempt to instantiate more than one instance of the class.
- A failure to initialize the SSL server context.
- An attempt by a Policy Info Manager to register for a type of policy document already claimed by another Policy Info Manager object.

### 5.6.3 Future Considerations

Currently the Policy Editor only supports Inter-Domain Security Policies. In the future, the Policy Editor should also support different types of policies as well as the editing of the XML Address Resolution Mapping file used by the XML Address Resolution Service and the XML Trusted Authorities file used by the Simple Authorization Service. The generic design of the PolicySubmitProvider will support these different types of policy documents without any modifications.

Currently the Policy Editor stores policy documents on its local disk and submits new or modified policy documents to the PDP. In the future, policy documents should only reside in the Policy Repository and the Policy Editor should acquire the latest version of a policy document from the PDP prior to editing. The generic design of the PolicySubmitProvider will support the retrieval of the policy document without any modifications.

### 5.7 Comm Handler

The Comm Handler manages the communication between the PDP and the PNP.

Figure 7 shows the UML class diagram for the Comm Handler. The PNPHandler class implements the CommHandler interface, which mandates the implementation of the following public methods:

- **submit()** Submit a PNU to the CommHandler from the PPU.
- **isConnected()** Determine if the PDP is connected to the PNP.
- **close()** Close the communication channel to the PNP.

These methods execute in the context of the caller’s thread – the PPU. They perform their intended function without the use of blocking I/O operations and as such it will not cause the caller’s thread to block for an extended period of time.
The `PNPHandler` class also implements the `AlertListener` interface, which mandates the implementation of the following public method:

```java
alert()
```
Submit a PNU to the `CommHandler` from the PNP.

The `alert()` method executes in the context of the caller’s thread. It performs its intended function without the use of blocking I/O operations and as such it will not cause the caller’s thread to block for an extended period of time. However, the `alert()` method does call the `alert()` method of the associated `PPU`, which must also not cause the caller’s thread to block on I/O operations.

The `PNPHandler` instantiates a distinct `CommWorker` object to establish and maintain the communication channel with the PNP. The `CommWorker` interface requires that the implementing class provide the following public methods:

```java
isConnected()
```
Determine if the PDP is connected to the PNP.

```java
submit()
```
Submit a PNU to the `CommWorker` from the PPU.

```java
close()
```
Close the communication channel to the PNP.

These methods execute in the context of the caller’s thread. They perform their intended functions without the use of blocking I/O operations and as such they will not cause the caller’s thread to block for an extended period of time.

The PDP currently includes a single implementation of the `CommWorker` based on the JGroups communication framework [JGROUPS]. In the future, different `CommWorker` implementations (i.e. Transport Layer Security, Session Initiation Protocol) can be added to the system.
5.7.1 Requirements
The PNPHandler must fulfill the following requirements:

1. Process requests from Policy Processing Units (PPU) to engage in communication with a remote administrative domain.
2. Multiplex PNU's for numerous remote administrative domains within a single PDP/PNP communication channel.
3. Process requests from PPU's to disengage from a remote administrative domain.
4. Forward PNU's received from the PPU to the PNP.
5. Forward PNU's received from the PNP to the appropriate PPU.

5.7.2 Design
The Main Program creates a single instance of the PNPHandler class. The lone PNPHandler constructor requires the network identity of the PNP and a boolean flag as its arguments. The boolean flag instructs the PNPHandler to actively connect to the PNP. The PNPHandler creates a single instance of a CommWorker, which in the current system is a JGroupsWorker. The CommWorker interface extends the java.langRunnable interface, which causes an implementing class to run in its own thread.

The PNPHandler processes control PNU's from PPU objects to engage and disengage from a remote administrative domain. The control PNU specifies the type of policy to be negotiated, identifies the PPU associated with the policy, provides the network information required by the PNP to communicate with the remote administrative domain, and assigns a connection identifier for use as a reference within subsequent data PNU's. The PNPHandler uses this information to create an internal routing table. The PNPHandler forwards slightly modified versions of control PNU's to the PNP through the CommWorker. The PNPHandler relays data PNU's between the PNP and the responsible PPU using its internal routing table.

The JGroupsWorker establishes and maintains the communication channel between the PDP and the PNP. The JGroupsWorker simply relays PNU's between the PNPHandler and the PNP. It accepts outgoing PNU's from the PNPHandler and delivers them to the PNP, and it accepts incoming PNU's from the PNP and delivers them to the PNPHandler.

5.7.2.1 Synchronization
The JGroupsWorker class synchronizes access to a shared queue where outgoing PNU's are deposited by the PNPHandler thread and retrieved by the JGroupsWorker thread.

5.7.2.2 Exceptions
The PNPHandler class throws the CommsException when a PPU submits an unknown type of object – not a valid PNU.
5.8 Policy Server

The Policy Server collects low level policies from Policy Processing Units (PPUs) and disseminates the low level policies to Policy Enforcement Point (PEP) devices through Policy Agents. The PBNM system currently supports a single Policy Agent based on COPS-PR implementation from the University of Murcia called UMU-JCOPS.

Figure 7 shows the UML class diagram for the Policy Server as implemented by the PolicyServer class. The PolicyServer class makes use of the Singleton pattern to ensure that only a single instance of the class executes within the PBNM system. The PolicyServer class provides public methods for initialization, to register device roles, as well as to submit policy updates.

![Policy Server UML Diagram](image)

**Figure 8 – Policy Server UML Diagram**

5.8.1 Requirements

The PolicyServer must fulfill the following requirements:
1. Create the PolicyAgent objects as required – i.e. UMU-JCOPS Agent.

2. Accept requests from PPUs to register device roles.

3. Accept policy updates from PPUs.

4. Disseminate policy updates to PolicyAgents.

5.8.2 Design

The PolicyServer class creates PolicyAgent objects for each supported policy dissemination method. The PolicyServer accepts requests from PPU objects within the PBNM system to register devices roles that the PolicyServer must support. The PolicyServer also receives policy updates from PPU objects as a list of old policies and new policies.

The PolicyServer relies on a protected class called the PolicyDecisionManager to determine the differences between the old policies and new policies and to formulate a list of policy decisions. The PolicyDecisionManager keeps track of the roles supported by the PolicyServer and accepts requests from PolicyAgent objects to register PEP clients for specific roles. The PolicyDecisionManager manages full policies for a specific role and maintains policy decisions for individual PEP clients based on their identified roles. Once a PEP client acquires a complete policy document, the PolicyDecisionManager simply provides deltas in the form of add and remove decisions.

The PolicyServer relies on PolicyAgent objects to disseminate policy decisions to network PEP devices. Currently network devices must acquire their device level policies through the COPS-PR protocol. The UMUCopsPolicyAgent class implements the PolicyAgent interface, which mandates the implementation of the following public methods:

```
addRole()                  Add a new device role. This informs the PolicyAgent that PEP devices will request policies for that specific role.
```

The UMUCopsPolicyAgent interacts with the UMU-JCOPS implementation through a single class called the COPSPdpAgent. The UMU-JCOPS also requires the extension of an abstract class called the COPSPdpDataProcess, which defines the call-back methods that its sub-class must implement in order to interact properly with the UMU-JCOPS protocol stack. The PolicyDataProcess class extends the COPSPdpDataProcess class to provide the needed functionality.

The COPSPdpAgent object listens for connections from COPS clients, processes COPS Client-Open messages to confirm support for the COPS Client-Type, and creates the necessary COPS objects needed to service the COPS client. Further interactions between the UMU-JCOPS protocol stack and the PolicyServer are facilitated through call-back method calls on the PolicyDataProcess object. The PolicyDataProcess object possesses a reference to the PolicyDecisionManager object and obtains complete policy documents as well as policy decisions directly from the PolicyDecisionManager object.

5.8.2.1 Low-Level Policy Objects

The PBNM system provides an interface called PolicyManager to manage low-level policies. The abstract class DOMPolicyManager implements the PolicyManager interface and provides a DOM specific PolicyManager. The system also provides concrete PolicyManager classes for
different types of low-level policies such as IPSec, Firewall, Routing and DNS. The DOMPolicyManager provides static methods for creating policy elements such as IP Addresses, Selectors and Time Periods.

The `PolicyDecisionManager` creates concrete `PolicyManager` objects as required to manage policies for specific roles. The `PolicyManager` accepts policy updates, determines the difference between the old policies and the new policies and produces deltas in the form of a list of policy (add/remove) decisions.

Figure 9 shows the UML class diagram for the `PolicyManager` interface, DOMPolicyManager abstract class as well as for the `FWPolicyManager` concrete class. Figure 9 also illustrates the `PolicyDecisions` class that the `PolicyManager` class uses to return its policy decisions.

![Figure 9 - Policy Manager UML Diagram](image)

### 5.8.2.2 Low-Level Policy Elements

The PBNM system provides a series of classes to create and maintain low-level policy elements such as rules, IP Addresses, Selectors and Time Periods. Each policy element class must
implement a method called `toDOM()` to convert the object to a DOM object and a method called `getXpathConditions()` to produce a list of XPATH query strings which uniquely identify the object. Policy elements based on rules must also implement a method called `compare()` to compare itself against another rule and a method called `getXpathQuery()` to produce an XPATH query string which uniquely identifies the object.

Figure 10 shows the UML class diagram for the low-level policy element classes.

Figure 10 - Policy Element UML Diagram

### 5.8.2.3 The COPSPdpDataProcess Abstract Class

The `PolicyServer` implements a `COPSPdpDataProcess` sub-class to manage and maintain low-level policies. The `COPSPdpDataProcess` abstract class mandates the implementation of the following methods:

- `addRole()` Add a new device role. PEP devices will request policies for this specific role.
- `getDecisions()` Retrieve outstanding policy decisions (remove, install).
- `setClientData()` Set the COPS client data contained in the Client Specific Information (Client-SI). This identifies the device role and indicates whether the COPS client is requesting a complete state update. UMU-JCOPS implements a subset of RFC-3318
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>failReport()</td>
<td>Process a COPS Failure report.</td>
</tr>
<tr>
<td>successReport()</td>
<td>Process a COPS Success report.</td>
</tr>
<tr>
<td>acctReport()</td>
<td>Process a COPS Accounting report.</td>
</tr>
<tr>
<td>notifyNoAcctReport()</td>
<td>An expected accounting report was not received when expected.</td>
</tr>
<tr>
<td>notifyNoKAliveReceived()</td>
<td>An expected Keepalive message was not received.</td>
</tr>
<tr>
<td>notifyClosedConnection()</td>
<td>The COPS client closed the connection.</td>
</tr>
<tr>
<td>notifyDeleteRequestState()</td>
<td>The COPS client deleted its request state.</td>
</tr>
</tbody>
</table>

### 5.8.2.4 The PolicyDataProcess Class

The `PolicyDataProcess` class maintains mappings between COPS clients and their declared roles and only supplies decisions associated with these declared roles. `PolicyDataProcess` relies exclusively on the `PolicyDecisionManager` to manage policy decisions. It registers COPS clients with the `PolicyDecisionManager` when COPS clients connect and identify their roles.

### 5.8.2.5 Synchronization

The `PolicyDataProcess` object executes in various threads that include PPUs threads as well as threads created by UMU-JCOPS objects. The `PolicyDataProcess` object makes use of object based synchronization to prevent concurrent access to its internal data structures.

### 5.8.2.6 Exceptions

The `PolicyServer` class throws the `PolicyServerException` if it exhibits difficulties in instantiating `PolicyAgent` objects or submitting policy decisions to `PolicyAgent` objects.

### 5.9 Policy Processing Unit

The Policy Processing Unit (PPU) forms the core of the PDP and is the only component that possesses knowledge of policy structure, syntax and encoding. The PDP requires the implementation of a distinct `PPU` class for each type of policy supported by the system.

Figure 11 illustrates how a distinct `PPU` that implements negotiable inter-domain security policies is implemented by extending a pair of abstract Java classes.
Figure 11 - Creating a Distinct PPU

The BasePPU abstract class provides the generic capabilities required by all PPU implementations and as such it must be included as a super class by all PPU implementations. The BasePPU abstract class accepts new policies from the Policy Editor via the Policy Info Provider. The BasePPU abstract class does not perform any policy specific processing. As such, the BasePPU abstract class requires that one of its sub classes implement the following methods:

getPolicyType() Return the type of policy that this PPU processes.
getPolicyTypeName() Return the name of the type of policy that this PPU processes.
validate() Validate a policy document.
getPolicyID() Return the unique identifier from a policy document.
process() Process an asynchronous event.
The NegotiablePPU abstract class extends the BasePPU. Since it negotiates policies with foreign administrative domains, it must be included as a super class by all PPU implementations that require inter-domain policy negotiation. The NegotiablePPU class implements the policy negotiation protocol described in the PBNM System Design Document [PBNM]. The NegotiablePPU abstract class does not perform any policy specific processing. As such, the NegotiablePPU abstract class requires that one of its sub classes implement the following methods:

- policyCompare() Compare the existing policy with the newly received policy.
- buildPolicyProposal() Build a Policy Proposal object.
- buildPolicyWithdraw() Build a Policy Withdraw object.
- buildNegotiationTranscript() Build a Negotiation Transcript object.
- validatePolicyProposal() Validate a Policy Proposal object.
- validateNegotiationTranscript() Validate a Negotiation Transcript object.
- validatePolicyWithdraw() Validate a Policy Withdraw object.
- getValidityPeriod() Return the validity period for a policy object.
- setValidityPeriod() Set the validity period in a policy object.
- negotiationAccepted() Look inside the Negotiation Transcript objects to determine if the negotiation was successful.
- policyMerge() Create a Merged Policy object from two Negotiation Transcript objects.

The IDSecurityPolicyPPU class extends the NegotiablePPU to implement a complete PPU that negotiates inter-domain security policies with foreign administrative domains. The IDSecurityPolicyPPU class simply provides the policy specific methods mandated by its super classes (BasePPU and NegotiablePPU) and as such is the only class within the PDP that possesses any knowledge of the structure, format and encoding of inter-domain security policies.

The PDP can be easily extended to process a different type of negotiated policy by implementing a distinct PPU class that extends the NegotiablePPU class. To support a static (non-negotiated) policy, the PDP must implement a StaticPPU abstract class that extends the BasePPU class in addition to a distinct PPU class that extends the StaticPPU abstract class.

### 5.9.1 PPU Design Overview

Figure 12 shows the UML class diagram for a complete Negotiable PPU implemented by the IDSecurityPolicyPPU class. The BasePPU class acquires references to several infrastructure
services from the *Main Program*. Similarly, the *NegotiablePPU* class acquires references to the *Comm Handler* and the *XML Address Resolution Service* from the *Main Program*. The *BasePPU* class includes an inner class called the *PolicyConsumer*, and the *NegotiablePPU* includes an inner class called the *Negotiator*. Both the *BasePPU* class and the *Negotiator* class implement the java.lang.Runnable interface, which provides a different thread of execution for each object, and the AlertListener interface, which facilitates the delivery of asynchronous events from objects executing in a different thread. The AlertListener interface provides the inter-thread communication mechanism between the Negotiable PPU executing in the BasePPU thread and each Negotiator executing in its respective thread.

The *PolicyConsumer* implements the PolicyInfoConsumer interface in order to receive policy documents from the Policy Editor via the Policy Info Provider. The PolicyConsumer makes use of a PolicyInfoSessionManager to manage the session between the PPU and the Policy Info Provider.

The **PolicyInfoConsumer** implements the **PolicyInfoSessionManager** interface in order to receive policy documents from the Policy Editor via the Policy Info Provider. The PolicyInfoConsumer makes use of a PolicyInfoSessionManager to manage the session between the PPU and the Policy Info Provider.

---

**Figure 12 - Negotiable PPU UML Diagram**

### 5.9.2 The Base PPU

The *BasePPU* provides the generic capabilities required by all PPU implementations.
5.9.2.1 Requirements

The BasePPU must meet the following requirements:

1. Accept and validate new policy documents from the Policy Editor via the Policy Info Provider.

2. Dispatch asynchronous events to subclasses for processing.

In the future, the BasePPU should also accept commands from the Policy Console via the Main Program.

5.9.2.2 Design

The BasePPU class implements the AlertListener interface, which mandates the implementation of the following public method:

```
alert() Process the alert associated with the supplied object.
```

The alert() method executes in the context of the caller’s thread – a Negotiator, a Reminder or the PolicyConsumer. It performs its intended function without the use of blocking I/O operations and as such it will not cause the caller’s thread to block for an extended period of time.

Since the BasePPU class is abstract, it is only instantiated when the Main Program creates a distinct and concrete PPU object. The BasePPU class implements the java.lang.Runnable interface and therefore the resulting distinct PPU object runs in its own thread.

The BasePPU maintains the current and new policy document within LockableDocument objects.

The lone BasePPU constructor takes a single argument: a reference to the Main Program. The BasePPU retrieves a reference to the Policy Repository, the XML Digital Signature Service, the Authorization Service, and the Policy Info Provider from the Main Program. The BasePPU determines the type of policy that the distinct PPU object implements. Finally, the BasePPU object creates an inner class called the PolicyConsumer to process policy documents submitted by the Policy Editor.

The BasePPU provides the BasePPU execution thread for the distinct PPU object. Within its run() method, the BasePPU continually retrieves objects from a SynchronizedQueue and calls upon the abstract process() method to process the asynchronous event contained within the object. The BasePPU does not interpret the asynchronous events contained within these objects.

Policy Consumer

The PolicyConsumer processes policy documents submitted by the Policy Editor via the Policy Info Provider. The PolicyConsumer makes use of a PolicyInfoSessionManager to manage the session with the Policy Info Provider. The PolicyInfoSessionManager registers with the PolicyInfoProvider to receive the appropriate type of policy documents from the Policy Editor.

The PolicyConsumer class implements the PolicyInfoConsumer interface, which mandates the implementation of the following public methods:

```
retrieve() Retrieve and supply the latest policy document from the Policy Repository. This method is not currently implemented.
```
The retrieve() and submit() methods execute in the context of the caller’s thread – the 
PolicyInfoSessionManager on behalf of the Policy Info Provider. They perform their intended 
functions with the aid of the Policy Repository and as such they will cause the caller’s thread to 
block until the I/O operation completes.

When the PolicyConsumer receives a policy document, it verifies the digital signature on the 
document, it ensures that the policy document was signed by an authorized individual and it 
validates the policy document against the appropriate policy specification. If the policy 
document is authentic, authorized and valid, the PolicyConsumer applies the PDP’s digital 
signature to the policy document and stores two copies in the Policy Repository – one copy based 
on its unique identifier and one copy as the latest policy document. The PolicyConsumer stores a 
reference to the new policy document in a LockableDocument and notifies the BasePPU via the 
BasePPU alert() method.

Synchronization
Access to the BasePPU SynchronizedQueue is automatically synchronized.

The PolicyConsumer applies a write lock to the LockableDocument that stores the new policy 
document within the BasePPU. The write lock ensures that the previously submitted policy 
document was fully processed before the new policy document is submitted to the BasePPU.

Exceptions
The BasePPU class throws the PolicyProcessingException if it encounters the following 
difficulties:

- The registration with the Policy Info Provider fails.

5.9.3 The Negotiable PPU
The Negotiable PPU class implements the policy negotiation protocol described in the PBNM 
System Design Document [PBNM].

5.9.3.1 Requirements
The NegotiablePPU class must meet the following requirements:

1. Process new policy notifications from the PolicyConsumer.
2. Negotiate policies with remote administrative domains.
3. Submit merged policy information to the Policy Server as required.
4. Retract merged policy information from the Policy Server as required.
5. Process shutdown notifications from the Main Program.

---

4 The PolicyConsumer calls an abstract method implemented by the distinct PPU class to perform the validation.
5.9.3.2 Design

The NegotiablePPU class extends the BasePPU class and runs in the context of the BasePPU thread. The NegotiablePPU includes an inner class called the Negotiator that performs the policy negotiation. Each Negotiator executes within its own thread and interacts with a single remote administrative domain. The NegotiablePPU, in the context of the BasePPU thread, communicates with its numerous Negotiator objects within their respective threads using the AlertListener interface. This inter-thread communication is facilitated with a SynchronizedQueue – one SynchronizedQueue for each PPU thread.

The NegotiablePPU maintains several shared lists within LockableHashtable objects. They include:

- The priority associated with each remote administrative domain.
- The current negotiation state for each remote administrative domain.
- The last Policy Proposal sent to each remote administrative domain.
- The last Policy Proposal received by each remote administrative domain.
- The Negotiation Transcript sent to each remote administrative domain.
- The Negotiation Transcript received by each remote administrative domain.
- The Merged Policy created for each remote administrative domain.

When the NegotiablePPU receives a new policy document, it invokes the abstract policyCompare() to compare the new policy against the existing policy. This comparison yields a list of deleted administrative domains, a list of modified administrative domains, and a list of new administrative domains. For a deleted administrative domain, the NegotiablePPU sends a policy withdraw notification to the associated Negotiator and informs all lower priority administrative domains to recheck their policy. For modified administrative domain, the NegotiablePPU sends a recheck policy notification to the associated Negotiator. For a new administrative domain, the NegotiablePPU creates a new Negotiator, starts the corresponding Negotiator thread, and sends a recheck policy notification to the newly created Negotiator.

When the NegotiablePPU receives a notification from a Negotiator that a negotiation sequence completed successfully, the NegotiablePPU provides the merged policy information for the associated administrative domain to the Policy Server. The NegotiablePPU also sends a recheck policy notification to all Negotiators associated with a lower priority administrative domain.

When the NegotiablePPU receives a notification from a Negotiator that a negotiation sequence was restarted, the NegotiablePPU sets a time limit on the duration of a negotiation sequence. When the associated Reminder expires, the NegotiablePPU retracts the merged policy information, if any, for the associated administrative domain from the Policy Server.

When the NegotiablePPU receives a notification from a Negotiator class that a foreign administrative domain withdrew its previously negotiated policy, the NegotiablePPU retracts the merged policy information for the associated administrative domain from the Policy Server. The NegotiablePPU also sends a recheck policy notification to all the Negotiators associated with a lower priority administrative domain.

The Negotiator

The Negotiator class implements the policy negotiation protocol described by the policy negotiation state transition diagram that appears in the PBNM System Design Document [PBNM]. A detailed state transition table for the policy negotiation protocol appears in Error! Reference source not found. of this document.
Each instance of the **Negotiator** class runs in its own thread and undertakes a negotiation sequence with a distinct remote administrative domain. The **Negotiator**, executing within its own thread, and the **NegotiablePPU**, executing in the context of the **BasePPU** thread, communicate using the **AlertListener** interface. This inter-thread communication is facilitated with a **SynchronizedQueue** – one **SynchronizedQueue** for each PPU thread.

The **Negotiator** accepts all internal requests and external policy negotiation objects from its **SynchronizedQueue**. Internal requests include requests to recheck a policy, requests to withdraw a policy as well as **Reminder** notifications. External policy objects are the policy objects generated by a remote administrative domain and received as part of the policy negotiation sequence. The private **refineEvent()** method takes an object from the **SynchronizedQueue** and refines it to produce one of the events identified in the top row of the state transition table. The private **processEvent()** method takes a refined event and the associated object and dispatches it to the processing method associated with the refined event.

The **Negotiator** sends notifications to the **NegotiablePPU** to announce the following events:

- A negotiation sequence completed successfully
- A negotiation sequence restarted. This is usually caused by the reception of a Policy Proposal object from the remote administrative domain.
- A negotiation sequence completed in failure.
- The remote administrative domain withdrew its policy.

**Synchronization**

The **NegotiablePPU** and **Negotiator** classes synchronize access to shared lists by setting read and write locks as required on the associated **LockableHashtable** objects. The **NegotiablePPU** and **Negotiator** classes apply these read/write locks as required prior to invoking the abstract methods within the distinct **PPU** implementation. The distinct **PPU** implementation is not aware that these objects are lockable.

Access to the various **SynchronizedQueue** objects are automatically synchronized.

**Exceptions**

The **NegotiablePPU** class throws the **PolicyProcessingException** if the registration with the **Policy Info Provider** fails.

The **Negotiator** class throws the **ResolverException** if it cannot acquire the network address information for a specific remote administration domain.

The **Negotiator** class throws the **UnknownHostException** if the network address supplied for the administrative domain is incorrect.

### 5.9.4 The Inter-Domain Security Policy PPU

The **Inter-Domain Security Policy PPU** implements the policy specification described in [IDSP].

#### 5.9.4.1 Requirements

The **Inter-Domain Security Policy PPU** must meet the following requirements:

1. Validate inter-domain security policy documents.
2. Compare two inter-domain security policy documents and report on the differences
3. Produce inter-domain security policy negotiation objects.
4. Validate inter-domain security policy negotiation objects.
5. Produce merged inter-domain security policy objects.

5.9.4.2 Design
The IDSecurityPolicyPPU class extends the NegotiablePPU class. The resulting PPU object runs in the context of either the BasePPU thread or a Negotiator thread.

The IDSecurityPolicyPPU class simply implements the abstract methods defined by its super classes. The super PPU classes call upon the IDSecurityPolicyPPU to perform specific operations at specific times. The IDSecurityPolicyPPU does not control the execution flow of the PPU object.

The IDSecurityPolicyPPU methods mandated by its super classes perform the policy specific processing. They validate new policy documents, compare policy documents, generate policy negotiation objects and validate policy negotiation objects. All policy documents and policy negotiation objects are encoded with XML and as such these methods typically return an org.w3c.dom.Document object as an output or accept an org.w3c.dom.Document object as an input.

Synchronization
The IDSecurityPolicyPPU class is not aware of the multi-threaded environment and does not concern itself synchronization. Its super classes are responsible for applying the locks on shared objects as and when required.

Exceptions
The IDSecurityPolicyPPU class throws the PolicyProcessingException if encounters any difficulties in performing its policy specific processing.

5.10 Status Code Manager
The Status Code Manager maps PBNM status codes to informative strings.

Figure 13 shows the UML class diagram for the Status Code Manager. The EnglishStatusCodeManager class implements the StatusCodeManager interface, which mandates the implementation of the following public methods:

```
load()  Load the status code translation information.
getStatusString()  Translate a PBNM status code to an informative string.
```

The load() and getStatusString() methods execute in the context of the caller’s thread. These methods, as implemented by the EnglishStatusCodeManager class, perform their intended functions without the use of blocking I/O operations and as such they will not cause the caller’s thread to block for an extended period of time. However, future implementations of the StatusCodeManager interface may choose to load the translation information from files,
directories or databases, which may cause the caller’s thread to block waiting for the completion of an I/O operation.

Figure 13 - Status Code Manager UML Diagram

5.10.1 Requirements
The *EnglishStatusCodeManager* must fulfill the following requirements:

1. Loads English language status strings into an internal mapping table indexed by the status code.

2. Maps PBNM status codes to informative strings.

5.10.2 Design
The *Main Program* creates a single instance of the *EnglishStatusCodeManager* class. The public load() method, during its first invocation, loads the English language status strings into a mapping table using the status code as the key and the status string as the value. The public getStatusString() method simply retrieves the status string from the mapping table based on the supplied status code.

5.10.2.1 Synchronization
The public load() and getStatusString() methods are fully synchronized to prevent the concurrent access by the getStatusString() method when the load() method populates the translation table.

5.10.2.2 Exceptions
The *EnglishStatusCodeManager* class does not throw any exceptions.
5.11 Main Program

The Main Program creates all the PDP software components and provides references to those objects as requested.

Figure 14 shows the UML class diagram for the Main Program. The Main class implements the MainProgram interface, which mandates the implementation of the following public methods:

- getStatusCodeManager() Provide a reference to the Status Code Manager.
- getAuthService() Provide a reference to the Authorization Service.
- getPolicyProvider() Provide a reference to the Policy Info Provider.
- getXMLDsigService() Provide a reference to the XML Digital Signature Service.
- getResolver() Provide a reference to the Address Resolution Service.
- getPNPHandler() Provide a reference to the PNP Handler.
- getPNPAddress() Provide the network address for the PNP Handler.

These methods execute in the context of the caller’s thread. These methods perform their intended functions without the use of blocking I/O operations and as such they will not cause the caller’s thread to block for an extended period of time.
### 5.11.1 Requirements

The Main must fulfill the following requirements:

1. Acquire configuration information from the PDP configuration file.
2. Collect passwords for necessary digital credentials from the Policy Console.
3. Create the necessary PDP software components.
4. Provides references to PDP software component objects as requested.

In the future, the Main should use reflection to create the PBNM software components. The class names of these components would instead be specified in the PDP configuration file.

In the future, the Main should provide a simple command line interface via the Policy Console.

### 5.11.2 Design

The Main opens the PDP configuration file and retrieves the following configuration items:

- The name of the file containing the digital credentials to be used for PDP digital signatures operations.
- An optional alias associated with the PDP digital credentials.
- The IP address of the XML database server.
The transport layer port number used by the XML database server.

The name of the file containing the digital credentials to be used by the Policy Info Provider.

An optional alias associated with the Policy Info Provider digital credentials.

The transport layer port number used by the Policy Info Provider.

The IP address used by the PDP system when communicating with the PNP system.

The transport layer port number used by the PDP system when communicating with the PNP system.

The IP address used by the PNP system when communicating with the PDP system.

The transport layer port number used by the PNP system when communicating with the PDP system.

The Main prompts the operator to enter the passwords to unlock the PDP and Policy Info Provider digital credentials. The Main collects the passwords and creates the PDP software component objects.

The Main provides references to PDP software component objects when requested by other PDP software components.

5.11.2.1 Synchronization

The Main class does not concern itself with synchronization issues.

5.11.2.2 Exceptions

The Main class does not throw any exceptions. However, the Main terminates the PDP process (the Java Virtual Machine) if it encounters an error when creating the PDP software components.
References


[IDPE] “Inter-Domain Policy Editor - System Implementation”, Version DRAFT 0.1, NRNS Incorporated, January 2005


Annex A Sample Trusted Authorities File

The Trusted Authorities file identifies trusted remote certification authorities (CA) by the distinguished name of the CA and the key identifier of the CA’s key.

```xml
<TrustedAuthorities>
  <AD name="AD1">
    <IssuerDN>CN=Root CA,OU=PBNM,O=AD1,C=CA</IssuerDN>
    <IssuerKeyID>-2033668182</IssuerKeyID>
  </AD>
  <AD name="AD2">
    <IssuerDN>CN=Root CA,OU=PBNM,O=AD2,C=CA</IssuerDN>
    <IssuerKeyID>7870182438</IssuerKeyID>
  </AD>
  <AD name="AD3">
    <IssuerDN>CN=Root CA,OU=PBNM,O=AD3,C=CA</IssuerDN>
    <IssuerKeyID>2549814277</IssuerKeyID>
  </AD>
  <AD name="AD4">
    <IssuerDN>CN=Root CA,OU=PBNM,O=AD4,C=CA</IssuerDN>
    <IssuerKeyID>4537265685</IssuerKeyID>
  </AD>
  <AD name="AD5">
    <IssuerDN>CN=Root CA,OU=PBNM,O=AD5,C=CA</IssuerDN>
    <IssuerKeyID>7645639105</IssuerKeyID>
  </AD>
</TrustedAuthorities>
```
Annex B  Sample XML Address Resolution Mapping File

The XML Address Resolution Mapping file describes how the local Policy Negotiation Proxy (PNP) communicates with the remote PNP for the associated administrative domain.

```xml
<AddressResolution>
  <AD name="AD1">
    <Address>10.1.1.1</Address>
    <Port>7100</Port>
    <LocalPort>7101</LocalPort>
  </AD>
  <AD name="AD2">
    <Address>10.2.3.3</Address>
    <Port>7200</Port>
    <LocalPort>7201</LocalPort>
  </AD>
  <AD name="AD3">
    <Address>10.3.3.3</Address>
    <Port>7300</Port>
    <LocalPort>7301</LocalPort>
  </AD>
  <AD name="AD4">
    <Address>10.4.4.4</Address>
    <Port>5800</Port>
    <LocalPort>5801</LocalPort>
  </AD>
  <AD name="AD5">
    <Address>10.5.5.5</Address>
    <Port>5800</Port>
    <LocalPort>5801</LocalPort>
  </AD>
</AddressResolution>
```
Annex C  Negotiator State Transition Table

The next two pages contain the state transition table for the Negotiator inner class of the NegotiablePPU. The current state appears in blue in the left column, while the events appear in blue in the top row. Actions appear in black and “alert” denotes an alert sent to the NegotiablePPU. Finally, the next state in the transition appears in red.

<table>
<thead>
<tr>
<th>Current State</th>
<th>RECHECK Exception</th>
<th>Recheck New Proposal</th>
<th>Recheck Null Proposal</th>
<th>Policy Withdraw</th>
<th>RECV PP w GOOD NT</th>
<th>RECV PP w BAD NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCAL CONFLICT</td>
<td>alert: NEGOTIATION_FAILURE</td>
<td>Reminder, alert: NEW_NEGOTIATION</td>
<td>Do Nothing</td>
<td>Send PW, alert: END_NEGOTIATION</td>
<td>Send BAD NT</td>
<td>Send BAD NT</td>
</tr>
<tr>
<td>LOCAL CONFLICT</td>
<td>WAIT PP</td>
<td>IDLE</td>
<td>DISENGAGED</td>
<td>LOCAL CONFLICT</td>
<td>LOCAL CONFLICT</td>
<td></td>
</tr>
<tr>
<td>IDLE</td>
<td>alert: NEGOTIATION_FAILURE</td>
<td>Reminder, alert: NEW_NEGOTIATION</td>
<td>Do Nothing</td>
<td>Send PW, alert: END_NEGOTIATION</td>
<td>Send BAD NT, Set a Reminder, alert: NEW_NEGOTIATION</td>
<td>Send BAD NT</td>
</tr>
<tr>
<td>LOCAL CONFLICT</td>
<td>WAIT PP</td>
<td>IDLE</td>
<td>DISENGAGED</td>
<td>WAIT NT</td>
<td>IDLE</td>
<td></td>
</tr>
<tr>
<td>WAIT PP</td>
<td>Cancel Reminder, alert: NEGOTIATION_FAILURE</td>
<td>Reminder, alert: NEW_NEGOTIATION</td>
<td>Do Nothing</td>
<td>Reminder, alert: END_NEGOTIATION</td>
<td>SEND GOOD NT, Set a Reminder</td>
<td>Reminder, alert: NEGOTIATION_FAILURE</td>
</tr>
<tr>
<td>LOCAL CONFLICT</td>
<td>WAIT PP</td>
<td>WAIT PP</td>
<td>DISENGAGED</td>
<td>WAIT NT</td>
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<td></td>
</tr>
<tr>
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<td>WAIT NT</td>
<td>DISENGAGED</td>
<td>WAIT NT</td>
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<td></td>
</tr>
<tr>
<td>LOCAL CONFLICT</td>
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<td>WAIT PR</td>
<td>DISENGAGED</td>
<td>WAIT NT</td>
<td>IDLE</td>
<td></td>
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<td>NEGOTIATED</td>
<td>SEND PW, Cancel Reminder, alert: NEGOTIATION_FAILURE</td>
<td>Reminder, alert: NEW_NEGOTIATION</td>
<td>Do Nothing</td>
<td>SEND PW, Cancel Reminder, alert: NEW_NEGOTIATION</td>
<td>Send BAD NT</td>
<td>Send BAD NT</td>
</tr>
<tr>
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<td>NEGOTIATED</td>
<td>DISENGAGED</td>
<td>WAIT NT</td>
<td>IDLE</td>
<td></td>
</tr>
<tr>
<td>LOCAL CONFLICT</td>
<td>WAIT PP</td>
<td>TRY REFRESH</td>
<td>DISENGAGED</td>
<td>WAIT NT</td>
<td>IDLE</td>
<td></td>
</tr>
<tr>
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<td>Do nothing</td>
<td>Do nothing</td>
<td>Send PW, alert: END_NEGOTIATION</td>
<td>Set a Reminder, alert: NEW_NEGOTIATION</td>
<td>Cancel Reminder, alert: NEGOTIATION_FAILURE</td>
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<td>REMOTE WITHDRAW</td>
<td>REMOTE WITHDRAW</td>
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<tr>
<td>Current State</td>
<td>RCV GOOD NT</td>
<td>RCV BAD NT</td>
<td>RCV GOOD PR</td>
<td>RCV BAD PR</td>
<td>RCV GOOD PW</td>
<td>NEG STALLED</td>
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</tr>
<tr>
<td>LOCAL CONFLICT</td>
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<td>Error</td>
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<td>Send PW alert: END_NEGOTIATION</td>
<td>ERROR</td>
<td></td>
</tr>
<tr>
<td>LOCAL CONFLICT</td>
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<td>LOCAL CONFLICT</td>
<td>LOCAL CONFLICT</td>
<td>LOCAL CONFLICT</td>
<td>REMOTE WITHDRAW</td>
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<td>ERROR</td>
<td>Send PW alert: END_NEGOTIATION</td>
<td>ERROR</td>
<td></td>
</tr>
<tr>
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<td>IDLE</td>
<td>IDLE</td>
<td>IDLE</td>
<td>WAIT PP</td>
<td>REMOTE WITHDRAW</td>
<td>IDLE</td>
</tr>
<tr>
<td>WAIT PP</td>
<td>Enter</td>
<td>Error</td>
<td>ERROR</td>
<td>Send PR, Set a Reminder, alert: NEW_NEGOTIATION</td>
<td>Send PR, Set a Reminder, alert: NEW_NEGOTIATION</td>
<td>Send PR, Set a Reminder, alert: NEW_NEGOTIATION</td>
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<td></td>
</tr>
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<td>ERROR</td>
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<td>Cancel Reminder, alert: END_NEGOTIATION</td>
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</tr>
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<td>WAIT PP</td>
<td>REMOTE WITHDRAW</td>
<td>WAIT PP</td>
</tr>
<tr>
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<td>Error</td>
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</tr>
<tr>
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<td>Send PR, Set a Reminder, alert: NEW_NEGOTIATION</td>
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</table>
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Inter-domain security policy
Network Management
Policy
Policy-based network management (PBNM)
Policy Decision Point (PDP)
Policy enforcement
Policy Enforcement Point (PEP)
Policy negotiation
Policy Negotiation Proxy (PNP)
Policy object
Policy Processing Unit (PPU)
Security Policy
XML Policy