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Introduction

CNRI's goal in this project is to federate the information managed by various clearinghouses in different clusters in GENI providing the users a logically centralized location to discover resources (and other entities) across GENI (and not just those specific to a cluster). The GENI Federated Clearinghouse (GFC), hosted at http://geni.doregistry.org/GFC/, is a collection of Registries that allows the discovery of various GENI entities, namely users, slices, slivers, resources, components, aggregates, and services. (Here services are the various managers and authorities that enable the control framework, e.g., slice authority, aggregate manager, etc.). CNRI has defined a data model to capture the current state information, aka metadata, pertaining to each of the aforementioned entities. That data model, which is implemented by the GFC, is discussed later in this document.

The GFC is designed to be accessible from a browser or by programmatic means. Accessing the GFC using a browser is straightforward and involves visiting the GFC URL, selecting the appropriate registry from the selection list, and listing the clearinghouse records (or searching using keywords), and following the links from the resulting page to either get more information about the resulting records or to access the entire record in XML. The GFC may also be accessed using programmatic means. The GFC is designed to be REST compatible with the mode of access being HTTP and the transaction message being encoded in XML. The rest of this document highlights the various APIs, Data Model, and XML schemas necessary to use the defined API.

Currently, the GFC is integrated with an adapter to parse the ProtoGENI clearinghouse information and crosswalk to its own data model. As a result, the GFC holds the ProtoGENI clearinghouse records which are refreshed on a regular basis. Note that the information in the GFC is currently pulled from ProtoGENI once every week in an automated fashion. It is, therefore, likely that the information in GFC is obsolete if the rate of change of such information at ProtoGENI is more frequent than a week.

The GFC is also integrated with CNRI's implementation of a PKI-based security architecture that provides freedom from certificate revocation lists (CRLs). Consequently, once integrated into GENI, new users may be added and removed from the GENI infrastructure without requiring the various security databases to update their certificate stores. The details of the security implementation are made available at:

http://groups.geni.net/geni/attachment/wiki/DigitalObjectRegistry/ClearinghouseSecurityReqmnts.pdf

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Goals, Definitions, and Namespaces

Theory of a Registry

A Registry is a service that allows the registration of current-state data, aka metadata, of an entity, in order to enable discovery (search and browse) and access to such metadata. Discovered metadata will further enable the access to, or dissemination of, the entity the metadata describes. Finally, persistent identifiers (Handles, in GFC) are assigned to registered metadata in order to enable various workflows involving the entities where resolution of those persistent identifiers will disseminate the recent metadata pertaining to the entity.

Clearinghouse

From GPO's perspective, a clearinghouse:

- Should minimize the number of trust relationships required between **researchers** and **aggregates** to perform any transaction to reserve or use resources for conducting experiments, etc.
- Should log transactions and, by using the logs, enable **forensics** and **kill-the-experiment** functionality.
- Should enforce global policies.

Note that the requirements do not address implementation of registries, slice authorities, or component/aggregate managers.

From GENI Member's perspective, a clearinghouse:

- Should provide functionality such as authentication, authorization, registry services, and policy enforcement systems.
- Should not bundle the functionality into a single component/service, but provide the clients a way to use the functionality separately on an as-needed basis.

Conceptual Goals for GFC

To enable the GFC to meet both sets of requirements for a clearinghouse, the GFC is designed to meet the following goals:

- Minimize the number of trust relationships required between researchers and aggregates to perform any transaction.
- Provide authentication, authorization, registration, resolution, and discovery services on user records, slices, resources, components, aggregates, component/aggregate managers, and slice managers.

   a. Leave the Slice Authority and Component/Aggregate functionality to individual clearinghouses, and instead just disseminate the current state of such components (URLs, access points, etc.).

- Provide the above services discretely by not bundling the services into one big service.

   a. That is, allow intermediary clients to bundle only required services to offer value-added services to end users.

- Allow fine-grained administration with distributed access.

   a. Fine-grained administration implies allowing individual participants to administer their data – that is, logically distribute the data.

   b. Distributed access implies decentralizing the service to enhance scalability and reliability – that is, physically distribute the services.

- Implement and Integrate PKI as the underlying security enablement.

- Provide a place holder for plug-in policy enforcement modules.

Identifier Namespace

All entities registered in the GFC are assigned unique, persistent identifiers. Those identifiers are enabled using the Handle System (http://www.handle.net/). While the clearinghouses deployed in GENI already assign identifiers at cluster-level, the identifiers assigned in the GFC are universal and allows global access to metadata regardless of the entities locations. In order to deterministically be able to map between the global identifiers that the GFC enables and the cluster-level identifiers that clusters enable, we follow a prefix-suffix scheme. The GFC assigned defined prefixes to the participating organizations. The suffixes are identifiers assigned by individual clusters. Figure 1 illustrates the namespace management of Handles.

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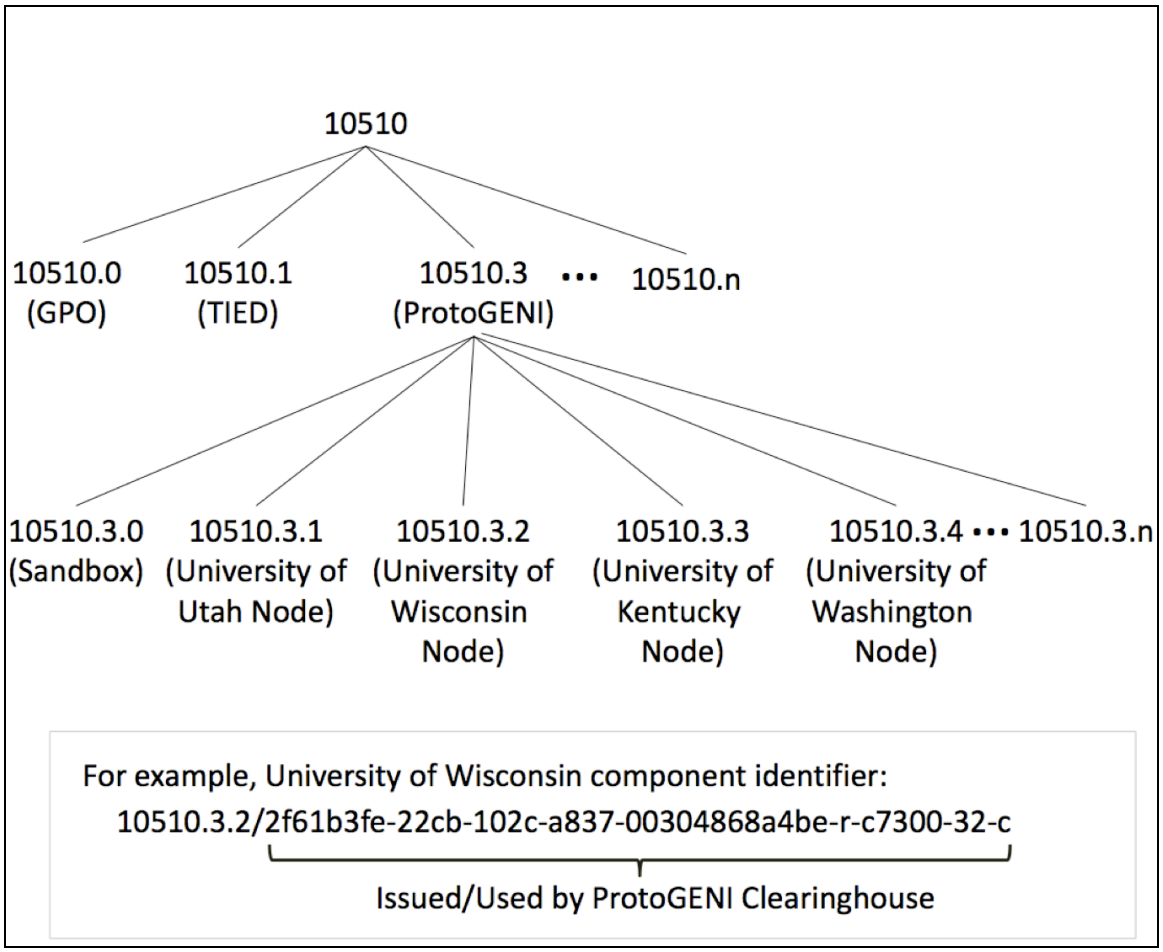

Figure 1: Identifier Namespace in the GFC

Data Model

We analyzed the various aspects of the GENI entities (resources, slices, slivers, etc.), identified the interdependence between them, and defined the metadata that describes the current state of each of those entities in the instantiation of a GENI system. The result of that work is a data model illustrated in a set of figures below.

Figure 2 captures the interdependency between various GENI entities, highlighting some of the metadata elements that capture the current state of those entities as implemented in GFC v1.0.

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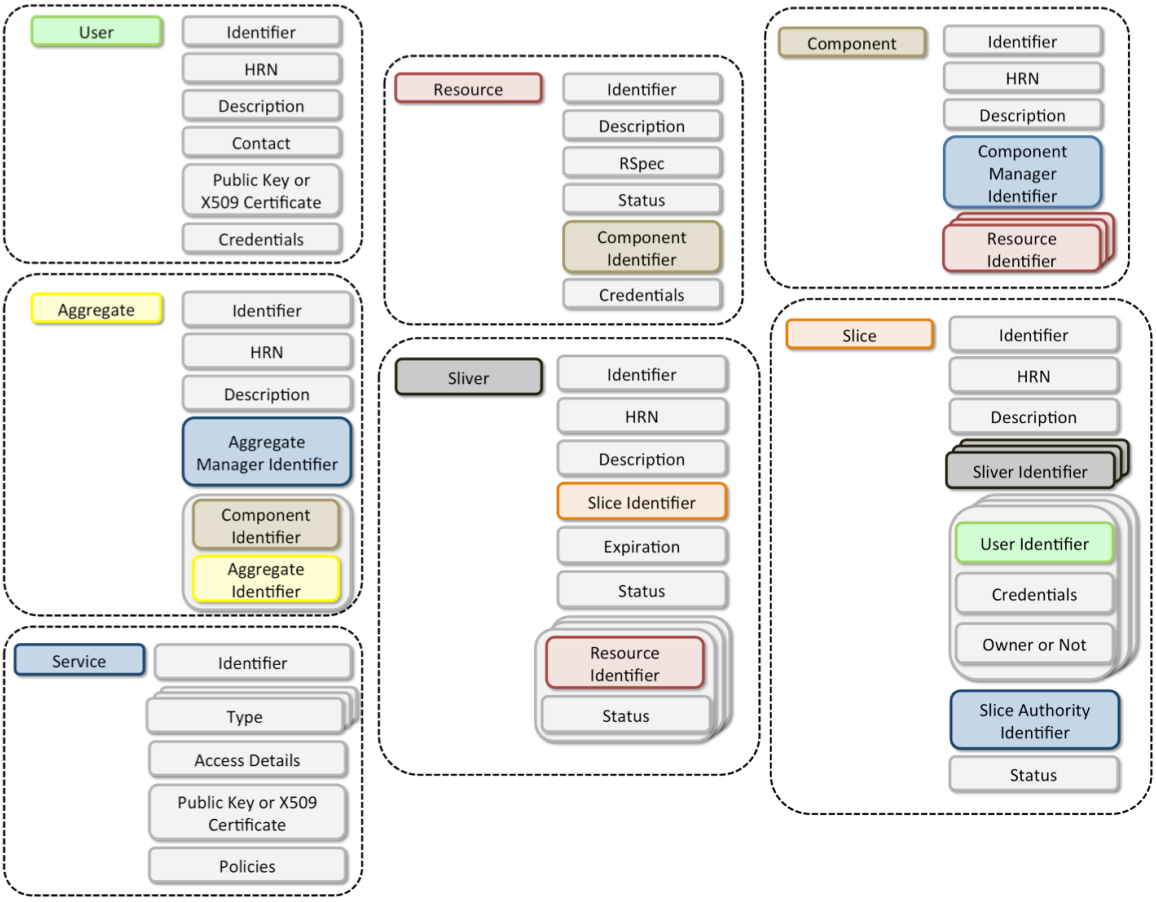

Figure 2: GENI Registry Data Model

Each of the Figures 3 through 9 illustrates various metadata fields that capture the current state of GENI entities, but categorized into

- **Recommended** fields: the fields that CNRI recommends to be associated with corresponding GENI entity going forward.
- **Version 1.0 Implementation Choice:** the fields that are implemented in the GFC v1.0 in order to be compatible with ProtoGENI implementation.

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Recommended (Going Forward)	Version 1.0 Impl. choice	Items	Comments
☑	☑	ID	
☑	☐ (Optional)	Contact	Name, Email, Address, Phone.
	☐	HRN	Human Readable Name
	☒	XML-RPC Web Server URL	
☑	☑	X509 Certificate or Public key	Pem format (X509) or Base64 (Public key)
	☒	Credential	Use ACS
☑	☐	ACS	Access Credential Set. Placeholder.
☑	☐	Description	

ProtoGENI Defined

Figure 3: User Metadata

Recommended	Version 1.0 Impl. choice	Items	Comments
☑	☑	RSpec	
☑	☑	Status	
☑	☑	ID	
☑	☐	ARS	Access Rules Set
☑	☑	Component ID	
☑	☐	Description	

ProtoGENI Defined

Figure 4: Resource Metadata

Recommended	Version 1.0 Impl. choice	Items	Comments
☑	☑	ID	
☑	☐	HRN	
☑	☑	Component Manager ID	
☑	☑	Resource ID Array	
☑	☐	Description	

ProtoGENI Defined

Figure 5: Component Metadata

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Recommended	Version 1.0 Impl. choice	Items	Comments
☑	☑	ID	
☑	☐	Name	
☑	☑	Aggregate Manager ID	
☑	☑	Component/Aggregate ID Array	
☑	☐	Description	

ProtoGENI Defined

Figure 6: Aggregate Metadata

Recommended	Version 1.0 Impl. choice	Items	Comments
☑	☑	ID	
	☐	HRN	Human Readable Number
	☒	XML-RPC Web Server URL	
☑	☑	Status	Overall Status
	☒	Details	Status of individual resources. See Resource Array
☑	☑	Resource Array of {Resource ID, status}	The status of resources are w.r.t. this sliver. The status of resources, when the resource IDs are resolved, describe the resource's overall status across all slivers.
☑	☐	Description	
☑	☑	Slice ID	
☑	☐	Expiration	Absolute timestamp

ProtoGENI Defined

Figure 7: Sliver Metadata

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Recommended	Version 1.0 Impl. choice	Items	Comments
☑	☑	ID	
	☐	HRN	Human Readable Number
	☒	XML-RPC Web Server URL	
		X509 Certificate	Pem format
	☒	Owner	See Administrators Array
	☒	Administrators	See Administrators Array
☑	☑	Status	
☑	☑	Administrators Array of {user ID, (optional) ACS, (optional) type}	The ACS here will take care of the "ticket". Type could be "owner".
☑	☑	Sliver ID Array	
☑	☐	Description	
☑	☑	Slice Authority ID	

ProtoGENI Defined

Figure 8: Slice Metadata

Recommended	Version 1.0 Impl. choice	Items	Comments
☑	☑	ID	
☑	☑	Type Array	An improper subset of {Slice Authority, Component Manager, Aggregate Manager}
☑	☑	Access Point	URL, for example
☑	☑	X509 Certificate or Public key	Pem format (X509) or Base64(Public key)
☑	☐	ARS	Access Rules Set

ProtoGENI Defined

Figure 9: Service Metadata

For some additional information on the data model approach, please refer to http://groups.geni.net/geni/attachment/wiki/DigitalObjectRegistry/FederatedClearinghouse.pdf

REST API

The GFC allows register, de-register, search, and resolve functions on the various registries (each specific to a GENI entity). The various registries implemented in the GFC are

- user
- resource
- component
- aggregate
- sliver
- slice
- service

The following tables define the various HTTP (REST) calls to each of the functions:

Name		**Value**
URL		http://geni.doregistry.org/<registry name>/register
Method		HTTP POST
Encoding		multipart/form-data
HTTP Headers		
Name	**Type**	**Notes**
Accept		Optional. Text/xml
HTTP POST Parameters		
Name	**Type**	**Notes**
recordData	XML	Metadata XML specific to the registry. See Section "XML Schemas and Examples".

Table 1: Register API Definition

The response is an XML that indicates the success or failure of the register request.

Name		**Value**
URL		http://geni.doregistry.org/<registry name>/deregister/<ID>
Method		HTTP GET
Encoding		none
HTTP Headers		
Name	**Type**	**Notes**
Accept		Optional. Text/xml

Table 2: Deregister API Definition

Here <ID> is the Handle assigned when the metadata record is registered in the GFC. The response is an XML that indicates the success or failure of the de-register request.

Name		**Value**
URL		http://geni.doregistry.org/<registry name>/<query>|<pagenumber>|<pagesize>
Method		HTTP GET
Encoding		None
HTTP Headers		
Name	**Type**	**Notes**
Accept		Optional. Text/xml

Table 3: Search API Definition

Here

- <query> is a string (a keyword or space-separated (but URL encoded) keywords)
- <page number> is the number of the page to be returned paginated per <page size>
- <page size> is the size of each page to be returned in the search results

<page number> and <page size> must both either exist or not. If they don't exist, a maximum of top ten results will be displayed.

The response is an XML that indicates the success or failure of the register request. If the request is a

Name	**Value**	
URL	http://geni.doregistry.org/<registry name>/resolve/<ID>	
Method	HTTP GET	
Encoding	None	
HTTP Headers		
Name	**Type**	**Notes**
Accept		Optional. Text/xml

Table 4: Resolve API Definition

Here <ID> is the Handle assigned when the metadata record is registered in the GFC. If the <ID> exists in the system, a metadata XML corresponding to the <ID> as registered in the GFC is returned, otherwise an error status is returned in XML.

XML Schemas and Examples

The various XML schemas defining the metadata for the GENI entities are available on the GFC. Examples of metadata records are also available from the GFC. Table 5 provides the URLs to the schemas and some of the examples. All schemas are additionally listed in Listings 1 through 7.

GENI Entity	**XML Schema**	**Example**
User	http://hdl.handle.net/10510.0/1	http://geni.doregistry.org/GFC/user/resolve/10510.3.0/b06dfbb9-818a-102d-930f-001143e459e8
Resource	http://hdl.handle.net/10510.0/4	http://geni.doregistry.org/GFC/resource/resolve/10510.3.1/urn_publicid_IDN+emulab.net+node+pc45-pc45.1
Component	http://hdl.handle.net/10510.0/5	

Aggregate	http://hdl.handle.net/10510.0/6	
Slice	http://hdl.handle.net/10510.0/2	http://geni.doregistry.org/GFC/slice/resolve/10510.3.2/049b47a4-fa06-11dd-906f-00304868a4be
Sliver	http://hdl.handle.net/10510.0/3	
Service	http://hdl.handle.net/10510.0/7	http://geni.doregistry.org/GFC/service/resolve/10510.3.1/urn_publicid_IDN+emulab.net+authority+sa

Table 5: XML Schemas and Examples

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- User XML Schema as defined for the GENI Federated Clearinghouse (GFC)
     Copyright 2009 Corporation for National Research Initiatives -->
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://hdl.handle.net/10510.0/1"
xmlns:gfc="http://hdl.handle.net/10510.0/1" xmlns:gfcc="http://hdl.handle.net/10510.0/0"
    elementFormDefault="qualified" attributeFormDefault="qualified">
    <xs:import namespace="http://hdl.handle.net/10510.0/0"
schemaLocation="http://hdl.handle.net/10510.0/0"></xs:import>
    <!-- A user element requires only two elements: an ID and a public key or X509
certificate. -->
    <xs:element name="identifier" type="gfcc:identifiertype"/>
    <xs:element name="hrn" type="gfcc:hrntype"/>
    <xs:element name="description" type="gfcc:descriptiontype"/>
    <xs:element name="firstname" type="xs:string"/>
    <xs:element name="middlename" type="xs:string"/>
    <xs:element name="lastname" type="xs:string"/>
    <xs:element name="email" type="xs:string"/>
    <xs:element name="primaryaddressline" type="xs:string"/>
    <xs:element name="secondaryaddressline" type="xs:string"/>
    <xs:element name="city" type="xs:string"/>
    <xs:element name="state" type="xs:string"/>
    <xs:element name="zipcode" type="xs:string"/>
    <xs:element name="country" type="xs:string"/>
    <xs:element name="phone" type="xs:string"/>
    <xs:element name="contact">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:firstname" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:middlename" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:lastname" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:email" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:phone" minOccurs="0" maxOccurs="1"/>
```

```
                <xs:element ref="gfc:primaryaddressline" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:secondaryaddressline" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:city" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:state" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:zipcode" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:country" minOccurs="0" maxOccurs="1"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>

    <!-- This defines an Authentication Set (AS) element. -->
    <xs:element name="as" type="gfcc:astype"/>

    <!-- This defines a wildcard placeholder for the Access Credential Set (ACS) element. It
        will accept any element/attribute in another namespace and
        perform validation on the other schema if one is supplied. -->
    <xs:element name="acs" type="gfcc:acstype"/>

    <xs:element name="user">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:hrn" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:description" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:contact" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:as" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:acs" minOccurs="0" maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute ref="gfcc:version" use="required"/>
        </xs:complexType>
    </xs:element>

</xs:schema>
```

Listing 1: User Metadata XML Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Resource XML Schema as defined for the GENI Federated Clearinghouse (GFC)
    Copyright 2009 Corporation for National Research Initiatives -->
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://hdl.handle.net/10510.0/4"
xmlns:gfc="http://hdl.handle.net/10510.0/4" xmlns:gfcc="http://hdl.handle.net/10510.0/0"
elementFormDefault="qualified" attributeFormDefault="qualified">
    <xs:import namespace="http://hdl.handle.net/10510.0/0"
schemaLocation="http://hdl.handle.net/10510.0/0"></xs:import>

    <xs:element name="identifier" type="gfcc:identifiertype"/>
    <xs:element name="description" type="gfcc:descriptiontype"/>
    <xs:element name="rspec">
        <xs:complexType>
            <xs:sequence>
```

```
                <xs:any namespace="##other" minOccurs="0" maxOccurs="unbounded"
                    processContents="lax"/>
            </xs:sequence>
            <xs:anyAttribute namespace="##other" processContents="lax"/>
        </xs:complexType>
    </xs:element>
    <!-- Access Rules Set (ars) element -->
    <xs:element name="ars" type="gfcc:arstype"/>

    <xs:element name="componentidentifier" type="gfcc:identifiertype"/>
    <xs:element name="status">
        <xs:simpleType>
            <xs:restriction base="xs:string">
                <xs:enumeration value="available"/>
                <xs:enumeration value="busy"/>
                <xs:enumeration value="unknown"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:element>

    <xs:element name="resource">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:description" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:rspec" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:ars" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:componentidentifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:status" minOccurs="1" maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute ref="gfcc:version"/>
        </xs:complexType>
    </xs:element>
</xs:schema>
```

Listing 2: Resource Metadata XML Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Component XML Schema as defined for the GENI Federated Clearinghouse (GFC)
    Copyright 2009 Corporation for National Research Initiatives -->
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://hdl.handle.net/10510.0/5"
xmlns:gfc="http://hdl.handle.net/10510.0/5" xmlns:gfcc="http://hdl.handle.net/10510.0/0"
elementFormDefault="qualified" attributeFormDefault="qualified">
    <xs:import namespace="http://hdl.handle.net/10510.0/0"
schemaLocation="http://hdl.handle.net/10510.0/0"></xs:import>

    <xs:element name="identifier" type="gfcc:identifiertype"/>
    <xs:element name="hrn" type="gfcc:hrntype"/>
    <xs:element name="description" type="gfcc:descriptiontype"/>
    <xs:element name="componentmanageridentifier" type="gfcc:identifiertype"/>
```

```
    <xs:element name="resources">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="1" maxOccurs="unbounded"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>
    <xs:element name="component">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:hrn" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:description" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:componentmanageridentifier" minOccurs="1"
maxOccurs="1"/>
                <xs:element ref="gfc:resources" minOccurs="1" maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute ref="gfcc:version"/>
        </xs:complexType>
    </xs:element>
</xs:schema>
```

Listing 3: Component Metadata XML Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Aggregate XML Schema as defined for the GENI Federated Clearinghouse (GFC)
    Copyright 2009 Corporation for National Research Initiatives -->
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://hdl.handle.net/10510.0/6"
xmlns:gfc="http://hdl.handle.net/10510.0/6" xmlns:gfcc="http://hdl.handle.net/10510.0/0"
elementFormDefault="qualified" attributeFormDefault="qualified">
    <xs:import namespace="http://hdl.handle.net/10510.0/0"
schemaLocation="http://hdl.handle.net/10510.0/0"></xs:import>

    <xs:element name="identifier" type="gfcc:identifiertype"/>
    <xs:element name="hrn" type="gfcc:hrntype"/>
    <xs:element name="description" type="gfcc:descriptiontype"/>
    <xs:element name="aggregatemanageridentifier" type="gfcc:identifiertype"/>
    <xs:element name="componentoraggregateidentifier" type="gfcc:identifiertype"/>
    <xs:element name="units">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:componentoraggregateidentifier" minOccurs="1"
maxOccurs="unbounded"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>
    <xs:element name="aggregate">
        <xs:complexType>
```

```
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:hrn" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:description" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:aggregatemanageridentifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:units" minOccurs="1" maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute ref="gfcc:version"/>
        </xs:complexType>
    </xs:element>
</xs:schema>
```

Listing 4: Aggregate Metadata XML Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Sliver XML Schema as defined for the GENI Federated Clearinghouse (GFC)
    Copyright 2009 Corporation for National Research Initiatives -->
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://hdl.handle.net/10510.0/2" xmlns:gfc="http://hdl.handle.net/10510.0/2" xmlns:gfcc="http://hdl.handle.net/10510.0/0" elementFormDefault="qualified" attributeFormDefault="qualified">
    <xs:import namespace="http://hdl.handle.net/10510.0/0" schemaLocation="http://hdl.handle.net/10510.0/0"></xs:import>

    <xs:element name="identifier" type="gfcc:identifiertype"/>
    <xs:element name="hrn" type="gfcc:hrntype"/>
    <xs:element name="description" type="gfcc:descriptiontype"/>
    <xs:element name="sliceidentifier" type="gfcc:identifiertype"/>
    <xs:element name="expiration" type="xs:dateTime"/>
    <xs:simpleType name="statusvalues">
        <xs:restriction base="xs:string">
            <xs:enumeration value="active"/>
            <xs:enumeration value="inactive"/>
            <xs:enumeration value="unknown"/>
        </xs:restriction>
    </xs:simpleType>
    <xs:element name="status" type="gfc:statusvalues"/>
    <xs:element name="resourcedetails">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:status" minOccurs="1" maxOccurs="1"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>
    <xs:element name="detailedstatus">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:resourcedetails" minOccurs="1" maxOccurs="unbounded"/>
            </xs:sequence>
```

```
        </xs:complexType>
    </xs:element>

    <xs:element name="sliver">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:hrn" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:description" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:sliceidentifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:expiration" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:status" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:detailedstatus" minOccurs="1" maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute ref="gfcc:version"/>
        </xs:complexType>
    </xs:element>
</xs:schema>
```

Listing 5: Sliver Metadata XML Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Slice XML Schema as defined for the GENI Federated Clearinghouse (GFC)
    Copyright 2009 Corporation for National Research Initiatives -->
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://hdl.handle.net/10510.0/3"
xmlns:gfc="http://hdl.handle.net/10510.0/3" xmlns:gfcc="http://hdl.handle.net/10510.0/0"
elementFormDefault="qualified" attributeFormDefault="qualified">
    <xs:import namespace="http://hdl.handle.net/10510.0/0"
schemaLocation="http://hdl.handle.net/10510.0/0"></xs:import>

    <xs:element name="identifier" type="gfcc:identifiertype"/>
    <xs:element name="hrn" type="gfcc:hrntype"/>
    <xs:element name="description" type="gfcc:descriptiontype"/>
    <xs:element name="sliceauthorityidentifier" type="gfcc:identifiertype"/>
    <xs:element name="slivers">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="0" maxOccurs="unbounded"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>
    <xs:element name="useridentifier" type="gfcc:identifiertype"/>
    <!-- This defines a wildcard placeholder for the Access Credential Set (ACS) element. It
        will accept any element/attribute in another namespace and
        perform validation on the other schema if one is supplied. -->
    <xs:element name="acs" type="gfcc:acstype"/>

    <xs:element name="type">
        <xs:simpleType>
            <xs:restriction base="xs:string">
```

```
                <xs:enumeration value="owner"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:element>
    <xs:element name="administrator">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:useridentifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:acs" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:type" minOccurs="0" maxOccurs="1"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>
    <xs:element name="administrators">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:administrator" minOccurs="1" maxOccurs="unbounded"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>
    <xs:element name="status">
        <xs:simpleType>
            <xs:restriction base="xs:string">
                <xs:enumeration value="active"/>
                <xs:enumeration value="inactive"/>
                <xs:enumeration value="unknown"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:element>

    <xs:element name="slice">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:hrn" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:description" minOccurs="0" maxOccurs="1"/>
                <xs:element ref="gfc:sliceauthorityidentifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:slivers" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:administrators" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:status" minOccurs="1" maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute ref="gfcc:version"/>
        </xs:complexType>
    </xs:element>
</xs:schema>
```

Listing 6: Slice Metadata XML Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Service XML Schema as defined for the GENI Federated Clearinghouse (GFC)
    Copyright 2009 Corporation for National Research Initiatives -->
```

```
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
    targetNamespace="http://hdl.handle.net/10510.0/7"
xmlns:gfc="http://hdl.handle.net/10510.0/7" xmlns:gfcc="http://hdl.handle.net/10510.0/0"
elementFormDefault="qualified" attributeFormDefault="qualified">
    <xs:import namespace="http://hdl.handle.net/10510.0/0"
schemaLocation="http://hdl.handle.net/10510.0/0"></xs:import>

    <xs:element name="identifier" type="gfcc:identifiertype"/>

    <xs:element name="type">
        <xs:simpleType>
            <xs:restriction base="xs:string">
                <xs:enumeration value="componentmanager"/>
                <xs:enumeration value="aggregatemanager"/>
                <xs:enumeration value="sliceauthority"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:element>
    <xs:element name="types">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:type" minOccurs="1" maxOccurs="3"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>

    <!-- Access Point element -->
    <xs:element name="accesspoint">
        <xs:complexType>
            <xs:sequence>
                <xs:any namespace="##other" minOccurs="0" maxOccurs="unbounded"
                    processContents="lax"/>
            </xs:sequence>
            <xs:anyAttribute namespace="##other" processContents="lax"/>
        </xs:complexType>
    </xs:element>

    <!-- This defines an Authentication Set (AS) element. -->
    <xs:element name="as" type="gfcc:astype"/>

    <!-- Access Rules Set (ars) element -->
    <xs:element name="ars" type="gfcc:arstype"/>

    <xs:element name="service">
        <xs:complexType>
            <xs:sequence>
                <xs:element ref="gfc:identifier" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:types" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:accesspoint" minOccurs="1" maxOccurs="1"/>
                <xs:element ref="gfc:as" minOccurs="1" maxOccurs="1"/>
```

```
                <xs:element ref="gfc:ars" minOccurs="0" maxOccurs="1"/>
            </xs:sequence>
            <xs:attribute ref="gfcc:version"/>
        </xs:complexType>
    </xs:element>
</xs:schema>
```

Listing 7: Service Metadata XML Schema