

An Extensible Protocol for Network Measurement and Control

DRAFT

Status of This Document

This document provides information to the Grid community regarding the design of protocols to control software engaged in the creation, storage, and exchange of network measurements. Distribution is unlimited.

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1 Abstract

The exchange of network measurement and performance data is a common problem for communities that rely on distributed computing methods such as the Grid and dynamic provisioning of network circuits. Work produced in related efforts, such as the Network Measurements Working Group (**NM-WG**) [5], has provided an extensible mechanism for the *representation* of these data sets but does not provide guidance for *collection*, *storage*, or *exchange*.

The Network Measurement Control Working Group (**NMC-WG**) [3] has taken the task of designing flexible *protocols* to be implemented by software systems that are interested in working with network measurements as encoded by the **NM-WG** standards. These protocols provide the basic communication recommendations that a service should implement. The recommendations brought forward in this work should not reflect any one implementation: these protocols are kept general and are extensible to many use cases and potential software systems.

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2 Introduction

This document describes a *protocol* designed to manage the interaction between systems focused on the *collection*, *storage*, and eventual *exchange* of network performance information. This protocol becomes relevant in an incarnation of a performance measurement framework; said construct consists of a set of services, each acting as an intermediate layer, between the performance measurement tools and the diagnostic or visualization applications all within a federated environment. The proposed architecture **SHOULD** make this functionality available via *Web Services* (WS) and to use a service-oriented design style, implying that a set of elementary functions has been isolated and can be delivered by potentially different software entities. In this model, all services **MUST** communicate using well-defined protocols.

The work presented here builds upon the output of other working groups focused on the accurate description of network measurements [5] and topological representation of network elements [4]. When applicable, we will directly cite terminology and ideas from these working groups. We do not describe a particular system currently in use, although several prototypes exist that implement messaging similar to this work.

3 Motivation

A common message exchange pattern for web services in general is a *Request* followed by a *Response*. This particular communication pattern is important and involves two actors for the general case. Consider the example in Figure 1 of a *client* application interacting with some *measurement service* in search of data. This exchange assumes that both the client and the service speak a common dialect of communication protocol.

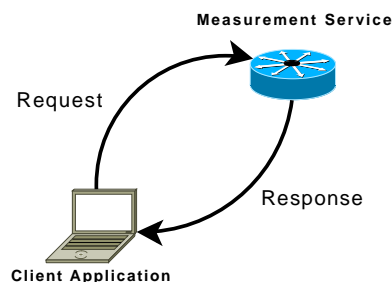


Figure 1: Simple two way exchange between a client and a service.

It becomes the burden of both the service developer and the client developer to document what an exchange consists of as well as how it takes place (albeit from different points of view). A second example pictured in Figure 2 involves different actors but is exactly the same as the previous.

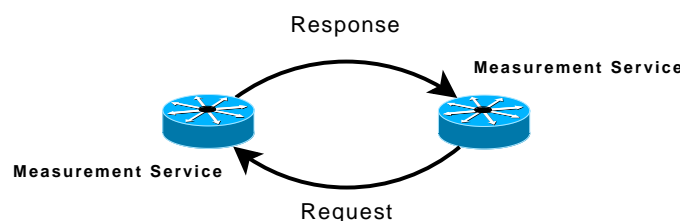


Figure 2: Simple two way exchange between two services.

A less common interaction is the notion of a *Subscription*, *Notification* or other form of “one-sided” exchange. Services may use this to perform tasks such as subscribing to status updates from a service, or otherwise alerting a service or client about the existence of some key piece of information. Figure 3 describes this exchange in detail.

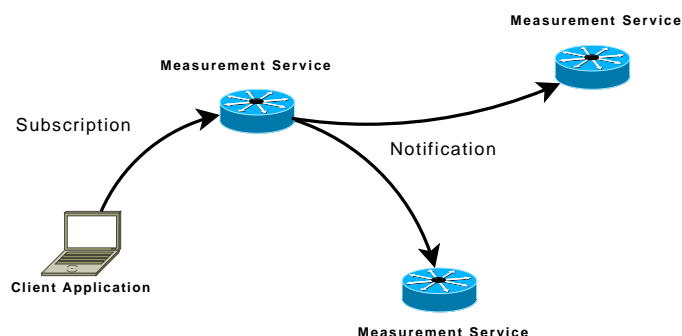


Figure 3: One way exchange where a client subscribes to a service. Other services may already receive notifications.

The acts of sending *requests*, receiving *responses*, and being able to discern success or failure are common across many specific interactions. One aim of this document is to prevent the following redundancies:

- **Duplicate Schemata** - *Messages SHALL* differ from service to service, but the overarching concepts **SHALL NOT**; we present some of the common features that **MUST** be present in every exchange and describe how extension is possible.
- **Duplicate Semantic Principals** - Concepts used in services designed in the past **SHALL** carry over into future iterations. Identifying and describing common practices will save time in the documentation of common features.
- **Duplicate Error Conditions** - Some errors **SHALL** occur across services and **MUST NOT** be defined repeatedly (e.g. *Unknown Message Type*).
- **Duplication of Common Exchanges** - Common protocols **MUST** be the same among services in a framework. For example being able to retrieve the “status” of a neighbor or wrapping your communication in a secure channel are communication patterns that will no doubt be required everywhere. A common *Echo* protocol is presented in this document as an example.

With a set design and format to this base functionality, it is possible to define protocol extensions on a “type by type” basis instead of a “service by service” approach. This also allows for a sufficient reduction in documentation due to service types implementing the same underlying *format* of messages (e.g. services that store measurements may implement the same message types with notable exceptions and data differences). It is expected that the following extensions to this base document will be prepared to describe specific service interactions:

- **Measurement Collection** - Describes the process of communicating with services that perform and gather measurements
- **Measurement Storage** - Describes communication with services that archive measurements

- **Information Location** - Interacting with services that index and locate services and data
- **Service Authentication** - Describes communication within secure data channels in a federated environment

4 Messages

As described in Section 3, the communication protocol is simple and based on the notion of *Request* and *Response* messages. The construction of the *message* itself takes advantage of work produced in the **NM-WG** by re-using several key constructs. Both message types are fundamentally the same: a series of *metadata* and *data* units linked via identifying attributes (e.g. *id* and *idRef* attribute values). These concepts, shown in [9, 12], observe the same rules with regards to splitting both measurement and communication.

4.1 Preliminary Example

To cement an early understanding of how the messages work, consider this rudimentary query for some data from a service:

```
<message type="request">
  <metadata id="m1">
    <!-- some partial metadata the service may or may not understand -->
  </metadata>
  <data id="d1" metadataIdRef="m1" />
</message>
```

There are some important things to note about this query:

- **Message Type** - Every *message* **MUST** contain a *type*, these facilitate the semantic intentions of the internal data
- **Message Structure** - There **MAY** be *metadata* and/or *data* elements in each message, and there **MAY NOT** need to be a matching data for every metadata (e.g. *Chaining*, see Section 5)
- **Metadata** - **SHOULD** contain measurement data, identifying information about a service, or even information meant to serve as a modifier (see see Section 5). Note that we still loosely observe the static rule of thumb
- **Data** - Serves a dual role: in request messages this **MAY** be empty (e.g. this is a *data trigger*, it lets the service know we need action on the accompanying metadata), or it **MAY** contain dynamic measurement data or even other metadata elements

Simply stated, we are sending a request (either partial or complete) to a capable service to perform some interactive behavior. We are interested in having the service verify that it **MAY** or **MAY NOT** be able to service our request. We are interested in either setting or retrieving information on this target data set - subsequent operations may be required. When the service receives this request it will check for several things:

- **Syntax** - Does the request parse correctly? Incorrect syntax will trigger *error routines*.

- **Message Type** - Can this service accept and act on this kind of message? An unexpected message **MUST** be rejected outright.
- **Structure** - Is there at least a single metadata and data pair that is capable of being acted on? A service that cannot determine if there is actionable content in the request will *reject* the message with an *error routine*.
- **Semantics** - Does the request make sense according to the schematic rules; can the metadata be acted upon; are the chains resolved properly? Handling of semantic rules are the discretion of the service: *error routines* are possible or perhaps some form of *panic parsing* may result in partial completion of a request.

The service has two options at this point: acting on the message (e.g. returning data) or reporting some other form of “status” (e.g. an *error* message). We will explore the first option initially:

```
<message type="response">

  <metadata id="m1">
    <!-- specific metadata that matched -->
  </metadata>

  <data id="d1" metadatIdRef="m1">
    <!-- data, or perhaps a pointer (key) to data -->
  </data>

</message>
```

Note this message is similar to the response in many ways. The major differences:

- **Message Type** - This becomes the foil of the previous request; it is common to simply replace the word “Request” with “Response”.
- **Message Structure** - All valid metadata and data pairings **MUST** be acted on, chained items **MAY** be truncated
- **Metadata** - **MAY** be completed if it was not this way in the request
- **Data** - **MUST** contain information, especially if it was empty in the initial request

The second situation is not very different, but is indicative of something occurring that was not expected. We don’t explicitly use the term “error” to describe this situation because many paths that lead to this are not *wrong*. Some examples of status may be:

- **Message Syntax/Structure/Semantics** - The service **MUST** be able to understand the request, if it cannot be parsed on either the syntactic or semantic levels the status **SHOULD** reflect this.
- **Metadata/Data Search** - The backend storage **MAY** simply be devoid of references to what a request is interested in, this **MAY** be expressed by returning nothing in the response or having an explicit message to do so.
- **Catastrophic Events** - Internal events **MAY** trigger some sort of panic in the service; note that not all events **MAY** be recovered from and are not the fault of the service itself (host machine failures, etc.).

The general format of a status message is as follows, parallels between the previous response as well as the request can easily be drawn.

```

<message type="response">

  <metadata id="m1">
    <!-- some (machine level) status information -->
  </metadata>

  <data id="d1" metadataIdRef="m1">
    <!-- some human readable status information -->
  </data>

</message>

```

4.2 Message Actions

The examples from Section 4.1 characterizes many of the common actions services perform on receipt of a request message. A more formal description of this interaction is described in Figure 4. Note that this is a generalized attempt, and **SHOULD NOT** directly reflect the actions of any particular service. Protocol extensions **MUST** provide a description where this example is lacking.

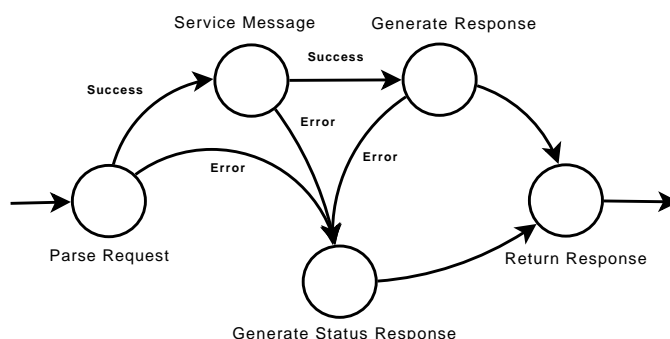


Figure 4: Typical programmatic flow of a messages through a measurement service.

The example illustrates that any stage of processing a request **MAY** trigger entry into the status routine. Specifics regarding available status messages **SHOULD** be categorized by service type and **SHALL** appear in the protocol extensions; specifics based on a particular action a service **MAY** take, based on internal conditions, **SHALL** appear in the service documentation.

4.3 Request Message

The *Request Message* is a container for submitting communication to capable services. Enclosed in this simple envelope **MUST** be a series of *metadata* and *data* pairs containing various instructions to act out. We first present a very simple schema in Section 4.3.1 along with an analysis of the elements in Section 4.3.2. We conclude with examples in Section 4.3.3.

4.3.1 Request Message Schema

The following schema is a native description of the request schema as in the RELAX-NG[8] language. Through the use of tools such as Trang[10] and MSV[2] it is possible to convert this to other widely accepted formats such as XSD[11].

```

# Begin Schema
namespace nmwg = "http://ggf.org/ns/nmwg/base/2.0/"

```



```

start =
  element nmwg:message {
    Identifier? &
    MessageIdRef? &
    attribute type { "Request" } &
    Parameters? &
    (
      Metadata |
      Data
    )+
  }

Parameters =
  element nmwg:parameters {
    Identifier &
    Parameter+
  }

Parameter =
  element nmwg:parameter {
    attribute name { xsd:string } &
    (
      attribute value { xsd:string } |
      (
        anyElement |
        text
      )
    )
  }

Metadata =
  element nmwg:metadata {
    Identifier &
    MetadataIdentifierRef? &
    anyElement*
  }

Data =
  element nmwg:data {
    Identifier &
    MetadataIdentifierRef &
    anyElement*
  }

Identifier =
  attribute id { xsd:string }

MessageIdRef =
  attribute messageIdRef { xsd:string }

MetadataIdentifierRef =
  attribute metadataIdRef { xsd:string }

anyElement =
  element * {
    anything
  }

anyAttribute =
  attribute * { text }

anything =
  (
    anyElement |
    anyAttribute |
    text
  )*

# End Schema

```

4.3.2 Request Message Analysis

The following is a breakdown of the elements featured in the schema. Note that services in general **MUST NOT** implement or attempt to understand this, it is provided as a tool to aid in the development of extensions.

4.3.2.1 Message

```
<nmwg:message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  id="message1"
  type="Request">

  <nmwg:parameters />

  <nmwg:metadata />

  <nmwg:data />

</nmwg:message>
```

Table 1: Message Element Specifics

| Message Element | |
|------------------------|----------------------------------|
| localname | message |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, messageIdRef, type |
| nested elements | parameters, metadata, data |
| required | yes |

The message construct is meant to serve as a container for transporting *requests* to capable services. The message element itself is unremarkable, it features *attributes* to aid in the identification of messages (e.g. *ids*) and contains elements with measurement or instructional content. We first examine the available attributes:

- **id** - Identifier that **MAY** be used to track state between messages and services
- **messageIdRef** - **OPTIONAL** identifier that *MAY* be used to track state to previous message exchanges.
- **type** - **MUST** designate the message to a particular type; fully enumerated in each protocol extension

There are three major elements that **MAY** be contained in the message element:

- **Parameters** - Described in Section 4.3.2.2
- **Metadata** - Described in Section 4.3.2.4
- **Data** - Described in Section 4.3.2.8

4.3.2.2 Parameters

```
<nmwg:parameters xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="parameters1">

  <nmwg:parameter />

</nmwg:parameters>
```

The parameters element encloses a series of parameter elements that **MAY** be used to adjust variable aspects of this schema. This element serves as a container for the *Parameter* (see Section 4.3.2.3) elements that **SHOULD** populate it. The single available attribute is described first:

Table 2: Parameters Element Specifics

| Parameters Element | |
|------------------------|----------------------------------|
| localname | parameters |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id |
| nested elements | parameter |
| required | no |

- **id** - Identifying attribute that **MAY** be used to track state.

The element (only one possible in this case) is described next:

- **Parameter** - Described in Section 4.3.2.3

Note that the use of this element (in this particular location) is **OPTIONAL**. Services are not required to understand this element and in some cases **MAY** view inclusion as an error. Please consult service documentation before proceeding.

4.3.2.3 Parameter

```
<nmwg:parameter xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  name="NAME">VALUE</nmwg:parameter>

<!-- OR -->

<nmwg:parameter xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  name="NAME" value="VALUE" />
```

Table 3: Parameter Element Specifics

| Parameter Element | |
|------------------------|----------------------------------|
| localname | parameter |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | name, value |
| nested elements | text, undefined |
| required | yes |

The parameter element features a generic structure that allows easy adaptation to the needs of a particular schema. Possible names and values **SHALL NOT** be enumerated here, but **SHALL** be done both at the protocol extension and service level.

- **name** - **MUST** specify the name of some variable value
- **value** - **MAY** be used instead a text element (or enclosed element) to set the value of the *name*

In lieu of the *value* attribute, a *text* (or unspecified *complex*) element may be used for the same purpose. It is **RECOMMENDED** that protocol extensions adopt a single method for all uses of this element. The other possibility for element containment is left unspecified. We do not rule out that “alternate” elements would be useful in this case, but the exact use is left up to other extensions.

4.3.2.4 Metadata

```
<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  id="metadata2" metadataIdRef="metadata1">

  <!-- Possible Values Include: -->

  <nmwg:subject />

  <nmwg:key />

  <nmwg:eventType />

  <nmwg:parameters />

</nmwg:metadata>
```

Table 4: Metadata Element Specifics

| Metadata Element | |
|------------------------|---|
| localname | metadata |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, metadataIdRef |
| nested elements | undefined, (<i>subject</i> , <i>key</i> , <i>eventType</i> , and <i>parameters</i> are common) |
| required | yes |

The metadata element normally contains the static parts of measurements, and **SHALL** differ from service to service. Besides measurement data it is possible to send other items such as *service descriptions*. The schema description itself of what is possible inside of this element uses vague language that allows for *any* reasonable XML to be contained within. The most common elements that are included are *Subject* (see Section 4.3.2.5), *Key* (see Section 4.3.2.6), *EventType* (see Section 4.3.2.7), and *Parameters* (see Section 4.3.2.2). We will present only a brief discussion of these within this document; a more exact definition **MAY** be found in specific measurement documentation.

There are two attributes possible. These **MAY** be used to both track state and perform the various forms of chaining (e.g. *operator* or *merge*) that a request message **MAY** require. A detailed description of this element follows:

- **id** - Identifying attribute that **MAY** be used to track state.
- **metadataIdRef** - Identifying attribute that **MAY** be used to track state or for *chaining* procedures.

4.3.2.5 Subject

```
<nmwg:subject xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  id="subject1" metadataIdRef="metadata1" />
```

The subject element normally contains *topological* specifications that relate directly to a measurement or **MAY** refer to a specific service. We leave a full description of this element up to individual implementations but mention it here due to common use. There are two **RECOMMENDED** attributes, these are used to both track state and perform a specific type of *chaining* (e.g. *subject* chaining) that **MAY** be required in a request message. A detailed description follows:

- **id** - Identifying attribute that **MAY** be used to track state.

Table 5: Subject Element Specifics

| Subject Element | |
|------------------------|---|
| localname | subject |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, metadataIdRef |
| nested elements | undefined, (topology elements are common) |
| required | N/A |

- **metadataIdRef** - Identifying attribute that **MAY** be used to track state or used in *chaining*.

4.3.2.6 Key

```
<nmwg:key xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/">
  <nmwg:parameters />
</nmwg:key>
```

Table 6: Key Element Specifics

| Key Element | |
|------------------------|----------------------------------|
| localname | key |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id |
| nested elements | parameters |
| required | N/A |

The key structure **SHALL** be used to convey sensitive or private information to and from the service. For this reason the contents of the key **SHOULD** be viewed as “opaque”, and **MUST NOT** be dissected. The key **SHOULD** contain a *Parameters* (see Section 4.3.2.2) element. There is only one attribute possible: *id*. This **MAY** be used to track state. A detailed description follows:

- **id** - Identifying attribute that **MAY** be used to track state.

4.3.2.7 EventType

```
<nmwg:eventType xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/">TEXT</nmwg:eventType>
```

The eventType element **SHOULD** be used to describe a measurement’s specific data type (e.g. closely matching the definitions from the NM-WG’s “Characteristic” document) or **MAY** be used to trigger an internal event within the service. This element contains no attributes, and **MUST** only contain text, normally in the form of a *URI*. There **MAY** be *many* eventType elements in a single metadata.

Table 7: EventType Element Specifics

| EventType Element | |
|------------------------|----------------------------------|
| localname | eventType |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | N/A |
| nested elements | text |
| required | N/A |

4.3.2.8 Data

```
<nmwg:data xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  id="data2" metadataIdRef="metadata2" />
```

Table 8: Data Element Specifics

| Data Element | |
|------------------------|----------------------------------|
| localname | data |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, metadataIdRef |
| nested elements | undefined |
| required | yes |

The data element **SHOULD** contain the dynamic parts of measurements, and **SHALL** differ from service to service. Besides collected measurements the data field **MAY** also be populated with query data, or even other other metadata information in certain applications. We leave the description of what is possible inside of *data* blank, and use vague schema language that allows for *any* reasonable content to be contained within.

There are two attributes possible. These **MAY** used to track state inside of a request message. A detailed description follows:

- **id** - Identifying attribute that **MAY** be used to track state.
- **metadataIdRef** - **MUST** be used to link data to metadata.

4.3.3 Request Message Example

The following examples demonstrate some of the possible uses and layouts of request messages in the base protocol. These examples are not an attempt to be exhaustive, but rather some examples of ways to perform common tasks. Note that these messages are not indicative of a particular service.

The first example demonstrates the most common use case: a single metadata and data pair. This message represents the layouts of most request messages in a generic measurement framework.

```
<!-- Begin XML -->
<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
```

```

        type="request"
        id="message1">

<metadata id="m1">
  <!-- metadata -->
</metadata>

<data id="d1" metadatIdRef="m1" />

</message>

<!-- End XML -->

```

The second example is similar, but incorporates a parameters block that **MAY** be populated with **OPTIONAL** behaviors of a service.

```

<!-- Begin XML -->

<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="request"
  id="message2">

  <nmwg:parameters id="parameters1">
    <nmwg:parameter name="something">something else</nmwg:parameter>
  </nmwg:parameters>

  <metadata id="m1">
    <!-- metadata -->
  </metadata>

  <data id="d1" metadatIdRef="m1" />

</message>

<!-- End XML -->

```

The third example is also similar to the first, but shows it is possible to ask for multiple pairs of metadata and data in a single message. Note that there are two empty data triggers to signify that each message be acted upon.

```

<!-- Begin XML -->

<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="request"
  id="message3">

  <metadata id="m1">
    <!-- metadata -->
  </metadata>

  <data id="d1" metadatIdRef="m1" />

  <metadata id="m2">
    <!-- another metadata -->
  </metadata>

  <data id="d2" metadatIdRef="m2" />

</message>

<!-- End XML -->

```

This example features merge chaining. Note there is only one data trigger, and it is at the tail of the chain. A service would perform the necessary chaining first, then act on the result of this operation.

```

<!-- Begin XML -->

<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="request"

```

```

        id="message4">

<metadata id="m1">
  <!-- metadata -->
</metadata>

<metadata id="m2" metadataIdRef="m1">
  <!-- more metadata -->
</metadata>

<data id="d1" metadatIdRef="m2" />
</message>
<!-- End XML -->

```

The final example is an invalid case where the metadata does not have an appropriate data trigger.

```

<!-- Begin XML -->
<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="request"
  id="message5">

  <metadata id="m1">
    <!-- metadata -->
  </metadata>

  <data id="d1" metadatIdRef="m2" />
</message>
<!-- End XML -->

```

4.4 Response Message

The response message is a container filled with the results of a *Request Message* from a capable service. Enclosed in this simple envelope **SHALL** be a series of metadata and data pairs containing the results of actions performed by a service. We first present a very simple schema in Section 4.4.1 along with an analysis of the elements in Section 4.4.2. We conclude with examples in Section 4.4.3.

4.4.1 Response Message Schema

The following schema is a native description of the request schema as in the RELAX-NG[8] language. Through the use of tools such as Trang[10] and MSV[2] it is possible to convert this to other widely accepted formats such as XSD[11].

```

# Begin Schema
namespace nmwg = "http://ggf.org/ns/nmwg/base/2.0/"

start =
  element nmwg:message {
    Identifier? &
    attribute messageIdRef { xsd:string }? &
    attribute type { "Response" } &
    Parameters? &
    (
      Metadata |
      Data
    )+
  }

Parameters =
  element nmwg:parameters {
    Identifier &
    Parameter+
  }

```



```

Parameter =
  element nmwg:parameter {
    attribute name { xsd:string } &
    (
      attribute value { xsd:string } |
      (
        anyElement |
        text
      )
    )
  }

Metadata =
  element nmwg:metadata {
    Identifier &
    MetadataIdentifierRef? &
    anyElement*
  }

Data =
  element nmwg:data {
    Identifier &
    MetadataIdentifierRef &
    anyElement*
  }

Identifier =
  attribute id { xsd:string }

MetadataIdentifierRef =
  attribute metadataIdRef { xsd:string }

anyElement =
  element * {
    anything
  }

anyAttribute =
  attribute * { text }

anything =
  (
    anyElement |
    anyAttribute |
    text
  )*

# End Schema

```

4.4.2 Response Message Analysis

The following is a breakdown of the elements featured in the schema. Note that services in general **MUST NOT** implement or attempt to understand this, it is provided as a tool to aid in the development of extensions.

4.4.2.1 Message

```

<nmwg:message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  id="message2"
  messageIdRef="message1"
  type="Response">

  <nmwg:parameters />

  <nmwg:metadata />

  <nmwg:data />

</nmwg:message>

```

The message element, like it's counterpart seen in Section 4.3.2.1 serves as a container for transporting responses from capable services. The message itself is unremarkable, it features attributes to aid in the iden-

Table 9: Message Element Specifics

| Message Element | |
|------------------------|----------------------------------|
| localname | message |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, type, messageIdRef |
| nested elements | parameters, metadata, data |
| required | yes |

tification of messages and contains elements with measurement or instructional content. We first examine the available attributes:

- **id** - Identifier that **MAY** be used to track state between messages and services
- **type** - **MUST** designate the message to a particular type; fully enumerated in each protocol extension
- **messageIdRef** - Identifier that **MAY** be used to track state between messages and services

There are three major elements that may be contained in the message element:

- **Parameters** - Described in Section 4.4.2.2
- **Metadata** - Described in Section 4.4.2.4
- **Data** - Described in Section 4.4.2.5

4.4.2.2 Parameters

```
<nmwg:parameters xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="parameters1">
  <nmwg:parameter />
</nmwg:parameters>
```

Table 10: Parameters Element Specifics

| Parameters Element | |
|------------------------|----------------------------------|
| localname | parameters |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id |
| nested elements | parameter |
| required | no |

The parameters element **SHOULD** only be present in the message element if there was a corresponding element in the *Request Message* (see Section 4.3.2.1). It **MAY** also be used by services to relay back other forms of information. As in Section 4.3.2.2, it encloses a series of *parameter* elements. This element serves merely as a container for the Parameter elements (see Section 4.4.2.3) that will populate it. The single available attribute is described first:

- **id** - Identifying attribute that **MAY** be used to track state.

There is only one available element, although it **MAY** be used multiple times

- **Parameter** - Described in Section 4.4.2.3

4.4.2.3 Parameter

```
<nmwg:parameter xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  name="NAME">VALUE</nmwg:parameter>

<!-- OR -->

<nmwg:parameter xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  name="NAME" value="VALUE" />
```

Table 11: Parameter Element Specifics

| Parameter Element | |
|------------------------|----------------------------------|
| localname | parameter |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | name, value |
| nested elements | text, undefined |
| required | yes |

The parameter element features a generic structure that allows it to easily adapt to the needs of a particular schema. Possible names and values **SHALL NOT** be enumerated here, but **SHALL** be done both at the protocol extension and service level.

- **name** - **MUST** generically specify the name of some variable value
- **value** - **MAY** be used instead a text element to set the value of the *name*

In lieu of the *value* attribute, a text element **MAY** be used for the same purpose. It is **RECOMMENDED** that protocol extensions adopt a single method for all uses of this element. The other possibility for element containment is left unspecified. We do not rule out that many elements would be useful in this case, but the exact use is left up to other extensions.

4.4.2.4 Metadata

```
<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  id="metadata2" metadataIdRef="metadata1">

  <!-- These elements are commonly used: -->

  <nwmw:subject />

  <nwmw:key />

  <nwmw:eventType />

  <nwmw:parameters />

</nmwg:metadata>
```

Table 12: Metadata Element Specifics

| Metadata Element | |
|------------------------|---|
| localname | metadata |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, metadataIdRef |
| nested elements | undefined, (subject, key, eventType, and parameters are common) |
| required | yes |

The metadata element in the response is normally an exact copy of the sent *Metadata* (see Section 4.3.2.4). We leave the description of what is possible inside of a metadata blank, and use vague schema language that allows for any reasonable XML to be contained within.

There are two attributes possible. These **MAY** be used to track state, possibly back to the sent *Metadata*. A detailed description follows:

- **id** - Identifying attribute that **MAY** be used to track state.
- **metadataIdRef** - Identifying attribute that **MAY** be used to track state.

4.4.2.5 Data

```
<nmwg:data xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  id="data2" metadataIdRef="metadata2">

  <nmwg:datum />

  <nmwg:key />

  <nmwg:metadata />

</nmwg:data>
```

Table 13: Data Element Specifics

| Data Element | |
|------------------------|--|
| localname | data |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, metadataIdRef |
| nested elements | undefined, (datum, key, and metadata are common) |
| required | yes |

The data element will contain results and is usually not empty like the trigger that is used in *Data* (see Section 4.3.2.8). We leave the description of what is possible inside of a data blank, and use vague schema language that allows for any reasonable XML to be contained within.

There are two attributes possible. These **MAY** be used to both track state inside of a response message. A detailed description follows:

- **id** - Identifying attribute that **MAY** be used to track state.
- **metadataIdRef** - **MUST** be used to link data to metadata.

4.4.2.6 Key

```
<nmwg:key xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/">
  <nmwg:parameters />
</nmwg:key>
```

Table 14: Key Element Specifics

| Key Element | |
|------------------------|----------------------------------|
| localname | key |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id |
| nested elements | parameters |
| required | no |

The key structure **SHOULD** be used to convey sensitive or private information to and from the service. For this reason the contents of the key **SHOULD** be viewed as opaque, and generally not be dissected. The key **SHOULD** contain the *Parameters* (see Section 4.4.2.2) element. There is only one attributes possible: id. This **MAY** be used to track state. A detailed description follows:

- **id** - Identifying attribute that **MAY** be used to track state.

4.4.2.7 Datum

```
<nmwg:datum xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" />
```

Table 15: Datum Element Specifics

| Datum Element | |
|------------------------|----------------------------------|
| localname | datum |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | undefined |
| nested elements | undefined |
| required | no |

The datum element **SHOULD** be used to relay information. Common uses are to return measurement observations (e.g. time and value pairs) or even status (e.g. error messages). We leave the attributes and nested elements purposely undefined as they **MAY** differ in various profiles of this document.

4.4.3 Response Message Example

The following examples demonstrate some of the possible uses and layouts of response messages in the base protocol. These examples are not an attempt to be exhaustive and are not indicative of a particular service.

The first example is the most common form of response message containing a single metadata and data pair. This would be indicative of success.

```

<!-- Begin XML -->

<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="response"
  id="message1"
  messageIdRef="someothermessage">

  <metadata id="m1">
    <!-- metadata -->
  </metadata>

  <data id="d1" metadatIdRef="m1">
    <!-- datum stuffs -->
  </data>

</message>

<!-- End XML -->

```

The second example is similar, although it features two pairs.

```

<!-- Begin XML -->

<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="response"
  id="message1"
  messageIdRef="someothermessage">

  <metadata id="m1">
    <!-- metadata -->
  </metadata>

  <data id="d1" metadatIdRef="m1">
    <!-- datum stuffs -->
  </data>

  <metadata id="m2">
    <!-- another metadata -->
  </metadata>

  <data id="d2" metadatIdRef="m2">
    <!-- datum stuffs -->
  </data>

</message>

<!-- End XML -->

```

The final example demonstrates an error condition. Note that this **MAY** contain multiple pairs if sent, and it **MAY** be possible to have success for some, and errors for others.

```

<!-- Begin XML -->

<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="response"
  id="message1"
  messageIdRef="someothermessage">

  <metadata id="m1">
    <!-- some error -->
  </metadata>

  <data id="d1" metadatIdRef="m1">
    <!-- some error message -->
  </data>

</message>

<!-- End XML -->

```

5 Information Chaining

Since inception a key goal has been extension. The authors of the original schemata realized that not every situation could easily be described through the basic constructs; extending the basic building blocks to complex situations **MUST** be paramount. Uncharted concepts could be represented with newly created constructs each time a foreign abstraction came to light; but extension and backwards compatibility **MUST** be favored over quick and easy solutions. Therefore, basic extension mechanisms, known as chaining, are the recognized procedure to extend metadata constructs as well as express other operations on the underlying data.

This section presents the major uses of chaining; note that individual service implementations **MAY** choose to strictly or loosely interpret these guidelines for the sake of performance or protection. The protocol itself offers no specific guidance on these issues in favor of simply describing the structural composition of both the input data and the resulting output.

Chaining itself has taken on two major forms: *merge chaining* described in Section 5.1 and *filter chaining* described in Section 5.2. These two instances will be described first in broad terms that explain the logic and reasoning of why each operation makes sense, and in what context they **SHOULD** be employed. The specific syntax and transformation steps will be presented in the next section.

5.1 Merge Chaining

As the name implies, we intend to *merge* or combine metadata elements through this structure. There are many things we **MAY** consider when describing this operation:

- Which elements are *mergeable*?
- How much *recursion* is needed for merge-able elements?
- When **SHOULD** we *duplicate* elements?
- When **SHOULD** we *replace* elements in the course of merging?

As stated previously, the schemata itself does not offer any suggestions as to what is a *good merge* vs. a *bad merge*. There are no rules regarding which *types* of data **SHOULD** and **SHOULD NOT** be merged. There is no guidance on when we **SHOULD** duplicate or replace elements.

We **RECOMMEND** some very simple and succinct guidelines that services may implement for this particular style of merging. There **SHALL** always be exceptions to rules, therefore the reader is encouraged to think carefully about what a specific service **MAY** need when implementing this recommendation.

5.1.1 Mergeable Elements and Recursion

When merging we **SHOULD** first look at the *top-level* elements; namely subject, eventType, and parameters. When faced with two metadata blocks to be merged, we only wish to combine:

- *Like* Elements (e.g. sharing the same localname)
- Elements in the same namespace
- Elements sharing the same (or “similar”) eventType

When this first criteria is met, we **SHOULD** recurse downward and keep trying until we reach the bottom of the structure. How far should we venture into the XML structure looking for similarities or differences? This question does not have a definite answer such as *stop at the grandchild of the current element*. While this **MAY** be frustrating, domain knowledge **MAY** help you make a passable decision especially with regards to topology based elements.

Like elements that do not share a common namespace **SHALL** require special rules that **MAY** differ from service to service. Depending on the level of protection or speed we wish to attain, these rules **MAY** vary. Service and protocol documentation **SHALL** fill in details beyond the scope of this work.

5.1.2 Duplication, Augmentation, and Replacement

When are faced with *like* elements that **MAY NOT** share a common namespace, we **SHOULD NOT** combine. We **MAY** try to find the *least significant* namespace and work from there. Additionally we **MAY** run into items that are *exactly* the same (such as certain *parameters*, or *eventTypes*). In some cases we **SHOULD** take care to *add* all of these together to make duplicates; other cases **MAY** dictate total replacement. Specific rule such as these are best left to a service designer.

As an example of extreme cases, consider taking a very safe approach to the combining of elements (i.e. not merging *like* elements with different namespaces). This approach will ensure that we protect the schema differences but **MAY** result in many more *wrong* answers when it comes to searching. The converse is a very dangerous approach where we merge items that could be different on the inside. This **MAY** result in an approach similar to *I know what you meant* and could yield a more robust query mechanism (providing intuitive answers when something may not completely match, rejecting outright things that do not make sense).

5.1.3 Merge Chaining Examples

A classic example of merge chaining is to partially specify a metadata (leaving out perhaps one unspecified element) and then constructing new elements from this original. This example does not feature any *overwriting* of duplicate elements.

Take for example a physical *Layer 3* interface used to measure SNMP data. If we wanted to specify the two common *directions* (*in* and *out*) we could construct a chain similar to the below example.

```
<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
    </nmwgt:interface>
  </netutil:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="m1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s2">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:direction>in</nmwgt:direction>
    </nmwgt:interface>
  </netutil:subject>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m3" metadataIdRef="m1">
```



```

<netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s3">
  <nmgwt:interface xmlns:nmgwt="http://ggf.org/ns/nmwg/topology/2.0/">
    <nmgwt:direction>out</nmgwt:direction>
  </nmgwt:interface>
</netutil:subject>
</nmwg:metadata>

```

Note that the chaining is performed via the use of the *metadataIdRef* tag in the metadata element. This is a signal for services (specifically the SNMP MA or RRD MA) to keep looking deeper in an effort to resolve the chains. The Figure 5 demonstrates the linking between the metadata elements. The resulting XML structure after chaining is also listed below.

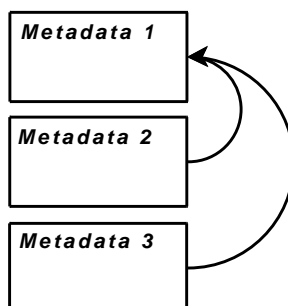


Figure 5: Graphical representation of chaining.

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s1">
    <nmgwt:interface xmlns:nmgwt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmgwt:ifAddress type="ipv4">127.0.0.1</nmgwt:ifAddress>
      <nmgwt:hostName>localhost</nmgwt:hostName>
      <nmgwt:ifName>eth0</nmgwt:ifName>
      <nmgwt:ifIndex>2</nmgwt:ifIndex>
      <nmgwt:capacity>1000000000</nmgwt:capacity>
    </nmgwt:interface>
  </netutil:subject>
  <nmgwt:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmgwt:eventType>
  <nmgwt:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmgwt:eventType>
  <nmgwt:parameters id="p1">
    <nmgwt:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmgwt:parameter>
    <nmgwt:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmgwt:parameter>
  </nmgwt:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="m1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s1">
    <nmgwt:interface xmlns:nmgwt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmgwt:ifAddress type="ipv4">127.0.0.1</nmgwt:ifAddress>
      <nmgwt:hostName>localhost</nmgwt:hostName>
      <nmgwt:ifName>eth0</nmgwt:ifName>
      <nmgwt:ifIndex>2</nmgwt:ifIndex>
      <nmgwt:capacity>1000000000</nmgwt:capacity>
      <nmgwt:direction>in</nmgwt:direction>
    </nmgwt:interface>
  </netutil:subject>
  <nmgwt:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmgwt:eventType>
  <nmgwt:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmgwt:eventType>
  <nmgwt:parameters id="p1">
    <nmgwt:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmgwt:parameter>
    <nmgwt:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmgwt:parameter>
  </nmgwt:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m3" metadataIdRef="m1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s1">
    <nmgwt:interface xmlns:nmgwt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmgwt:ifAddress type="ipv4">127.0.0.1</nmgwt:ifAddress>
      <nmgwt:hostName>localhost</nmgwt:hostName>
      <nmgwt:ifName>eth0</nmgwt:ifName>
      <nmgwt:ifIndex>2</nmgwt:ifIndex>
      <nmgwt:capacity>1000000000</nmgwt:capacity>

```

```

    <nmwgt:direction>out</nmwgt:direction>
  </nmwgt:interface>
</netutil:subject>
<nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
<nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
<nmwg:parameters id="p1">
  <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
  <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
</nmwg:parameters>
</nmwg:metadata>

```

For continuity, this example has not attempted to modify the *metadataIdRef* attribute. Implementations **MAY** choose to do so if they feel the need. Because eventTypes **MAY** be repeated (either as the *eventType* element or as *parameters*) we **MUST** take special care when merging them. The next example features multiple eventType merging. This example also features a so called *double chain* where the results of the first chaining operation **SHALL** feed into the process for the second. This is a common occurrence, and **SHOULD** be supported in services.

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostName>localhost</nmwgt:hostName>
      <nmwgt:ifName>eth0</nmwgt:ifName>
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
      <nmwgt:direction>in</nmwgt:direction>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="m1">
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m3" metadataIdRef="m2">
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

```

The resulting output and cartoon are pictured below. We did take two major issues into consideration: multiple *parameters* and *eventType* elements that did conflict, and the double chaining. Services that do not support multiple eventTypes (or simply wish to not implement a naive form of chaining) **SHOULD NOT** worry about special cases such as Figure 6.

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostName>localhost</nmwgt:hostName>
      <nmwgt:ifName>eth0</nmwgt:ifName>
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
      <nmwgt:direction>in</nmwgt:direction>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="m1">

```

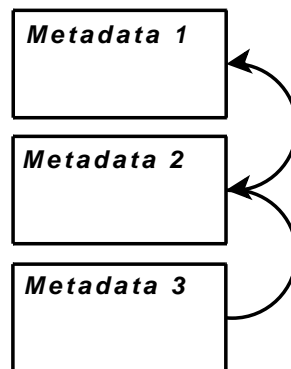


Figure 6: Alternate graphical representation of chaining.

```
<nmwg:subject id="s1">
  <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
    <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
    <nmwgt:hostname>localhost</nmwgt:hostname>
    <nmwgt:ifName>eth0</nmwgt:ifName>
    <nmwgt:ifIndex>2</nmwgt:ifIndex>
    <nmwgt:capacity>1000000000</nmwgt:capacity>
    <nmwgt:direction>in</nmwgt:direction>
  </nmwgt:interface>
</nmwg:subject>
<nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
<nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
<nmwg:parameters id="p1">
  <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
  <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
</nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m3" metadataIdRef="m2">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
      <nmwgt:direction>in</nmwgt:direction>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>
```

Services **MAY** treat particular elements (such as eventTypes and parameters with certain *name* attributes) in a special way. The service is careful not to overwrite or lose any information and will only *add* these items together. This is not the case for any element though, consider the following example.

```
<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
      <nmwgt:direction>in</nmwgt:direction>
    </nmwgt:interface>
  </nmwg:subject>
```

```

<nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
<nmwg:parameters id="p1">
  <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
</nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifName>eth1</nmwgt:ifName>
      <nmwgt:direction>out</nmwgt:direction>
    </nmwgt:interface>
  </nmwg:subject>
</nmwg:metadata>

```

Note that we probably wanted to change the direction for this particular interface, not necessarily the *ifName* element. The output of this chain is shown below.

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
      <nmwgt:direction>in</nmwgt:direction>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth1</nmwgt:ifName>
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
      <nmwgt:direction>out</nmwgt:direction>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

```

This example shows that it is very easy to introduce semantic errors when designing a chain instance. It also shows that the service **MAY NOT** be interested in protecting a poorly designed chain from being accepted. It is possible to build in different rules instead of *last seen value* such as *first seen*, *original*, or other combinations. It is imperative that services describe their own implementations of chaining, particularly when interoperability becomes an issue.

A final example comes when we deal with items with the same *localname*, but perhaps a different *namespace*. There are several approaches that can be taken to dealing with this type of situation. The SNMP example follows a safe approach of simply adding all of the elements in question and not attempting to internally merge at all. This causes *unreadable* metadata in many cases, but does not permit *data pollution*.

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>

```

```

<nmwg:parameters id="p1">
  <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
</nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s2">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:direction>in</nmwgt:direction>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
    </nmwgt:interface>
  </netutil:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

```

There are three approaches that I will illustrate here: *safe yet stupid*, *dangerous yet intelligent*, and finally *slow and steady*. The last approach is sometimes used in practice; finding the proper balance will require some thought (depending on how sensing or accurate a service wishes to become). Approach one yields output similar to the below example.

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s2">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:direction>in</nmwgt:direction>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
    </nmwgt:interface>
  </netutil:subject>
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

```

Note that this is not schema valid, and presumably would not return results from the backend storage. This is rather ironic given that we are trying to preserve validity on the schema side, yet still generate a clearly invalid result. The other end of the spectrum gives a result such as the example below.

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>

```

```

</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s2">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:direction>in</nmwgt:direction>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
    </nmwgt:interface>
  </netutil:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

```

The *stupid* part of this comes from not caring about *namespaces*, and only merging based on *localname*. Because the source metadata featured the *netutil* namespace it remains and all other items are added to it.

The approach taken by some services is to have a little *domain* knowledge before making a quick judgement. Knowing full well that *nmwg* is a more general namespace than *netutil*, the service tries to guess the intent and goes with the most general namespace in order to support a richer query set. Internally anything that utilizes the *nmwg* namespace receives a wild card when performing searches. When we are faced with a choice between specific and general, the service errs on the side of general. An example of this merge is below.

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="1">
  <nmwg:subject id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostname>localhost</nmwgt:hostname>
      <nmwgt:ifName>eth0</nmwgt:ifName>
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:direction>in</nmwgt:direction>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

```

A final question remains: what happens if you are dealing with two very specific namespaces such as this example.

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <neterr:subject xmlns:neterr="http://ggf.org/ns/nmwg/characteristic/errors/2.0/" id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
    </nmwgt:interface>
  </neterr:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:parameter>
  </nmwg:parameters>

```

```

</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s2">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:hostName>localhost</nmwgt:hostName>
    </nmwgt:interface>
  </netutil:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

```

Some services will still guess “general” and convert to the *nmwg* namespace. The resulting data set will take on an interesting look:

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <neterr:subject xmlns:neterr="http://ggf.org/ns/nmwg/characteristic/errors/2.0/" id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
    </nmwgt:interface>
  </neterr:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2" metadataIdRef="1">
  <nmwg:subject id="s2">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:hostName>localhost</nmwgt:hostName>
    </nmwgt:interface>
  </nmwg:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/errors/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

```

Clearly the two eventTypes (for utilization and errors) **MAY NOT** appear in the same metadata description, but again the service can try to help out a bit. eventType descriptions are interpreted as *or* operations when performing a query. Therefore even if our chain was constructed poorly, our final results will be rather robust (perhaps a bit more robust than needed). The service designers will no doubt settle on an approach that fits well for the data they are exposing.

5.2 Filter Chaining

Filter chaining involves the application of a *filter* (or function) to the underlying dataset that a particular metadata describes. We can think of this much like a database operation, where the first metadata is used to select a broad range of data, and subsequent metadata elements that are chained in this manner are used to slowly whittle down the dataset to a very specific range.

Figure 7 illustrates the distinction between the various operators of a filter chain. The circles themselves represent the actual metadata description of a dataset (taken from the universe of all data). The intersection of these two metadata descriptions becomes the data set that we are interested in.

It is important to note that even though we are manipulating the data through this form of chaining, we **SHOULD** not be harming it, or the related metadata elements. Chaining in general is a non-destructive operation, although it is very possible that when implemented poorly response data corruption **MAY** occur.

Filter operations themselves can vary from time range selection to aggregations such as performing a cumulative distribution function (CDF). Describing all possible operators is well beyond the scope of this

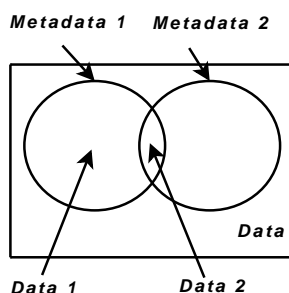


Figure 7: Diagram showing the intersection of information sets.

work. Current experience has named most statistical and database operations as candidates for filtering, although new uses being devised.

5.2.1 Operator Chaining Examples

Filter chaining is an easier concept to manage than merge chaining, partially because there are less rules and nuances to grasp. As stated above, it is easy to think of the dataset for the source metadata to be *input* to a function that is named by the metadata utilizing the filter chain. Consider Figure 8 as an example of the internal process of resolving a filter chain.

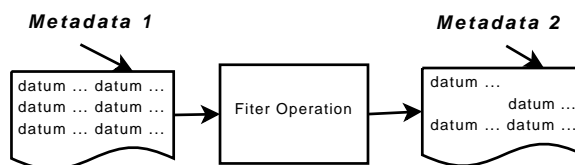


Figure 8: Graphical results of a filtering step on a dataset.

The syntax of filter chaining is similar to that of merge chaining (by using *metadataIdRef* attributes) but the placement is a bit different. Consider this example.

```
<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m1">
  <netutil:subject xmlns:netutil="http://ggf.org/ns/nmwg/characteristic/utilization/2.0/" id="s1">
    <nmwgt:interface xmlns:nmwgt="http://ggf.org/ns/nmwg/topology/2.0/">
      <nmwgt:ifAddress type="ipv4">127.0.0.1</nmwgt:ifAddress>
      <nmwgt:ifName>eth0</nmwgt:ifName>
      <nmwgt:ifIndex>2</nmwgt:ifIndex>
      <nmwgt:direction>in</nmwgt:direction>
      <nmwgt:capacity>1000000000</nmwgt:capacity>
    </nmwgt:interface>
  </netutil:subject>
  <nmwg:eventType>http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:eventType>
  <nmwg:eventType>http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:eventType>
  <nmwg:parameters id="p1">
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/tools/snmp/2.0</nmwg:parameter>
    <nmwg:parameter name="supportedEventType">http://ggf.org/ns/nmwg/characteristic/utilization/2.0</nmwg:parameter>
  </nmwg:parameters>
</nmwg:metadata>

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="m2">
  <select:subject id="s2" metadataIdRef="m1" xmlns:select="http://ggf.org/ns/nmwg/ops/select/2.0/" />
</nmwg:metadata>
```



```

<select:parameters id="param2c" xmlns:select="http://ggf.org/ns/nmwg/ops/select/2.0/">
  <nmwg:parameter name="startTime">1121472000</nmwg:parameter>
  <nmwg:parameter name="endTime">1121904000</nmwg:parameter>
  <nmwg:parameter name="consolidationFunction">AVERAGE</nmwg:parameter>
  <nmwg:parameter name="resolution">60</nmwg:parameter>
</select:parameters>
<nmwg:eventType>http://ggf.org/ns/nmwg/ops/select/2.0</nmwg:eventType>
</nmwg:metadata>

```

The reference is placed in the *subject* element in this case, as in merge chaining this is a signal to the service that filter chaining **SHALL** be required. This indicates that the *input* is the data pointed to by the first metadata and the *output* will be a subset of this. For the sake of these examples we **SHALL** be dealing with the *select* namespace as our filter of choice due to an abundance of examples and its common goal of filtering based on time. Other filter examples **SHOULD** work in the same manner.

Because the operations of a filter chain are essentially *internal* we do not present what resultant XML should look like. Currently services ignore many of the steps that may go into reforming the XML for response messages in favor of simply returning the *backend* representation of metadata. While quick and easy, this does lead to information loss (specifically when dealing with the various ways to implement merge chaining). Client applications may have no reason to see the original filter information, and therefore are built not to need it.

6 Result Codes

There are currently two hierarchical systems that **MAY** be used to return status information about services. Each of these approaches takes into account the facts that there are many diverse services as well as different status messages that **MAY** be returned. The later system also allows for versioning and backwards compatibility that the original attempt did not consider. Either system will accomplish the goal of providing a scalable and readable result code tree. It is recommended that the latter approach be adopted as it contains superior features.

The original idea for result codes comes from the perfSONAR[6] framework and is explained in [7]. This approach relies on a static tree of status information that is branched first by general features (i.e. success, error) and later by more specific characteristics such as service and error type. This hierarchy is missing the ability to offer versions of different codes that could become forward or backwards compatible (seen now in the *eventType* system that takes the form of *URI* strings).

```

success.
  ls.
    something
    somethingelse

error.
  ls.
    something
  ma.
    something
    somethingelse

```

The most recent description of this status paradigm follows the URI syntax already in use by other eventTypes and does allow version numbers to be assigned to the various messages. This **SHALL** allow services to pick and choose which versions they may support more readily.

```

http://schemas.perfsonar.net/status/
    success/
        ls/
            something/      1.0
            somethingelse/  1.0
                           1.1
        ma/
            something/      1.0
    error/
        ma/
            something/      1.0
                           1.1
            somethingelse/  1.0

```

7 Extension

This document **MUST** become the basis for all extension protocols. As a demonstration we include a protocol that **SHOULD** be implemented by all measurement services: the *Echo Protocol*. This protocol will incorporate the preceding work to eliminate duplication as much as possible, only specifying parts that are necessary for clarification. Each protocol extension may be treated as a separate work, and will include the necessary schema, analysis, and example sections.

7.1 Echo Protocol

The sole purpose of certain services, in a measurement framework, is to aid in the discovery and protection of the enterprise. The tasks undertaken by these critical components also require sound communication protocols based on the same formats used to exchange and store measurement data as defined by the **NM-WG** [5].

The *Echo Protocol* can be used by client applications as well as other services to ascertain the *liveness* of a given service. A well formatted **EchoRequest** message, when sent to a service, should trigger a similar **EchoResponse**. This interaction allows a client or service to gauge the responsiveness of a service; the potential to learn more information is also available for services who wish to implement more functionality.

The core functionality of the *Echo Protocol* is to provide a simple *request* and *response* capable of delivering rudimentary status information. This protocol for exchange is similar to other types of communication,

notably *ping*. While this protocol may seem to be a reinvention of existing tooling, the extension possibility far outweighs the duplication of functionality.

We present an overview of the messages used in this protocol, including both schematic designs and examples for the *Request Message* (see Section 7.1.2) and *Response Message* (see Section 7.1.3). We conclude with a brief description of where extensions are possible followed by some current examples in *Protocol Extension* (see Section 7.1.5).

7.1.1 Architecture

To ensure availability, each service **MUST** be able to respond to simple queries regarding status. Services that fail to answer a direct question **MAY** be experiencing difficulty, and therefore **MAY NOT** be able to complete interaction with interested parties. Client applications, services, or external monitoring tools **MAY** use this simple method to quickly come to conclusions regarding framework availability.

All services **MUST** contain the ability to respond to the most basic of *Echo Protocol* messages as described by this document. The minimum requirement of an *Echo Protocol* exchange is simply responding to a properly encoded request. *Echo Protocol* extensions **MAY** be built from this general protocol to elicit additional functionality on a service by service basis to do tasks such as test the capabilities of the service, receive statistics, or monitor erroneous behavior. The assignment of these other tasks within an **EchoRequest** message is valid provided that the basic structure is not compromised.

7.1.2 Request Message

The **EchoRequest** message can be initiated by a client application or service wanting to know the availability of some other service. The format of this message is minimal with respect to other protocol messages as the input is rather simple. The basic format described in this work for measurements has been adapted as a template for use in service communication as well, keeping the concept of metadata and data intact.

7.1.2.1 Request Message Schema

The following schema is a native description of the request schema as in the RELAX-NG[8] language. Through the use of tools such as Trang[10] and MSV[2] it is possible to convert this to other widely accepted formats such as XSD[11]. The following describes the **EchoRequest** schema. Note that this will only validate **EchoRequest** messages.

```
# Begin Schema

namespace nmwg="http://ggf.org/ns/nmwg/base/2.0/"

start =
  element nmwg:message {
    attribute id { xsd:string } &
    attribute messageIdRef { xsd:string }? &
    attribute type {
      "EchoRequest" |
      "http://schemas.perfsonar.net/messages/EchoRequest/1.0"
    } &
    element nmwg:metadata {
      attribute id { xsd:string } &
      element nmwg:eventType {
        "http://schemas.perfsonar.net/tools/admin/echo/2.0"
      }
    } &
    element nmwg:data {
      attribute id { xsd:string } &
      attribute metadataIdRef { xsd:string }
    }
  }
```

```
# End Schema
```

7.1.2.2 Request Message Analysis

The following is a breakdown of the elements featured in the schema.

7.1.2.2.1 Message

```
<nmwg:message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="EchoRequest"
  id="STRING">

  <nmwg:metadata />

  <nmwg:data />

</nmwg:message>
```

Table 16: Message Element Specifics

| Message Element | |
|------------------------|----------------------------------|
| localname | message |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, type |
| nested elements | metadata, data |
| required | yes |

This appears the same as it does in Section 4.3.2.1, the only notable exception is a requirement that the *type* attribute contain the values **EchoRequest** or **http://schemas.perfsonar.net/messages/EchoRequest/1.0**.

7.1.2.2.2 Metadata

```
<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="STRING">

  <nmwg:eventType />

</nmwg:metadata>
```

Table 17: Metadata Element Specifics

| Metadata Element | |
|------------------------|----------------------------------|
| localname | metadata |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, MetadataIdRef |
| nested elements | eventType |
| required | yes |

This appears the same as it does in Section 4.3.2.4, the only exception is specifying that *EventType* can be the *only* child.

7.1.2.2.3 EventType

```
<nmwg:eventType xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  http://schemas.perfsonar.net/tools/admin/echo/2.0
</nmwg:eventType>
```

Table 18: EventType Element Specifics

| EventType Element | |
|------------------------|----------------------------------|
| localname | eventType |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | N/A |
| nested elements | text |
| required | yes |

The *eventType* element is normally used to specify an action for a service or measurement. We utilize it for this role in the *Echo Protocol* by specifying the action of responding to an **EchoRequest**. There are no attributes permitted for this element, and only text can be used as a child, specifically text reporting <http://schemas.perfsonar.net/tools/admin/echo/2.0>.

Because this element is currently well defined into a specific role and purpose, the eventType is non-negotiable. **Extensions**, as discussed in Section 7.1.5, may be employed on a service by service basis to expand this basic specification, as long as the role is preserved.

7.1.2.2.4 Data

```
<nmwg:data xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  id="STRING"
  metadataIdRef="STRING" />
```

Table 19: Data Element Specifics

| Data Element | |
|------------------------|----------------------------------|
| localname | data |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, metadataIdRef |
| nested elements | N/A |
| required | yes |

This appears the same was as it does in Section 4.3.2.8.

7.1.2.3 Request Message Example

The first example shows a correct configuration for an **EchoRequest** message.

```
<!-- Begin XML -->
<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="EchoRequest"
```

```

        id="message1">

<metadata id="m1">
  <nmwg:eventType>
    http://schemas.perfsonar.net/tools/admin/echo/2.0
  </nmwg:eventType>
</metadata>

  <data id="d1" metadatIdRef="m1" />

</message>

<!-- End XML -->

```

The final example shows two incorrect items: the message *type* and *eventType* are both wrong. This **MUST** be rejected by a service.

```

<!-- Begin XML -->

<message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="EchoRequest"
  id="message2">

  <metadata id="m1">
    <nmwg:eventType>
      echo
    </nmwg:eventType>
  </metadata>

  <data id="d1" metadatIdRef="m1" />

</message>

<!-- End XML -->

```

7.1.3 Response Message

The **EchoResponse** message is a reply to a given **EchoRequest** message from a client application or service. The format of this message is minimal with respect to other protocol messages as the input is rather simple. The basic format described in this work for measurements has been adapted as a template for use in service communication as well, keeping the concept of metadata and data intact.

7.1.3.1 Response Message Schema

The following schema is a native description of the request schema as in the RELAX-NG[8] language. Through the use of tools such as Trang[10] and MSV[2] it is possible to convert this to other widely accepted formats such as XSD[11]. The following describes the **EchoRequest** schema. Note that this will only validate **EchoRequest** messages.

```

# Begin Schema

namespace nmwg="http://ggf.org/ns/nmwg/base/2.0/"
namespace nmwgr="http://ggf.org/ns/nmwg/result/2.0/"

start =
  element nmwg:message {
    attribute id { xsd:string } &
    attribute messageIdRef { xsd:string }? &
    attribute type {
      "EchoResponse" |
      "http://schemas.perfsonar.net/messages/EchoResponse/1.0"
    } &
    element nmwg:metadata {
      attribute id { xsd:string } &
      element nmwg:eventType {
        xsd:string
      }
    }
  }

```

```

    }
  } &
  element nmwg:data {
    attribute id { xsd:string } &
    attribute metadataIdRef { xsd:string } &
    element nmwgr:datum {
      xsd:string |
      attribute value { xsd:string }
    } |
    element nmwg:datum {
      xsd:string |
      attribute value { xsd:string }
    } |
  }
}
# End Schema

```

7.1.3.2 Response Message Analysis

The following is a breakdown of the elements featured in the schema.

7.1.3.2.1 Message

```

<nmwg:message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  type="EchoResponse"
  id="STRING">

  <nmwg:metadata />

  <nmwg:data />

</nmwg:message>

```

Table 20: Message Element Specifics

| Message Element | |
|------------------------|----------------------------------|
| localname | message |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, type |
| nested elements | metadata, data |
| required | yes |

This appears the same as it does in Section ??, the only exception is a requirement that the *type* attribute contain the values **EchoResponse** or **http://schemas.perfsonar.net/messages/EchoResponse/1.0**.

7.1.3.2.2 Metadata

```

<nmwg:metadata xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/" id="STRING">

  <nmwg:eventType />

</nmwg:metadata>

```

This appears the same as it does in Section 4.4.2.4, the only exception is specifying that *EventType* can be the *only* child.

Table 21: Metadata Element Specifics

| Metadata Element | |
|------------------------|----------------------------------|
| localname | metadata |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, metadataIdRef |
| nested elements | eventType |
| required | yes |

7.1.3.2.3 EventType

```
<nmwg:eventType xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/">
  http://schemas.perfsonar.net/tools/admin/echo/2.0
</nmwg:eventType>
```

or

```
<nmwg:eventType xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/">
  http://schemas.perfsonar.net/status/success/echo/1.0
</nmwg:eventType>
```

Table 22: EventType Element Specifics

| EventType Element | |
|------------------------|----------------------------------|
| localname | eventType |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | N/A |
| nested elements | text |
| required | yes |

The *eventType* element is normally used to specify an *action* for a service or measurement. We utilize it for this role in the *Echo Protocol* by specifying the action of a response to an **EchoRequest**. There are no attributes permitted for this element, and only text can be used as a child, specifically text reporting the *status* of the transaction. A complete list of available status strings is available in Section 7.1.4.

7.1.3.2.4 Data

```
<nmwg:data xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  id="STRING"
  metadataIdRef="STRING" />
```

This appears the same as it does in Section 4.4.2.5 with the exception of allowing **Datum** as a child element.

7.1.3.2.5 Datum

```
<nmwgr:datum xmlns:nmwgr="http://ggf.org/ns/nmwg/result/2.0">
  TEXT
</nmwgr:datum>
```


Table 23: Data Element Specifics

| Data Element | |
|------------------------|----------------------------------|
| localname | data |
| namespaces | http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | id, metadataIdRef |
| nested elements | datum |
| required | yes |

```
<!-- OR -->

<nmwg:datum xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/">
  TEXT
</nmwg:datum>
```

Table 24: Datum Element Specifics

| Datum Element | |
|------------------------|--|
| localname | datum |
| namespaces | http://ggf.org/ns/nmwg/result/2.0/, http://ggf.org/ns/nmwg/base/2.0/ |
| attributes | value |
| nested elements | text |
| required | yes |

The *datum* element describes measurements in most circumstances; the intent in the *Echo Protocol* is to report back a human readable *status* message. There is only one possible attribute accepted for this element, *value*, and it may be used in place of an enclosed text element. The text could be any message the service wishes to return.

7.1.3.3 Response Message Example

The first example shows a correct configuration for an **EchoResponse** message.

```
<!-- Begin XML -->

<nmwg:message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  xmlns:nmwgr="http://ggf.org/ns/nmwg/result/2.0/"
  type="EchoResponse"
  id="message3"
  messageIdRef="message1">

  <metadata id="m1">
    <nmwg:eventType>success.echo</nmwg:eventType>
  </metadata>

  <data id="d1" metadatIdRef="m1">
    <nmwgr:datum>The echo request has passed.</nmwgr:datum>
  </data>

</nmwg:message>

<!-- End XML -->
```

The final example shows the result of a failed **EchoRequest**.

```

<!-- Begin XML -->

<nmwg:message xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/"
  xmlns:nmwgr="http://ggf.org/ns/nmwg/result/2.0/"
  type="EchoResponse" id="message4" messageIdRef="message2">

  <metadata id="m1">
    <nmwg:eventType>error.echo</nmwg:eventType>
  </metadata>

  <data id="d1" metadatIdRef="m1">
    <nmwgr:datum>The echo request has failed.</nmwgr:datum>
  </data>

</nmwg:message>

<!-- End XML -->

```

7.1.4 Result Codes

The following new result codes can be incorporated into the echo protocol based on Section 6. We will introduce these into both styles to allow for backwards compatibility. The original style is presented first:

```

success.
    echo
error.
    echo

```

We can express the same information using the new URI style:

```

http://schemas.perfsonar.net/status/
    success/
        echo/
            1.0
    error/
        echo/
            1.0

```

Note that it is possible to add more specific error conditions as the functionality of this protocol increases. For example, if we are testing database connectivity it **MAY** make sense to add an *echo.db.* range of status. This is left as an exercise for extensions to this protocol.

7.1.5 Protocol Extension

There are two avenues for extension within the *Echo Protocol* as described in this document. It is possible to manipulate the values contained within the *eventType* to advance functionality, or through *schema modification* it is possible to add additional elements capable of handling a wider range of actions. Extensions that modify the schema for a given service **SHOULD NOT** change the themes presented in this protocol specification. It is imperative that all services respect the basic functionality in their quest to add new features.

7.1.5.1 eventType Extension

The current accepted eventType for the *Echo Protocol*'s **EchoRequest** message is <http://schemas.perfsonar.net/tools/admin/echo/2.0>. This *action* **MUST** be accepted by all services. By adding additional eventTypes with the same format it is possible to extract additional information via a service.

Consider simple service X. The designer of this service wishes to create a special behaviour for specific eventTypes. The following new eventTypes are added to her service code (and to her implementation of the schema):

- <http://schemas.perfsonar.net/tools/admin/echo/X/2.0> - Allows service contact information to be returned via *nmwgr:datum*
- <http://schemas.perfsonar.net/tools/admin/echo/X/contact/2.0> - Allows service contact information to be returned via *nmwgr:datum*
- <http://schemas.perfsonar.net/tools/admin/echo/X/stats/2.0> - Allows service usage statistics to be returned via *nmwgr:datum*
- <http://schemas.perfsonar.net/tools/admin/echo/X/db/2.0> - Allows a basic database test to be performed, the results of which are returned via *nmwgr:datum*

By simply allow some additional string matching to occur in the eventType it is now possible to receive additional data to check the health and status of the system.

7.1.5.2 Other Extensions

Similar to the above approach, it is possible to extend the schema by adding additional elements to increase functionality. Individuals pursuing this route should be comfortable with schema design in general and the layout of the **NM-WG** and **NMC-WG** schema descriptions specifically.

A simple extension involves allowing the commonly used parameters structure to reside in the **Message** of the **EchoRequest** message. This modification is presented below.

```
# Begin Schema

namespace nmwg="http://ggf.org/ns/nmwg/base/2.0/"

start =
  element nmwg:message {
    attribute id { xsd:string } &
    attribute messageIdRef { xsd:string }? &
    attribute type {
      "EchoRequest" |
      "http://schemas.perfsonar.net/messages/EchoRequest/1.0"
    } &
    element nmwg:metadata {
      attribute id { xsd:string } &
      element nmwg:eventType {
        "http://schemas.perfsonar.net/tools/admin/echo/2.0"
      } &
      element nmwg:parameters {
        element nmwg:parameter {
          attribute name { xsd:string }
        }
      }?
    } &
    element nmwg:data {
      attribute id { xsd:string } &
      attribute metadataIdRef { xsd:string }
    }
  }
```

End Schema

Building on the example in Section 7.1.5.1, the following example message shows how to ask for similar information as previously described.

```
<nmwg:message type="http://schemas.perfsonar.net/messages/EchoRequest/1.0"
  id="message.96587"
  xmlns:nmwg="http://ggf.org/ns/nmwg/base/2.0/">

  <nmwg:metadata id="metadata.21324">
    <nmwg:eventType>
      http://schemas.perfsonar.net/tools/admin/echo/2.0
    </nmwg:eventType>
    <nmwg:parameters>
      <nmwg:parameter name="status" />
    </nmwg:parameters>
  </nmwg:metadata>

  <nmwg:data id="data.54365" metadataIdRef="metadata.21324"/>

</nmwg:message>
```

While this method does require some additional schema modification, the result produced is the same as described in Section 7.1.5.1. An important consideration is the inclusion of *parameters* in an **EchoRequest**.

It **SHOULD** be noted that the extension methods proposed here preserve the underlying base protocol completely. Existing services that provide strict validation **MAY** reject messages that do not fit this standard explicitly, so be sure to design client applications appropriately.

8 Conclusion

The preceding work has described a simple protocol that will form the basis of communication for software exchanging both network measurements and topological information. This protocol is both minimal and flexible — extension to specific use cases is possible and expected. This work has been careful to retain the concepts described in other working groups including **NM-WG** and **NML-WG** in an effort to remain compatible with the primary data types.

9 Acknowledgements

The authors gratefully acknowledge the contributions of the perfSONAR consortium to this work. Specifically staff and member institutions from ESnet, Geant, Internet2, and RNP have provided extensive input and feedback into the implementation of this and all NMC protocols.

10 Notational Conventions

The key words “MUST”, “MUST NOT”, “REQUIRED”, “SHALL”, “SHALL NOT”, “SHOULD”, “SHOULD NOT”, “RECOMMENDED”, “MAY”, and “OPTIONAL” are to be interpreted as described in RFC 2119 [1]

11 Security Considerations

There are no security considerations.

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