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J. Case
SNMP Research, Inc.
K. McCloghrie
Hughes LAN Systems
M. Rose
Dover Beach Consulting, Inc.
S. Waldbusser
Carnegie Mellon University
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Structure of Management Information
for version 2 of the
Simple Network Management Protocol (SNMPv2)

Status of this Memo

This RFC specifies an IAB standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "IAB Official Protocol Standards" for the standardization state and status of this protocol. Distribution of this memo is unlimited.

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1. Introduction

A network management system contains: several (potentially many) nodes, each with a processing entity, termed an agent, which has access to management instrumentation; at least one management station; and, a management protocol, used to convey management information between the agents and management stations. Operations of the protocol are carried out under an administrative framework which defines both authentication and authorization policies.

Network management stations execute management applications which monitor and control network elements. Network elements are devices such as hosts, routers, terminal servers, etc., which are monitored and controlled through access to their management information.

Management information is viewed as a collection of managed objects, residing in a virtual information store, termed the Management Information Base (MIB). Collections of related objects are defined in MIB modules. These modules are written using a subset of OSI's Abstract Syntax Notation One (ASN.1) [1]. It is the purpose of this document, the Structure of Management Information (SMI), to define that subset.

The SMI is divided into three parts: module definitions, object definitions, and, trap definitions.

- (1) Module definitions are used when describing information modules. An ASN.1 macro, MODULE-IDENTITY, is used to concisely convey the semantics of an information module.
- (2) Object definitions are used when describing managed objects. An ASN.1 macro, OBJECT-TYPE, is used to concisely convey the syntax and semantics of a managed object.
- (3) Notification definitions are used when describing unsolicited transmissions of management information. An ASN.1 macro, NOTIFICATION-TYPE, is used to concisely convey the syntax and semantics of a notification.

1.1. A Note on Terminology

For the purpose of exposition, the original Internet-standard Network Management Framework, as described in RFCs 1155, 1157, and 1212, is termed the SNMP version 1 framework (SNMPv1). The current framework is termed the SNMP version 2 framework (SNMPv2).

2. Definitions

SNMPv2-SMI DEFINITIONS ::= BEGIN

-- the path to the root

internet OBJECT IDENTIFIER ::= { iso 3 6 1 }

directory OBJECT IDENTIFIER ::= { internet 1 }

mgmt OBJECT IDENTIFIER ::= { internet 2 }

experimental OBJECT IDENTIFIER ::= { internet 3 }

private OBJECT IDENTIFIER ::= { internet 4 }

enterprises OBJECT IDENTIFIER ::= { private 1 }

security OBJECT IDENTIFIER ::= { internet 5 }

snmpV2 OBJECT IDENTIFIER ::= { internet 6 }

-- transport domains

snmpDomains OBJECT IDENTIFIER ::= { snmpV2 1 }

-- transport proxies

snmpProxys OBJECT IDENTIFIER ::= { snmpV2 2 }

-- module identities

snmpModules OBJECT IDENTIFIER ::= { snmpV2 3 }

```
-- definitions for information modules

MODULE-IDENTITY MACRO ::=
BEGIN
    TYPE NOTATION ::=
        "LAST-UPDATED" value(Update UTCTime)
        "ORGANIZATION" Text
        "CONTACT-INFO" Text
        "DESCRIPTION" Text
        RevisionPart

    VALUE NOTATION ::=
        value(VALUE OBJECT IDENTIFIER)

    RevisionPart ::=
        Revisions
        | empty
    Revisions ::=
        Revision
        | Revisions Revision
    Revision ::=
        "REVISION" value(Update UTCTime)
        "DESCRIPTION" Text

    -- uses the NVT ASCII character set
    Text ::= "" string ""
END
```

```
OBJECT-IDENTITY MACRO ::=
BEGIN
    TYPE NOTATION ::=
        "STATUS" Status
        "DESCRIPTION" Text
        ReferPart

    VALUE NOTATION ::=
        value(VALUE OBJECT IDENTIFIER)

    Status ::=
        "current"
        | "obsolete"

    ReferPart ::=
        "REFERENCE" Text
        | empty

    Text ::= "" string ""
END
```



```
-- names of objects

ObjectName ::=
    OBJECT IDENTIFIER

-- syntax of objects

ObjectSyntax ::=
    CHOICE {
        simple
            SimpleSyntax,

        -- note that SEQUENCES for conceptual tables and
        -- rows are not mentioned here...

        application-wide
            ApplicationSyntax
    }

-- built-in ASN.1 types

SimpleSyntax ::=
    CHOICE {
        -- INTEGERS with a more restrictive range
        -- may also be used
        integer-value
            INTEGER (-2147483648..2147483647),

        string-value
            OCTET STRING,

        objectID-value
            OBJECT IDENTIFIER,

        -- only the enumerated form is allowed
        bit-value
            BIT STRING
    }
```

```
-- indistinguishable from INTEGER, but never needs more than
-- 32-bits for a two's complement representation
Integer32 ::=
    [UNIVERSAL 2]
    IMPLICIT INTEGER (-2147483648..2147483647)

-- application-wide types

ApplicationSyntax ::=
    CHOICE {
        ipAddress-value
            IpAddress,

        counter-value
            Counter32,

        gauge-value
            Gauge32,

        timeticks-value
            TimeTicks,

        arbitrary-value
            Opaque,

        nsapAddress-value
            NsapAddress,

        big-counter-value
            Counter64,

        unsigned-integer-value
            UInteger32
    }

-- in network-byte order
-- (this is a tagged type for historical reasons)
IpAddress ::=
    [APPLICATION 0]
    IMPLICIT OCTET STRING (SIZE (4))
```

```
-- this wraps
Counter32 ::=
    [APPLICATION 1]
        IMPLICIT INTEGER (0..4294967295)

-- this doesn't wrap
Gauge32 ::=
    [APPLICATION 2]
        IMPLICIT INTEGER (0..4294967295)

-- hundredths of seconds since an epoch
TimeTicks ::=
    [APPLICATION 3]
        IMPLICIT INTEGER (0..4294967295)

-- for backward-compatibility only
Opaque ::=
    [APPLICATION 4]
        IMPLICIT OCTET STRING

-- for OSI NSAP addresses
-- (this is a tagged type for historical reasons)
NsapAddress ::=
    [APPLICATION 5]
        IMPLICIT OCTET STRING (SIZE (1 | 4..21))

-- for counters that wrap in less than one hour with only 32 bits
Counter64 ::=
    [APPLICATION 6]
        IMPLICIT INTEGER (0..18446744073709551615)

-- an unsigned 32-bit quantity
UInteger32 ::=
    [APPLICATION 7]
        IMPLICIT INTEGER (0..4294967295)
```

```

-- definition for objects

OBJECT-TYPE MACRO ::=
BEGIN
    TYPE NOTATION ::=
        "SYNTAX" type(Syntax)
        UnitsPart
        "MAX-ACCESS" Access
        "STATUS" Status
        "DESCRIPTION" Text
        ReferPart
        IndexPart
        DefValPart

    VALUE NOTATION ::=
        value(VALUE ObjectName)

    UnitsPart ::=
        "UNITS" Text
        | empty

    Access ::=
        "not-accessible"
        | "read-only"
        | "read-write"
        | "read-create"

    Status ::=
        "current"
        | "deprecated"
        | "obsolete"

    ReferPart ::=
        "REFERENCE" Text
        | empty

    IndexPart ::=
        "INDEX"      "{ " IndexTypes " }"
        | "AUGMENTS" "{ " Entry      " }"
        | empty
    IndexTypes ::=
        IndexType
        | IndexTypes ", " IndexType

```

```
IndexType ::=
    "IMPLIED" Index
    | Index
Index ::=
    -- use the SYNTAX value of the
    -- correspondent OBJECT-TYPE invocation
    value(Indexobject ObjectName)
Entry ::=
    -- use the INDEX value of the
    -- correspondent OBJECT-TYPE invocation
    value(Entryobject ObjectName)

DefValPart ::=
    "DEFVAL" "{" value(Defval Syntax) "}"
    | empty

-- uses the NVT ASCII character set
Text ::= "" string ""
END
```

```
-- definitions for notifications

NOTIFICATION-TYPE MACRO ::=
BEGIN
    TYPE NOTATION ::=
        ObjectsPart
        "STATUS" Status
        "DESCRIPTION" Text
        ReferPart

    VALUE NOTATION ::=
        value(VALUE OBJECT IDENTIFIER)

    ObjectsPart ::=
        "OBJECTS" "{" Objects "}"
    | empty
    Objects ::=
        Object
    | Objects "," Object
    Object ::=
        value(Name ObjectName)

    Status ::=
        "current"
    | "deprecated"
    | "obsolete"

    ReferPart ::=
        "REFERENCE" Text
    | empty

    -- uses the NVT ASCII character set
    Text ::= "" string ""
END

END
```

3. Information Modules

An "information module" is an ASN.1 module defining information relating to network management.

The SMI describes how to use a subset of ASN.1 to define an information module. Further, additional restrictions are placed on "standard" information modules. It is strongly recommended that "enterprise-specific" information modules also adhere to these restrictions.

Typically, there are three kinds of information modules:

- (1) MIB modules, which contain definitions of inter-related managed objects, make use of the OBJECT-TYPE and NOTIFICATION-TYPE macros;
- (2) compliance statements for MIB modules, which make use of the MODULE-COMPLIANCE and OBJECT-GROUP macros [2]; and,
- (3) capability statements for agent implementations which make use of the AGENT-CAPABILITIES macros [2].

This classification scheme does not imply a rigid taxonomy. For example, a "standard" information module might include definitions of managed objects and a compliance statement. Similarly, an "enterprise-specific" information module might include definitions of managed objects and a capability statement. Of course, a "standard" information module may not contain capability statements.

All information modules start with exactly one invocation of the MODULE-IDENTITY macro, which provides contact and revision history. This invocation must appear immediately after any IMPORTs or EXPORTs statements.

3.1. Macro Invocation

Within an information module, each macro invocation appears as:

```
<descriptor> <macro> <clauses> ::= <value>
```

where <descriptor> corresponds to an ASN.1 identifier, <macro>

names the macro being invoked, and <clauses> and <value> depend on the definition of the macro.

An ASN.1 identifier consists of one or more letters, digits, or hyphens. The initial character must be a lower-case letter, and the final character may not be a hyphen. Further, a hyphen may not be immediately followed by another hyphen.

For all descriptors appearing in an information module, the descriptor shall be unique and mnemonic, and shall not exceed 64 characters in length. This promotes a common language for humans to use when discussing the information module and also facilitates simple table mappings for user-interfaces.

The set of descriptors defined in all "standard" information modules shall be unique. Further, within any information module, the hyphen is not allowed as a character in any descriptor.

Finally, by convention, if the descriptor refers to an object with a SYNTAX clause value of either Counter32 or Counter64, then the descriptor used for the object should denote plurality.

3.1.1. Textual Clauses

Some clauses in a macro invocation may take a textual value (e.g., the DESCRIPTION clause). Note that, in order to conform to the ASN.1 syntax, the entire value of these clauses must be enclosed in double quotation marks, and therefore cannot itself contain double quotation marks, although the value may be multi-line.

3.2. IMPORTing Symbols

To reference an external object, the IMPORTS statement must be used to identify both the descriptor and the module defining the descriptor.

Note that when symbols from "enterprise-specific" information modules are referenced (e.g., a descriptor), there is the possibility of collision. As such, if different objects with the same descriptor are IMPORTed, then this ambiguity is

resolved by prefixing the descriptor with the name of the information module and a dot ("."), i.e.,

"module.descriptor"

(All descriptors must be unique within any information module.)

Of course, this notation can be used even when there is no collision when IMPORTing symbols.

Finally, the IMPORTS statement may not be used to import an ASN.1 named type which corresponds to either the SEQUENCE or SEQUENCE OF type.

4. Naming Hierarchy

The root of the subtree administered by the Internet Assigned Numbers Authority (IANA) for the Internet is:

```
internet      OBJECT IDENTIFIER ::= { iso 3 6 1 }
```

That is, the Internet subtree of OBJECT IDENTIFIERS starts with the prefix:

```
1.3.6.1.
```

Several branches underneath this subtree are used for network management:

```
mgmt          OBJECT IDENTIFIER ::= { internet 2 }
experimental  OBJECT IDENTIFIER ::= { internet 3 }
private       OBJECT IDENTIFIER ::= { internet 4 }
enterprises   OBJECT IDENTIFIER ::= { private 1 }
```

However, the SMI does not prohibit the definition of objects in other portions of the object tree.

The mgmt(2) subtree is used to identify "standard" objects.

The experimental(3) subtree is used to identify objects being designed by working groups of the IETF. If an information module produced by a working group becomes a "standard" information module, then at the very beginning of its entry onto the Internet standards track, the objects are moved under the mgmt(2) subtree.

The private(4) subtree is used to identify objects defined unilaterally. The enterprises(1) subtree beneath private is used, among other things, to permit providers of networking subsystems to register models of their products.

5. Mapping of the MODULE-IDENTITY macro

The MODULE-IDENTITY macro is used to provide contact and revision history for each information module. It must appear exactly once in every information module. It should be noted that the expansion of the MODULE-IDENTITY macro is something which conceptually happens during implementation and not during run-time.

5.1. Mapping of the LAST-UPDATED clause

The LAST-UPDATED clause, which must be present, contains the date and time that this information module was last edited.

5.2. Mapping of the ORGANIZATION clause

The ORGANIZATION clause, which must be present, contains a textual description of the organization under whose auspices this information module was developed.

5.3. Mapping of the CONTACT-INFO clause

The CONTACT-INFO clause, which must be present, contains the name, postal address, telephone number, and electronic mail address of the person to whom technical queries concerning this information module should be sent.

5.4. Mapping of the DESCRIPTION clause

The DESCRIPTION clause, which must be present, contains a high-level textual description of the contents of this information module.

5.5. Mapping of the REVISION clause

The REVISION clause, which need not be present, is repeatedly used to describe the revisions made to this information module, in reverse chronological order. Each instance of this clause contains the date and time of the revision.

5.6. Mapping of the DESCRIPTION clause

The DESCRIPTION clause, which must be present for each REVISION clause, contains a high-level textual description of the revision identified in that REVISION clause.

5.7. Mapping of the MODULE-IDENTITY value

The value of an invocation of the MODULE-IDENTITY macro is an OBJECT IDENTIFIER. As such, this value may be authoritatively used when referring to the information module containing the invocation.

5.8. Usage Example

Consider how a skeletal MIB module might be constructed: e.g.,

```
FIZBIN-MIB DEFINITIONS ::= BEGIN

IMPORTS
    MODULE-IDENTITY, OBJECT-TYPE, experimental
    FROM SNMPv2-SMI;

fizbin MODULE-IDENTITY
    LAST-UPDATED "9210070433Z"
    ORGANIZATION "IETF SNMPv2 Working Group"
    CONTACT-INFO
        "
            Marshall T. Rose

            Postal: Dover Beach Consulting, Inc.
                  420 Whisman Court
                  Mountain View, CA 94043-2186
                  US

            Tel: +1 415 968 1052
            Fax: +1 415 968 2510

            E-mail: mrose@dbc.mtview.ca.us"
    DESCRIPTION
        "The MIB module for entities implementing the xxxx
        protocol."
    REVISION      "9210070433Z"
    DESCRIPTION
        "Initial version of this MIB module."
-- contact IANA for actual number
   ::= { experimental xx }

END
```

6. Mapping of the OBJECT-IDENTITY macro

The OBJECT-IDENTITY macro is used to define information about an OBJECT IDENTIFIER assignment. It should be noted that the expansion of the OBJECT-IDENTITY macro is something which conceptually happens during implementation and not during run-time.

6.1. Mapping of the STATUS clause

The STATUS clause, which must be present, indicates whether this definition is current or historic.

The values "current", and "obsolete" are self-explanatory.

6.2. Mapping of the DESCRIPTION clause

The DESCRIPTION clause, which must be present, contains a textual description of the object assignment.

6.3. Mapping of the REFERENCE clause

The REFERENCE clause, which need not be present, contains a textual cross-reference to an object assignment defined in some other information module.

6.4. Mapping of the OBJECT-IDENTITY value

The value of an invocation of the OBJECT-IDENTITY macro is an OBJECT IDENTIFIER.

6.5. Usage Example

Consider how an OBJECT IDENTIFIER assignment might be made:
e.g.,

```
fizbin69 OBJECT-IDENTITY
    STATUS current
    DESCRIPTION
        "The authoritative identity of the Fizbin 69
        chipset."
    ::= { fizbinChipSets 1 }
```

7. Mapping of the OBJECT-TYPE macro

The OBJECT-TYPE macro is used to define a managed object. It should be noted that the expansion of the OBJECT-TYPE macro is something which conceptually happens during implementation and not during run-time.

7.1. Mapping of the SYNTAX clause

The SYNTAX clause, which must be present, defines the abstract data structure corresponding to that object. The data structure must be one of the alternatives defined in the ObjectSyntax CHOICE.

Full ASN.1 sub-typing is allowed, as appropriate to the underlyingly ASN.1 type, primarily as an aid to implementors in understanding the meaning of the object. Any such restriction on size, range, enumerations or repertoire specified in this clause represents the maximal level of support which makes "protocol sense". Of course, sub-typing is not allowed for the Counter32 or Counter64 types, but is allowed for the Gauge32 type.

The semantics of ObjectSyntax are now described.

7.1.1. Integer32 and INTEGER

The Integer32 type represents integer-valued information between -2^{31} and $2^{31}-1$ inclusive (-2147483648 to 2147483647 decimal). This type is indistinguishable from the INTEGER type.

The INTEGER type may also be used to represent integer-valued information, if it contains named-number enumerations, or if it is sub-typed to be more constrained than the Integer32 type. In the former case, only those named-numbers so enumerated may be present as a value. Note that although it is recommended that enumerated values start at 1 and be numbered contiguously, any valid value for Integer32 is allowed for an enumerated value and, further, enumerated values needn't be contiguously assigned.

Finally, the hyphen character is not allowed as a part of the label name for any named-number enumeration.

7.1.2. OCTET STRING

The OCTET STRING type represents arbitrary binary or textual data. Although there is no SMI-specified size limitation for this type, MIB designers should realize that there may be implementation and interoperability limitations for sizes in excess of 255 octets.

7.1.3. OBJECT IDENTIFIER

The OBJECT IDENTIFIER type represents administratively assigned names. Any instance of this type may have at most 128 sub-identifiers. Further, each sub-identifier must not exceed the value $2^{32}-1$ (4294967295 decimal).

7.1.4. BIT STRING

The BIT STRING type represents an enumeration of named bits. This collection is assigned non-negative, contiguous values, starting at zero. Only those named-bits so enumerated may be present in a value.

A requirement on "standard" MIB modules is that the hyphen character is not allowed as a part of the label name for any named-bit enumeration.

7.1.5. IPAddress

The IPAddress type represents a 32-bit internet address. It is represented as an OCTET STRING of length 4, in network byte-order.

Note that the IPAddress type is a tagged type for historical reasons. Network addresses should be represented using an invocation of the TEXTUAL-CONVENTION macro [3].

7.1.6. Counter32

The Counter32 type represents a non-negative integer which monotonically increases until it reaches a maximum value of $2^{32}-1$ (4294967295 decimal), when it wraps around and starts increasing again from zero.

Counters have no defined "initial" value, and thus, a single value of a Counter has (in general) no information content. Discontinuities in the monotonically increasing value normally occur at re-initialization of the management system, and at other times as specified in the description of an object-type using this ASN.1 type. If such other times can occur, for example, the creation of an object instance at times other than re-initialization, then a corresponding object should be defined with a SYNTAX clause value of TimeStamp (a textual convention defined in [3]) indicating the time of the last discontinuity.

The value of the MAX-ACCESS clause for objects with a SYNTAX clause value of Counter32 is always "read-only".

A DEFVAL clause is not allowed for objects with a SYNTAX clause value of Counter32.

7.1.7. Gauge32

The Gauge32 type represents a non-negative integer, which may increase or decrease, but shall never exceed a maximum value. The maximum value can not be greater than $2^{32}-1$ (4294967295 decimal). The value of a Gauge has its maximum value whenever the information being modeled is greater or equal to that maximum value; if the information being modeled subsequently decreases below the maximum value, the Gauge also decreases.

7.1.8. TimeTicks

The TimeTicks type represents a non-negative integer which represents the time, modulo 2^{32} (4294967296 decimal), in hundredths of a second between two epochs. When objects are defined which use this ASN.1 type, the description of the object identifies both of the reference epochs.

For example, [3] defines the TimeStamp textual convention which is based on the TimeTicks type. With a TimeStamp, the first reference epoch is defined as when MIB-II's sysUpTime [7] was zero, and the second reference epoch is defined as the current value of sysUpTime.

7.1.9. Opaque

The Opaque type is provided solely for backward-compatibility, and shall not be used for newly-defined object types.

The Opaque type supports the capability to pass arbitrary ASN.1 syntax. A value is encoded using the ASN.1 Basic Encoding Rules [4] into a string of octets. This, in turn, is encoded as an OCTET STRING, in effect "double-wrapping" the original ASN.1 value.

Note that a conforming implementation need only be able to accept and recognize opaquely-encoded data. It need not be able to unwrap the data and then interpret its contents.

A requirement on "standard" MIB modules is that no object may have a SYNTAX clause value of Opaque.

7.1.10. NsapAddress

The NsapAddress type represents an OSI address as a variable-length OCTET STRING. The first octet of the string contains a binary value in the range of 0..20, and indicates the length in octets of the NSAP. Following the first octet, is the NSAP, expressed in concrete binary notation, starting with the most significant octet. A zero-length NSAP is used as a "special" address meaning "the default NSAP" (analogous to the IP address of 0.0.0.0). Such an NSAP is encoded as a single octet, containing the value 0. All other NSAPs are encoded in at least 4 octets.

Note that the NsapAddress type is a tagged type for historical reasons. Network addresses should be represented using an invocation of the TEXTUAL-CONVENTION macro [3].

7.1.11. Counter64

The Counter64 type represents a non-negative integer which monotonically increases until it reaches a maximum value of $2^{64}-1$ (18446744073709551615 decimal), when it wraps around and starts increasing again from zero.

Counters have no defined "initial" value, and thus, a single value of a Counter has (in general) no information content. Discontinuities in the monotonically increasing value normally occur at re-initialization of the management system, and at other times as specified in the description of an object-type using this ASN.1 type. If such other times can occur, for example, the creation of an object instance at times other than re-initialization, then a corresponding object should be defined with a SYNTAX clause value of TimeStamp (a textual convention defined in [3]) indicating the time of the last discontinuity.

The value of the MAX-ACCESS clause for objects with a SYNTAX clause value of Counter64 is always "read-only".

A requirement on "standard" MIB modules is that the Counter64 type may be used only if the information being modeled would wrap in less than one hour if the Counter32 type was used instead.

A DEFVAL clause is not allowed for objects with a SYNTAX clause value of Counter64.

7.1.12. UInteger32

The UInteger32 type represents integer-valued information between 0 and $2^{32}-1$ inclusive (0 to 4294967295 decimal).

7.2. Mapping of the UNITS clause

This UNITS clause, which need not be present, contains a textual definition of the units associated with that object.

7.3. Mapping of the MAX-ACCESS clause

The MAX-ACCESS clause, which must be present, defines whether it makes "protocol sense" to read, write and/or create an instance of the object. This is the maximal level of access for the object. (This maximal level of access is independent of any administrative authorization policy.)

The value "read-write" indicates that read and write access make "protocol sense", but create does not. The value "read-create" indicates that read, write and create access make "protocol sense". The value "not-accessible" indicates either an auxiliary object (see Section 7.7) or an object which is accessible only via a notificationn (e.g., snmpTrapOID [5]).

These values are ordered, from least to greatest: "not-accessible", "read-only", "read-write", "read-create".

If any columnar object in a conceptual row has "read-create" as its maximal level of access, then no other columnar object of the same conceptual row may have a maximal access of "read-write". (Note that "read-create" is a superset of "read-write".)

7.4. Mapping of the STATUS clause

The STATUS clause, which must be present, indicates whether this definition is current or historic.

The values "current", and "obsolete" are self-explanatory. The "deprecated" value indicates that the object is obsolete, but that an implementor may wish to support that object to foster interoperability with older implementations.

7.5. Mapping of the DESCRIPTION clause

The DESCRIPTION clause, which must be present, contains a textual definition of that object which provides all semantic definitions necessary for implementation, and should embody any information which would otherwise be communicated in any ASN.1 commentary annotations associated with the object.

7.6. Mapping of the REFERENCE clause

The REFERENCE clause, which need not be present, contains a textual cross-reference to an object defined in some other information module. This is useful when de-osifying a MIB module produced by some other organization.

7.7. Mapping of the INDEX clause

The INDEX clause, which must be present if that object corresponds to a conceptual row (unless an AUGMENTS clause is present instead), and must be absent otherwise, defines instance identification information for the columnar objects subordinate to that object.

Management operations apply exclusively to scalar objects. However, it is convenient for developers of management applications to impose imaginary, tabular structures on the ordered collection of objects that constitute the MIB. Each such conceptual table contains zero or more rows, and each row may contain one or more scalar objects, termed columnar objects. This conceptualization is formalized by using the OBJECT-TYPE macro to define both an object which corresponds to a table and an object which corresponds to a row in that table. A conceptual table has SYNTAX of the form:

SEQUENCE OF <EntryType>

where <EntryType> refers to the SEQUENCE type of its subordinate conceptual row. A conceptual row has SYNTAX of the form:

<EntryType>

where <EntryType> is a SEQUENCE type defined as follows:

<EntryType> ::= SEQUENCE { <type1>, ... , <typeN> }

where there is one <type> for each subordinate object, and each <type> is of the form:

<descriptor> <syntax>

where <descriptor> is the descriptor naming a subordinate

object, and <syntax> has the value of that subordinate object's SYNTAX clause, optionally omitting the sub-typing information. Further, these ASN.1 types are always present (the DEFAULT and OPTIONAL clauses are disallowed in the SEQUENCE definition). The MAX-ACCESS clause for conceptual tables and rows is "not-accessible".

For leaf objects which are not columnar objects, instances of the object are identified by appending a sub-identifier of zero to the name of that object. Otherwise, the INDEX clause of the conceptual row object superior to a columnar object defines instance identification information.

The instance identification information in an INDEX clause must specify object(s) such that value(s) of those object(s) will unambiguously distinguish a conceptual row. The syntax of those objects indicate how to form the instance-identifier:

- (1) integer-valued: a single sub-identifier taking the integer value (this works only for non-negative integers);
- (2) string-valued, fixed-length strings (or variable-length preceded by the IMPLIED keyword): 'n' sub-identifiers, where 'n' is the length of the string (each octet of the string is encoded in a separate sub-identifier);
- (3) string-valued, variable-length strings (not preceded by the IMPLIED keyword): 'n+1' sub-identifiers, where 'n' is the length of the string (the first sub-identifier is 'n' itself, following this, each octet of the string is encoded in a separate sub-identifier);
- (4) object identifier-valued: 'n+1' sub-identifiers, where 'n' is the number of sub-identifiers in the value (the first sub-identifier is 'n' itself, following this, each sub-identifier in the value is copied);
- (5) IpAddress-valued: 4 sub-identifiers, in the familiar a.b.c.d notation.
- (6) NsapAddress-valued: 'n' sub-identifiers, where 'n' is the length of the value (each octet of the value is encoded in a separate sub-identifier);

Note that the IMPLIED keyword can only be present for objects having a variable-length syntax (e.g., variable-length strings or object identifier-valued objects). Further, the IMPLIED keyword may appear at most once within the INDEX clause, and if so, is associated with the right-most object having a variable-length syntax. Finally, the IMPLIED keyword may not be used on a variable-length string object if that string might have a value of zero-length.

Instances identified by use of integer-valued objects should be numbered starting from one (i.e., not from zero). The use of zero as a value for an integer-valued index object should be avoided, except in special cases.

Objects which are both specified in the INDEX clause of a conceptual row and also columnar objects of the same conceptual row are termed auxiliary objects. The MAX-ACCESS clause for newly-defined auxiliary objects is "not-accessible". However, a conceptual row must contain at least one columnar object which is not an auxiliary object (i.e., the value of the MAX-ACCESS clause for such an object is either "read-only" or "read-create").

Note that objects specified in a conceptual row's INDEX clause need not be columnar objects of that conceptual row. In this situation, the DESCRIPTION clause of the conceptual row must include a textual explanation of how the objects which are included in the INDEX clause but not columnar objects of that conceptual row, are used in uniquely identifying instances of the conceptual row's columnar objects.

7.7.1. Creation and Deletion of Conceptual Rows

For newly-defined conceptual rows which allow the creation of new object instances and the deletion of existing object instances, there should be one columnar object with a SYNTAX clause value of RowStatus (a textual convention defined in [3]) and a MAX-ACCESS clause value of read-create. By convention, this is termed the status column for the conceptual row.

7.8. Mapping of the AUGMENTS clause

The AUGMENTS clause, which must not be present unless the object corresponds to a conceptual row, is an alternative to the INDEX clause. Every object corresponding to a conceptual row has either an INDEX clause or an AUGMENTS clause.

If an object corresponding to a conceptual row has an INDEX clause, that row is termed a base conceptual row; alternatively, if the object has an AUGMENTS clause, the row is said to be a conceptual row augmentation, where the AUGMENTS clause names the object corresponding to the base conceptual row which is augmented by this conceptual row extension. Instances of subordinate columnar objects of a conceptual row extension are identified according to the INDEX clause of the base conceptual row corresponding to the object named in the AUGMENTS clause. Further, instances of subordinate columnar objects of a conceptual row extension exist according to the same semantics as instances of subordinate columnar objects of the base conceptual row being augmented. As such, note that creation of a base conceptual row implies the correspondent creation of any conceptual row augmentations.

For example, a MIB designer might wish to define additional columns in an "enterprise-specific" MIB which logically extend a conceptual row in a "standard" MIB. The "standard" MIB definition of the conceptual row would include the INDEX clause and the "enterprise-specific" MIB would contain the definition of a conceptual row using the AUGMENTS clause.

Note that a base conceptual row may be augmented by multiple conceptual row extensions.

7.8.1. Relation between INDEX and AUGMENTS clauses

When defining instance identification information for a conceptual table:

- (1) If there is a one-to-one correspondence between the conceptual rows of this table and an existing table, then the AUGMENTS clause should be used.

- (2) Otherwise, if there is a sparse relationship between the conceptual rows of this table and an existing table, then an INDEX clause should be used which is identical to that in the existing table.
- (3) Otherwise, auxiliary objects should be defined within the conceptual row for the new table, and those objects should be used within the INDEX clause for the conceptual row.

7.9. Mapping of the DEFVAL clause

The DEFVAL clause, which need not be present, defines an acceptable default value which may be used at the discretion of a SNMPv2 entity acting in an agent role when an object instance is created.

During conceptual row creation, if an instance of a columnar object is not present as one of the operands in the correspondent management protocol set operation, then the value of the DEFVAL clause, if present, indicates an acceptable default value that a SNMPv2 entity acting in an agent role might use.

The value of the DEFVAL clause must, of course, correspond to the SYNTAX clause for the object. If the value is an OBJECT IDENTIFIER, then it must be expressed as a single ASN.1 identifier, and not as a collection of sub-identifiers.

Note that if an operand to the management protocol set operation is an instance of a read-only object, then the error 'notWritable' [6] will be returned. As such, the DEFVAL clause can be used to provide an acceptable default value that a SNMPv2 entity acting in an agent role might use.

By way of example, consider the following possible DEFVAL clauses:

ObjectSyntax	DEFVAL clause
-----	-----
Integer32	1
	-- same for Gauge32, TimeTicks, UInteger32
INTEGER	valid -- enumerated value
OCTET STRING	'ffffffffffff'H
OBJECT IDENTIFIER	sysDescr
BIT STRING	{ primary, secondary } -- enumerated values
IpAddress	'c0210415'H -- 192.33.4.21

Object types with SYNTAX of Counter32 and Counter64 may not have DEFVAL clauses, since they do not have defined initial values. However, it is recommended that they be initialized to zero.

7.10. Mapping of the OBJECT-TYPE value

The value of an invocation of the OBJECT-TYPE macro is the name of the object, which is an OBJECT IDENTIFIER, an administratively assigned name.

When an OBJECT IDENTIFIER is assigned to an object:

- (1) If the object corresponds to a conceptual table, then only a single assignment, that for a conceptual row, is present immediately beneath that object. The administratively assigned name for the conceptual row object is derived by appending a sub-identifier of "1" to the administratively assigned name for the conceptual table.
- (2) If the object corresponds to a conceptual row, then at least one assignment, one for each column in the conceptual row, is present beneath that object. The administratively assigned name for each column is derived by appending a unique, positive sub-identifier to the administratively assigned name for the conceptual row.
- (3) Otherwise, no other OBJECT IDENTIFIERS which are subordinate to the object may be assigned.

Note that the final sub-identifier of any administratively assigned name for an object shall be positive. A zero-valued final sub-identifier is reserved for future use.

Further note that although conceptual tables and rows are given administratively assigned names, these conceptual objects may not be manipulated in aggregate form by the management protocol.

7.11. Usage Example

Consider how one might define a conceptual table and its subordinates.

evalSlot OBJECT-TYPE

SYNTAX INTEGER

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The index number of the first unassigned entry in the evaluation table.

A management station should create new entries in the evaluation table using this algorithm: first, issue a management protocol retrieval operation to determine the value of evalSlot; and, second, issue a management protocol set operation to create an instance of the evalStatus object setting its value to underCreation(1). If this latter operation succeeds, then the management station may continue modifying the instances corresponding to the newly created conceptual row, without fear of collision with other management stations."

::= { eval 1 }

evalTable OBJECT-TYPE

SYNTAX SEQUENCE OF EvalEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"The (conceptual) evaluation table."

::= { eval 2 }

evalEntry OBJECT-TYPE

SYNTAX EvalEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry (conceptual row) in the evaluation table."

INDEX { evalIndex }

::= { evalTable 1 }

```
EvalEntry ::=
    SEQUENCE {
        evalIndex      Integer32,
        evalString      DisplayString,
        evalValue       Integer32,
        evalStatus      RowStatus
    }

evalIndex OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS   not-accessible
    STATUS      current
    DESCRIPTION
        "The auxiliary variable used for identifying
        instances of the columnar objects in the
        evaluation table."
    ::= { evalEntry 1 }

evalString OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS   read-create
    STATUS      current
    DESCRIPTION
        "The string to evaluate."
    ::= { evalEntry 2 }

evalValue OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS   read-only
    STATUS      current
    DESCRIPTION
        "The value when evalString was last executed."
    DEFVAL { 0 }
    ::= { evalEntry 3 }

evalStatus OBJECT-TYPE
    SYNTAX      RowStatus
    MAX-ACCESS   read-create
    STATUS      current
    DESCRIPTION
        "The status column used for creating, modifying,
        and deleting instances of the columnar objects in
        the evaluation table."
    DEFVAL { active }
    ::= { evalEntry 4 }
```

8. Mapping of the NOTIFICATION-TYPE macro

The NOTIFICATION-TYPE macro is used to define the information contained within an unsolicited transmission of management information (i.e., within either a SNMPv2-Trap-PDU or InformRequest-PDU). It should be noted that the expansion of the NOTIFICATION-TYPE macro is something which conceptually happens during implementation and not during run-time.

8.1. Mapping of the OBJECTS clause

The OBJECTS clause, which need not be present, defines the ordered sequence of MIB objects which are contained within every instance of the notification.

8.2. Mapping of the STATUS clause

The STATUS clause, which must be present, indicates whether this definition is current or historic.

The values "current", and "obsolete" are self-explanatory. The "deprecated" value indicates that the notification is obsolete, but that an implementor may wish to support that object to foster interoperability with older implementations.

8.3. Mapping of the DESCRIPTION clause

The DESCRIPTION clause, which must be present, contains a textual definition of the notification which provides all semantic definitions necessary for implementation, and should embody any information which would otherwise be communicated in any ASN.1 commentary annotations associated with the object. In particular, the DESCRIPTION clause should document which instances of the objects mentioned in the OBJECTS clause should be contained within notifications of this type.

8.4. Mapping of the REFERENCE clause

The REFERENCE clause, which need not be present, contains a textual cross-reference to a notification defined in some other information module. This is useful when de-osifying a

MIB module produced by some other organization.

8.5. Mapping of the NOTIFICATION-TYPE value

The value of an invocation of the NOTIFICATION-TYPE macro is the name of the notification, which is an OBJECT IDENTIFIER, an administratively assigned name.

Sections 4.2.6 and 4.2.7 of [6] describe how the NOTIFICATION-TYPE macro is used to generate a SNMPv2-Trap-PDU or InformRequest-PDU, respectively.

8.6. Usage Example

Consider how a linkUp trap might be described:

```
linkUp NOTIFICATION-TYPE
  OBJECTS { ifIndex }
  STATUS  current
  DESCRIPTION
    "A linkUp trap signifies that the SNMPv2 entity,
    acting in an agent role, recognizes that one of
    the communication links represented in its
    configuration has come up."
  ::= { snmpTraps 4 }
```

According to this invocation, the trap authoritatively identified as

```
{ snmpTraps 4 }
```

is used to report a link coming up.

Note that a SNMPv2 entity acting in an agent role can be configured to send this trap to zero or more SNMPv2 entities acting in a manager role, depending on the contents of the `aclTable` and `viewTable` [8] tables. For example, by judicious use of the `viewTable`, a SNMPv2 entity acting in an agent role might be configured to send all linkUp traps to one particular SNMPv2 entity, and linkUp traps for only certain interfaces to other SNMPv2 entities.

9. Refined Syntax

Some macros allow an object's syntax to be refined (e.g., the SYNTAX clause in the MODULE-COMPLIANCE macro [2]). However, not all refinements of syntax are appropriate. In particular, the object's primitive or application type must not be changed.

Further, the following restrictions apply:

object syntax	Restrictions to Refinement on			
	range	enumeration	size	repertoire
-----	-----	-----	----	-----
INTEGER	(1)	(2)	-	-
OCTET STRING	-	-	(3)	(4)
OBJECT IDENTIFIER	-	-	-	-
BIT STRING	-	(2)	-	-
IpAddress	-	-	-	-
Counter32	-	-	-	-
Gauge32	(1)	-	-	-
TimeTicks	-	-	-	-
NsapAddress	-	-	-	-
Counter64	-	-	-	-

where:

- (1) the range of permitted values may be refined by raising the lower-bounds, by reducing the upper-bounds, and/or by reducing the alternative value/range choices;
- (2) the enumeration of named-values may be refined by removing one or more named-values;
- (3) the size in characters of the value may be refined by raising the lower-bounds, by reducing the upper-bounds, and/or by reducing the alternative size choices; or,
- (4) the repertoire of characters in the value may be reduced by further sub-typing.

Otherwise no refinements are possible.

Note that when refining an object with a SYNTAX clause value of Integer32 or UInteger32, the refined SYNTAX is expressed as an INTEGER and the restrictions of the table above are used.

10. Extending an Information Module

As experience is gained with a published information module, it may be desirable to revise that information module.

To begin, the invocation of the MODULE-IDENTITY macro should be updated to include information about the revision. Usually, this consists of updating the LAST-UPDATED clause and adding a pair of REVISION and DESCRIPTION clauses. However, other existing clauses in the invocation may be updated.

Note that the module's label (e.g., "FIZBIN-MIB" from the example in Section 5.8), is not changed when the information module is revised.

10.1. Object Assignments

If any non-editorial change is made to any clause of a object assignment, then the OBJECT IDENTIFIER value associated with that object assignment must also be changed, along with its associated descriptor.

10.2. Object Definitions

An object definition may be revised in any of the following ways:

- (1) A SYNTAX clause containing an enumerated INTEGER may have new enumerations added or existing labels changed.
- (2) A STATUS clause value of "current" may be revised as "deprecated" or "obsolete". Similarly, a STATUS clause value of "deprecated" may be revised as "obsolete".
- (3) A DEFVAL clause may be added or updated.
- (4) A REFERENCE clause may be added or updated.
- (5) A UNITS clause may be added.
- (6) A conceptual row may be augmented by adding new columnar objects at the end of the row.

- (7) Entirely new objects may be defined, named with previously unassigned OBJECT IDENTIFIER values.

Otherwise, if the semantics of any previously defined object are changed (i.e., if a non-editorial change is made to any clause other than those specifically allowed above), then the OBJECT IDENTIFIER value associated with that object must also be changed.

Note that changing the descriptor associated with an existing object is considered a semantic change, as these strings may be used in an IMPORTS statement.

Finally, note that if an object has the value of its STATUS clause changed, then the value of its DESCRIPTION clause should be updated accordingly.

10.3. Notification Definitions

A notification definition may be revised in any of the following ways:

- (1) A REFERENCE clause may be added or updated.

Otherwise, if the semantics of any previously defined notification are changed (i.e., if a non-editorial change is made to any clause other than those specifically allowed above), then the OBJECT IDENTIFIER value associated with that notification must also be changed.

Note that changing the descriptor associated with an existing notification is considered a semantic change, as these strings may be used in an IMPORTS statement.

Finally, note that if an object has the value of its STATUS clause changed, then the value of its DESCRIPTION clause should be updated accordingly.

11. Appendix: de-OSIfying a MIB module

There has been an increasing amount of work recently on taking MIBs defined by other organizations (e.g., the IEEE) and de-OSifying them for use with the Internet-standard network management framework. The steps to achieve this are straight-forward, though tedious. Of course, it is helpful to already be experienced in writing MIB modules for use with the Internet-standard network management framework.

The first step is to construct a skeletal MIB module, as shown earlier in Section 5.8. The next step is to categorize the objects into groups. Optional objects are not permitted. Thus, when a MIB module is created, optional objects must be placed in a additional groups, which, if implemented, all objects in the group must be implemented. For the first pass, it is wisest to simply ignore any optional objects in the original MIB: experience shows it is better to define a core MIB module first, containing only essential objects; later, if experience demands, other objects can be added.

11.1. Managed Object Mapping

Next for each managed object class, determine whether there can exist multiple instances of that managed object class. If not, then for each of its attributes, use the OBJECT-TYPE macro to make an equivalent definition.

Otherwise, if multiple instances of the managed object class can exist, then define a conceptual table having conceptual rows each containing a columnar object for each of the managed object class's attributes. If the managed object class is contained within the containment tree of another managed object class, then the assignment of an object is normally required for each of the "distinguished attributes" of the containing managed object class. If they do not already exist within the MIB module, then they can be added via the definition of additional columnar objects in the conceptual row corresponding to the contained managed object class.

In defining a conceptual row, it is useful to consider the optimization of network management operations which will act upon its columnar objects. In particular, it is wisest to avoid defining more columnar objects within a conceptual row,

than can fit in a single PDU. As a rule of thumb, a conceptual row should contain no more than approximately 20 objects. Similarly, or as a way to abide by the "20 object guideline", columnar objects should be grouped into tables according to the expected grouping of network management operations upon them. As such, the content of conceptual rows should reflect typical access scenarios, e.g., they should be organized along functional lines such as one row for statistics and another row for parameters, or along usage lines such as commonly-needed objects versus rarely-needed objects.

On the other hand, the definition of conceptual rows where the number of columnar objects used as indexes outnumbers the number used to hold information, should also be avoided. In particular, the splitting of a managed object class's attributes into many conceptual tables should not be used as a way to obtain the same degree of flexibility/complexity as is often found in MIBs with a myriad of optionals.

11.1.1. Mapping to the SYNTAX clause

When mapping to the SYNTAX clause of the OBJECT-type macro:

- (1) An object with BOOLEAN syntax becomes a TruthValue [3].
- (2) An object with INTEGER syntax becomes an Integer32.
- (3) An object with ENUMERATED syntax becomes an INTEGER with enumerations, taking any of the values given which can be represented with an Integer32.
- (4) An object with BIT STRING syntax but no enumerations becomes an OCTET STRING.
- (5) An object with a character string syntax becomes either an OCTET STRING, or a DisplayString [3], depending on the repertoire of the character string.
- (6) A non-tabular object with a complex syntax, such as REAL or EXTERNAL, must be decomposed, usually into an OCTET STRING (if sensible). As a rule, any object with a complicated syntax should be avoided.

- (7) Tabular objects must be decomposed into rows of columnar objects.

11.1.2. Mapping to the UNITS clause

If the description of this managed object defines a unit-basis, then mapping to this clause is straight-forward.

11.1.3. Mapping to the MAX-ACCESS clause

This is straight-forward.

11.1.4. Mapping to the STATUS clause

This is straight-forward.

11.1.5. Mapping to the DESCRIPTION clause

This is straight-forward: simply copy the text, making sure that any embedded double quotation marks are sanitized (i.e., replaced with single-quotes or removed).

11.1.6. Mapping to the REFERENCE clause

This is straight-forward: simply include a textual reference to the object being mapped, the document which defines the object, and perhaps a page number in the document.

11.1.7. Mapping to the INDEX clause

If necessary, decide how instance-identifiers for columnar objects are to be formed and define this clause accordingly.

11.1.8. Mapping to the DEFVAL clause

Decide if a meaningful default value can be assigned to the object being mapped, and if so, define the DEFVAL clause accordingly.

11.2. Action Mapping

Actions are modeled as read-write objects, in which writing a particular value results in a state change. (Usually, as a part of this state change, some action might take place.)

11.2.1. Mapping to the SYNTAX clause

Usually the Integer32 syntax is used with a distinguished value provided for each action that the object provides access to. In addition, there is usually one other distinguished value, which is the one returned when the object is read.

11.2.2. Mapping to the MAX-ACCESS clause

Always use read-write or read-create.

11.2.3. Mapping to the STATUS clause

This is straight-forward.

11.2.4. Mapping to the DESCRIPTION clause

This is straight-forward: simply copy the text, making sure that any embedded double quotation marks are sanitized (i.e., replaced with single-quotes or removed).

11.2.5. Mapping to the REFERENCE clause

This is straight-forward: simply include a textual reference to the action being mapped, the document which defines the action, and perhaps a page number in the document.

11.3. Event Mapping

Events are modeled as SNMPv2 notifications using NOTIFICATION-TYPE macro. However, recall that SNMPv2 emphasizes trap-directed polling. As such, few, and usually no, notifications, need be defined for any MIB module.

11.3.1. Mapping to the STATUS clause

This is straight-forward.

11.3.2. Mapping to the DESCRIPTION clause

This is straight-forward: simply copy the text, making sure that any embedded double quotation marks are sanitized (i.e., replaced with single-quotes or removed).

11.3.3. Mapping to the REFERENCE clause

This is straight-forward: simply include a textual reference to the notification being mapped, the document which defines the notification, and perhaps a page number in the document.

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Michael Sapich
Mike Scanlon, Interlan
Sam Schaen, MITRE
John Seligson, Ultra Network Technologies
Paul A. Serice, Corporation for Open Systems
Chris Shaw, Banyan Systems
Timon Sloane
Robert Snyder, Cisco Systems
Joo Young Song
Roy Spitier, Sprint
Einar Stefferud, Network Management Associates
John Stephens, Cayman Systems, Inc.
Robert L. Stewart, Xyplex, Inc. (chair)
Kaj Tesink, Bellcore
Dean Throop, Data General

Ahmet Tuncay, France Telecom-CNET
Maurice Turcotte, Racal Datacom
Warren Vik, INTERACTIVE Systems Corporation
Yannis Viniotis
Steven L. Waldbusser, Carnegie Mellon University
Timothy M. Walden, ACC
Alice Wang, Sun Microsystems
James Watt, Newbridge
Luanne Waul, Timeplex
Donald E. Westlake III, Digital Equipment Corporation
Gerry White
Bert Wijnen, IBM Corporation
Peter Wilson, 3Com Corporation
Steven Wong, Digital Equipment Corporation
Randy Worzella, IBM Corporation
Daniel Woycke, MITRE
Honda Wu
Jeff Yarnell, Protools
Chris Young, Cabletron
Kiho Yum, 3Com Corporation

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14. Security Considerations

Security issues are not discussed in this memo.

15. Authors' Addresses

Jeffrey D. Case
SNMP Research, Inc.
3001 Kimberlin Heights Rd.
Knoxville, TN 37920-9716
US

Phone: +1 615 573 1434
Email: case@snmp.com

Keith McCloghrie
Hughes LAN Systems
1225 Charleston Road
Mountain View, CA 94043
US

Phone: +1 415 966 7934
Email: kzm@hls.com

Marshall T. Rose
Dover Beach Consulting, Inc.
420 Whisman Court
Mountain View, CA 94043-2186
US

Phone: +1 415 968 1052
Email: mrose@dbc.mtview.ca.us

Steven Waldbusser
Carnegie Mellon University
4910 Forbes Ave
Pittsburgh, PA 15213
US

Phone: +1 412 268 6628
Email: waldbusser@cmu.edu

