                     Structure of Management Information
                            for Version 2 of the
              Simple Network Management Protocol (SNMPv2)

Status of this Memo

   This document specifies an Internet standards track protocol for the
   Internet community, and requests discussion and suggestions for
   improvements. Please refer to the current edition of the "Internet
   Official Protocol Standards" (STD 1) for the standardization state
   and status of this protocol. Distribution of this memo is unlimited.

1. Introduction

   A 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
   authentication, authorization, access control, and privacy policies.

   Management stations execute management applications which monitor and
   control managed elements. Managed elements are devices such as
   hosts, routers, terminal servers, etc., which are monitored and
   controlled via 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 an adapted 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 adapted subset, and to assign a set of associated
   administrative values.

   The SMI is divided into three parts: module definitions, object
   definitions, and, notification 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 (STD 16), 1157 (STD
   15), and 1212 (STD 16), 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

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

directory   OBJECT IDENTIFIER ::= { internet 1 }

mgmt   OBJECT IDENTIFIER ::= { internet 2 }
mib-2   OBJECT IDENTIFIER ::= { mgmt 1 }
transmission   OBJECT IDENTIFIER ::= { mib-2 10 }

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"
                  | "deprecated"
                  | "obsolete"

     ReferPart ::=
                   "REFERENCE" Text
                 | empty

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


-- names of objects

ObjectName ::=
     OBJECT IDENTIFIER

NotificationName ::=
     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                 -- includes Integer32
             INTEGER (-2147483648..2147483647),
```

```
            -- OCTET STRINGs with a more restrictive size
            -- may also be used
            string-value
                OCTET STRING (SIZE (0..65535)),

            objectID-value
                OBJECT IDENTIFIER
        }


-- 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,

        timeticks-value
            TimeTicks,

        arbitrary-value
            Opaque,

        big-counter-value
            Counter64,

        unsigned-integer-value  -- includes Gauge32
            Unsigned32
    }

-- 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)


-- an unsigned 32-bit quantity
-- indistinguishable from Gauge32
Unsigned32 ::=
    [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 counters that wrap in less than one hour with only 32 bits
Counter64 ::=
    [APPLICATION 6]
        IMPLICIT INTEGER (0..18446744073709551615)



-- definition for objects

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

    VALUE NOTATION ::=
                value(VALUE ObjectName)

    Syntax ::=
```

```
                    type(ObjectSyntax)
                  | "BITS" "{" Kibbles "}"
        Kibbles ::=
                    Kibble
                  | Kibbles "," Kibble
        Kibble ::=
                   identifier "(" nonNegativeNumber ")"

        UnitsPart ::=
                    "UNITS" Text
                  | empty

        Access ::=
                    "not-accessible"
                  | "accessible-for-notify"
                  | "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 NotificationName)

    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

-- definitions of administrative identifiers

zeroDotZero    OBJECT-IDENTITY
    STATUS     current
    DESCRIPTION
```

```
              "A value used for null identifiers."
     ::= { 0 0 }

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 will normally 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.

   The constructs of ASN.1 allowed in SNMPv2 information modules
   include: the IMPORTS clause, value definitions for OBJECT
   IDENTIFIERs, type definitions for SEQUENCEs (with restrictions),
   ASN.1 type assignments of the restricted ASN.1 types allowed in
   SNMPv2, and instances of ASN.1 macros defined in this document and in
   other documents [2, 3] of the SNMPv2 framework. Additional ASN.1
   macros may not be defined in SNMPv2 information modules.

   The names of all standard information modules must be unique (but
   different versions of the same information module should have the
   same name). Developers of enterprise information modules are
   encouraged to choose names for their information modules that will
   have a low probability of colliding with standard or other enterprise

   information modules. An information module may not use the ASN.1
   construct of placing an object identifier value between the module
   name and the "DEFINITIONS" keyword.

   All information modules start with exactly one invocation of the
   MODULE-IDENTITY macro, which provides contact information as well as
   revision history to distinguish between versions of the same
   information module. This invocation must appear immediately after
   any IMPORTs 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. (Note that this definition of a descriptor
   applies to all macros defined in this memo and in [2].)

   For the purposes of this specification, an ASN.1 identifier consists
   of one or more letters or digits, and its initial character must be a
   lower-case letter. (Note that hyphens are not allowed by this
   specification, even though hyphen is allowed by [1]. This
   restriction enables arithmetic expressions in languages which use the
   minus sign to reference these descriptors without ambiguity.)

   For all descriptors appearing in an information module, the
   descriptor shall be unique and mnemonic, and shall not exceed 64
   characters in length. (However, descriptors longer than 32
   characters are not recommended.) 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.

   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 in which the
descriptor is defined, where the module is identified by its ASN.1
module name.

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.

3.3. Exporting Symbols

The ASN.1 EXPORTS statement is not allowed in SNMPv2 information
modules. All items defined in an information module are
automatically exported.

3.4. ASN.1 Comments

Comments in ASN.1 commence with a pair of adjacent hyphens and end
with the next pair of adjacent hyphens or at the end of the line,
whichever occurs first.

3.5. OBJECT IDENTIFIER values

An OBJECT IDENTIFIER value is an ordered list of non-negative
numbers. For the SNMPv2 framework, each number in the list is
referred to as a sub-identifier, there are at most 128 sub-
identifiers in a value, and each sub-identifier has a maximum value
of $2^{32}-1$ (4294967295 decimal). All OBJECT IDENTIFIER values have at
least two sub-identifiers, where the value of the first sub-
identifier is one of the following well-known names:

```
         Value    Name
           0      ccitt
           1      iso
           2      joint-iso-ccitt
```

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.

Note that reference in an IMPORTS clause or in clauses of SNMPv2
macros to an information module is NOT through the use of the
'descriptor' of a MODULE-IDENTITY macro; rather, an information
module is referenced through specifying its module name.

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. The date and time
are represented in UTC Time format (see Appendix B).

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 (including the initial version) made to this
information module, in reverse chronological order (i.e., most recent
first). Each instance of this clause contains the date and time of
the revision. The date and time are represented in UTC Time format
(see Appendix B).

5.5.1. Mapping of the DESCRIPTION sub-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.

5.6. 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

   specifying an OBJECT IDENTIFIER value to refer to the information
   module containing the invocation.

5.7. 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 "9505241811Z"
    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      "9505241811Z"
    DESCRIPTION
            "The latest version of this MIB module."
    REVISION      "9210070433Z"
    DESCRIPTION
            "The 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. All administrative OBJECT IDENTIFIER
   assignments which define a type identification value (see
   AutonomousType, a textual convention defined in [3]) should be
   defined via the OBJECT-IDENTITY macro. 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. The
   "deprecated" value indicates that the definition is obsolete, but
   that an implementor may wish to support it to foster interoperability
   with older implementations.

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 type of 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.

   For leaf objects which are not columnar objects (i.e., not contained
   within a conceptual table), 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.

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 following: a base type, the BITS construct, or a textual
   convention. (SEQUENCE OF and SEQUENCE are also possible for
   conceptual tables, see section 7.1.12). The base types are those
   defined in the ObjectSyntax CHOICE. A textual convention is a
   newly-defined type defined as a sub-type of a base type [3].

   A extended subset of the full capabilities of ASN.1 sub-typing is
   allowed, as appropriate to the underingly ASN.1 type. Any such
   restriction on size, range, enumerations or repertoire specified in
   this clause represents the maximal level of support which makes
   "protocol sense". Restrictions on sub-typing are specified in detail
   in Section 9 and Appendix C of this memo.

   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. Both the INTEGER
   and Integer32 types may be sub-typed to be more constrained than the
   Integer32 type.

   The INTEGER type may also be used to represent integer-valued
   information as named-number enumerations. In this 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, a label for a named-number enumeration must consist of one
or more letters or digits (no hyphens), up to a maximum of 64
characters, and the initial character must be a lower-case letter.
(However, labels longer than 32 characters are not recommended.)

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. The BITS construct

The BITS construct 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.
(Thus, enumerations must be assigned to consecutive bits; however,
see Section 9 for refinements of an object with this syntax.)

Although there is no SMI-specified limitation on the number of
enumerations (and therefore on the length of a value), MIB designers
should realize that there may be implementation and interoperability
limitations for sizes in excess of 128 bits.

Finally, a label for a named-number enumeration must consist of one
or more letters or digits (no hyphens), up to a maximum of 64
characters, and the initial character must be a lower-case letter.
(However, labels longer than 32 characters are not recommended.)

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 either "read-only" or "accessible-for-notify".

   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 the time when sysUpTime [5] was zero, and the
   second reference epoch is defined as the current value of sysUpTime.

   The TimeTicks type may not be sub-typed.

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. 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 either "read-only" or "accessible-for-notify".

   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.

7.1.11. Unsigned32

   The Unsigned32 type represents integer-valued information between 0
   and 2^32-1 inclusive (0 to 4294967295 decimal).

7.1.12. Conceptual Tables

   Management operations apply exclusively to scalar objects. However,
   it is sometimes convenient for developers of management applications
   to impose an imaginary, tabular structure on an ordered collection of
   objects within 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,
   normally 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".

7.1.12.1. Creation and Deletion of Conceptual Rows

   For newly-defined conceptual rows which allow the creation of new
   object instances and/or 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.

7.2. 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, or to include its value in a notification. 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 an auxiliary object (see Section
   7.7). The value "accessible-for-notify" indicates an object which is
   accessible only via a notification (e.g., snmpTrapOID [5]).

   These values are ordered, from least to greatest: "not-accessible",
   "accessible-for-notify", "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 definition 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.

   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 (when preceded by the IMPLIED keyword):
     'n' sub-identifiers, where 'n' is the number of sub-identifiers in
     the value (each sub-identifier of the value is copied into a
     separate sub-identifier);

(5) object identifier-valued (when not preceded by the IMPLIED
     keyword): '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);

(6) IpAddress-valued: 4 sub-identifiers, in the familiar a.b.c.d
     notation.

   Note that the IMPLIED keyword can only be present for an object
   having a variable-length syntax (e.g., variable-length strings or
   object identifier-valued objects), Further, the IMPLIED keyword can

only be associated with the last object in the INDEX clause.
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 auxiliary objects is
"not-accessible", except in the following circumstances:

(1) within a MIB module originally written to conform to the SNMPv1
     framework, and later converted to conform to the SNMPv2 framework;
     or

(2) a conceptual row must contain at least one columnar object which is
     not an auxiliary object. In the event that all of a conceptual
     row's columnar objects are also specified in its INDEX clause, then
     one of them must be accessible, i.e., have a MAX-ACCESS clause of
     "read-only". (Note that this situation does not arise for a
     conceptual row allowing create access, since such a row will have a
     status column which will not be an auxiliary object.)

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.

7.8. 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 augmentation. (Thus, a conceptual row augmentation
cannot itself be augmented.) Instances of subordinate columnar
objects of a conceptual row augmentation 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 augmentation 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. On the other hand, it would be incorrect to use
the AUGMENTS clause for the relationship between RFC 1573's ifTable
and the many media-specific MIBs which extend it for specific media
(e.g., the dot3Table in RFC 1650), since not all interfaces are of
the same media.

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

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.
     For example, the relationship between RFC 1573's ifTable and a
     media-specific MIB which extends the ifTable for a specific media
     (e.g., the dot3Table in RFC 1650), is a sparse relationship.

(3) Otherwise, if no existing objects have the required syntax and
     semantics, then 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            DEFVAL { 1 }
                       -- same for Gauge32, TimeTicks, Unsigned32
  INTEGER              DEFVAL { valid } -- enumerated value
  OCTET STRING         DEFVAL { 'ffffffffffff'H }
  OBJECT IDENTIFIER    DEFVAL { sysDescr }
  BITS                 DEFVAL { { primary, secondary } }
                       -- enumerated values that are set
  IpAddress            DEFVAL { '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. (This example uses the RowStatus textual convention
   defined in [3].)

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 createAndGo(4) or createAndWait(5). 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 object types which are contained within every
   instance of the notification. An object type specified in this
   clause may not have an MAX-ACCESS clause of "not-accessible".

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 definition is obsolete, but
   that an implementor may wish to support the notification 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 notification. 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. In order to achieve compatibility
   with the procedures employed by proxy agents (see Section 3.1.2 of
   [7]), the next to last sub-identifier in the name of any newly-
   defined notification must have the value zero.

   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.

9. Refined Syntax

   Some macros have clauses which allows syntax to be refined,
   specifically: the SYNTAX clause of the OBJECT-TYPE macro, and the
   SYNTAX/WRITE-SYNTAX clauses of the MODULE-COMPLIANCE and AGENT-
   CAPABILITIES macros [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:

```
                         Restrictions to Refinement on
   object syntax       range    enumeration    size    repertoire
   ----------------    -----    -----------    ----    ----------
           INTEGER      (1)        (2)          -          -
         Integer32      (1)         -           -          -
        Unsigned32      (1)         -           -          -
       OCTET STRING      -          -          (3)        (4)
 OBJECT IDENTIFIER       -          -           -          -
              BITS       -         (2)          -          -
          IpAddress      -          -           -          -
         Counter32       -          -           -          -
         Counter64       -          -           -          -
           Gauge32      (1)         -           -          -
          TimeTicks      -          -           -          -
```

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 (note that for BITS, a refinement may cause the
      enumerations to no longer be contiguous);

(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. Further details on sub-typing
   are provided in Appendix C.

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
   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 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 A: 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 having enumerations becomes a BITS
     construct.

(5) An object with BIT STRING syntax but no enumerations becomes an
     OCTET STRING.

(6) An object with a character string syntax becomes either an OCTET
     STRING, or a DisplayString [3], depending on the repertoire of the
     character string.

(7) 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.

(8) 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.

12. Appendix B: UTC Time Format

   Several clauses defined in this document use the UTC Time format:

      YYMMDDHHMMZ

      where: YY - last two digits of year
             MM - month (01 through 12)
             DD - day of month (01 through 31)
             HH - hours (00 through 23)
             MM - minutes (00 through 59)
              Z - the character "Z" denotes Greenwich Mean Time (GMT).

   For example, "9502192015Z" represents 8:15pm GMT on 19 February 1995.

13. Appendix C: Detailed Sub-typing Rules

13.1. Syntax Rules

   The syntax rules for sub-typing are given below. Note that while
   this syntax is based on ASN.1, it includes some extensions beyond
   what is allowed in ASN.1, and a number of ASN.1 constructs are not
   allowed by this syntax.

      <integerSubType>
          ::= <empty>
            | "(" <range> ["|" <range>]... ")"

      <octetStringSubType>
          ::= <empty>
            | "(" "SIZE" "(" <range> ["|" <range>]... ")" ")"

      <range>
          ::= <value>
            | <value> ".." <value>

      <value>
          ::= "-" <number>
            | <number>
            | <hexString>
            | <binString>

      where:
          <empty>   is the empty string
          <number>   is a non-negative integer
          <hexString> is a hexadecimal string (i.e. 'xxxx'H)
          <binString> is a binary string (i.e. 'xxxx'B)

        <range> is further restricted as follows:
            - any <value> used in a SIZE clause must be non-negative.
            - when a pair of values is specified, the first value
              must be less than the second value.
            - when multiple ranges are specified, the ranges may
              not overlap but may touch. For example, (1..4 | 4..9)
              is invalid, and (1..4 | 5..9) is valid.
            - the ranges must be a subset of the maximum range of the
              base type.

13.2. Examples

Some examples of legal sub-typing:

        Integer32 (-20..100)
        Integer32 (0..100 | 300..500)
        Integer32 (300..500 | 0..100)
        Integer32 (0 | 2 | 4 | 6 | 8 | 10)
        OCTET STRING (SIZE(0..100))
        OCTET STRING (SIZE(0..100 | 300..500))
        OCTET STRING (SIZE(0 | 2 | 4 | 6 | 8 | 10))

Some examples of illegal sub-typing:

    Integer32 (150..100)   -- first greater than second
    Integer32 (0..100 | 50..500) -- ranges overlap
    Integer32 (0 | 2 | 0)   -- value duplicated
    Integer32 (MIN..-1 | 1..MAX) -- MIN and MAX not allowed
    Integer32 ((SIZE (0..34))   -- must not use SIZE
    OCTET STRING (0..100)   -- must use SIZE
    OCTET STRING (SIZE(-10..100)) -- negative SIZE

13.3. Rules for Textual Conventions

   Sub-typing of Textual Conventions (see [3]) is allowed but must be
   valid. In particular, each range specified for the textual
   convention must be a subset of a range specified for the base type.
   For example,

   Tc1 ::= INTEGER (1..10 | 11..20)
   Tc2 ::= Tc1 (2..10 | 12..15)   -- is valid
   Tc3 ::= Tc1 (4..8)   -- is valid
   Tc4 ::= Tc1 (8..12)   -- is invalid

14. Security Considerations

   Security issues are not discussed in this memo.

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16. Acknowledgements

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