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Management Information Base for Virtual Machines Controlled by a Hypervisor
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Abstract

This document defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet community. In particular, this specifies objects for managing virtual machines controlled by a hypervisor (a.k.a. virtual machine manager).

Status of this Memo

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1. Introduction

This document defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet community. In particular, this specifies objects for managing virtual machines controlled by a hypervisor (a.k.a. virtual machine managers). A hypervisor controls multiple virtual machines on a single physical machine by allocating resources to each virtual machine using virtualization technologies. Therefore, this MIB module contains information on virtual machines and their resources controlled by a hypervisor as well as hypervisor’s hardware and software information.

The design of this MIB module has been derived from enterprise specific MIB modules, namely a MIB module for managing guests of the Xen hypervisor, a MIB module for managing virtual machines controlled by the VMware hypervisor, and a MIB module using the libvirt programming interface to access different hypervisors.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. The Internet-Standard Management Framework

For a detailed overview of the documents that describe the current Internet-Standard Management Framework, please refer to section 7 of RFC 3410 [RFC3410]. Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies a MIB module that is compliant to the SMIv2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

3. Managed Objects for Virtual Machines Controlled by a Hypervisor

3.1. Managed Objects on Virtualization Environment

```
    +------------------------------------------------------------------+
    | +-------------------------------------------+                    |
    | | Virtual machine                           |                    |
    | |                                           |                    |
    | | +---------+ +---------+ +---------+       | .........          |
    | | | Virtual | | Virtual | | Virtual |       |                    |
    | +-| CPU     |-| memory  |-| storage |... ---+                    |
    |   +---------+ +---------+ +---------+                            |
    |            Virtual resources                                     |
    |                   ^                                              |
    |                   | Allocation using virtualization technologies |
    |                   |                                              |
    |                   +---------- Physical resources   ._____.       |
    |                       +--------+    .--------.    /       \      |
    |  +==============+     |        |   /________/|   *\_______/*     |
    +- || SNMP agent || - - |  CPU   | - | Memory |/ - | Storage | .. -+
    |  +==============+     +--------+   +--------+     \_______/      |
    | Hypervisor                                                       |
    +------------------------------------------------------------------+
```

A hypervisor allocates resources as virtual devices such as virtual CPU, virtual memory, virtual storage, and virtual network interface to multiple virtual machines controlled by the hypervisor from physical resources.

Figure 1: An example of a virtualization environment

On the common implementations of hypervisor softwares, a hypervisor allocates resources as virtual devices such as virtual CPUs, virtual memory, virtual storage, and virtual network interface to multiple virtual machines controlled by the hypervisor from physical resources. This document defines objects related to system and software information of a hypervisor, the list of virtual machines controlled by the hypervisor, and virtual resources allocated by the hypervisor to virtual machines. As shown in Figure 1, the virtual resource objects are defined as virtual devices. Consequently, this document specifies four specific types of virtual devices; CPUs (processors), memory, network interfaces, and storage devices. Note that physical resources are managed in HOST-RESOURCES-MIB [RFC2790]. In case that each virtual resource device object has a corresponding parent physical device managed in HOST-RESOURCES-MIB, the object of the virtual resource device contains a pointer to the physical device. The objects related to virtual network interfaces are mapped to the objects managed in IF-MIB [RFC2863].

The objects defined in this document are managed at a hypervisor and an SNMP agent is launched at the hypervisor to provide access to the objects. The objects are managed from the viewpoint of the operators of hypervisors, but not the operators of virtual machines; i.e., the objects do not take into account the actual resource utilization on each virtual machine but the resource allocation from the physical resources. For example, vmNetworIfIndex indicates the virtual interface associated with an interface of a virtual machine at the hypervisor, and consequently, the ‘in’ and ‘out’ directions denote ‘from a virtual machine to the hypervisor’ and ‘from the hypervisor to a virtual machine’, respectively. Moreover, vmStorageAllocatedSize denotes the size allocated by the hypervisor, but not the size actually used by the operating system on the virtual machine. This means that vmStorageDefinedSize and vmStorageAllocatedSize must not take different values when the vmStorageSourceType is ‘block’ or ‘raw’.

3.2. Overview of the MIB Module

The MIB module is organized into a group of scalars and tables. The scalars below ‘hypervisor’ provide basic information about the hypervisor. The ‘vmTable’ lists the virtual machines (guests) that are known to the hypervisor. The ‘vmCpuTable’ and ’vmCpuAffinityTable’ provide the mapping of virtual CPUs and their affinity to virtual machines. The ‘vmStorageTable’ and the ‘vmNetworkTable’ provide the mapping of logical storage areas and network interfaces to virtual machines.

```
    *: ‘vmAdminState’ write access
    !: Notification
    +-------------+   + - - - - - - - +
    | finite      |   | transient   |
    | vmOperState |   | vmOperState |
    +-------------+   + - - - - - - - +

    ================================================================

    +--------------+   + - - - - - - - +     +-------------+
    |  suspended   |<--| suspending  |     |   paused    |
    | !vmSuspended |   |             |     |  !vmPaused  |
    +--------------+   + - - - - - - - +     +-------------+
          |                ^ *suspended         ^ *paused
          |                |                    |
          v  *running      |         *running   |
    + - - - - - - - +   +-------------+<----------+    + - - - - - - - +
    |  resuming   |-->|   running   |<-------------->|  migrating  |
    |             |   |  !vmRunning |                |             |
    + - - - - - - - +   +-------------+                + - - - - - - - +
                           |      ^ *running               ^
                           |      |                        |
                           |      +-------------------+    |
                           |                          |    |
                           v *shutdown       *destroy v    v
                      + - - - - - - - - +          +-------------+
                      | shuttingdown  |--------->|  shutdown   |
                      |               |          | !vmShutdown |
                      + - - - - - - - - +          +-------------+
                                                     ^      |
                                                     |      v !vmDeleted
    + - - - - - - - +   +-------------+     + - - - - - - - +  (Deleted from
    |   blocked     |   |   crashed   |     |  preparing  |   vmTable)
    |             |   |  !vmCrashed |     |             |
    + - - - - - - - +   +-------------+     + - - - - - - - +
```

The state transition of a virtual machine

Figure 2: State transition of a virtual machine

The vmAdminState’ and ‘vmOperState’ textual conventions define an administrative state and an operational state model for virtual machines. Events causing transitions between major operational states will cause the generation of notifications. Per-VM notifications (vmRunning, vmShutdown, vmPaused, vmSuspended, vmCrashed, vmDeleted) are generated if vmPerVMNotificationsEnabled is true(1). Bulk notifications (vmBulkRunning, vmBulkShutdown, vmBulkPaused, vmBulkSuspended, vmBulkCrashed, vmBulkDeleted) are generated if vmBulkNotificationsEnabled is true(1). The transition of ‘vmOperState’ by the write access to ‘vmAdminState’ and the notifications generated by the operational state changes are summarized in Figure 2. Note that the notifications shown in this figure are per-VM notifications. In the case of Bulk notifications, the prefix ‘vm’ is replaced with ’vmBulk’.

The bulk notification mechanism is designed to reduce the number of notifications that are trapped by an SNMP manager. This is because the number of virtual machines managed by a bunch of hypervisors in a datacenter possibly becomes several thousands or more, and consequently, many notifications could be trapped if these virtual machines frequently change their administrative state. The per-VM notifications carry more detailed information, but the scalability shall be a problem. An implementation shall support both, either of, or none of per-VM notifications and bulk notifications. The notification filtering mechanism described in section 6 of RFC 3413 [RFC3413] is used by the management applications to control the notifications.

The MIB module provides a few writable objects that can be used to make non-persistent changes, e.g., changing the memory allocation or the CPU allocation. It is not the goal of this MIB module to provide a configuration interface for virtual machines since other protocols and data modeling languages are more suitable for this task.

The OID tree structure of the MIB module is shown below.

```
--vmMIB (1.3.6.1.2.1.yyy)
  +--vmNotifications(0)
  |  +--vmRunning(1) [vmName, vmUUID, vmOperState]
  |  +--vmShutdown(2) [vmName, vmUUID, vmOperState]
  |  +--vmPaused(3) [vmName, vmUUID, vmOperState]
  |  +--vmSuspended(4) [vmName, vmUUID, vmOperState]
  |  +--vmCrashed(5) [vmName, vmUUID, vmOperState]
  |  +--vmDeleted(6) [vmName, vmUUID, vmOperState, vmPersistent]
  |  +--vmBulkRunning(7) [vmAffectedVMs]
  |  +--vmBulkShutdown(8) [vmAffectedVMs]
  |  +--vmBulkPaused(9) [vmAffectedVMs]
  |  +--vmBulkSuspended(10) [vmAffectedVMs]
  |  +--vmBulkCrashed(11) [vmAffectedVMs]
  |  +--vmBulkDeleted(12) [vmAffectedVMs]
  +--vmObjects(1)
  |  +--vmHypervisor(1)
  |  |  +-- r-n SnmpAdminString    vmHvSoftware(1)
  |  |  +-- r-n SnmpAdminString    vmHvVersion(2)
  |  |  +-- r-n OBJECT IDENTIFIER  vmHvObjectID(3)
  |  |  +-- r-n TimeTicks          vmHvUpTime(4)
```

```
     |  +-- r-n Integer32  vmNumber(2)
     |  +-- r-n TimeTicks  vmTableLastChange(3)
     |  +--vmTable(4)
     |  |  +--vmEntry(1) [vmIndex]
     |  |     +-- --- VirtualMachineIndex  vmIndex(1)
     |  |     +-- r-n SnmpAdminString      vmName(2)
     |  |     +-- r-n UUIDorZero           vmUUID(3)
     |  |     +-- r-n SnmpAdminString      vmOSType(4)
     |  |     +-- rwn VirtualMachineAdminState
     |  |     |                            vmAdminState(5)
     |  |     +-- r-n VirtualMachineOperState
     |  |     |                            vmOperState(6)
     |  |     +-- rwn VirtualMachineAutoStart
     |  |     |                            vmAutoStart(7)
     |  |     +-- r-n VirtualMachinePersistent
     |  |     |                            vmPersistent(8)
     |  |     +-- r-n Integer32            vmCurCpuNumber(9)
     |  |     +-- rwn Integer32            vmMinCpuNumber(10)
     |  |     +-- rwn Integer32            vmMaxCpuNumber(11)
     |  |     +-- r-n Integer32            vmMemUnit(12)
     |  |     +-- r-n Integer32            vmCurMem(13)
     |  |     +-- rwn Integer32            vmMinMem(14)
     |  |     +-- rwn Integer32            vmMaxMem(15)
     |  |     +-- r-n TimeTicks            vmUpTime(16)
     |  |     +-- r-n Counter64            vmCpuTime(17)
     |  +--vmCpuTable(5)
     |  |  +--vmCpuEntry(1) [vmIndex, vmCpuIndex]
     |  |     +-- --- VirtualMachineCpuIndex
     |  |     |                            vmCpuIndex(1)
     |  |     +-- r-n Counter64            vmCpuCoreTime(2)
     |  +--vmCpuAffinityTable(6)
     |  |  +--vmCpuAffinityEntry(1) [vmIndex,
     |  |     |                      vmCpuIndex,
     |  |     |                      vmCpuPhysIndex]
     |  |     +-- --- Integer32            vmCpuPhysIndex(1)
     |  |     +-- rwn Integer32            vmCpuAffinity(2)
     |  +--vmStorageTable(7)
     |  |  +--vmStorageEntry(1) [vmStorageVmIndex, vmStorageIndex]
     |  |     +-- --- VirtualMachineIndexOrZero
     |  |     |                            vmStorageVmIndex(1)
     |  |     +-- --- VirtualMachineStorageIndex
     |  |     |                            vmStorageIndex(2)
     |  |     +-- r-n Integer32            vmStorageParent(3)
     |  |     +-- r-n VirtualMachineStorageSourceType
     |  |     |                            vmStorageSourceType(4)
     |  |     +-- r-n SnmpAdminString      vmStorageSourceTypeString(5)
     |  |     +-- r-n SnmpAdminString      vmStorageResourceID(6)
     |  |     +-- r-n VirtualMachineStorageAccess
     |  |     |                            vmStorageAccess(7)
     |  |     +-- r-n VirtualMachineStorageMediaType
     |  |     |                            vmStorageMediaType(8)
     |  |     +-- r-n SnmpAdminString      vmStorageMediaTypeString(9)
     |  |     +-- r-n Integer32            vmStorageSizeUnit(10)
     |  |     +-- r-n Integer32            vmStorageDefinedSize(11)
     |  |     +-- r-n Integer32            vmStorageAllocatedSize(12)
     |  |     +-- r-n Counter64            vmStorageReadIOs(13)
     |  |     +-- r-n Counter64            vmStorageWriteIOs(14)
     |  +--vmNetworkTable(8)
     |  |  +--vmNetworkEntry(1) [vmIndex, vmNetworkIndex]
     |  |     +-- --- VirtualMachineNetworkIndex
     |  |     |                            vmNetworkIndex(1)
     |  |     +-- r-n InterfaceIndexOrZero vmNetworIfIndex(2)
     |  |     +-- r-n InterfaceIndexOrZero vmNetworkParent(3)
     |  |     +-- r-n SnmpAdminString      vmNetworkModel(4)
     |  |     +-- r-n PhysAddress          vmNetworkPhysAddress(5)
     |  +-- rwn TruthValue           vmPerVMNotificationsEnabled(9)
     |  +-- rwn TruthValue           vmBulkNotificationsEnabled(10)
     |  +-- --n VirtualMachineList   vmAffectedVMs(11)
     +--vmConformance(2)
        +--vmCompliances(1)
        |  +--vmFullCompliances(1)
        |  +--vmReadOnlyCompliances(2)
        +--vmGroups(2)
           +--vmHypervisorGroup(1)
           +--vmVirtualMachineGroup(2)
           +--vmCpuGroup(3)
           +--vmCpuAffinityGroup(4)
           +--vmStorageGroup(5)
           +--vmNetworkGroup(6)
           +--vmPerVMNotificationOptionalGroup(7)
           +--vmBulkNotificationsVariablesGroup(8)
           +--vmBulkNotificationOptionalGroup(9)
```

3.3. Definitions

```
   VM-MIB DEFINITIONS ::= BEGIN

   IMPORTS
       MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE, TimeTicks,
       Counter64, Integer32, mib-2
           FROM SNMPv2-SMI
       OBJECT-GROUP, MODULE-COMPLIANCE, NOTIFICATION-GROUP
           FROM SNMPv2-CONF
       TEXTUAL-CONVENTION, PhysAddress, TruthValue
           FROM SNMPv2-TC
       SnmpAdminString
```

```
               FROM SNMP-FRAMEWORK-MIB
           UUIDorZero
               FROM UUID-TC-MIB
           InterfaceIndexOrZero
               FROM IF-MIB;

       vmMIB MODULE-IDENTITY
           LAST-UPDATED "201307020000Z"        -- 2 July 2013
           ORGANIZATION "IETF Operations and Management Area Working Group"
           CONTACT-INFO
                   "
                   WG E-mail: (To be added after approved by WG)
                   Mailing list subscription info:
                     http:// (To be added after approved by WG)

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                   "

           DESCRIPTION
                   "This MIB module is for use in managing a hypervisor and
                   virtual machines controlled by the hypervisor.  The OID
                   ‘yyy’ is temporary one, and it must be assigned by IANA
                   when this becomes an official document.

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                   IETF Trust’s Legal Provisions Relating to IETF Documents
                   (http://trustee.ietf.org/license-info)."

           REVISION "201307020000Z"        -- 2 July 2013
           DESCRIPTION
                   "The original version of this MIB, published as
                   RFCXXXX."
           ::= { mib-2 yyy }


       vmNotifications OBJECT IDENTIFIER ::= { vmMIB 0 }
       vmObjects       OBJECT IDENTIFIER ::= { vmMIB 1 }
       vmConformance   OBJECT IDENTIFIER ::= { vmMIB 2 }
       -- Textual conversion definitions
       --
       VirtualMachineIndex ::= TEXTUAL-CONVENTION
           DISPLAY-HINT "d"
           STATUS       current
           DESCRIPTION
                   "A unique value, greater than zero, identifying a
                   virtual machine.  The value for each virtual machine
                   must remain constant at least from one re-initialization
                   of the hypervisor to the next re-initialization."
           SYNTAX       Integer32 (1..2147483647)

       VirtualMachineIndexOrZero ::= TEXTUAL-CONVENTION
           DISPLAY-HINT "d"
           STATUS       current
           DESCRIPTION
                   "This textual convention is an extension of the
                   VirtualMachineIndex convention.  This extension permits
                   the additional value of zero.  The meaning of the value
                   zero is object-specific and must therefore be defined as
                   part of the description of any object which uses this
                   syntax.  Examples of the usage of zero might include
                   situations where a virtual machine is unknown, or when
                   none or all virtual machines need to be referenced."
           SYNTAX       Integer32 (0..2147483647)

       VirtualMachineAdminState ::= TEXTUAL-CONVENTION
           STATUS      current
           DESCRIPTION
                   "The administrative state of a virtual machine:

                   running(1)    The administrative state of the virtual
                                 machine indicating the virtual machine
                                 should be brought online.

                   suspended(2)  The administrative state of the virtual
                                 machine where its memory and CPU execution
                                 state has been saved to persistent store
                                 and will be restored at next running(1).

                   paused(3)     The administrative state indicating the
                                 virtual machine is resident in memory but
                                 is no longer scheduled to execute by the
                                 hypervisor.

                   shutdown(4)   The administrative state of the virtual
                                 machine indicating the virtual machine
                                 should be taken shuttingdown.
                   destroy(5)    The administrative state of the virtual
                                 machine indicating the virtual machine
                                 should be forcibly shutdown.  After the
                                 destroy operation, the administrative
                                 state should be automatically changed to
                                 shutdown."
           SYNTAX       INTEGER {
                           running(1),
                           suspend(2),
                           pause(3),
                           shutdown(4),
                           destroy(5)
                        }

       VirtualMachineOperState ::= TEXTUAL-CONVENTION
           STATUS       current
           DESCRIPTION
                   "The operational state of a virtual machine:

                   unknown(1)     The state is unknown, e.g., because the
                                  implementation failed to obtain the state
                                  from the hypervisor.

                   other(2)       The state has been obtained but it is not
                                  a known state.

                   preparing(3)   The virtual machine is currently in the
                                  process of preparation, e.g., allocating
                                  and initializing virtual storage are
                                  after creating (defining) virtual
                                  machine.

                   running(4)     The virtual machine is currently running.

                   blocked(5)     The virtual machine is currently blocked.

                   suspending(6)  The virtual machine is currently in the
                                  process of suspending.

                   suspended(7)   The virtual machine is currently
                                  suspended.

                   resuming(8)    The virtual machine is currently in the
                                  process of resuming.  This is a transient
                                  state from suspended state to running
                                  state.

                   paused(9)      The virtual machine is currently paused.
                   migrating(10)  The virtual machine is currently
                                  migrating.

                   shuttingdown(11)
                                  The virtual machine is currently in the
                                  process of shutting down.

                   shutdown(12)   The virtual machine is down.

                   crashed(13)    The virtual machine has crashed."
           SYNTAX       INTEGER {
                           unknown(1),
                           other(2),
                           preparing(3),
                           running(4),
                           blocked(5),
                           suspending(6),
                           suspended(7),
                           resuming(8),
                           paused(9),
                           migrating(10),
                           shuttingdown(11),
                           shutdown(12),
                           crashed(13)
                        }

       VirtualMachineAutoStart ::= TEXTUAL-CONVENTION
           STATUS       current
           DESCRIPTION
                   "The autostart configuration of a virtual machine:

                   unknown(1)     The autostart configuration is unknown,
                                  e.g., because the implementation failed
                                  to obtain the autostart configuration
                                  from the hypervisor. (read-only)

                   enable(2)      The autostart configuration of the
                                  virtual machine is enabled.

                   disable(3)     The autostart configuration of the
                                  virtual machine is disabled."
           SYNTAX      INTEGER {
                           unknown(1),
                           enable(2),
                           disable(3)
                       }

       VirtualMachinePersistent ::= TEXTUAL-CONVENTION
```

```
       STATUS       current
       DESCRIPTION
               "This value indicates whether a virtual machine has a
               persistent configuration which means the virtual machine
               will still exist after shutting down:

               unknown(1)     The persistent configuration is unknown,
                              e.g., because the implementation failed
                              to obtain the persistent configuration
                              from the hypervisor. (read-only)

               persistent(2)  The virtual machine is persistent.

               transient(3)   The virtual machine is transient, i.e.,
                              the virtual machine does not exist after
                              its power-off."
       SYNTAX       INTEGER {
                       unknown(1),
                       persistent(2),
                       transient(3)
                    }

   VirtualMachineCpuIndex ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "d"
       STATUS       current
       DESCRIPTION
               "A unique value, greater than zero, identifying a
               virtual CPU assigned to a virtual machine.  The value
               for each virtual CPU must remain constant at least from
               one re-initialization of the virtual machine to the next
               re-initialization."
        SYNTAX      Integer32 (1..2147483647)

   VirtualMachineStorageIndex ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "d"
       STATUS       current
       DESCRIPTION
               "A unique value, greater than zero, identifying a
               virtual storage device allocated to a virtual machine.
               The value for each virtual storage device must remain
               constant at least from one re-initialization of the
               virtual machine to the next re-initialization."
        SYNTAX      Integer32 (1..2147483647)

   VirtualMachineStorageSourceType ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "The source type of a virtual storage device:
```

```
               unknown(1)     The source type is unknown, e.g., because
                              the implementation failed to obtain the
                              media type from the hypervisor.

               other(2)       The source type is other than those
                              defined in this conversion.

               block(3)       The source type is a block device.

               raw(4)         The source type is a raw-formatted file.

               sparse(5)      The source type is a sparse file.

               network(6)     The source type is a network device."
       SYNTAX       INTEGER {
                       unknown(1),
                       other(2),
                       block(3),
                       raw(4),
                       sparse(5),
                       network(6)
                    }

   VirtualMachineStorageAccess ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "The access permission of a virtual storage:

               readwrite(1)   The virtual storage is a read-write
                              device.

               readonly(2)    The virtual storage is a read-only
                              device."
       SYNTAX       INTEGER {
                       readwrite(1),
                       readonly(2)
                    }

   VirtualMachineStorageMediaType ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "The media type of a virtual storage device:

               unknown(1)     The media type is unknown, e.g., because
                              the implementation failed to obtain the
                              media type from the hypervisor.

               other(2)       The media type is other than those
```

```
                              defined in this conversion.

               hardDisk(3)    The media type is hard disk.

               opticalDisk(4) The media type is optical disk."
       SYNTAX       INTEGER {
                       other(1),
                       unknown(2),
                       hardDisk(3),
                       opticalDisk(4)
                    }

   VirtualMachineNetworkIndex ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "d"
       STATUS       current
       DESCRIPTION
               "A unique value, greater than zero, identifying a
               virtual network interface allocated to a virtual
               machine.  The value for each virtual network interface
               must remain constant at least from one re-initialization
               of the virtual machine to the next re-initialization."
        SYNTAX      Integer32 (1..2147483647)

   VirtualMachineList ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "1x"
       STATUS       current
       DESCRIPTION
               "Each octet within this value specifies a set of eight
               Virtual Machine vmIndex, with the first octet specifying
               Virtual Machine 1 through 8, the second octet specifying
               Virtual Machine 9 through 16, etc.  Within each octet,
               the most significant bit represents the lowest numbered
               vmIndex, and the least significant bit represents the
               highest numbered vmIndex.  Thus, each Virtual Machine of
               the host is represented by a single bit within the value
               of this object.  If that bit has a value of ’1’, then
               that Virtual Machine is included in the set of Virtual
               Machines; the Virtual Machine is not included if its bit
               has a value of ’0’."
       SYNTAX      OCTET STRING

   -- The hypervisor group
   --
   -- A collection of objects common to all hypervisors.
   --
   vmHypervisor    OBJECT IDENTIFIER ::= { vmObjects 1 }

   vmHvSoftware OBJECT-TYPE
```

```
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual description of the hypervisor software.  This
               value should not include its version, and it should be
               included in ‘vmHvVersion’."
       ::= { vmHypervisor 1 }

   vmHvVersion OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual description of the version of the hypervisor
               software."
       ::= { vmHypervisor 2 }

   vmHvObjectID OBJECT-TYPE
       SYNTAX       OBJECT IDENTIFIER
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The vendor’s authoritative identification of the
               hypervisor software contained in the entity.  This value
               is allocated within the SMI enterprises
               subtree (1.3.6.1.4.1).  Note that this is different from
               sysObjectID in the SNMPv2-MIB [RFC3418] because
               sysObjectID is not the identification of the hypervisor
               software but the device, firmware, or management
               operating system."
       ::= { vmHypervisor 3 }

   vmHvUpTime OBJECT-TYPE
       SYNTAX       TimeTicks
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The time (in centi-seconds) since the hypervisor was
               last re-initialized.  Note that this is different from
               sysUpTime in the SNMPv2-MIB [RFC3418] and hrSystemUptime
               in the HOST-RESOURCES-MIB [RFC2790] because sysUpTime is
               the uptime of the network management portion of the
               system, and hrSystemUptime is the uptime of the
               management operating system but not the hypervisor
               software."
       ::= { vmHypervisor 4 }
   -- The virtual machine information
   --
   -- A collection of objects common to all virtual machines.
   --
   vmNumber  OBJECT-TYPE
       SYNTAX       Integer32 (0..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The number of virtual machines (regardless of their
               current state) present on this hypervisor."
       ::= { vmObjects 2 }

   vmTableLastChange  OBJECT-TYPE
       SYNTAX       TimeTicks
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The value of vmHvUpTime at the time of the last creation
               or deletion of an entry in the vmTable."
       ::= { vmObjects 3 }

   vmTable OBJECT-TYPE
       SYNTAX       SEQUENCE OF VmEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A list of virtual machine entries.  The number of
               entries is given by the value of vmNumber."
       ::= { vmObjects 4 }

   vmEntry OBJECT-TYPE
       SYNTAX       VmEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "An entry containing management information applicable
               to a particular virtual machine."
       INDEX   { vmIndex }
       ::= { vmTable 1 }

   VmEntry ::=
       SEQUENCE {
           vmIndex                VirtualMachineIndex,
           vmName                 SnmpAdminString,
           vmUUID                 UUIDorZero,
           vmOSType               SnmpAdminString,
           vmAdminState           VirtualMachineAdminState,
           vmOperState             VirtualMachineOperState,
           vmAutoStart             VirtualMachineAutoStart,
           vmPersistent            VirtualMachinePersistent,
           vmCurCpuNumber          Integer32,
           vmMinCpuNumber          Integer32,
           vmMaxCpuNumber          Integer32,
           vmMemUnit               Integer32,
           vmCurMem                Integer32,
           vmMinMem                Integer32,
           vmMaxMem                Integer32,
           vmUpTime                TimeTicks,
           vmCpuTime               Counter64
       }

   vmIndex OBJECT-TYPE
       SYNTAX       VirtualMachineIndex
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A unique value, greater than zero, identifying the
               virtual machine. The value assigned to a given Virtual
               machine may not persist across a reboot. A command
               generator must use the vmUUID to identify a given
               Virtual Machine of interest."
       ::= { vmEntry 1 }

   vmName OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual name of the virtual machine."
       ::= { vmEntry 2 }

   vmUUID OBJECT-TYPE
       SYNTAX       UUIDorZero
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The virtual machine’s 128-bit UUID or the zero-length
               string when a UUID is not available. The UUID if set
               must uniquely identify a VM from all other Virtual
               Machines in an administrative region. (*mrm -note-
               explain case when this value may be empty."
       ::= { vmEntry 3 }

   vmOSType OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual description containing operating system
               information installed on the virtual machine.  This
               value corresponds to the operating system the hypervisor
               assumes to be running when the virtual machine is
               started.  This may differ from the actual operating
               system in case the virtual machine boots into a
               different operating system."
       ::= { vmEntry 4 }

   vmAdminState OBJECT-TYPE
       SYNTAX       VirtualMachineAdminState
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The administrative power state of the virtual machine.
               Note that a virtual machine is supposed to be resumed
               when vmAdminState of the virtual machine is changed from
               pause(3) to on(1)."
       ::= { vmEntry 5 }

   vmOperState OBJECT-TYPE
       SYNTAX       VirtualMachineOperState
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The current operational state of the virtual machine."
       ::= { vmEntry 6 }

   vmAutoStart OBJECT-TYPE
       SYNTAX       VirtualMachineAutoStart
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The autostart configuration of the virtual machine."
       ::= { vmEntry 7 }

   vmPersistent OBJECT-TYPE
       SYNTAX       VirtualMachinePersistent
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "This value indicates whether the virtual machine has a
               persistent configuration which means the virtual machine
               will still exist after shutting down."
       ::= { vmEntry 8 }
   vmCurCpuNumber OBJECT-TYPE
       SYNTAX       Integer32 (0..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The number of virtual CPUs currently assigned to the
               virtual machine."
       ::= { vmEntry 9 }

   vmMinCpuNumber OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The minimum number of virtual CPUs that are assigned to
               the virtual machine when it is in a power-on state.  The
               value -1 indicates that there is no hard boundary for
               the minimum number of virtual CPUs.  Changes to this
               object may not persist across restarts of the
               hypervisor."
       ::= { vmEntry 10 }

   vmMaxCpuNumber OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The maximum number of virtual CPUs that are assigned to
               the virtual machine when it is in a power-on state.  The
               value -1 indicates that there is no limit.  Changes to
               this object may not persist across restarts of the
               hypervisor."
       ::= { vmEntry 11 }

   vmMemUnit OBJECT-TYPE
       SYNTAX       Integer32 (1..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The multiplication unit for vmCurMem, vmMinMem, and
               vmMaxMem.  For example, when this value is 1024, the
               memory size unit for vmCurMem, vmMinMem, and vmMaxMem is
               KiB."
       ::= { vmEntry 12 }

   vmCurMem OBJECT-TYPE
       SYNTAX       Integer32 (0..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The current memory size currently allocated to the
               virtual memory module in the unit designated by
               vmMemUnit."
       ::= { vmEntry 13 }

   vmMinMem OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The minimum memory size defined to the virtual machine
               in the unit designated by vmMemUnit.  The value -1
               indicates that there is no hard boundary for the minimum
               memory size.  Changes to this object may not persist
               across the restart of the hypervisor."
       ::= { vmEntry 14 }

   vmMaxMem OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The maximum memory size defined to the virtual machine
               in the unit designated by vmMemUnit.  The value -1
               indicates that there is no limit.  Changes to this
               object may not persist across the restart of the
               hypervisor."
       ::= { vmEntry 15 }


   vmUpTime OBJECT-TYPE
       SYNTAX       TimeTicks
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The time (in centi-seconds) since the administrative
               state of the virtual machine was last changed to power
               on."
       ::= { vmEntry 16 }

   vmCpuTime OBJECT-TYPE
       SYNTAX       Counter64
       UNITS        "microsecond"
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
```

```
               "The total CPU time used in microsecond.  If the number
               of virtual CPUs is larger than 1, vmCpuTime may exceed
               real time."
       ::= { vmEntry 17 }

   -- The virtual CPU on each virtual machines
   vmCpuTable OBJECT-TYPE
       SYNTAX       SEQUENCE OF VmCpuEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "The table of virtual CPUs provided by the hypervisor."
       ::= { vmObjects 5 }

   vmCpuEntry OBJECT-TYPE
       SYNTAX       VmCpuEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "An entry for one virtual processor assigned to a
               virtual machine."
       INDEX { vmIndex, vmCpuIndex }
       ::= { vmCpuTable 1 }

   VmCpuEntry ::=
       SEQUENCE {
           vmCpuIndex              VirtualMachineCpuIndex,
           vmCpuCoreTime           Counter64
       }

   vmCpuIndex OBJECT-TYPE
       SYNTAX       VirtualMachineCpuIndex
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A unique value identifying a virtual CPU assigned to
               the virtual machine."
       ::= { vmCpuEntry 1 }

   vmCpuCoreTime OBJECT-TYPE
       SYNTAX       Counter64
       UNITS        "microsecond"
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The total CPU time used by this virtual CPU in
               microsecond."
       ::= { vmCpuEntry 2 }
   -- The virtual CPU affinity on each virtual machines
   vmCpuAffinityTable OBJECT-TYPE
       SYNTAX       SEQUENCE OF VmCpuAffinityEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A list of CPU affinity entries of a virtual CPU."
       ::= { vmObjects 6 }

   vmCpuAffinityEntry OBJECT-TYPE
       SYNTAX       VmCpuAffinityEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "An entry containing CPU affinity associated with a
               particular virtual machine."
       INDEX   { vmIndex, vmCpuIndex, vmCpuPhysIndex }
       ::= { vmCpuAffinityTable 1 }

   VmCpuAffinityEntry ::=
       SEQUENCE {
           vmCpuPhysIndex           Integer32,
           vmCpuAffinity            Integer32
       }

   vmCpuPhysIndex OBJECT-TYPE
       SYNTAX       Integer32 (1..2147483647)
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A value identifying a physical CPU on the hypervisor.
               On systems implementing the HOST-RESOURCES-MIB, the
               value must be the same value that is used as the index
               in the hrProcessorTable (hrDeviceIndex)."
       ::= { vmCpuAffinityEntry 2 }

   vmCpuAffinity OBJECT-TYPE
       SYNTAX       INTEGER {
                       unknown(0),   -- unknown
                       enable(1),    -- enabled
                       disable(2)    -- disabled
                    }
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "The CPU affinity of this virtual CPU to the physical
               CPU represented by ‘vmCpuPhysIndex’."
       ::= { vmCpuAffinityEntry 3 }
   -- The virtual storage devices on each virtual machine.  This
   -- document defines some overlapped objects with hrStorage in
   -- HOST-RESOURCES-MIB [RFC2790], because virtual resources shall be
   -- allocated from the hypervisor’s resources, which is the ‘host
   -- resources’
   vmStorageTable OBJECT-TYPE
       SYNTAX       SEQUENCE OF VmStorageEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "The conceptual table of virtual storage devices
               attached to the virtual machine."
       ::= { vmObjects 7 }

   vmStorageEntry OBJECT-TYPE
       SYNTAX       VmStorageEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "An entry for one virtual storage device attached to the
               virtual machine."
       INDEX { vmStorageVmIndex, vmStorageIndex }
       ::= { vmStorageTable 1 }

   VmStorageEntry ::=
       SEQUENCE {
           vmStorageVmIndex        VirtualMachineIndexOrZero,
           vmStorageIndex          VirtualMachineStorageIndex,
           vmStorageParent         Integer32,
           vmStorageSourceType     VirtualMachineStorageSourceType,
           vmStorageSourceTypeString
                                   SnmpAdminString,
           vmStorageResourceID     SnmpAdminString,
           vmStorageAccess         VirtualMachineStorageAccess,
           vmStorageMediaType      VirtualMachineStorageMediaType,
           vmStorageMediaTypeString
                                   SnmpAdminString,
           vmStorageSizeUnit       Integer32,
           vmStorageDefinedSize    Integer32,
           vmStorageAllocatedSize  Integer32,
           vmStorageReadIOs        Counter64,
           vmStorageWriteIOs       Counter64
       }

   vmStorageVmIndex OBJECT-TYPE
       SYNTAX       VirtualMachineIndexOrZero
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "This value identifies the virtual machine (guest) this
               storage device has been allocated to.  The value zero
               indicates that the storage device is currently not
               allocated to any virtual machines."
       ::= { vmStorageEntry 1 }

   vmStorageIndex OBJECT-TYPE
       SYNTAX       VirtualMachineStorageIndex
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A unique value identifying a virtual storage device
               allocated to the virtual machine."
       ::= { vmStorageEntry 2 }

   vmStorageParent OBJECT-TYPE
       SYNTAX       Integer32 (0..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The value of hrStorageIndex which is the parent (i.e.,
               physical) device of this virtual device on systems
               implementing the HOST-RESOURCES-MIB.  The value zero
               denotes this virtual device is not any child represented
               in the hrStorageTable."
       ::= { vmStorageEntry 3 }

   vmStorageSourceType OBJECT-TYPE
       SYNTAX       VirtualMachineStorageSourceType
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The source type of the virtual storage device."
       ::= { vmStorageEntry 4 }

   vmStorageSourceTypeString OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A (detailed) textual string of the source type of the
               virtual storage device.  For example, this represents
               the specific format name of the sparse file."
       ::= { vmStorageEntry 5 }

   vmStorageResourceID OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual string that represents the resource
               identifier of the virtual storage.  For example, this
               contains the path to the disk image file that
               corresponds to the virtual storage."
       ::= { vmStorageEntry 6 }

   vmStorageAccess OBJECT-TYPE
       SYNTAX       VirtualMachineStorageAccess
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The access permission of the virtual storage device."
       ::= { vmStorageEntry 7 }

   vmStorageMediaType OBJECT-TYPE
       SYNTAX       VirtualMachineStorageMediaType
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The media type of the virtual storage device."
       ::= { vmStorageEntry 8 }

   vmStorageMediaTypeString OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A (detailed) textual string of the virtual storage
               media.  For example, this represents the specific driver
               name of the emulated media such as ‘IDE’ and ‘SCSI’."
       ::= { vmStorageEntry 9 }

   vmStorageSizeUnit OBJECT-TYPE
       SYNTAX       Integer32 (1..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The multiplication unit for vmStorageDefinedSize and
               vmStorageAllocatedSize.  For example, when this value is
               1048576, the storage size unit for vmStorageDefinedSize
               and vmStorageAllocatedSize is MiB."
       ::= { vmStorageEntry 10 }

   vmStorageDefinedSize OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The defined virtual storage size defined in the unit
               designated by vmStorageSizeUnit.  If this information is
               not available, this value shall be -1."
       ::= { vmStorageEntry 11 }

   vmStorageAllocatedSize OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The storage size allocated to the virtual storage from
               a physical storage in the unit designated by
               vmStorageSizeUnit.  When the virtual storage is block
               device or raw file, this value and vmStorageDefinedSize
               are supposed to equal.  This value must not be different
               from vmStorageDefinedSize when vmStorageSourceType is
               ‘block’ or ‘raw’.  If this information is not available,
               this value shall be -1."
       ::= { vmStorageEntry 12 }

   vmStorageReadIOs OBJECT-TYPE
       SYNTAX       Counter64
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The number of read I/O requests."
       ::= { vmStorageEntry 13 }

   vmStorageWriteIOs OBJECT-TYPE
       SYNTAX       Counter64
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The number of write I/O requests."
       ::= { vmStorageEntry 14 }

   -- The virtual network interfaces on each virtual machine.
   vmNetworkTable OBJECT-TYPE
       SYNTAX       SEQUENCE OF VmNetworkEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "The conceptual table of virtual network interfaces
               attached to the virtual machine."
       ::= { vmObjects 8 }
   vmNetworkEntry OBJECT-TYPE
       SYNTAX       VmNetworkEntry
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "An entry for one virtual storage device attached to the
               virtual machine."
       INDEX { vmIndex, vmNetworkIndex }
       ::= { vmNetworkTable 1 }

   VmNetworkEntry ::=
       SEQUENCE {
           vmNetworkIndex           VirtualMachineNetworkIndex,
           vmNetworkIfIndex         InterfaceIndexOrZero,
           vmNetworkParent          InterfaceIndexOrZero,
           vmNetworkModel           SnmpAdminString,
           vmNetworkPhysAddress     PhysAddress
       }

   vmNetworkIndex OBJECT-TYPE
       SYNTAX       VirtualMachineNetworkIndex
       MAX-ACCESS   not-accessible
       STATUS       current
       DESCRIPTION
               "A unique value identifying a virtual network interface
               allocated to the virtual machine."
       ::= { vmNetworkEntry 1 }

   vmNetworkIfIndex OBJECT-TYPE
       SYNTAX       InterfaceIndexOrZero
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The value of ifIndex which corresponds to this virtual
               network interface.  If this device is not represented in
               the ifTable, then this value shall be zero."
       ::= { vmNetworkEntry 2 }

   vmNetworkParent OBJECT-TYPE
       SYNTAX       InterfaceIndexOrZero
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The value of ifIndex which corresponds to the parent
               (i.e., physical) device of this virtual device on.  The
               value zero denotes this virtual device is not any child
               represented in the ifTable."
       ::= { vmNetworkEntry 3 }
   vmNetworkModel OBJECT-TYPE
       SYNTAX       SnmpAdminString (SIZE (0..255))
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "A textual string containing the (emulated) model of
               virtual network interface.  For example, this value is
               ‘virtio’ when the emulation driver model is virtio."
       ::= { vmNetworkEntry 4 }

   vmNetworkPhysAddress OBJECT-TYPE
       SYNTAX       PhysAddress
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The MAC address of the virtual network interface."
       ::= { vmNetworkEntry 5 }


   -- Notification definitions:

   vmPerVMNotificationsEnabled OBJECT-TYPE
       SYNTAX       TruthValue
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "Indicates if notification generator will send
               notifications per VM."
       ::= { vmObjects 9 }

   vmBulkNotificationsEnabled OBJECT-TYPE
       SYNTAX       TruthValue
       MAX-ACCESS   read-write
       STATUS       current
       DESCRIPTION
               "Indicates if notification generator will send
               notifications per set of VMs."
       ::= { vmObjects 10 }

   vmAffectedVMs OBJECT-TYPE
       SYNTAX       VirtualMachineList
       MAX-ACCESS   accessible-for-notify
       STATUS       current
       DESCRIPTION
               "A complete list of Virtual Machines whose state has
               changed.  This object is the only object sent with bulk
               notifications."
       ::= { vmObjects 11 }
   vmRunning NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               ‘running’ from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 1 }

   vmShutdown NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               ‘shutdown’ from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 2 }

   vmPaused NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               ‘paused’ from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 3 }

   vmSuspended NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of a virtual machine has been changed to
               ‘suspended’ from some other state.  The other state is
               indicated by the included value of vmOperState."
       ::= { vmNotifications 4 }

   vmCrashed NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when a virtual machine
               has been crashed.  The previos state of the virtual
               machine is indicated by the included value of
               vmOperState."
       ::= { vmNotifications 5 }

   vmDeleted NOTIFICATION-TYPE
       OBJECTS      {
                       vmName,
                       vmUUID,
                       vmOperState,
                       vmPersistent
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when a virtual machine
               has been deleted. The prior state of the virtual
               machine is indicated by the included value of
               vmOperState."
       ::= { vmNotifications 6 }

   vmBulkRunning NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machine has been changed to
               ‘running’ from a all prior states except for ’running.’
               Management stations are encouraged to subsequently
               poll the subset of VMs of interest for vmOperState."
       ::= { vmNotifications 7 }

   vmBulkShutdown NOTIFICATION-TYPE
       OBJECTS      {
                      vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machine has been changed to
               ‘shutdown’ from a state other than ‘shutdown‘.
               Management stations are encouraged to subsequently poll
               the subset of VMs of interest for vmOperState."
       ::= { vmNotifications 8 }

   vmBulkPaused NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machines have been changed
               to ‘paused’ from a state other than ‘paused.‘
               Management stations are encouraged to subsequently poll
               the subset of VMs of interest for vmOperState."
       ::= { vmNotifications 9 }


   vmBulkSuspended NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
               "This notification is generated when the operational
               state of one or more virtual machines have been changed
               to ‘suspended’ from a state other than ’suspended.’
               Management stations are encouraged to subsequently poll
               the subset of VMs of interest for vmOperState."
       ::= { vmNotifications 10 }

   vmBulkCrashed NOTIFICATION-TYPE
       OBJECTS      {
                       vmAffectedVMs
                    }
       STATUS       current
       DESCRIPTION
```

```
                "This notification is generated when one or more virtual
                machines have been crashed.  Management stations are
                encouraged to subsequently poll the subset of VMs of
                interest for vmOperState."
        ::= { vmNotifications 11 }

    vmBulkDeleted NOTIFICATION-TYPE
        OBJECTS      {
                        vmAffectedVMs
                     }
        STATUS       current
        DESCRIPTION
                "This notification is generated when one or more virtual
                machines have been deleted.  Management stations are
                encouraged to subsequently poll the subset of VMs of
                interest for vmOperState."
        ::= { vmNotifications 12 }

    -- Compliance definitions:
    vmGroups       OBJECT IDENTIFIER ::= { vmConformance 1 }
    vmCompliances  OBJECT IDENTIFIER ::= { vmConformance 2 }

    vmFullCompliances MODULE-COMPLIANCE
        STATUS       current
        DESCRIPTION
                "Compliance statement for implementations supporting
                read/write access, according to the object definitions."
        MODULE     -- this module
        MANDATORY-GROUPS {
            vmHypervisorGroup,
            vmVirtualMachineGroup,
            vmCpuGroup,
            vmCpuAffinityGroup,
            vmStorageGroup,
            vmNetworkGroup
        }
        GROUP  vmPerVMNotificationOptionalGroup
        DESCRIPTION
                "Support for per-VM notifications is optional.  If not
                implemented then vmPerVMNotificationsEnabled must report
                false(2)."
        GROUP  vmBulkNotificationsVariablesGroup
        DESCRIPTION
                "Necessary only if vmPerVMNotificationOptionalGroup is
                implemented."
        GROUP  vmBulkNotificationOptionalGroup
        DESCRIPTION
                "Support for bulk notifications is optional.  If not
                implemented then vmBulkNotificationsEnabled must report
                false(2)."

        ::= { vmCompliances 1 }

    vmReadOnlyCompliances MODULE-COMPLIANCE
        STATUS       current
        DESCRIPTION
                "Compliance statement for implementations supporting
                only readonly access."
        MODULE     -- this module
        MANDATORY-GROUPS {
            vmHypervisorGroup,
            vmVirtualMachineGroup,
            vmCpuGroup,
            vmCpuAffinityGroup,
            vmStorageGroup,
            vmNetworkGroup
        }

        OBJECT vmAdminState
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."

        OBJECT vmAutoStart
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."

        OBJECT vmMinCpuNumber
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."

        OBJECT vmMaxCpuNumber
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."

        OBJECT vmMinMem
        MIN-ACCESS   read-only
        DESCRIPTION
                "Write access is not required."

        OBJECT vmMaxMem
        MIN-ACCESS   read-only
        DESCRIPTION
```

```
               "Write access is not required."

       OBJECT vmCpuAffinity
       MIN-ACCESS   read-only
       DESCRIPTION
               "Write access is not required."

       OBJECT vmPerVMNotificationsEnabled
       MIN-ACCESS   read-only
       DESCRIPTION
               "Write access is not required."

       OBJECT vmBulkNotificationsEnabled
       MIN-ACCESS   read-only
       DESCRIPTION
               "Write access is not required."
       ::= { vmCompliances 2 }

   vmHypervisorGroup OBJECT-GROUP
       OBJECTS {
           vmHvSoftware,
           vmHvVersion,
           vmHvObjectID,
           vmHvUpTime,
           vmNumber,
           vmTableLastChange,
           vmPerVMNotificationsEnabled,
           vmBulkNotificationsEnabled
       }
       STATUS       current
       DESCRIPTION
               "A collection of objects providing insight into the
               hypervisor itself."
        ::= { vmGroups 1 }

   vmVirtualMachineGroup OBJECT-GROUP
       OBJECTS {
           -- vmIndex
           vmName,
           vmUUID,
           vmOSType,
           vmAdminState,
           vmOperState,
           vmAutoStart,
           vmPersistent,
           vmCurCpuNumber,
           vmMinCpuNumber,
           vmMaxCpuNumber,
           vmMemUnit,
           vmCurMem,
           vmMinMem,
           vmMaxMem,
           vmUpTime,
           vmCpuTime
       }
       STATUS       current
       DESCRIPTION
               "A collection of objects providing insight into the
               virtual machines) controlled by a hypervisor."
       ::= { vmGroups 2 }

   vmCpuGroup OBJECT-GROUP
       OBJECTS {
           -- vmCpuIndex,
           vmCpuCoreTime
       }
       STATUS       current
       DESCRIPTION
               "A collection of objects providing insight into the
               virtual machines) controlled by a hypervisor."
       ::= { vmGroups 3 }

   vmCpuAffinityGroup OBJECT-GROUP
       OBJECTS {
           -- vmCpuPhysIndex,
           vmCpuAffinity
       }
       STATUS       current
       DESCRIPTION
               "A collection of objects providing insight into the
               virtual machines) controlled by a hypervisor."
       ::= { vmGroups 4 }

   vmStorageGroup OBJECT-GROUP
       OBJECTS {
           -- vmStorageVmIndex,
           -- vmStorageIndex,
           vmStorageParent,
           vmStorageSourceType,
           vmStorageSourceTypeString,
           vmStorageResourceID,
           vmStorageAccess,
           vmStorageMediaType,
           vmStorageMediaTypeString,
           vmStorageSizeUnit,
           vmStorageDefinedSize,
           vmStorageAllocatedSize,
           vmStorageReadIOs,
           vmStorageWriteIOs
       }
       STATUS       current
       DESCRIPTION
               "A collection of objects providing insight into the
               virtual storage devices controlled by a hypervisor."
       ::= { vmGroups 5 }

   vmNetworkGroup OBJECT-GROUP
       OBJECTS {
           -- vmNetworkIndex,
           vmNetworkIfIndex,
           vmNetworkParent,
           vmNetworkModel,
           vmNetworkPhysAddress
       }
       STATUS       current
       DESCRIPTION
               "A collection of objects providing insight into the
               virtual network interfaces controlled by a hypervisor."
       ::= { vmGroups 6 }

   vmPerVMNotificationOptionalGroup NOTIFICATION-GROUP
       NOTIFICATIONS {
           vmRunning,
           vmShutdown,
           vmPaused,
           vmSuspended,
           vmCrashed,
           vmDeleted
       }
       STATUS       current
       DESCRIPTION
               "A collection of notifications for per-VM notification
               of changes to virtual machine state (vmOperState) as
               reported by a hypervisor."
       ::= { vmGroups 7 }

   vmBulkNotificationsVariablesGroup OBJECT-GROUP
       OBJECTS {
           vmAffectedVMs
       }
       STATUS       current
       DESCRIPTION
               "The variables used in vmBulkNotificationOptionalGroup
               virtual network interfaces controlled by a hypervisor."
```

```
       ::= { vmGroups 8 }

   vmBulkNotificationOptionalGroup NOTIFICATION-GROUP
       NOTIFICATIONS {
           vmBulkRunning,
           vmBulkShutdown,
           vmBulkPaused,
           vmBulkSuspended,
           vmBulkCrashed,
           vmBulkDeleted
       }
       STATUS       current
       DESCRIPTION
               "A collection of notifications for bulk notification of
               changes to virtual machine state (vmOperState) as
               reported by a given hypervisor."
       ::= { vmGroups 9 }

   END
```

4. IANA Considerations

The MIB module in this document uses the following IANA-assigned OBJECT IDENTIFIER values recorded in the SMI Numbers registry:

Descriptor	OBJECT IDENTIFIER value
vmMIB	{ mib-2 TBD }

5. Security Considerations

There are a number of management objects defined in this MIB that have a MAX-ACCESS clause of read-write and/or read-create. Such objects may be considered sensitive or vulnerable in some network environments. The support for SET operations in a non-secure environment without proper protection can have a negative effect on hypervisor and virtual machine operations.

There are a number of managed objects in this MIB that may contain sensitive information. The objects in the vmHvSoftware and vmHvVersion list information about the hypervisor’s software and version. Some may wish not to disclose to others which software they are running. Further, an inventory of the running software and versions may be helpful to an attacker who hopes to exploit software bugs in certain applications. Moreover, the objects in the vmTable, vmCpuTable, vmCpuAffinityTable, vmStorageTable and vmNetworkTable list information about the virtual machines and their virtual resource allocation. Some may wish not to disclose to others how many and what virtual machines they are operating.

It is thus important to control even GET access to these objects and possibly to even encrypt the values of these object when sending them over the network via SNMP. Not all versions of SNMP provide features for such a secure environment.

It is recommended that attention be specifically given to implementing the MAX-ACCESS clause in a number of objects, including vmAdminState, vmAutoStart, vmMinCpuNumber, vmMaxCpuNumber, vmMinMem, vmMaxMem, and vmCpuAffinity in scenarios that DO NOT use SNMPv3 strong security (i.e. authentication and encryption). Extreme caution must be used to minimize the risk of cascading security vulnerabilities when SNMPv3 strong security is not used. When SNMPv3 strong security is not used, these objects should have access of read-only, not read-create.

SNMPv1 by itself is not a secure environment. Even if the network itself is secure (for example by using IPsec), even then, there is no control as to who on the secure network is allowed to access and GET/SET (read/change/create/delete) the objects in this MIB.

It is recommended that the implementers consider the security features as provided by the SNMPv3 framework. Specifically, the use of the User-based Security Model [RFC3414] and the View-based Access Control Model [RFC3415] is recommended.

It is then a customer/user responsibility to ensure that the SNMP entity giving access to an instance of this MIB, is properly configured to give access to the objects only to those principals (users) that have legitimate rights to indeed GET or SET (change/ create/delete) them.

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