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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 monitor).

Status of this Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on April 16, 2014.

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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 monitor). 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. However, this MIB module attempts to generalize the managed objects to support other 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].

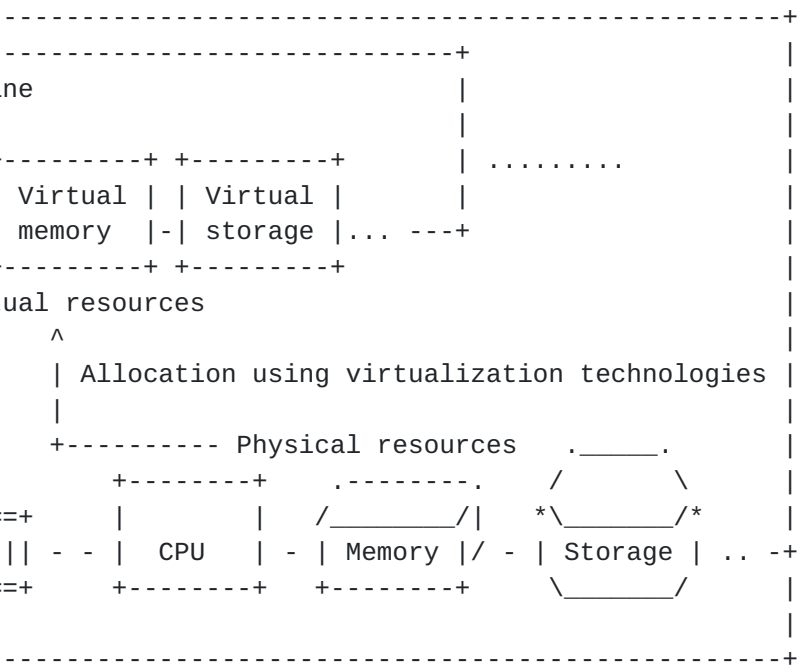
2. The Internet-Standard Management Framework

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

On the common implementations of hypervisor softwares, a hypervisor allocates virtual resources such as virtual CPUs, virtual memory, virtual storage devices, and virtual network interfaces to virtual machines 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. This document specifies four specific types of virtual resources that are common to general hypervisors; CPUs (processors), memory, network interfaces, and storage devices.



A hypervisor allocates virtual resources such as virtual CPUs, virtual memory, virtual storage devices, and virtual network interfaces to virtual machines from physical resources.

Figure 1: An example of a virtualization environment

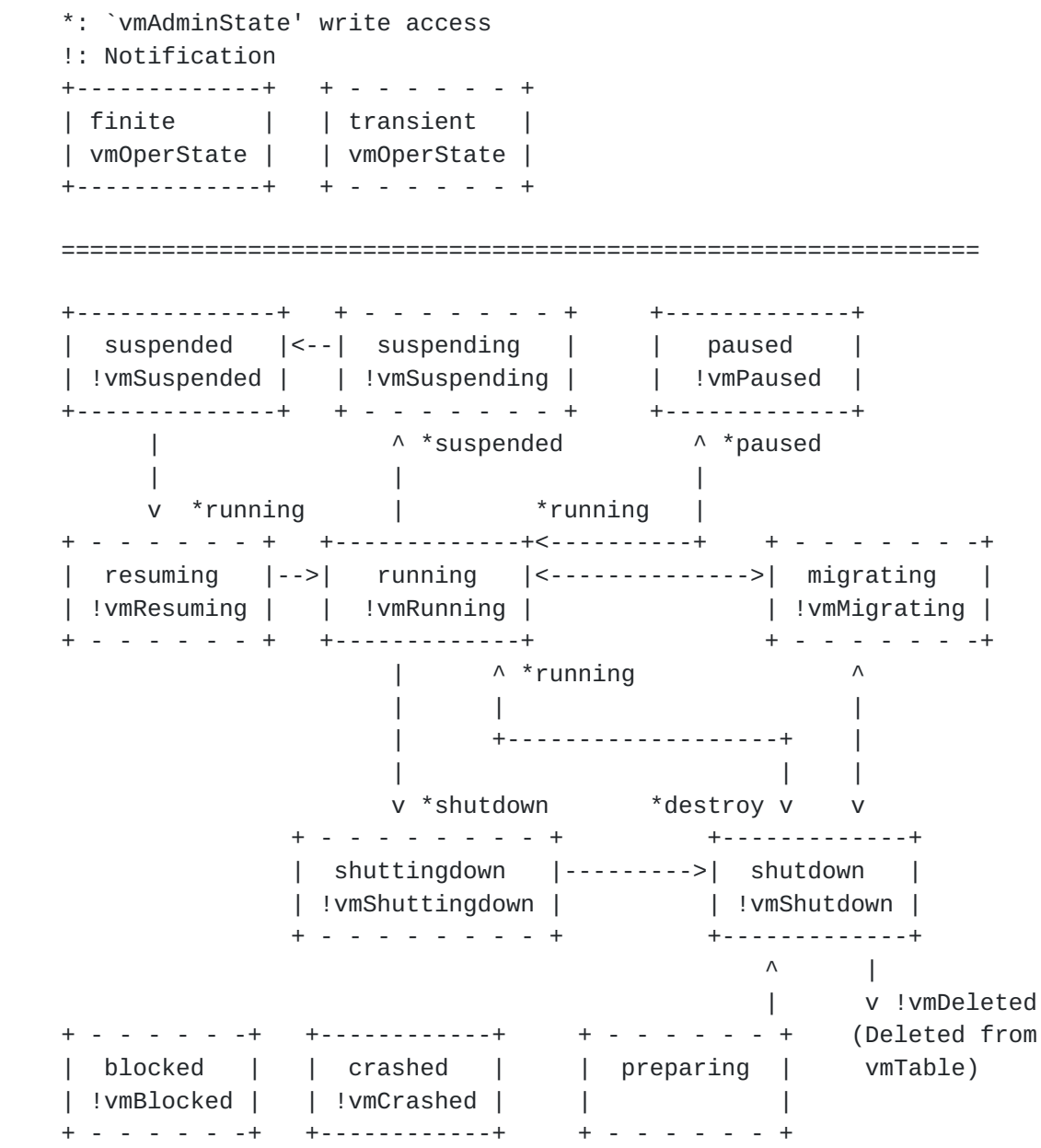
As shown in Figure 1, the objects defined in this document are managed at a hypervisor and an SNMP agent is launched at the hypervisor to provide access to the objects. The objects are managed from the viewpoint of the operators of hypervisors, but not the operators of virtual machines; i.e., the objects 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 do not take different values when the vmStorageSourceType is `block' or `raw'.

The other objects related to virtual machines such as management IP addresses of a virtual machine are not included in this MIB module because this MIB module defines the objects common to general hypervisors but they are specific to some hypervisors. They may be included in the entLogicalTable of ENTITY-MIB [RFC4133]. The objects related to virtual switches are not also included in this MIB module though virtual switches shall be placed on a hypervisor. This is because the virtual network interfaces are the lowest abstraction of network resources allocated to a virtual machine. Instead of including the objects related to virtual switches, for example, BRIDGE-MIB [RFC4188] and Q-BRIDGE-MIB [RFC4363] could be used.

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' provides the mapping table of virtual CPUs to virtual machines, including CPU time used by each virtual CPU. The 'vmCpuAffinityTable' provides the affinity of each virtual CPU to a physical CPU. The `vmStorageTable' provides the list of virtual storage devices and their mapping to virtual machines. In case that an entry in the `vmStorageTable' has a corresponding parent physical storage device managed in `hrStorageTable' of HOST-RESOURCES-MIB [RFC2790], the entry contains a pointer `vmStorageParent' to the physical storage device. The `vmNetworkTable' provides the list of virtual network interfaces and their mapping to virtual machines. Each entry in the `vmNetworkTable' also provides a pointer `vmNetworIfIndex' to the corresponding entry in the `ifTable' of IF-MIB [RFC2863]. In case that an entry in the `vmNetworkTable' has a corresponding parent physical network interface managed in `ifTable' of IF-MIB, the entry contains a pointer `vmNetworkParent' to the physical network interface.



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 virtual machine (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]
  |  +--vmShuttingdown(2) [vmName, vmUUID, vmOperState]
  |  +--vmShutdown(3) [vmName, vmUUID, vmOperState]
  |  +--vmPaused(4) [vmName, vmUUID, vmOperState]
  |  +--vmSuspending(5) [vmName, vmUUID, vmOperState]
  |  +--vmSuspended(6) [vmName, vmUUID, vmOperState]
  |  +--vmResuming(7) [vmName, vmUUID, vmOperState]
  |  +--vmMigrating(8) [vmName, vmUUID, vmOperState]
  |  +--vmCrashed(9) [vmName, vmUUID, vmOperState]
  |  +--vmBlocked(10) [vmName, vmUUID, vmOperState]
  |  +--vmDeleted(11) [vmName, vmUUID, vmOperState, vmPersistent]
  |  +--vmBulkRunning(12) [vmAffectedVMs]
  |  +--vmBulkShutdown(13) [vmAffectedVMs]
  |  +--vmBulkShuttingdown(14) [vmAffectedVMs]
  |  +--vmBulkPaused(15) [vmAffectedVMs]
  |  +--vmBulkSuspending(16) [vmAffectedVMs]
  |  +--vmBulkSuspended(17) [vmAffectedVMs]
```

```
|  +--vmBulkResuming(18) [vmName, vmUUID, vmOperState]
|  +--vmBulkMigrating(19) [vmAffectedVMs]
|  +--vmBulkCrashed(20) [vmAffectedVMs]
|  +--vmBulkBlocked(21) [vmAffectedVMs]
|  +--vmBulkDeleted(22) [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)
|  |     +-- r-n VirtualMachineAutoStart
|  |     |                            vmAutoStart(7)
|  |     +-- r-n VirtualMachinePersistent
|  |     |                            vmPersistent(8)
|  |     +-- rwn Integer32            vmCurCpuNumber(9)
|  |     +-- rwn Integer32            vmMinCpuNumber(10)
|  |     +-- rwn Integer32            vmMaxCpuNumber(11)
|  |     +-- r-n Integer32            vmMemUnit(12)
|  |     +-- rwn 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 "201310130000Z"        -- 13 October 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.

```
        REVISION "201310130000Z"        -- 13 October 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
                              is currently online or 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
                          is currently offline or should be taken
                          shutting down.

            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(4)."
        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 operational state of the virtual
                               machine is unknown, e.g., because the
                               implementation failed to obtain the state
                               from the hypervisor.

                other(2)       The operational state of the virtual
                               machine indicating that an operational
                               state is obtained from the hypervisor but
                               it is not a state defined in this MIB
                               module.

                preparing(3)   The operational state of the virtual
                               machine indicating the virtual machine is
                               currently in the process of preparation,
```

e.g., allocating and initializing virtual storage after creating (defining) virtual machine.

running(4) The operational state of the virtual machine indicating the virtual machine is currently executed but it is not in the process of preparing(3), suspending(6), resuming(8), migrating(10), and shuttingdown(11).

blocked(5) The operational state of the virtual machine indicating the execution of the virtual machine is currently blocked, e.g., waiting for some action of the hypervisor to finish. This is a transient state from/to other states.

suspending(6) The operational state of the virtual machine indicating the virtual machine is currently in the process of suspending to save its memory and CPU execution state to persistent store. This is a transient state from running(4) to suspended(7).

suspended(7) The operational state of the virtual machine indicating the virtual machine is currently suspended, which means the memory and CPU execution state of the virtual machine are saved to persistent store. During this state, the virtual machine is not scheduled to execute by the hypervisor.

resuming(8) The operational state of the virtual machine indicating the virtual machine is currently in the process of resuming to restore its memory and CPU execution state from persistent store. This is a transient state from suspended(7) to running(4).

paused(9) The operational state of the virtual machine indicating the virtual machine is resident in memory but no longer scheduled to execute by the hypervisor.

```
              migrating(10)  The operational state of the virtual
                             machine indicating the virtual machine is
                             currently in the process of migration
                             from/to another hypervisor.

              shuttingdown(11)
                             The operational state of the virtual
                             machine indicating the virtual machine is
                             currently in the process of shutting
                             down.  This is a transient state from
                             running(4) to shutdown(12).

              shutdown(12)   The operational state of the virtual
                             machine indicating the virtual machine is
                             down, and CPU execution is no longer
                             scheduled by the hypervisor and its
                             memory is not resident in the hypervisor.

              crashed(13)    The operational state of the virtual
                             machine indicating 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.

              enable(2)      The autostart configuration of the
```

```
                            virtual machine is enabled.  The virtual
                            machine should be automatically brought
                            online at the next re-initialization of
                            the hypervisor.

                disable(3)  The autostart configuration of the
                            virtual machine is disabled.  The virtual
                            machine should not be automatically
                            brought online at the next
                            re-initialization of the hypervisor."
        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, i.e.,
                            the virtual machine will exist after its
                            shutting down.

                transient(3)  The virtual machine is transient, i.e.,
                            the virtual machine will not exist after
                            its shutting down."
        SYNTAX      INTEGER {
                        unknown(1),
                        persistent(2),
                        transient(3)
                    }

    VirtualMachineCpuIndex ::= TEXTUAL-CONVENTION
        DISPLAY-HINT "d"
        STATUS      current
        DESCRIPTION
                "A unique value for each virtual machine, 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
              hypervisor to the next re-initialization."
       SYNTAX      Integer32 (1..2147483647)

   VirtualMachineStorageIndex ::= TEXTUAL-CONVENTION
       DISPLAY-HINT "d"
       STATUS      current
       DESCRIPTION
              "A unique value for each virtual machine, 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 hypervisor 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 for each virtual machine, greater than
              zero, identifying a virtual network interface allocated
              to the virtual machine.  The value for each virtual
              network interface must remain constant at least from one
              re-initialization of the hypervisor 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 re-initialization of the
                hypervisor.  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 virtual machine from all other
               virtual machines in an administrative region.  A
               zero-length octet string is returned if no UUID
               information is known."
       ::= { 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
               suspended(2) or paused(3) to running(1)."
       ::= { vmEntry 5 }

   vmOperState OBJECT-TYPE
       SYNTAX       VirtualMachineOperState
```

```
        MAX-ACCESS   read-only
        STATUS       current
        DESCRIPTION
                "The operational state of the virtual machine."
        ::= { vmEntry 6 }

    vmAutoStart OBJECT-TYPE
        SYNTAX       VirtualMachineAutoStart
        MAX-ACCESS   read-only
        STATUS       current
        DESCRIPTION
                "The autostart configuration of the virtual machine.  If
                this value is enable(2), the virtual machine
                automatically starts at the next initialization of the
                hypervisor."
        ::= { 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 its shutdown."
        ::= { vmEntry 8 }

    vmCurCpuNumber OBJECT-TYPE
        SYNTAX       Integer32 (0..2147483647)
        MAX-ACCESS   read-write
        STATUS       current
        DESCRIPTION
                "The number of virtual CPUs currently assigned to the
                virtual machine.  Changes to this object MUST NOT
                persist across re-initialization of the hypervisor."
        ::= { 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 MUST NOT persist across re-initialization 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 MUST NOT persist across re-initialization 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-write
        STATUS       current
        DESCRIPTION
                "The current memory size currently allocated to the
                virtual memory module in the unit designated by
                vmMemUnit.  Changes to this object MUST NOT persist
                across re-initialization of the hypervisor."
        ::= { 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 MUST NOT persist
                across re-initialization 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 MUST NOT persist across re-initialization 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 from
               shutdown(4) to running(1)."
       ::= { 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.

               Discontinuities in the value of this counter can occur
               at re-initialization of the hypervisor, and
               administrative state (vmAdminState) changes of the
               virtual machine."
       ::= { 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.

               Discontinuities in the value of this counter can occur
               at re-initialization of the hypervisor, and
               administrative state (vmAdminState) changes of the
               virtual machine."
       ::= { 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.

               Discontinuities in the value of this counter can occur
               at re-initialization of the hypervisor, and
               administrative state (vmAdminState) changes of the
               virtual machine."
       ::= { vmStorageEntry 13 }

   vmStorageWriteIOs OBJECT-TYPE
       SYNTAX       Counter64
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The number of write I/O requests.

               Discontinuities in the value of this counter can occur
               at re-initialization of the hypervisor, and
               administrative state (vmAdminState) changes of the
               virtual machine."
       ::= { 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 network interfaces 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 virtual machine."
        ::= { vmObjects 9 }

    vmBulkNotificationsEnabled OBJECT-TYPE
        SYNTAX       TruthValue
        MAX-ACCESS   read-write
        STATUS       current
        DESCRIPTION
                "Indicates if notification generator will send
                notifications per set of virtual machines."
        ::= { 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(4) 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(12) from some other state.  The other state is
                indicated by the included value of vmOperState."
        ::= { vmNotifications 2 }

    vmShuttingdown 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
                shuttingdown(11) from some other state.  The other state
                is indicated by the included value of vmOperState."
        ::= { vmNotifications 3 }

    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(9) from some other state.  The other state is
                indicated by the included value of vmOperState."
        ::= { vmNotifications 4 }

    vmSuspending 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
                suspending(6) from some other state.  The other state is
                indicated by the included value of vmOperState."
        ::= { vmNotifications 5 }

    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(7) from some other state.  The other state is
                indicated by the included value of vmOperState."
        ::= { vmNotifications 6 }

    vmResuming 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
                resuming(8) from some other state.  The other state is
                indicated by the included value of vmOperState."
        ::= { vmNotifications 7 }

    vmMigrating 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
                migrating(10) from some other state.  The other state is
                indicated by the included value of vmOperState."
        ::= { vmNotifications 8 }

    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 9 }

    vmBlocked 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
                blocked(5).  The previos state of the virtual machine is
                indicated by the included value of vmOperState."
        ::= { vmNotifications 10 }
```

```
   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 11 }

   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(4) from a all prior states except for
               running(4).  Management stations are encouraged to
               subsequently poll the subset of virtual machines of
               interest for vmOperState."
       ::= { vmNotifications 12 }

   vmBulkShuttingdown 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
               shuttingdown(11) from a state other than
               shuttingdown(11).  Management stations are encouraged to
               subsequently poll the subset of virtual machines of
               interest for vmOperState."
       ::= { vmNotifications 13 }

   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(12) from a state other than shutdown(12).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 14 }

    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(9) from a state other than paused(9).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 15 }


    vmBulkSuspending 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 suspending(6) from a state other than suspending(6).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 16 }

    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(7) from a state other than suspended(7).
                Management stations are encouraged to subsequently poll
```

```
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 17 }

    vmBulkResuming 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 resuming(8) from a state other than resuming(8).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 18 }

    vmBulkMigrating 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 migrating(10) from a state other than migrating(10).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 19 }

    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 virtual
                machines of interest for vmOperState."
        ::= { vmNotifications 20 }

    vmBulkBlocked 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 blocked(5) from a state other than blocked(5).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 21 }

    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 virtual
                machines of interest for vmOperState."
        ::= { vmNotifications 22 }

    -- 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 vmCurCpuNumber
        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 vmCurMem
        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,
            vmShuttingdown,
            vmShutdown,
            vmPaused,
            vmSuspending,
            vmSuspended,
            vmResuming,
            vmMigrating,
            vmCrashed,
            vmBlocked,
            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,
            vmBulkShuttingdown,
            vmBulkShutdown,
            vmBulkPaused,
            vmBulkSuspending,
            vmBulkSuspended,
            vmBulkResuming,
            vmBulkMigrating,
            vmBulkCrashed,
            vmBulkBlocked,
            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, 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.

6. Acknowledgements

The authors like to thank Joe Marcus Clarke, Randy Presuhn, and David Black for providing helpful comments during the development of this specification.

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7. References

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7.2. Informative References

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Appendix A. State Transition Table

State	Action or (Event)	Next state	Notification
suspended	running	resuming	vmResuming | vmBulkResuming
suspending	(suspend operation completed)	suspended	vmSuspended | vmBulkSuspended
running	suspended	suspending	vmSuspending | vmBulkSuspending
	shutdown	shuttingdown	vmShuttingdown | vmBulkShuttingdown
	destroy	shutdown	vmShutdown | vmBulkShutdown
	(migration to other hypervisor initiated)	migrating	vmMigrating | vmBulkMingrating
resuming	(resume opeartion completed)	running	vmRunning | vmBulkRunning
paused	running	running	vmRunning | vmBulkRunning
shuttingdown	(shutdown operation completed)	shutdown	vmShutdown | vmBulkShutdown
shutdown	running	running	vmRunning | vmBulkRunning
	(if this state entry is created by a migration operation (*)	migrating	vmMigrating | vmBulkMigrating

	(deletion operation completed)	(no state)	vmDeleted vmBulkDeleted	
migrating	(migration from other hypervisor completed)	running	vmRunning vmBulkRunning	
	(migration to other hypervisor completed)	shutdown	vmShutdown vmBulkShutdown	
preparing	(preparation completed)	shutdown	vmShutdown vmBulkShutdown	
blocked	(blocking operation completed)	(previous state)	-	
crashed	-	-	-	
(any)	(blocking operation initiated)	blocked	vmBlocked vmBulkBlocked	
	(crashed)	crashed	vmCrashed vmBulkCrashed	
(no state)	(preparation initiated)	preparing	-	
	(migrate from other hypervisor initiated)	shutdown (*)	vmShutdown vmBulkShutdown	

State transition table

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