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Management Information Base for Virtual Machines Controlled by a Hypervisor

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 is an Internet Standards Track document.

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Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at http://www.rfc-editor.org/info/rfc7666.

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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 information about a hypervisor's hardware and software.

The design of this MIB module has been derived from product-specific MIB modules -- namely, a MIB module for managing guests of the Xen hypervisor [Xen], a MIB module for managing virtual machines controlled by the VMware hypervisor [VMware], and a MIB module using the libvirt programming interface [libvirt] to access different hypervisors. However, this MIB module attempts to generalize the managed objects to support other implementations of hypervisors.

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. Overview and Objectives

This document defines a portion of MIB for the management of virtual machines controlled by a hypervisor. This MIB module consists of the managed objects related to system and software information of a hypervisor, the list of virtual machines controlled by the hypervisor, and information of virtual resources allocated to virtual machines by the hypervisor. This document specifies four specific types of virtual resources that are common to many hypervisor implementations: processors (CPUs), memory, network interfaces (NICs), and storage devices. These managed objects are independent of the families of hypervisors or operating systems running on virtual machines.

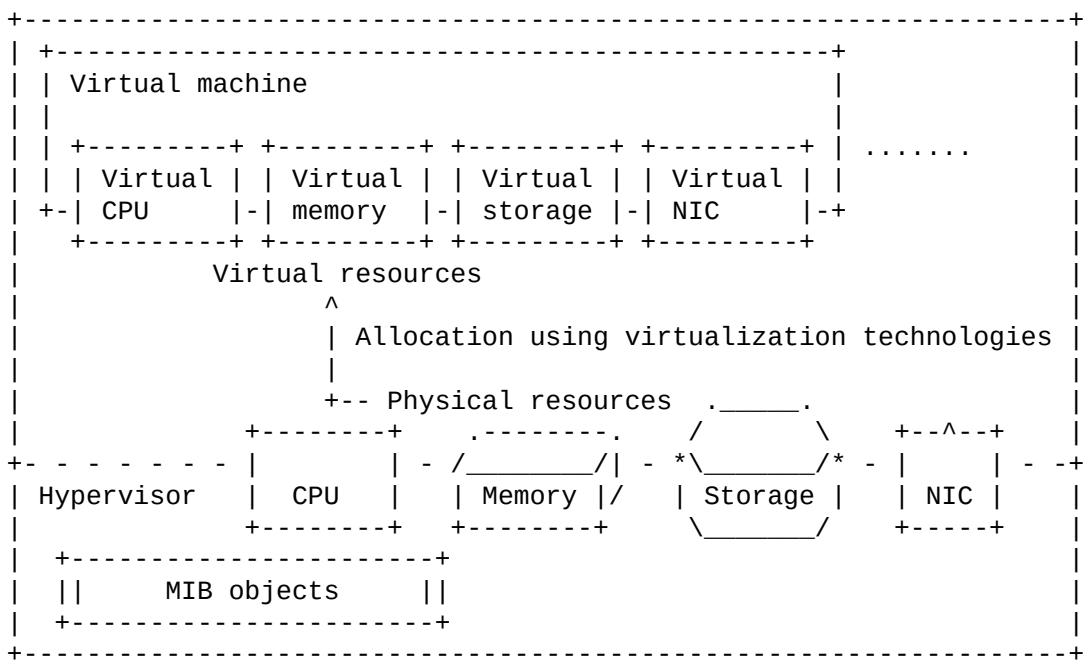

Figure 1: An Example of a Virtualization Environment

On the common implementations of hypervisors, a hypervisor allocates virtual resources from physical resources: virtual CPUs, virtual memory, virtual storage devices, and virtual network interfaces to virtual machines as shown in Figure 1. Since the virtual resources allocated to virtual machines are managed by the hypervisor, the MIB objects are managed at the hypervisor. In case that the objects are accessed through the SNMP, 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; that is, the objects do not take into account the actual resource utilization on each virtual machine but rather the resource allocation from the physical resources. For example, vmNetworkIfIndex 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 objectives of this document are the following: 1) this document defines the MIB objects common to many hypervisors for the management of virtual machines controlled by a hypervisor, and 2) this document clarifies the relationship with other MIB modules for managing host computers and network devices.

4. Structure of the VM-MIB Module

The MIB module is organized into a group of scalars and tables. The scalars below 'vmHypervisor' 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 'vmStorageTable' 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 'vmNetworkIfIndex' 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 the 'ifTable' of IF-MIB, the entry contains a pointer 'vmNetworkParent' to the physical network interface.

Notation:

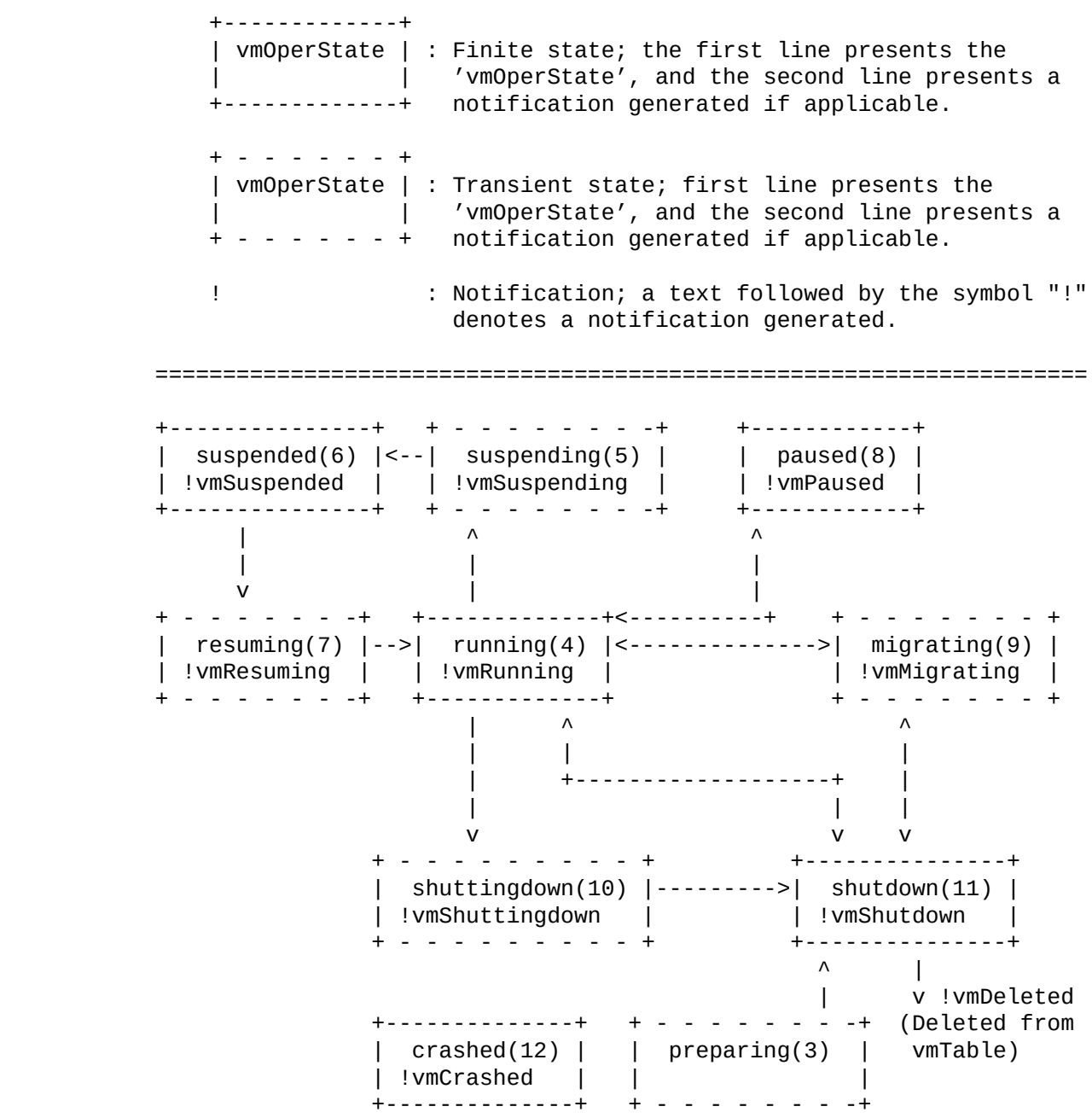

Figure 2: State Transition of a Virtual Machine

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 overview of the transition of 'vmOperState' by the write access to 'vmAdminState' and the notifications generated by the operational state changes are illustrated in Figure 2. The detailed state transition is summarized in Appendix A. 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 data center 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 is a problem. The notification filtering mechanism described in Section 6 of RFC 3413 [RFC3413] is used by the management applications to control the notifications.

5. Relationship to Other MIB Modules

The HOST-RESOURCES-MIB [RFC2790] defines the MIB objects for managing host systems. On systems implementing the HOST-RESOURCES-MIB, the objects of HOST-RESOURCES-MIB indicate resources of a hypervisor. Some objects of HOST-RESOURCES-MIB are used to indicate physical resources through indexes. On systems implementing HOST-RESOURCES-MIB, the 'vmCpuPhysIndex' points to the processor's 'hrDeviceIndex' in the 'hrProcessorTable'. The 'vmStorageParent' also points to the storage device's 'hrStorageIndex' in the 'hrStorageTable'.

The IF-MIB [RFC2863] defines the MIB objects for managing network interfaces. Both physical and virtual network interfaces are required to be contained in the 'ifTable' of IF-MIB. The virtual network interfaces in the 'ifTable' of IF-MIB are pointed from the 'vmNetworkTable' defined in this document through a pointer 'vmNetworkIfIndex'. In case that an entry in the 'vmNetworkTable'

has a corresponding parent physical network interface managed in the 'ifTable' of IF-MIB, the entry contains a pointer 'vmNetworkParent' to the physical network interface.

The objects related to virtual switches are not included in the MIB module defined in this document though virtual switches MAY 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, IEEE8021-BRIDGE-MIB [IEEE8021-BRIDGE-MIB] and IEEE8021-Q-BRIDGE-MIB [IEEE8021-Q-BRIDGE-MIB] could be used.

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 [RFC6933].

The SNMPv2-MIB [RFC3418] provides an object 'sysObjectID' that identifies the network management subsytem and an object 'sysUpTime' that reports the uptime of the network management portion of the system. The HOST-RESOURCES-MIB [RFC2790] provides an object 'hrSystemUptime' that reports the uptime of the host's operating system. To complement these objects, the new 'vmHvUpTime' object reports the time since the hypervisor was last re-initialized, and the new 'vmHvObjectID' provides an identification of the hypervisor software.

6. Definitions

6.1. VM-MIB

```
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
```

```
        IANAStorageMediaType
            FROM IANA-STORAGE-MEDIA-TYPE-MIB;

    vmMIB MODULE-IDENTITY
        LAST-UPDATED "201510120000Z"        -- 12 October 2015
        ORGANIZATION "IETF Operations and Management Area Working Group"
        CONTACT-INFO
                "WG Email: opsawg@ietf.org
                Mailing list subscription info:
                https://www.ietf.org/mailman/listinfo/opsawg

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                Huawei Technologies (USA)
                2330 Central Expressway
                Santa Clara, CA 95050
                United States
                Email: tina.tsou.zouting@huawei.com"

        DESCRIPTION
                "This MIB module is for use in managing a hypervisor and
                virtual machines controlled by the hypervisor.
```

```
    REVISION "201510120000Z"        -- 12 October 2015
    DESCRIPTION
            "The initial version of this MIB, published as
            RFC 7666."
    ::= { mib-2 236 }

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 that 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
                              shutting down."
        SYNTAX       INTEGER {
                        running(1),
                        suspended(2),
                        paused(3),
                        shutdown(4)
                     }

    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) the 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(5), resuming(7), migrating(9), and shuttingdown(10).

suspending(5) 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(6).

suspended(6) 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(7) 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(6) to running(4).

paused(8) 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(9) The operational state of the virtual machine indicating the virtual machine is currently in the process of migration from/to another hypervisor.

shuttingdown(10)

```
                              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(11).

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

    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.

                enabled(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.

                disabled(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),
                        enabled(2),
                        disabled(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 it
                               shuts down.

                transient(3)   The virtual machine is transient, i.e.,
                               the virtual machine will not exist after
                               it shuts 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:

                unknown(1)     The access permission of the virtual
                               storage is unknown.

                readwrite(2)   The virtual storage is a read-write
                               device.
```

```
                readonly(3)    The virtual storage is a read-only
                               device."
        SYNTAX       INTEGER {
                        unknown(1),
                        readwrite(2),
                        readonly(3)
                     }

    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 values, 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 as 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 (RFC 3418) 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 centiseconds) since the hypervisor was
                last re-initialized.  Note that this is different from
                sysUpTime in the SNMPv2-MIB (RFC 3418) and hrSystemUptime
                in the HOST-RESOURCES-MIB (RFC 2790) 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 Universally Unique
                Identifier (UUID) or the zero-length string when a
                UUID is not available.  If set, the UUID MUST uniquely
                identify a virtual machine from all other virtual
                machines in an administrative domain.  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-only
        STATUS       current
        DESCRIPTION
                "The administrative state of the virtual machine."
        ::= { 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-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-only
       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."
       ::= { vmEntry 10 }

   vmMaxCpuNumber OBJECT-TYPE
       SYNTAX       Integer32 (-1|0..2147483647)
       MAX-ACCESS   read-only
       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."
       ::= { vmEntry 11 }

   vmMemUnit OBJECT-TYPE
       SYNTAX       Integer32 (1..2147483647)
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
               "The multiplication unit in bytes 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-only
        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."
        ::= { vmEntry 14 }

    vmMaxMem OBJECT-TYPE
        SYNTAX       Integer32 (-1|0..2147483647)
        MAX-ACCESS   read-only
        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."
        ::= { vmEntry 15 }


    vmUpTime OBJECT-TYPE
        SYNTAX       TimeTicks
        MAX-ACCESS   read-only
        STATUS       current
        DESCRIPTION
                "The time (in centiseconds) 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 microseconds.  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
                microseconds.

                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           INTEGER
        }

    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-only
```

```
        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 (RFC 2790), because virtual resources are
    -- 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      IANAStorageMediaType,
            vmStorageMediaTypeString
                                    SnmpAdminString,
            vmStorageSizeUnit       Integer32,
            vmStorageDefinedSize    Integer32,
            vmStorageAllocatedSize  Integer32,
            vmStorageReadIOs        Counter64,
            vmStorageWriteIOs       Counter64,
```

```
            vmStorageReadOctets     Counter64,
            vmStorageWriteOctets    Counter64,
            vmStorageReadLatency    Counter64,
            vmStorageWriteLatency   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       IANAStorageMediaType
        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 in bytes 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 MUST 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 MUST 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 }

    vmStorageReadOctets OBJECT-TYPE
        SYNTAX       Counter64
        MAX-ACCESS   read-only
        STATUS       current
        DESCRIPTION
                "The total number of bytes read from this device.

                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 15 }

    vmStorageWriteOctets OBJECT-TYPE
        SYNTAX       Counter64
        MAX-ACCESS   read-only
        STATUS       current
        DESCRIPTION
                "The total number of bytes written to this device.

                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 16 }

    vmStorageReadLatency OBJECT-TYPE
        SYNTAX       Counter64
        MAX-ACCESS   read-only
        STATUS       current
        DESCRIPTION
                "The total number of microseconds read requests have
                been queued for this device.

                This would typically be implemented by storing the high
                precision system timestamp of when the request is
```

```
                received from the virtual machine with the request, the
                difference between this initial timestamp and the time
                at which the requested operation has completed SHOULD be
                converted to microseconds and accumulated.

                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 17 }

    vmStorageWriteLatency OBJECT-TYPE
        SYNTAX       Counter64
        MAX-ACCESS   read-only
        STATUS       current
        DESCRIPTION
                "The total number of microseconds write requests have
                been queued for this device.

                This would typically be implemented by storing the high
                precision system timestamp of when the request is
                received from the virtual machine with the request; the
                difference between this initial timestamp and the time
                at which the requested operation has completed SHOULD be
                converted to microseconds and accumulated.

                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 18 }


    -- 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 interface 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 MUST 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.  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 the
                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 Media Access Control (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 the notification generator will send
                notifications per virtual machine.  Changes to this
                object MUST NOT persist across re-initialization of
                the management system, e.g., SNMP agent."
        ::= { vmObjects 9 }

    vmBulkNotificationsEnabled OBJECT-TYPE
        SYNTAX       TruthValue
        MAX-ACCESS   read-write
        STATUS       current
        DESCRIPTION
                "Indicates if the notification generator will send
                notifications per set of virtual machines.  Changes to
                this object MUST NOT persist across re-initialization of
                the management system, e.g., SNMP agent."
        ::= { 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 }

   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(10) from some other state.  The other state
               is indicated by the included value of vmOperState."
       ::= { vmNotifications 2 }

   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(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(8) 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(5) 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(6) 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(7) 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(9) 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 previous state of the virtual
                machine is indicated by the included value of
                vmOperState."
        ::= { vmNotifications 9 }

    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 10 }

    vmBulkRunning NOTIFICATION-TYPE
        OBJECTS      {
                        vmAffectedVMs
```

```
                }
        STATUS      current
        DESCRIPTION
                "This notification is generated when the operational
                state of one or more virtual machines has been changed
                to running(4) from any prior state, except for
                running(4).  Management stations are encouraged to
                subsequently poll the subset of virtual machines of
                interest for vmOperState."
        ::= { vmNotifications 11 }

    vmBulkShuttingdown NOTIFICATION-TYPE
        OBJECTS     {
                      vmAffectedVMs
                    }
        STATUS      current
        DESCRIPTION
                "This notification is generated when the operational
                state of one or more virtual machines has been changed
                to shuttingdown(10) from a state other than
                shuttingdown(10).  Management stations are encouraged to
                subsequently poll the subset of virtual machines of
                interest for vmOperState."
        ::= { vmNotifications 12 }

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

    vmBulkPaused NOTIFICATION-TYPE
        OBJECTS     {
                       vmAffectedVMs
                    }
        STATUS      current
        DESCRIPTION
                "This notification is generated when the operational
                state of one or more virtual machines has been changed
                to paused(8) from a state other than paused(8).
```

```
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 14 }

    vmBulkSuspending NOTIFICATION-TYPE
        OBJECTS      {
                        vmAffectedVMs
                     }
        STATUS       current
        DESCRIPTION
                "This notification is generated when the operational
                state of one or more virtual machines has been changed
                to suspending(5) from a state other than suspending(5).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 15 }

    vmBulkSuspended NOTIFICATION-TYPE
        OBJECTS      {
                        vmAffectedVMs
                     }
        STATUS       current
        DESCRIPTION
                "This notification is generated when the operational
                state of one or more virtual machines has been changed
                to suspended(6) from a state other than suspended(6).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 16 }

    vmBulkResuming NOTIFICATION-TYPE
        OBJECTS      {
                        vmAffectedVMs
                     }
        STATUS       current
        DESCRIPTION
                "This notification is generated when the operational
                state of one or more virtual machines has been changed
                to resuming(7) from a state other than resuming(7).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 17 }

    vmBulkMigrating NOTIFICATION-TYPE
```

```
        OBJECTS      {
                        vmAffectedVMs
                     }
        STATUS       current
        DESCRIPTION
                "This notification is generated when the operational
                state of one or more virtual machines has been changed
                to migrating(9) from a state other than migrating(9).
                Management stations are encouraged to subsequently poll
                the subset of virtual machines of interest for
                vmOperState."
        ::= { vmNotifications 18 }

    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 19 }

    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 20 }

    -- Compliance definitions:
    vmCompliances  OBJECT IDENTIFIER ::= { vmConformance 1 }
    vmGroups       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 read-only access."
        MODULE     -- this module
        MANDATORY-GROUPS {
            vmHypervisorGroup,
            vmVirtualMachineGroup,
            vmCpuGroup,
            vmCpuAffinityGroup,
            vmStorageGroup,
            vmNetworkGroup
        }

        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,
            vmStorageReadOctets,
            vmStorageWriteOctets,
            vmStorageReadLatency,
            vmStorageWriteLatency
        }
        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,
            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,
            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
```

6.2. IANA-STORAGE-MEDIA-TYPE-MIB

```
    IANA-STORAGE-MEDIA-TYPE-MIB DEFINITIONS ::= BEGIN

    IMPORTS
        MODULE-IDENTITY, mib-2
            FROM SNMPv2-SMI
        TEXTUAL-CONVENTION
            FROM SNMPv2-TC;

    ianaStorageMediaTypeMIB MODULE-IDENTITY
        LAST-UPDATED "201510120000Z"        -- 12 October 2015
        ORGANIZATION "IANA"
        CONTACT-INFO
                "Internet Assigned Numbers Authority
                 Postal: ICANN
                         12025 Waterfront Drive, Suite 300
                         Los Angeles, CA 90094-2536
                         United States
                 Tel:    +1 310-301-5800
                 Email: iana@iana.org"

        DESCRIPTION
                "This MIB module defines Textual Conventions
                representing the media type of a storage device.

                Copyright (c) 2015 IETF Trust and the persons identified
                as authors of the code.  All rights reserved.

                Redistribution and use in source and binary forms, with
                or without modification, is permitted pursuant to, and
                subject to the license terms contained in, the
```

```
              Simplified BSD License set forth in Section 4.c of the
              IETF Trust's Legal Provisions Relating to IETF Documents
              (http://trustee.ietf.org/license-info)."

          REVISION "201510120000Z"        -- 12 October 2015
          DESCRIPTION
                  "The initial version of this MIB, published as
                  RFC 7666."
          ::= { mib-2 237 }

   IANAStorageMediaType ::= TEXTUAL-CONVENTION
       STATUS       current
       DESCRIPTION
               "The media type of a 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.

               floppyDisk(5)  The media type is floppy disk."

       SYNTAX       INTEGER {
                       other(1),
                       unknown(2),
                       hardDisk(3),
                       opticalDisk(4),
                       floppyDisk(5)
                    }

   END
```

7. IANA Considerations

This document defines the first version of the IANA-maintained IANA-STORAGE-MEDIA-TYPE-MIB module, which allows new storage media types to be added to the enumeration in IANAStorageMediaType. An Expert Review, as defined in RFC 5226 [RFC5226], is REQUIRED for each modification.

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-2 236 }
ianaStorageMediaTypeMIB	{ mib-2 237 }

8. Security Considerations

This MIB module is typically implemented on the hypervisor not inside a virtual machine. Virtual machines, possibly under other administrative domains, would not have access to this MIB as the SNMP service would typically operate in a separate management network.

There are two objects defined in this MIB module, vmPerVMNotificationsEnabled and vmBulkNotificationsEnabled, that have a MAX-ACCESS clause of read-write. Enabling notifications can lead to a substantial number of notifications if many virtual machines change their state concurrently. Hence, 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 the management system. It is RECOMMENDED that these objects have access of read-only instead of read-write on deployments where SNMPv3 strong security (i.e., authentication and encryption) is not used.

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 objects when sending them over the network via SNMP. Not all versions of SNMP provide features for such a secure environment.

SNMPv1 by itself is not a secure environment. Even if the network itself is secure (for example by using IPsec), 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 module.

It is recommended that the implementers consider using 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.

9. References

9.1. Normative References

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Appendix A. State Transition Table

State	Change to vmAdminState at the hypervisor 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
	(migration to other hypervisor initiated)	migrating	vmMigrating | vmBulkMigrating
resuming	(resume operation 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
crashed	-	-	-
	(crashed)	crashed	vmCrashed | vmBulkCrashed
(no state)	(preparation initiated)	preparing	-
	(migrate from other hypervisor initiated)	shutdown (*)	vmShutdown | vmBulkShutdown

State Transition Table for vmOperState

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