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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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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.

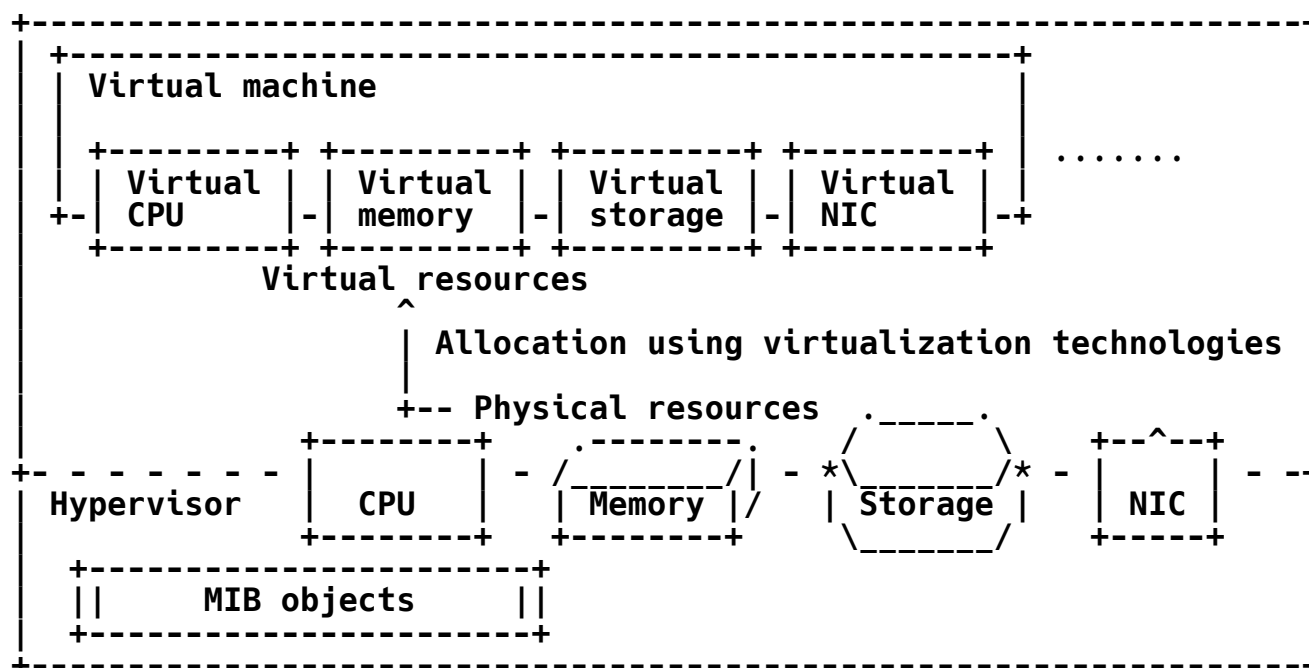


Figure 1: An Example of a Virtualization Environment

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:

`+-----+
| vmOperState | : Finite state; the first line presents the
+-----+ notification generated if applicable.`

`+ - - - - +
| vmOperState | : Transient state; first line presents the
+ - - - - + notification generated if applicable.`

`! : Notification; a text followed by the symbol "!" denotes a notification generated.`

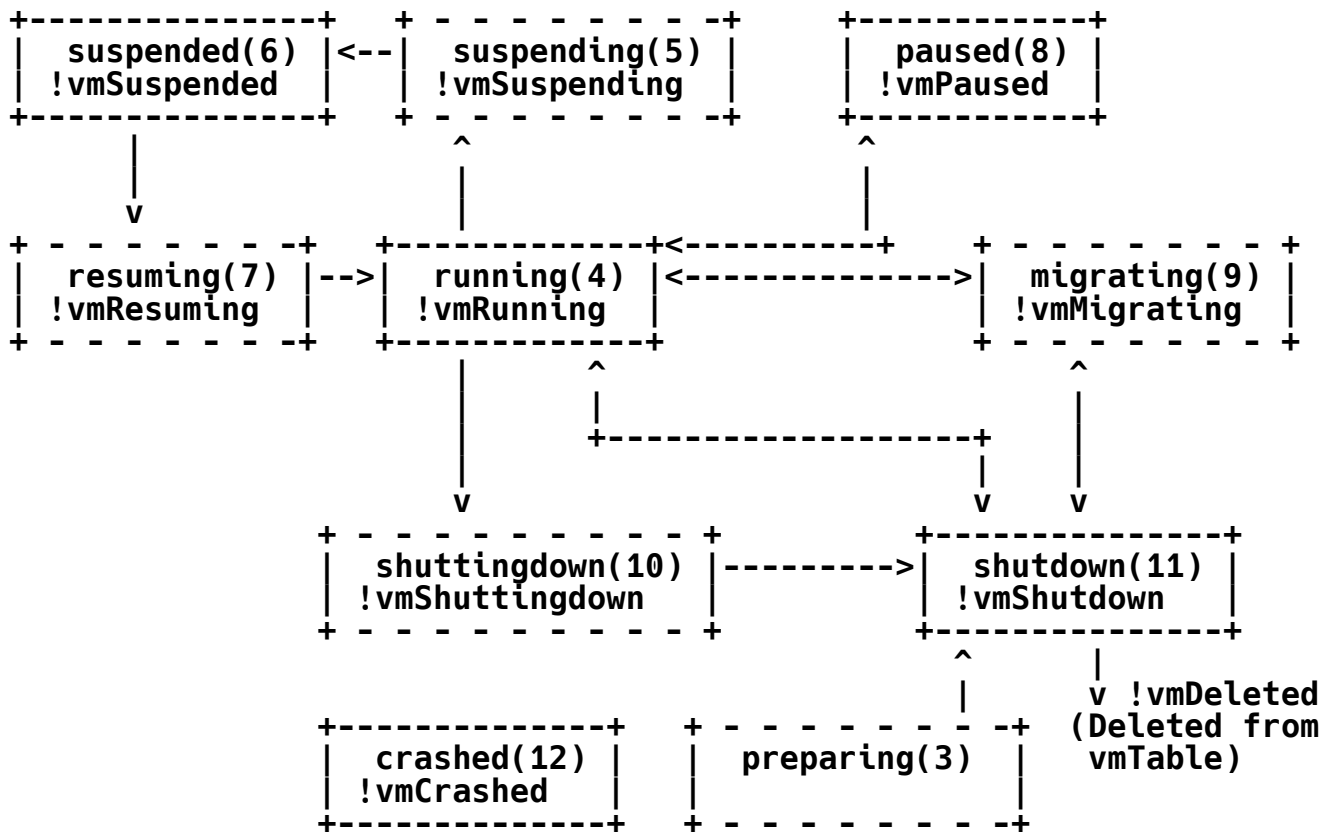


Figure 2: State Transition of a Virtual Machine

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 subsystem 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

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DESCRIPTION

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

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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 }

vmStorageSourceTimeString 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.

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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

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<http://www.rfc-editor.org/info/rfc2119>>.
- [RFC2578] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Structure of Management Information Version 2 (SMIv2)", STD 58, RFC 2578, DOI 10.17487/RFC2578, April 1999, <<http://www.rfc-editor.org/info/rfc2578>>.
- [RFC2579] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Textual Conventions for SMIv2", STD 58, RFC 2579, DOI 10.17487/RFC2579, April 1999, <<http://www.rfc-editor.org/info/rfc2579>>.
- [RFC2580] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Conformance Statements for SMIv2", STD 58, RFC 2580, DOI 10.17487/RFC2580, April 1999, <<http://www.rfc-editor.org/info/rfc2580>>.

- [RFC2790] Waldbusser, S. and P. Grillo, "Host Resources MIB", RFC 2790, DOI 10.17487/RFC2790, March 2000, <<http://www.rfc-editor.org/info/rfc2790>>.
- [RFC2863] McCloghrie, K. and F. Kastenholz, "The Interfaces Group MIB", RFC 2863, DOI 10.17487/RFC2863, June 2000, <<http://www.rfc-editor.org/info/rfc2863>>.
- [RFC3413] Levi, D., Meyer, P., and B. Stewart, "Simple Network Management Protocol (SNMP) Applications", STD 62, RFC 3413, DOI 10.17487/RFC3413, December 2002, <<http://www.rfc-editor.org/info/rfc3413>>.
- [RFC3414] Blumenthal, U. and B. Wijnen, "User-based Security Model (USM) for version 3 of the Simple Network Management Protocol (SNMPv3)", STD 62, RFC 3414, DOI 10.17487/RFC3414, December 2002, <<http://www.rfc-editor.org/info/rfc3414>>.
- [RFC3415] Wijnen, B., Presuhn, R., and K. McCloghrie, "View-based Access Control Model (VACM) for the Simple Network Management Protocol (SNMP)", STD 62, RFC 3415, DOI 10.17487/RFC3415, December 2002, <<http://www.rfc-editor.org/info/rfc3415>>.
- [RFC3418] Presuhn, R., Ed., "Management Information Base (MIB) for the Simple Network Management Protocol (SNMP)", STD 62, RFC 3418, DOI 10.17487/RFC3418, December 2002, <<http://www.rfc-editor.org/info/rfc3418>>.
- [RFC5226] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 5226, DOI 10.17487/RFC5226, May 2008, <<http://www.rfc-editor.org/info/rfc5226>>.
- [RFC6933] Bierman, A., Romascanu, D., Quittek, J., and M. Chandramouli, "Entity MIB (Version 4)", RFC 6933, DOI 10.17487/RFC6933, May 2013, <<http://www.rfc-editor.org/info/rfc6933>>.

9.2. Informative References

- [IEEE8021-BRIDGE-MIB]
IEEE, "IEEE8021-BRIDGE-MIB", October 2008, <<http://www.ieee802.org/1/files/public/MIBs/IEEE8021-BRIDGE-MIB-200810150000Z.txt>>.

[IEEE8021-Q-BRIDGE-MIB]

IEEE, "IEEE8021-Q-BRIDGE-MIB", October 2008,
<<http://www.ieee802.org/1/files/public/MIBs/IEEE8021-Q-BRIDGE-MIB-200810150000Z.txt>>.

[libvirt] The libvirt developers, "The libvirt virtualization API",
<<http://www.libvirt.org/>>.

[RFC3410] Case, J., Mundy, R., Partain, D., and B. Stewart,
"Introduction and Applicability Statements for Internet-
Standard Management Framework", RFC 3410,
DOI 10.17487/RFC3410, December 2002,
<<http://www.rfc-editor.org/info/rfc3410>>.

[VMware] VMware, Inc., "The VMware Hypervisor",
<<http://www.vmware.com/>>.

[Xen] The Xen Project, "The Xen Hypervisor",
<<http://www.xenproject.org/>>.

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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