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.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 5741.

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.
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.
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:

+-------------+  : Finite state; the first line presents the 'vmOperState', and the second line presents a notification generated if applicable.
| vmOperState |
+-------------+

+-------------+  : Transient state; first line presents the 'vmOperState', and the second line presents a notification generated if applicable.
| vmOperState |
+-------------+

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

!vmSuspended   :
!vmSuspending  :
!vmPaused      :
!vmResuming    :
!vmRunning     :
!vmMigrating   :
!vmShuttingdown:
!vmShutdown    :
!vmCrashed     :
!vmDeleted     :

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

Asai, et al.                 Standards Track                    [Page 8]
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: opawg@ietf.org
Mailing list subscription info:
https://www.ietf.org/mailman/listinfo/opawg

Hirochika Asai
The University of Tokyo
7-3-1 Hongo
Bunkyo-ku, Tokyo 113-8656
Japan
Phone: +81 3 5841 6748
Email: panda@hongo.wide.ad.jp

Michael MacFadden
VMware Inc.
Email: mrm@vmware.com

Juergen Schoenwaelder
Jacobs University
Campus Ring 1
Bremen 28759
Germany
Email: j.schoenwaelder@jacobs-university.de

Keiichi Shima
IIJ Innovation Institute Inc.
3-13 Kanda-Nishikicho
Chiyoda-ku, Tokyo 101-0054
Japan
Email: keiichi@iiijlab.net

Tina Tsou
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."
DESCRIPTION
"The initial version of this MIB, published as RFC 7666."
 ::= { mib-2 236 }

::= { vmMIB 0 }
::= { vmMIB 1 }
::= { 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
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**

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 "lx"
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 }

Asai, et al.                 Standards Track                   [Page 20]
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

Asai, et al.                 Standards Track                   [Page 22]
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
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

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 }
-- vmNetworkIndex,
vmNetworkIfIndex,
vmNetworkParent,
vmNetworkModel,
vmNetworkPhysAddress
}
STATUS       current
DESCRIPTION
"A collection of objects providing insight into the
global 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
are used in the 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
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:

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>OBJECT IDENTIFIER value</th>
</tr>
</thead>
<tbody>
<tr>
<td>vmMIB</td>
<td>{ mib-2 236 }</td>
</tr>
<tr>
<td>ianaStorageMediaTypeMIB</td>
<td>{ mib-2 237 }</td>
</tr>
</tbody>
</table>

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


9.2. Informative References

Asai, et al. Standards Track [Page 48]
### Appendix A. State Transition Table

<table>
<thead>
<tr>
<th>State</th>
<th>Change to vmAdminState at the hypervisor or (Event)</th>
<th>Next State</th>
<th>Notification</th>
</tr>
</thead>
<tbody>
<tr>
<td>suspended</td>
<td>running</td>
<td>resuming</td>
<td>vmResuming</td>
</tr>
<tr>
<td>suspending</td>
<td>(suspend operation completed)</td>
<td>suspended</td>
<td>vmSuspending</td>
</tr>
<tr>
<td>running</td>
<td>suspended</td>
<td>suspending</td>
<td>vmSuspending</td>
</tr>
<tr>
<td>shutdown</td>
<td>shuttingdown</td>
<td>shuttindown</td>
<td>vmShuttingdown</td>
</tr>
<tr>
<td></td>
<td>(migration to other hypervisor initiated)</td>
<td>migrating</td>
<td>vmMigrating</td>
</tr>
<tr>
<td>resuming</td>
<td>(resume operation completed)</td>
<td>running</td>
<td>vmRunning</td>
</tr>
<tr>
<td>paused</td>
<td>running</td>
<td>running</td>
<td>vmRunning</td>
</tr>
<tr>
<td>shuttingdown</td>
<td>(shutdown operation completed)</td>
<td>shutdown</td>
<td>vmShutdown</td>
</tr>
<tr>
<td>shutdown</td>
<td>running</td>
<td>running</td>
<td>vmRunning</td>
</tr>
<tr>
<td></td>
<td>(if this state entry is created by a migration operation (*)</td>
<td>migrating</td>
<td>vmMigrating</td>
</tr>
<tr>
<td>State</td>
<td>Operation</td>
<td>State</td>
<td>MIB Variables</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------------------</td>
<td>-------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>migrating</td>
<td>migration from other hypervisor</td>
<td>running</td>
<td>vmRunning</td>
</tr>
<tr>
<td></td>
<td>completed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(migration to other hypervisor</td>
<td>shutdown</td>
<td>vmShutdown</td>
</tr>
<tr>
<td></td>
<td>completed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>preparing</td>
<td>preparation initiated</td>
<td>shutdown (*)</td>
<td>vmShutdown</td>
</tr>
<tr>
<td></td>
<td>(migrate from other hypervisor</td>
<td>preparing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>initiated)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>crashed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(crashed)</td>
<td>crashed</td>
<td>vmCrashed</td>
</tr>
<tr>
<td>(no state)</td>
<td>(preparation initiated)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(migrate from other hypervisor</td>
<td>shutdown (*)</td>
<td>vmShutdown</td>
</tr>
<tr>
<td></td>
<td>initiated)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

State Transition Table for vmOperState
Acknowledgements

The authors would like to thank Andy Bierman, David Black, Joe Marcus Clarke, C.M. Heard, Joel Jaeggli, Tom Petch, Randy Presuhn, and Ian West for providing helpful comments during the development of this specification.

Juergen Schoenwaelder was partly funded by Flamingo, a Network of Excellence project (ICT-318488) supported by the European Commission under its Seventh Framework Programme.

Contributors

Yuji Sekiya
The University of Tokyo
2-11-16 Yayoi
Bunkyo-ku, Tokyo 113-8658
Japan

Email: sekiya@wide.ad.jp

Cathy Zhou
Huawei Technologies
Bantian, Longgang District
Shenzhen 518129
China

Email: cathyzhou@huawei.com

Hiroshi Esaki
The University of Tokyo
7-3-1 Hongo
Bunkyo-ku, Tokyo 113-8656
Japan

Email: hiroshi@wide.ad.jp
Authors’ Addresses

Hirochika Asai
The University of Tokyo
7-3-1 Hongo
Bunkyo-ku, Tokyo 113-8656
Japan

Phone: +81 3 5841 6748
Email: panda@hongo.wide.ad.jp

Michael MacFaden
VMware Inc.

Email: mrm@vmware.com

Juergen Schoenwaelder
Jacobs University
Campus Ring 1
Bremen 28759
Germany

Email: j.schoenwaelder@jacobs-university.de

Keiichi Shima
IIJ Innovation Institute Inc.
2-10-2 Fujimi
Chiyoda-ku, Tokyo 102-0071
Japan

Email: keiichi@iiilab.net

Tina Tsou
Huawei Technologies (USA)
2330 Central Expressway
Santa Clara, CA 95050
United States

Email: tina.tsou.zouting@huawei.com