

Internet Engineering Task Force (IETF)
Request for Comments: 7666
Category: Standards Track
ISSN: 2070-1721

H. Asai
Univ. of Tokyo
M. MacFaden
VMware Inc.
J. Schoenwaelder
Jacobs University
K. Shima
IIJ Innovation Institute Inc.
T. Tsou
Huawei Technologies (USA)
October 2015

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>.

Copyright Notice

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

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction	2
2. The Internet-Standard Management Framework	3
3. Overview and Objectives	3
4. Structure of the VM-MIB Module	5
5. Relationship to Other MIB Modules	7
6. Definitions	8
6.1. VM-MIB	8
6.2. IANA-STORAGE-MEDIA-TYPE-MIB	43
7. IANA Considerations	45
8. Security Considerations	45
9. References	46
9.1. Normative References	46
9.2. Informative References	47
Appendix A. State Transition Table	49
Acknowledgements	51
Contributors	51
Authors' Addresses	52

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.

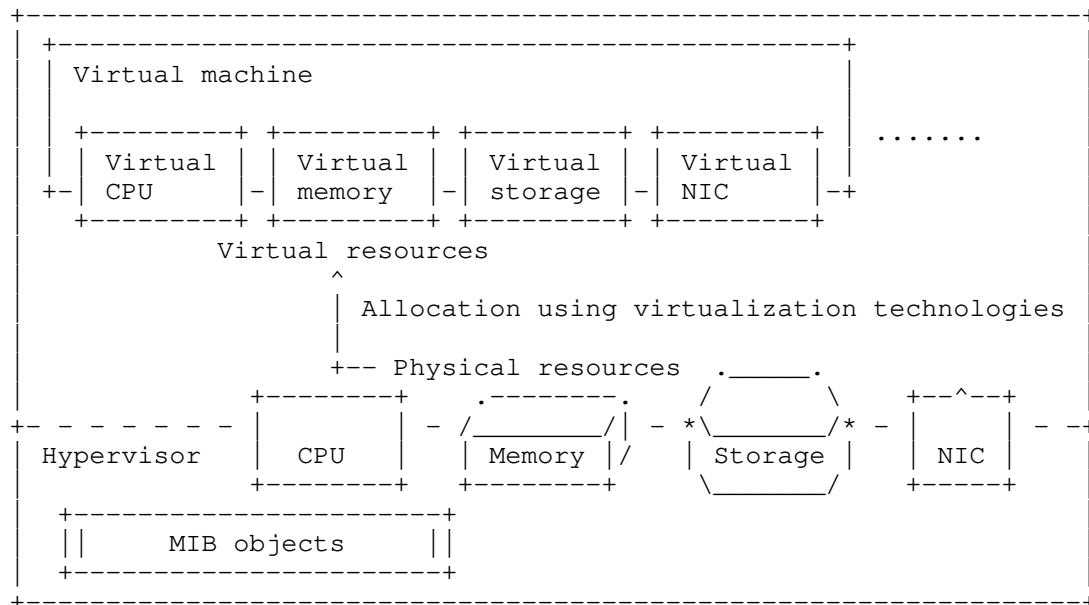


Figure 1: An Example of a Virtualization Environment

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
+-----+      | '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.
+ - - - - - +
!               : Notification; a text followed by the symbol "!"
                  | denotes a notification generated.

```

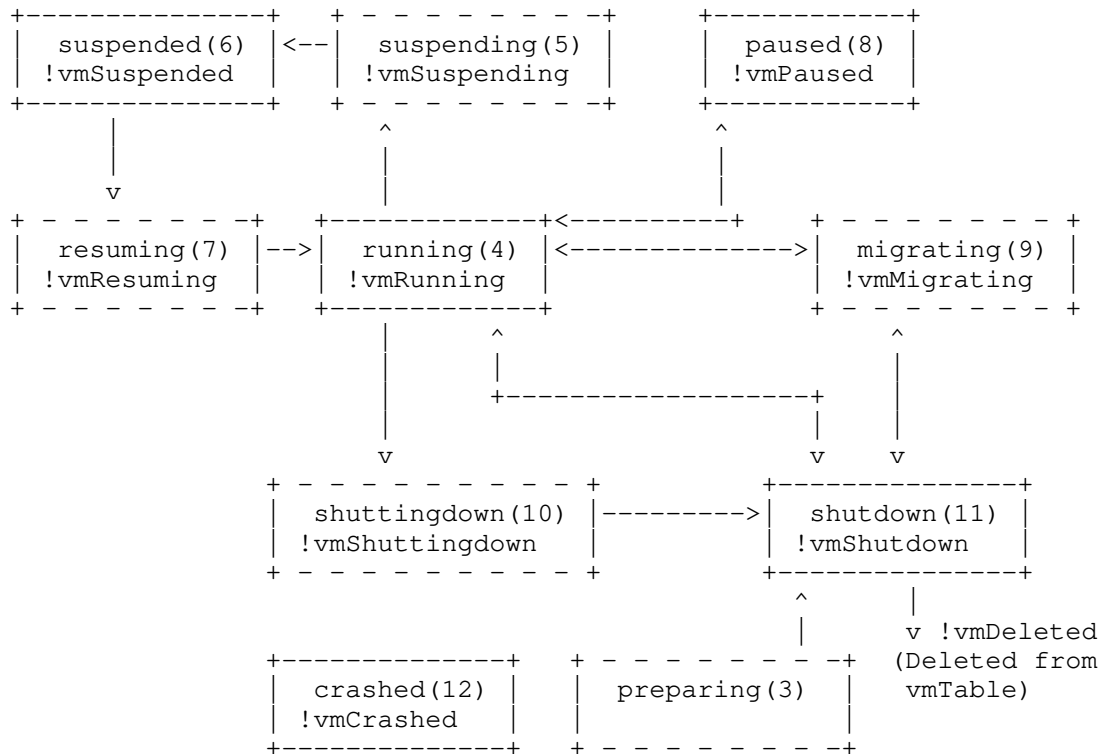


Figure 2: State Transition of a Virtual Machine

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
SnmppAdminString
FROM SNMP-FRAMEWORK-MIB
UUIDorZero
FROM UUID-TC-MIB
InterfaceIndexOrZero
FROM IF-MIB

RFC 7666

Virtual Machine Monitoring MIB

October 2015

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

vmMIB MODULE-IDENTITY

LAST-UPDATED "201510120000Z" -- 12 October 2015

ORGANIZATION "IETF Operations and Management Area Working Group"

CONTACT-INFO

"WG Email: opsawg@ietf.org
Mailing list subscription info:
<https://www.ietf.org/mailman/listinfo/opsawg>

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.
3-13 Kanda-Nishikicho
Chiyoda-ku, Tokyo 101-0054
Japan
Email: keiichi@iijlab.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.

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

Redistribution and use in source and binary forms, with or without modification, is permitted pursuant to, and subject to the license terms contained in, the Simplified BSD License set forth in Section 4.c of the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>).

REVISION "201510120000Z" -- 12 October 2015

DESCRIPTION

"The initial version of this MIB, published as RFC 7666."

::= { mib-2 236 }

vmNotifications OBJECT IDENTIFIER ::= { vmMIB 0 }

vmObjects OBJECT IDENTIFIER ::= { vmMIB 1 }

vmConformance OBJECT IDENTIFIER ::= { vmMIB 2 }

-- Textual conversion definitions

--

VirtualMachineIndex ::= TEXTUAL-CONVENTION

DISPLAY-HINT "d"

STATUS current

DESCRIPTION

"A unique value, greater than zero, identifying a virtual machine. The value for each virtual machine MUST remain constant at least from one re-initialization of the hypervisor to the next re-initialization."

SYNTAX Integer32 (1..2147483647)

VirtualMachineIndexOrZero ::= TEXTUAL-CONVENTION

DISPLAY-HINT "d"

STATUS current

DESCRIPTION

"This textual convention is an extension of the VirtualMachineIndex convention. This extension permits the additional value of zero. The meaning of the value zero is object-specific and MUST therefore be defined as part of the description of any object that uses this syntax. Examples of the usage of zero might include situations where a virtual machine is unknown, or when none or all virtual machines need to be referenced."

SYNTAX Integer32 (0..2147483647)

VirtualMachineAdminState ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"The administrative state of a virtual machine:

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

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

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

shutdown(4) The administrative state of the virtual machine indicating the virtual machine is currently offline or should be shutting down."

SYNTAX INTEGER {
running(1),
suspended(2),
paused(3),
shutdown(4)
}

VirtualMachineOperState ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"The operational state of a virtual machine:

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

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

preparing(3) The operational state of the virtual machine indicating the virtual machine is

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

- running(4) The operational state of the virtual machine indicating the virtual machine is currently executed, but it is not in the process of preparing(3), suspending(5), resuming(7), migrating(9), and shuttingdown(10).

- suspending(5) The operational state of the virtual machine indicating the virtual machine is currently in the process of suspending to save its memory and CPU execution state to persistent store. This is a transient state from running(4) to suspended(6).

- suspended(6) The operational state of the virtual machine indicating the virtual machine is currently suspended, which means the memory and CPU execution state of the virtual machine are saved to persistent store. During this state, the virtual machine is not scheduled to execute by the hypervisor.

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

- paused(8) The operational state of the virtual machine indicating the virtual machine is resident in memory but no longer scheduled to execute by the hypervisor.

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

- shuttingdown(10)

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

shutdown(11) The operational state of the virtual machine indicating the virtual machine is down, and CPU execution is no longer scheduled by the hypervisor and its memory is not resident in the hypervisor.

crashed(12) The operational state of the virtual machine indicating the virtual machine has crashed."

SYNTAX INTEGER {
 unknown(1),
 other(2),
 preparing(3),
 running(4),
 suspending(5),
 suspended(6),
 resuming(7),
 paused(8),
 migrating(9),
 shuttingdown(10),
 shutdown(11),
 crashed(12)
 }

VirtualMachineAutoStart ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"The autostart configuration of a virtual machine:

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

enabled(2) The autostart configuration of the virtual machine is enabled. The virtual machine should be automatically brought online at the next re-initialization of the hypervisor.

disabled(3) The autostart configuration of the virtual machine is disabled. The virtual

machine should not be automatically
brought online at the next
re-initialization of the hypervisor."

SYNTAX INTEGER {
 unknown(1),
 enabled(2),
 disabled(3)
 }

VirtualMachinePersistent ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

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

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

persistent(2) The virtual machine is persistent, i.e.,
 the virtual machine will exist after it
 shuts down.

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

SYNTAX INTEGER {
 unknown(1),
 persistent(2),
 transient(3)
 }

VirtualMachineCpuIndex ::= TEXTUAL-CONVENTION

DISPLAY-HINT "d"

STATUS current

DESCRIPTION

"A unique value for each virtual machine, greater than
zero, identifying a virtual CPU assigned to a virtual
machine. The value for each virtual CPU MUST remain
constant at least from one re-initialization of the
hypervisor to the next re-initialization."

SYNTAX Integer32 (1..2147483647)

VirtualMachineStorageIndex ::= TEXTUAL-CONVENTION

DISPLAY-HINT "d"

STATUS current

DESCRIPTION

"A unique value for each virtual machine, greater than zero, identifying a virtual storage device allocated to a virtual machine. The value for each virtual storage device MUST remain constant at least from one re-initialization of the hypervisor to the next re-initialization."

SYNTAX Integer32 (1..2147483647)

VirtualMachineStorageSourceType ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"The source type of a virtual storage device:

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

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

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

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

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

network(6) The source type is a network device."

SYNTAX INTEGER {
 unknown(1),
 other(2),
 block(3),
 raw(4),
 sparse(5),
 network(6)
}

VirtualMachineStorageAccess ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"The access permission of a virtual storage:

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

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

readonly(3) The virtual storage is a read-only device."

SYNTAX INTEGER {
 unknown(1),
 readwrite(2),
 readonly(3)
 }

VirtualMachineNetworkIndex ::= TEXTUAL-CONVENTION

DISPLAY-HINT "d"

STATUS current

DESCRIPTION

"A unique value for each virtual machine, greater than zero, identifying a virtual network interface allocated to the virtual machine. The value for each virtual network interface MUST remain constant at least from one re-initialization of the hypervisor to the next re-initialization."

SYNTAX Integer32 (1..2147483647)

VirtualMachineList ::= TEXTUAL-CONVENTION

DISPLAY-HINT "1x"

STATUS current

DESCRIPTION

"Each octet within this value specifies a set of eight virtual machine vmIndex values, with the first octet specifying virtual machine 1 through 8, the second octet specifying virtual machine 9 through 16, etc. Within each octet, the most significant bit represents the lowest-numbered vmIndex, and the least significant bit represents the highest-numbered vmIndex. Thus, each virtual machine of the host is represented by a single bit within the value of this object. If that bit has a value of '1', then that virtual machine is included in the set of virtual machines; the virtual machine is not included if its bit has a value of '0'."

SYNTAX OCTET STRING

-- The hypervisor group

--

-- A collection of objects common to all hypervisors.

--

vmHypervisor OBJECT IDENTIFIER ::= { vmObjects 1 }

vmHvSoftware OBJECT-TYPE

SYNTAX SnmpAdminString (SIZE (0..255))

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"A textual description of the hypervisor software. This value SHOULD NOT include its version as it SHOULD be included in 'vmHvVersion'."

::= { vmHypervisor 1 }

vmHvVersion OBJECT-TYPE

SYNTAX SnmpAdminString (SIZE (0..255))

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"A textual description of the version of the hypervisor software."

::= { vmHypervisor 2 }

vmHvObjectID OBJECT-TYPE

SYNTAX OBJECT IDENTIFIER

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The vendor's authoritative identification of the hypervisor software contained in the entity. This value is allocated within the SMI enterprises subtree (1.3.6.1.4.1). Note that this is different from sysObjectID in the SNMPv2-MIB (RFC 3418) because sysObjectID is not the identification of the hypervisor software but the device, firmware, or management operating system."

::= { vmHypervisor 3 }

vmHvUpTime OBJECT-TYPE

SYNTAX TimeTicks

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The time (in centiseconds) since the hypervisor was last re-initialized. Note that this is different from sysUpTime in the SNMPv2-MIB (RFC 3418) and hrSystemUptime in the HOST-RESOURCES-MIB (RFC 2790) because sysUpTime is the uptime of the network management portion of the system, and hrSystemUptime is the uptime of the management operating system but not the hypervisor software."

::= { vmHypervisor 4 }

-- The virtual machine information

--

```
-- A collection of objects common to all virtual machines.
--
vmNumber OBJECT-TYPE
    SYNTAX      Integer32 (0..2147483647)
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "The number of virtual machines (regardless of their
        current state) present on this hypervisor."
    ::= { vmObjects 2 }

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

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

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

VmEntry ::=
    SEQUENCE {
        vmIndex          VirtualMachineIndex,
        vmName            SnmpAdminString,
        vmUUID            UUIDorZero,
        vmOSType          SnmpAdminString,
        vmAdminState      VirtualMachineAdminState,
        vmOperState       VirtualMachineOperState,
        vmAutoStart       VirtualMachineAutoStart,
```

```

    vmPersistent          VirtualMachinePersistent,
    vmCurCpuNumber       Integer32,
    vmMinCpuNumber        Integer32,
    vmMaxCpuNumber        Integer32,
    vmMemUnit             Integer32,
    vmCurMem             Integer32,
    vmMinMem              Integer32,
    vmMaxMem              Integer32,
    vmUpTime              TimeTicks,
    vmCpuTime             Counter64
}

```

vmIndex OBJECT-TYPE

```

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

```

vmName OBJECT-TYPE

```

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

```

vmUUID OBJECT-TYPE

```

SYNTAX          UUIDorZero
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
    "The virtual machine's 128-bit Universally Unique
    Identifier (UUID) or the zero-length string when a
    UUID is not available. If set, the UUID MUST uniquely
    identify a virtual machine from all other virtual
    machines in an administrative domain. A zero-length
    octet string is returned if no UUID information is
    known."
 ::= { vmEntry 3 }

```

vmOSType OBJECT-TYPE

```

SYNTAX          SnmpAdminString (SIZE (0..255))

```

```

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

```

```

vmAdminState OBJECT-TYPE
    SYNTAX      VirtualMachineAdminState
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "The administrative state of the virtual machine."
    ::= { vmEntry 5 }

```

```

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

```

```

vmAutoStart OBJECT-TYPE
    SYNTAX      VirtualMachineAutoStart
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "The autostart configuration of the virtual machine.  If
        this value is enable(2), the virtual machine
        automatically starts at the next initialization of the
        hypervisor."
    ::= { vmEntry 7 }

```

```

vmPersistent OBJECT-TYPE
    SYNTAX      VirtualMachinePersistent
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "This value indicates whether the virtual machine has a
        persistent configuration, which means the virtual machine
        will still exist after its shutdown."
    ::= { vmEntry 8 }

```

```

vmCurCpuNumber OBJECT-TYPE
    SYNTAX      Integer32 (0..2147483647)
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "The number of virtual CPUs currently assigned to the
        virtual machine."
    ::= { vmEntry 9 }

vmMinCpuNumber OBJECT-TYPE
    SYNTAX      Integer32 (-1|0..2147483647)
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "The minimum number of virtual CPUs that are assigned to
        the virtual machine when it is in a power-on state. The
        value -1 indicates that there is no hard boundary for
        the minimum number of virtual CPUs."
    ::= { vmEntry 10 }

vmMaxCpuNumber OBJECT-TYPE
    SYNTAX      Integer32 (-1|0..2147483647)
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "The maximum number of virtual CPUs that are assigned to
        the virtual machine when it is in a power-on state. The
        value -1 indicates that there is no limit."
    ::= { vmEntry 11 }

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

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

```

```

        vmMemUnit."
 ::= { vmEntry 13 }

vmMinMem OBJECT-TYPE
    SYNTAX      Integer32 (-1|0..2147483647)
    MAX-ACCESS   read-only
    STATUS      current
    DESCRIPTION
        "The minimum memory size defined to the virtual machine
        in the unit designated by vmMemUnit. The value -1
        indicates that there is no hard boundary for the minimum
        memory size."
 ::= { vmEntry 14 }

vmMaxMem OBJECT-TYPE
    SYNTAX      Integer32 (-1|0..2147483647)
    MAX-ACCESS   read-only
    STATUS      current
    DESCRIPTION
        "The maximum memory size defined to the virtual machine
        in the unit designated by vmMemUnit. The value -1
        indicates that there is no limit."
 ::= { vmEntry 15 }

vmUpTime OBJECT-TYPE
    SYNTAX      TimeTicks
    MAX-ACCESS   read-only
    STATUS      current
    DESCRIPTION
        "The time (in centiseconds) since the administrative
        state of the virtual machine was last changed from
        shutdown(4) to running(1)."
```

```

 ::= { vmEntry 16 }

vmCpuTime OBJECT-TYPE
    SYNTAX      Counter64
    UNITS       "microsecond"
    MAX-ACCESS   read-only
    STATUS      current
    DESCRIPTION
        "The total CPU time used in microseconds. If the number
        of virtual CPUs is larger than 1, vmCpuTime may exceed
        real time.

        Discontinuities in the value of this counter can occur
        at re-initialization of the hypervisor and
        administrative state (vmAdminState) changes of the
```

```

        virtual machine."
 ::= { vmEntry 17 }

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

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

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

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

vmCpuCoreTime OBJECT-TYPE
    SYNTAX      Counter64
    UNITS       "microsecond"
    MAX-ACCESS   read-only
    STATUS      current
    DESCRIPTION
        "The total CPU time used by this virtual CPU in
        microseconds.

        Discontinuities in the value of this counter can occur
        at re-initialization of the hypervisor and

```

```

        administrative state (vmAdminState) changes of the
        virtual machine."
 ::= { vmCpuEntry 2 }

-- The virtual CPU affinity on each virtual machines

vmCpuAffinityTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF VmCpuAffinityEntry
    MAX-ACCESS   not-accessible
    STATUS      current
    DESCRIPTION
        "A list of CPU affinity entries of a virtual CPU."
    ::= { vmObjects 6 }

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

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

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

vmCpuAffinity OBJECT-TYPE
    SYNTAX      INTEGER {
        unknown(0),    -- unknown
        enable(1),     -- enabled
        disable(2)     -- disabled
    }
    MAX-ACCESS   read-only

```



```

STATUS          current
DESCRIPTION
    "The CPU affinity of this virtual CPU to the physical
    CPU represented by 'vmCpuPhysIndex'."
 ::= { vmCpuAffinityEntry 3 }

-- The virtual storage devices on each virtual machine.  This
-- document defines some overlapped objects with hrStorage in
-- HOST-RESOURCES-MIB (RFC 2790), because virtual resources are
-- allocated from the hypervisor's resources, which is the 'host
-- resources'.
vmStorageTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF VmStorageEntry
    MAX-ACCESS   not-accessible
    STATUS       current
    DESCRIPTION
        "The conceptual table of virtual storage devices
        attached to the virtual machine."
    ::= { vmObjects 7 }

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

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

```

```

        vmStorageReadOctets      Counter64,
        vmStorageWriteOctets     Counter64,
        vmStorageReadLatency     Counter64,
        vmStorageWriteLatency    Counter64
    }

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

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

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

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

vmStorageSourceTypeString OBJECT-TYPE
    SYNTAX      SnmpAdminString (SIZE (0..255))

```

```

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

```

```

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

```

```

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

```

```

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

```

```

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

```

```

vmStorageSizeUnit OBJECT-TYPE
    SYNTAX      Integer32 (1..2147483647)
    MAX-ACCESS   read-only

```

STATUS current

DESCRIPTION

"The multiplication unit in bytes for
vmStorageDefinedSize and vmStorageAllocatedSize. For
example, when this value is 1048576, the storage size
unit for vmStorageDefinedSize and vmStorageAllocatedSize
is MiB."

::= { vmStorageEntry 10 }

vmStorageDefinedSize OBJECT-TYPE

SYNTAX Integer32 (-1|0..2147483647)

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The defined virtual storage size defined in the unit
designated by vmStorageSizeUnit. If this information is
not available, this value MUST be -1."

::= { vmStorageEntry 11 }

vmStorageAllocatedSize OBJECT-TYPE

SYNTAX Integer32 (-1|0..2147483647)

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The storage size allocated to the virtual storage from
a physical storage in the unit designated by
vmStorageSizeUnit. When the virtual storage is block
device or raw file, this value and vmStorageDefinedSize
are supposed to equal. This value MUST NOT be different
from vmStorageDefinedSize when vmStorageSourceType is
'block' or 'raw'. If this information is not available,
this value MUST be -1."

::= { vmStorageEntry 12 }

vmStorageReadIOs OBJECT-TYPE

SYNTAX Counter64

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The number of read I/O requests.

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

::= { vmStorageEntry 13 }

vmStorageWriteIOs OBJECT-TYPE

SYNTAX Counter64
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"The number of write I/O requests.

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

::= { vmStorageEntry 14 }

vmStorageReadOctets OBJECT-TYPE

SYNTAX Counter64
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"The total number of bytes read from this device.

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

::= { vmStorageEntry 15 }

vmStorageWriteOctets OBJECT-TYPE

SYNTAX Counter64
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"The total number of bytes written to this device.

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

::= { vmStorageEntry 16 }

vmStorageReadLatency OBJECT-TYPE

SYNTAX Counter64
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"The total number of microseconds read requests have been queued for this device.

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

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

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

::= { vmStorageEntry 17 }

vmStorageWriteLatency OBJECT-TYPE

SYNTAX Counter64

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The total number of microseconds write requests have been queued for this device.

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

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

::= { vmStorageEntry 18 }

-- The virtual network interfaces on each virtual machine.

vmNetworkTable OBJECT-TYPE

SYNTAX SEQUENCE OF VmNetworkEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"The conceptual table of virtual network interfaces attached to the virtual machine."

::= { vmObjects 8 }

vmNetworkEntry OBJECT-TYPE

SYNTAX VmNetworkEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry for one virtual network interface attached to

```

        the virtual machine."
INDEX { vmIndex, vmNetworkIndex }
 ::= { vmNetworkTable 1 }

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

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

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

vmNetworkParent OBJECT-TYPE
    SYNTAX      InterfaceIndexOrZero
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "The value of ifIndex, which corresponds to the parent
        (i.e., physical) device of this virtual device.  The
        value zero denotes this virtual device is not any
        child represented in the ifTable."
    ::= { vmNetworkEntry 3 }

vmNetworkModel OBJECT-TYPE
    SYNTAX      SnmpAdminString (SIZE (0..255))
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION

```

```

        "A textual string containing the (emulated) model of the
        virtual network interface.  For example, this value is
        'virtio' when the emulation driver model is virtio."
 ::= { vmNetworkEntry 4 }

```

vmNetworkPhysAddress OBJECT-TYPE

```

SYNTAX      PhysAddress
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
    "The Media Access Control (MAC) address of the virtual
    network interface."
 ::= { vmNetworkEntry 5 }

```

-- Notification definitions:

vmPerVMNotificationsEnabled OBJECT-TYPE

```

SYNTAX      TruthValue
MAX-ACCESS  read-write
STATUS      current
DESCRIPTION
    "Indicates if the notification generator will send
    notifications per virtual machine.  Changes to this
    object MUST NOT persist across re-initialization of
    the management system, e.g., SNMP agent."
 ::= { vmObjects 9 }

```

vmBulkNotificationsEnabled OBJECT-TYPE

```

SYNTAX      TruthValue
MAX-ACCESS  read-write
STATUS      current
DESCRIPTION
    "Indicates if the notification generator will send
    notifications per set of virtual machines.  Changes to
    this object MUST NOT persist across re-initialization of
    the management system, e.g., SNMP agent."
 ::= { vmObjects 10 }

```

vmAffectedVMs OBJECT-TYPE

```

SYNTAX      VirtualMachineList
MAX-ACCESS  accessible-for-notify
STATUS      current
DESCRIPTION
    "A complete list of virtual machines whose state has
    changed.  This object is the only object sent with bulk
    notifications."
 ::= { vmObjects 11 }

```



```

vmRunning NOTIFICATION-TYPE
    OBJECTS      {
                    vmName,
                    vmUUID,
                    vmOperState
                }
    STATUS        current
    DESCRIPTION   "This notification is generated when the operational
                    state of a virtual machine has been changed to
                    running(4) from some other state. The other state is
                    indicated by the included value of vmOperState."
    ::= { vmNotifications 1 }

vmShuttingdown NOTIFICATION-TYPE
    OBJECTS      {
                    vmName,
                    vmUUID,
                    vmOperState
                }
    STATUS        current
    DESCRIPTION   "This notification is generated when the operational
                    state of a virtual machine has been changed to
                    shuttingdown(10) from some other state. The other state
                    is indicated by the included value of vmOperState."
    ::= { vmNotifications 2 }

vmShutdown NOTIFICATION-TYPE
    OBJECTS      {
                    vmName,
                    vmUUID,
                    vmOperState
                }
    STATUS        current
    DESCRIPTION   "This notification is generated when the operational
                    state of a virtual machine has been changed to
                    shutdown(11) from some other state. The other state is
                    indicated by the included value of vmOperState."
    ::= { vmNotifications 3 }

vmPaused NOTIFICATION-TYPE
    OBJECTS      {
                    vmName,
                    vmUUID,
                    vmOperState
                }

```

STATUS current

DESCRIPTION

"This notification is generated when the operational state of a virtual machine has been changed to paused(8) from some other state. The other state is indicated by the included value of vmOperState."

::= { vmNotifications 4 }

vmSuspending NOTIFICATION-TYPE

OBJECTS {
vmName,
vmUUID,
vmOperState
}

STATUS current

DESCRIPTION

"This notification is generated when the operational state of a virtual machine has been changed to suspending(5) from some other state. The other state is indicated by the included value of vmOperState."

::= { vmNotifications 5 }

vmSuspended NOTIFICATION-TYPE

OBJECTS {
vmName,
vmUUID,
vmOperState
}

STATUS current

DESCRIPTION

"This notification is generated when the operational state of a virtual machine has been changed to suspended(6) from some other state. The other state is indicated by the included value of vmOperState."

::= { vmNotifications 6 }

vmResuming NOTIFICATION-TYPE

OBJECTS {
vmName,
vmUUID,
vmOperState
}

STATUS current

DESCRIPTION

"This notification is generated when the operational state of a virtual machine has been changed to resuming(7) from some other state. The other state is indicated by the included value of vmOperState."

```

 ::= { vmNotifications 7 }

vmMigrating NOTIFICATION-TYPE
    OBJECTS
        {
            vmName,
            vmUUID,
            vmOperState
        }
    STATUS
        current
    DESCRIPTION
        "This notification is generated when the operational
        state of a virtual machine has been changed to
        migrating(9) from some other state. The other state is
        indicated by the included value of vmOperState."
 ::= { vmNotifications 8 }

vmCrashed NOTIFICATION-TYPE
    OBJECTS
        {
            vmName,
            vmUUID,
            vmOperState
        }
    STATUS
        current
    DESCRIPTION
        "This notification is generated when a virtual machine
        has been crashed. The previous state of the virtual
        machine is indicated by the included value of
        vmOperState."
 ::= { vmNotifications 9 }

vmDeleted NOTIFICATION-TYPE
    OBJECTS
        {
            vmName,
            vmUUID,
            vmOperState,
            vmPersistent
        }
    STATUS
        current
    DESCRIPTION
        "This notification is generated when a virtual machine
        has been deleted. The prior state of the virtual
        machine is indicated by the included value of
        vmOperState."
 ::= { vmNotifications 10 }

vmBulkRunning NOTIFICATION-TYPE
    OBJECTS
        {
            vmAffectedVMs

```

```

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

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

vmBulkShutdown NOTIFICATION-TYPE
    OBJECTS      {
        vmAffectedVMs
    }
    STATUS      current
    DESCRIPTION
        "This notification is generated when the operational
        state of one or more virtual machine has been changed to
        shutdown(11) from a state other than shutdown(11).
        Management stations are encouraged to subsequently poll
        the subset of virtual machines of interest for
        vmOperState."
    ::= { vmNotifications 13 }

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

```

```

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

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

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

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

vmBulkMigrating NOTIFICATION-TYPE

```

```

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

vmBulkCrashed NOTIFICATION-TYPE
OBJECTS      {
                vmAffectedVMs
            }
STATUS       current
DESCRIPTION   "This notification is generated when one or more virtual
                machines have been crashed. Management stations are
                encouraged to subsequently poll the subset of virtual
                machines of interest for vmOperState."
 ::= { vmNotifications 19 }

vmBulkDeleted NOTIFICATION-TYPE
OBJECTS      {
                vmAffectedVMs
            }
STATUS       current
DESCRIPTION   "This notification is generated when one or more virtual
                machines have been deleted. Management stations are
                encouraged to subsequently poll the subset of virtual
                machines of interest for vmOperState."
 ::= { vmNotifications 20 }

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

vmFullCompliances MODULE-COMPLIANCE
STATUS       current
DESCRIPTION   "Compliance statement for implementations supporting
                read/write access, according to the object definitions."
MODULE       -- this module
MANDATORY-GROUPS {

```

```

    vmHypervisorGroup,
    vmVirtualMachineGroup,
    vmCpuGroup,
    vmCpuAffinityGroup,
    vmStorageGroup,
    vmNetworkGroup
}
GROUP vmPerVMNotificationOptionalGroup
DESCRIPTION
    "Support for per-VM notifications is optional. If not
    implemented, then vmPerVMNotificationsEnabled MUST report
    false(2)."
```

GROUP vmBulkNotificationsVariablesGroup

DESCRIPTION

"Necessary only if vmPerVMNotificationOptionalGroup is implemented."

GROUP vmBulkNotificationOptionalGroup

DESCRIPTION

"Support for bulk notifications is optional. If not implemented, then vmBulkNotificationsEnabled MUST report false(2)."

::= { vmCompliances 1 }

vmReadOnlyCompliances MODULE-COMPLIANCE

STATUS current

DESCRIPTION

"Compliance statement for implementations supporting only read-only access."

MODULE -- this module

MANDATORY-GROUPS {

vmHypervisorGroup,

vmVirtualMachineGroup,

vmCpuGroup,

vmCpuAffinityGroup,

vmStorageGroup,

vmNetworkGroup

}

OBJECT vmPerVMNotificationsEnabled

MIN-ACCESS read-only

DESCRIPTION

"Write access is not required."

OBJECT vmBulkNotificationsEnabled

MIN-ACCESS read-only

DESCRIPTION

"Write access is not required."

```

 ::= { vmCompliances 2 }

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

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

vmCpuGroup OBJECT-GROUP
    OBJECTS {
        -- vmCpuIndex,

```



```

        vmCpuCoreTime
    }
    STATUS          current
    DESCRIPTION
        "A collection of objects providing insight into the
        virtual machines controlled by a hypervisor."
    ::= { vmGroups 3 }

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

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

vmNetworkGroup OBJECT-GROUP
    OBJECTS {

```

```

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

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

vmBulkNotificationsVariablesGroup OBJECT-GROUP
    OBJECTS {
        vmAffectedVMs
    }
    STATUS          current
    DESCRIPTION
        "The variables used in vmBulkNotificationOptionalGroup
        virtual network interfaces controlled by a hypervisor."
    ::= { vmGroups 8 }

vmBulkNotificationOptionalGroup NOTIFICATION-GROUP
    NOTIFICATIONS {
        vmBulkRunning,
        vmBulkShuttingdown,
        vmBulkShutdown,
        vmBulkPaused,

```

```

    vmBulkSuspending,
    vmBulkSuspended,
    vmBulkResuming,
    vmBulkMigrating,
    vmBulkCrashed,
    vmBulkDeleted
}
STATUS          current
DESCRIPTION
    "A collection of notifications for bulk notification of
    changes to virtual machine state (vmOperState) as
    reported by a given hypervisor."
::= { vmGroups 9 }

```

END

6.2. IANA-STORAGE-MEDIA-TYPE-MIB

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

IMPORTS

```

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

```

ianaStorageMediaTypeMIB MODULE-IDENTITY

```

    LAST-UPDATED "201510120000Z"          -- 12 October 2015
    ORGANIZATION "IANA"
    CONTACT-INFO

```

```

        "Internet Assigned Numbers Authority
        Postal: ICANN
            12025 Waterfront Drive, Suite 300
            Los Angeles, CA 90094-2536
            United States
        Tel:      +1 310-301-5800
        Email: iana@iana.org"

```

DESCRIPTION

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

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

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

RFC 7666

Virtual Machine Monitoring MIB

October 2015

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

REVISION "201510120000Z" -- 12 October 2015

DESCRIPTION

"The initial version of this MIB, published as
RFC 7666."

::= { mib-2 237 }

IANAStorageMediaType ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"The media type of a storage device:

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

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

hardDisk(3) The media type is hard disk.

opticalDisk(4) The media type is optical disk.

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

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

END

7. IANA Considerations

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

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

Descriptor -----	OBJECT IDENTIFIER value -----
vmMIB	{ mib-2 236 }
ianaStorageMediaTypeMIB	{ mib-2 237 }

8. Security Considerations

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

There are two objects defined in this MIB module, vmPerVMNotificationsEnabled and vmBulkNotificationsEnabled, that have a MAX-ACCESS clause of read-write. Enabling notifications can lead to a substantial number of notifications if many virtual machines change their state concurrently. Hence, such objects may be considered sensitive or vulnerable in some network environments. The support for SET operations in a non-secure environment without proper protection can have a negative effect on the management system. It is RECOMMENDED that these objects have access of read-only instead of read-write on deployments where SNMPv3 strong security (i.e., authentication and encryption) is not used.

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

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

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

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

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

9. References

9.1. Normative References

- [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

RFC 7666

Virtual Machine Monitoring MIB

October 2015

	(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

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@iijlab.net

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

Email: tina.tsou.zouting@huawei.com

